THE ENVIRONMENTAL HISTORY OF THE NATIONAL GRID

The Process of Electrification: Infrastructure and Influence

Katherine Shillabeer Button

Magdalene College

August 2018

This dissertation is submitted for the degree of Doctor of Philosophy in History

This dissertation is the result of my own work and includes nothing which is the outcome of work done in collaboration except as declared in the Preface and specified in the text.

It is not substantially the same as any that I have submitted, or, is being concurrently submitted for a degree or diploma or other qualification at the University of Cambridge or any other University or similar institution except as declared in the Preface and specified in the text. I further state that no substantial part of my dissertation has already been submitted, or, is being concurrently submitted for any such degree, diploma or other qualification at the University of Cambridge or any other University or similar institution except as declared in the Preface and specified in the text.

Abstract

British electrification began in the 1880s but it was the late 1920s before the 'GridIron' was constructed providing the capacity for uniformly accessible electricity.

This enabled electricity to touch people's lives in the intimacy of their own homes, and provided cheaper electricity to workplaces, causing a shift from local suppliers to national coordination. Consequences for pollution, its visual impact on rural and urban landscapes, and an unparalleled and rapid intrusion on property rights were considered at the time. It was these effects that were the most controversial, although the damage through fossil fuels was arguably much greater with hindsight. The provision of electricity across the whole country took decades and was subject to exogenous pressures and was influenced by individuals, institutions and innovations. Electrification generally, and the Grid in particular has received scant attention from historians, especially regarding its environmental and social impacts and the fuel it consumed.

This work tells the story of electricity as a commodity; initially sold by hundreds of individual companies operating generating stations providing a local electrical supply, and how this slowly transformed into a nationally coordinated system. The Grid, a vast network of towers and cables, transmitted bulk electricity generated by large power stations burning enormous quantities of coal. This work considers how this affected the environments in which people lived and worked and how these changes impacted the 'natural' environment. This work has only just begun to explore the changes that electricity brought spatially and how it impacted lifestyles and working methods. It explores how change was negotiated by actors and considers 'unintentional conservation', brought about by a drive to continuously improve efficiency and which occurred before the need for such environmental protection was well understood.

Table of Contents

Glossary

Electrical Terminology[1]

Alternating Current (AC)

Type of electricity in which electrons flow forwards and backwards in regular cycles. The cycles are measured in Hertz (Hz). In Britain, as in most of Europe, the standard is 240-volt, 50 hertz alternating current (AC).

British Thermal Unit (BTU)

The measurement of electricity to heat a pound of water by one-degree Fahrenheit at one atmosphere. This is equivalent to 251.9958 calories. This is the unit used to measure volumes of energy produced, lost and consumed through this study.

Demand

The amount of electricity demanded by the consumers at any time. Demand is the volume of electricity required to meet consumer's needs at any point in time and dictates the load on the system. The electricity system responds to demand in real time because AC could not be stored in any meaningful way during the period of this study although there is promising contemporary research.

Direct Current (DC)

Type of electricity in which the electrons flow in one direction. DC can be stored in small quantities and is still used in batteries, it is more easily stored than AC which, to date, cannot be stored efficiently.

[1] Definitions are adapted from the European Commission definitions accessed via http://ec.europa.eu/health/scientific_committees/opinions_layman/en/electromagnetic-fields/glossary/abc/alternating-current.htm and the National Grid, 'Glossary of Terms' accessed via http://www2.nationalgrid.com/WorkArea/DownloadAsset.aspx?id=36706.

Distribution

The transportation of electricity, transformed from high voltages to distribution voltages, distributed through supplier networks to consumers.

Electric Current

The displacement of electrons which is often compared to flowing water and this 'electron flow' forms the current which creates the energy which powers equipment and appliances. Electrical current intensity is measured in Amperes (A) and the pressure difference, which causes the electron movement is measured in Volts (V). The standard in Britain is 240v.

Frequency

For electricity this is the number of cycles of electron movements per second and is measured in Hertz (hz). In Britain the standard in 50hz.

Generating Station

The site at which machinery and wiring to produce energy from a primary fuel source, primarily coal for the period of this study. The conversion of one form of energy whether stored energy in fossil fuels, or renewable energy like hydropower or wind power converted into electricity. This electricity is then transmitted through the transmission and distribution networks the generating station is connected to. The term's generating station and power station are used interchangeably in this work, although power station tended to be used for larger stations from the 1920's.

Load

The active, reactive or apparent power, as the context requires generated, transmitted or distributed which is the amount of electricity present in which every part of the supply system is being considered.

Load Factor

The ratio of the actual output of a generating unit to the maximum possible output of the generating unit. This is a measure of efficiency, but it must be balanced. Any generating unit must be able to generate enough electricity to meet the maximum that might be demanded but ordinarily meets average day to day demands. Load factors in the UK ran at 47% in 2016, yet around the turn of the century 20% was a good load capacity and average in 1921-22 was 30%.[2]

Plant

The machinery used in the generation and supply of electricity.

Power Company

A person, company of local government who generated and supplied electricity to consumers directly. From the early 1900s onwards, some power companies generated and sold large quantities (bulk supply) of electricity to a different power company to sell to consumers.

Supplier

A person, company or local government which is supplying electricity directly to consumers. They may or may not be generating electricity for sale as well.

Transmission

The transportation of high voltage electricity around the Grid's transmission network before being transformed into lower voltages for Distribution.

---

[2] Electricity Commissioners, *Twenty Third Report*, 1947-48, HMSO, 1950, 47, p.6.

Acronyms Used

ANOB	Area of Outstanding Natural Beauty
BEA	British Electricity Authority
BEAMA	British Electrical Allied Manufacturers' Association
CEB	Central Electricity Board
CEGB	Central Electricity Generating Board
CPRE	Council for the Protection of Rural England
EDA	Electricity Development Authority, also known as the British Electricity Association (BEDA)
ERA	British Electrical and Allied Industries Research Association
IEEE	Institute of electrical and electronics engineers, previously the IEE Institute of Electrical Engineers
IMEA	Incorporated Municipal Electrical Association
NESCo.	Newcastle Electrical Supply Company
RGS	Royal Geographical Society
SSSI	Site of Special Scientific Interest
WPEHS	Western Power Electricity Historical Society, previously SWEHS South West Electrical Historic Society
WEA	Women's Electrical Association

Chronology of Select Events Significant to this Study[3]

1831 Michael Faraday discovered electromagnetic induction and makes the first transformer and generator.

1871 The Society of Telegraph Engineers was founded later to become The Institute of Electrical Engineers.

1878 Joseph Swann and Thomas Edison invented the lightbulb.

1881 The first continuous electric public lighting began in Godalming Surrey.

1882 The Electric Lighting Act (1882) was passed.

1883 The First Electric Railway was begun.

1888 The Electric Lighting Act (1882) was amended.

1889 The Electric Lighting Act (1889) was passed.

1909 The Electric Lighting Act (1909) was passed.

1919 Birchenough reports on Industries after the War.

1919 The Williamson report was published. The Electricity (Supply) Act 1919 was passed and the Electricity Commissioners were appointed.

1922 The Electricity (Supply) Act 1922 was passed.

1924 The World's first World Energy Conference.

1926 The Weir Report was published. The Electricity (Supply) Act 1926 was passed, the CEB was established and the work to establish the Grid undertaken.

[3] Information taken from J. Sheail, *Power in Trust: The Environmental History of the Central Electricity Generating Board* (Oxford, 1991), pp.xv-xvii and Electrical Timeline for the United Kingdom, The Higher Education Academy accessed via http://www.engineering-timelines.com/how/electricity/timeline.asp.

1927 The first stages for Battersea power Station were given.

1929 The government Scientists Committee was appointed.

1930 Practical methods to remove sulphur from flue gasses is discovered and assisted wiring schemes began.

1933 The Grid was declared complete and began trading at a standard AC electricity of 240 volts and 50 Hertz. It was operating as a system of interconnected regional grids and without the North-West region which had still not completed the process of standardisation. Battersea Power Station opened.

1936 The Electricity Supply (Meters) Act was passed. The McGowen Report was published.

1938 The Grid becomes fully integrated as a national system including the North-East region.

1942 Ministry of Fuel and Power formed.

1947 The Electricity Act 1947 was passed enabling Nationalisation to merge 625 electricity companies to be vested into twelve regional electricity boards, the Grid and electricity generation and transmission was vested from the CEB to the BEA. The Town and Country Planning Act (1947) was passed.

1948 Electricity Supply was Nationalised on the first of April.

1952 The Great Smog of London.

1953 The first section of the 275Kv Grid 'upgrade' was commissioned and the Morton Hampstead Agreement was made.

1956 The Clean Air Act was passed.

It happened during the night of Friday, 29 October 1937. Quite unofficially, the control engineer on shift issued the switching instructions; one by one the seven areas were all coupled – and it worked. Every power station throughout the country which was connected to the grid that night was operating as one completely integrated system.[4]

The Environmental History of the National Grid

THE PROCESS OF ELECTRIFICATION: INFRASTRUCTURE AND INFLUENCE

A Truly National System

The British electricity Grid was the first planned transmission system for electricity. It aimed to increase accessibility, reduce costs and introduce standardisation for generated and supplied electricity. Despite becoming known as 'The National Grid' and being technologically capable of functioning at the national scale it was never intended to do so. Originally the design was for seven interconnected, but operationally self-contained, regional grids. However, as the opening quote from Cochrane reported, a night shift of engineers engaged in unofficial experimentation to prove the system could function successfully, operating nationally. However, the experiments were not initially welcomed by their managers but when demand began outstripping supply in some regions, permanent connections were established, creating a truly National Grid.

Regional schemes were created with the expectation that power stations within them would supply adequate electricity to meet consumer demand in the same geographic area. Each region had a control room from which the network was monitored, and supply and demand was balanced.

[4] R. Cochrane, *Power to the People – The Story of the National Grid 1935-1985* (London, 1985), p.28.

Cooper, who was employed in grid management, recalled the role and London's control room: 'At the heart of it all was the control room with two engineers facing a mimic diagram of the complete system in their own area, so they could see at a glance what generating units were actually connected to the system at any moment and which transmission line circuits were in use'.[5]

This was a completely new system, huge scale engineering in which engineers were developing their skills 'largely by the seat of their pants'.[6] Operations went without difficulty for the most part, and the grid began trading on the 1st January 1933.[7] The first major disruption occurred in 1934 when parts of the South and South-East schemes lost power for thirty to fifty minutes. *The Times* reported it as 'Big Electricity Breakdown', saying: 'Trouble which developed at the Battersea power station yesterday dislocated the grid system in South-East and East England, and places as far away as Peterborough in the North and Twickenham in the West, and Brighton in the South as well as parts of London and the Home Counties were affected'.[8] The Central Electricity Board (CEB) responded giving assurances that, had it not been a Sunday, other power stations would have been online to compensate, and that these circumstances were unlikely to recur.

The problems were due to restrictions of regionality. Despite high voltage transmission lines to move power between generating stations and suppliers, operationally, they it only worked within a region. There were no active connections between regions, so power could not be transmitted between regions to compensate for the losses from Battersea power in that instance. Tie-lines connecting the regions together had not been designed to continuously handle high voltage power, although running all the schemes together would have increased the scale of production and provided even greater efficiencies. However, the CEB had concluded that this might cause 'uncontrollable load swings' and as a result a regional structure was considered best. However, as Cochrane wrote, 'In

---

[5] *Ibid.*, p.23.
[6] *Ibid*.
[7] Central Electricity Board (CEB), *Central Electricity Board Annual Reports and Accounts* (20 vols. London, 1927 to 1947), 7, pp.9-15.
[8] 'Big Electricity Breakdown' *The Times* (London, 1934), 46819, p.12.

reaching that reluctant conclusion, the CEB's senior officers had taken into account every relevant factor – except one: the inborn curiosity of the engineers running the grid control rooms'.[9]

In many respect, electrical engineers had led the electricity supply industry to this point, from initial trial and error installations into a regulated profession. Therefore, it seems fitting that this final step was also led by engineers. One of them recalled his experience:

> The South-Eastern control room in London had facilities for observing what was happening in other areas, and it was from there we issued the instructions to close the switches that would connect one area with another. We'd done it often enough before for short periods and everything had gone smoothly… and the temptation to find out what would happen if all seven areas were switched together was irresistible![10]

Their managers warned that regions should stand on their own and coupling them together was too dangerous. Predicted power shortages for the following winter meant that national connection eventually became necessary to balance supply and demand, and further experimentation proved that it was possible, with no adverse effects. From October 1938 the system was coupled together again and remained connected becoming The National Grid, the largest integrated network in the world at that time.[11]

The introduction of the Grid can be viewed as revolutionary for electricity generation, yet for consumers there was little noticeable difference. Often presented as a *fait accompli,* although construction of its infrastructure took just six years and trading began in the early 1930s, providing supply to the whole country took decades. When companies first sold electricity in the 1880s they did so under licences which effectively provided a supply monopoly over a defined territory. Consumers remained dependent on the licence holder for the area in which their home or workplace was located until nationalisation of the whole industry in 1948. Even beyond

[9] Cochrane, *Power to the People*, p.28.
[10] *Ibid*.
[11] *Ibid.*, p.29.

nationalisation parts of Britain, particularly rural areas, were still not connected to the Grid. This thesis will explore this development process, particularly the contribution of the Grid to the electrification of Britain, and its impact on the environment in which peopled, lived, worked and spent their leisure time.

1. Introduction

Today, the term ‘environment’ conjures up images of conserved landscapes and endangered species, of clean air and clear water. Alternatively, the opposite is true, mountains of waste, oil, plastic in the oceans and barren wastelands are imagined. However, the use of the term ‘environment’ in this context has only been widespread since the 1970s. In this work the word ‘environment’ refers to the immediate and wider situations within which people lived, considering impacts on domestic and working environments as well as the ‘natural environment’ which at the time was termed ‘countryside’. In this way, I do not try to project modern ideas of ‘environment’ backwards but instead attempt to consider how relationships between people and their surroundings was changing, the reactions to these changes, and how these were communicated, particularly when challenges were presented.

Constructed over six years from 1926, the Grid became the first centrally-directed infrastructure embracing almost the entirety of the country using highly visible pylons and transformers connecting power stations. The Grid transformed the efficiency of power use in Britain and provided the capacity for a broad electrification of society. It touched people’s lives in the intimacy of their own homes. It reduced prices whilst increasing availability of electricity to workplaces. The shift from municipal or local supply companies to national co-ordination, its consequences for pollution and safety (in contradistinction to coal and coal-gas), its visual impact on the rural and urban landscape, and an unparalleled and rapid intrusion on property rights. This great infrastructural transformation of the country has received very little attention from historians, especially in its environmental and social aspects (despite John Sheail’s post-war history of the Central Electricity Generating Board). Questions remain regarding how it was visualised, designed, and implemented and the responses of people and communities to the expansion and imposition of national infrastructure and its appearance across the country. Concerns about health and safety, or the association of electricity with improved lives, modernity, national advance, and competitiveness need to be addressed. How was the new networked world perceived to shift relations of economic and social power, opportunities for personal or community empowerment and development, connections with extra-local places and governance?

In Britain, electricity as a technology, was first provided through small monopolies with exclusive supply rights to individual territories. This primarily supplied urban areas where profits could be made while rural areas, where financial returns were smaller or negligible, there was little, or no, supply. The construction of the Grid marked a significant change in British electricity supply, imposing a national infrastructure facilitating more efficient generation of electricity which could be nationally transmitted. However, despite the Grid transmitting electricity across the whole of England, Wales and South Scotland, electricity was not accessible wherever the Grid was visible. Monopolistic distribution networks persisted as the link between generated electricity and the consumer was at the whim of the existing supply companies. The promise of 'cheap and abundant' electricity that the Grid brought with it took decades, and further reforms, to be realised.[12]

This was a paradox; the Grid transformed generation and transmission of electricity supply it did little to change the experience of the end consumer. Whilst the consumers electricity was provided through the Grid when it was trading in a wholesale market, the consumer purchased from the same supplier, governed by the same licence, as they had since supply began. Rather than revolutionising electricity supply, as it is often presented, the Grid was a significant development in the long process of British electrification. While Britain, as a great industrial nation with abundant coal supplies was at the forefront of scientific development, supply of electricity for use in homes and workplaces was slow and even reduced its competitiveness as a leading industrial nation. This suggests that its

[12] 'Cheap and Abundant' was a phrase that was linked to the future of electricity and was used by many different people, particularly around the parliamentary reports which led to the Grid. It will be explored further in Chapter 2.

development and impacts have been complex, distant from its consumes and has to be examined through case studies, which has been my approach.

An article declaring the Grid complete reported, ‘a common complaint that a supply of electricity cannot be had although a Grid line passes “the back door” or a “pylon” is situated in an adjacent field’.[13] This reflected the frustration caused by Grids infrastructure, visible to almost everyone but only providing accessible electricity to a minority. The article suggested that such argument ‘has no validity’, explaining the purpose of the Grid, stating;

> As and when distribution systems are extended and developed, however, the completely co-ordinated main transmission system in the shape of the grid is ready and able to play its appropriate part in the provision of electrical energy to all who may want it, whether they live in the cities or in the outlying parts of the countryside.[14]

Despite the Grid being ‘ready and able’ consumers, particularly rural ones, had to wait for additional infrastructure and reforms to access it which took at twenty years in urban areas and longer in rural ones before connection to the grid became universal.

This work explores how the uses of electricity stimulated this change and how the Grid was the result of negotiation between many actors to embed it into everyday life, which inevitably impacted the whole environment. Cronon stated that one practical lesson that can be learned from environmental history is that ‘Tools and technology are immensely important in shaping natural environments, but their effects are powerfully mediated by the cultures in which they are imbedded’.[15] Electrification was a lengthy process in which engineers, entrepreneurs, financiers, lobbyists and politicians all played significant roles, leading at different times. Whether active or passive they all ‘mediated’ the effect that the technology, its infrastructure, resources and products,

[13] ‘National Grid Complete’ *The Times* (London, 1933), 46619, p.34.
[14] *Ibid.*
[15] W. Cronon, ‘ASEH Presidential Address, The Uses of Environmental History’, *Environmental History Review*, (1993), 17, 3, p.8.

had on the 'natural environment' and in people's homes and workplaces. Whilst electrification is now complete, electricity's role in everyday life is still being negotiated and is changing, particularly its primary fuels, but the Grid's infrastructure, has remained essentially unchanged.

Electricity challenged existing methods of working and domestic chores. The responses of business owners and households to electricity, whether they promoted, opposed or were passive towards it, were part of this negotiated acceptance and ultimate reliance on electricity in everyday life. However this acceptance was not at any price; pockets of resistance formed, either responding to local issues such as smoke or noise from a nearby power station or the aesthetics of pylons in the landscape. Debates were hard fought, and compromise found or enforced when necessary; Luckin's work concentrates on these negotiations, particularly around the Grid.[16] Where impacts were less obvious, or unknown at the time, such as fossil fuel damage, resistance took longer. Fossil fuel damage became widely accepted in the 1970s, resulting in protests and negotiation regarding primary fuels for electricity generation and these negotiations are still ongoing.

Given the length and importance of this process there is surprisingly little written about its history, and less about the Grid.[17] Yet electricity developed from an arcane scientific wonder to become a pervasive entity, considered essential to civilized society, with over eighty-seven percent of the world's population having access to it in 2016.[18] Previous work considering the Grid and electricity supply has concentrated on the ingenuity of individuals and the development of technology which allowed generation and distribution.

Given less attention, particularly in British history, are the enormous changes that electricity brought to the organisation of where and how people lived and worked, adopting the new services it provided. Before electricity individual household tasks took longer; with electricity expectations for

---

[16] B. Luckin, *Questions of Power* (Manchester, 1990), discusses the changes in the interwar period through the preservationists, triumphalists and traditionalists and their propaganda and campaigns.
[17] R.A.S. Hennessey, *The Electric Revolution* (Newcastle-upon-Tyne, 1972), p.v.
[18] World Bank data accessed via https://data.worldbank.org/indicator/EG.ELC.ACCS.ZS.

performance and standards of domestic labour rose and additional tasks were added. This was shaped, of course, by income and gender, which in turn affected participation in labour markets and leisure time. Similarly, workplaces without electricity needed more manual labour and/or alternative power sources. Electricity enabled production lines and mass production allowing more equal roles for men and women in the labour force. The demand for electrical power came initially from industry as its benefits were realised for increasing productivity.

WW1 was a catalyst, discussed later in this chapter, which increased industrial development and led to parliamentary enquiries which eventually culminated in the Grid. However, development of the domestic market involved many factors, discussed further in Chapter 4, and introduced new ways to spend leisure time. Improved transport and communication during the same period contributed to these changes too with radio, faster printing of newspapers, telegrams, tramways and production line manufacture of vehicles, all reliant on electricity. Electricity itself did not drive the changes, but its benefits became desirable, and development of a system to deliver the electricity demanded to power them increased in amount and urgency particularly after WW1.

Electricity has become fundamental to everyday life. This study also investigates how concentration of electricity production, instant accessibility and reliability, independently of where it was generated, has helped create this dependency. It explores how the plethora of tools, appliances and technologies electricity powers have been adopted by society with little understanding or regard for the downstream processes and resources involved in its production.

Environmental History, Technology and the Grid.

Environmental history has emerged as a subject as the extent of the damage that human activity has, and continues to have, on the planet has been realised.[19] It is arguably one of the most interdisciplinary subjects, drawing on humanities, arts and sciences, and provides a useful way to consider the Grid and its impacts. While its breadth allows a comprehensive assessment of research questions, it can also be frustrating because of the demands of integrating or assessing diverse types of evidence, and the difficulty of combining these into clear narratives. Oosthoek explored these ideas and suggested that 'Environmental history is studying the interaction between humans and the environment in the past. This interaction is a two-way affair and not just humans impacting on the environment'.[20] Warde suggested that the wide remit of the subject is one of its strengths but that the lack of boundaries is also a weakness.[21] This has certainly been true for this project for two reasons. First, embedding the Grid and associated electricity, occurred over a long period and therefore exogenous changes have had large impacts. Secondly, the fundamental changes the Grid facilitated are so vast that defining where its role begins, and ends, is challenging. Since its construction the Grid has provided an integral part of the supply system and separating the physical entity from its function does not do justice to the question of its environmental impact.

Many discourses on environmental history discuss the impacts of human activity on specific landscapes, habitats, species or other natural resources or features. Others consider a specific influence, such as a political aim or technology.[22] The common themes are the conflict between the

[19] S. Sörlin and P. Warde, *Nature's end: History and the Environment* (Basingstoke, 2011), pp.1-18.
[20] J. Oosthoek, 'What is Environmental History', Podcast 1 on Environmental History Resources accessed via https://www.eh-resources.org/podcast-1/.
[21] P. Warde, 'Environmental history: definitions, methods and challenges', Podcast 23 on Environmental History Resources, 2009 accessed via https://www.eh-resources.org/podcast-23/.
[22] S.B. Pritchard, *Confluence – The Nature of Technology and the Remaking of the Rhone* (Massachusetts, 2011), G. Hecht, *The Radiance of France – Nuclear Power and National Identity after World War II* (Massachusetts, 1998), L. Skelton, *Tyne after Tyne: An Environmental History of a River's Battle for Protection, 1529-2015* (Cambridgeshire, 2017), G. Summers, *Consuming Nature: Environmentalism in the Fox River Valley,*

rights to use a natural resource and the public right to a clean and healthy environment in which to live and work. This study, which has only just begun to 'scratch the surface' of possibilities, considers the impacts of a nation-wide, manmade infrastructure delivering a technology which underpins British life, enabling and facilitating electricity large quantities of generated electricity to be transmitted to meet demand. To enable something is to make it possible and facilitating something, meaning to make it easier. The Grid did both providing access to electricity independently of location.

Having identified that environmental history and the subject matter have far reaching boundaries, the specific question of what environmental impact the Grid made, must be defined. The Grid is not just about wires and pylons, any more than the environment is just about nature. Much of this work concentrates on 'impact', defined as either a forceful collision or to have great influence on something. For the Grid, again both apply; the physical Grid brought a forceful collision of pylons and wires marching across the landscape resulting in battles for occupancy in different parts of the country and exerted influence though its enabling and facilitation properties.

'Environment' is a word used progressively since the 1850s, with a rapid increase in the 1970s and 1990s as environmental movements gathered momentum. '[T]he environment only became synonymous with the natural world during the twentieth century, and probably only widely recognised as such during the 1960s', almost thirty years after the grid began trading.[23] Protections afforded through legislation such as the Clean Air Act, Areas of Outstanding Natural Beauty, National Parks and Sites of Special Scientific Interest, along with the institutions that regulated and enforced them, offered a new framework and language within which dialogue pertaining to the environment could become consistent. However, these Acts were invoked long after the Grid was established of

1850-1950 (Kansas, 2006), R. White, *The Organic Machine* (New York, 1995), and S. Sörlin and P. Warde, *Nature's End* are examples of works which demonstrate these different approaches to environmental history.
[23] P. Warde, 'The Environment' in P. Coates, D. Moon and P. Warde, (Eds.), *Local Places, Global Processes* (Oxford, 2016), p.32.

under the CEB's management. 'Environment' was not, as we will see, a word widely applied in contemporary debates while the Grid was being imagined, constructed and established.

For these reasons, environment in this study describes the situation and surroundings which people occupied. People's influences and responses to landscapes, technology, resources and their interactions are included; although most direct consideration is given to people, location and resources, other factors must remain in focus and are included. To ensure that a holistic view is taken the 'environment' cannot be reduced to a narrower definition unless there is a specific reason to do so because no process within any environment is isolated. The interdependence of relationships and feedback is fundamental to environmental interactions, whether natural or man-made. Ignoring the influence of wider environmental actions is often why changes to processes, partly or fully, can produce both expected and unexpected consequences. Interdependent relationships are vital to maintaining balance in natural systems though feedback mechanisms, and management systems in manmade systems. The cascading effects of change can be widespread; lasting longer, spreading further and sometimes diverging from its intention.

Therefore, limitations must be imposed upon the issues studied in this case, although they doubtless compose only part of a wider impact. Whilst as many actors as possible are incorporated, I will primarily consider the very direct consequences of the Grid as I defined it, although its 'ripple effect' still impact many aspects people's lives and interactions with the environment. This is similar to the way Sheail, in his book, subtitled 'an environmental history of the CEGB', approached his work concerning the Central Electricity Generating Board (CEGB), considering immediate impacts but being mindful of wider implications.[24]

The Grid transmitted power to where people were situated. Transport for people, and industry improved, making longer commutes and goods movement easier as tramways and railways were electrified. This enabled people to live outside of town and city centres, further from their

[24] J. Sheail, *Power in Trust.*

workplaces where housing was cheaper in the emerging suburbs. Over time new areas, such as the garden cities, were completely designed from scratch, including utilities, while others were 'retrofitted'. Power was transmitted to the people where suppliers could make profits and people moved to the power when it was beneficial.

Industry migrated further inland as electricity developed, and reliance, developed during the industrial revolution, on waterways for energy and transport reduced. Towns and cities expanded into sprawling suburbs, not because of electricity itself, but because of the changes it enabled. New roads and reliable vehicles, better railways and accessible power allowed priorities dictating where people lived and worked to shift, albeit over many years. New production methods, precision engineering and interchangeable parts, alongside new materials influencing products which changed lifestyles and domestic roles too.

This demonstrates some of the difficulties determining and limiting the impacts of 'The Grid' despite its seemingly obvious tangible parameters. The Grid as a system of pylons and wires reached between power stations and distributors but at different moments in time it has included different physical and management attributes. For example, when first constructed it was regional before interconnection making it national. Grid operation also contributed to these difficulties; whilst the CEB controlled generation in power stations which supplied power to the Grid, they had little control over the distributors to whom they sold. After nationalisation, the British Electricity Authority (BEA), successors to the CEB took ownership and operation of all aspects of generation, transmission *and* distribution.

Having defined what environmental impact of the National Grid means, a further difficulty is the lack of an established historiography. There is little mention of electricity, and even less about the Grid, in many general histories of Britain, even social or economic histories.[25] There are biographies of the

[25] A. Marr, *The making of modern Britain* (London, 2009) and S. Broadberry, *Market Services and the Productivity Race 1850-2000 – British Performance in International Perspective* (Cambridge, 2006), C.P.

famous electrical engineers, such as, Edison, Ferranti and Swan and work by dedicated enthusiasts writing histories specific to their interests but rarely, if ever, is any attention to the Grid. Even a work reporting the history of the Newcastle Electricity Supply Company, (NESCo.), and Merz does not discuss the Grid in any detail, despite Merz being highly influential in promoting interconnection and designing the technical specification for the Grid alongside Snell.[26] For this reason, I will review the historiography which is directly relevant to the grid's conception, construction or use. Other works will be discussed as they become relevant in later chapters.

The Grid has only been the main focus of one single work, *Power to The People – The Story of the National Grid,* by Cochrane, an electrical engineer, published in 1985 to celebrate its fiftieth anniversary.[27] Most historiography has focused on either the business and regulatory history of the wider electricity industry or the technology. There are eight works directly relevant to the British Grid, of which five were published in the 1970s, reflecting a desire to document the history of electrification after the first generation of the nationalised industry. These works will be briefly introduced here before a more thematic discussion.

The earliest work was Ballin's, *The Organisation of Electricity Supply in Great Britain* published by Electrical Press Ltd in 1946, just before nationalisation.[28] He provided a full discussion of municipal and private ownership, alongside political changes from the late 1800s to the early 1940s. It addressed the industry prior to the Grid demonstrating how movement towards centralised generation and transmission were slowly taken. Despite the period it discussed, and details it provided, the Grid is only briefly mentioned and seen a means to an end. [29]

Kindleberger, *Economic development if England and France 1850 to 1950* (Massachusetts, 1964), p.50 mentions electricity standardisation but not the grid, and other works mention electricity but not the grid.

[26] J. Rowland, *Progress in Power – The Contribution of Charles Merz and his Associates to Sixty Years of Electrical Development 1899-1959* (London, 1960).

[27] Cochrane, *Power to the People,* in which these are chapter titles given in this book.

[28] H.H. Ballin, *The Organisation of Electricity Supply in Great Britain* (London, 1946).

[29] R.Y. Sanders, 'The Organisation of Electricity Supply in Great Britain. by H.H. Ballin' *The Economic Journal,* Vol. 56 (September, 1946), No.223, pp.476-478.

Electricity Supply in Great Britain, of 1952*,* by Self and Watson traces the development of electricity supply as a national industry, primarily concerned with the political and administrative controls it was subject to both before and after the Grid. The authors' own rationale suggested that 'Its primary objective is to review the development and organisation of the public service which is charged with the execution of these technical services'.[30] It should be noted that they referred to electricity supply as a public service which is not obvious from other works. Much of the book discussed the governing Acts and concentrated primarily on the beginnings of the new structures under nationalisation at the end of the 1940s.

Hannah's *Electricity Before Nationalisation,* subtitled *A study of the Development of the Electricity Supply Industry in Britain to 1948,* provided exactly what the subtitle promised. As a business and economic historian, he provided a detailed chronology of electricity supply development in Britain from the late 1800s to the middle of the twentieth century. The preface to the book described how the Electricity Council commissioned him to write it and explained the reasons it was needed. 'The industry had been neglected by historians, yet its claims to attention were not inconsiderable', and that the industry 'exemplifies, arguably more than any other industry, the profound impact of technical innovation and economies of large-scale operation on modern economic life'.[31]

As Hannah agreed to the request of the Electricity Council, he had access to their records and more importantly they agreed 'that the judgements made in the history should be on a "warts and all" basis, and that final responsibility for it should rest entirely with the author'.[32] The resulting book placed the origin of the supply industry within the context of the economy and scientific understanding of the late nineteenth century and traced its development through time. He followed technological and business challenges for the industry, its regulation, mixed private and municipal

[30] H. Self and E.M. Watson, *Electricity Supply in Great Britain – Its development and organisation* (London, 1952).
[31] L. Hannah, *Electricity before Nationalisation – A study of the development of the electricity supply industry in Britain to 1948* (London, 1979).
[32] *Ibid.,* Preface.

ownership, and the catalytic effects of war. He included information regarding the design of, legislation for, and construction of the National Grid and its first decade of trading.

Hannah's work was published in 1979, as was Hennessey's work *The Electric Revolution.* In his introduction Hennessey stated that historians have neglected the secondary fuel industries of gas and electricity and suggested that any idea that this is 'because they seem in anyway less interesting or important, or even less romantic than railways, steelmaking, coal mining or grand engineering' is a 'misconception' and that he aimed to 'rectify' through his work.[33] He encompassed a shorter historical period, of 1880 to 1930, and used his term 'Electric Revolution' as a 'convenience' to describe the first fifty years of development.[34]

Both Hannah and Hennessey's work covered similar issues: the plethora of small companies providing electricity, Britain's failure to keep up with other countries and the impact of politics and legislation. Both authors recognised the importance of organisational coordination, using examples from London and NESCo. They were written to ensure a historical record of how the industry developed and Hannah's work in particular has informed, if not underpinned, much of the literature that followed it.

Other works published in 1979, were *The British Electrical Industry 1875-1914, The economic returns to a new technology* by Byatt and *Heavy Current Electricity in the United Kingdom* by Hinton. Byatt's work was based on his PhD Thesis, available from 1962, and referenced by Hennessey and Hannah. It is an economic history exploring the costs and returns of investment in electrical power supply and manufacturing.[35] However, he only considered the period before 1914 and does not include the period in which the Grid was conceived and constructed. Byatt was primarily interested in how new

[33] R. A. S. Hennessey, *The Electric Revolution,* (Newcastle-upon-Tyne, 1972).
[34] *Ibid*., Introduction.
[35] I.C.R. Byatt, *The British Electric Industry 1875 to 1914 – The economic returns to a new Industry* (Oxford, 1979).

technology and industry developed economically, particularly regarding returns on capital investment in new and unproven technologies.

Similarly, Hinton's work, followed British electricity supply development tracing the pioneers of electricity who created a parochial supply working within the confines of government legislation. His works extended through the period when the Grid was constructed until nationalisation. Hinton described how his work was written to draw attention to the political framework in which the first electricity companies operated, and the governance of the National Grid. His preface references the lag of Britain 'behind all other industrial countries in the later stages of development up to 1947 when the industry was nationalised' saying 'It shows that by 1926 Britain was the most backward of all industrial countries in the structure of its electrical power industry and its use of electricity. It shows the crippling effect of the Second World War and the brave efforts to catch up with the rest of the world after government shackles had been loosed'.[36] Hinton was Chairman of the board at the CEGB and Self was Deputy Chairman of the BEA and the Chairman of the Electricity Commission. The histories they provided were informed by their experiences within the industry and could not have been written by anyone without that background.

In 1983, Hughes published *Networks of Power – Electrification in Western Society 1880-1930* and is a comparative analysis of electricity development in three different nations, America, Germany and Britain. This comparative study used foundations set by the other authors and primary sources to consider the technological systems built or developed over the long term and examined the networks of expertise and resulting educational and professional structures. He linked previous histories to begin to explore the drivers of change and the responses and interactions of technology, its engineers, politicians and society to such large-scale changes. Hughes's work on electricity and

[36] C. Hinton, *Heavy Current Electricity in the United Kingdom – History and Development* (Oxford, 1979).

other large technology systems expanded the area of study, using electricity as a case study to explore interactions between technology and people.[37]

In 1990 Luckin's work *Questions of Power, followed* in 1991 by Sheail's *Power in Trust,* examined the impacts of electricity on the environment, but also on society and culture. Luckin provided a real sense of the constant negotiation between the politicians, experts and enthusiasts with particular interests, whether he defined the as triumphalist or preservationist. He produced the story of the electrical supply industry growing through adolescence, testing its boundaries and maturing as it found its place in society. The Grid played its role as it developed from a local to national operating scale, distributing power more evenly, although not yet universally. Sheail picked up the story after nationalisation, although he referred back to earlier events pertinent to his arguments, such as the construction of Battersea Power Station in the 1920s and '30s as an important moment in the story of air pollution. The twenty-year difference between the CEB and Central Electricity generating Board (CEGB) when the BEA operated the Grid is important because it was during this period that the 'environmental' movement solidified, with local struggles beginning to amalgamate and national bodies consolidating and championing these concerns. The early 1990s established environmental history as its own discipline and these works compliment the earlier ones.

Progression is evident through the works, with earlier ones being about recording events and experience for people who had worked in the industry. Hughes and Hennessey, themselves suggested they wrote their works to record the history of the electricity supply industry. Hughes introduced more comparative history and theoretical frameworks and environmental histories in the early 1990's. However, the small number and disparate nature of the historiography make it difficult to discuss them collectively. Therefore, the discussion of the core historiography is based around themes prominent through these works and important to British electricity history, particularly changes regarding the Grid.

[37] T.P. Hughes, *Networks of Power – Electrification in Western Society 1880-1930* (Baltimore, 1983).

Scales of Visibility

Electricity is invisible. It only becomes visible through pylons, posts, wires and power stations that create and transport it, and the 'life' that it brings to appliances and devices which make it visible to consumers. The benefits of these appliances, devices and methods of working, were the stimulus to increase and spread electricity use. Changes in ownership, control, generation and transmission systems gradually promoted electricity from an expensive local commodity to become an essential national utility. Its visibility has increased because the distribution networks, supply and consumption have expanded and paradoxically visibility has decreased as sockets and wires have become further integrated into structures, and rechargeable devices have become more common. The following sections will set out how these themes have been developed in the historiography.

A Parochial System

Initially, in the 1880s and '90s, electricity was sold for lighting. The first years of public supply were essentially experimental with no governing legislation, and electricity for lighting was purchased by people had access to it and wealth to afford it. These first suppliers were entrepreneurs creating businesses where they identified a market. Often first contracts were to supply street lighting and retailers in town centres. Suppliers offered electricity in densely populated areas where the potential for profit was greatest.

Hughes described the emergence of this system, calling it a 'parochial industry' but this description seems to have been used by Stanley Baldwin first, in his leader's speech in 1926, when he talked about 'Cheap Electricity' and referred to 'the parochial line upon which electricity has grown up in this country'.[38] Hinton suggested that early legislation introduced to control electrical supply created a difficult environment, forcing development along parochial lines. There is general agreement that the electricity industry might have been different without the restrictions imposed in 1882 Act, which restricted suppliers by including a 'compulsory purchase clause' in licenses allowing the appropriate local authority to purchase, under favourable conditions, any private supplier in their locality after twenty-one years. This almost certainly did slow development. Alongside reducing the number of willing investors, it reduced competition and meant that the fledgling industry was, at best, left in a state of inertia. This is demonstrated by the reduced numbers of applications for licences after first Act was invoked followed by a rapid increase as the 'compulsory purchase clause' was revised to forty-two years in the 1888 Act, discussed in detail in Chapter 2.

Only Hinton and Hannah briefly discuss the environmental impact of this early development. Hinton described difficulties including discharges of hot water preventing sewer men carrying out their work, and complaints such as the 'tremendous vibration and noise, added to the fumes of smoke and steam [which] produced such a nuisance as to be almost unbearable' and of 'vibration so extensive it stopped neighbouring clocks'.[39] His chapter title 'Development, thoughtless of the environment' described this well - both in terms of attitudes at the time, and also the complete lack of an environmental framing of such issues at the turn of the twentieth century.[40] There were interventions, such as cleaning up rivers, and interventions to curb the issues Hinton described. However, these were not about protecting the environment, as it is currently understood but was to protect people and property.

[38] S. Baldwin, 'Leader's speech', Conservative Party Conference,1926 accessed via http://www.britishpoliticalspeech.org/speech-archive.htm?speech=87.
[39] Hinton, *Heavy Current,* p.34.
[40] *Ibid.,* p.33.

A Regional System

A precursor to the Grid was the Newcastle Electric Supply Company Limited (NESCo.), and it features throughout the literature as an anomaly when the rest of the industry was parochial. A history of the company focused particularly on the vision of its founder, explaining, 'it was largely owing to [Theodore] Merz's insistence on the benefits of a large supply area fed by fewer larger power stations, that this part of Britain attained such importance in electrical development'.[41] Theodore Merz, was an academic and businessman from Newcastle. His son Charles Merz was heavily invested in the successful company and would go on to develop a successful international consulting engineering partnership with McLellen. Charles is the Merz referred to through this work. Ballin noted his importance as an individual to shaping this regional system, saying, 'His Policy was to anticipate load and not wait for it'.[42] Having a larger capacity to generate without having guaranteed consumers was considered risky and few supply companies attempted it but NESCo. benefitted from the savings achieved through large scale supply.[43]

Helping their large-scale approach was demand from shipbuilding and other heavy industry they supplied, and 'there was another local advantage, too. All power stations in those days relied entirely upon coal; and coal in the Newcastle area was cheap'.[44] Moreover, Merz's attention to detail meant the site of Carville power station had been arranged so that the coal was delivered directly to the boiler room with no manual labour, and it was this forethought and detailed planning which led to his successes as an electrical engineer and businessman.

Byatt reported that NESCo. opened Carville Power Station in 1905 which at the time supplied the lowest cost electricity in the country. Regional interconnection of all their power stations meant the

---

[41] Rowland, *Progress in Power,* p.4.
[42] Ballin, *The Organisation of Electricity Supply*, p.16.
[43] Hughes, *Networks of Power*, p.449.
[44] Roland, *Progress in Power*, p.23.

most efficient ones could be operated continuously and the less efficient ones included when demand increased. As a result, their load very efficient with a load factor from forty to fifty percent when the high twenty percent range was considered efficient in most power stations.[45] This was essentially the principle behind the Grid, concentrated efficient generation which could widely distributed.

Unsurprisingly Hannah devoted attention to NESCo., reporting that whilst one-twentieth of the UK population lived in the North-East it accounted for about one-eighth of all UK electricity sales but had only about one-sixteenth of the UK's generating power.[46] The success of the company is attributed to its forward-thinking technical choices, such as using AC current, a well-managed load factor and the scale of production and distribution. However, several suggest that there were advantages specific to its location: agreements with other suppliers and a customer base of heavy electricity users, such as shipbuilders, including some family connections, making it an ideal place for electricity supply. I suspect that Merz would have been successful wherever he was located, and he had very successful international projects which provided his good reputation. Even with the advantages mentioned, without the foresight to interconnect the power stations for load efficiency, and their choice of AC rather than the more common DC at that time, it is unlikely they would have been as successful. This is because their efficient production methods enabled them to charge favourable prices of 1.03d. per kWh, reduced from 4.12d. per kWh just six years earlier. Merz claimed, in 1908, 'that there were no shipbuilders or engineers on the north bank of the Tyne who did not obtain at least 95% of their power from the company'.[47] This was a huge claim because as late as 1948 over forty percent of industry was still generating its own electricity rather than purchasing it from a public supply.

[45] Byatt, *The British Electric Industry,* pp.118-122.
[46] Hannah, *Electricity before Nationalisation,* p.33.
[47] *Ibid*., pp.32-33.

All authors, except Byatt, pay close attention to the period between 1919 and 1926 when the Electricity Commissioners, five appointed electrical experts with a brief to direct policy, were actively encouraging interconnection and larger scale generation through cooperative working but lacked enforcement powers.[48] Ballin discussed the difficulties the Electricity Commissioners had promoting cooperative working, particularly between municipal and private companies as they attempted to introduce a coordinating layer of control. The aim was for Individual undertakers to control local distribution, cooperative supplier partnerships to control regional generation and sell to local undertakers and the commissioners would 'oversee' these new regional partnerships. However, despite this resulting in a handful of cases where cooperation worked, there was also fierce opposition. This was led by Balfour, one of the founders of Balfour Beatty, and later a politician. Hannah described how part of his motivation was because he felt like an outsider to 'the establishment' despite his commercial successes. This, alongside resentment at not being selected to serve on the Williamson Committee, which led to the establishment of the Electricity Commissioners, and his dislike of Snell, the chief electrical engineer, government advisor and Chair of the Electricity Commission, contributed towards his robust opposition.[49]

Regional operation was only successful in a handful of places because the Electricity Commissioners never had sufficient authority to enforce the cooperation necessary.[50] They were described by Hinton 'as a toothless organisation; they could only act by persuasion'.[51] Although the Williamson Committee had recommended greater powers this was not converted into legislation, identified as a problem by all historians of this issue. During this time though, the Electricity Commissioners had been effectively auditing the country's electricity system and suppliers as part of their role, and this provided evidence which together with the regional principles set out by the Williamson committee,

[48] Hannah, *Electricity Before Nationalisation,* p.70.
[49] *Ibid.,* pp.70-74. This provides detailed analysis of this opposition and suggests potential origins in more detail.
[50] Ballin, *The Organisation of Electricity*, pp.116-118.
[51] Hinton, *Heavy Current*, p.43.

was used by the next parliamentary committee, chaired by Weir, on which Williamson served. The question posed to this committee was almost the same as the one the Williamson Committee had previously addressed but was phrased differently: it became a ‘national problem of electricity supply’, rather than just ‘the problem of electricity supply’.

A National System

All of the authors cited above discussed the slow development of a national supply and accompanying policy and legislative framework. Ballin, whose work was published closest to the Grid’s introduction, wrote primarily about legislation and the reactions of companies and municipalities who were providing supply at the time. He suggested that important concessions were made to these interests by the government in the Act of 1926 empowering the Grid, to ensure the legislation was passed. He referred to the interests of private companies and municipalities, which were mostly unchanged, or indeed actually more valuable after the Act was passed. Merz described the legislation as ‘in many ways a typical British compromise’.[52] Hinton, who wrote candidly about his views on the political reasons behind these changes, suggested that the 1924 First World Energy Conference prepared the way for the Weir Committee whose ideas would shape the Grid; Britain was shown to be ‘a sorry laggard, hardly fit to be compared with the great industrial nations’.[53] He extensively compared systems and prices for electricity internationally, and quoted Heineman from Brussels who said at the conference, ‘Does not the marked difference in prices of electricity suggest some fundamental error in the organisation of its production and distribution in Great Britain?’. Heineman also suggested the reasons might be ‘an unnecessary multiplicity of producing and distributing companies…this results in an excessive number of networks. These are

[52] Rowland, *Progress in Power*, p.80., Hannah, *Electricity before Nationalisation*, p.94. and G. Lincoln, *The Public Corporation in Great Britain* (Oxford, 1938), p.96.
[53] Hinton, *Heavy Current*, p.47.

frequently superimposed and intertwined but, despite this, are unable to render mutual assistance'. Further, he stated that there was 'the strict rigidity of operation, resulting from legal restrictions, which affords a liberty totally insufficient for private initiative'.[54]

This conference, and reports by Birchenough into Britain's industries post WW1, helped to promote a sense of urgency around the changes suggested by Weir and implemented by Parliament to create the Grid.[55] Hannah addressed many of the business, financial, personnel and institutional factors affecting these decisions. He paid more attention to the structure of the Grid and its supporting institutions than the other authors. Hughes and Cochrane noted the enormous physicality of the Grid whilst Luckin and Sheail considered its impacts using language more familiar to the environmental movement of the 1970s. However, the wider impacts of the Grid such as changes to where and how people lived and worked as abundant energy became more widely available, and the resultant changes to lifestyles and relationships are less well studied. These issues have been addressed by Nye in his work *Electrifying America*, writing:

> It is fundamentally mistaken to think of 'the home' or 'the factory' or the 'city' as passive, solid objects that undergo an abstract transformation called 'electrification'. Rather, every institution is a terrain, a social space that incorporates electricity at a certain historical juncture as part of its ongoing development. Electrification is a series of choices based only partly on technical considerations, and its meaning must be looked into for the many contexts in which Americans decided how to use it.[56]

Nye examined the enormity of change brought by electricity which created a twenty-four-hour society, able to carry out everyday life around the clock rather than being tempered by natural daylight, along with a plethora of new appliances. These impacts are studied by contemporary

[54] *Ibid.,* p.49.
[55] 'Industries After the War', *Journal of the Royal Society of Arts* (1918), 66, 3432, pp.644-645. The Birchenough reports are discussed in further detail in Chapter 2, the articles were not attributed an author when printed in the Journal.
[56] D.E. Nye, *Electrifying America – Social Meanings of a new technology 1880-1940* (Massachusetts, 1990), p.x.

ethnologists and anthropologists in developing parts of the world where electricity is still novel but have received relatively little attention from historians in Britain.

Electricity, Society, Domesticity and Industry

It should be clear by now that the literature gives considerable attention to the personalities and qualities of individuals as part of the story of the developing electricity industry. It is useful to discuss this theme through the categories of actor to which they belonged, and how agency is portrayed in these histories.

Politicians

Both Hinton's and Self & Watson's books are written in the light of their experience as former chairmen of the CEGB, BEA or Electricity Council. Both works suggests they found difficulties in the political landscape and they felt restricted in different ways at different times. Hinton suggested that legislation created a restrictive environment in which industry was expected to deliver large quantities of cheap electrical power and blamed its parochial nature on the 'shackles' of governmental control during the 1920s and '30s.[57] Self & Watson discussed having to navigate a route through controlling legislation; indeed, they suggested that restrictions were imposed from outside the electricity supply industry in the 1940s and '50s, and presented for example the need to invest capital expenditure in flue-scrubbing as a 'nuisance' to the electricity supply industry.[58] Hinton used the same word to describe reduced air quality and noisiness from local generation. He described flue emissions as a 'nuisance' for the environment and its inhabitants but maintained that

[57] Hinton, *Heavy Current*, pp.42-55.
[58] Self and Watson, *Electricity Supply in Great Britain*, pp.170-176.

legislation itself had created this. Politicians and legislation emerges as an interference in these accounts from inside the industry.

Politics is a major theme of Hughes's work. Indeed, his section on the British system is titled 'The Primacy of Politics'. He discussed the responses of politicians to developments that engineers were trying to promote, quoting Lloyd George, president of the Board of Trade at the time, telling Merz, already a well-known electrical engineer, 'My dear young friend, this is not a question of engineering, it is a question of politics'.[59] Hughes, like Hinton, suggested that early legislation to control supply created a difficult environment resulting in parochial development. To varying degrees, all the works suggested that politicians were trying to catch up with technology, creating legislation to control what was already in place and which inevitably shaped, but did not intentionally determine future development. I would agree that politics was important, but its significance and the form that influence took varied over time. And such influence was not limited to politicians. Engineers, interest groups and consumers, and potential consumers also had significant roles.

Engineers

Alongside core historical works there are also biographies of individual electrical engineers.[60] This is particularly true of early periods when they appear as innovators. Hughes described engineers throughout his writing noting their inventions, schemes and companies, opening his work with the

[59] Hughes, *Networks of Power*, p.251.
[60] Merz is discussed in Hughes, *Networks of Power*, Rowland, *Progress in Power* and many others. Ferranti is also discussed most works but has a number of specific papers written about his life and work including J.F. Wilson, *Ferrante and the British Electrical Industry – 1864-1930* (Manchester, 1988), A. Ridding, 'S.Z.de Ferranti Pioneer of Electric Power' *(A Science Museum Booklet, London, 1964)* and B. Spear, 'Sebastian de Ferranti – Electrical engineering pioneer and enthusiastic patentee', *World Patent Information* (2013), 14, pp.230-234. There are also a number engineers, particularly British ones, discussed in G. Weightman, *Children of Light, How Electricity Changed Britain Forever* (London, 2011).

‘Pioneers', the first generation electrical engineers at the forefront of public electricity supply.[61] Hennessey also dedicated a full chapter to ‘The Engineers’.[62] Byatt talked about the ‘Engineers and Entrepreneurs’, drawing out distinctions between practising engineers and business men, demonstrating how the ability to manage the financing of supply was vital for a successful enterprise alongside good engineering.[63] Hinton went further separating ‘The Scientist and The Pioneer’ distinguishing between the engineers who were inventing and those entering the world of commerce.[64] Interestingly, engineers are not discussed in Self & Watson. Their narrative relates to administration and legislation rather than technology.

Engineers are important to Hughes because of his interest in technology transfer and comparative view of different nations. He examined how connected professionals interacted inside and outside of their professional bodies and how ideas were transferred between them.[65] Hughes differentiated between electrical engineers using terms such as inventors, entrepreneurs or systems thinkers. The terms Hughes used tend to be related directly to specific engineers, and he reported the complex relationships that developed over time. The distinction between engineers and entrepreneurs is important because engineers required finance for their projects, usually provided by wealthy backers who believed they would profit from any investment. Edison, for example, was backed by Stone and Webster and Ferranti was backed by Sir Lyndsay Coutts. The engineer’s role in the arrangement was to convert ideas into profitable enterprises. Although, Edison and Ferranti were brilliant engineers, Edison was also commercial in his approach whereas Ferranti was more interested in pushing his knowledge and the limits of technology and proved to be more experimental than commercial.[66]

[61] Hannah, *Electricity before Nationalisation*, pp.1-35.
[62] Hennessey, *The Electric Revolution*, pp.105-115.
[63] Byatt, *The British Electric Industry*, p.184.
[64] Hinton, *Heavy Current*, pp.5-9.
[65] Hughes, *Networks of Power,* pp.47-78.
[66] *Ibid.,* p.97 and pp.387-394.

In a rather different fashion, Luckin treated the engineers as a group of protagonists rather than as individuals, fitting into his narrative based around a split between propaganda from triumphalists (advocating expanded infrastructure) and traditionalists (campaigning for conservation). In this regard they are seen more as representative of a type than actors with their own importance and networks.

People

This section is entitled 'people' rather than 'consumers' because many people who were unable to be electricity consumers for many years after its introduction were still a part of the electrification process, whether actively or passively. There is a larger body of work about electricity supply than for its consumption, although there is a growing interest in this theme. Like most work seeking to reflect the views of large populations, studies are either detailed and based on small samples or large samples with an attendant loss of detail and variation. Mainstream electrical historiography tends to consider the consumer in respect to interactions with suppliers, advertising, and how aggregate supply and demand changed over time. Bowers took a quantitative approach, considering the number of wired homes and the proportion of household expenditure spent on appliances based on a national study, which will be discussed in Chapter 4.[67] A more recent article by Carlson-Hyslop considered a specific case study of underfloor heating in a high-rise building in the post-war period. This study had more detail about consumer behaviour but only considered a few individuals.[68] Similar work has used housing provision to investigate consumer responses to electrical technology but ensuring representation of all consumer types is almost impossible. Hankin

[67] B. Bowers, 'Electricity' in Williams, T.I., (Ed.), *A History of Technology, Volume VI, The Twentieth Century, c. 1900 to 1950* (Part 1, London, 1978), pp.284-97.
[68] A. Carlson-Hyslop, 'Past Management of Energy Demand: Promotion and Adoption of Electric Heating in Britain', *Environment and History*, 22, 1 (2016).

discussed the impact of electrical appliances in households and ideas around 'Buying Modernity'.[69] This work demonstrated the slow adoption of new appliances available, as do studies by Bowden and Offer.[70] Hankin emphasised the role of women in the domestication of electricity and considered electrical advertising, quoting Luckins' description of promotions aimed at women: 'Electricity, in a social environment such as this, became a quasi-magical elixir which would abolish not only housework but every discomfort and inconvenience which detracted from leisure and narcissism'.[71] This applied to advertisements aimed at both women and men, and whilst Hankin investigated this for the domestic sphere, Luckin extended it to other literature promoting all aspects of electricity.

A wider consideration of the Grid's impacts and the influence it has had in all aspects of life can be found in Trentmann's *Empire of Things.* This takes a long view of consumerism and argues many of the developments from the turn of the twentieth century were only possible because of increased energy availability primarily, but not exclusively, made possible by electricity. This was recognised in the introduction, where he described our 'materially intensive lifestyles' as 'fired by fossil fuels'.[72] He described the period during inception and development of electricity through to nationalisation and beyond, which was fuelled almost exclusively by coal. Where electricity was inaccessible or unaffordable, coal-gas, or coal itself was used for household needs. The consumption of coal, gas and electricity has increased as they have increasingly made everyday tasks easier. Trentmann points out that it is habits we have formed in everyday activities which contribute more to carbon-dioxide emissions than 'conspicuous consumerism'. He suggested: 'It is precisely the usefulness of such

---

[69] E. Hankin, 'Buying Modernity? The Consumer Experience of Domestic Electricity in the Era of the Grid' (PhD Thesis, University of Manchester, 2012). The second half of this thesis considers the advertising and take-up of domestic appliances.
[70] S. Bowden and A. Offer, 'Household Appliances and the use of Time: The United States and Britain' *The Economic History Review,* (1994), 47, 4, pp.725-748.
[71] Luckin, *Questions of Power*, p.44.
[72] F. Trentmann, *Empire of Things: How We Became a World of Consumers, From the Fifteenth Century to the Twenty-first* (London, 2016), p.2.

habitual forms of consumption and their 'normality which makes changing them so difficult'.[73] I would suggest that alongside such engrained habits, performed with little thought, the actual resources consumed have become increasingly removed from people's consciousness. Electrification made tasks like pressing a switch for central heating and hot water rather than maintaining coal fires for these tasks very easy. Whilst coal-gas made this easier it was less flexible than electricity and still visible as it was consumed. Electricity has become increasingly invisible where it is consumed, and its infrastructure hides in plain sight. However, the contribution electrification made, and continues to make to everyday life is often underestimated and, this is, I would suggest, because if it is thought about at all, it is considered mundane and taken for granted until supply is disrupted.

Conflicts and Resolutions

In addition to identifying key groups of actors, the literature on electrification between the late nineteenth century and 1930s has also highlighted some crucial wider forces and events in shaping development, discussed in the following sections.

External Conflict - War as a Catalyst for Electrical Reform

Many authors recorded the changes WW1 brought, reporting how Britain found it difficult, or sometimes technically impossible, to meet the war's demands for electricity to produce munitions and leading to the Williamson Committee being tasked to consider the future of electrical supply. Hannah discussed these events in detail, including the contributions of engineers and changes brought about by the demands of producing additional electricity when resources, including coal,

[73] *Ibid*., p.15.

became increasingly scarce.[74] Self & Watson stated, 'It is an inevitable feature of war, and especially war on a world-wide basis, that it should provide a forcing period for technological development: the electricity supply industry was no exception to this rule'.[75] Hughes referred to it as 'War and Acquired Characteristics' and suggested it led to the 'distinct surprise' of the Grid's development among those who were observing the 'tense and frustrating efforts to reorganize Britain's electrical supply industry'.[76] In fact, all authors writing about this period, suggested that WW1 either catalysed change or indeed represented change itself which eventually culminated in a national system. Ballin and Bowers included the most quantitative information regarding the effects of WW1 but Ballin also emphasised security issues surrounding power stations. He referred to 'broken links of efficiency' reported by the press and suggests that 'small plant was uneconomical and possibly dangerous', which was partly why interconnection was so important.[77]

Later, WW2 brought changes to the Grid, catalysing further technological development after 1945. Hannah dedicated a whole chapter to the 'War and Post-War Crisis', the crisis being more about fuel scarcity than the Grid.[78] The main impacts of WW2 on the Grid are summarised by Cochrane, reporting the memories of an engineer from the main control centre;

> The air raids that knocked out Fulham power station and badly damaged the one at Battersea left London desperately short of electricity, but we were able to get heavy imports of power from South Wales and Scotland: and it was the same time and time again with the other attacks on Coventry, Portsmouth, Plymouth and other large cities. By mobilizing the resources in other parts of the country, help could be brought wherever it was needed in a matter of minutes.[79]

---

[74] Hannah, *Electricity before Nationalisation*, pp.53-62. This was scarcity due to mining issues, not lack of coal itself.
[75] Self and Watson, *Electricity Supply in Great Britain*, p.32.
[76] Hughes, *Networks of Power*, p.323.
[77] Bowers, 'Electricity', p.287, and Ballin, *The Organisation of Electricity*, pp.95-101, quotes from p.96.
[78] Hannah, *Electricity before Nationalisation*, pp.318-28.
[79] Cochrane, *Power to the People*, p.32.

This was demonstrated locally too, for example, Plymouth's power station was bombed in 1941. Electricity was off for up to three days, except for essential supplies which were provided by the local naval dockyard through its Grid connection. Despite the disruption only two complaints were received and, compared to the gas supply, which after similar damage, was out of service for six weeks, this was considered successful.[80] Table 1 shows that, despite some losses from bombing, it was the defensive actions, which alongside the weather which caused the most difficulty for the Grid during WW2.[81]

TABLE 1. FAULTS ON THE GRID DURING WW2.[82]

Cause	Total Number of Faults	Percentage (total no faults)
Faults directly Attributable to the war		
1. Hostile Action		
Normal Bombs	303	6.9
Flying Bombs	40	0.9
Rocket Bombs	13	1.3
Enemy Aircraft	6	0.1
Enemy Shellfire	4	0.8
Total due to hostile action	366	8
2. Defensive Action		
Barrage Balloons	1,614	35
Allied and unidentified Aircraft	215	4.7
Anti-aircraft devices	115	2.5
Military Exercises	72	1.5
Total due to defensive action	2,016	51.7
Total of War Faults	2,382	51.7
Faults not totally attributable for War	2,225	48.3
Total of All Faults	4,607	100

[80] E. Luscombe and C. Buck, *Plymouth's Electrical Revolution* (Bristol, 2014), pp.51-52.
[81] Cochrane, *Power to the People*, p.32.
[82] Source: *Ibid.*, p.3.

Internal Conflict – Battle of the Systems

'Battle of the Systems' is the term describing how electrical engineers contested whether AC (alternating current) or DC (direct current) was best. Different engineers held different opinions manifesting in the multiple types of electricity offered through Britain's parochial system, although in many ways it was primarily fought between American electrical engineers Edison, and Westinghouse.[83] Their battlefield was the American courts as Edison proposed electrocuting a man on death row using AC current with Westinghouse opposing it. The state backed Edison who won the case. However, the initial 1,000 volts of AC current failed and it eventually took 2,000 volts and 80 minutes to finally kill the prisoner. This did not help Edison, whose intention had been to demonstrate that AC was incredibly dangerous, easily fatal, and should not be pursued. However, this was just one incident in a series of publicity stunts. [84]

The issue divided electrical engineers in Britain too, although Weightman suggested that 'the disagreement was much less fractious, so that a DC man like Crompton would happily have dinner with the AC advocate Ferranti, and they were in fact part of an informal group of electrical engineers who called themselves the 'Dynamicables'.[85] Ferranti was a young man, new to electrical engineering and was a big advocate for AC in Britain, while distinguished engineers such as Kelvin, Hopkinson, Crompton and Kennedy supported DC.[86] Ferranti took over the Grosvenor Gallery power station in London from 1887. Like Merz, he saw the potential of larger networks to increase efficiency and reduce prices to encourage demand. He expanded the company rapidly attracting large investments and built a large power station at Deptford in London to generate electricity to be distributed using AC current at an unprecedented 10,000 volts. Despite being visited by Edison, who

[83] 'Obituary of George Westinghouse', *The Engineer* (1914), *117,* pp.315-16.
[84] Weightman, *Children of Light*, p.76.
[85] *Ibid.,* p.69.
[86] Hinton, *Heavy Current,* p.28.

conceded that the power station would 'go', it ultimately proved unreliable, consumers lost confidence and financiers lost faith in Ferranti and he eventually left the company.[87] This battle of the systems is extensively discussed in the literature, usually to praise Ferranti's technical skill but criticise his business sense.

A retired engineer suggested to me that the battle lines for AC or DC were in many respects attributable to the engineers' background. His perception was that DC advocates had come from a general engineering background, while AC advocates had been brought up with a more electrical one or had more exposure to electricity and is true of British engineers. This, he maintained, was because in DC systems the electricity flows in one direction working like most forces whereas AC flows in different directions and is therefore less like forces in other engineering disciplines. The reasons engineers gave included that DC could be transmitted further and stored in batteries, while AC lent itself to being transformed into different voltages and retained more power over longer transmission distances, although it could not be stored and therefore had to be continuously generated.

Like other aspects of electrification this was part of the negotiation process stimulated by the technology itself. Small generating stations and private installations, initially set up, lent themselves to DC because there were short transmission distances with little need for voltage transformation, and the ability to store some excess power reduced the need for continuous generation. However, as Ferranti, Westinghouse and others began to create, larger centralised systems they advocated for AC which NESCo., had used for their Neptune Power Station built in 1899.[88] AC was continuously generated at higher loads, transformed into high voltages for transmission and transformed down for consumer distribution. Eventually, polyphase AC won this battle, patented by Tesla, amongst others and eventually those who had championed DC conceded.[89]

---

[87] Weightman, *Children of Light,* p.76.
[88] Hannah, *Electricity Before Nationalisation*, p.29.
[89] Hughes, *Networks of Power*, p.247.

While these struggles are often told through competing personalities, it is clear that the shape and potential of the market was important in decision-making. AC was an obvious choice for the Grid particularly because it was good for long distance transmission and was generally accepted as better by this time. This is an example of the negotiation process and included debates, experimentation, media coverage and to some extent trial and error, ultimately leading to an agreed solution.

Nationalisation

Nationalisation in 1948 provides a convenient break in this story and has been chosen as a 'soft' endpoint because before 1948 there is little consideration of how environmental issues were perceived, communicated and managed. There was no developed language within which to frame environmental issues, internal to industry or in the media. The term which encompassed all environmental damage was 'nuisance' and was first addressed in the 1909 Act which required planned power stations to consult their potential neighbours before construction. Some 'nuisances', such as smoke and sulphur, are now generically termed air pollution, but the term 'atmospheric pollution' was used in scientific circles and is first mentioned in the Electricity Commissioners' annual report for 1927-28.[90] However, environmental protections were afforded in these periods because they coincided with efficiency and business aims. The environmental history of the period after 1948, particularly under the CEGB, has been addressed by Sheail, who anchors it in some earlier historic events.

Nationalisation of the whole electricity supply industry was strongly contested by many within it, who saw their undertakings vested in April 1948. There is general agreement across the authors who addressed it that wholescale change was necessary. Hinton stated, 'The industry was at last free to

[90] Electricity Commissioners, *Electricity Commissioner Annual Reports* (London, 1921 – 1948), 8, pp.31-32.

build modern plants' but suggested this was done 'slowly and hesitatingly'.[91] With the benefit of hindsight, full national ownership seems almost inevitable after the succession of measures designed to try to make electricity universally available, affordable and standardise it never quite delivered. Hannah opened his chapter outlining 'The Road to Nationalisation' with a quote from a letter in the *Electrical Times.* The letter was from Fippard, chairman of the Electrical Supply Corporation from 1946, and demonstrated this sense of inevitability. 'No one with any intimate knowledge of the electricity supply industry can maintain that changes are not overdue and would be brought about by any Government in power, Labour, Conservative or Liberal'.[92]

Hannah provided a comprehensive insight into politics, people and the interests of those directly affected by nationalisation, particularly supply companies. Whilst he mentions the opposition to change in the industry by those with interests in it, he reports it in a way that suggests nationalisation was an inevitability. Despite opposition national oversight and control was advocated by engineers in particular but also by other groups within the industry and beyond as the only way to impose a standard type and pricing structure. Privately owned companies were compensated for their assets at stock market values, although Hannah suggested they perhaps could have done better if the government had been Conservative rather than Labour, whilst concluding they had a reasonably good deal. The municipally owned companies, however, were treated differently because 'the whole transaction represented a change from one form of public ownership to another'. They received only their net debt, not the equivalent value of their assets, as private companies had. Although over half of the assets came from the municipalities they received only about a third of the total compensation awarded.[93] Works on the post-nationalisation period concentrate primarily on national and private ownership models rather than as a continuation of the process of electrification and its role in society.

---

[91] Hinton, *Heavy Current*, p.73.
[92] Hannah, *Electricity Before Nationalisation*, p.329.
[93] *Ibid.,* p.351.

Regardless of the political merits of ownership models, after nationalisation, rural electrification was tackled and national uniformity of supply and pricing were eventually reached. However, as a 'reminiscence' by Melling (an engineer before nationalisation and chairman of the Eastern Electricity Boards afterwards) pointed out the difficulties for the government and the industry. He reported the government's requirement to respond to the 'needs of the moment' was 'incompatible with the long-term planning' needed for electricity supply. He stated that government control was under constant scrutiny, which led to innovation being withheld and risks not being taken. His own thoughts on mistakes made, included maintaining area tariffs, inefficiencies and slow progress in staffing and opposition to the nuclear power programme, and other issues.[94] Throughout the literature, regardless of the period, one can find a constant interest in increasing efficiency through better ways of working, improved technology and cleaner and purer fuels. For some, efficiency improvements were behind nationalisation, for others it was universal supply, and for others it was more politically motivated. The same drive for efficiency still remains, although to some extent the scale has increased beyond national, as Britain has power lines connecting it to other parts of Europe for electricity exchange. At earlier dates, and historiographically, international developments were important for context and comparison rather than connection.

International: Electrical Comparisons

There are many international works which provide context and greater understanding of the potential options Britain had.[95] Hughes compared Britain, Germany and America technologically, in

---

[94] C.T. Melling, 'Nationalisation of Electricity Supply 1947, Reasons and Problems', *Engineering Science and Education Journal* (1998), p.17.
[95] Nye, *Electrifying America* and P. Schewe, *The Grid: A Journey Through the Heart of Our Electrified World* (Washington DC, 2007), a work about the American Grid. The Grid is used as a vehicle for the book to investigate the American electrical system rather than the Grid itself but, as the Grid developed through a more evolutionary process rather than the planned infrastructure of the British Grid, it is a very different story.

his famed *Networks of Power.*[96] Broadberry's *Market Services and the Productivity Race, 1850 to 2000,* and *The Productivity Race: British Manufacturing in International Perspective, 1850-1990,* are important economic histories of the period considering the same leading industrial countries.[97] The same countries were also compared at the time in industrial reports such as the BEAMA survey of 1929 into *the Electrical Industry of Great Britain: Organisation, Efficiency in Production and World Competitive Position*.[98] This survey also considered the import and export markets of 'The Dominion' countries, including Canada, India, Australia, New Zealand and South Africa, which had 'been responsible between them for about 60 per cent of British Electrical Exports, while the Empire as a whole, including the Colonies, absorbed rather more than 65 per cent'.[99] This was considered both a strength and weakness because in the market outside the Empire 'other countries were able to extend more fully in markets where the British product has not yet penetrated to any great extent'.[100] However, the report was optimistic stating that the British electrical exporter 'is not markedly dissimilar from his German or American confrère', and that Britain's place alongside America, Germany, France and Switzerland, which comprised eighty-seven percent of the world's export requirements, was secure.[101]

Other comparative work included Bowers, who compared generating capacity, units generated and units per head of population across six countries, including America but not Germany, although the latter is discussed in the narrative.[102] Chick carried out comparative work on Britain, France and

---

Other works include R. Milward, *Private and Public Enterprise in Europe – Energy telecommunications and transport 1830 – 1990* (Cambridge, 2005), A. Kander, P. Malanima, and P. Warde, *Power to the people: Energy in Europe over the last five centuries* (New Jersey, 2013), Prichard, *Confluence* and Hecht, *The Radiance of France*.

[96] Hughes, *Networks of Power*, primarily Chapters 7-9.

[97] S.N. Broadberry, *Market Services and the Productivity Race 1850-2000 – British Performance in International Perspective* (Cambridge, 2006) and S.N. Broadberry, *The productivity race*.

[98] British Electrical Allied Manufacturers' Association (BEAMA), Economic Statistical Department., *The Electrical Industry of Great Britain: Organization, Efficiency in Production and World Competitive Position* (London, 1929).

[99] BEAMA, *The Electrical Industry Report*, p.223.

[100] *Ibid*.

[101] *Ibid*.

[102] Bowers, 'Electricity', pp.284-97.

America, primarily discussing policies and economics of electricity and energy policy in the three countries after WW2.[103] Chick asked why Britain, unlike the Industrial Revolution, where it was very much the leader, fell behind its international competitors. Hinton had already apportioned blame to the 'shackles' restricting the industry and personal interests in electrical manufacturing companies preventing mergers and creating duplication of effort which could have been avoided.[104] However, these comparisons came to focus more on manufacturing and output from electrically powered machinery because that was the closest link to its economic value. At the time of the BEAMA report the Grid was not fully trading and was already becoming less visible as the activities it powered, and their economic benefits, became the subject of scrutiny rather than the energy source itself. It was Hughes' work that introduced a more theoretical explanatory framework and direct comparisons with other nations.

Hughes introduced the framework of 'technological momentum' and 'technology transfer' via a comparative history of electrical systems. He explored the reasons for differences and suggested, as Hinton did, that politics was a primary reason for how the industry developed in Britain. In contrast he stressed the role of technology in shaping American electricity systems, whilst in Germany, greater coordination between politics and technology prevailed. He also explored histories by earlier authors and demonstrated how knowledge and invention were shared through networks of engineers and financiers.

Gabrielle Hecht's study of the history of electricity generated from nuclear power in France has some similarities with Hughes' approach, examining how education systems, institutions and politics were intertwined. Politicians were led by a President who declared 'This achievement will add to the radiance of France' when the first milligram of plutonium was isolated by French scientists.[105] The

[103] M. Chick, *Electricity and Energy Policy in Britain, France, and the United States Since 1945* (Cheltenham, 2007).
[104] Hinton, *Heavy Current,* p.vii.
[105] Hecht, *The Radiance of France*, p.2.

desire to rebuild a specifically French energy system after WW2 is explored through Hecht's examination of the institutional culture of technological development. She suggested that by considering these ideas across different countries, like Hughes did, national patterns could be identified which might not be visible when considering a single nation. The issues in Britain were certainly not unique but the responses were specific to Britain. However, as Chapter 3 will demonstrate, sometimes this led to technological lock-in or interconnectedness which then required further investment, financial or otherwise, to maintain the viability of the whole technological system.

In *The Grid,* Schewe considered American electricity using the Grid as a metaphor. He explored its physicality including places where it was absent as well as present. He captured the difficulty of defining a grid, stating:

> The electrical grid is not a single *thing* but several things: a highway for delivering a product to millions of customers, a sort of NATO defence alliance of utilities pledged to help each other in a time of need, a platform supporting a worldwide movement of information, and a commodities exchange dispatching vast resources on a second's notice. The grid seems alive, like some enormous nervous system.[106]

His work also shows the pervasiveness of a grid. The work stemmed from his realisation that when a grid fails, it causes significant distress. He described what followed the loss of power in New York in 2003 and suggested it brought about 'withdrawal symptoms'. His work was, in some ways, aligned with Nye's *Electrifying America,* in which Nye described an America evolving alongside electricity developing. He described energy substitutions, such as conversion to electric light that was brighter than previous types and could be positioned in harder to reach places because the switch could be placed at a distance from the light itself. There were new uses, such as traction companies using it for funfairs as well as streetcars for example. Nye described a new electrical landscape and

[106] Schewe, *The Grid,* p.1.

described the brightening of places, 'theatre marques, shop windows, a street of arc lamps, ostentatious homes along Chicago's North Shore or New York's most fashionable streets'.[107] He demonstrated some of the negotiation process from the public viewpoint in terms of their influence through behaviour alongside the viewpoints of politicians and businessmen.[108]

Nye described electricity as 'a raw material itself' because it is difficult to extricate it from the traditional inputs needed for production of capital, labour, materials and machinery.[109] It is this intrinsic value of electricity to facilitate benefits which makes it so important. Schewe suggested that 'you might say we are caught in the grid as if it were a net, as indeed it is – hence our ambivalence. It liberates us and it ties us down. It enables and ensnares. It simplifies some things and makes others more complicated'.[110] I would add that the Grid is visible but covert in everyday life, and electricity it transmits is invisible but manifested in almost all daily tasks.

Electrical Legacies in the Environment

Any investigation of the Grid's environmental history must begin with Luckin and Sheail. Luckin investigated the relationship between electricity as a new technology with an increasingly physical impact on land, water and air quality and lifestyles in Britain through a narrative of protagonists and antagonists. He called them 'triumphalists' and 'preservationists', and through the various groups and propaganda he traced arguments for and against electrical development, primarily between the two world wars. Most of his case studies were based around the Grid and its infrastructure, particularly issues of amenity and aesthetics. It is the most closely-related book to themes of this work and covers the period when the CEB had oversight of the National Grid, from 1927 to 1948.

107 Nye, *Electrifying America*, p.32.
108 *Ibid*.
109 *Ibid.*, p.234.
110 Schewe, *The Grid,* p.23.

However, Luckin does not consider the implications of the debates he presents, such where people were able to live and work, changes to consumerism, transportation and artificial lighting. This work endeavours to explore the changes brought about by the people and institutions that 'won' those debates.

Sheail covered a slightly longer period beginning after nationalisation, briefly delving into earlier periods, and extending to privatisation in 1990. He takes a more chronological narrative approach and explores the environmental impacts within these timeframes. Most occurred after WW2 when the BEA (1948-57) or the CEGB (1957-90) was responsible for the National Grid.

Except for Hinton's work, little regard is given to environmental issues in any of the core works. Hannah discussed overhead lines as being opposed on 'aesthetic and environmental grounds' and later extended this to pylons and difficulties in obtaining wayleaves.[111] He discussed the aesthetic and amenity issues and considered smoke nuisance from power station chimneys. Smoke and noise were the main environmental problems Hinton addressed presenting it as the result of restrictive legislation.[112] Self and Watson discussed environmental issues under the title of 'Non-productive Capital Expenditure and Amenity Preservation' in which they considered the siting of power plants, flue scrubbers and having to accommodate amenity areas. However, as their title suggested this was regarded as an inconvenience and an unnecessary expense foisted upon the industry by outside agencies.[113]

Mosley's *The Chimney of the World*, specifically investigated smoke pollution in Manchester in the Victorian and Edwardian periods.[114] His work comprehensively described the problems smoke caused and explored the ways in which solutions were sought and offered through technology,

[111] Hannah, *Electricity before Nationalisation,* p.80.
[112] *Ibid.*, p.139.
[113] Self and Watson, *Electricity Supply in Great Britain*, p.174-176.
[114] S. Mosley, *The chimney of the world: A history of Smoke Pollution in Victorian and Edwardian Manchester* (White Horse, Cambridge, 2001).

politics and people. Wider environmental impacts of electricity have also been addressed in international literature: Pritchard's *Confluence,* in which she explored the changing technologies around the River Rhone, and Hecht's *The Radiance of France,* discussed the social, cultural and political impacts of their subjects.[115] Julie Cohen's PhD thesis, based on the American grid system, investigated engineers as conservationists in their quest for ever increasing efficiency in all aspects of providing electricity to as many people as possible, a view also found in this work.[116]

Energy History – Methodologies

Defining a specific methodology for such a wide-reaching, interdisciplinary study is difficult. Environmental History is a growing discipline and literature about the impacts of human activity such as those just described, is increasing. As it has become established a strong tradition in environmental history is simply to be eclectic. As William Cronon suggested:

> 'The job of historic scholarship is to provide the richest possible contextual field within which to frame and discipline our analogies, not because we expect historical insight to give absolute answers - it won't - but because it is the best source we have for questions whose subtlety and complexity can mirror that of the world we wish to understand'.[117]

A non-prescriptive approach allows complex relationships between social, cultural, political, technological and natural aspects of the environment and its inhabitants to be explored from a range of different perspectives.

A more specific framework used within this tradition is 'techno-politics', used by Hecht to 'refer to the strategic practice of designing or using technology to constitute, embody or enact political

[115] Pritchard, *Confluence*, pp.1-27 and Hecht, *The Radiance of France*, pp.8-47.
[116] Cohn, J., 'Expansion for Conservation: The Growth of Americas Power Grid through the Twentieth Century' (PhD Thesis, University of Houston, 2010).
[117] W. Cronon, 'The Uses of Environmental History', p.17.

goals'. In *The Radiance of France,* she uses this idea to frame the development of nuclear power under the leadership of President De Gaulle. The political presentation of this technology emphasises the cultural dynamics of the time. Nuclear power was developed and governed by a group of technocrats operating in a centralised fashion with a common educational and institutional background, framed as part of a national mission.[118] This has been useful in approaching this study. There was political influence in all aspects of electricity supply in Britain, including property and private business rights, local government and war time changes, but politics was not the only influence.

In *Confluence,* Pritchard used 'the concepts of envirotechnical systems and environmental regimes' that 'demonstrate how technical objects and systems are productive sites of enquiry for environmental historians while drawing attention to non-human nature within studies of technology'.[119] These ideas also link politicians, national ideals, technology and nature through the changes in a river. Her work demonstrated how the river responded to the changes, whether imposed directly by people, technology or actions of the river itself. Again, this is conceptually broad but can be focused on specific technologies and/or environments and could be viable for studying the Grid. However, the Grid is a vast, man-made infrastructure imposed on a changing landscape in which its structures touch on almost every environmental type. The concept of 'envirotechnical systems' and 'environmental regimes' forwarded by Pritchard provide an attractive framework to consider aesthetic changes brought about by the Grid but reducing the whole landscape and society as affected by the Grid to a 'system' or 'regime' is too simplistic.

Other theoretical frameworks arise from the history of technology and institutions. Hughes's study of electrical supply included 'technological determinism', promoting the idea that technology itself is an historic actor causing change. He, as a trained mechanical engineer, described it as an object: 'the

[118] Hecht, *The Radiance of France*, p.15.
[119] Pritchard, *Confluence,* p.23.

mass [that] consists of machines, devices, structure, and other physical artefacts in which considerable capital have been invested'. The force applied to it, he described as 'the involvement of persons whose professional skills are particularly applicable to the system. Business concerns, government agencies, professional societies, educational institutions, and other organisations that shape, and are shaped by the technical core of the system also add to the momentum'.[120] I would advocate the term 'technical stimulation' to describe the British electricity industry. Stimulation means 'Encouraging or arousing interest or enthusiasm in' or 'Encouraging development of' and more accurately describes development in Britain. This allows a place for the technology to stimulate or begin the process; its infrastructure and effects stimulated the entrepreneurs, the experts, politicians, consumers and potential consumers. Their interactions with electricity and other people negotiated how much electricity was used, where it was used and how it was accesses over time. The stimulus, however, was different for different people. For scientists, engineers and entrepreneurs it was a new and exciting phenomenon to work with. For financiers and shareholders, it was an opportunity to make profits. For manufacturing, it offered increased productivity through new methods of working and new products. New appliances, particularly home entertainment through the wireless and television, created demand in the domestic setting. Other home appliances, especially the clothes iron, were perceived as beneficial and gradually incorporated into daily life. Electricity stimulated an energy revolution but it was the people who found benefit in the work that it enabled through the machines and appliance it powered that created demand and negotiated its role which determined its environmental impact. It was not a simple process, and its continuously expanding uses allowed it to be exploited by different protagonists and traditionalists at different times.

[120] Hughes, *Networks of Power*, pp.140-74.

The Process of Electrification and the Role of the Grid

This study forms part of a larger project which considers 'The Power and the Water', an environmental history initiative focussing on environmental connectivity's that have emerged in Britain since industrialisation. It includes work in the South West, Derbyshire and Tyneside in particular. Of particular interest are aesthetic changes, energy infrastructures both natural, such as rivers and the Severn Bore and manmade structures such as barrages for the River Severn, or the Derbyshire Soughs. This individual work traces the process of electrification and the role of the Grid, in transmitting electricity generated form its primary energy source through to consumption as a secondary fuel. The wider project has shaped the choices of case study, as will be discussed further.

Chapter 2 explores the legal frameworks in which the Grid operated, examining how these evolved over time and accommodated changing concerns for business, politicians, public safety and the environment, amongst other actors. It places the Weir Report, produced by parliamentary committee which invoked legislation for the Grid and technical plans for its construction, within the context of the developing electricity supply industry.

Chapter 3 explores the internal and external changes electricity brought to the industry and the work environment. It includes a case study of industrial location in the Lea Valley, located in Greater London which enjoyed industrial expansion and demonstrates how the Grid influenced industrial location. It is not included to represent Britain during this period because links to the Thames and overseas markets helped it to be an area at the forefront of change, but it provides an industrially diverse location. It also has an associated literature regarding changing industry that has not, however, explored how availability of electricity through the Grid affected outcomes.

Chapter 4, in contrast, explores electrification of the domestic market using the South-West as a case study. It examines homes and appliances, how demand for electricity was encouraged, enabled and spread. Like Chapter 3, it is not representative of Britain but it demonstrates differences between urban and rural electrification and includes different types of electricity suppliers. Combined, these chapters begin to demonstrate the impacts that the Grid brought to everyday life and its environments. Spatial rearrangements and new methods of working developed and impacted expectations, lifestyles, and the variety and volume of products which could be manufactured.

How these changes impacted the countryside, the 'natural environment', using the contemporary meaning of 'environment', is explored in Chapter 5. The initial focus is on pylons and high voltage wires connecting the transmission system, constituting the Grid as a single physical entity, despite its extension into the extremities of the system for interconnection. Nevertheless, the locations and impacts of these extremities, generating stations, distributors and consumers is never far from the discussion because the Grid's influence extended into all parts of the system.

The Grid is paradoxical; it revolutionised generation and transmission but, for many years, had little effect on distribution. Its external visibility has become more prominent with pylons and wires towering overhead as internal wiring, lights and sockets have become less conspicuous. People have become heavily reliant on electricity yet take it entirely for granted, with limited understanding of the primary fuel source consumed. As early as WW2, reminders that electricity and coal-gas, also a secondary fuel, were both produced from coal were needed when reduced consumption of coal became necessary during the conflict. Rechargeable devices and the resultant reduction of cables joining appliances to electrical sockets makes the connection to fuel source consumed, perhaps even less obvious.

The Grid was, and remains, a critical piece of British infrastructure, literally powering the nation and part of a process of change which is still developing as politicians, financiers, scientists, experts and the public continue to debate its future. Discussions about keeping the lights on and the capacity of the Grid in its current form abound as winter arrives each year. New developments, batteries, for example, which can store large quantities of electrical power are still sought after and the use of renewable fuels inspire contemporary debates.

The Grid's current head of network strategy stated; 'What we are really talking about is finding ways to make the way we generate and consume energy more interconnected'.[121] This comment could have been made at any time during electrical supply development, yet the drive for greater interconnectivity leading to increasing efficiency continues.

The Grid will celebrate its eighty-fifth anniversary in 2020, taking 1935 as its official starting year as recognised by its current operator. The Grid's flexibility as a technological system has enabled it to be resilient to changes in fuels for generation, extensions and higher voltages which were imposed to increased transmission capacity. It has, as a part of Britain's electrification story, been quietly transformative and this work begins to consider its impact on all the environments in which we live, work and enjoy.

---

[121] P. Sheppard, 'Smart Thinking', on National Grid Blog 'Connecting' accessed via http://nationalgridconnecting.com/towards-smart-energy-systems/.

2. The National Story

It took over half a century for electricity to be supplied nationally, and distribution to all households took considerably longer. Legislative changes and relationships between national government, local government, and private enterprise were shaped by different actors at different times. The pattern for many early changes was demonstrated at Faraday's first exhibition of his electrical discoveries in 1831, held at the Royal Institution. Sir Robert Peel asked him what it was for, to which Faraday replied; 'I know not but I wager one day your government will tax it'.[122] Politicians followed in the wake of the experts and business managers who led the rapidly developing technology. Politicians responded to technological advances with legislation from the first Electric Lighting Act in 1882 to the 1926 Electricity Supply Act invoking the grid. During this period legislation was reactive rather than proactive.

The essence of most enquiries, committees, and legislation was the need to address the balance of interests of suppliers, consumers or the wider population, evaluating the arguments the many lobby groups, engineers, and a wider public. It is perhaps surprising that, despite legislative changes, the Grid made very little difference to consumers for years after its construction. By the mid-1930s, whilst ninety-nine percent of the population lived in areas where companies had supply powers, only half of households were connected, and this was possible only if the premises were situated close to the mains cable.[123] Primarily, this was because potential profits from providing electricity to areas of less dense housing were less attractive to supply companies. In 1953 a conference about rural electricity agreed a target of eighty-five percent of farms and a higher proportion of other premises needed to be connected to the grid within fifteen years. This target was achieved sooner in

[122] I. Glynn, *Elegance in Science: The Beauty of Simplicity* (Oxford, 2010), p.99.
[123] National Archive, Kew, 'Electricity Commission Report into Distribution of Electricity in Great Britain, General Review of Existing Organisations: Possible Methods of Improvement', September 1935, POWE 13/95. p.20.

some places, for example in 1964 eighty-eight percent of farms were connected in the South-West, but additional financial assistance from the government had been essential.[124]

A recent newspaper article discussed electrification of high-speed railway lines. Commenting on the time and money spent before any work has even begun, the journalist quoted from *The Blunders of Our Government*, 'British Politicians meet, discuss, debate, manoeuvre, read submissions, read the newspapers, make speeches, answer questions, visit their constituencies, chair meetings and frequently give interviews, but they seldom deliberate'.[125]

This might be true of politicians in a post-electrified world, where everything they say and do is immediately communicated in a myriad of formats, in the late nineteenth and early twentieth centuries politicians did, most definitely, deliberate. Electricity became of national interest for politicians and public when it became a traded commodity because of its potential benefits, dangers and the 'nuisance' that it brought.

Previous Legislative Experience – Pre-1882

Electricity supply was carried out by public authorities and private companies under licence from Parliament. Private or public ownership was a significant consideration at the turn of the twentieth century. As public sales of electricity began provision was already established for gas, water, and sewage services, which were increasingly being taken over by local authorities. This experience provided the context in which electricity was regulated, tending towards encouraging public ownership in the 1870s and '80s. Byatt suggested that, 'By 1880 the old idea that utilities could be

[124] G. Warburton, 'The History of SWEBs Electrification', (HistElec Article, S17, 2001) accessed via http://emep.worldonline.co.uk/SWEHS/docs/news17su.html, p.4.
[125] A. King, and I. Crewe, *The Blunders of our Government* (London, 2014), pp.87.

regulated by competition was over'.[126] The 1870 Tramways Act, which 'inaugurated the system of granting limited time franchises', reflected the changes seen in services for gas, water and transport including turnpikes and tramways, all leaning towards municipal ownership.[127] The underlying assumption was that local authorities should take precedence in supplying public services within their geographical boundaries. The Tramways Act bestowed power on the local authority to purchase a private company undertaking supplying their area, after a specified time, known as 'compulsory purchase'. This was still the political thinking when the development of electricity supply and its governing legislation began.

Questions about ownership and safety arose concerning wires and works of individual undertakings which led to a parliamentary investigation led by Lord Playfair, a former Postmaster General, an obvious choice because of his experience of the telegraph system constructed from poles and wires. His report informed the first legislation affecting the fledgling electricity industry, citing the need to regulate supply because as the number of suppliers, posts and wires increased, so did safety concerns.

Creating Isolation – 1882-1909

Legislation

Public supplies were first installed in the 1880s and electricity was supplied by overhead, open-laid or underground cables. Laying the cable underground required permission through private parliamentary bills. When licenses, termed Electricity Provisional Orders, were required to supply electricity, the license holder, termed an 'authorised supplier' had permission to lay cables as

[126] Byatt, *The British Electric Industry*, p.8.
[127] *Ibid.*

specified by the license, without further Acts. If the supplier did not need such permission but supplied electricity without a license, they were termed ‘unauthorised suppliers’, usually individuals who generated for themselves but sold any surplus to nearby properties through overhead cables.

The Electric Lighting Act of 1882, which introduced licenses, was designed to regulate supply, controlling cables and to improve safety. However, the Act allowed municipal authorities first refusal to supply their areas because municipal ownership of services was still considered best. The first draft allowed local authorities to exercise the right of ‘compulsory purchase’ to acquire private company’s supplying their area after seven years, at a price exclusive of goodwill or profitability, the same clause used in the Tramways Act of 1870.[128] The seven-year timespan was contentious. Debate in the House of Commons extended this to fourteen years, and it was further extended to twenty-one years after consideration in the House of Lords. During these debates Fowler, MP for Cambridgeshire, suggested that compulsory purchase was like ‘Heads I win, tails you lose’ for local authorities as they could not lose, having a veto over supply and ‘compulsory purchase’ if companies proved supply was successful.[129] Sometimes a private supply company was contracted by the authority under its licence or they hired their own electrical engineers to set up electric lighting committees to supply residents.

Discussion of the 1882 Act in *The Times* primarily revolved around the supremacy of local authorities, municipal socialism and ownership of electrical enterprises, with the legacy of older legislation evident. Bramwell, president of the Institute of Mechanical Engineers, a member of the Royal Society and known expert witness, wrote:

> This Bill will deprive the general public of the benefits of electric lighting. The local authorities will not dare to embark in a comparatively unknown undertaking and private

---

[128] ‘The Electric Lighting Act 1882’ (H.M. Stationery Office, London, 1882).
[129] Parliamentary Debate, ‘Electric Lighting Act 1882’, HC Deb 15 July 1882 vol 272 cc565-632 accessed via http://hansard.millbanksystems.com/commons/1882/jul/15/committee#S3V0272P0_18820715_HOC_35.

> companies will refrain from doing so with these inequitable conditions of payment on compulsory purchase staring them in the face.[130]

Similarly, Moulton, president of the Junior Institute of Engineers, later Lord Justice, and by Mr. White, wrote expressing the same sentiment, as secretary of the Edison Electric Light Company.[131]

However, one writer sought to redress the balance, suggesting that:

> The report of the [Playfair, 1879] committee does not recommend that an exclusive right to supply electricity should be given to municipal authorities, but that municipal authorities should have power to give facilities to companies or private individuals to conduct experiments.[132]

The second reading of the 1888 Electric Lighting Act was debated in the House of Lords and Thurlow, who described himself as an electricity user and enthusiast, said, 'Electric lighting was no longer a dream of the future but a reality, and a commercial possibility but for the Act of 1882'.[133] This second Act doubled the time before the compulsory purchase could be invoked to 42 years. This resulted from many debates which considered how long investors needed to make a return, the need to encourage further investment, and local authority ownership.

Historians have debated the impact of the 1882 Act and whether it really impeded growth of electricity supply in Britain. Hannah suggested, 'Early electrical pressure groups soon established a belief, often repeated since that the 1882 Act stifled the private enterprise electricity at birth'.[134]

---

[130] F. Bramwell, 'Something More Than the Electric Lighting Bill' *The Times* (London, 1882), 30565, p.4.
[131] J.F. Moulton, 'The Electric Lighting Bill', *The Times* (London, 1882), 30579, p.4. This is a long exposition on how the compulsory purchase clause is the only part of the Act which the electric lighting companies do not consider to be 'of general excellence', and how this will impact distribution, and White states: 'these cruel provisions [compulsory purchase] inflict a grievous blow on the consuming public', A. White, 'To the Editor of The Times', *The Times* (London, 1882), 30574, p.4.
[132] 'The Government Electric Lighting Bill', *The Times* (London, 1882), 30418, p.8. Two letters discussing whether municipalities should have the right to supply. Mr. Farrer, the respondent who is quoted here, gave evidence to the Playfair committee investigating the question of electric lighting, which reported in 1879.
[133] Parliamentary Debate, 'Second Reading Electric Lighting Act 1888' Deb 01 March 1887 vol 311 c856 accessed via http://hansard.millbanksystems.com/lords/1887/mar/01/second-reading#column_855.
[134] Hannah, *Electricity Before Nationalisation*, p.5. He suggests the '*locus classicus*' of this view is from Emile Garcke, an electrical engineer and businessman working in London, and founder of *Garcke's Manual* of

However, he also suggested that the infant, unproven nature of electricity supply was at least as much to blame, because early disappointment for financial speculators meant they became cautious as regulations and competition emerged. Conversely, putting the blame firmly on the legislation, Hinton maintained the 1882 Act was restrictive and 'until it was amended it put shackles on the development of the electricity supply industry'.[135]

The potential to be bought out by the local authority at a basic cost, after a short period, was likely to discourage speculative investors. Electricity was unproven and posed a risk to spending public money in substantial schemes. By 1883 seventy licences had been granted, sixty-three of which were subsequently revoked. Licence revocation usually occurred because it was superseded by a new scheme, often by the local authority, or because the licensee had not exercised its powers or, even attempted to progress supply. Increased applications occurred in 1889 after the 1888 Act was passed, introducing a forty-two year period before compulsory purchase could be invoked. This strongly suggests that the 1882 Act retarded progress. Only twelve licences were granted between 1883 and 1888, in 1889 there were fifteen, in 1890 there were eighty-one before settling to approximately thirty per year.[136] This is likely to be a combination of electricity being a new

Electrical Undertakings, a yearly publication about electrical, communication, and transportation industries. The work from which this originates is E. Garcke, *The Progress of Electrical Enterprise; Reprints of Articles from the Engineering Supplement of The Times on the British Electrical Industries* (London, 1907).
135 Hinton, *Heavy Current,* p.22.
136 Data from *Garcke's Manual* showing the number of licences issued and revoked:

Year	Granted	Subsequently Revoked	Still in Force	
			Company	Local Authority
1883	70	63	-	7
1884	6	6	-	-
1885	2	2	-	-
1886	2	-	1	1
1887	1	1	-	-
1888	3	3	-	-

technology but he limited time available for profiting from investment if compulsory purchase was invoked slowed progress.

Garcke had interests in electricity businesses from 1883 when he joined the Anglo-American Brush Electric Light Company. He published widely on electricity in Britain and edited *Garcke's Manual of Electrical Undertakings,* a yearly report about electricity, communications and rail industries from 1896 until the mid-1950s. In 1907 he wrote, 'A great deal is written about the more picturesque achievements of electricity, but little is known by the general public of the exceptional conditions under which this science has been commercially developed'.[137] Garcke felt very strongly that legislation, particularly compulsory purchase, greatly hindered electrical development, saying, 'electrical industries have not merely had to overcome the difficulties inherent in all new industries, but have also had to expand amid experimental legislation of a socialist character and under tariff conditions which have favoured manufacturers in other countries'.[138]

This regulation meant that individual suppliers effectively became monopolies of small, protected territories. This allowed for heterogenous electricity systems because of rapidly developing

1889	15	4	9	2
1890	81	19	19	43
1891	59	13	12	34
1892	26	1	8	17
1893	19	5	3	11
1894	27	3	8	16
1895	23	-	9	14
1896	33	-	7	26
1897	51	-	9	42
Total	416	118	85	213

Source: E. Garcke, *Garcke's Manual of Electrical Undertakings*, (Vols. 1-57, London, 1896-1960), 3, p.136.
[137] *Ibid*., p.3.
[138] *Ibid*.

technology and nature of bespoke systems for each supplier designed by individual electrical engineers. Licensed areas tended to be small, and systems were designed to meet the needs of the local population. Lack of competition meant there was little pressure to make improvements over the lifetime of the licence. Neither was there incentive to cooperate with neighbouring suppliers, something which happened more cooperatively in other countries and helped encourage standardisation, and no national standard was imposed.[139] High initial investment costs meant there was also an inevitable 'lock-in' to the system, resulting from system interconnectedness, once it was *in situ*.[140] As license were granted at different times and technology changed rapidly, parochial development was almost inevitable. Combined with licences issued by the Board of Trade, consented to by local government, the 'red tape' as it would be described today, is likely to have reduced the willingness of electricity suppliers to give up their autonomy once it was granted.

Garcke was robust with his arguments during this time, including 'the hostile attitude' he ascribed to local authorities. He named them 'the chief obstacle' to the law reformation, meaning that undertakers had been 'forced to adopt the unbusiness-like standard which had been set up in municipal tramway enterprise'.[141] He described the postponed reading of a new electricity bill by 1903, which would have modified the veto local authorities had over private companies, as being 'silenced in the massacre of the innocents', suggesting the government could not reform the veto because municipal opposition was too strong.[142] Garcke and other electrical engineers were keen to make use of new power bills allowing power stations to supply to more than one electricity supplier or local authority, rather than just to consumers. Power bills were opposed by many municipalities, who suggested 'that such Bills are against public policy in interfering with local authorities' and did not want licences for these types of electrical companies. The same article credited The Association

[139] There is a good comparison of Germany, Britain and the USA in Hughes, *Networks of Power*.
[140] Lock-In and interconnectedness is discussed in detail in Chapter 3.
[141] Garcke, *The Progress of Electrical Enterprise,* p.4.
[142] *Ibid.*

of Municipal Corporations for having the bill postponed again in 1900, like Garcke.[143] The frustration of the time is perhaps encapsulated by the writer to *The Times* who suggested the best verb describing the progress of Britain's electricity system was 'crawl'.[144]

In 1898 Cross presented the findings of a parliamentary committee which recognised the value generating larger quantities of power and selling 'bulk supply' for other undertakers to distribute. Such wholesale suppliers were termed 'power companies'.[145] This was a small step towards large-scale generation but permission was still required from the local authority for any area supplied leading to power companies often having peculiar geographies. In 1902 parochial development was recognised when Mr. Swinburne, representing the Institute of Electrical Engineers (IEE) to Balfour, president of the Board of Trade, reported, 'We hold that electrical enterprises should have their limits and boundaries set by economic considerations only, and that arbitrary boundaries, mostly of medieval ecclesiastical origin, should not limit the distribution or the growth of electrical systems'.[146] *The Engineer* reports this deputation as 'a strong protest against the hampering of electrical industries by legal restraints, especially in the hands of local authorities', suggesting that electricity was now ready to breach the current territories but stated, like Garcke, that 'Parliament seems to be entirely under the thumb of the local authorities'.[147] Balfour suggested that two new Acts would be put before Parliament but not during that current session, and it was 1909 before the next Act, extended legislation and included power companies, recognising them as suppliers and imposing regulations applicable to all authorised undertakers.

---

[143] 'The Electric Power Bills-The Association', *The Times* (London, 1900), 36071, p.4.
[144] In 1900 *The Times* tried to create a new verb which would describe the progress of electricity to that date. The competition it launched was so oversubscribed it had to be ended after just 4 days, indicating an acute interest in the subject. Amongst the offerings were tributes to inventors using their names, such as 'Farade' or 'Joule', and variations using 'electro' as a prefix or 'trice' as a suffix. There were also many based around existing words such as 'travel', 'speed', 'spark', and 'motor'. However, perhaps the most telling entry remarks was, 'Might I suggest the word "crawl" as the aptest verb to express present electricity progression?' and is signed by 'Speed'. There are all letters from April 1890.
[145] Bulk supply was the provision of large quantities of electricity from one electricity provider to another, the second of which distributed and sold it on to their consumers.
[146] Hughes, *Networks of Power*, pp.233-234.
[147] 'The Commercial Situation', *The Engineer* (June, 1902), p.610.

Ownership

Ownership was either held by local authorities or private companies which were self-financing or attracted investors, like the common model for gas and water suppliers. Electricity was not a recognised utility at this time, remaining a luxury item for domestic consumers but industry was developing it as a power source, as shown in the 1907 Census of Production, discussed further in Chapter 3.

A difficulty for legislation was the perceived intrusion into the rights of investors financing this new and largely unproven technology. Byatt discussed this at length, arguing that control by licence via acts of parliament was ineffective for public utilities, particularly as they grew. He reported 'The whole machinery of private acts of Parliament, municipal objections, and amendments in parliament committee led to unsatisfactory and expensive compromises which had to be totally recast after the First World War'.[148] The controls for these acts, manifest in the licences, included maximum pricing, maximum dividends, and municipal operation; when electricity was being sold as a commodity municipal ownership of gas and waterworks was substantial.[149]

Investment in both municipal and private enterprises was considerable. Once profitability of an electrical venture was proven the local authority would often buy the company or individual owners out and manage it, as a municipal undertaking. An example of this was Massingham, discussed further in Chapter 4. He reported in a speech that it was 'owing to my ardent advocacy of a pure light for our homes, and my determination to bring about a system of house to house lighting by means of electricity' that he personally invested in and pioneered electrical supply across much of the South-West.[150] He later struggled for finance and was bought out by local authorities in towns he

---

[148] Byatt, *The British Electrical Industry*, p.10.
[149] *Ibid.,* pp.8-10.
[150] H.G. Massingham, *The Past and Future Developments of Electricity and its bearing on World Peace,* (London, 1935), p.21. A booklet containing the speech he gave at the Taunton Corporation Golden Jubilee, recorded in *The Times* (London, 1935), 47246, p.16.

supplied. His proposals to supply Bristol with street lights were rejected by the local authority which several years later established a very successful municipal undertaking, vested in 1948. Other examples include the Pullman brothers in Godalming, the first town to be lit by electricity, and Volk, who lit Brighton Pavilion, both vying to be the first to introduce electric lighting to Britain. These were people without specialist training, inspired by demonstrations of electric lighting at shows and special events or by the science itself.

Sometimes, this work was carried out alongside bigger companies, the German company Siemens in Godalming and Brighton, or like Massingham, bringing 'pure light into people's homes' really was a personal mission. These ownership models were maintained for many years but around the turn of the century, bulk supply from power companies became more common. Power companies were not covered by legislation until 1909 because they were not selling for private consumption, and prior to 1909, each company required an Act of parliament.

Prices

The electricity market was small during this period and capital investment was high. Early public supply consumers included local authorities providing electric street lighting, retailers and other businesses who benefitted from bright lighting, which was believed to discourage burglars, who preferred operating under cover of darkness.[151]

Licences dictated the maximum which could be charged per unit, effectively price capping. Supply companies charged different prices for different uses to encourage uses which made their load and generation as efficient and economic as possible.[152] Lighting was the original and most popular use

[151] 'Electricity v. Burglars', *The Times* (London, 1882), 30593, p.7 describes The Glasgow Supply Company's electrician who marketed electricity as an inexpensive way to detect and discourage burglars using electric bells, which he described to the Glasgow Herald in 1882.
[152] Load is fully explained in the glossary but is a measure of volume of electricity generated to electricity demanded; the closer the ratio, the more efficient the process. The more predictable the demand the easier it is to balance load and as a result pricing was used to encourage predicable loads.

but the most inefficient and expensive load for the supplier. As a result, domestic lighting was expensive comparative to other uses, such as domestic cooking and heating. Separate meters were installed to measure consumption for different uses. Industrial power often ran continually during daylight hours making it beneficial to the supplier, so was cheaper per unit than its domestic equivalent. Power for traction was cheaper again because it further increased load efficiency. As supply companies grew and became more efficient, prices reduced to some extent but expanding generation and distribution was expensive requiring continual investment. Technology continually improved and keeping prices low enough to encourage more consumption but retaining enough capital to expand provision and be profitable was the supplier's role. For local authorities this could be more difficult because they often owned the gas undertakings which electricity was competing with, and amongst councillors who had shares in either gas and/or electricity suppliers, this could be contentious. Authorities were also responsible to their rate payers and was sometimes presented as the reason for not supplying electricity because it could be considered irresponsible before electricity was proven beneficial.[153] Prices relating to industrial and domestic electricity are discussed in further detail in Chapters 3 and 4 respectively.

Encouraging Cooperation – 1909 -1918

Legislation

The Electric Lighting Act of 1909 did little to change the parochial nature of supply but bulk supply by licensed power companies. However, it began an upscaling of supply where permission could be granted to supply premises beyond the boundary of an undertaker's licence. Permission for an

---

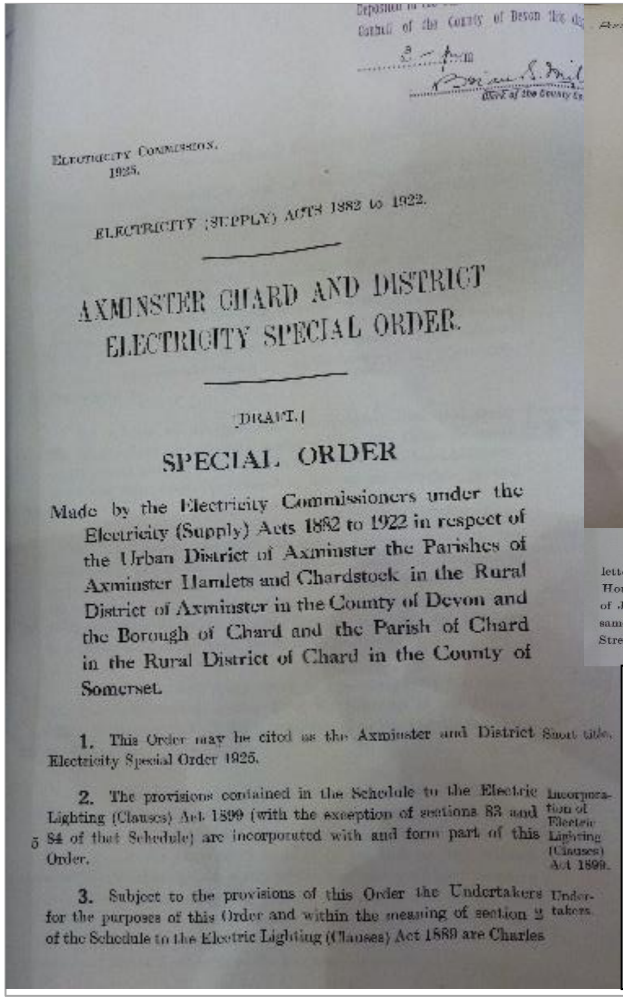
[153] Hennessey, *The Electric Revolution,* pp.19-20 and Ballin, *The Organisation of Electricity Supply,* pp.22-31 and Luscombe and Buck, *Plymouth's Electrical Revolution,* p.7. It is generally accepted amongst local electricity engineers/historians I have spoken with that many councillors had interests in local gas undertakings which may have influenced their views on electrical undertakings.

outside supplier required consent from the local authority and the current licensed supplier for the area in which the premises were situated. Similarly to the lighting Acts of 1882 and 1888, this Act was partly about legislation catching up with new working methods, larger machinery and improving distribution technology. This did not go far enough for everyone. Hinton demonstrated this frustration stating, 'The new Act of 1909 was *still* the Electric *Lighting* Act; even in nomenclature legislation had still not caught up with technology'.[154]

The 1909 Act began to address the 'nuisance' of the generating station, although this could also be considered legislative catch-up because complaints were not new. This introduced a new stage to the application process, making it necessary for applicants to make plans to build power stations known 'to the local authority of the district in which the land is situated, and to owners and lessees of land situated within three hundred yards of the land upon which the generating station is to be constructed'.[155] An opportunity had to be given for objections to be raised. The applications to the Board of Trade, were initially considered at local council quarter sessions and lists of the people consulted are given alongside their property details. This became part of the licence application and is shown in Figure 1, an example from the Quarter Sessions for Devon for Axminster and Chard, dated 1925. It shows, alongside the licence (Special Order), a map giving the position of the proposed generating station and a statement explaining how to object to the plan and details of people who were consulted. These applications are a rich source of information providing details about the company, supply area and street names in which mains cables would be laid within two years of the licence being granted. Each record office visited during this work held at least tens of these, if not more. They hold enough information that given enough resource, reconstruction of infrastructural development of electricity would be possible. A small example of maps at a reginal scale is shown in the case study in Chapter 4.

[154] Hinton, H*eavy Current,* p.41.
[155] 'The Electric Lighting Act 1909' (H.M. Stationery Office, London, 1909).

FIGURE 1 PARTS OF A SPECIAL ORDER SHOWING THE RESIDENTS CONSULTED.[156]



Deposited in the ... of the County of Devon the ... day ...

Clerk of the County ...

ELECTRICITY COMMISSION, 1925.

ELECTRICITY (SUPPLY) ACTS 1882 to 1922.

AXMINSTER CHARD AND DISTRICT ELECTRICITY SPECIAL ORDER.

[DRAFT.]

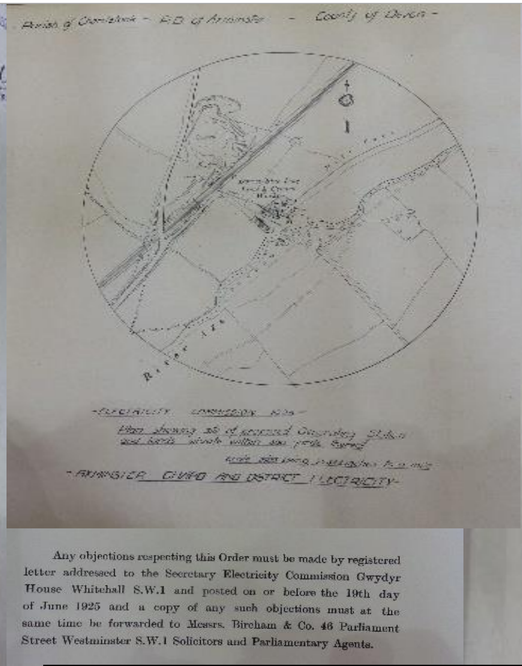
SPECIAL ORDER

Made by the Electricity Commissioners under the Electricity (Supply) Acts 1882 to 1922 in respect of the Urban District of Axminster the Parishes of Axminster Hamlets and Chardstock in the Rural District of Axminster in the County of Devon and the Borough of Chard and the Parish of Chard in the Rural District of Chard in the County of Somerset.

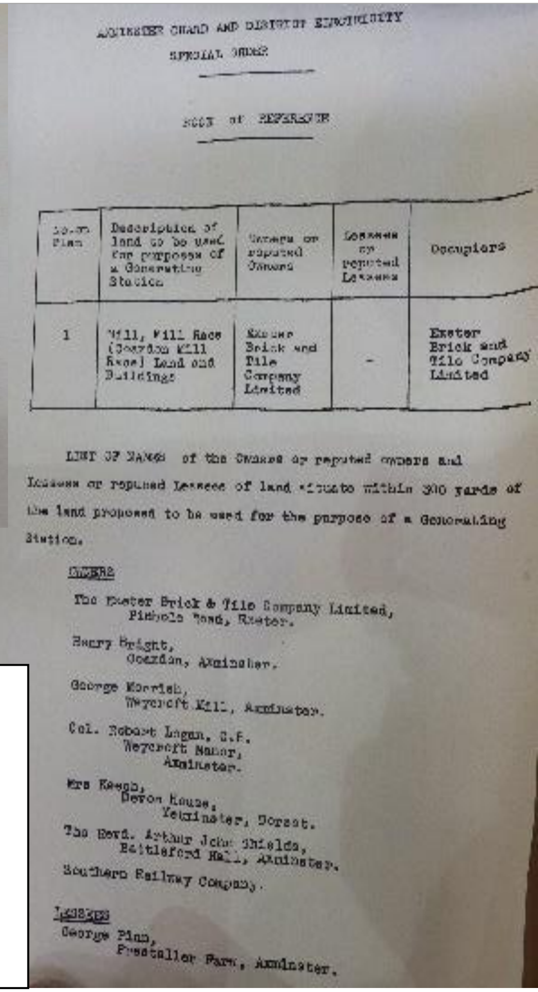
1. This Order may be cited as the Axminster and District Electricity Special Order 1925. — Short title.

2. The provisions contained in the Schedule to the Electric Lighting (Clauses) Act 1899 (with the exception of sections 83 and 84 of that Schedule) are incorporated with and form part of this Order. — Incorporation of Electric Lighting (Clauses) Act 1899.

3. Subject to the provisions of this Order the Undertakers for the purposes of this Order and within the meaning of section 2 of the Schedule to the Electric Lighting (Clauses) Act 1889 are Charles — Undertakers.



Any objections respecting this Order must be made by registered letter addressed to the Secretary Electricity Commission Gwydyr House Whitehall S.W.1 and posted on or before the 19th day of June 1925 and a copy of any such objections must at the same time be forwarded to Messrs. Bircham & Co. 46 Parliament Street Westminster S.W.1 Solicitors and Parliamentary Agents.



AXMINSTER CHARD AND DISTRICT ELECTRICITY

SPECIAL ORDER

BOOK OF REFERENCE

No. on Plan	Description of land to be used for purposes of a Generating Station	Owners or reputed Owners	Lessees or reputed Lessees	Occupiers
1	Mill, Mill Race (Coaxdon Mill Race) Land and Buildings	Exeter Brick and Tile Company Limited	-	Exeter Brick and Tile Company Limited

LIST OF NAMES of the Owners or reputed owners and Lessees or reputed Lessees of land situate within 300 yards of the land proposed to be used for the purpose of a Generating Station.

OWNERS

The Exeter Brick & Tile Company Limited, Pinhoe Road, Exeter.

Henry Bright, Coaxdon, Axminster.

George Morrish, Weycroft Mill, Axminster.

Col. Robert Logan, C.B., Weycroft Manor, Axminster.

Mrs Keogh, Devon House, Yetminster, Dorset.

The Revd. Arthur John Shields, Battleford Hall, Axminster.

Southern Railway Company.

LESSEES

George Pinn, Prestaller Farm, Axminster.

Parts of an Electricity Special Order demonstrating how the generating station will be located and the beginning of the list of people consulted over its construction.

[156] Source: Exeter, The South West Heritage Centre, 'Axminster, Chard and District Electricity Special Order, 1925', QS/DP/717.

This was perhaps the first step towards considering the 'environment', albeit the immediate environment around the power station and its impact on the people nearby. This allowed concerns to be addressed early, and although it was motivated by the need to reduce complaints, it was a tiny step towards the comprehensive environmental impact studies undertaken in the twenty-first century.

An enquiry into 'nuisance' by the London Electrical Supply Company in 1889 took evidence from Siemens, the eminent German-born electrical engineer who founded the company bearing his name. He, when asked about the 'alleged nuisance of generating stations from noise, vibration and smoke, replied that he did not know of such complaints in Berlin'. He continued, possibly to ensure he did not suggest the British are complainers, to say, 'at the Savoy Theatre in London an installation had been run without any complaints; and in fact, people did not know the station existed'.[157] However, Siemens was in favour of large generating stations because his was one of the companies supplying them with equipment. In fact, in 1900, a report Siemens contributed to, commissioned by the London Chamber of Commerce, suggested that 'the greater elasticity of all restrictive rules and the greater freedom for the individual exercise of good judgement…the better it will be, both for the community at large and the electrical development of this country'. He attributed the advisor to the Board of Trade at that time, Trotter, as having this attitude, making it easier for electricity supply companies. [158]

Around the same time Cross reported for his parliamentary committee making recommendations which echoed the thoughts of many electrical engineers, promoting larger power stations, higher voltages, longer distribution distances, and larger supply areas. This was essentially the model that NESCo. would make a success from.[159] They had licenses for several local authorities, who had consented, and bought out other suppliers to obtain licenses and build a regional supply in the

[157] 'Electric Lighting in The Metropolis', *The Times* (London, 1889), 32668, p.10.
[158] 'Electric Power Supply and Transmission', *The Times* (London, 1901), 36550, p.10.
[159] Rowland, *Progress in Power*, p.4.

North-East of England. A small number of generating stations ran at increased capacity and others were downgraded becoming substations. These transformed the higher transmission voltages into lower voltages to distribute to consumers, upscaling and centralising supply.

Much of this development was enabled through acts of parliament, which by then, had begun to give rights to supply in perpetuity. Even for private companies the compulsory purchase clause was sometimes not included, perhaps in recognition of the investment required. However, where a supplier was already licensed permission had to be obtained from them, and the local authority, for the Power Act to extend into their territory. This was the embryonic stage of wider transmission and distribution but differences between technologies installed in the hundreds of undertakers made large-scale cooperation difficult and costly.

Despite power company creation the system was still based on a disparate set of electricity types and technologies. The extraordinary conditions of WW1 led to suspension of much existing legislation to meet munitions requirements, and brought new legislation, including The Special Acts (Extension of Time) Act of 1915, amongst others, 'with the object of making provision to meet the changes in conditions brought abought by the war'.[160] Under these new conditions demand for electricity grew quickly, as did interconnection and the scale of generation, with industrial consumption being prioritised. Consumption increased dramatically, as did the efficiency of production. Bowers reported that generation capacity increased by thirty-nine percent (from 1120 MW to 1555MW) but units sold increased by 106% (from 1318m per year to 2716m) concluding, 'electricity supply was becoming increasingly significant in British industrial and economic life'.[161] The proportionally larger increase in units sold compared to capacity increase demonstrates an increase in efficiency, which may partly due to improved machinery but also resulted from improved load factors and management.

[160] Elec. Comms., *Annual Report*, 1, p.5.
[161] Bowers, 'Electricity', p.287.

Interest in electricity and its contribution to the war effort drew interest but there was a tension between releasing information and the need for secrecy during war, particularly as electricity was discussed within regard to coal shortages affecting industry and domestic settings. In December 1916 *The Observer* interviewed 'Mr Edison on the War - Using Science in the Battlefield'. Given that Edison was renowned for his electrical work in America and Britain it can be assumed that his thoughts would relate to electricity. 'Science', said Edison, 'will give us anything. I have been astonished by the fact that there is nothing new in this war'.[162] He talked about his 'disappointment' at the Germans, from whom he expected 'new things', and how he felt they underestimated the British. He was not entirely flattering towards the British, though, stating: 'England has made great and fundamental mistakes, most of which have been laid bare before the world by the progress of events connected with this war. She kept wages too low and stupefied her working men with alcohol in order to make this possible and make profit for her titled brewers'.[163] However, he said, 'But though the Englishman is slow when he starts he can't be stopped. He is heavy. Momentum will carry him much farther than it will the Germans, or the French or the Americans'. The term 'momentum' was later adopted by Hughes; who knows if this interview was the inspiration. However, 'momentum' arguably also suggests direction, and despite an increasing pace of change it was another decade before the direction of British electrification was finally determined.

Ownership

Over this period 'bigger being better' applied. Companies were increasingly being formed and incorporated as power companies. These companies built and managed large power stations, generating and supplying high voltage electricity to sell to other undertakers for distribution under

[162] E. Marshall, 'Mr. Edison on the War: Science in the Battlefield', *The Observer* (London, 1916), p.9.
[163] *Ibid.*

their supply licences. In many places the power company owners also owned the undertakers to whom they sold bulk power. As a result, competition was not effective to manage suppliers. The practices of these companies, and other contracting arrangements, were investigated in the 1930s and are discussed later in this chapter.

Prices

Companies which are included as part of this work had no adjustments made to the maximum price per unit authorised on their licences prior to WW1, although actual prices tended to reduce slowly. There were difficulties during WW1 because the War Office took over the running of certain factories and electrical companies, altering legislation to increase interconnections between suppliers and factories. In some cases, this meant compulsory connection to a public supplier even if the factory owner would not have chosen that option.[164]

It was necessary to revoke and reinstate many legislative changes from wartime. British Summer Time continued after WW1 reducing the time electric lighting was required, which impacted prices and was part of the justification companies used for two-part tariffs being necessary. These tariffs included a fixed cost towards the investment and capital costs of supply, and a variable charge dependent on consumption. At the end of the war authorised undertakers, where they applied, were granted permission to temporarily increase their maximum charges to help compensate for losses over wartime and from the 1920s strikes, primarily for coal costs. The Electricity Commissioners reported: ‘Some 200 applications for an increase in maximum price were dealt with by the Commissioners during the year 1920/21, the number of applications decreasing in subsequent years to 50 in 1920/21; 48 in 1921/22 and 1922/23; and 42 in 1923/24’.[165]

---

[164] This will be discussed further in Chapter 3.
[165] Elec. Comms., *Annual Report*, 23, p.11.

Increasing Scale

Legislation

In 1916, when Edison was interviewed British electrical engineers were promoting their ideas for large-scale generation forward. An example was a paper by IEE member Williams, advocating for power schemes, ideally including national generation distributed through existing local networks. The tone of his final conclusions suggested it was a desired outcome rather than something he was expecting to see achieved, saying;

> Can we not see the dawn of a new era when an efficient electricity supply at low cost and with the new means of transport will enable men to work under better economic and more humane conditions in the country, instead of extending the already densely packed towns? A future in which we shall be conserving our resources to the utmost and by greater efficiency be preparing for the next war. [166]

Alongside these experts, politicians were considering post-war reconstruction. In 1918 Williams, liberal politician, chairman of several Board of Trade committees and financial officer for the War Office, reported on the outcome of a two-year investigation into 'The Question of Electric Power Supply'. The committee was tasked to consider how to ensure an 'adequate and economical supply' of electricity for 'all classes of consumers' but particularly a cheap supply for industrial development. The reducing competitiveness of Britain, especially when 'subjected to the test of keen international competition after the war', prompted this investigation and determined that reducing manufacturing costs was necessary for success.[167] The recommendations reflected Williams's earlier paper but the suggestion of imposing a national system of supply was rejected. Instead, Williams'

---

[166] E.T. Williams, 'The Electricity Supply of Great Britain', *Journal of the Institution of Electrical Engineers* (1916), 131, 260, p.587.

[167] 'Report of the Committee appointed by the Board of Trade to consider the question of Electric Power Supply', (H.M. Stationery Office, London, 1918), p.3. Hereafter 'The Williamson Report'.

report led to the creation of the Electricity Commissioners, five electrical experts who wielded little real power. Despite lacking mandatory authority, they were tasked with coordinating electrical power generation, supply and consumption into twelve geographical areas which they also defined. It was hoped that the Electricity (Supply) Act of 1919 would facilitate cooperative working through the formation of Joint Electricity Authorities (JEAs) that would manage supply and demand in their own area as efficiently as possible, including municipal and private companies. This was generally well received; for example, Burns, a renowned thinker at the time, wrote in 1919, 'It appears that some action is being taken which may be preparatory to a large scheme of electric power supply for the whole of Great Britain; but the scheme is only at its initial stage'.[168] However, there was little incentive for suppliers to engage as they already had licences and could continue to hold them regardless of their participation in a JEA. Consequently, this relied entirely on good relationships between suppliers and their willingness to work cooperatively under the Electricity Commissioners' guidance.

With hindsight, and without exception, authors concluded that the 1919 Act provided no real power for the Electricity Commissioners, and their best weapon was verbal persuasion. The profile of the supply industry when they began is shown in Table 2.

.

[168] C.D. Burns, 'The Readjustment of Industry in the United Kingdom', *Annals of the American Academy of Political and Social Science* (1919), 22, p.73.

TABLE 2 GENERATION OF ELECTRICITY IN THE UK – C.1918.[169]

Undertakings		Generating Plant Installed	Capital expended on Lands, Buildings, Sidings, Wharves, etc., and Generating Plant, *excluding* distribution items	
Class	Number of Undertakings	KW	Total	Average per K.W. Installed
Local Authorities		KW	£	£
London	14	131,791	3,375,396	25-6
Rest of Great Britain	214	1,290,133	26,312,862	20-3
Ireland	11	28,695	624,853	21-8
Total	239	1,450,619	30,313,111	20-9
Companies				
London	15	216,037	6,282,071	29-1
Rest of Great Britain	162	135,645	4,310,586	31-8
Ireland	5	2,801	128,428	45-9
Total	182	354,483	10,721,085	30-2
Power Companies	17	370,053	7,258,840	19-6
Totals	438	2,175,155	48,293,036	22-2

The first annual report outlined the enormity of the task before the Electricity Commissioners, 'As illustrating the complexity of the position, in the area of Greater London alone there are some 70 generating stations representing between them 50 different systems of supply, 24 different voltages and 10 different frequencies'.[170] The Act also transferred responsibility for electricity supply from the Board of Trade to the Minister of Transport, and enabled the Electricity Commissioners to perform

[169] Source: Elec. Comms., *Annual Report*, 1, p.8.
[170] *Ibid*.

duties and powers delegated by the Minister of Transport, alongside being available in an advisory capacity. They were responsible to this Minister rather than directly to parliament.

Perhaps most telling, was the first listing on their duties and powers, which was, 'To conduct experiments'.[171] The expectation was for undertakers to create schemes for their areas and submit them to the Electricity Commissioners. If none was forthcoming the commissioners would propose schemes, undertake enquiries, and put them into place. This was to encourage a more coordinated and standardised system which reduced wastefulness and increased efficiency.[172]

Schemes for JEAs were submitted by electricity undertakers, including six possible plans for the London and Home Counties district. Each JEA would be governed by a district board made up of the suppliers from the area. The board would reorganise the area by purchasing and controlling the most efficient generating stations (with the owners' consent), build new generating stations, and manage overhead wires in the same way. Although this was regional coordination it had national oversight by the Electricity Commissioners. Competitiveness with gas suppliers was addressed in this legislation, lifting the compulsion for gas suppliers to supply areas in which electricity was also being supplied.[173]

The first Electricity Commissioners were led by Snell, a successful electrical engineer working for various undertakers carrying out installations, then as a consulting engineer with Preece before becoming an advisor to the Board of Trade. The Electricity Commissioners held enquiries into contentious issues, successfully obtaining some cooperation in a few of the created regions. There were two successful JEAs, the Midlands and London and the Home Counties which had longevity and suppliers worked mostly cooperatively and increased efficiency. The JEAs and other supply

[171] *Ibid.,* p.13.
[172] *Ibid.,* p.7.
[173] *Ibid.,* p.14.

companies now applied to the Electricity Commissioners, rather than parliament, for changes to their licences, extensions of any kind, and to sanction government borrowing for local authorities.

Whilst the Electricity Commissioners made some progress towards greater coordination another important achievement was the compilation of a comprehensive study of electricity provision across the country. They found there were 572 Authorized Undertakings with supply powers, with 438 generating stations (excluding railway and tramway undertakings), and a total of £161,750,000 of capital expenditure.[174] It was partly this knowledge that enabled the next committee, appointed to review 'The National Problem of the Supply of Electrical Energy' just six years later, to propose the 'Gridiron', a national system of generation and transmission, published in the Weir Report in 1926.

Ownership

Ownership did not change much over this period except for JEA formation where they took ownership of generation, forming regional networks operating as NESCo. did in the North-East. This meant that licences had to be applied for in several local authority areas and other supply companies' assets needed to be bought. Transfer of ownership had to be agreed by the station's owners but, as the generating stations usually belonged to the larger suppliers in the area, it was likely the owners would be on the district board governing the JEA.

[174] 'Report of the Committee appointed to review the National Problem of the Supply of Electrical Energy, Ministry of Transport – Including the Technical Scheme by John Snell and Charles Merz 1926: Includes Additional Reports from the committee to review the national problem of Electricity Supply' (H.M. Stationery Office, London, 1926). Hereafter known as 'The Weir Report'.

Prices

Whilst ownership remained fairly stable, it was a period of price adjustment; prices tended to be between 4d. and 5d. per unit for domestic lighting. Industrial lighting was treated differently, often provided to a factory or workshop without charge, or at favourable rates, provided it did not exceed twenty percent of the total electricity bill. The maximum price allowed under licence for the Lea Valley suppliers, for example, was 8d. and was often charged in the early 1920s because of high coal prices. As previously discussed, temporary price increases were granted after WW1 to ensure electricity supply continued despite the shortages and reduced quality of coal available.

Pricing became increasingly complicated as new uses, such as domestic cooking, heating and water heating became available and supply companies needed to consider how each use affected the load factor of their operations. As undertakers, private or local authority, began by providing public and domestic lighting an existing price structure usually existed for these. Traction and industrial power had their own separate tariffs, as did agriculture. Further complexity was incorporated, creating many sub-categories within each type. For example, domestic lighting costs depended on whether it was Daylight Savings Time or Greenwich Mean Time. Discounts were available, some for prompt payment others dependent on the number of units consumed, the time of day they were consumed and so on, alongside the number of electricity types metered and consumed on the premises. Consumers installed and paid for, a meter for each electricity use to measure units consumed, as explained in many books and pamphlets, because although the actual cost of each unit was the same to produce, the predictability and volume of the load factor affected efficiency, and therefore the costs of generation.[175]

[175] These are tariffs as shown in E. Garcke, E., (Ed.), *Garcke's Manual of Electrical Undertakings* (50 vols. London, 1886-1953) and as explained in; Electrical Association for women, *The EAW Electrical Handbook (*London, 1965), pp.101-116 and a full discussion can be found in D. Bolton, *Costs and Tariffs in Electricity Supply* (London, 1938). The load factor is affected by demand for electricity because the most efficient way to provide it is by the generated amount being equal to the demand as this produces the least waste.

Pricing was slightly simplified when two-part tariffs were gradually introduced which arguably better reflected the real costs of supply. However, even after this many companies still offered 'flat-rates' which had no fixed cost components, but initial unit prices were higher and reduced as units consumed increased, within the billing period. Electricity suppliers were happy to negotiate costs with industrial users because they were large, predictable consumers. This resulted in different unit prices between suppliers; differences of 1.5d. was common for power and 2d. or 3d. for domestic lighting in the late 1920s. This led to a 'postcode lottery' because consumers could only purchase electricity from the supplier licenced for their area. As a result, depending on the area boundary, two sides of the same street or even neighbours could be paying very different prices. The tiny monopolies could charge up to the maximum prices allowed by their licences, which were granted, in many cases, at least 25 years earlier. As Chapter 4 demonstrates, as a national system seemed increasingly inevitable areas without a licensed supplier had an inherent value, demonstrated by increased license applications to supply these areas during the early 1920s.

To demonstrate pricing complexity, Hackney is typical of a supplier with a mix of industrial and domestic consumers but was very urban and the tariff was;

- In 1912; Price authorised, 8d. Charged-Lighting, 6d. and 1d.; flat, 3 1/2d. Power, £1 per K.W. per qr., and ½ d per unit. Flat 1 1/2d.[176]
- In 1924; Price authorised, 8d. Charged-Lighting, £2 10s. per K.W. per quarter and 1d. per unit; flat, 5d; prepayment meter 8d. Power, £1 5s per K.W per quarter and 3/4 d. per unit. Flat, 1 1/2d. Heating and Cooking, 1d. per unit. Discount for prompt payment, 5%.[177]

Predictability of demand is important: the more predictable the load to meet the demand, the less likely there are to be wasted resources and the cost is lower. Traction and industrial power are the most predictable demands, and, at the other end of the scale, domestic lighting is much less predictable and therefore likely to be the most wasteful, which is why its costs are higher per unit.

[176] Garcke, *Garcke's Manual,* 17, p.485.

[177] *Ibid.*, 29, p.345.

National Scale – 1926 to 1948

Legislation

The Grid, 'the world's first national system of supply, can be characterised as an invention and a development by committees'.[178] Hughes's words described years of work undertaken by parliamentary committees trying to create a coherent industry from the chaos of small and technologically incompatible suppliers. With hindsight, small steps towards this national supply system were slowly creeping into earlier legislation, albeit to regulate technological and business development rather than deliberately promoting system integration. The final steps to create national scale generation and transmission was introduced after more than a decade of advocacy from electrical engineers, by politicians who were increasingly under pressure to improve electrical supply for industry to meet wider economic concerns.

The Electricity Commissioners reported in 1924 that,

> The general reduction in the cost of generation and in the charges for electricity which was a marked feature of the preceding year was followed by further similar reductions in many parts of the country during the year 1923-24, with results beneficial to the supply undertaking themselves and to industrial and domestic consumers generally.[179]

They further suggested that whilst this was 'substantially aided' by reductions in coal costs, plant and materials with technical and commercial development of the industry also contributing. They expected, at this time, to see continued steady progress in developments in the years to come after the pressures of war which prompted large efficiency savings in generation. 'Increased attention

[178] T.P. Hughes, 'Managing Change - Regional Power Systems 1910-30', *Business and Economic History* (1977), 62, p.65.
[179] Elec. Comms., *Annual Report*, 4, p.4.

devoted to publicity and propaganda' were also listed as 'contributing to the lowering of costs of production'.[180]

However, whilst generally positive there was an underlying message in this report that more must be done; an example was the phrase 'It is apparent that there is great scope for re-organisation on lines which will lead to the more economical production of electricity' when discussing generation still primarily being carried out in 'small discrete power stations'.[181] They suggested using modern power stations, which used just two pounds of coal per unit of electricity produced, could have saved twenty percent of total coal consumption over the year and demonstrated 'the further economies to be achieved by the centralisation of generation' and that the 'desirable process [where local generation at 37 small stations had been entirely superseded by bulk supplies] needs to be accelerated'.[182]

They concluded that, despite progress being made through voluntary cooperation they encouraged,

> It has become apparent that a real organisation, which will adequately serve the requirements of the country, can only be achieved on the voluntary basis of the Act of 1919 by a radical change in the attitude of authorised undertakers in general, and that failing the early disappearance of the obstacles which have hitherto retarded progress the whole position will call for review.[183]

A year later the Electricity Commissioners reported that Merz and McLellan had been appointed to consider a programme for complete industry standardisation of supply, and that Weir would lead a committee to 'consider the question of the immediate and future electrical development of the country'. One advantage this new committee had was the wealth of official statistics the Electricity Commissioners had collected. These provided a comprehensive picture of generating and supply,

[180] *Ibid.*
[181] *Ibid.,* p.10.
[182] *Ibid.*
[183] *Ibid*., p.17.

which the Electricity Commissioners thought were a 'necessity', and data from these statistical returns was 'essential for the purposes of the [Weir] Committee'.[184] Although, as their own reports show, the Electricity Commissioners made some progress in reducing electricity prices, and increased cooperation, the Weir Report explained that 'We are still today neither generating, transmitting nor distributing electrical energy as cheaply as we might, nor are we consuming electrical energy to anything like the same extent as other highly civilised industrial countries'.[185] The realisation that development was still behind competitors such as France, Germany and America, alongside reports into 'Industries After The War' conducted by Birchenough, reinforced this position after WW1 and was still the case as Weir began his work.[186] Whilst progress had been made towards working regionally, the use of the term 'National' in the question considered by this committee perhaps showed greater political willingness to find a truly national solution.

Weir was an industrialist and had served, unpaid, in the Ministry for Munitions in Scotland, and had been involved in previous committees including civil aviation, economies in the fighting services, and co-ordination between the army, navy and air force. Hinton reported 'No committee of which Lord Weir was chairman would pull any punches' and after the Williamson report recommendations for national supply had not been fully enacted and essentially the same question was being re-addressed, but a national solution was being sought.[187] Less than flattering remarks about Britain's electrical system at the first World Energy Conference in 1924 and falling industrial competitiveness all led to increasing pressure for real change.

The Weir Report contained two parts: the report itself and a technical scheme presenting statistics about electricity for comparison to other countries, and technical specifications for the proposed 'Gridiron'.[188] Dalton wrote an annotated version of the Act when it was published and explained

[184] Elec. Comms., *Annual Report*, 5, p.7.
[185] The Weir Report, p.3.
[186] H. Birchenough, 'Industries After the War', *Journal of the Royal Society of Arts* (1918), 66, 3432, pp.644-645.
[187] Hinton, *Heavy Current,* p.44.
[188] The Weir Report, p.9.

that, 'The advantages to be derived from the production of electricity on as large a scale as is practicable have always been recognised by experts and the principle has been endorsed by a series of Parliamentary Committees'.[189] Unlike previous reports the Weir Report was accepted and adopted into legislation with little change and it is worth noting, as Dalton did, that much of it reflected the Williamson Report.

> It is significant that the principal recommendations of the Weir Committee, the original provisions of the Bill as presented to parliament and the eventual provisions of the Act differ in few material respects, and thus appear to disclose the confidence of the Government and their expert advisors in the success of the measure.[190]

The way Dalton wrote suggests that he viewed this legislation as a turning point. He went further, saying, 'Of the Electricity (Supply) Act 1926, it is true to say that the legislature has looked ahead and has endeavoured to direct into co-ordinated channels the development of the future'.[191] This was an attempt to consider the possible and seek to enable it, rather than controlling the current situation or just adding more regulation. This forward thinking was informed by the data collected by the Electricity Commissioners and their five years of experience providing a comprehensive picture of British electricity supply and formed the basis of the proposed technical scheme and forecasted future scenarios.

The Weir Report emphasised the potential of the domestic market, something not considered by Williamson who was primarily focussed on improving electricity for industry to improve productivity. The enormous potential for both markets was demonstrated, and a practical plan was presented.

---

[189] J. Dalton, *The Electricity Supply Act, 1926 Annotated and Explained, with an Introduction* (London, 1927), p.1.
[190] *Ibid.*, p.v.
[191] *Ibid.*

TABLE 3. POSITION OF BRITISH ELECTRICAL SUPPLY IN 1925 AS REPORTED BY THE ELECTRICITY COMMISSIONERS.[192]

Number of Authorised Undertakings with Supply Powers	
Local Authorities	335
Electrical Companies	209
Power Companies	28
Total	572

Number of Generating Stations owned by Authorised Undertakings	
Local Authorities	248
Companies	190
Total	438

Capital Invested by local Authorities	
Local Authorities	£
On Generation	49,360,000
On Distribution and other items	54,120,000
Total	103,480,000

Capital Invested by Companies	
Companies	£
On Generation	24,320,000
On Distribution and other items	33,950,000
Total	58,270,000

Total Capital Expenditure	£
Local Authorities	103,480,000
Companies	58,270,000
Total	161,750,000

In Britain after WW1, there were promises of reconstruction made by government, including new housing. Substantial proportions of this were to be delivered by local authorities, who increasingly traded in electricity and invested in transportation. Britain largely followed international patterns, with an economic slump between 1920 and ’22 followed by slow recovery in the later 1920s before

[192] Source: The Weir Report, p.4.

declining again from 1929 into the 1930s. Where Britain differed was with high levels of unemployment and workforce discontent leading to widespread strikes, particularly in the coal industry.[193] This long-running dispute contributed to increasing numbers of strikes in various other industries over the period, leading to the general strike in 1926 when many industries shut down as workers withdrew their labour. Despite some violence the miners were eventually effectively beaten by the government after reports presenting wage reductions as inevitable. During this process Duncan, who would become the first chairman of the CEB, was chairman of the Coal Enquiry Committee. He was described as a 'wise and sympathetic coal controller' in the Commons by the president of the Board of Trade, Lloyd-Graeme, for the way in which he dealt with the miners' dispute.[194]

This was a difficult period of adjustment; the country was in serious debt with reduced credit levels and high interest rates. During this time many British firms were becoming larger units to benefit from economies of scale and in 1926 the same idea for electricity, and its potential benefits were perhaps more palatable than before the difficulties of adjusting to post-war life were felt.

Weir submitted a covering letter which conveyed the sense of necessary urgency that the committee realised was needed. Reinforced by the additional jobs it could bring at a time of prevalent unemployment, the letter stated 'that it would benefit the national situation if this employment could be made available at the earliest possible moment'.[195] The committee proposed establishing an expert advisory committee including those who had produced the technical scheme so, 'the staffs of two or three leading firms of consulting electrical engineers' could carry out a survey of existing

[193] 'Coal Peace Urgent', *The Times* (London, 1921), 42697, p.10 with further information which can be found in Kindleberger, *Economic development of England and France* and W. Ashworth, *An Economic History of England, 1870-1939* (London, 1960). These discuss issues around economic development in Britain related to employment, technology and the economy.
[194] Parliamentary Debate, 'Government and Coal Industry' HC Deb 07 December vol. 211, c.1245 accessed via 'http://hansard.millbanksystems.com/commons/1927/dec/07/government-and-coal-industry#column_1425.
[195] The Weir Report, 'Covering Letter'.

suppliers quickly and efficiently. The letter then addressed the wider context and demonstrated the enormity of the changes the committee foresaw, including railway electrification.

During consultation the committee considered whether combining gas and electricity undertakings might be more efficient. Despite owning both types of undertakings no authorities had yet combined them. Whether gas could provide the heat required for a large power station generation process, as the primary fuel, was deemed doubtful. Snell reported it was unlikely to be at a cost lower than coal could provide but stated he was open 'in the natural interest' to any options the gas industry could provide.[196]

The report stated:

> The terms of reference, the necessities of the case, and the whole course of our investigations have led us to adopt, as this goal, the reduction in price and the greatest availability of electrical energy to the consumer, ranging from the largest industrial user to the artisan in his home. We felt that if this was kept steadily in view, individual and local interest would fall into their proper place.[197]

This concise statement, to which the committee largely adhered, summarised their vison for the Gridiron which would achieve their goal by increasing demand, supply, and efficiency. In turn, this was expected to facilitate increased production scale, reduced prices, and make electricity more accessible and affordable. Dalton agreed, 'The Bill has been framed to protect existing undertakings, and at the same time to ensure that the scheme shall come into operation at the earliest moments, and that the benefits shall be passed on to the consumer'.[198] The domestic market which compared to other countries was small, was seen as a way to increase demand and affect the other desired outcomes. However, the undertakers' interests were never far from the forefront of the Weir Report either.

[196] 'Electricity Supply', *The Engineer* (August, 1926), p.173.
[197] The Weir Report, 'Covering Letter'.
[198] Dalton, *The Electricity Supply Act,* p.71.

Imposing the Gridiron onto the existing supply system was designed to handle increased output from fifty-eight selected power stations, generating enough electricity for the whole country. High voltage lines would transmit electricity between them and existing networks continue distribution. The idea was to make it self-perpetuating: increasing efficiency and capital savings from an increased scale, reducing prices to encourage demand, resulting in further efficiency savings and so on. The report stated: 'It is commonplace that the coming age will be one of electricity and it is well known that the uses to which electricity can be put are continually being augmented', they let the future was exciting.[199] These preoccupations, focused in the present on industrial demand and employment, but anticipating future domestic expansion, were prescient. Figure 2 shows how high industrial consumption was compared to domestic through to the mid-1930s. Commercial consumption is included on the graph and shows consumption was comparatively small with a low but had a stable growth rate. Domestic consumption grew from 742 million units in 1926 to over 13,000 million in 1948. Figure 3 shows the percentages of industrial and domestic consumption were sixty-nine and eight percent respectively in 1920, only changing to sixty-two and thirteen percent in 1926 (LHS). Other consumers, farms, street lighting and traction have a small percentage share (LHS).

The Times reported that The Joint Unions Committee in 1920 'carefully abstains from advocating increased productivity on the part of labour, and instead to the need for an improvement in productive production methods and a far-reaching re-organisation of industry'.[200] Weir himself wrote in 1924 that 'the country's wealth producing performance today is approximately sixteen per cent poorer than in 1913, and we have about 1 3/4 million additional mouths to feed'. He also argued that no nation could manage to increase the costs 'unless it is able to multiply its productivity correspondingly', something he did not see in Britain at the time or in any impending policy.[201]

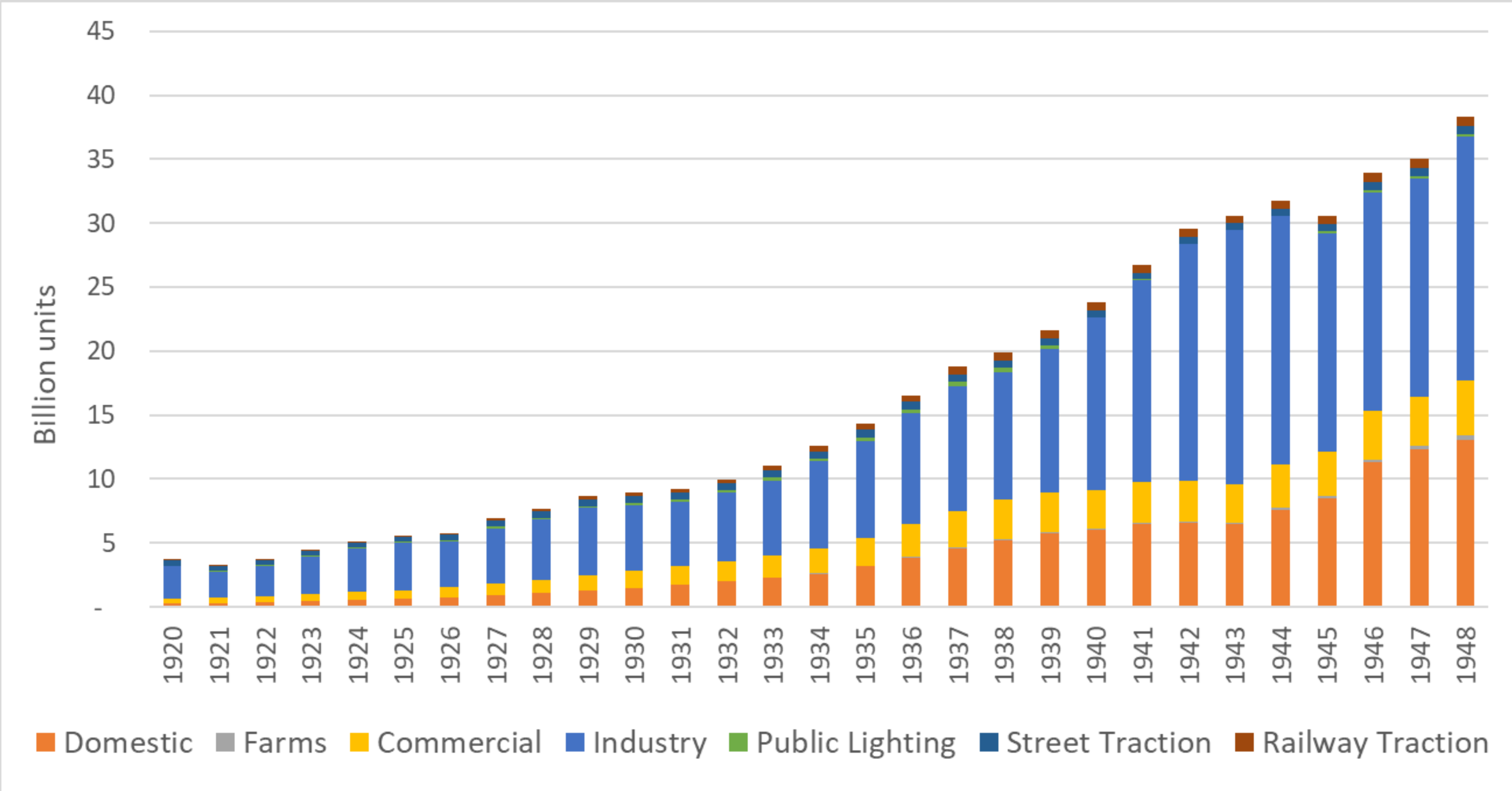
[199] The Weir Report, p.5.
[200] Broadberry, *Market Services*, p.1 and 'Prices and Production' *The Times* (London, 1920), 42511, p.9.
[201] W. Weir, 'The Handicaps of Industry, *The Times* (London, 1924), 43628, p.10.

Weir demonstrated in his report that consumption in Britain was just 110 units per head of population compared to 500 units in Sweden, Norway and the whole of the USA. California consumed most units per head, using 1,200, over ten times British consumption. Although the report acknowledged that there was more private supply in Great Britain than in other nations, not counted in the undertakings' statistics, it was not considered enough to make up the difference. This was another consequence of parochial development, where wealthy households, and some businesses, generated a private supply, either because it was cheaper or public supply was inaccessible.[202] Having invested in a private supply, which was reported to take twenty years to make returns, it was only advantageous to change to a public supply if it was cheaper.[203]

The report by Weir and his committee followed work by Birchenough considering British industries after WW1, Williamson's Report, and the Electricity Commissioners, all consisting of primarily electrical engineers or politicians. It also came after the World Energy Conference, of which Hinton commented, 'It is no wonder that the Weir Committee was set up 18 months later'.[204] The aims of the 1926 legislation were to promote electricity to all potential users, increase demand, create large scale generation to provide abundant low-cost electricity.

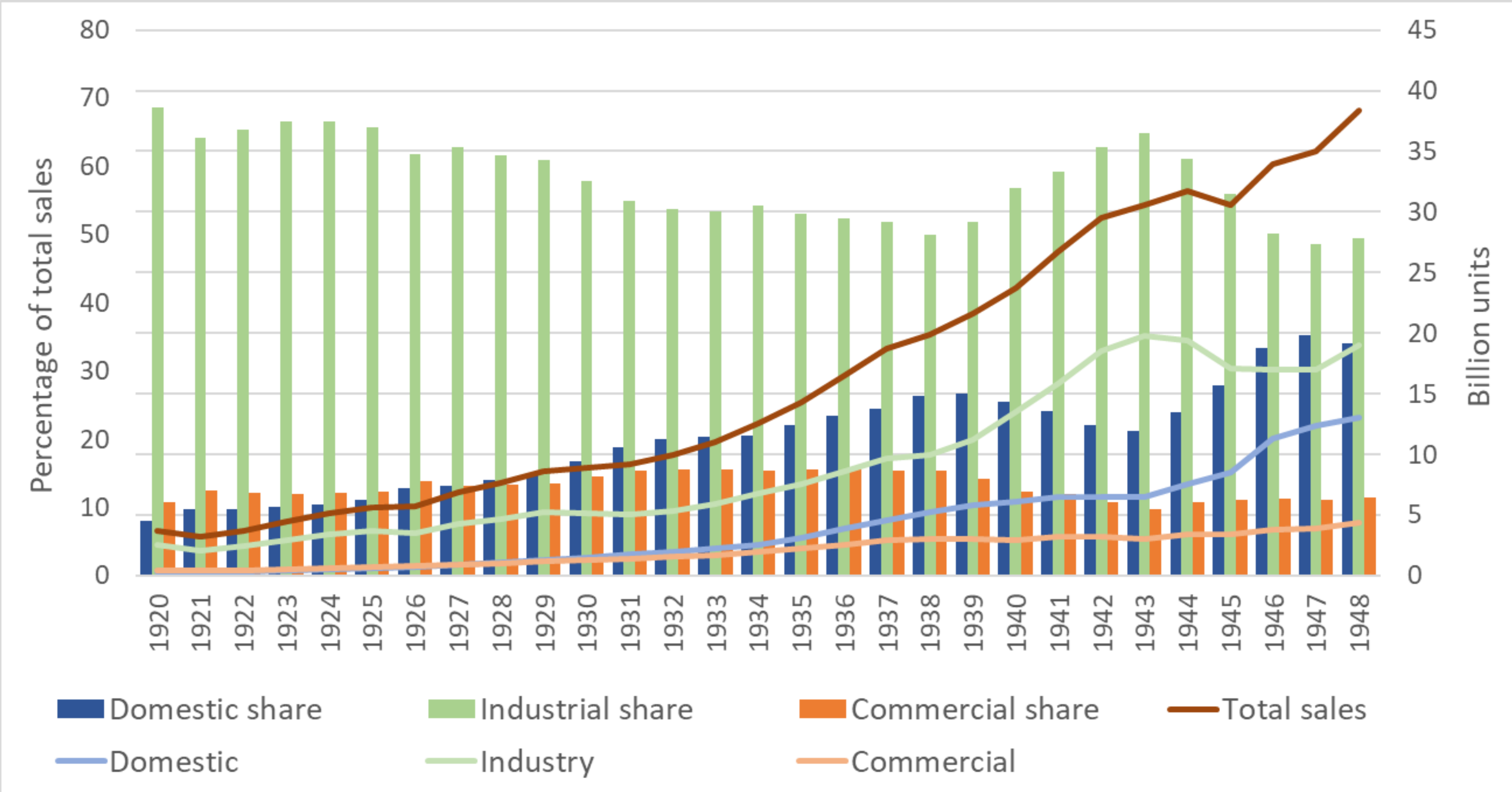
[202] The Weir Report, p.5.
[203] 20 years at 4% inflation was the generally accepted view of the timescale to break even on electrical generating equipment reported by Byatt, *The British Electrical Industry,* p.128 and in Bolton, *Costs and Tariffs.*
[204] Hinton, *Heavy Current*, p.50.

Figure 2 Units of Electricity sold by consumer type.[205]



205 Source: British Electricity Authority (BEA), *British Electricity Authority Annual Report and Accounts* (9 vols., London, 1949 to 1958), 1, p.249.

FIGURE 3 GRAPH SHOWING PERCENTAGE SHARE OF DOMESTIC, COMMERCIAL AND INDUSTRIAL CONSUMERS.[206]



[206] Source: *Ibid.*

The future that the committee envisioned when the 1926 legislation was passed, was a system which would provide affordable electricity for all with the following salient points:

1. All energy will be generated in certain main and secondary power stations, of which 43 are existing and 15 are new
2. 432 existing stations will eventually be closed down
3. A 'gridiron' of high tension transmission mains will be erected inter-connecting all the selected stations and coupling up with existing regional transmission systems and other existing stations.[207]

The committee anticipated that imposing generation and transmission at this larger scale would create economic conditions forcing many of the existing undertakers to close their generating stations, and distribution would be undertaken by fewer companies. This did not happen. The legislation provided powers enabling the Electricity Commissioners to close generating stations provided 'a supply from the "Gridiron" is available at cheaper prices'. 'Selected stations' could purchase electricity for their own operations and areas 'either at the actual cost [as directed by the board] from their own stations (adjusted for load factors) or the "Gridiron" price, whichever is the lower' but never at a cost higher than they could have generated it themselves.[208] For 'non-selected stations' the picture was more complicated because the conditions under which the electricity commissioners could invoke their power to close a station was practically impossible to demonstrate. The 'Gridiron' price included the investment and depreciation costs of the grid generating equipment, the costs to which these were compared did not include these costs. This resulted from trying to keep state interference in private enterprise to a minimum. The CEB, who managed the Grid, recognised this weakness in their own report from 1936, which stated, 'No such undertaker can be compelled to close down his station and buy his supplies from the Grid unless the

[207] The Weir Report, pp.9-10.
[208] *Ibid.*, p.12.

cost of the Grid supply can be shown to be less than the cost of production at the station excluding the capital charges which he will still have to meet'.[209]

The persistence of small undertakers meant that a fundamental part of this re-organisation was ultimately unsuccessful and if non-selected stations continued regardless of the Grid then the system would never work. The CEB made informal arrangements with undertakers to purchase their usual requirement of electricity from the grid rather than generating it less efficiently themselves. When additional electricity was required some of these stations would generate for the Grid. The Electricity (Supply) Act 1935 formalised these arrangements; legislation catching up with the managerial and engineering solutions, again. The CEB paid rental to undertakers for this arrangement, and as the capital charges on the individual stations decreased so did the rental allowance. Arrangements had to be approved by the Electricity Commissioners, and it is a testament to the ingenuity of managers and flexibility of the Grid that this succeeded. However, instead of fifty-eight selected stations, envisioned by the Weir Committee there were still 'some 300 generating stations of which about half had a capacity of less than 10 MW'.[210] The 1935 Act also provided for the CEB to supply industrial users, via a supplier, at reduced prices if they had electrical needs of an 'exceptional nature', which enabled public supply to begin to compete with industries who were still self-generating.[211] This is discussed further in Chapter 3.

Merz, involved in the technical planning for the Grid, spoke of 'understandable criticism from both the Association of Electric Power Companies and from the Municipal Authorities which owned power stations and feared the loss of local autonomy'.[212] Garcke maintained a neutral tone on the new legislation, writing: 'Its function may be briefly described as the reorganisation and control of generation throughout Great Britain'. However, he saw that 'The principal objective of the Act is the

[209] CEB, *Annual Report,* 8, p.12.
[210] Hinton, *Heavy Current,* p.55.
[211] 'The Electricity (Supply) Act 1935' (H.M. Stationery Office, London, 1935), p.4.
[212] Rowland, *Progress in Power*, p.80.

supersession of small scale generation at a multiplicity of power stations'.[213] During debates in the House of Lords concerns were raised about the interests of the current owners of undertakings. For example, Russell talked about opposition from companies, saying, 'There are a large number of small companies supplying electricity at enormous prices 7d. or 6d. per unit - going on quite comfortably from their own point of view. I have no doubt that they are unwilling to be disturbed, and to be absorbed into some larger scheme, and to have their generating plant scrapped'.[214] This was the main opposition argument but was ultimately overridden because enough electrical engineers supported the scheme and dissenters could be accused of purely considering their own interests. Equally, the estimated £25 million of private capital invested in the electricity supply industry paled against the £194 million invested by local authorities.[215]

The Spectator weighed in on the side of the proposed bill. 'This country is behind nearly every other civilised country in the provision, use and cost of electricity. The time has come to set our house in order. It would be humiliating if we were to let things drift any longer'. They reported that politically, socialists felt it was lacking while some on the right felt it was too socialist, and suggested, 'taken together these forces effectively cancelled each other out, making it seem relatively unopposed'.[216] Other authors have written about how difficult the nine months of debate in both houses was, with disagreements running along party lines in relation to the merits of private enterprise or public ownership. Whilst there were issues, mostly practical arrangements, overall the electrical engineers were supportive of the 1926 legislation because it would lead to greater efficiency and cheaper electricity. The history of the Institute of Electrical Engineering recorded that the 1926 Act 'secured careful analysis of the facts relating to the industry', 'stimulated electrical engineering' and 'led all

[213] Garcke, *Garcke's Manual*, 31, p.20.
[214] Parliamentary Debate, 'Electricity (Supply) Bill', HL Deb 24 November 1926 vol. 65 cc787-839 accessed via http://hansard.millbanksystems.com/lords/1926/nov/24/electricity-supply-bill#column_820.
[215] These are figures quoted in the debate in the previous footnote, the actual investment numbers can be found in The Weir Report, p.4.
[216] 'The Electricity Bill', *The Spectator* (London, 1926), p.624.

who sought for the principles [of efficiency in *materiel* and *personnel*] of approved electrical practice to the institution'.[217] Although there were some attempts to delay the bill using parliamentary procedures it became law quickly, passing responsibility to the CEB, to ensure the vision of Weir and his committee was realised. The resulting solution was neither national nor private, and perhaps Mertz described it best as 'in many ways a typical British Compromise'.[218]

The reality was that undertakings could purchase electricity more cheaply than they could generate it making them financially better off because they had fewer costs and retained a supply monopoly. This was intentional but the fact that small, individual undertakers continued to thrive was seemingly unexpected. The maximum prices dictated by their licences had not been revised since they were first awarded, other than the temporary increases after WW1. This meant that many electrical suppliers could make substantial profits without changing their interaction with their consumers. The Weir Report stated, 'To-day, distribution is a practical monopoly; under our proposals the commodity to be distributed will become available to the monopolist at a lower price, and, therefore his monopoly will become more valuable'.[219] This is because the owners of electricity companies were able to purchase their electricity increasingly cheaply but maintain the prices they were charging their consumers. It is likely that this was understood within the industry because, there was a rush for obtain licences for areas with no existing supplier, and larger companies began purchasing smaller companies in the early 1920s. It is difficult to determine whether the difficulties over compulsory closure was an unintentional or was, perhaps, as Ballin suggested, a concession the government made to reduce opposition to the legislation. Removing the distributors would have essentially been full nationalisation and there was little political appetite for it. Weir's report suggested increased profits would be invested in new and better distribution networks but there was no compulsion to do so, again keeping interference in private enterprise to a minimum.

[217] R. Appleyard, *History of the Institution of Electrical Engineers 1871-1931* (London, 1939), p.252.
[218] Rowland, *Progress in Power,* p.80 and Lincoln, *The Public Corporation*, pp.84-115.
[219] The Weir Report, p.14.

Investigations were carried out by the Electricity Commissioners throughout the early 1930s into ownership of undertakings, pricing, and the estimated cost of bringing all electricity supply into public ownership. They suggested the high profitability was unintended but also demonstrate that nationalisation of the whole supply industry was being considered far in advance of 1947.[220]

Weir's report realised that national standardisation of electricity was necessary to improve interconnectivity and coordination. Electrical machinery and apparatus prior to standardisation needed to be compatible with the supply it was powered by and a new supplier, or electricity type might require equipment to be replaced.[221] When electricity undertakers purchased from the Grid, effectively becoming distributors, they bought standardised electricity; three phase AC, 240v and 50hz. If this was sold directly to consumers they would need to ensure compatibility. For large commercial concerns, this could be expensive with financial assistance available although it had to be agreed by Grid engineers, the supply company and the consumer.

Suppliers could easily avoid this difficulty by converting the standard electricity back to the type of electricity they had previously generated and distributed. Meeting minutes from Taunton and Cheltenham electrical suppliers, both local authorities, show that this was their strategy and is supported by Stiel, who wrote about the need for textile works to convert external supply for certain types of machinery.[222] Whilst Hannah does not explicitly state that authorised suppliers bought standard electricity and converted it to earlier types, he does allude to the power that the small monopolies held over the Grid and how the CEB negotiated to supply at different rates preventing additional private generation where possible.[223] An entry from Taunton's company minutes in 1935

---

220 London, The National Archives (TNA), 'Electricity Commission Report into Distribution of Electricity', POWE 13/95.

221 Bristol, Western Power Historical Electrical Society, 'Taunton minutes - entry for June 11, 1935' (ARC-4, --- *Sub-records Cabinet A1* Minutes 1893-1947, Reports 1884 - 1911 Consents & Orders 1912-47).

222 W. Stiel and A. Rodger, *Textile Electrification: A Treatise on the Application of Electricity in Textile Factories* (London, 1933). This is discussed in relation to various textile trades throughout the work.

223 Hannah, *Electricity before Nationalisation*, pp.234-41.

shows that conversion was carried out openly as shown by this entry to borrow money for the equipment necessary:

> The committee report that the arrangements with the CEB with regard to the supply of electricity to Taunton provide that the corporation shall install at their generating station two AC to DC converting plants (in order to convert the grid supply to direct current) each of 400KW capacity, the capital charges on which will be repaid by the CEB to the corporation The engineer suggests £2,750 and the Board want it done asap so the committee recommends the council get the tender done and apply to the ECs to borrow £2,750.[224]

Ultimately, the Grid had little influence on the consumers' experience. It was hoped by the Weir Committee and others that the changes would enable supply companies to concentrate on investment into their distribution networks. However, these continued largely as before. The differences were in the newly created wholesale market with negotiated prices, impacting profitability. This was largely why, ironically, NESCo. was the last area to be connected to the Grid; it supplied at 40 rather than 50hz resulting in the replacement of commercial equipment. An agreement was made in 1935 for the North-East to finish the standardisation process in their region with compensatory funding.[225]

Ultimately standardising prices for equality of access was an aim, although varied fuel prices dependent on quality and transport costs for generating stations was given as the main reason why it was not yet possible. The legislation promoted reduced prices, and the slow journey towards standardisation began but with hundreds of undertakers remaining in service, price disparity continued. Realising that reducing the number of suppliers would remain problematic and the market introduced by the Grid was unlikely to create fewer larger suppliers meant that alternative

---

[224] Bristol, Western Power Historical Electrical Society, 'Taunton minutes - entry for June 11, 1935' (ARC-4, --- *Sub-records Cabinet A1* Minutes 1893-1947, Reports 1884 - 1911 Consents & Orders 1912-47).
[225] CEB, *Annual Report*, 8, p.11.

solutions had to be sought. Additional legislation in 1935 and 1944 permitting supply direct to railways and improving factory safety respectively did not fundamentally change the way the wholesale electricity market functioned.

In 1935 the Electricity Commissioners also began enquiries into electricity distribution, partly because standardisation had not been achieved. 288 undertakings supplied AC, 278 undertakings supplied AC and DC, and sixty-nine supplied only DC and across these combinations, nineteen different principal voltages were supplied. 407 undertakings supplied at the standard 240v but appliance manufacturers still had a market for compatible electrical apparatus because other voltages were still supplied. Of the 607 undertakings operating in 1934-5, 400 of them, each selling less than ten million units, made up less than ten percent of all sales. As a legacy of earlier legislation, if all compulsory purchase rights allowable under license were exercised a potential 334 additional undertakings could have been created.

In 1934, McGowen chaired a committee set up to consider electricity supply and distribution. A cabinet meeting which discussed the report stated, ‘We share the views of that [McGowen] Committee that the existing ‘chaotic’ situation results in hardship and inconvenience to consumers and is prejudicial to the cheap and abundant supply of electricity’.[226] The debate had now shifted, becoming about distribution to consumers rather than generation and supply to other undertakers. Similarly to earlier ideas of voluntary cooperation for the generation and supply of electricity, voluntary measures were recommended to try to reduce the number distribution companies from over 600 to less than 250.

However, this never materialised, partly because of preparations for war, and partly because debates continued in Parliament, with De La Bere asking the Transport Minister questions like;

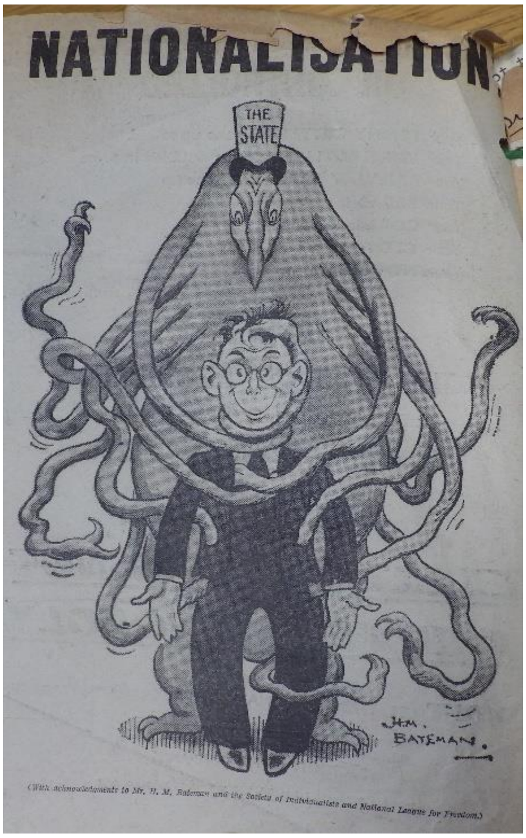
[226] ‘Report of the Cabinet meeting held February 1937’, National Archives, Reference: CAB/24/268, p.4 accessed via http://filestore.nationalarchives.gov.uk/pdfs/large/cab-24-267.pdf.

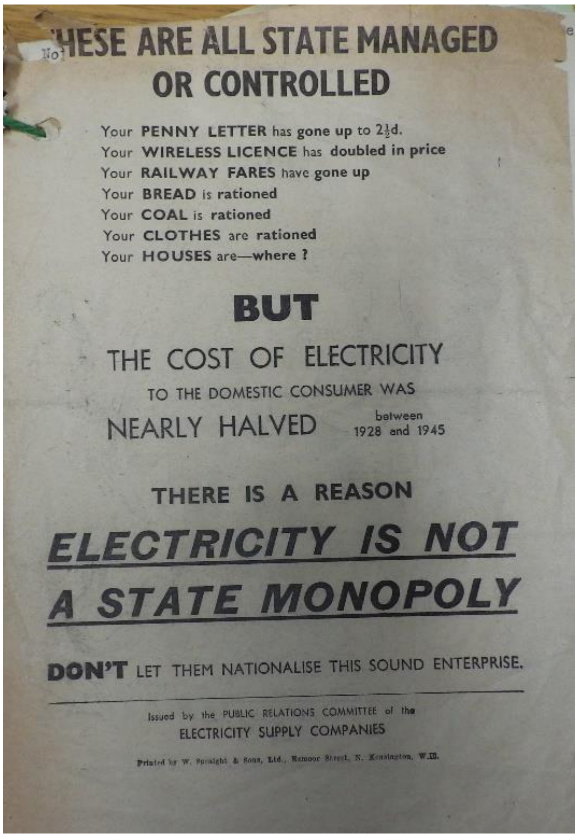
> Is my right hon. and gallant Friend aware that three years have passed since the McGowan report, that there are 9,000,000 users of electricity in this country mostly dissatisfied, and that promise after promise has been made; and will he say why the Government do not fulfil their pledge to end the electricity muddle once and for all?[227]

After WW2, under the coalition government in 1943, a further committee under Lloyd George reported on electricity supply and 'advocated for the transfer of the industry to a Central Generating Board and 14 Regional Distribution Boards'.[228] However, it was under the Labour government elected in 1945 that several nationwide industries, including electricity supply, were nationalised. The arguments were mostly about the principles of nationalisation but the interests of the 561 existing undertakings, comprising 373 public authorities and 188 private companies, were vested, despite their strong opposition, as discussed by Hannah and demonstrated by an example of literature produced by supply companies in Figure 4.[229] This was a new era, and from this period standardisation and national coordination were eventually realised.

[227] Parliamentary Debate, 'Electricity Supply Prices' HC Deb 12 July 1939 vol., 349 cc2221-22 accessed via http://hansard.millbanksystems.com/commons/1939/jul/12/electricity-supply-charges#column_2221.
[228] 'Report of the Cabinet Meeting Held, July 1946' National Archives, Reference CAB/129/11, p.1. accessed via http://filestore.nationalarchives.gov.uk/pdfs/small/cab-129-11-cp-270.pdf.
[229] Cambridge, Churchill College, Lord Hinton of Bankside, 1961, 'The British Electricity Transmission System', HINT 3/5.

FIGURE 4 IMAGES PROTESTING AGAINST NATIONALISATION BY ELECTRICITY SUPPLY COMPANIES.[230]





Ownership

As discussed previously, the Grid was originally constructed to operate regionally, with supply meeting demand within each region. However, engineers, through unauthorised experiments connected the regions, believing that national scale supply was practicable. Hannah wrote, ‘The crucial problem that remained was not technical but political’, because in 1926 there was little support for nationalisation or the government interfering with private assets.[231] There is no indication in the Act, the CEB or Electricity Commissioners’ annual reports that the system was expected to be anything other than regional despite ‘tie lines’ providing limited interconnection for maintenance or emergencies. The negative response of managers to the experimental

[230] Source: London, TNA, ‘Correspondence with Association for Electric Power Companies’ POWE 38/5.
[231] Hannah, *Electricity before Nationalisation*, p.93.

interconnection of the Grid proving its potential for national operation, also suggest it was intended to operate regionally. As it became apparent that demand would outstrip supply in the South-East, the Grid was coupled together permanently, and a central operating room was introduced, directing surplus power from the North to meet demand in the South, ensuring electricity was available during the particularly cold winter of 1938.

As for earlier periods, ownership of electricity undertakings remained largely unchanged until all suppliers were vested in 1948. The municipal and private owners, the umbrella organisations and their various power companies, suppliers and JEAs were fairly stable, although tending towards larger parent companies and concerns. This stability of ownership made the grid system acceptable to the supply companies in many ways, described by Hannah as 'a real breakthrough' as private interests were left alone.[232]

The CEB was chaired at its outset by Duncan who had grown up with the electrical supply industry, being born in 1884, and later trained as a solicitor, particularly in industrial affairs. He had successfully helped manage relationships in the coalmining industry as post-war public ownership reverted to private, contributing to his knighthood in 1921. He was active on various industrial boards and was instrumental in dispute resolution. He held chairmanship of the Board until 1934, just after the Board began trading electricity through the Grid.[233] Other board members included Page, an Electricity Commissioner since 1919 and Wright, who had been an engineer of all ranks. Hodge, experienced with trade unions and served as an MP, while Lithgow had interests in shipbuilding, steel and coal industries, primarily in Scotland.

Although the Board were appointed by Parliament they were not a government department.[234] The new model for the CEB was described by Lincoln as;

---

[232] Ibid.
[233] 'Sir Andrew Duncan Obituary', *The Engineer* (April 4th, 1952), p.474 and a full discussion of the appointments to the board in Hannah, *Electricity before Nationalisation,* pp.105-107 and Lincoln, *The Public Corporation,* pp.99-118.
[234] Hannah, *Electricity before Nationalisation*. pp.105-107.

> Inspired in general form by the local *ad hoc* port trust but covering a nation-wide area' and had been used also for the British Broadcasting Company' and they were semi-autonomous commercial organisations, regulating their own personnel and, in the main, their financial arrangements, but forbidden to draw profit from their services and governed by boards appointed for stated terms by Ministers of the Crown [235]

They were, in fact, an electrical undertaker, providing bulk supply suppliers and railway companies but not directly to the public. They sent returns to *Garcke's Manual* and were listed with the other undertakers. The Weir Report described is as 'not a change of ownership, but the partial subordination of vested interests in generation to that of a new authority for the benefit of all, and this only under proper safeguards and in a manner which will preserve the value of the incentive of private enterprise'.[236] There was friction because of the inequitable position of the selected stations, which all contributed to the Grid but the more efficient ones did not derive any additional benefit from being so because the generation burden was spread evenly around all the selected stations. This problem was addressed in the 1934 Act.

As a result, the CEB operated independently of government, referring to the Minister of Transport for the wayleaves for which compulsory purchase was required. This was done through the Electricity Commissioners who remained in office with a similar advisory role to the CEB and the Minister of Transport: a regulatory role and arbitrator between the Board and other interested parties when disagreements arose, holding enquiries if deemed necessary. The Electricity Commissioners drafted the plans for each of the regional schemes which constituted the Grid, which they submitted to the CEB who published them, starting a period of consultation with the undertakers and other interested parties in the area affected, and had the power to make any necessary alterations. The 1926 Act provided options for arbitration, and these, combined with the

[235] Lincoln, *The Public Corporation*, p.2.
[236] The Weir Report, p.13.

various controls and responsibilities between the electricity commissioners and the CEB, meant the latter operated quite smoothly, constructing the Grid within time and budget.

The electricity commissioners held just fourteen formal enquiries into prices over ten years perhaps because the Commissioners endeavoured 'to secure satisfaction to complaints from companies without resort to a formal enquiry'.[237] The Electricity Commissioners could not dictate prices, the maximum was set by, and could only be altered by, the Minister of Transport and was a flat rate listed on any licence that granted supply powers but by this period tariffs had become complex. The Minister chose not to get involved in pricing because the reduction of the overall flat rate, or rate at which a unit is capped, would influence the rest of the tariff, which in most cases was already below this flat rate, leaving the market to set prices. There were also an increasing number of umbrella or parent companies with substantial interests in electricity supply.

The Electricity Commissioners defined the holding companies as:

- The company not being an authorised undertaker but concerned as electrical contractors or in association with a firm of contractors for the carrying out of works on behalf of subsidiaries and in many cases assuming responsibility for management.
- The company who is also an authorised undertaker exercising control over its subsidiaries chiefly in regard to management and purchase of goods and materials.
- The company not being an authorised undertaker whose main concern is in the investment of money in its subsidiaries.[238]

In their 1935 report, the Electricity Commissioners acknowledged allegations against holding companies making substantial profits through electrical supply companies may have had some substance. However, they suggested this did not keep prices high, preventing development of

[237] London, TNA, 'Memorandum by the Electricity Commissioners for the Committee on Electricity Distribution on the Control of Electricity Companies by Other Companies' POWE 13/95, p.5.
[238] *Ibid*.

electrical supply. Edmondson's were given as an example and are discussed further in Chapter 4 regarding the South-West but they also had interests in the London and Home Counties JEA. Edmondson's was registered as a company in 1897, 'formed to carry on as a going concern the business of Electrical engineers and contractors carried on by Edmondson's limited'.[239] In the 1905 edition of *Garcke's Manual* Edmondson's is reported as owning electrical undertakings in the South-West.[240] By 1933-4, *Garcke's Manual* explained that 'Parliamentary powers were obtained for electric lighting and tramways in the names of the Urban Electric Supply Co Ltd. and others, and this corporation entered into contracts for carrying out the works required' For Edmundson's.[241] It also recorded that 'the Greater London Counties Trust Ltd. acquired control of the company in 1928' and then lists the electric supply undertakings over which Edmondson's has control or a financial interest in. To show the size of the company its *Garcke's Manual* return for 1933-4 shows nominal capital was increased to over £3 million, by creating 1,500,000 ordinary shares at £1 each. £800,000 were paid to the Greater London Counties Trust Ltd. for ninety percent of the issue share capital of the East Anglian Electricity Company Ltd. and the Wessex Electricity Company, and some other smaller supply companies including the Urban Electric Supply Co. in which the Greater London Counties Trust Ltd. had a controlling interest. The return stated that interests transferred to Edmondson's were for the purpose of management and development, and this internal transaction between Edmondson's and the Trust was to ensure closer coordination and management of properties of a similar nature. Three years later, the nominal capital was doubled to £6 million with additional shares to acquire assets. What *Garcke's Manual* does not show is that the Greater London Counties Trust Ltd. was controlled by other holding companies from Canada and the United States. This meant that Edmondson's had both direct control over authorised undertakers and indirect control over other undertakers through holding companies, and as well, owned additional holding

[239] Garcke, *Garcke's Manual*, 3, Edmondson's Entry.
[240] *Ibid.*, 10, Edmondson's Entry.
[241] *Ibid.,* 37, Edmondson's Entry.

companies. The Electricity Commissioners used the East Cornwall Electric Supply Co. Ltd. as another example, first registered in 1914 as the Torpoint Electric Supply Co. Ltd. Its entry in *Garcke's Manual* 1933-4, now listed as the East Cornwall Electric Power Supply Co., was controlled by Urban Electric Supply Co Ltd., which is listed in the same manual showing that Edmondson's Electricity Co. Ltd. held a controlling interest in it.[242]

Ownership was further complicated because the East Cornwall Electricity Supply Co. Ltd. bought its electricity from the Cornwall Electric Power Co., itself a subsidiary company of the Cornwall Power Co. Ltd., which in turn was controlled by the Urban Electric Supply Co. These relationships were not uncommon, The Christy Brothers and the Electricity Supply Company Ltd. also holding interests in the South-West. Tracing the history of ownership is incredibly complex, described by Bloomfield as 'a daunting task'.[243] Eventually the report concluded, that additional control should be imposed to make holding companies or trusts seek statutory powers to amalgamate the companies they held. That holdings and other authorised companies should have to be declared to the Electricity Commissioners and that associations with companies or people working as unauthorised undertakers holding substantial interests in electrical undertakings should be reported to the Electricity Commissioners or other statutory authority.[244]

The difficulty for the Electricity Commissioners was striking a balance between the advantages that these kinds of holding companies provided, such as bulk purchasing, and providing capital for expansion of the supply industry against prices charged and returns to shareholders. Although it is not explicitly stated, concern was expressed by the Electricity Commissioners about how construction work was undertaken amongst electrical supply companies and electrical construction companies owned by the same holding companies and whether costs charged for work were fair and

---

242 *Ibid*., 37, Urban Electric Supply Company Entry.
243 G.T. Bloomfield, 'Notes for the Study of Regional and Local Electricity Systems in Britain – The South Western Electricity Board Area', University of Guelph (2014) through personal communication and unpublished notes were kindly forwarded to me by Professor Bloomfield.
244 London, TNA, 'Memorandum by the Electricity Commissioners for the Committee on Electricity Distribution on the Control of Electricity Companies by Other Companies' POWE 13/95, p.27.

reasonable. One of the difficulties was that additional percentages, or 'prime costs', added for such works were not transparent about exactly what they covered and ranged from 2.5% to twenty five percent. The same difficulties extended to management fees where holding companies centralised services such as accounting or consulting engineers. The Commissioners suggested that where there were contiguously located areas these could be beneficial but where companies were located miles apart this seemed less appropriate.[245]

By the time the Weir Report was published there had been over twenty years of slow progression towards interconnection and a national electricity generation and supply system, promoted by engineers, followed by politicians trying to regulate it. Whilst electricity was extensively used by industry the domestic market was still embryonic. Domestic electric lighting was becoming more common but electrical domestic appliances were not, only reaching half of households in Britain in the mid '30s, with rapid expansion after WW2 when household expenditure on domestic appliances increased dramatically (Table 4).

TABLE 4 NUMBERS OF WIRED HOUSES IN BRITAIN.[246]

Year	Number of Households wired for electricity (millions)	% of households wired for electricity	Total (£m)	Expenditure on domestic electrical appliances per wired household (£)
1921	1.1	12	2.7	2-45
1931	3.5	32	4.2	1-20
1938	8.7	65	12.6	1-45
1951	12.2	86	78	6-39
1961	16	96	279	17-44

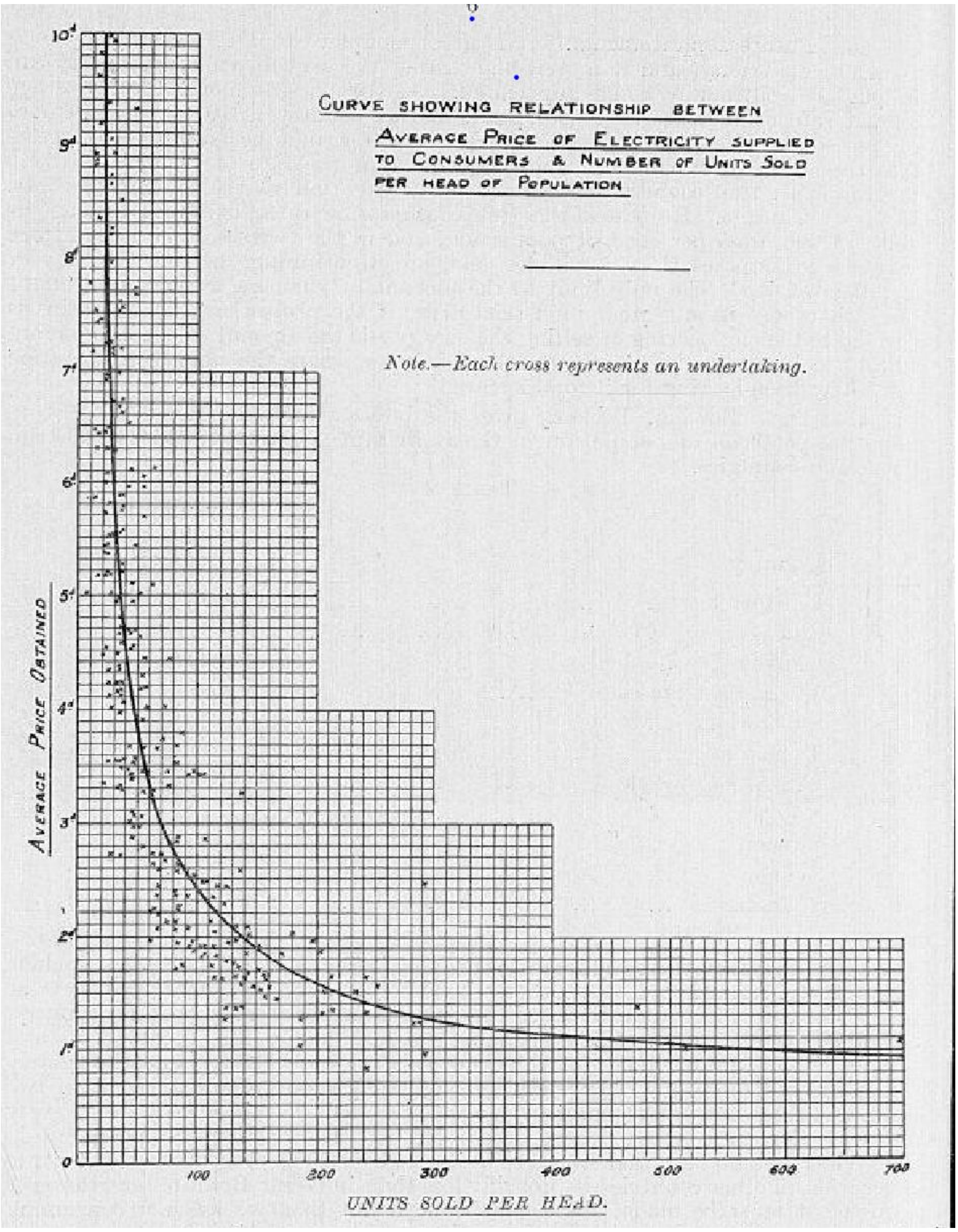
[245] *Ibid.,* pp.14-15.
[246] Source: Bowers 'Electricity' p.293.

Prices

Cheaper electricity was expected to encourage greater consumption and was based on the graph presented with the Weir Report (Figure 5). This demonstrated the main principle behind much of the legislation from 1926, namely that, as the number of consumers increased, the price per unit decreased. To achieve cheaper electricity the savings from larger scale generation needed to be passed on to the consumer. This meant that undertakers providing bulk supplies to other undertakers, rather than being bypassed could purchase electricity from the Grid at cost price and add a mark-up of 6.5% was permitted to cover overhead, and their transmission networks. The rationale was that this would still pass savings onto the authorised undertakers purchasing their bulk supply from these additional middlemen. This was in recognition of the 'valuable development' and the risks that these businesses had taken, with few of them having reaped the reward of the standard dividend and is a good example of the types of measures which enabled private enterprise to remain autonomous.[247] Little changed for companies who would no longer generate but instead purchase electricity at 'Gridiron' prices. However, changes were made to the compulsory purchase clause compelling local authorities declare their intention to purchase an undertaking, under the provision of the clause, seven years prior to the purchase date. It there were to purchase they had to advance funds to the company through a loan to ensure investment continued in the undertaking, including the supply network.

[247] The Weir Report, p.15.

FIGURE 5 GRAPH SHOWING CHANGES IN ELECTRICITY CONSUMED AND NUMBER OF UNITS SOLD PER HEAD OF POPULATION.[248]



[248] Source: *Ibid.*, p.6.

The aim was to reach consumption of 500 units per head of population produced by an average cost of less than 1.5d. per unit by the 1940s. The predicted cost of the new system was £80 million, of which the Grid itself, being the towers and cables, would cost £25 million. The CEB were enabled borrowing powers of £33.5 million subject to Treasury approval.[249] However, the Treasury guarantee was not used because the CEB wanted to maintain political independence.[250] This amount was later raised, primarily due to standardisation costs rising, becoming double the original estimate of £8 million. Other borrowing needed to be sanctioned by the Electricity Commissioners, and a range of options were open, but capital was primarily raised through markets stocks over which the CEB determined prices, interest and amounts. In their first Annual Report the CEB reported that the Electricity Commissioners had sanctioned borrowing for a sum of up to £5 million for the purpose of standardisation, and a further £5 million for the 'construction of main transmission lines and preliminary expenses in connection with schemes'.[251] The CEB also had to pay the expenses of the Electricity Commissioners and the Minister of Transport for wok in preparing schemes.[252]

Duncan and Whigham, both on the CEB board, were also directors of the Bank of England, 'The nominal financial advisers to the CEB', the Minister of Transport, the Electricity Commissioners and the Treasury.[253] The repayment period for the Grid was sixty years, with any changes needing to be agreed by the Minister of Transport. The repayments worked on the basis of no return whilst the Grid was constructed but as it began to work and become profitable, repayment of the loans would increase over time.[254]

This approach, accounting for higher profits over time, was also applied to tariffs. For the first two tariff areas formed, Central Scotland and Mid-East England, the Electricity Commissioners approved

---

[249] The Weir Report, p.18.
[250] Lincoln, *The Public Corporation*, p.123.
[251] CEB, *Annual Report*, 1, p.29.
[252] *Ibid*.
[253] Lincoln, *The Public Corporation,* p.123.
[254] CEB, *Annual Report*, 6, p.32.

ten years as the tariff period. They were set in 1932, when there was a 'world trade depression', so predictions for electricity usage were reduced from the initial estimates when the scheme was devised, although the depression affected Central Scotland more than Mid-East England, where predicted demand was almost unchanged.[255] The tariffs' general form was created in conjunction with the National Consultative Committee which, it was claimed, 'embodies the principle of a charge per kilowatt of maximum demand, adjusted according to power factor and to meet changes in the local taxation, plus a running charge per unit, varying with the price of coal'.[256] Following the principle of falling prices and increased demand, there were four grades of pricing per kilowatt charge. The first was the basic demand, the volume consumed, as recorded in 1932, and the next ranged over three increments of increasing demand. This was to encourage overall as an efficient operation as possible so incentive was removed from the owners of the stations, now operating under the 'coordination' of the CEB.

Each region had its own tariff because each was different but *The Economist* reported, 'these terms compare favourably with the average contract for the supply of electricity by undertakings' in their evaluation, for their readers who might have invested in the Grid.[257] The North Wales Power Company, for example, retained ownership of their overhead transmission lines but this meant that these lines were paid for by their consumers only, rather than being part of the whole Grid costs. Likewise, the South-East and East Anglia, due to the former's denser and more urbanised population, and therefore greater capital investment, became two areas for tariffs although they shared one control station. Scotland was also different because of the hydroelectricity that was generated. As a result, South-West and Central Scotland were linked and there were specific agreements between

[255] *Ibid.*, pp.27-28.
[256] *Ibid.*, p.28.
[257] 'Investment Notes', *The Economist*, (London, Nov 26, 1932), p.992.

hydroelectric companies and the Grid to purchase from them year on year.[258] The tariffs from 1939 are shown in Table 5 5.

However, this was the price that companies paid to the CEB, the consumer was still being charged the prices set by their local supplier, who still retained the monopoly and were incredibly variable in structure and price, Discussed in more detail in Chapters 3 and 4.

Debates continued regarding how much of the savings introduced by the Grid were being passed to the consumer. Perhaps the most compelling of the statements was made was by Lewis, MP for Bolton, whilst discussing the 1947 Act for nationalising the industry;

> The cost of generation between 1924 and 1934 fell from .963d. to .5231d. per unit. The cost of distribution, however, remained constant at about .766d of a penny per unit over the whole field of electricity supply which includes the private companies and the municipalities. The fall in the cost of generation and transmission due to the efficient system which was imposed upon the industry in 1926 by the Central Electricity Board and the fact that the only section where there was no drop in costs was on the distributive side, clearly indicates that distribution should be nationalised, and I do not think there is any argument that can be put forward to refute this argument.[259]

[258] CEB, *Annual Report*, 6, pp.43-47, has specific details and it is further discussed in Gordon, *The Public Corporation*, pp.153-161.
[259] Parliamentary Debate, 'Electricity Bill' HC Deb 04 February 1947 vol. 432 cc1585-701 accessed via http://hansard.millbanksystems.com/commons/1947/feb/04/electricity-bill#column_1600.

TABLE 5 GRID TARIFFS FROM 1939.[260]

	Central Scotland	Mid-East England	South-East and East England	North-West England and North Wales	Central England	South-West England and South Wales	South Scotland	North-East England
Date of Introduction	1st Jan 1933	1st Jan 1933	1st Jan 1934	1st Jan 1934	1st Jan 1934	1st Jan 1935	1st Jan 1937	1st Jan 1938
KILOWATT CHARGE								
Basic Demand, per kW	£3 10 0	£3 10 0	£3 10 0	£3 7 6	£3 10 0	£3 10 0	£3 10 0	£3 10 0
1st Increment, per kW	£3 5 0	£3 5 0	£3 5 0	£3 3 0	£3 5 0	£3 5 0	£3 5 0	£3 5 0
2nd Increment, per kW	£3 0 0	£3 0 0	£3 0 0	£2 18 6	£3 0 0	£3 0 0	£3 0 0	£3 0 0
All more than above, per kW	£2 15 0	£2 15 0	£2 15 0	£2 15 0	£2 15 0	£2 15 0	£2 15 0	£2 15 0
VARIOATIONS OF KILOWATT CHARGE:								
(a)For Power Factor: Increase of kW charge, per 0.1 below 0.85 lagging	4s. 6d.	4s. 6d.	4s. 6d.	4s. 6d.	4s. 6d.	4s. 6d.	4s. 6d.	4s. 6d.
(b) For Rates: Basic Rates, per kW of plant installed at selected stations	6s. 0d.	5s. 3d.	4s. 3d.	4s. 0d.	4s. 0d.	4s. 6d.	3s. 0d.	6s. 8d.
Variation of kW charges per 1s. variation from basic rates	1s. 10d.	1s. 0d.	1s. 10d.	1s. 10d.	1s. 10d.	2s. 0d.	1s. 10d.	2s. 0d.
RUNNING CHARGE								
Per unit	.2d.	.186d.	.21d.	.2d.	.196d.	.225d.	.2d.	24d.
Variation of running charge:								
For Fuel: Basic cost of fuel, per ton	13s. 6d.	13s. 0d.	16s. 0d.	15s. 0d.	12s. 0d.	14s. 6d.	13s. 6d.	15s. 0d.
Basic Calorific value of fuel (B.TH.Us. per lb.)	11,000	11,500	11,500	11,600	10,000	12,700	11,000	11,600
Variation of running charge, per 1d. variation from basic cost of fuel at basic calorific value	.001d.	.001d.	.0008d.	.0009d.	.001d.	.0008d.	.001d.	.0009d

[260] Source: CEB, *Annual Report*, 11, p.40.

Conclusions

TABLE 6 NUMBER OF LOCAL AUTHORITY UNDERTAKINGS AND THEIR CONNECTIONS.[261]

	Year	1886	1909	1919	1925
Local Authorities	Number of Undertakings	33	267	230	259
	Number of Connections	664,816	23,326,822	74,359,321	126,863,200
	Average number of Connections per Undertaking	20,146	87,366	323,301	489,819
Private Companies	Number of Undertakings	27	188	143	221
	Number of Connections	1,366,582	20,471,938	49,728,172	72,008,600
	Average number of Connections per Undertaking	50,614	108,893	347,750	325,831

Table 6 shows the numbers of electrical undertakers, ownership type, and the number of connections provided before the establishment of the CEB in 1926. The table demonstrates similar increases in the numbers of both public and private undertakings. There is a slight reduction in numbers between 1909 and 1919 as some companies were taken over by the government during WW1. The profile for local authority and private companies is similar, except that towards 1925 the average number of connections per private company reduces, whereas it continues to increase for

[261] Source: Garcke, *Garcke's Manual*, 30, p.15. The number of connections relates to every individual connection that was recording a specific use of electricity. This included street lights, each meter which recorded separate uses and any individual machinery (domestic and industrial) connected directly into the network.

local authorities. This is likely to be due to the tendency for local authorities to supply more urban areas, and less densely populated rural areas supplied by private companies.

Parochial development, recognised at the time, was encouraged by the small territories for which licences were granted. This was partly due to legislation but also because early technology when public supply first became available could only transmit small amounts of electricity short distances from where was generated, resulting in small isolated pockets of supply. It was only as technology developed that up-scaling of generation and transmission enabling greater efficiency became possible. However, as development was limited to small geographies, and technologies were not automatically compatible, a technologically integrated system which did not interfere with private or public interests was practicably impossible. Some companies operated over larger areas with the consent of several local authorities, such as NESCo. but these were exceptions. Before WW1 some cooperation was encouraged through the licensing of power companies but this was not enough to change the direction of the industry.

Post war, interconnection and government takeover of some companies demonstrated that suspension of normal legislative controls increased generating efficiency resulting in further efforts to encourage voluntary interconnection and cooperation under the guidance of the Electricity Commissioners. While it had limited success, the Weir Committee, using comprehensive evidence gathered by the Electricity Commissioners and supported by reports from the Williamson Committee, World Energy Conference and reports into ‘Industry after the war’ by Birchenough provided a plan for the future. Weir’s committee provided not just a vision but a practical scheme for change and, despite the difficulties with legislation, increased efficiency changes were made and fewer, larger generating stations provided electricity for distribution but there was always a percentage of the population it was not profitable to supply that would not be reached in this way. Full nationalisation in 1948, vesting the whole system into public ownership and with additional funding the final steps to every property being connected to the Grid and standardisation were finally completed but it still took decades.

Criticism is easy with the benefit of hindsight but the situations and pressures at the time, as they are today, were real and demanding. Some decisions seem short sighted, such as the compulsory purchase clause in the 1882 Act, the appointment of electricity commissioners with no authority, and creating a system which increased profits, reduced costs and retained monopolies. However, they were responses to issues and society of the time and, to a large extent, responses to the loudest voices, a negotiation of interested people and institutions at different points in time. The 1926 Act finally enforced cooperation between companies who otherwise would have happily continued with their profitable monopolies with no real pressure to improve services or reduce prices. This took longer than it might have done had there been less concern over preserving the interests of supply companies but as they had most to lose they negotiated hard.

Other than NESCo. and the limited success of JEA's, there were two other attempts at constructing large interconnecting systems which might have led to different outcomes.[262] The first was Ferranti's attempt to generate at large scale and distribute electricity over a large proportion of London, discussed earlier. However, the response to the failure of his large station was most telling. Two consulting engineers were brought in who's recommendations retreated back to the traditional route of small generating stations located close to their consumers restoring the s*tatus quo.* The second attempt was never even licenced despite being proposed by Merz, instrumental in the Grid's design. He, and a consortium of backers, also tried to introduce a system for London in the early 1900s, similar to NESCo.'s proven model. However, there was fierce opposition from those with interests in London's current supply companies, and from beyond because of concerns it might set a precedent. After eventual compromise allowing London County Council to eventually buy out any new company, it was still ultimately rejected by parliament.

[262] Rowland, *Progress in Power,* p.80 reported this as Merz's description of the Grid.

These examples demonstrate that despite ideas and finances being in place there was reluctance to interfere with established interests, private or municipal. Around the turn of the 20th century there was a conservative attitude towards increasing supply area sizes, and therefore scale of supply. Merz's plan for London, even after considerable compromise on his part, had significant support but was still ultimately rejected mostly because of the opposition form supply owners. The difficulties the Electricity Commissioners found in obtaining cooperation after WW1 also show how fiercely personal and municipal interests were guarded. It took the crisis of WW1 and London being perceived as 'a backward metropolis' by other nations to reach the point at which the constraints of the institutions and various personal interests were outweighed by the national interest. Politicians and institutions had enough support, as the country was reconstructing, to make regional scale changes over the whole country whilst individual interests were still largely unchanged although the system governing them changed.[263] Whether complete nationalisation was the only option in 1947 is debateable but certainly some sort of national planning was necessary to complete standardisation and full electrification. The CEB published a report on their achievements up to this point stressing that electricity was now an essential public service, comparing its necessity to water and proposing that 'largely, as a result of the Grid, it [electricity] is becoming as commonly available as water itself'.[264] The CEB and the Grid certainly impacted electrification in Britain but the process was far from complete as it was handed over to the BEA in 1948.

[263] Hughes, *Networks of Power*, p.227.
[264] Central Electricity Board, 'The Grid, Electricity Supply in Great Britain', (booklet published by the CEB, London, 1946), p.7.

3. Electricity and Industry

Introduction

The potential of the large quantities of energy stored in fossil fuels to power industry was realised in eighteenth century Britain during the Industrial Revolution. This huge influx of potential energy made new products and processes possible through applying mechanical power transmitted through belts, pulleys, and shafts. The introduction of steam engines provided motive power well beyond that which men and horses could muster.

Increased production levels from industry meant that there was a higher throughput and a higher volume of goods in transit leading to large-scale changes in the landscape. Initially these manifested through improved and busier waterways for transport. Britain's coal consuming industries produced many 'intermediate products, or their distribution, such as metal smelting, manufacturing industry, or transport', and, industrial development was located on navigable waterways to facilitate imports and exports from localities.[265] Large quantities of water were also required for steam power, and later for electricity, alongside other processing such as dust suppression, cleaning and dilution of waste materials.

This chapter examines industry's choices during the transition from steam power and canal and rail transportation to electricity and roads, and the role of the Grid. These changes provided a more mobile workforce who could travel further from their homes to their workplaces.[266] Businesses were faced with new choices over which energy source was most beneficial with electricity being attractive to industry for many reasons. Figure 6 demonstrates that industrial users were the first to make use of electrical energy with over eight and a half times more terawatt hours consumed by

[265] Kander, Malanima and Warde, *Power to the people*, p.209.
[266] J. Morton, Cheaper than Peabody: Local authority housing from 1890 to 1919 (York, 1991), p.32.

industry than by domestic settings in 1920. It was not until the mid-1960s that domestic consumption slightly exceeded industrial and has remained stable at a ratio of just under one industrial terawatt hour to each domestic one (LHS).

However, the choice was not just about whether to use electricity but how to access it. Before the Grid the availability of electricity to purchase depended on a supplier being present for the area and the physical limits of its supply network; businesses had to be connected via cables to the generating station. The alternative was to self-generate at the factory or workshop, individually or in consortia. This resulted in a new set of variables for consideration by business owners when considering their location.

Many works examine the location of industry and the factors which influence it but very few of these consider energy requirements, instead concentrating on transport, property values, regionalisation, regulation or workforce availability. Therefore, the first half of this chapter explores the changes electricity brought to industry and how these manifested before and after the introduction of the Grid, and its influence on industrial location. The second half provides a case study of the Lea Valley in Greater London investigating locations of different industrial sectors using knowledge about their electricity usage from the national Census of Production. The Lea Valley was chosen for this work partly because there are earlier studies about how industry has changed in the valley. The first of these is Smith's book *The Industries of Greater London – Being a Survey of the Recent Industrialisation of the Northern and Western Sectors of Greater London,* published in 1933, which considers the potential of electricity for industry.[267] The second is Martin's *Greater London – An Industrial Geography,* published in 1966.[268] Both books, by geographers, consider industry both before and after electrification. The industrial historian Lewis wrote several books on specific

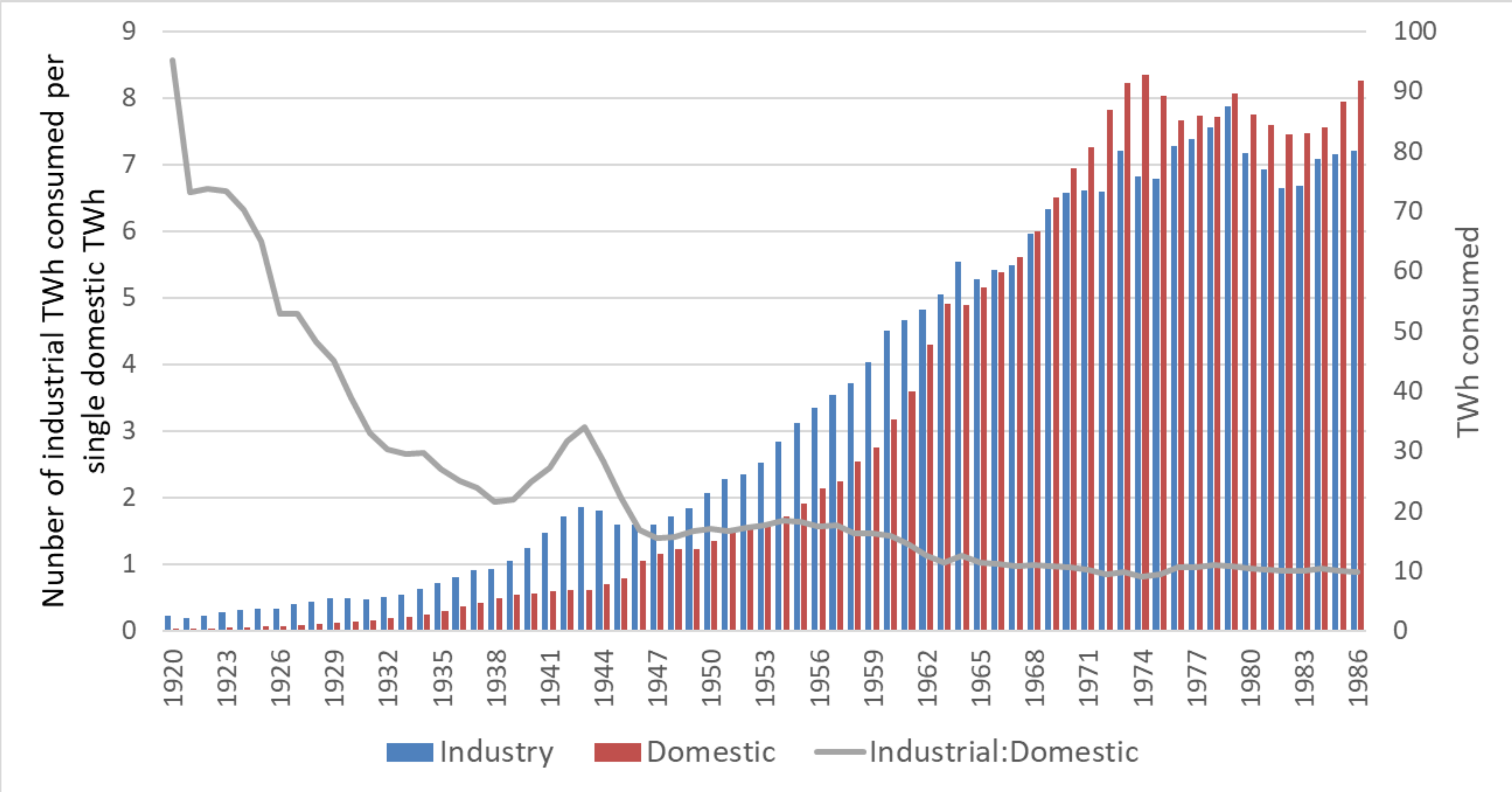
[267] D.H. Smith, *The Industries of Greater London – Being a Survey of the Recent Industrialisation of the Northern and Western Sectors of Greater London* (London, 1933).
[268] J.E Martin, *Greater London: An Industrial Geography* (London, 1966).

industries in the area, while several electrical 'firsts' also occurred in the Lea Valley including the Ediswann lamp factory at Ponders End in Enfield and the first diode valve, which initiated the electronics industry. It was also home to the manufacturing of radio valves, wires and cables in the early twentieth century.[269]

Alongside this Jim Clifford, a Canadian historian, has a long-term project mapping industry in this area and further along the Thames. He shared data with me which I used as a check on the methodology employed here. Finally, as a pioneering industrial district, mostly because of its easy access to London and international export markets, the Lea valley could be expected to be an early adopter of electricity. It is not used as representative of Britain but as a contrast to the more domestic study in Chapter 4. Within the context of the work of the Power and the Water project this study also provides balance for the studies undertaken by other members of the project on the Tyne Valley and Derbyshire tin mines.[270]

[269] J. Lewis, *London's Lea Valley: Britain's Best Kept Secret* (Chichester, 1999) and J. Lewis, *London's Lea Valley: More Secrets Revealed* (Chichester, 1999).
[270] Published to date, L. Skelton, 'Mastering North-East England's "River of Tine": Efforts to Manage a River's Flow, Functions and Form, 1529-c.1800', in S. Miglietti and J. Morgan, (Eds.) *Governing the Environment in the Early Modern World* (London, 2017), pp.76-96, L. Skelton, 'Stories of Life, Work and Nature Before and After the Clean-Up of North-East England's River Tyne, 1940-2015', in K. Holmes and H. Goodhall, (Eds.), *Telling Environmental Histories: Intersections of Memory, Narrative and Environment* (London, 2017), pp.153-177, L. Skelton, 'Regulating the Environment of the River Tyne's Estuary, 1530-1800', in C. Joanaz de Melo *et al*., (Eds.), *Environmental History in the Making: Volume II: Acting* (Berlin, 2017), pp.241-262 and C. Van Lieshout, 'Contested subterranean waterscapes: lead mining sough disputes in Derbyshire's Derwent Valley' in Francesco, V. and Visentin, F., (Eds.), *Waterways and the Cultural Landscape* (London, 2018), pp.86-103. Other works are forthcoming.

FIGURE 6 GRAPH SHOWING ELECTRICAL UNITS USED BY DIFFERENT CONSUMERS.[271]



[271] Department for Business, Energy and Industrial Strategy, 'Historic Electricity Data 1920 to 2013' accessed via https://www.gov.uk/government/statistical-data-sets/historical-electricity-data-1920-to-2011. Hereafter known as DECC Data, 1920-2013. This data demonstrates that coal made up at least 97% of the fuel for electricity generation up to 1948.

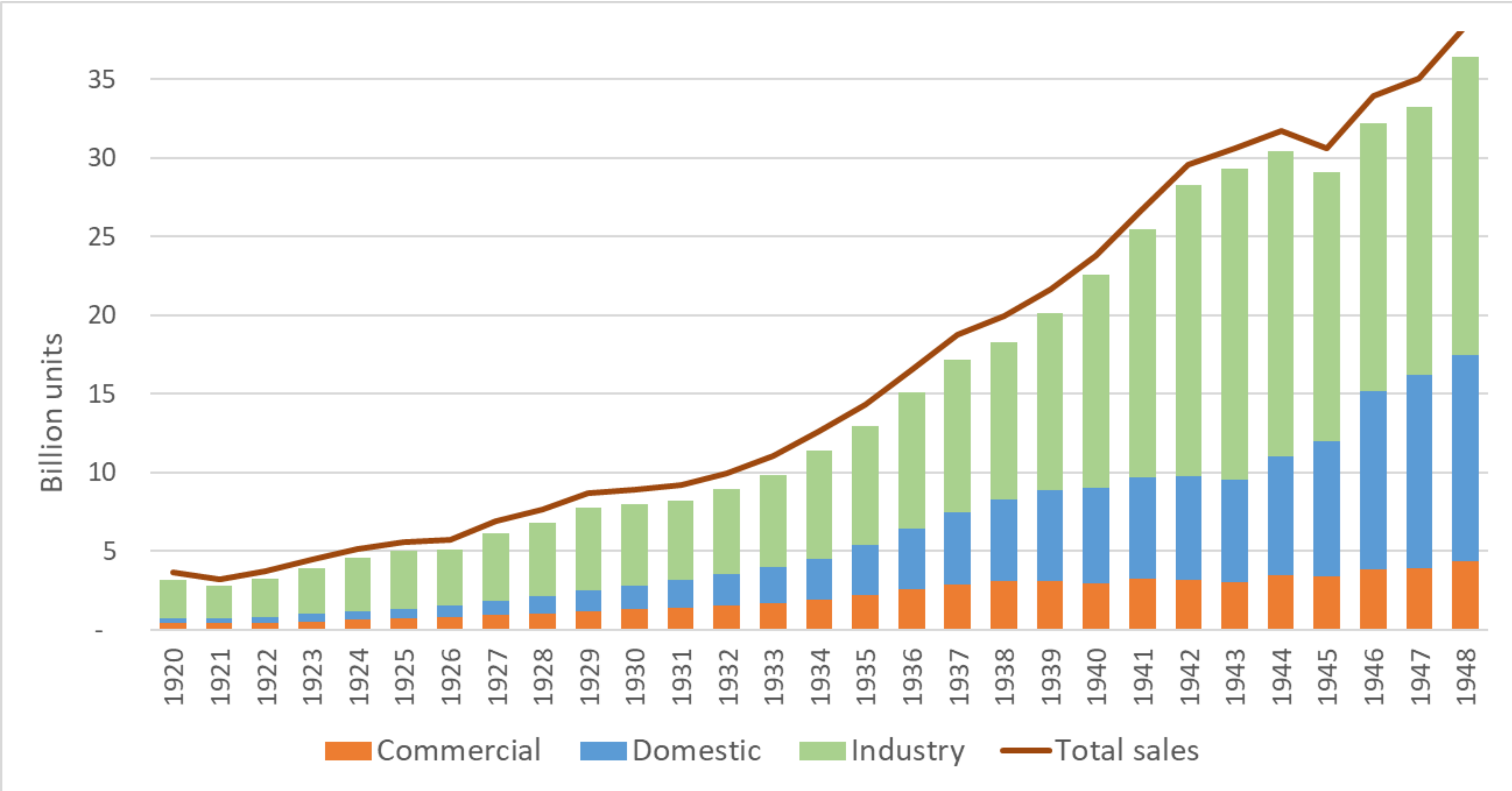
The National Picture in an International Context

Figure 7 shows national growth rates of sales of electricity for the industrial, commercial (offices and retail), and domestic sectors in Britain. A slight decrease is seen in industrial sales in the very late 1920s into the 1930s, likely to have been caused by the slump. During WW2 industrial electricity sales increased because electrification increased productivity (output per worker) in factories producing munitions for war, as it had during WW1. Domestic growth became more significant in the 1930s and plateaued during WW2 because priority was given to industry, consumption began to increase again after WW2.

The British economy and electrification has usually been compared to Germany and America. These comparisons became less favourable to Britain in the early 1900s when a political preference toward municipal ownership, lack of investment in electrification, and slow adoption of electricity by major industries led to reduced competitiveness or productivity comparatively. With specific regard to industry after WW1, Gridley, who had worked closely with Merz during war time, claimed 'The four years of war saw practically a development of electrical output equivalent to that of the previous 32 years', and supported this with examples from Coventry and Sheffield, where units of electricity sold rise by three and 6.5 times respectively from 1914 to 1918 because of heavy industry located there.[272]

[272] A. Gridley, and A. Human, 'Electric Power Supply During the Great War', *Journal of the Institution of Electrical Engineers* (1919), 57, 282, p.414.

Figure 7 Rate of sales of electricity.[273]



[273] Source: BEA, *Annual Report*, 1, p.249.

Post WW1 saw debates over who to blame for the difficulties in British industry as it was losing its foothold in various export markets and showed a sluggish export performance in the electrical industries. The figures in Table 7 show comparison to Germany, and it must be remembered that during this period Britain was still very much an empire with many potential trading partners.

TABLE 7 BRITISH AND GERMAN ELECTRIC PRODUCTS AND COUNTRY OF ORIGIN.[274]

	Great Britain £	Germany £
Total electrical products	22,500,000	60,000,000
Exports	7,500,000	15,000,000
Imports	2,933,000	631,000
Consumption of home-made machinery (electrical products made in the same country)	15,000,000	45,000,000

This table was published in a paper in *The Journal of The Royal Society of Arts* and reprinted fourteen months later by the American Association for the Advancement of Science, demonstrating its international importance. The paper suggested that, despite the achievements of British engineers such as Faraday, Kelvin, and Swann, Britain's pre-eminence in the electrical industry had not been realised. Blame was placed on Parliament and local authorities, citing their continuing debate about 'how the distribution and use of electricity might be prevented from infringing "conventional conceptions of public privileges and vested interests"'.[275] It also suggested that perhaps there were fewer incentives for adopting electricity because steam power was working successfully. Britain had a strong coal gas industry compared to America because of its abundant and cheap production.

[274] Source: H. Birchenough, 'Industries After the War. III.—Electrical', *Journal of the Royal Society of Arts* (1918), 66, 3434, p.672.
[275] *Ibid*.

Conversion to electricity considerably less financially attractive that in America where gas prices were less competitive.

The article claimed that specifically for electrical trades, many exported 'British' goods were actually produced by foreign owned companies, and prevention of further foreign takeovers halted by war was presented as something of a relief. The report called for better protection for national industry with either exclusion or implementation of high tariffs for, 'foreign imports'.[276]

Over this period, while electrical supply was still expanding parochially in Britain, the government was increasingly concerned about foreign competition, particularly from Germany and America. The reasons for Britain's comparatively slow economic growth during this period are still debated and considered more fully later in this chapter.[277]

The economist Broadberry suggested that, alongside difficulties in manufacturing, part of the reason for the relative decline in British productivity its slowness to engage with new technology in the services sector, such as telephones, copy and calculating machines.[278] He attributed relative performance to the 'transition from a world of customized, low volume, high-margin businesses with hierarchical management', stating, 'This transition began in the United States, and was slower to diffuse in Britain'.[279] This idea was supported by Merz who, during a consulting trip to America, wrote to his father noting '[America] is about 10 years ahead of England'.[280] This ten-year lag is also consistent with changes in factory processes, and other working methodologies, many of which were fuel type dependent.[281] In Jones' *Routes of Power* he described how five percent of America's

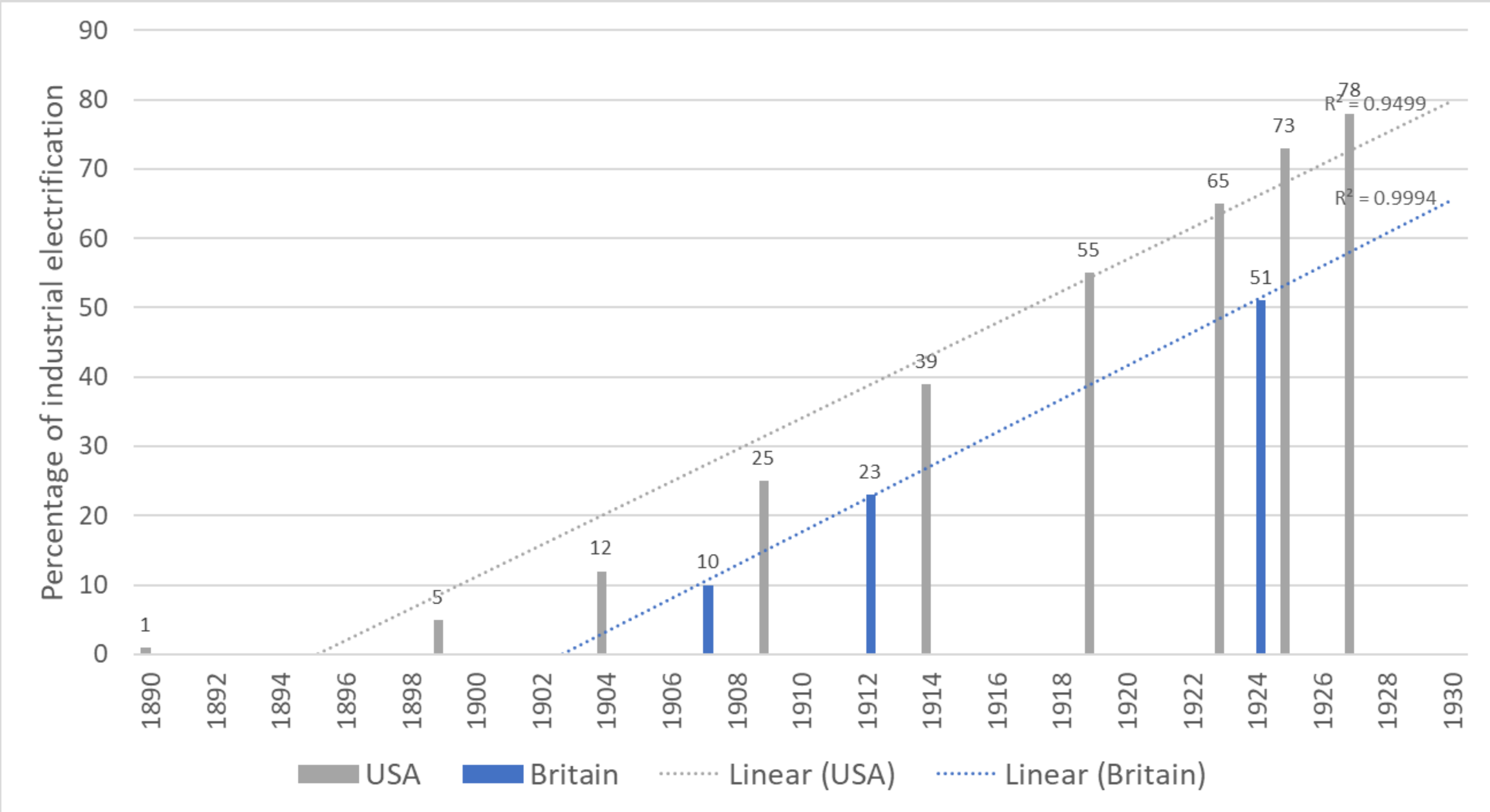
---

[276] *Ibid.,* p.673.
[277] D. Aldcroft, (Ed.), *The development of British industry and foreign competition, 1875-1914: Studies in industrial enterprise* (London, 1968), pp.11-36. The academic Aldcroft's introduction and essays present various issues pertinent to different economic sectors. They demonstrated the complex factors which led to changes in market shares of industries both at home and abroad, with themes including tariffs imposed by countries importing British goods, working methods, mechanisation levels, and home market conditions.
[278] Broadberry, *The Productivity Race*, p.89.
[279] *Ibid.,* p.5.
[280] London, The Institute of Engineering and Technology Archive (ITE Archive), 'Charles Merz, Letter from Charles Merz to his Father', UK0108 NAEST 014/1, 1902-1911.
[281] BEAMA, The Electrical Industry of Great Britain, p.121.

industry was electrified in 1899, increasing to forty percent by 1914.[282] For Britain Byatt calculated industrial electrification reached ten percent in 1907, increasing to roughly twenty five percent in 1912, and fifty percent in 1924.[283] A survey of Britain published by BEAMA in 1929 reported levels of electrification in Britain at fifty nine percent compared to seventy eight and sixty six percent in America and Germany respectively.[284] This ten year lag is demonstrated in Figure 8.

[282] C.F. Jones, *Routes of Power – Energy and Modern America Boston* (Massachusetts, 2014), p.197.
[283] Byatt, *The British Electrical Industry*, p.73.
[284] BEAMA, *The electrical Industry of Great Britain,* p.126. – note that Britain's figures are from 1924, whereas the USA and German figures are from 1925. This is based on the power source for prime movers.

FIGURE 8 GRAPH TO SHOW DIFFERENCE IN ELECTRIFICATION OF INDUSTRY BETWEEN AMERICA AND BRITAIN.[285]



[285] Source: W. Devine, 'From Shafts to Wires: Historical Perspective on Electrification', *The Journal of Economic History* (1983), 43, 2, p.354 and Byatt, *the British Electricity Industry,* p.79 and BEAMA, *The British Electricity Industry of Great Britain,* p.212.

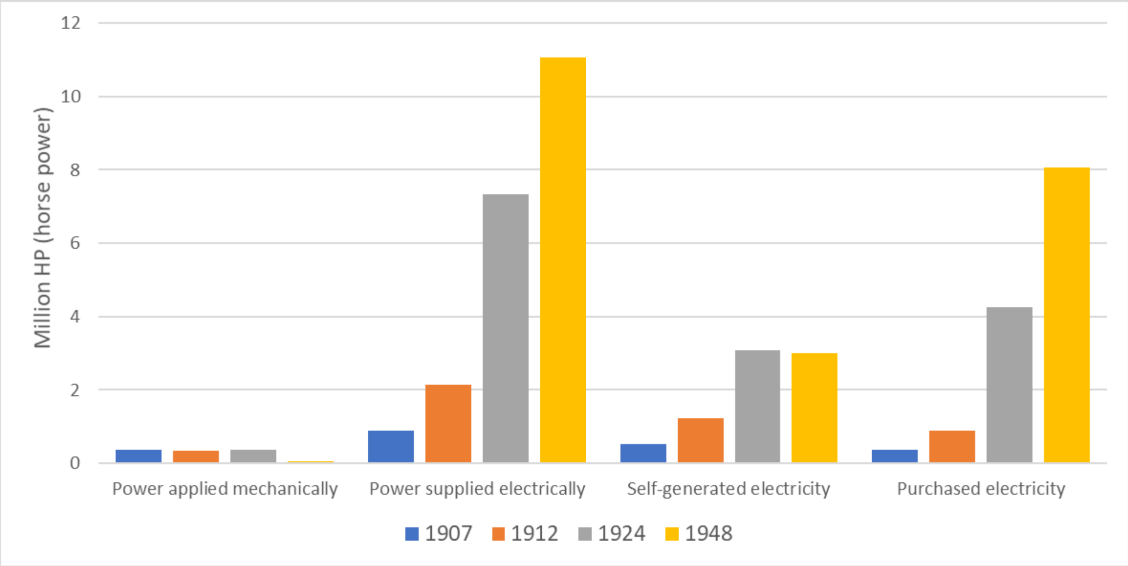
Broadberry's work highlighted important differences within the industrial sector where production methods varied for different trades. He makes a case for labour productivity as the main underlying cause of competitiveness changes, demonstrating that America had approximately 1.54 times the labour productivity of the UK in industry in 1869-71, with German productivity being 0.9 times the British productivity. By 1901 Germany had overtaken at 1.05 times the UK figure, rising to 1.28 times by 1911 but returning to just below British levels again by 1925. [286]

Total power in industry increased, as reported by the Censuses of Production taken in 1907, 1912 and 1924, from 8,395,000 HP to 15,058,000 HP. Whilst horse power is a capacity measure, the census distinguished between electrical and mechanical power for driving machinery ordinarily in use in the first three censuses. These provide a measure of power applied to the prime movers negating the need to try to separate out electricity non-power use.[287] By the 1948 Census of Production the main energy criteria measured was fuel use rather than technology types.

Figure 9 shows the changing profile of energy application, where total power increases and power applied electrically also increases. The final two bars of the graph show the proportions of electricity purchased from public supply or self-generated, self-generation remains similar in 1948 to 1924 and the increase is in purchased electricity. In 1907 forty one percent of electrical power was purchased, whereas the rest was generated on site. By 1924 this had increased to fifty eight percent and reached sixty-five percent in 1948.

[286] Broadberry, *Market Services,* p.22.
[287] Byatt, *The British Electrical Industry*, pp.74-76.

FIGURE 9. GRAPH SHOWING CHANGES TO AMOUNTS AND TYPES OF POWER SOURCES IN INDUSTRY.[288]



The 1930 census concluded there was 'a slight decline in the use of prime movers for the direct supply of motive power to industry', describing the change to electric motors, and was the last census of production which concentrated on this issue.[289] The data suggested that mechanically applied power remained stable at 7.7 million HP between 1907 and 1924, and that increased energy consumption was due to electricity. Total electrical power increased dramatically between 1907 and 1924. BEAMA concurred: 'Electricity has not only accounted for the increase in power capacity, but it has actually encroached on other forms of power, and this process of conversion is becoming more rapid every year'.[290]

In 1938, almost a decade after the BEAMA survey, Bolton wrote about electricity costs, comparing the scope of public and private supply. He estimated that in this year approximately sixty percent of industrial electricity use was from public supply, compared to fifty percent in 1930. A small increase

[288] Source: Byatt, *The British Electrical Industry,* pp.74-76 for 1907 to 1924, 1948 is calculated from Census of Production data and converted to horse power for equivalence.
[289] Board of Trade, *Final Report on the Fourth Census of Production of the United Kingdom (1930): Part V: General Report* (4th ed., H.M. Stationery Office, London, 1935), p.109. Hereafter known as The Census of Production, 1930.
[290] BEAMA, *The electrical Industry of Great Britain*, p.120.

but perhaps more telling was his estimation that private supply had seen an increase in power load of five percent whereas public supply had seen its power load increase by fifty four percent. The increase in public supply was increasingly being driven by demand from the domestic sector and is discussed in the following chapter.[291]

By 1948 sixty-four percent of industrial electricity came from public supply, twenty-seven percent was self-generated on the site where it was generated, and nine percent came from either another site under the same ownership or other private source.[292] That only sixty-four percent of industry was purchasing power from public supply in 1948 seems a low figure but, given the savings which could still be made at this time comparative to Grid prices, it is perhaps understandable.

TABLE 8 COSTS OF PURCHASE AND SELF-GENERATION OF ELECTRICITY IN 1948.[293]

	Electricity purchased from Public Supply		Electricity purchased from another Supply		Electricity from another supply but with same owner	
	000 BTU consumed	Total cost of electricity	000 BTU consumed	Total cost of electricity	000 BTU consumed	Total cost of electricity
Total cost (£)	18118253	£ 16346160	662392	£ 540480	1739575	£ 1307040
Cost per BTU (d)		0.90731642		0.81595188		0.751355935

These figures (Table 8) are averaged across all industries; for low users of up to half a million units the saving from self-generation could be up to £1,565 per year. The largest users, consuming 4.5 million units, could save up to £14,087 per annum on average but there were additional sunk costs making energy accessibility an important question.

[291] Bolton, *Costs and Tariffs*, p.202.
[292] Board of Trade, *Final Report on the Fifth Census of Production of the United Kingdom (1948): General Report* (H.M. Stationery Office, London, 1948). Hereafter known as The Census of Production, 1948.
[293] Source: Calculated from The Census of Production, 1948.

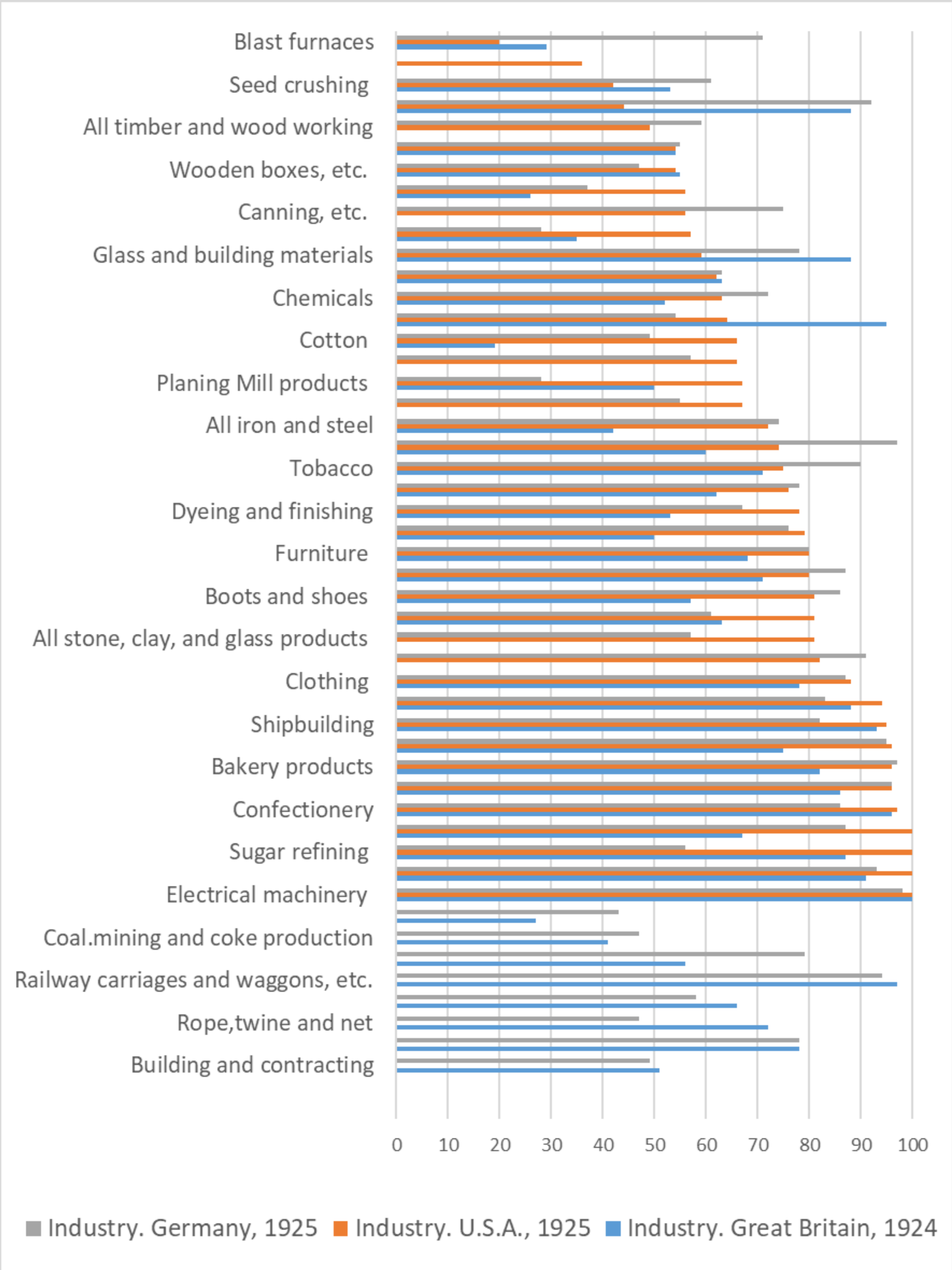
There were also differences in the adoption of electricity by different industries between Britain, Germany and America, demonstrated in the following charts. Figure 10 shows the degree of electrification in different sectors based on the 1924 census of production in Britain and other surveys in Germany and America from around 1925. It clearly demonstrates different profiles of electrification in the three countries, and that Britain was lagging in many industries, particularly textiles, clothing and food.

The radar chart (Figure 11) shows the same information but provides an easier comparison, with electrification beginning at one hundred percent in the electrical machinery industry to just under twenty percent in the cotton industry.

Haslam compared adoption of electricity in various trades. He agreed with Stiel, a German industrial historian, reporting the textile trades as being generally late adopters of new technology. Both suggested textile workers were experts in their current systems producing high quality outputs and were reluctant to invest time learning a new technique. However, printing was an early adopter, like engineering and some manufacturing, metals and chemical plant also adopted early because electricity enabled repeatable precision. For printing the benefit was the clear outputs the printing blocks produced from the first to last copy without requiring warm-up and cool-down periods to get the speed right.[294]

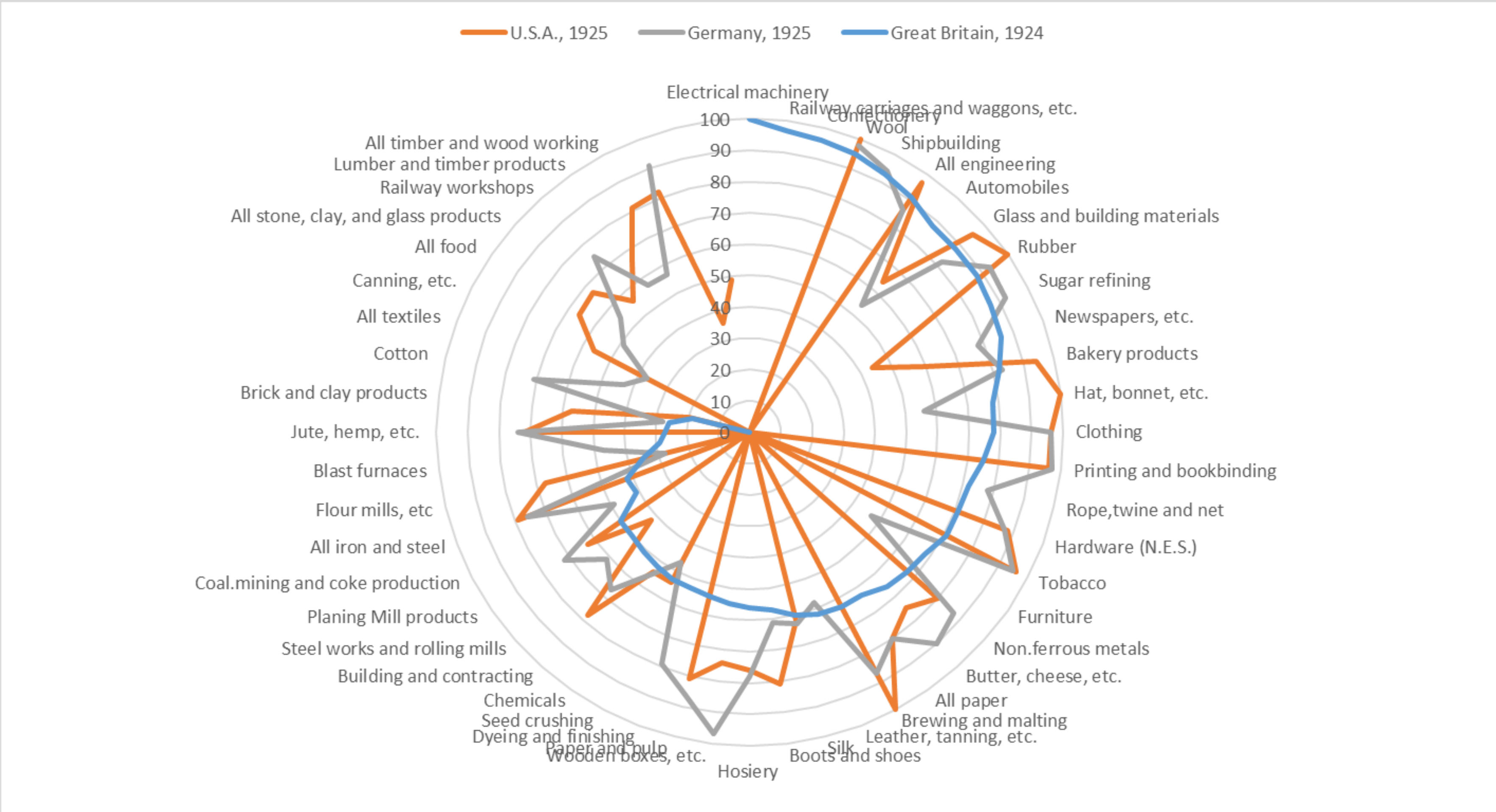
[294] A. Haslam, *Electricity in factories and workshops. Its cost and convenience. A handy book for power producers and power users* (London,1909), pp.207-251 and Stiel and Rodger, *Textile Electrification,* p.150.

FIGURE 10 DEGREE OF ELECTRIFICATION IN BRITAIN, USA AND GERMANY.[295]



[295] Source: BEAMA, *The Electrical Industry of Great Britain*, p.126. The data are calculated using the proportion of the capacity of prime movers driven by electrical or mechanical power to provide electrification.

Figure 11 Radar chart showing the percentages of electrification in Britain, Germany and America.[296]

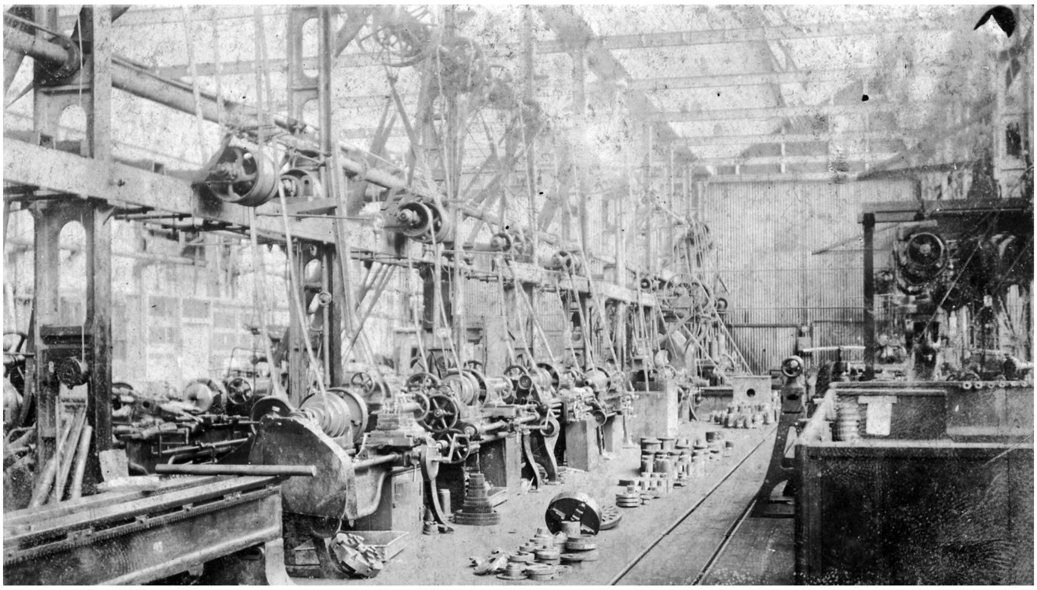


296 Source: *Ibid.*

Impacts Within the Factory

Industrial activity requires energy, from an artisan making hand-crafts to an intensive process such as smelting. Whatever the process, energy will be an integral part. Energy was produced by people, horses, and water-wheels or fires, before the Industrial Revolution, afterwards it was likely to be steam engines providing motive power to drive shafts and pulleys which, in turn, transferred power to machines. These systems were cumbersome, filling up large spaces inside factories and were inefficient, losing energy through friction. While steam power brought incredible quantities of power, the industrial process had to accommodate it. The most power-hungry machines had to be nearest to the power source, and as machines were connected and disconnected from belt drives power fluctuations reverberated throughout the remaining connected system. Turning the system off affected every machine on connected shafts, and changes affected whatever was being produced.[297]

FIGURE 12 STEAM POWERED FACTORY.[298]



[297] There are several works that discuss this including C.F. Jones, *Roots of Power – Energy and Modern America (Massachusetts, 2014),* W. Devine, 'From Shafts to Wires: Historical Perspective on Electrification', *The Journal of Economic History* (1983), 43, 2, pp.374-372 (1983) and N. Rose, and P. Joskow, 'The Diffusion of New Technologies: Evidence from the Electric Utility Industry', *The RAND Journal of Economics* (1990), 21, 3, p.354.
[298] Source: A. Barnett (Local Electrical Historian).

Electricity was a stable power source allowing homogeneous products to be made and this was important for industrial adoption. Manufacturing identical products consistently meant that products could include interchangeable parts whilst maintaining reliability. The changeover to electricity did not necessarily mean individual motors in each machine, it often began with electrical power turning the shafts replacing direct motive power. As individual motors were installed the shafts were removed making factories more open, lighter and removed some dangers. Mechanical engineers have described how they would lever belts back on to the machines connected to running shafts, with broom handles, when they inevitably slid off, while the shafts were running to avoid interrupting other attached machines. This continued into the late 1960s in some workshops.[299] As the shafts run in a singular direction, to reverse the direction of a machine the belt would be turned into figure of eight to turn the wheels in the opposite direction to the shaft and could be applied to individual machines, again without stopping the shaft. The adoption of electricity afforded space, a quieter cleaner environment, and allowed organisation in the factory to be independent of its energy source. The production line exploited these advantages by manufacturing in the most efficient way, meaning factory tasks were ordered consecutively irrespective of their energy consumption.[300] More efficient production methods led to higher productivity and were ultimately scaled up for mass production.

BEAMA suggested that mass production as part of electrical manufacturing 'is bound up fairly closely with the development and consumption of electricity itself'.[301] The term 'mass production' was first used just before 1905 as industry used electricity more widely, and some twenty-five years later use

[299] Personal communication with a retired turbine generator engineer who made and installed large electrical turbine turbines at GEC Rugby, c. 1980.

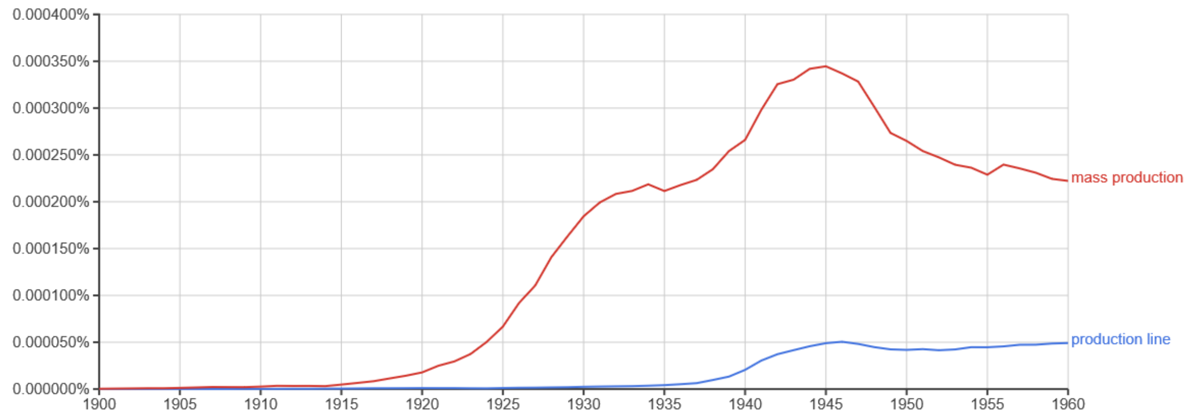
[300] G.E. Somers, E.L. Cushman and N. Weinberg, (Ed's.), *Adjusting to Technological Change* (New York, 1963), p.8. Chapter one suggests that production lines were simultaneously introduced in Britain and France and were not the invention of America

[301] BEAMA, *The Electrical Industry of Great Britain*, p.12.

of the term 'production line' began to increase.[302] Although debated, from the turn of the century the wages of the average worker seemed to stretch further and the rise of 'the consumer' began.[303] This was a noticeable trend and Trentmann described how, 'Consumption was attracting growing attention from economists of all types, but there remained a vehement disagreement about exactly what it was'.[304] Whether mass production created the mass consumer, or *vice versa*, is widely debated but whichever it was, without electricity underpinning it, neither would be possible. Whilst the impacts of the resulting 'disposable' or 'throw-away society' are beyond the scope of this study, it is nevertheless the case that consumerism developed a new relationship with the environment through the energy embodied in the objects of mass production, which included the raw materials which provided the electricity to manufacture them.

While electricity became more widely available transportation options were also increasing, trains and importantly, lorries, were replacing barges which increased potential industrial locations. Hennessey described how, 'The factories have necessarily sprung up along the water courses…new

[302] Source: Google's Ngram viewer. The Ngram below shows the relationship between the use of the phrases 'production line' and 'mass production'. It shows the percentage of the English Corpus from 1900 to 1960 which contains the phrases 'mass production' or 'production line'. The y axis shows the percentage of material that the phrases 'mass production and 'production line' is written in and shows the increase of the terms from 1915 and 1935 respectively (shown of the Y axis).



[303] A.B. Atkinson, 'Distribution of Income and Wealth in Britain over the Twentieth Century' in A. Halsey and J. Webb, (Ed's.), *Twentieth-century British social trends* (London, 2000), pp.1-35. The author suggests Williamson (1985), and Feinstein (1988) as two opposing views on disposable income over the period, pre-WW1.
[304] Trentmann, *Empire of Things,* p.153.

streets are rapidly extending in every direction and so great already is the expanse of the towns, that those who live in the more populous quarters can seldom hope to see the green face of nature'.[305] Locating industry and factories along rivers had been necessary for transportation but was also essential to meet increasing energy needs, although this has been little investigated. High energy consuming industries were already on sites suitable for self-generation because they had been utilising the waterways for steam power or water-wheels. Power stations were constructed next to waterways for the same reasons. However, as public electricity became more widely accessible, particularly through the Grid, high quantities of energy became available away from watercourses, breaking this linkage.

Impacts of Supply Availability

Substantial advantages of electrical power were available for industry even before the introduction of the Grid because there were various ways to obtain a supply, ranging across self-generated, a local public supplier, or a private supplier, usually a nearby business selling excess electricity that they were self-generating. Whilst public supply of electricity first became available in the 1880s, it was not until the 1920s that it was widely available in most urban areas and it was still rare in rural areas. Business had to consider which energy source to use and how to access it but as industry was beginning to embrace electricity, the electrical supply industry itself was undergoing rapid change, technologically and legislatively.

During WW1 electrical engineers and others promoted greater interconnectivity as being essential for industry and growth. Merz's paper 'Electric Power Distribution' read in 1918, described how the large regional power distribution system NESCo. developed on Tyneside could be extended to the

[305] R.A.S. Hennessey, *Factories, Past-Into-Present Series* (London, 1969), p.12.

rest of the country.[306] 'It was in the interests of the country that the electricity supply industry should be co-ordinated on a national basis', he asserted .[307] Matthews was promoting centralised supply in 1909, presenting electricity as an innovation with great potential in the first edition of *Electricity for Everybody*.[308] The third edition, in 1924, claimed, 'There is probably no question of greater interest to the small manufacturer using light machinery than that of a cheap, reliable, simple, and continuous source of energy. It is, in fact, frequently the dominating factor in determining the location of the factory'.[309] He described how new factories, worldwide were installing electrical equipment, and existing ones were converting to it. The difference between the editions suggests that he perceived progress towards centralisation and is reflected in newspaper reports from 1921 describing how the Electricity Commissioners had advanced 'Cheaper Electricity for Industry'. One article explained, 'Before the war, electricity for industrial use was not in great demand but from 1914 to 1918 the use of electricity for industry more than doubled'.[310] Centralised supply did not equate to national supply but was used to describe a system of larger generating capacity supplying larger, like the NESCo. model.

For new businesses at this time, decisions about which energy to use were made within a framework of wider considerations. Industry type was a major determining factor because it dictated the materials needed, energy needs for processing, supply chains and transportation. The more energy required the more significant its supply became because small price differences per unit of energy consumed could dramatically affect profitability. If electricity was chosen, accessibility became important. Pre-WW1 this was most likely to be determined by availability and costs of electricity

[306] Roland, *Progress in Power*, p.63.
[307] 'State Coal and Electricity', *The Times* (London, 1924), 43778, p.7. This was reported by The Times in their coverage of the Labour Party Conference, reporting on the words of Herbert Morrison MP., who put this forward as a resolution which was carried unanimously by the party just after they lost power to the Conservative Party.
[308] R. B. Matthews, *Electricity for Everybody: A Popular Handbook Dealing with the Uses of Electricity in Home and Business* (London, 1909).
[309] R. B. Matthews, *Electricity for Everybody: A Handbook for Central Station Engineers and all Users of Electricity* (London, 1924), p.150.
[310] 'Cheaper Electricity for Industry', *The Times* (London, 1921), 42836, p.7.

from an external supplier because electrical provision was still very parochial. Distribution of supply was constantly improving but entirely depended on the local supplier for the area in which any business was situated. Transport, workforce, and appropriate premises were also important and had to be accommodated.

The alternative to public supply was self-generation. Like large domestic properties where electricity could be afforded but not accessed installed private generators, discussed in Chapter 4, businesses could install equipment and generate themselves. However, this required access to large quantities of fuel and water. Other options included purchasing excess electricity form other self-generating businesses, who were selling to increase profits or sometimes providing it to employees living in the local area, as some collieries did for miners. Where a business owner had several sites they sometimes generated for all sites from one location. Some self-generating businesses entered agreements with the local public suppler who purchased their excess electricity. These arrangements, and combinations of them persisted because distribution continued through the existing local supply companies, effectively middlemen brokering supply between consumers and the Grid after its construction.

Self-Generation or Purchase

Both pre-Grid and post-Grid, electricity consumers were seeking the most efficient models for its supply. Ultimately, like most decisions, self-generation or purchase of electricity was based on a cost benefit analysis and largely depended on the size and type of business, its premises and investment capital available. Self-generation was very specialised, potentially dangerous, and required at least advice from a qualified and experienced engineer. It required significant long-term capital investment and because technology continuously improved, determining when to invest was also important.

Haslam, a British electrical engineer, concluded that for large intensive users self-generation was likely to be cheaper but qualified it suggesting that such a decision had to be made for each individual case. However, he did explicitly state that electricity was the cheapest power source.[311] Factors to consider were numerous and included the coal coasts and transport, access to water, generating plant and spare plant costs, alongside engineers to staff it, space for plant installation, and the cost of distributing power around the factory. Finally, depreciation values and timescales were important to ensure any savings from self-generation, rather than outside supply justified the capital investment. Byatt and others suggested capital investment would be realised over approximately twenty years.[312]

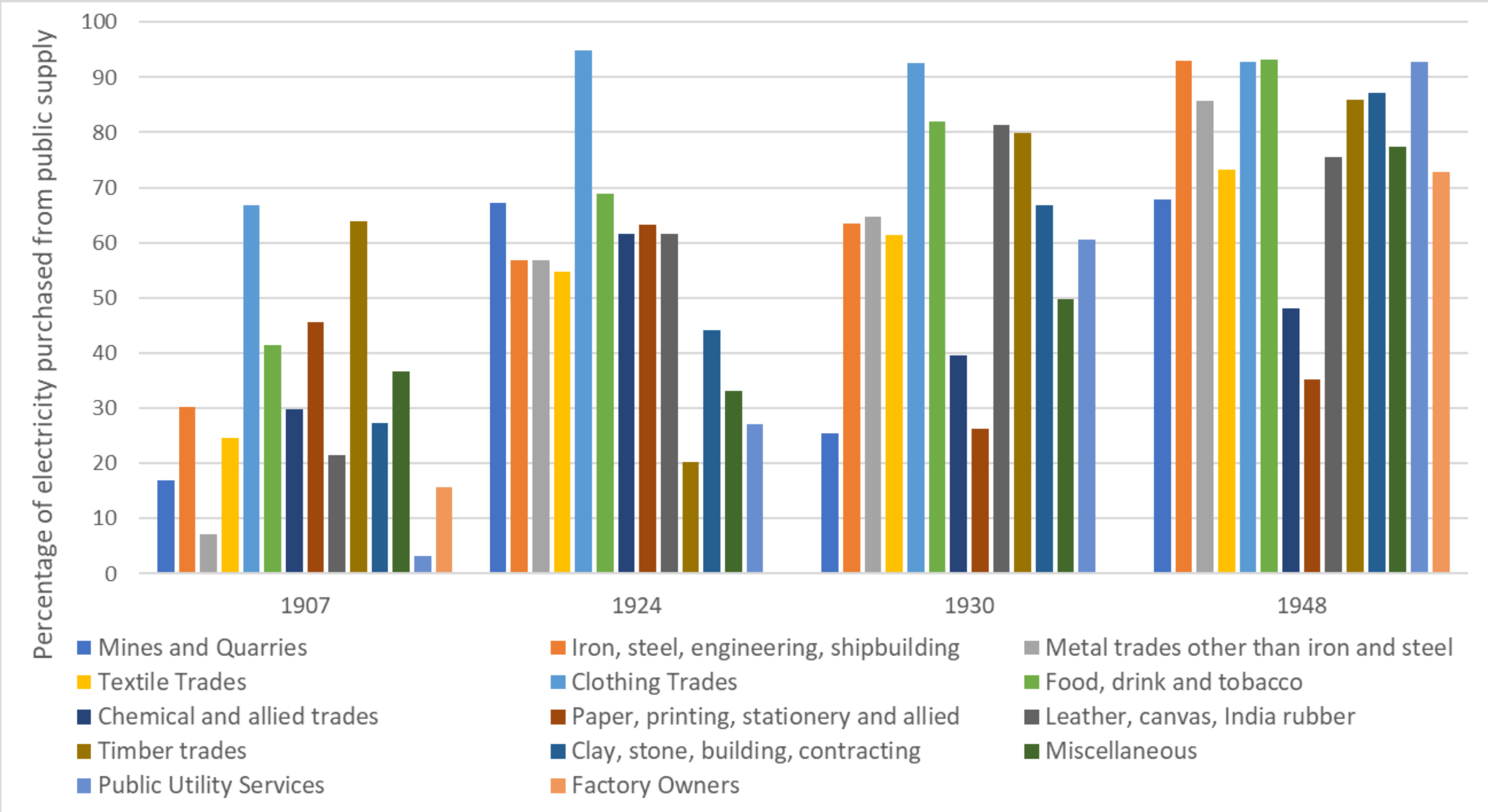
In a report from 1935 the electricity commissioners stated that:

> In addition to the authorised public supply of electricity in Great Britain, large amounts of electricity [are] generated for traffic purposes at the stations of railway and tramway authorities, and for general industrial purposes at the private generating plants installed throughout the country by manufacturing and trading associations such as collieries, iron and steel works, engineering and chemical works, and a great variety of factories, such private plant representing a very considerable aggregate.[313]

This report acknowledged the large market in electricity supply outside of the Grid supply which was by then fully trading.

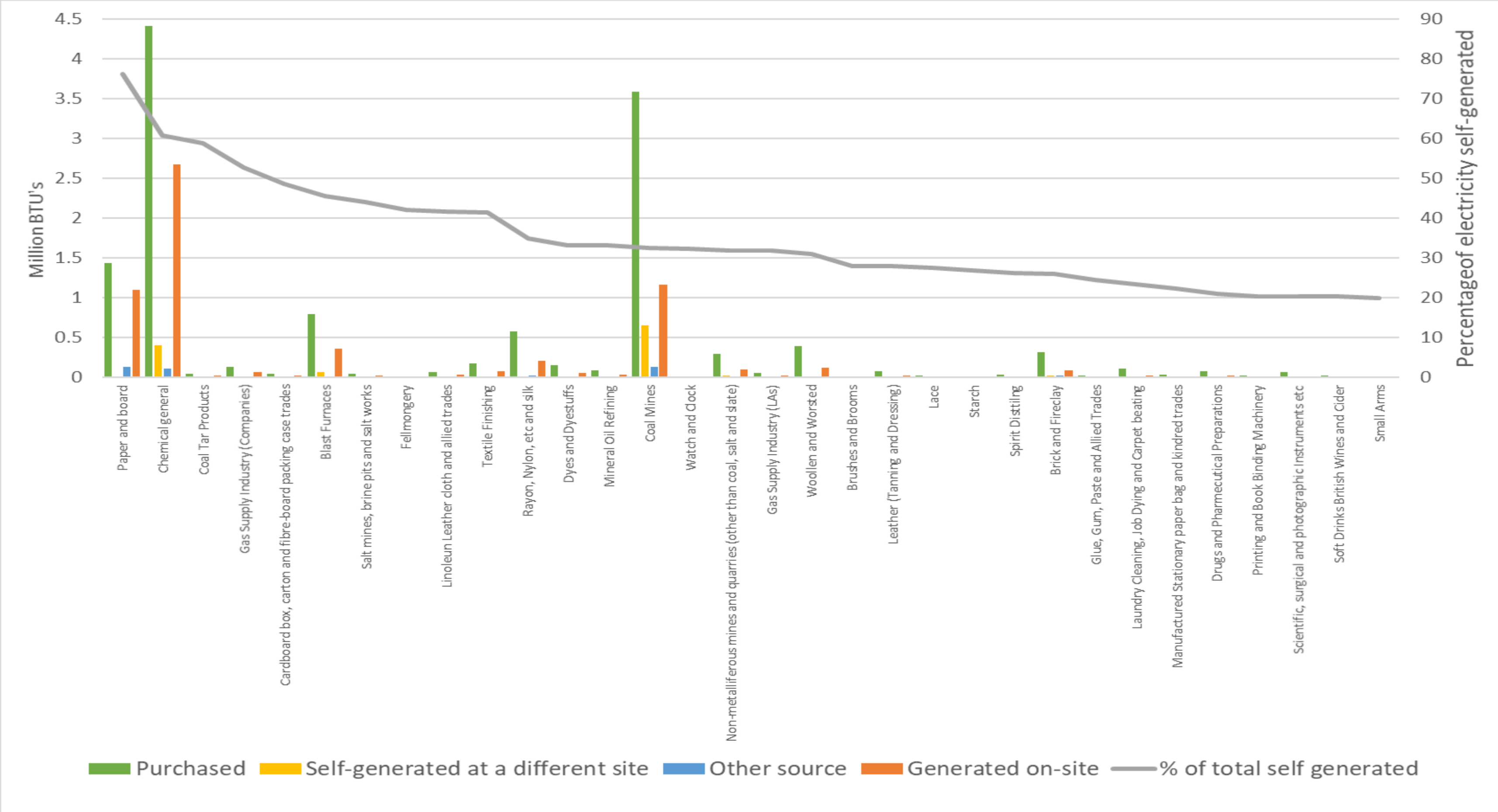
[311] Haslam, *Electricity in Factories and Workshops,* pp.105-204.
[312] Bolton, *Costs and Tariffs,* p.56 suggests 8% in 1938. E. Taylor and G. Boal, *Power System Economics,* (London, 1969) suggests 4% over 20 years as does Byatt, *The British Electrical Industry*. I.C.R. Byatt, 'The British Electrical Industry 1875 to 1914' (PhD Thesis, Oxford University, 1962), p.121, on which his book is based presents the reasons and calculations for this and is the generally accepted value.
[313] London, TNA, 'Electricity Commission Report into Distribution of Electricity', POWE 13/95, p.3.

FIGURE 13 PERCENTAGE OF PURCHASED ELECTRICITY FOR ALL INDUSTRY TYPES.[314]



[314] Source: Census of Production, 1907, 1912, 1930 and 1948.

FIGURE 14 GRAPH SHOWING TRADES SELF-GENERATING 20% OR MORE OF THEIR CONSUMED ELECTRICITY.[315]



[315] Source: Census of Production, 1948.

Figure 13 shows that by 1948 most industries were purchasing over seventy percent of their electricity from public supply, although the paper industry and chemical trades purchased less than fifty percent. This was likely due to the large volumes of water used in processes in these industries, making them more likely to self-generate because they were conveniently situated to do so. Mining also used large quantities of water and may be why it also had a lower purchase rate.

Figure 14 shows the trades self-generating twenty percent or more of their consumed electricity (RHS). The bars on the graph indicate number of units consumed from what supplier type (LHS). The industries are ordered along the horizontal axis from those which self-generated the most to the least electricity. In 1907 Haslam calculated the costs of self-generation under various hypothetical situations. For example, he a cost of £560 of capital to install ‘a gas engine capable of developing up to sixty-five BHP., a 40KW DC dynamo, all foundations and the necessary switchboard, dynamo connections, water vessels, pipe connections and erection ready for working’.[316] Using a 56-hour working week he estimated generating cost operating at one hundred, seventy-five, fifty, and twenty-five percent load capacity, resulting in costs per unit of 1.01d., 1.2d., 1.55d., and 2.64d respectively.[317]

This demonstrated the importance of load factor, the ratio of electrical units actually produced compared to the number which could be produced had the generators worked continuously at full load for the same period. The higher the load factor the more economic self-generation becomes per unit, and for extra costs of labour, repairs, depreciation and any interest incurred on the capital outlay which are balanced against greater numbers of cheaper units.

He concluded from his calculations that electricity was best for small users, estimating that the very small user (below six BHP) purchasing below 1.5d. per unit was preferable, and that where power use was intermittent savings increased. Where power needed was greater than six BHP electricity was still advantageous but self-generation could be beneficial; however, if the motors ran individual machines rather than shafting there were greater capital savings because there was no wastage when the machine was not in use.

---

[316] Haslam, *Electricity in Factories and Workshops*, p.110.
[317] *Ibid.,* pp.110-115.

However, like many engineers of the time, Haslam refuted the claim that self-generation provided cheap electricity. He promoted public supply, reasoning that investment in self-generation could be better spent on core business activities, as public supply was very reliable. Nevertheless, he provided the caveats that:

> The would-be purchaser of electrical generating plant has a wide choice. As soon as he ventilates his wishes he is waited on by a number of zealous representatives of manufacturing firms, who offer him steam plant, oil engine plant, or producer gas engines, either supplied by town's gas, or producer gas made in either suction or pressure gas producers, and all urge him to adopt the best and most economical plant made, namely, their own.[318]

Before electrification steam engines were the main energy source for prime industrial movers which many industries already had in place. Haslam suggested that, beyond electricity suppliers and some of the textile mills which considered efficiency as a science, so long as the steam engine did its work its costs were not considered provided it passed its annual insurance inspection.[319] Using the steam power to generate electrical energy seemed a natural progression. Haslam's calculations show that steam power was the most economic choice to generate large quantities of power. However, it depended on fuel used and its associated costs, which in the case of coal could be considerable, particularly transportation, but generally compared well to town-gas prices because that was also coal dependent. However, where coal was cheap, steam remained economical and a large textile factory could generate for little as 0.417d. per unit, costs similar to those suggested by the well-known electrical engineer Sparks, also in 1907.[320] Finally, Haslam compared self-generation costs to public supply and suggested that in many cases it should be possible to purchase more cheaply from

---

[318] *Ibid.,* p.141.
[319] *Ibid.,* p.163.
[320] 'Midland Institute of Mining Societies and Institutions', *The Times* (London, 1907), 38507, p.4.

an external supplier than by self-generating, unless it was an energy intensive business or had a very high load factor. However, public prices he quoted reflected the more efficient, cheaper suppliers and it is likely that self-generation was more favourable than he purported as an electrical engineer.

Generally, Stiel agreed with Haslam. Smaller units were more likely to be better off purchasing electricity from public suppliers whereas larger plants tended to be better off self-generating. Stiel wrote comprehensively about the factors determining these decisions for textile factories.[321] Like Haslam, he made it clear that each business, even within the same sector, was different. For textiles this included mechanical movement, heating, washing, dyeing and drying. Plant ranged from small 'out-workers' using a fraction of 1HP through to vast spinning and weaving concerns using thousands. For textiles, steam was needed as part of the industrial process, and as a result obtaining this as a biproduct of generating electricity was considered the most efficient way to work, therefore the primary decision was whether additional energy requirements should be self-generated or sought externally beyond the volume of steam necessary.

Stiel also reported methods for sharing generation amongst textile factories, providing innovative ways to keep costs low but reap its benefits. The first and most common was for public supply to be used as a top-up, when there was additional demand and meant that productivity was not limited by internal energy production capacity. In some cases, where a textile factory was heavily reliant on steam (dye works and finishing works) the factory sometimes sold electricity back to the public supplier when they produced excess but was dependent on the public supplier being willing to accept this and pay reasonable compensation.

Beyond public supply, factories could, as a group, construct and maintain their own power station from which they all took supply. Stiel maintained 'that there be no hesitation about conveying the

[321] Stiel, *Textile Electrification,* pp.71-76.

heating steam and hot water considerable distances (half a mile and more), since if the piping is well lagged, the losses are only a few per cent, whilst the installation costs are not high'.[322] The main message he conveyed was that the whole business process should be considered and energy needs integrated where possible; where not possible, it should be as economic and convenient as possible. Like waste heat recycling, discussed in Chapter 5, this was a forward-thinking environmental idea but originated from wanting to increase efficiency not from any desire to limit environmental damage.

Rose and McDonald investigated economic models of self and cogeneration, which they concluded depended on the demand within an enterprise, the price, and marginal costs. 'Specifically, an increase (decrease) in industrial self-generation occurs when:

- The demand for electricity increases (decreases);
- The price of purchased electricity increases (decreases);
- The marginal cost of self-generation decreases (increases)'.[323]

Their work, and levels of self-generation still prevalent in the 1948 census, suggested that the evaluation of resources was continuous, as was the balance of energy production and use. For consumers of large power volumes, any potential savings that could be achieved through self-generation were kept under consideration for a long time after the introduction of the Grid. From Stiel's work, and the propensity of businesses to retain self-generating potential, even after connection to the Grid, where the production processes of the industry and electricity production overlapped the likelihood of self-generation was higher.[324]

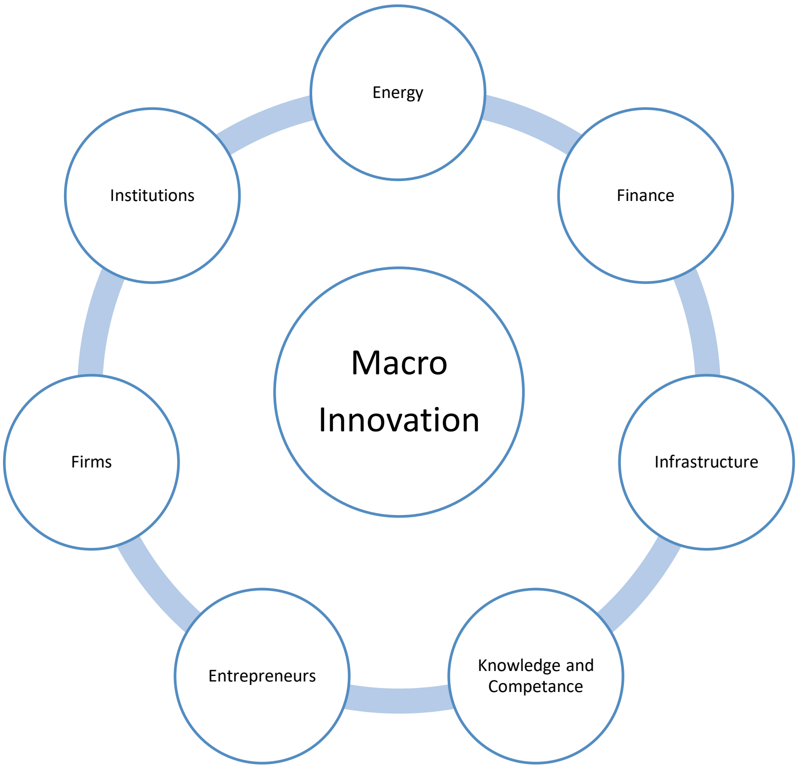
[322] Stiel, *Textile Electrification*, p.72.
[323] K. Rose, and J.F. McDonald, 'Economics of Electricity Self Generation by Industrial Firms', *The Energy Journal* (1991), 12, 2, p.63.
[324] Personal communication with J. Lewis regarding industries in the Lea Valley states it was normal practice to retain the capability for self-generation when connected to the grid even if it was not used.

Lock-in and the Problem of Co-ordination

In *Power to the People* Kander, Malanima and Warde promote the idea of development blocks, first described by Dahmén in the 1950s, to show how development spreads. This suggests that change originates in an initial alteration, but that its effect is small until the rest of a set of incremental changes are also in place allowing the initial change to enjoy a wider impact.[325] This is perhaps a more positive way of looking at Veblen's suggestion in 1915 that there is effectively a lock-in to any system which he termed 'interconnectedness'. All parts of a system work together and change to one part must be accommodated by the other parts of the system. To explain 'interconnectedness' Veblen used the example of small railway wagons that Britain continued to use for coal, even after other countries were using wagons taking twice the volume. He argued it was because the system locked them in, a product of railways which were all designed for this size of wagon. Kindleberger developed 'interconnectedness' further, suggesting it applied to technology and institutions but I suggest that it also applied to investments; where investment in one part of system prevents change because modification of the system requires even further investment or because previous investments have not yet been realised.[326]

[325] Kandar, Malanima, and Warde, *Power to the People*, p.28.
[128] Kindleberger, *Economic Development of England and France,* p.141.

FIGURE 15 DEVELOPMENT BLOCKS.[327]



The factors important for energy innovation are shown around the outside of the circle and align with decisions that individuals took for businesses and factors that influenced electricity at a national scale. The authors stated that they 'find discontinuities in energy history when a critical macro-innovation comes into existence and transforms the economy and society. The implementation, diffusion and wider impact on society of such macro-innovations are described by the concept of the development block'.[328] Whether these factors combine as 'development blocks' to make a change when the last one is placed, or whether change occurs when the last piece of the 'lock-in' to the previous regime is released, the important factors include what the change is, its drivers and when it was applied.

[327] Source: Kander, Malanima, and Warde, *Power to the People*, p.29.
[328] *Ibid.,* p.28.

‘Interconnectedness’ applied to electrification, with decisions taken by individuals and companies providing localised solutions because of the nature of the licenses. Tariffs and technology employed for generation and distribution were individualised by supplier which often prevented neighbouring undertakers from being able to fully cooperate and use each other’s networks, even if managers agreed in principle. Like the railway wagon example, further investment and re-organisation of the existing disparate system was impracticable because early decisions made by the companies caused lock-in. This meant that evolution of the system into something more national, if at all, would likely have taken many decades. Imposing a national system was a more immediate solution. Scott argues that America and Germany, had the advantage of industrialising slightly later and were able to make use of newer technologies and develop supporting organisations, which led the resulting electrification process to be less of a step change.[329]

‘Interconnectedness’ also applied beyond suppliers to their consumers. The type of electricity supplied played a role in determining which machinery could be used and it was supplied by the electrical supply company, or other endorsed supplier. Consumers self-generating, were locked into their investment for generating plant which was unlikely to be realised for about twenty years, creating financial lock-in. Moving from self-generation to local suppliers was not just about connection but about compatibility because there was no standardisation of supply.

Large scale generation of electricity through the Grid should have made these decisions easier because it provided a national standard from 1926, but as discussed earlier, this was not fully realised until after nationalisation. This perhaps guided investment decisions, as there was a standard to work toward but it should have made technological lock-in less likely, although the proportion of the business sunk in capital costs was important. For industry, arguably the most

[329] P. Scott, *Triumph of the South: A regional economic history of early twentieth century Britain* (Aldershot, 2007), pp.27-28.

important difference that large scale generation and transmission through the Grid made was primarily price reduction brought about through economies of scale. This would suggest that cost per unit for self-generated power in the early period would be comparable to a small public supply station. However, as power stations for public supply increased in size reducing costs per unit generated, the comparison became less favourable for self-generation, exacerbated by improving technological changes and lock-in issues already discussed.

This was likely to be why many electrical supply companies negotiated prices to supply large-scale industrial consumers. The supplier benefitted by having a steady predictable load, which in turn enabled them to increase their own scale of production. However, as development blocks, or interconnectedness applied to the suppliers too, it depended on their state of development as to how much they might need to invest to meet the needs of a large consumer and if they could offer attractive prices. Individual public suppliers generally charged lower rates for industrial and commercial users. Often there were large discounts for electric lighting of commercial premises or even free electric lighting if it made up less than twenty percent of the total bill with tariffs being extremely complex. They varied in charging structures and prices, which also added to the difficulty of decisions about whether to use electricity and where to source it.[330]

Effects on Location and Environmental Impact

What defined efficiency, its components, and what it is based upon is important and different for businesses. For example, if rail transport is the development block needed to make operating factors within the factory more efficient then moving to a railhead is beneficial, assuming all other business

[330] Bolton, *Costs and Tariffs* and Byatt, *The British Electric Industry* discuss this at length. Garcke, *Garcke's Manual* contains pricing for almost all electrical undertakings from 1896 to 1960.

requirements can be sufficiently met. However, if relocation costs are prohibitive, or investment is not transferrable or is too costly to be written off, remaining at the current location is most efficient. However, to take advantage of improving transport networks or cheaper property, industry had to adequately provide for its energy requirements in new locations. Reducing prices and slow expansion of supply across the country, with overhead lines often following roadways, meant that businesses purchasing from public supply could realise the benefits of these new locations. Businesses who chose to self-generate were more location limited as they needed access to large quantities of primary fuels and water.

Scott wrote about how industry migrated to regional centres and arterial roads for more convenient transport over this period. This was described as a 'nodal' system by a Royal Geographical Society (RGS) report of 1938.[331] which reported on the location of industry providing conclusions that are worth quoting in full and considering with respect to energy:

> Under the influence of a complex of historical and physical factors, the pattern of English industrial development began to take shape nearly a century and a half ago, … one of its elements was the concentration on localities suited to supply countries overseas; another was the concentration on the coal-fields. …. we can say that, with the growth of industrial activity overseas accentuated by economic nationalism, marginal or sea-board location has lost a considerable measure of its old importance. Hence areas that relied mainly on such a location for their prosperity are now distressed.[332]

It is interesting that a report from 1938 was already reporting 'distressed' locations, in areas of coalfields or ports, suggesting they were declining. The importance of being strategically located for coal fields was reducing, as was dependency on large shipping ports and watercourses for fuel and

[331] Scott, *Triumph of the South,* and G. Manley, 'Memorandum on the Geographical Factors Relevant to the Location of Industry', *The Geographical Journal* (1938), 92, 6, pp.499-526.
[332] Manley, 'Location of Industry', p.511.

goods transportation. This was partly due to improving inland transport, and partly due to increasing energy accessibility.

> This loss is in part balanced by the increased value of interior location, but only in so far as that interior location is nodal. Nodality has always carried with it a tendency to diversity, as opposed to specialisation, in industry, and it is obvious that the chances of a diversified industrial centre being adversely affected at every point by economic and political changes are relatively slight. …. Many if not all of the new industries that have sprung up in the last twenty years have arisen strictly in relation to the home market or to overseas markets reached through London. Clearly, they are most scientifically located at interior nodal points.[333]

Industry was moving inland and further from watercourses which had provided ‘nodality’. However, production was becoming more concentrated on home markets using the nodality provided by railway and road transportation. For example, engineering workshops making radio components moved onto the newly developed Cambridge Road north of London providing links, or nodality, into the city. This was because reliance on water to provide power was reducing and becoming available in new locations serviced by new road and rail networks. This had the additional benefit of providing easier mobility for the workforce opening new locations where industry thrived. These enormous infrastructural changes meant that people could commute further, living and working at places a greater distance apart and that power could ultimately be supplied independently of location. However, as explained throughout this work, this was a long process and changes were not implemented uniformly across the country. We have seen how WW1 catalysed electrification, particularly for industry, resulting in areas of greater industry tending to be better served, demonstrated by sales in the Lea Valley, where the most industrial areas developed most rapidly.

[333] *Ibid*.

> Then again, one of the most striking features revealed by the new occupational statistics is the marked increase in the proportion of the population finding work in what may be termed the 'services' transport, public utilities, retail trade as opposed to the manufacturing industries. Such services, and therefore such opportunities of employment, are also at a maximum at nodal points, of which, of course, London is the supreme example. The second force at work blurring the old pattern, namely the escape from the coal-field location, or perhaps it is more true to say, from location on the inland coal-fields … That the increasing use of electrical power, and the construction of the grid, have given a new freedom of location cannot be doubted.[334]

The ability of people and goods to move around the new, expanding nodal transport networks created jobs as the economy began shifting towards services and away from manufacturing. This is not to suggest that electrical power replaced manpower in manufacturing but to suggest that it changed products and processes and the resulting supply and distribution chains. 'Freedom of location' brought about by the Grid, slowly making electricity universally available developed alongside nodality. Individual piece of infrastructure, e.g. a road, has limited use without other roads connected, or place of value it reaches; similarly, electrical power in an inaccessible location is worthless. Determining which came first, or was even the dominant factor is difficult, but without power through the 'nodal' Grid industry would likely still be tied to water for energy requirements unless an alternative had been discovered. Equally, without a replacement for the nodal waterways universal electricity would be less valuable.

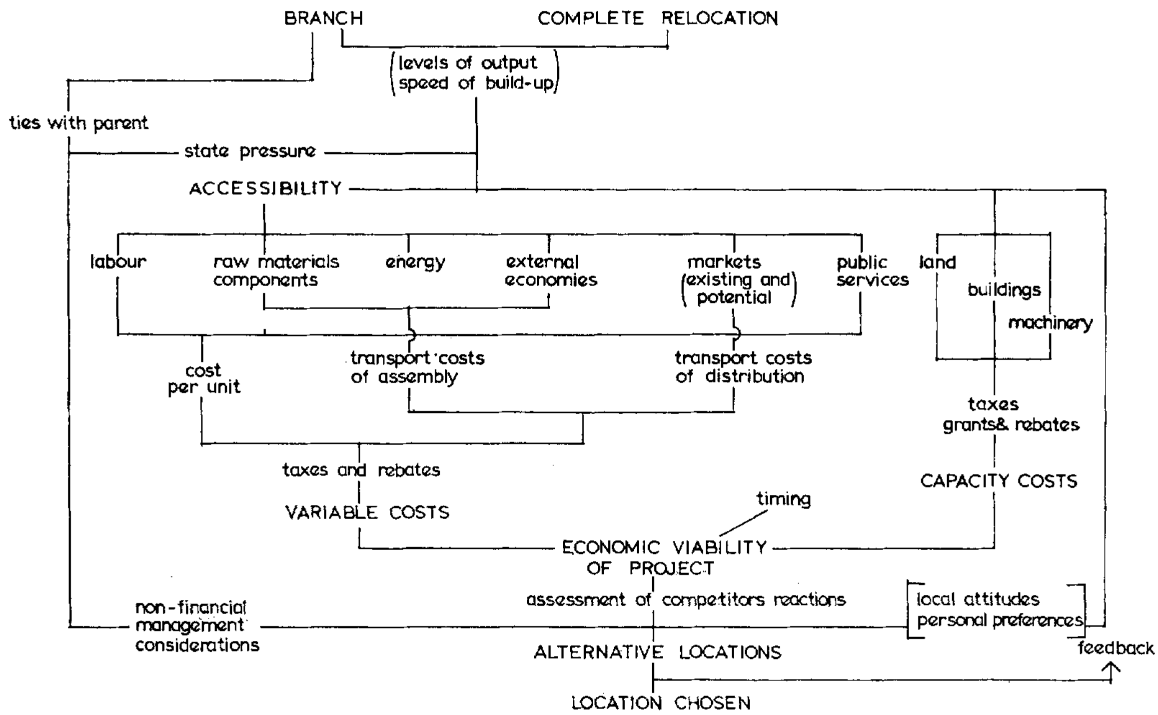
There are very few studies into how energy availability affects industrial location. As a result this chapter will proceed to do just that, by accounting for the role electricity in different industries, the

[334] *Ibid.*

propensity of the industry to self-generate or purchase its electricity. However, there have been many studies considering what determines industrial location.

One of the most comprehensive, is by Townroe. In his paper 'Locational Choice and the Individual Firm' he discussed factors including space, buildings, labour force, and transport networks, alongside energy and the tax/grants policy of an area, producing the model seen in Figure 16. In this work he acknowledged that deciding the location of an industry is not necessarily the sum of decisions made regarding all factors but that just one factor might pre-dominate.[335] Given the lack of historiography around the secondary fuel industries, and in many industry histories, electricity is likely to be 'passed over'.[336]

FIGURE 16 HOW BUSINESS DETERMINES LOCATION.[337]



[335] P.M. Townroe, 'Locational choice and the individual firm', *Regional Studies* (1969), 3, 1, pp.15-24.
[336] *Ibid.,* p.22.
[337] Source: *Ibid.,* p.22.

In 1983, Hewings and O'Huallachain began considering regional systems and what they described as 'a long tradition in economic geography' in a Western European and Northern American context. They suggested the energy crisis of the 1970s 'changed the connotation of 'footloose industry' and created uncertainty about the development of certain regions and, at a more local scale, 'the long-term shape, form and development of metropolitan areas' as alternative energies might need to be sought.[338] Other issues considered included communication, transportation, and telecoms. Interestingly the relative location of consumers is not discussed in these works but was likely to be more important for retail rather than these more power-hungry industries producing for wholesale markets rather than direct to end consumers. Dicken suggested that each stage of product life-cycle has a technology-demand relationship which in turn has a geographical expression. If this idea is applied to the Industrial Revolution steam power accepted as the technology in demand then location would be dictated by its required components, within the context of the other factors, as already discussed. Transition away from steam power would break this link to these components. Hewings and O'Huallachain concluded that further research is necessary to investigate links between energy and industrial systems and changes in transport systems in combination with population and energy systems. Further suggesting that, 'energy input substitution will have a pronounced spatial impact although the nature, direction and extent are at present unknown and the subject of much speculation'.[339] These studies all suggest that electricity enabled industry to locate irrespective of its energy requirements when it became universally available. The universal availability and presumed entitlement is perhaps why decisions about energy are considered as obvious and given little analytical thought, and why it is only when disruptions or threats arise that it is investigated.

[338] G.J.D. Hewings and B. O'Huallachain, 'Industrial factors' in F. Hamilton and G. Linge, (Eds), *Spatial Analysis, Industry and the Industrial Environment: Progress in Research and Applications. Regional Economics and Industrial Systems* (Chichester, 1983), p.45.
[339] *Ibid.*, p.49.

The Lea Valley

FIGURE 17 MAP OF THE LEA VALLEY ELECTRICITY SUPPLY AREAS.[340]

The River Lea is a tributary of the Thames whose banks and surrounding area have hosted many different industries for centuries. Poplar and West Ham include docks directly on the Thames where heavy industries such as shipyards and iron works operated, at least at the beginning of this period.

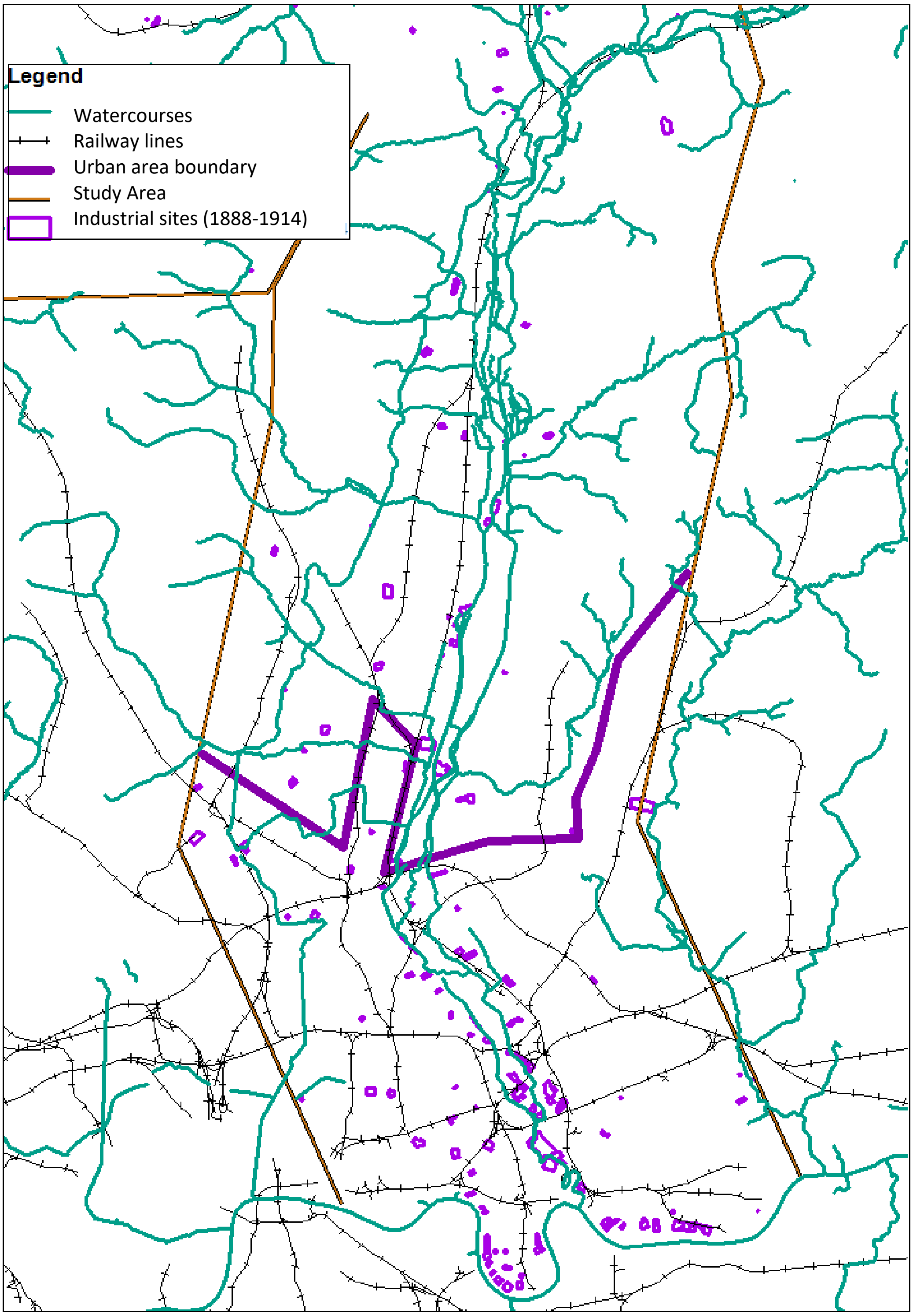
From the 1880s, the Lea Valley benefitted from people moving to cheaper land and housing; leaving the city of London and joining the rapidly expanding suburbs higher up the valley. The Survey of Greater London from the 1940s shows the population North of the Thames expanding from 1.746 to

340 Source: Garcke, *Garcke's Manual*, 25, 'Supplemental pages showing Authorised electrical undertaking in the area of Greater London'.

2.545 million between 1851 and 1928.[341] The electricity suppliers for the area are shown on the map in Figure 17. Readily available labour was probably one factor that attracted businesses here, alongside cheaper property prices outside of London. However, it is unclear whether the work moved to the population or *vice versa*. It was probably a little of both, as shown by the case of the Harris Lebus factory, which moved its furniture making business from the East End of London to Tottenham, like other previously East End based manufacturers, re-locating for relatively cheap property. Lewis' work explained that Lebus built housing for his workers near to the new factory to prevent them having to commute from the East End. The extensive, modernised watercourses provided transportation for goods and its running water for power, and the expansion of industry along the valley corridor can be seen in Figure 18, 19 and 20. These maps show the urban fringe reaching further up the valley, marked by the solid coloured line on each map.[342] The coloured outlines show the sites of individual businesses which also reached further up the valley over time.[343]

[341] H. Smith, *The New Survey of London Life and Labour* (London, 1930), p.72.
[342] Maps Derived from Ordnance Survey Data, 1:10 560 County Series 1st Revision, 1:10 560 County Series 2nd Revision, 1:10 560 County Series 3rd Revision, Ordnance Survey Open Rivers Data, Contains Ordnance Survey data © Crown copyright and database right 2016., With thanks to The Cambridge Group for the History of Population and Social Structure, particularly Max Satchell for the Railway Dataset. These details apply to all maps in this chapter.
[343] The maps covering three different time periods are used: 1888 to 1914 as revision 1, 1903 to 1950 as revision 2, and 1926 to 1969 as revision 3. These are explained further later in the chapter. The dates of the actual surveys included in revisions 1 to 3 are, respectively, Middlesex, 1891-95, 1911-13, and 1932-43 and Essex, 1893-96, 1913-1922, and 1936-40. The first revision is late nineteenth century, as electricity supply companies were being established in the area, the second revision around WW1, and the third just after the grid began full trading.

Figure 18 Industrial change in the Lea Valley, 1888 to 1914.



Points of industry 1888 to 1914
with boundary of urbanisation

FIGURE 19 INDUSTRIAL CHANGE IN THE LEA VALLEY, 1903 TO 1950.

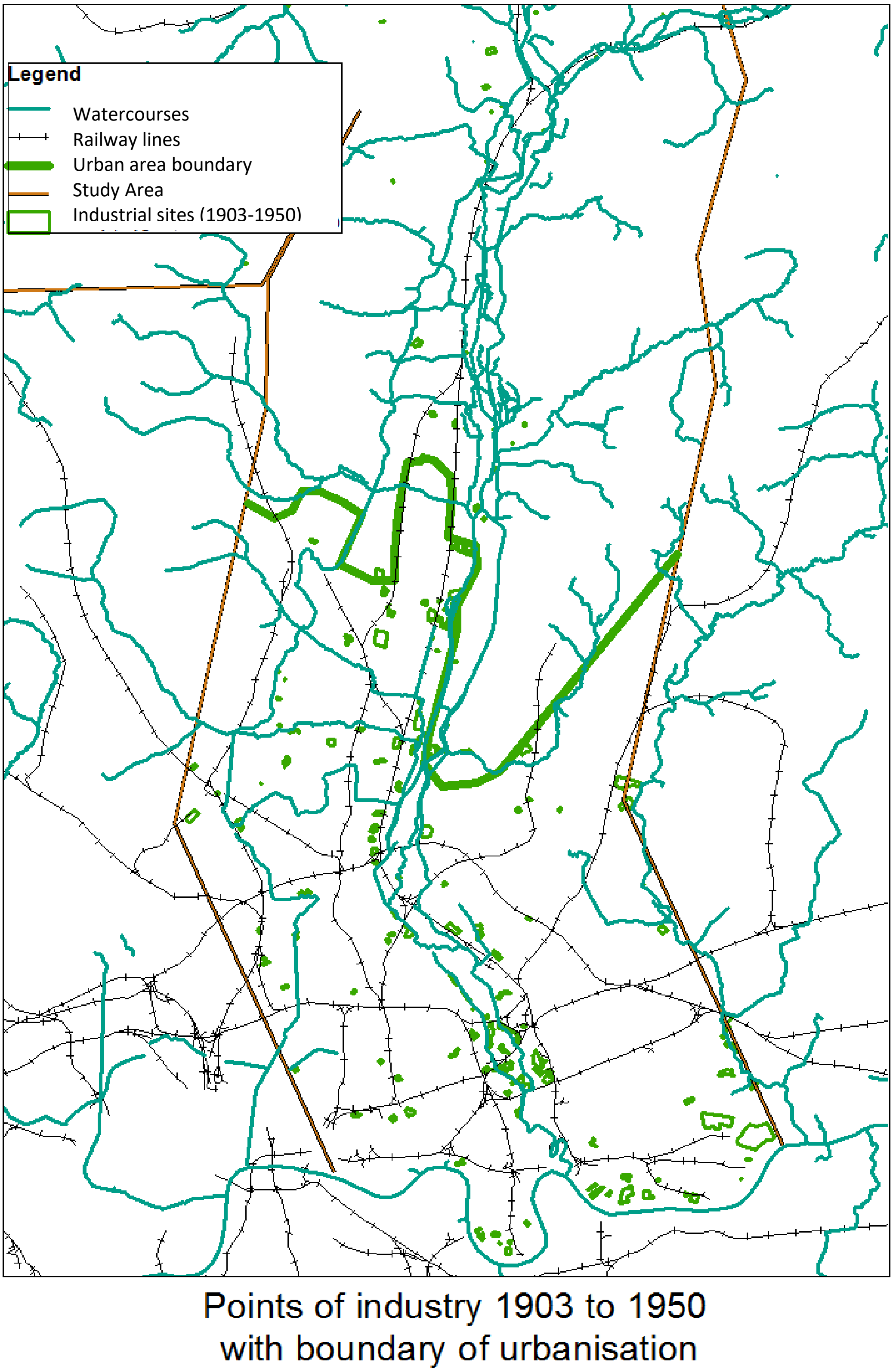
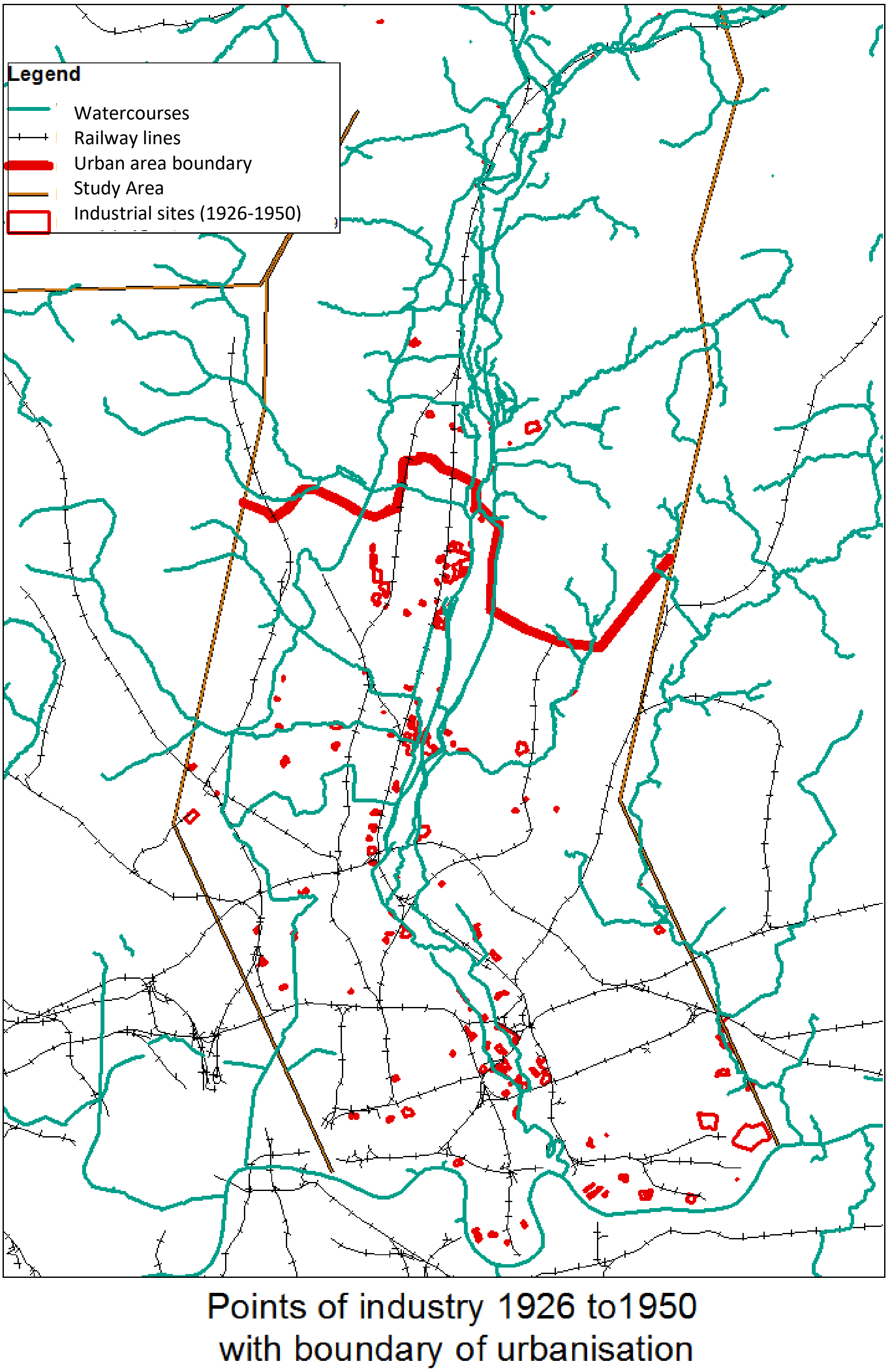


FIGURE 20 INDUSTRIAL CHANGE IN THE LEA VALLEY, 1926 TO 1950.



Electricity Provision in the Lea Valley

Before WW1 the Lea Valley had different electricity suppliers for nine of its eleven districts. They operated under licences granted under the Electric Lighting Act 1888. One of the earliest was Hackney Metropolitan Borough Lighting, issued in 1893, granted bulk supply rights to supply Stole Newington in 1903. In 1906 they were granted permission for a new power station. Poplar Metropolitan Borough Council Lighting also operated under a licence issued in 1893. Similarly, Leyton, Walthamstow and West Ham were supplied by municipally owned companies granted licences in the 1990s.

Poplar and West Ham are bordered by both the Lea and the Thames, on which there were heavy industries including metalworks, shipyards and foundries, which all consume large quantities of power. At Ponders End the first industrial public supply was taken up by the Ediswann factory in 1906 from Brimsdown power station. Lewis suggested that prior to this power came from 'a rather ancient and cumbersome steam engine driving a 20ft wood toothed wheel. This contraption in turn drove the main shaft which ran the length of the factory and provided power for the machinery'.[344] If businesses had invested in self-generating equipment around the turn of the century the depreciation write-off period would have been approaching around the 1920s and future supply would be under consideration.[345]

It is difficult to determine which supplier provided for any individual factory, or indeed whether a specific factory self-generated or purchased electricity externally. As a result, this case study uses national figures from the Census of Production, which reported the propensity of industries to purchase or self-generate their electricity. Where self-generation was high it would be expected that the industry's site would be located close to water, whereas an industry purchasing from an external

[344] Lewis, *More Secrets Revealed*, p.15.
[345] See footnote 311 for details on the investment cycles and depreciation.

supplier could locate independently of these requirements. Archaeologists' reports regarding the Lea Valley show that Wright's Flour Mill began using electricity in 1909, Abbey Mills used electric pumps from 1931, and electric cranes for transferring logs were introduced in 1912 in Hackney at the largest timber yard.[346] These could have used purchased electricity from local suppliers, who were generating by this time if they chose to.[347]

National figures demonstrate that before WW1 industry was using about half of all electricity sold by suppliers but this had increased to nearer to two-thirds by 1920. This was true for Poplar but in Hackney and Walthamstow industry still only accounted for about half of the total units sold. This is because they had a variety of other businesses as well as manufacturing munitions which were prioritised for electrical power during WW1, therefore other industries would lag behind.[348]

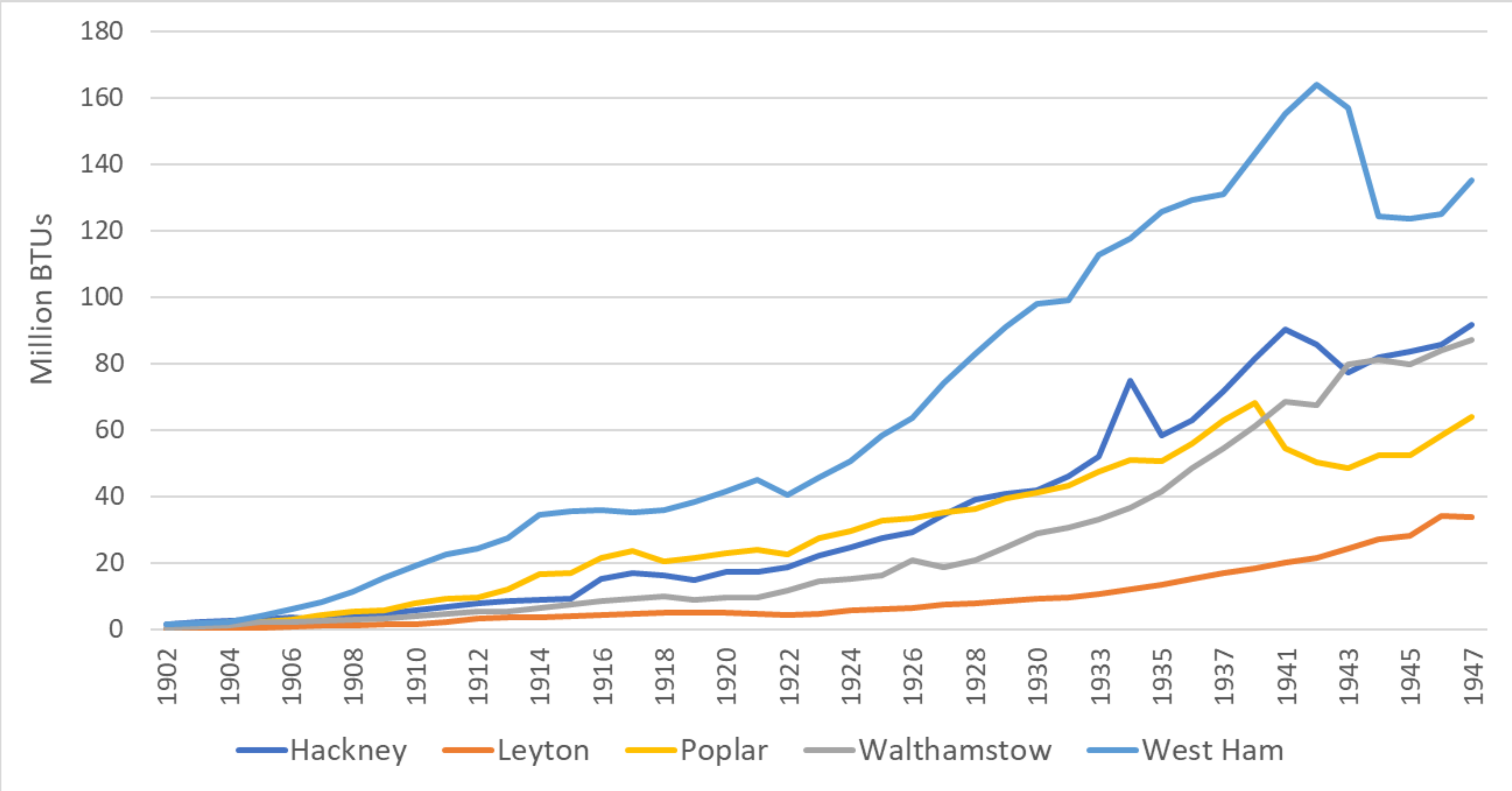
Figure 21 shows the number of units sold by individual public supply companies in the Lea Valley for each accounting year from 1902 to 1947. An increase in units sold over the course of WW1 and WW2 can be seen for West Ham, Hackney and Poplar with high munitions manufacture. There was less of an increase for Leyton and Walthamstow which were less industrial. The additional sudden increases are explained by the installation of new equipment enabling greater generation capacity but the sudden increase in Hackney in 1934 is more difficult to explain. The only significant change seems to be political from Labour to the Municipal Reform Party locally which might have affected the operation of policy of the electricity concern. It was a short-term change for which no other explanation has yet been found.

---

[346] T. Smith and B. Carr 'Guide to the Industrial Archaeology of Hertfordshire and the Lea Valley' (Association for Industrial Architecture, 2004), p.43.
[347] The Royal Small Arms Factory at Enfield was self-generating for electric lighting in 1887 which was beneficial because it increased potential working hours. Prior to this large glass roof panels were used to benefit from maximum natural daylight. Details are known about when this factory used public supply but he reiterated that companies kept their generators long after they stopped entirely self-generating. Personal Communication with J. Lewis about electrical changes in the Lea Valley.
[348] Scott, *The Triumph of the South*, p.47.

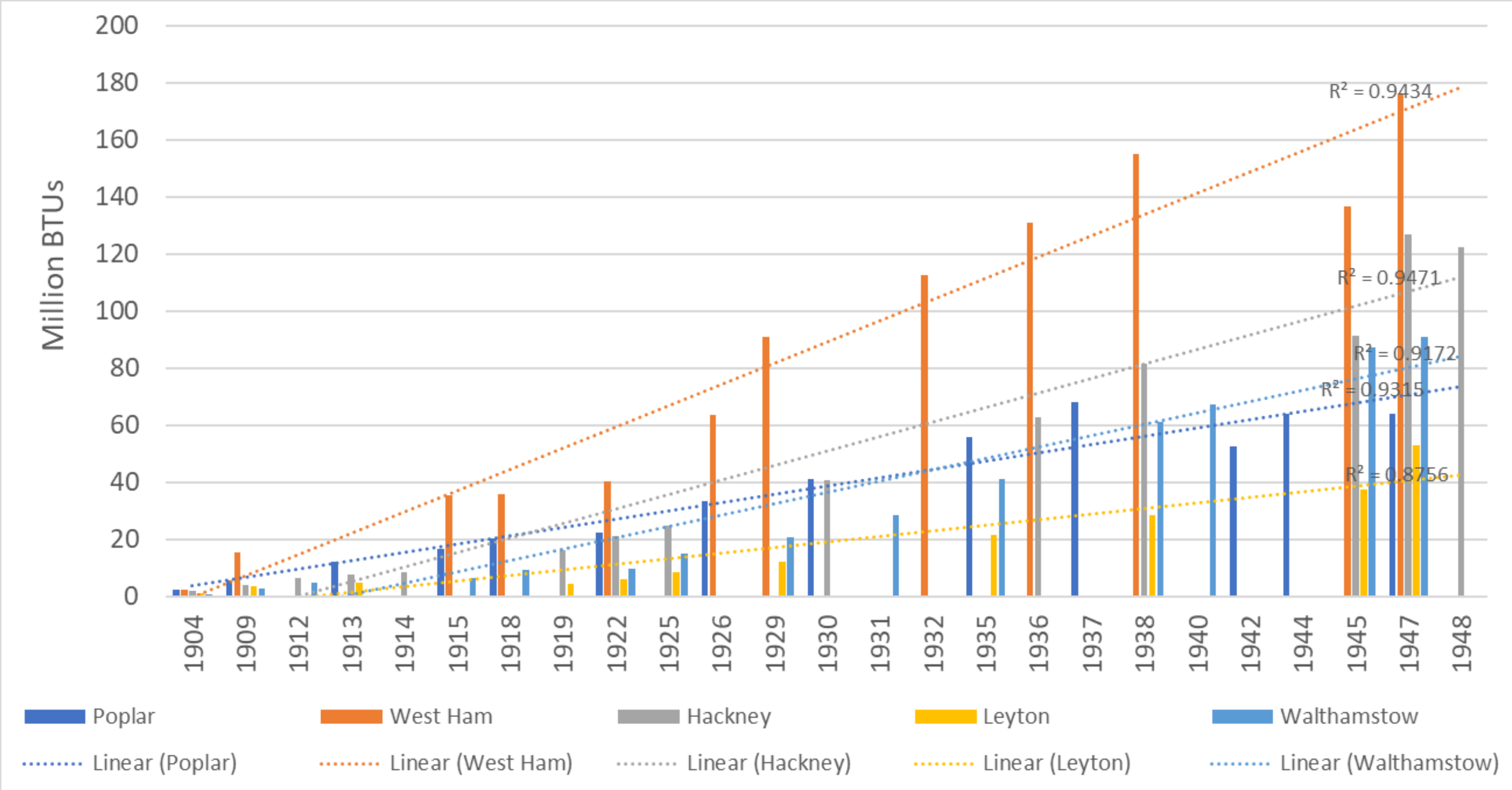
The figures in Table 9 and Figure 22 show the units of electricity sold by the suppliers in the Lea valley. It shows that the earliest growth in electricity sales was in Poplar and West Ham, both with boundaries on the Thames. As industry expanded up the river, so the electrical suppliers in the corresponding areas increased sales: Hackney expanded in the early 1920s, after Polar and West Ham, with Walthamstow and Leyton, less industrial, following later.

FIGURE 21 GRAPH SHOWING INCREASING SALES OF ELECTRICITY UNITS.[349]



[349] Source: Garcke, *Garcke's Manual*, 4-46, Entries for Hackney, Leyton, Poplar, Walthamstow and West Ham Electricity Supply Companies.

FIGURE 22 GRAPH SHOWING INCREASING SALES OF ELECTRICITY UNITS.[350]



350 Source: *Ibid.*

TABLE 9 MILLION UNITS OF ELECTRICITY SOLD BY LEA VALLEY SUPPLIERS.[351]

Year	Poplar (million BTU's)	West Ham (million BTU's)	Hackney (million BTU's)	Leyton (million BTU's)	Walthamstow (million BTU's)
1904	2.21	2.27	2.18	1.19	0.81
1909	5.85	15.52	4.21	3.53	2.73
1912			6.62		4.70
1913	12.01		7.81	4.79	
1914			8.58		
1915	16.87	35.64			6.43
1918	20.51	35.84			9.22
1919			16.22	4.57	
1922	22.53	40.51	21.21	6.26	9.56
1925			24.76	8.35	15.15
1926	33.36	63.52			
1929		90.79		12.00	20.63
1930	41.27		40.72		
1931					28.70
1932		113.00			
1935	55.90			21.63	41.34
1936		131.00	62.75		
1937	67.99				
1938		155.00	81.52	28.32	61.17
1940					67.30
1942	52.51				
1944	63.94				
1945		137.00	91.50	37.49	87.19
1947		176.00	127.00	53.16	90.87
1948			122.00		

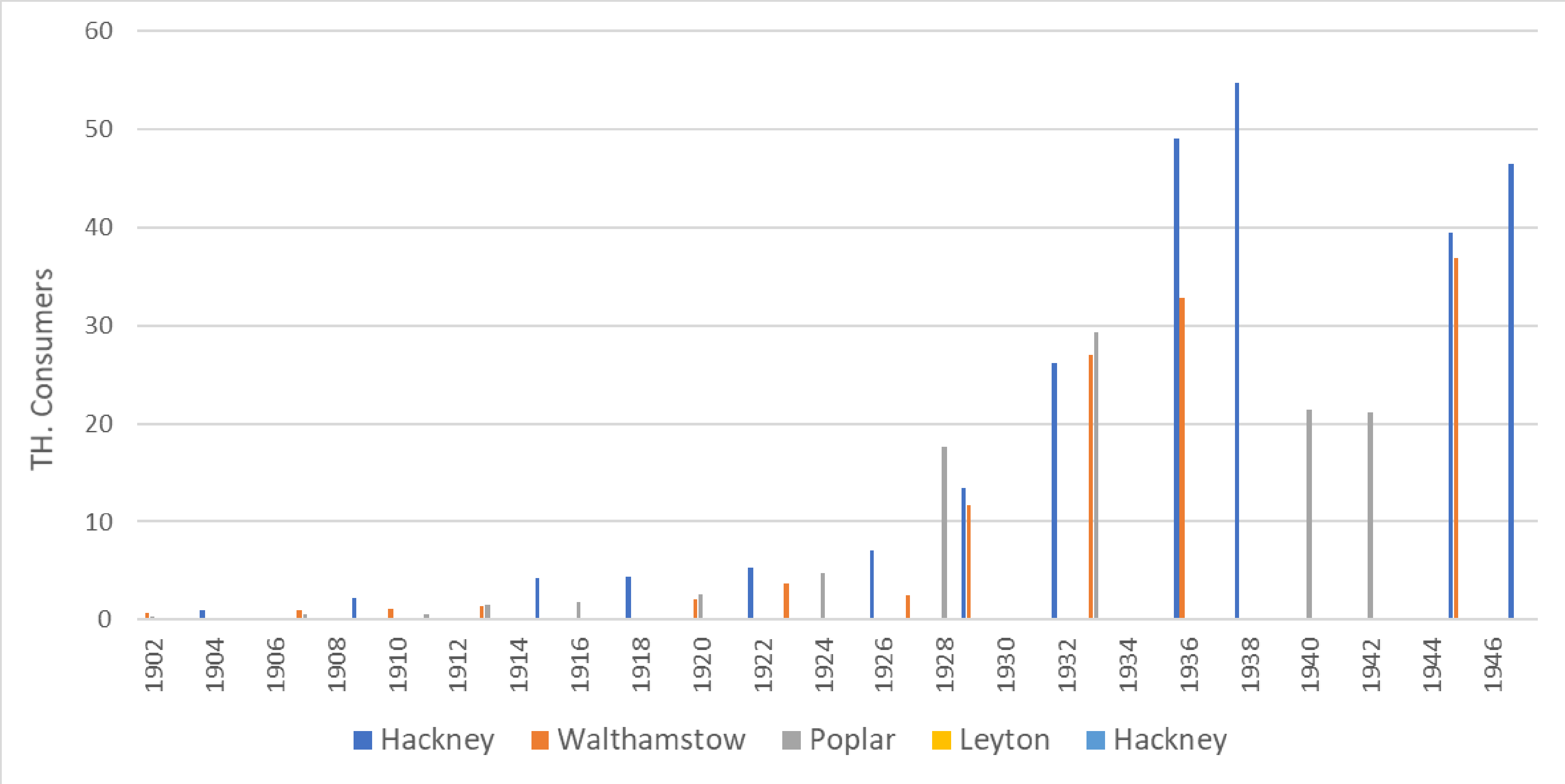
351 Source: *Ibid.*

Electricity sales continued rising until the 1990s with electricity companies driving expansion of supply. Commercial consumers were good for suppliers because they brought stability through predictable load and were encouraged through preferential tariffs. West Ham, a very successful corporation, was quite aggressive in its marketing. One brochure advertised vacant factory premises and promoted available building sites, promoting proximity of the sites to roads, rail sidings and river frontage and importantly where it was connected the availability of electricity. It appears that they were advertising municipally owned properties for sale or to let with electrical connections which would also be provided by the local authority. This strongly suggests that connections to industrial sites was considered desirable, with advertisements stating ‘to most of the properties a very cheap supply of electricity for power, lighting, and other industrial purpose’ in various forms.[352] Many newspaper adverts by electricity supply companies promoted the advantages of electricity for commercial and domestic purposes; the entrepreneurial West Ham Corporation even advertised its industrial sites in Germany.

---

[352] London, London Metropolitan Archive (LMA), ‘The West Ham Electrical Bulletin, 1914’, LMA/4278/01/064.

FIGURE 23 CONSUMER NUMBERS PURCHASING FROM LEA VALLEY ELECTRICAL SUPPLIERS.[353]



[353] Source: Garcke, *Garcke's Manual*, 6-46, Entries for Hackney, Leyton, Poplar, Walthamstow and West Ham Electricity Supply Companies.

By 1926 the number of recorded consumers of electricity reached 7,043, before more rapid expansion (Figure 23). Consumer numbers reduced in Hackney in 1944, possibly because of network changes during the war period or more likely because the method of recording changed, using household connections rather consumer numbers.

Ownership and Investment in the Lea Valley

Difficulties for development, lock-in, and lack of standardisation resulted from early decisions taken by individual municipal and private suppliers, and large industrial electricity consumers making individually beneficial decisions within legislative parameters. Byatt described this period as ‘a time when parliament was experimenting with methods of public utility regulation, and when the municipal trading movement was gaining ground rapidly’.[354] Technological innovation was also improving rapidly. For business owners, predicting when a public supply might be accessible at a price they were prepared to pay would have been almost impossible.

WW1 pressures led to ninety-five percent of munitions factories being electrified, suggesting that perhaps interconnection barriers stemmed less from technological boundaries and were more about costs and owner’s preferences. It was clearly possible to physically distribute electricity to these factories when normal legislation was suspended and power for industry was prioritised, and importantly finance was more easily obtainable. Ownership of power stations and distribution networks had created municipal and private owners, and individual self-generating factories and unauthorised owners. The CEB, did not have ownership or controls over distribution, which remained fundamentally unchanged. Therefore, undertakers purchasing electricity from the CEB,

[354] Byatt, *The British Electrical Industry*, p.8.

through the grid were still distributing to the same area and consumers under the same licenses as when they were generating.

FIGURE 24 THE STEPS AND OWNERSHIP OF THE ELECTRICITY SUPPLY SYSTEM AFTER THE GRID WAS INTRODUCED.

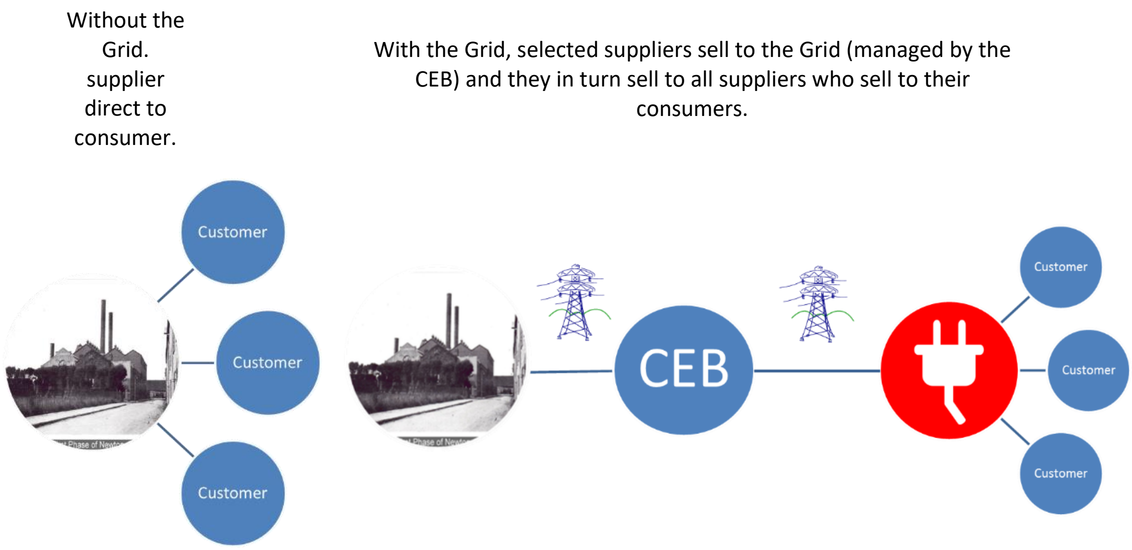


Figure 24 demonstrates the additional steps the CEB and the Grid added. The CEB bought electricity from selected power stations and sold it on, or back, to undertakers to distribute though their networks which remained unchanged. The only appreciable difference might include lower prices, a change in type of supply or some expansion of the network which would likely have occurred anyway. Whilst financial compensation was available for necessary changes in machinery there is very little information about how this provided. It is likely that there were schemes to trade in equipment or some sort of compensatory scheme, at least for industrial consumers, but to qualify, agreement had to be reached between the consumer, the supply company, and the Grid engineers.

Effects in the Lea Valley

In 1938 Bolton suggested, 'Kipling might well have said of electricity; There are nine-and-sixty ways in which the user pays and every single one of them is right' regarding electricity prices.[355] The intention of the Weir report was to reduce prices, ideally to less than 1.5d. per unit or less for all consumers. However, tariffs remained complex and the 'Kipling' variety continued even after nationalisation, despite these intentions.[356]

Table 10 show the complexity of tariffs, and variation between suppliers who were geographically contiguous.

TABLE 10 TARIFFS FOR LEA VALLEY SUPPLIERS.[357]

Electricity Supplier	1916	1937	1952-53
Hackney	£1 per KW plus 1/2d per unit	£4 5s per annum per KVA of max demand plus 1/2d per unit for the first 6,000 units per quarter sliding to 0.35d per unit, or alternatively 1 3/8d per unit as a flat rate	£5 12s 6d per annum per KVA of max demand, plus 3/4d per unit; for first 6,000 units per quarter, sliding to 0.55d; or flat 13/4d. Industrial Heating and Commercial Cooking 1d
Poplar	£1 per KW and then charge for current	£4 per annum per KW of max demand, plus ½ d per unit of AC, 6d per unit of DC, or a flat rate of 1 ½ d to 1d per unit	£6 per annum per KW of max. demand plus 1 1/8d per unit for factories and workshops. Other industry a fixed charge of £8 15s per annum per KW installed plus 1 ¼ d per unit.
West Ham	1 1/8 d per unit with negotiated discounts for lighting	3d for the first 40 units per HP installed per quarter, and 3/4 d per unit for those in excess. They then had special deals for factory lighting	£12 10s 0d per annum per kW. Of Max demand, plus 1d per unit. Power, 31/4d first 90 units per h.p. installed per qr.; 11/8d, all in excess

This demonstrates that again, despite the Grid, the parochial nature of British electricity continued to be felt by consumers. Although reducing long term, 'Kipling Prices' were still evident, even into

[355] Bolton, *Costs and Tariffs*, p.vi.
[356] The Weir Report, p.22.
[357] Source: Garcke, *Garcke's Manual*, 20-51, Hackney, Poplar and West Ham Entries.

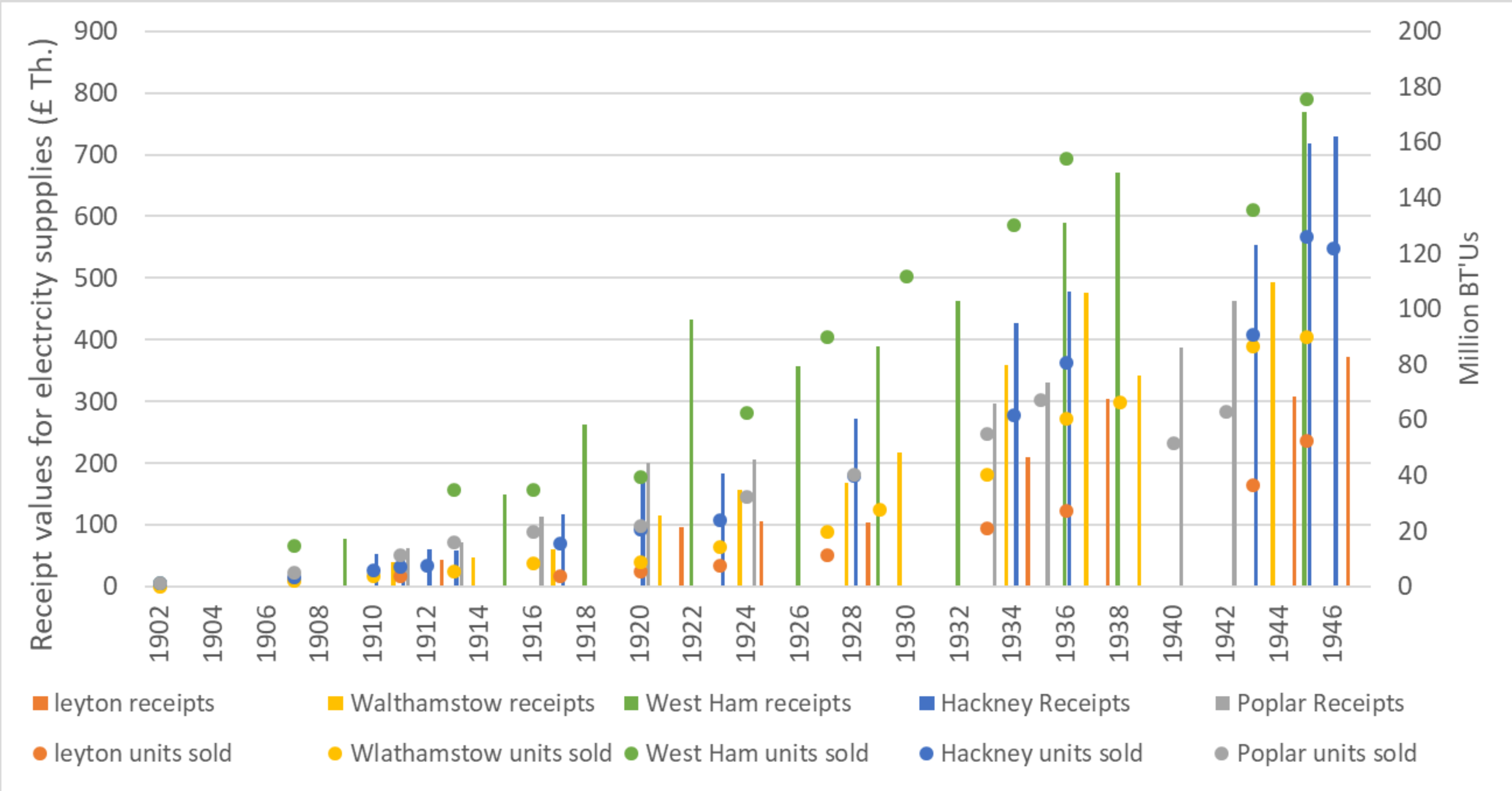
the 1950s; Poplar, Hackney and West Ham, with large numbers of industrial and domestic consumers, were still charging different prices, using different tariffs, despite all being included in London Electricity Board after nationalisation. However, industrial power remained cheaper than domestic power because it was beneficial for the efficiency of the electricity supplier.

Between 1904 and 1947 the units sold by the five municipal undertakings increased almost sixty-fold.[358] It is difficult to apportion this to industrial or domestic consumption because each company recorded information slightly differently. Figure 25 shows how pricing and expansion of each undertaking were aligned but that profitability between suppliers varied, even those in close proximity.

The decisions businesses had to take regarding energy were complex and essentially rooted in Veblen's ideas of 'interconnectedness' or Kander, Malanima and Warde's development blocks. It was a balance between when the advantages of using electricity became equal to, or greater than, the financial commitment and risks involved, within the framework of decisions for where to situate themselves.

[358] *Ibid.,* 6-46, This calculation uses the total units sold at all the undertakers for that accounting year except for Poplar, for which the total from 1944 is rolled forward.

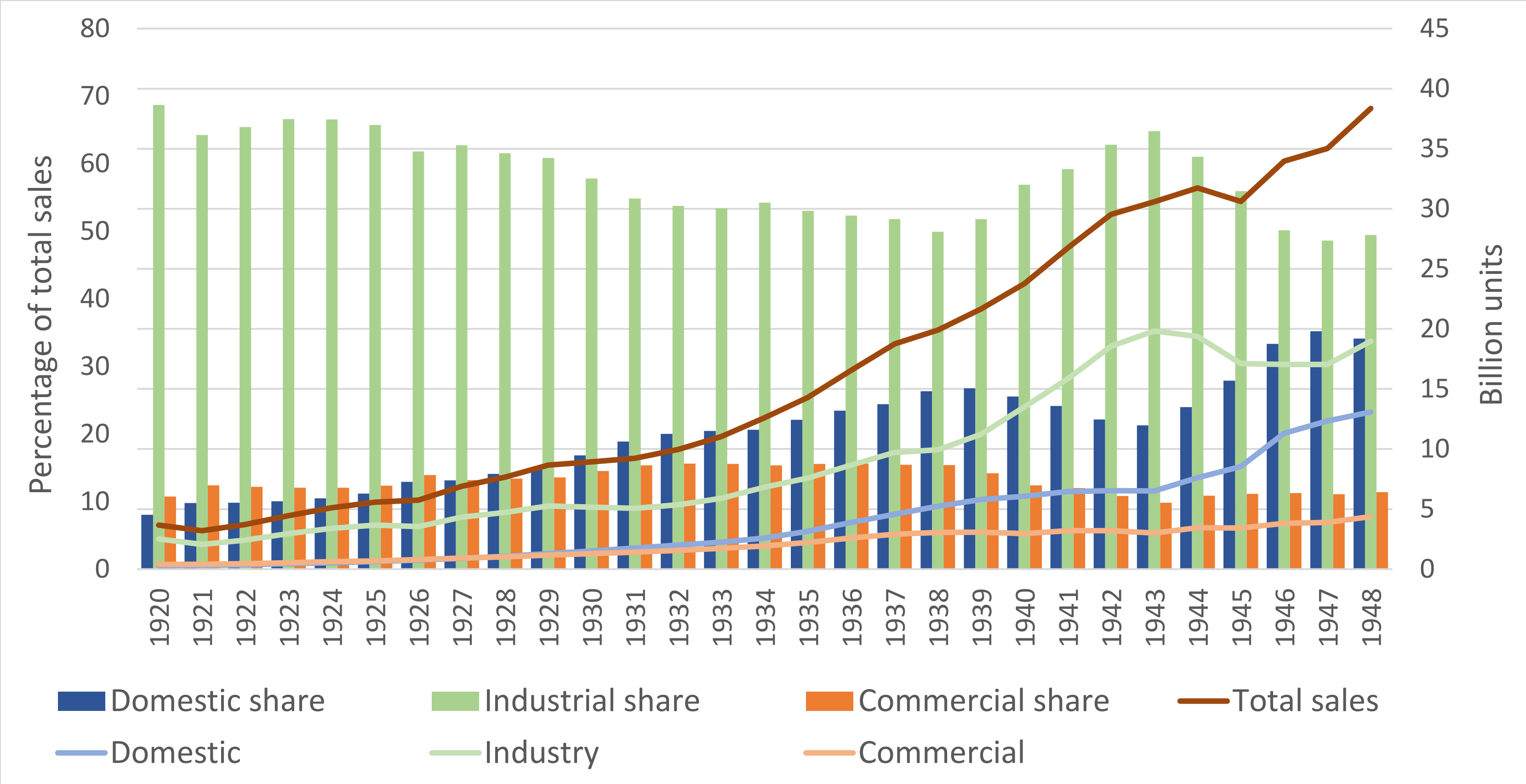
FIGURE 25 RECEIPTS FOR EACH OF THE ELECTRICAL UNDERTAKERS IN THE LEA VALLEY.[359]



---

[359] Source: *Ibid.*, vol., 6-46, Entries for Hackney, Leyton, Poplar, Walthamstow and West Ham Electricity Supply Companies.

FIGURE 26 PROPORTION OF INDUSTRIAL, DOMESTIC AND COMMERCIAL CONSUMERS.[360]



[360] Source: BEA, *Annual Report*, 1, p.249.

Case Study of the Lea Valley Industrial Location

Rationale, Methodology and Caveats

As just discussed, energy provision is just one variable which contributes to the decision regarding business location. The lack of studies considering energy accessibility makes identifying the changes brought by the Grid, if any, difficult to evidence. As a result, this small-scale study investigates individual site locations of industrial businesses in the Lea Valley over approximately 70 years. Without reports or accounts it is almost impossible to determine when individual businesses switched to electricity but what its main business was, and corresponding trade group is identifiable. In turn, this can be used to determine the propensity of the business to self-generate or purchase electricity from a supplier based on national figures from the Census of Production.

This study does not seek to provide definitive answers but simply to determine the truth of the assertion that 'the increasing use of electrical power, and the construction of the grid, have given a new 'freedom of location', as the RGS study, Smith, Matthews, and others suggested.[361] The assumption this study makes is that as the grid provided accessible energy everywhere, traditional links to water, for energy production and transportation, could be broken. As a result, the hypothesis being tested is that businesses moved to sites which prioritised transportation, workforce and other needs as reliance on watercourses reduced. Therefore self-generating businesses needed large quantities of water and remained near watersides but those purchasing from public supplies businesses could locate away from them.

Hall, a geographer, described the Lea Valley as 'by far the more important [core area for highly technological jobs] of London and the counties immediately north and west of it', and supported the

[361] Manley, 'Location of Industry', p.511, Smith, *The Industries of Greater London,* pp.176-177 and Matthews, *Electricity for Everybody* (3rd edn.), p.150.

idea of the Lea Valley as being pioneering in new technology take-up, although does not provide reasons.[362] Like many publications, this work glosses over electrification concentrating on the 'post industrial revolution', referred to as the 'electronic and information age', both of which are almost entirely dependent on electricity.

This study uses three revisions of Ordnance Survey maps 1:10 560 County Series, created by surveyors who manually observed, measured and recorded the environment and its uses. This means that some business premises (commercial) tend not to be identified on these maps but they used small quantities of electricity and their proportional share remained stable as shown in orange on Figure 26. Primarily, this study is interested in energy intensive industries with businesses which had space and capital to invest in self-generation. Normally this would be at least a modest engineering workshop according to Haslam's calculations. National statistics show commercial electricity (offices and retail) never exceeded sixteen percent of total sales, with industry consuming the highest proportion of consumption, never below forty-five per cent, and domestic consumption reaching more than twenty percent after 1935 (LHS, Figure 26).

The maps used to investigate whether this historic link with water breaks have three revisions covering the following time periods:

- Revision 1, 1888 to 1914,
- Revision 2, 1903 to 1950, and
- Revision 3, 1926 to 1969.

Whilst the date ranges appear to be very wide, these apply to the national maps. The survey dates for the counties studied are:

- Middlesex, 1. 1891-95, 2. 1911-13, and 3. 1932-43.

[362] P. Hall, 'The Geography of High Technology: An Anglo-American Comparison' in J. Brotche, and P. Hall, and P. Newton, (Ed's.), *The Spatial Impact of Technological Change* (London, 1987), p.146.

- Essex, 1. 1893-96, 2. 1913-1922, and 3. 1936-40.

The first revision from the late nineteenth century shows the period when supply companies were first established, the second revision around WW1, and the third revision when the Grid began trading. Dates given through the case study provide the maximum date ranges but because most of the industry is located in Middlesex, its dates are most applicable.

Pylons and cables often followed roadways, partly because these penetrated into built-up environments but also because roads provided convenient access for installation and maintenance. A Grid supply was more convenient if it was physically closer to its consumption point, although a substation was usually required. Increasing energy volumes available for industrial systems, improving efficiency, enabling mass production and increasing the diversity of manufactured products, required corresponding increases in fuel, materials and products transported through supply chains. Enormous structural changes for energy, water and transport were required to assemble development blocks, or release blockages in systems leading to spatial changes for industrial organisation. Much of this infrastructural growth and development happened simultaneously making the main drivers of the change difficult to identify and order.

There were, of course, other reasons for industry to be located near to water other than transport and energy. As a result, determining the reasons why the industry remained close to water and self-generated is difficult to unpick. Whether processing kept the industry riverside and self-generation was undertaken to improve profit margins as Stiel described or self-generation was deemed important enough that considering alternatives to water for processing was unnecessary is difficult to determine.[363] Chemical industries used water for processing but more importantly to dilute and remove waste products. A chemical site in the Lea Valley was situated on a sewer outlet, quite possibly for waste expulsion, but also provided the potential for self-generation if it was cost

[363] Stiel, *Textile Electrification*, p.237.

effective to make the water useable. There was already recognition from authorities that discharge from industry into water was a 'nuisance' issue, which was slowly being addressed, first for the Thames and then extended to its tributaries. Although determining the primary link to water is difficult, it should be considered with respect to spatial changes.

This work uses ArcMap, a geographical information system (GIS) to prepare and analyse maps to determine the proximity of each business to water using the following steps:

- Individual industry sites were digitised (Figure 27) as polygons providing digital representations of sites which are used by the GIS for calculations.
- Some of the industry sites changed shape or size between map revisions. As a result, centroids were calculated for each polygon to improve consistency across years. The centroid is the middle of the shape and remains more stable than the digitised edges.
- The 'intersect' calculation was used to determine which polygons are in the same location, to determine which sites are represented on each revision and which persist through all three revisions. From this, new maps were produced to demonstrate which sites disappear, and where new sites were established over the period.
- The 'near' calculation was used to calculate the straight-line distance between the centroid of each polygon and the nearest watercourse vector, showing, in meters, the distance from the site was to its nearest watercourse.[364] There are some difficulties with this:
    - The straight-line distance does not take accessibility into account but for the small distances considered it is not a significant issue and has been accounted for where necessary.

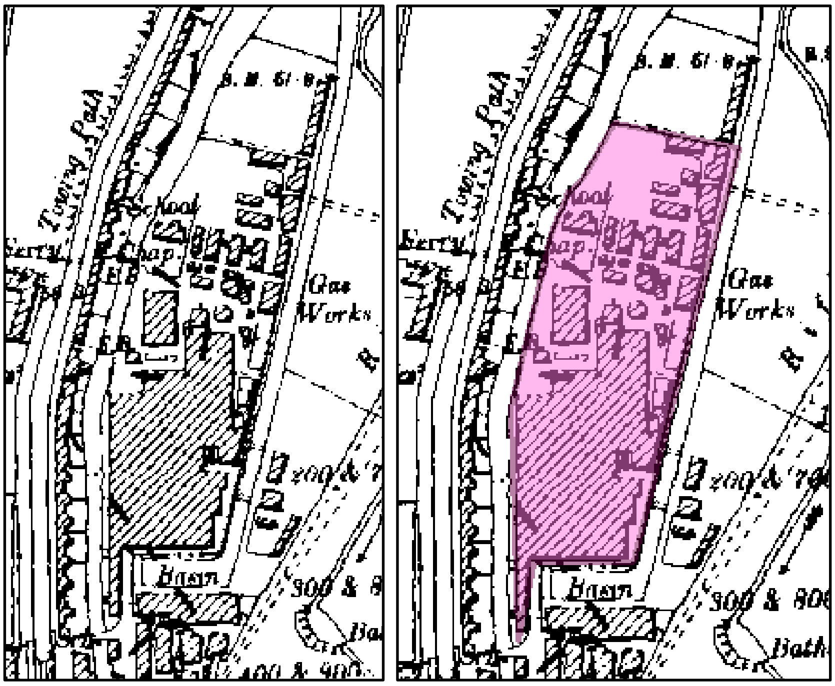
[364] The 'Near' function calculates the shortest distance between the nearest edges, lines or points between data layers within a GIS model. In this case between the water vectors and the nearest edge of the industry polygons.

- The water vector data set is modern. As there was a mixture of both navigable and non-navigable waterways it has not yet been possible to differentiate between the two. If the watercourse is not navigable it is unlikely that industry is there for transportation reasons.

For clarification, the following bullet points explain the terminology used to discuss the results:

- ‘Site of industry’ or ‘industry site’ – refers to the physical location of an individual business in which an industrial activity is undertaken.
- ‘Type of industry’ or ‘industry type’ – refers to the broad industry groupings used in the census of production. To maintain consistency these are as near to the 1948 census groupings as possible across all the work
- ‘Type of Trade’ or ‘Trade group’ or ‘Trade’ – refers to the more specific type of industry which are listed under an umbrella ‘industry group’ in the census of production. Again, consistency with the 1948 census has been maintained as far as possible.

FIGURE 27 A DIGITISED POINT OF INDUSTRY.[365]



The pink is a digitised polygon of the Gas-Works.

This is repeated for all marked areas of Industry across each revision of the maps.

Where data, or statistical information was revised between official reports, i.e. a different value was reported in a later version of the Census of Production, the later value is used; it is assumed the data was reviewed and corrected. A three-and-a-half-mile corridor each side the River Lea, from Poplar and West Ham, up the Valley to Hertford was used as the study area and is shown on the output maps.[366]

---

[365] The diagram shows how an image is digitised, with the pink shape being the polygon which becomes the digital representation of the site of industry, and it is this shape which is used as the basis of all the calculations regarding that point of industry for that map revision. Polygons are drawn for each labelled site of industry in each map revision.

[366] There were some labelled industrial sites which were not digitised, and these are:
'Brick fields'; 'brickworks' are included as they tend to contain buildings and/or kilns.
'Quarries': like brickfields these appear to be sites of excavation only, and the location is predicated on the natural resource being harvested.
'Malthouses': although in some cases these did implement electricity to dry the crops using hot air circulation, they were very specialised buildings and it is difficult to determine from the maps when these were used as malthouses and when they became used for alternative purposes, primarily converted to residential use. Malthouses have also been excluded There is also no specific electricity usage recorded for malthouses, some of which used electricity and some of which used manpower and spreading out of the grain across the floor of

Table 11 shows the number of industry types, each on its own site, on each map revision. It shows that between 1911 and 1922, (1911 and 13 for Middlesex), an additional thirty-six industry types and their sites are seen compared to industry types and sites, between 1891 to 96. There is a reduction of eighteen industry types and sites, after this date with 221 industry types in revision 3, meaning the business is present between 1932 to 43.

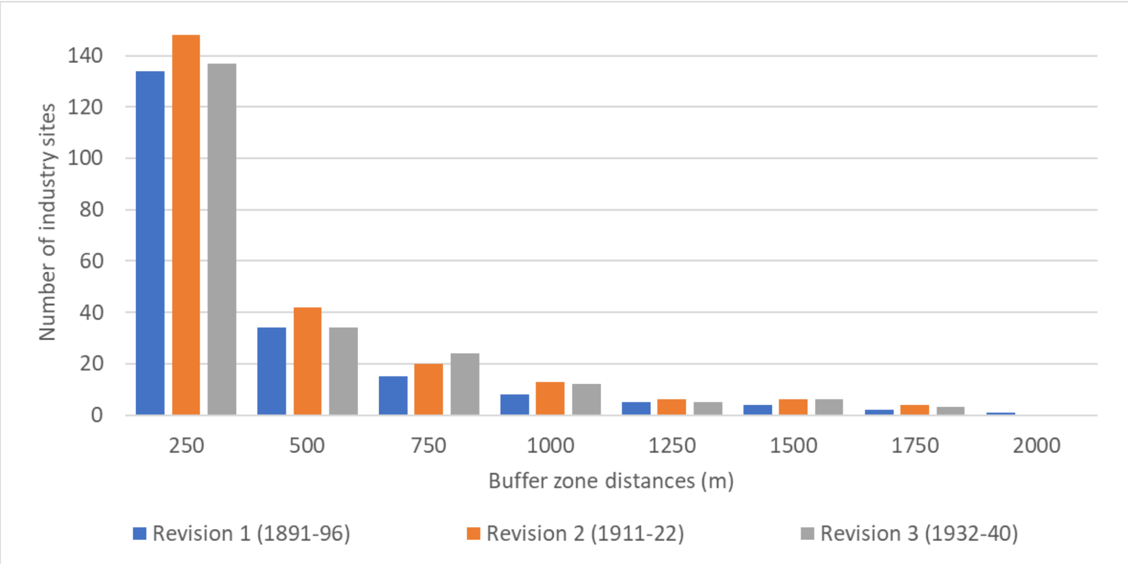
TABLE 11 NUMBER OF INDUSTRY TYPES PER MAP REVISION.

Distance to water (within m)	All of Revision 1 Middlesex, 1891-95 Essex, 1893-96	All of Revision 2 Middlesex, 1911-13 Essex, 1913-22	All of Revision 3 Middlesex, 1932-43 Essex, 1936-40
250	134	148	137
500	34	42	34
750	15	20	24
1000	8	13	12
1250	5	6	5
1500	4	6	6
1750	2	4	3
2000	1		
Total	203	239	221

the malthouse to dry it. There was a thriving malt industry up the valley over the late 19th century and into the 20th when it declined as brewing was transferred to the Midlands rather than London.
'Glasshouses': although there was, and remains, a thriving horticultural industry, primarily using glasshouses, these have not been included. Firstly, there is a natural split in the valley where the glasshouses were essentially situated beyond the urban boundaries, as shown in Figures 18 to 20, and secondly the nature of growing, and therefore watering, crops such as cucumbers required huge volumes of water and is therefore likely to be the reason they were close to water.

Figure 28 shows the profile for each revision, for the percentage of industry types situated in each buffer zone at 250m intervals from watercourses.[367] There is a little change between the 500, 750 and 1000m buffers with more sites in revisions 2 and 3.

FIGURE 28 NUMBER OF INDUSTRY SITES IN EACH BUFFER ZONE IN EACH REVISION.

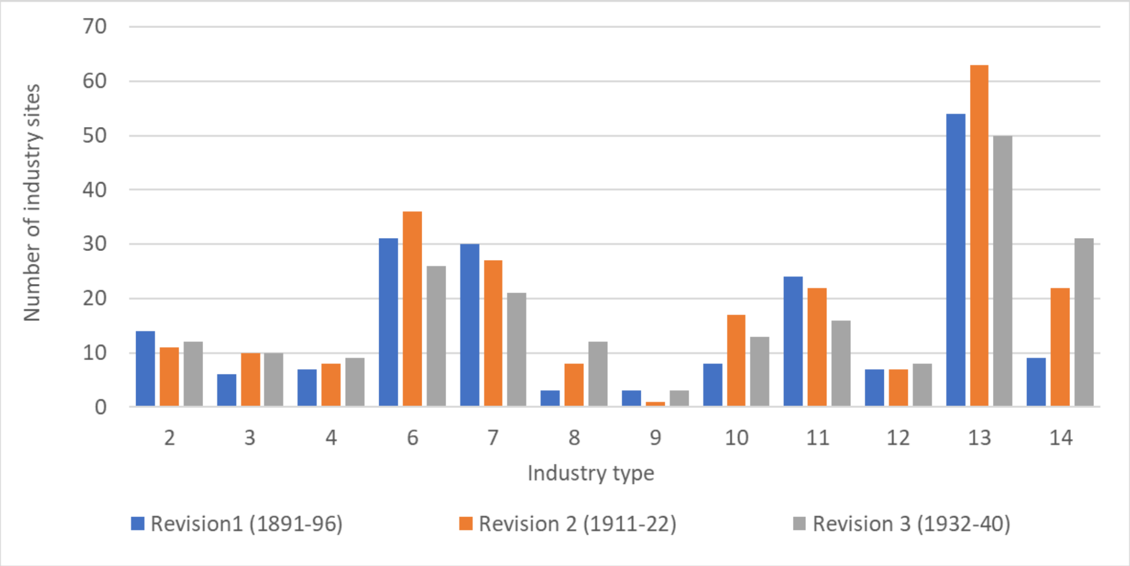


[367] Trade types and type of industry key

1	Mines and quarries	8	Paper, printing, stationery and allied
2	Iron, steel, engineering, shipbuilding	9	Leather, canvas, India rubber
3	Metal trades other than iron and steel	10	Timber trades
4	Textile Trades	11	Clay, stone, building, contracting
5	Clothing Trades	12	Miscellaneous
6	Food, drink and tobacco	13	Public utility services
7	Chemical and allied trades	14	Factory owners

Figure 29 shows within the corridor explored for this case study the total numbers of different industry types found in each revision. It demonstrates how losses were primarily from Food Drink and Tobacco (6), Chemical and Allied Industries (7) and Clay, Stone, Building and Contracting (11). The gains were primarily Paper, Printing and Stationary (8), Timber Trades (10), and Factory Owners (14). Other industry types saw changes but numbers remained fairly consistent. It should be noted that whilst Food Drink and Tobacco saw a decrease, this was primarily through loss of mills.

FIGURE 29 NUMBER OF INDUSTRY TYPES ON EACH MAP REVISION.[368]



[368] Trade types and type of industry key

1	Mines and quarries	8	Paper, printing, stationery and allied
2	Iron, steel, engineering, shipbuilding	9	Leather, canvas, India rubber
3	Metal trades other than iron and steel	10	Timber trades
4	Textile Trades	11	Clay, stone, building, contracting
5	Clothing Trades	12	Miscellaneous
6	Food, drink and tobacco	13	Public utility services
7	Chemical and allied trades	14	Factory owners

Figure 30 shows the cumulative percentage of industrial sites in each buffer zone correcting the slightly different total numbers present on each map revision and demonstrates the slight reduction (four percent) in sites 250m from water between revisions 1 and 2, which remains stable at sixty-two percent into revision 3. Similar reductions can be seen in the 500m buffer reducing by six percent between revision 2 and 3. The change in the 750m zone is just two percent between revision 1 and 2 and is maintained in revision 3. Beyond the 750m buffer there is very little difference.

FIGURE 30 CUMULATIVE PERCENTAGE OF INDUSTRY SITES IN EACH BUFFER ZONE.

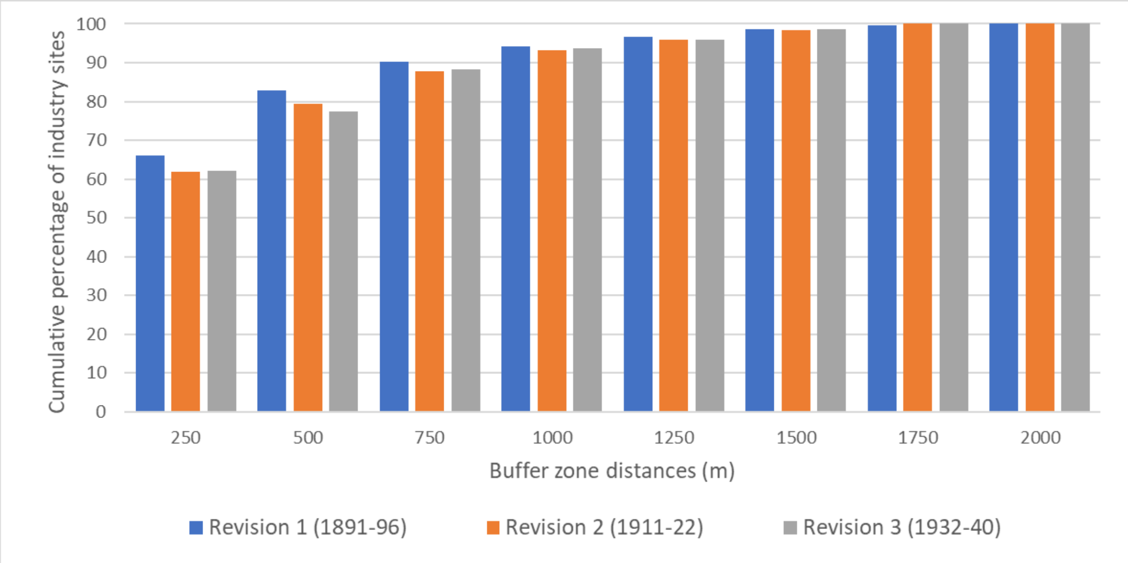


Figure 31 shows the distribution of industry types across the buffer zones, showing the numbers of each industry type on individual sites by map revision and distance from water. The columns are all independent values, only appearing once in each revision. They are allocated into categories using the following hierarchy, and once allocated to a group it remains within it, and the next step is carried out on the remaining data. The steps are:

1. Is the industry type and that site present in **all** map revisions?
2. Is the industry type and that site present in the **previous** map revision?

3. Is the industry type and that site present in **next** map revision?
4. The remaining industry type and site is present only in that revision

Each map revision measures the number of individual activities on individual sites. This means that types could change and depending on the industry, sites could change sizes, or were sometimes split into smaller sites making the results look a little confusing. For example, Public Utilities (13) have thirty-nine sites on revision 1, nineteen of which are on all revisions, in revision 2 there are fifty sites, of which twenty are present in all three revisions. Revision 3 shows twenty-one sites present in all three revisions. The reason for the discrepancies are firstly, a mill which is converted into a pumping station before revision 2, changing its industry type to be included in this group. The second is caused by the size of the site, it appears in the 250m buffer in revisions 1 and 3 but just falls in the 500m buffer in revision 2, however it is the only example of a site which changes buffer zones. During the discussion when the term 'loss of industry type' is used it refers to a specific industry type on a discrete site, and therefore loss refers either to the industrial site or the industrial type ceasing to exist within that buffer zone. This means that other types enter to fill an existing site or new sites are established and counted as gains.

The buffer zones refer to discrete 250m zones unless explicitly stated otherwise, therefore when referring to the 500m buffer zone it relates to the distance between 250m and 500m boundary and so forth.

Figure 31 shows numbers of industry types both lost and gained in each buffer. For example, in revision 1 (1891-96), the number of industry types only found on this map are lost between this revision and the next (1911-22). In this case eighty-four industry types were lost overall, fifty from the 250m buffer, sixteen from the 500m buffer, six from the 750m buffer with others reducing as distance increases.

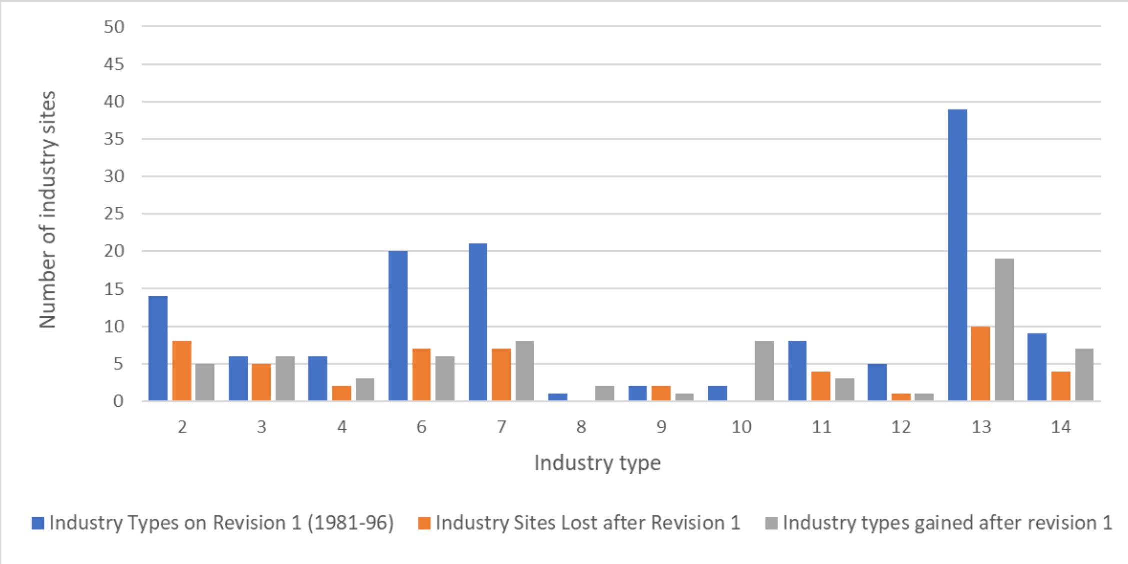
FIGURE 31 CHART SHOWING INDUSTRY TYPE BY 250M BUFFER ZONE.[369]

Row Labels	In Rev 1+2+3	In Next R	In Rev Only		In Rev 1+2	In Prev R	In Next R	In Rev Only		In Rev 1+2	In Prev R	In Rev Only	
250													
2	6		8	14	4	2	5		11	6	4	2	12
3	1		5	6			5	1	6	1	5	1	7
4	3	1	2	6	4		3		7	5	1	1	7
6	13	1	7	21	16	2	5	1	24	11	4		15
7	14		7	21	8		6	2	16	8	4		12
8	1			1	1		1	1	3	2	3		5
9			2	2			1		1		1	1	2
10	1	1		2	1	1	4	4	10	1	5	3	9
11	3	1	4	8	3	1	2	1	7	2	4	1	7
12	3	1	1	5			1		1	2	1		3
13	19	10	10	39	20	11	17	2	50	21	17	3	41
14	2	3	4	9	5		6	1	12	6	6	5	17
250 Total	**66**	**18**	**50**	**134**	**62**	**17**	**56**	**13**	**148**	**65**	**55**	**17**	**137**
500													
2	2	1	1	4		1	2		3	1		2	3
3					2			1	3	1			1
6			6	6		1	1	1	3		2		2
7	4	1	1	6	4	1	2		7	3	2		5
8								1	1			1	1
9			1	1									
10	2			2	1		1	1	3	1	1		2
11		1	6	7	1	1	1	1	4	1		1	2
12	1			1		1		1	2		1	1	2
13	3	3	1	7	2	2	3	2	9	3	2		5
14					1		5	1	7	1	7	3	11
500 Total	**12**	**6**	**16**	**34**	**11**	**7**	**15**	**9**	**42**	**11**	**15**	**8**	**34**
750													
2		1	1	2				1	1			5	5
3							1		1		1	1	2
4	1			1	1				1	2			2
6	1			1	1				1	1			1
7					1		1		2		1	1	2
8							2		2		2		2
10			1	1			1	1	2		1	1	2
11	4		2	6	2		1	1	4	3	1		4
12	1			1	2		1		3	1	1		2
13	1		2	3	1				1	1			1
14						1	1		2			1	1
750 Total	**8**	**1**	**6**	**15**	**8**	**1**	**8**	**3**	**20**	**8**	**7**	**9**	**24**
1000													
2							1		1		1	1	2
6			2	2			3		3		3		3
8							1		1		2	1	3
10			1	1				2	2				
11	1	1		2	2	1	1		4	1	1		2
13	1		2	3	1		1		2	1	1		2
1000 Total	**2**	**1**	**5**	**8**	**3**	**1**	**7**	**2**	**13**	**2**	**8**	**2**	**12**
1250													
2							2		2				
6			1	1				1	1			1	1
7			2	2									
9											1		1
11						1			1				
12								1	1				
13	1	1		2	1				1	1			1
14											1	1	2
1250 Total	**1**	**1**	**3**	**5**	**1**	**1**	**2**	**2**	**6**	**1**	**2**	**2**	**5**
1500													
6	1			1	1		1		2	1	1		2
7							1		1		1		1
8	1			1	1				1	1			1
10			2	2									
11							1		1		1		1
12												1	1
14								1	1				
1500 Total	**2**		**2**	**4**	**2**		**3**	**1**	**6**	**2**	**3**	**1**	**6**
1750													
6							2		2		2		2
7			1	1			1		1		1		1
11		1		1		1			1				
1750 Total		**1**	**1**	**2**		**1**	**3**		**4**		**3**		**3**
2000													
8			1	1									
2000 Total			**1**	**1**									
Grand Total	**91**	**28**	**84**	**203**	**87**	**28**	**94**	**30**	**239**	**89**	**93**	**39**	**221**

[369] See footnote 371 for key

Figure 32 shows the types of trades lost within the first 250m which were greatest from Iron and Steel (2), Food, Drink and Tobacco (6), and the Chemical and Allied trades (7) show change but its total numbers remain similar. Public Utilities (13) has the highest losses, but also gains, as additional water utilities and gas-works were introduced. Other gains were also in the Factory Owners group (14).

FIGURE 32 NUMBER OF INDUSTRY TYPES LOST AND GAINED BETWEEN REVISION 1 AND 2 (1896 TO 1911) WITHIN 250M BUFFER ZONE.[370]

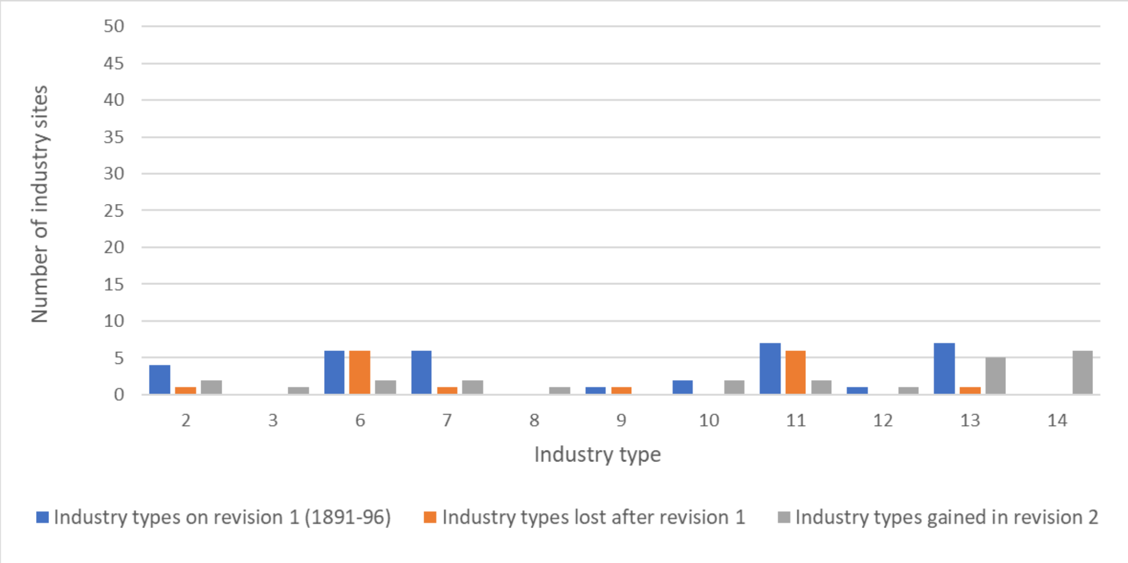


[370] Trade types and type of industry key

1	Mines and quarries	8	Paper, printing, stationery and allied
2	Iron, steel, engineering, shipbuilding	9	Leather, canvas, India rubber
3	Metal trades other than iron and steel	10	Timber trades
4	Textile Trades	11	Clay, stone, building, contracting
5	Clothing Trades	12	Miscellaneous
6	Food, drink and tobacco	13	Public utility services
7	Chemical and allied trades	14	Factory owners

There were also losses from the 500m buffer (Figure 33) where all the Food, Drink and Tobacco trades are lost (6), as are almost all the Clay, Stone and building contracting trades (11). There were a few gains in both industry types in revision 2 but like the 250m buffer these are primarily from the Public Utilities (13) and Factory Owners (14).

FIGURE 33 NUMBER OF INDUSTRY TYPES LOST AND GAINED BETWEEN REVISION 1 AND 2 (1896 AND 1911) WITHIN 500M BUFFER ZONE.[371]

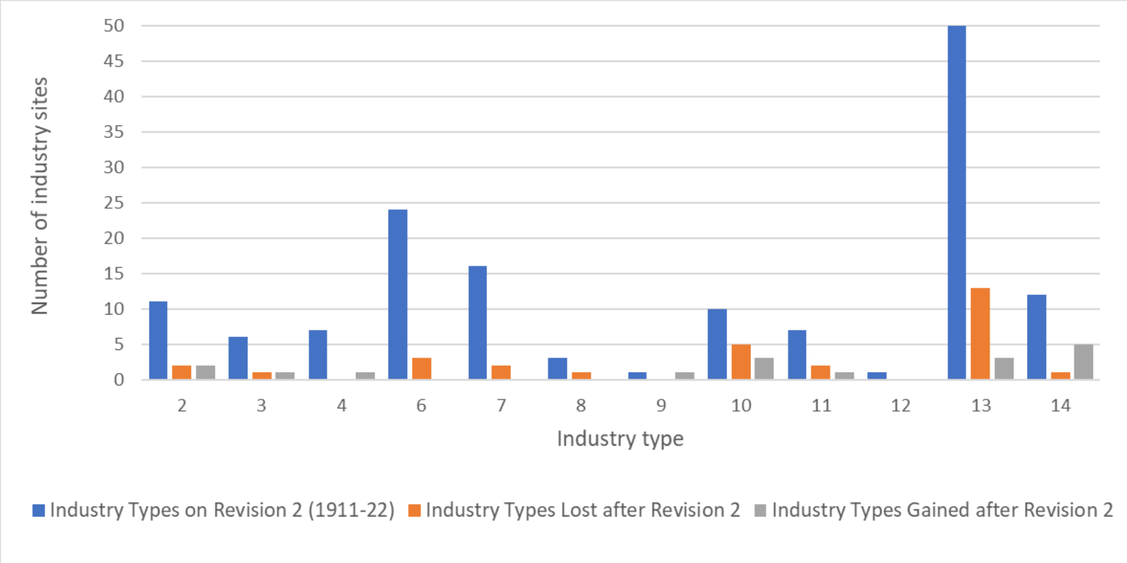


[371] Trade types and type of industry key

1	Mines and quarries	8	Paper, printing, stationery and allied
2	Iron, steel, engineering, shipbuilding	9	Leather, canvas, India rubber
3	Metal trades other than iron and steel	10	Timber trades
4	Textile Trades	11	Clay, stone, building, contracting
5	Clothing Trades	12	Miscellaneous
6	Food, drink and tobacco	13	Public utility services
7	Chemical and allied trades	14	Factory owners

Industry types lost from the second revision (1911-22) comprise those present just on this map and the industry sites that are on this map only combined with those present on this, and the previous revision. The total number of industry types lost was fifty-eight. Again, the majority of these are lost from the first 250m but there are only thirteen lost compared to fifty from the first revision. Nine industry types are lost from the 500m buffer and as distance increases only eight more are lost over the next four buffer zones. There is substantial loss of Public Utilities (13) between revisions 2 and 3 (1922 and 1932), primarily losses of gas-works but also water and sewage-works tending to be made into single larger sites. Again, the most substantial gains are in the Factory Owners industry type (14), (Figure 34).

FIGURE 34 NUMBER OF INDUSTRY TYPES LOST AND GAINED BETWEEN 1922 AND 1932 WITHIN 250M OF WATER.[372]



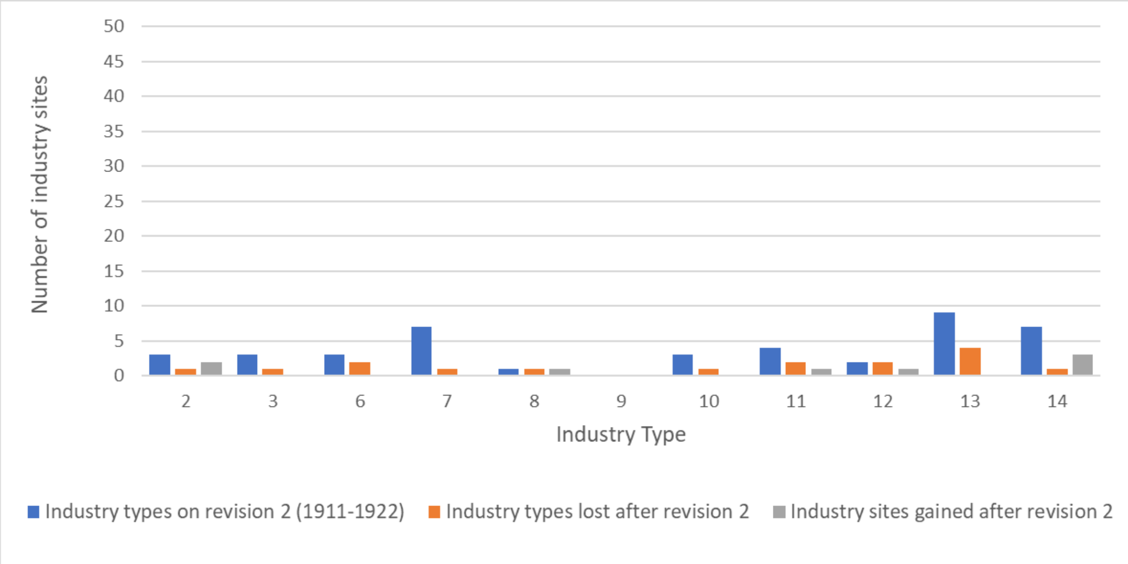
From the wider 500m buffer, again losses are from Public Utilities (13) with no further gains. There are gains made in the Chemical and Allied Industries (2) and for Factory Owners (14) but very small numbers, (Figure 35). It is not possible to determine losses from revision 3 because it is the last one in the series but it is possible to determine industry types gained between revision 1 and 2 alongside revision 2 and 3.

---

[372] Trade types and type of industry key

1	Mines and quarries	8	Paper, printing, stationery and allied
2	Iron, steel, engineering, shipbuilding	9	Leather, canvas, India rubber
3	Metal trades other than iron and steel	10	Timber trades
4	Textile Trades	11	Clay, stone, building, contracting
5	Clothing Trades	12	Miscellaneous
6	Food, drink and tobacco	13	Public utility services
7	Chemical and allied trades	14	Factory owners

FIGURE 35 NUMBER OF INDUSTRY TYPES LOST BETWEEN REVISION 2 AND 3 (1922 AND 1932) WITHIN 250M AND 500M OF WATER. [373]



[373] Trade types and type of industry key

1	Mines and quarries	8	Paper, printing, stationery and allied
2	Iron, steel, engineering, shipbuilding	9	Leather, canvas, India rubber
3	Metal trades other than iron and steel	10	Timber trades
4	Textile Trades	11	Clay, stone, building, contracting
5	Clothing Trades	12	Miscellaneous
6	Food, drink and tobacco	13	Public utility services
7	Chemical and allied trades	14	Factory owners

Figure 31 shows the groups in numeric order. The immediate observation is that the higher number of industrial types are in the first 250m buffer zone of water, and that there are reducing numbers the further the distance from water.

The data suggests a tendency towards diversity of businesses, with twenty-one each of Chemical and Allied Trades (7) and Food, Drink and Tobacco (6) reducing to fifteen and twelve of these respectively in the 1930s. There are 134 and 137 individual activities on sites in the periods depicted by revisions 1 and 3 of the maps respectively. This means that the percentage share of these two industry types reduces from thirty to twenty percent between the late 1900s to the 1930s.

As discussed earlier industries in general can be seen to be moving up the valley as transportation and the urban fringes of Greater London expanded. The following sequences of maps show where these changes were occurring. The first set of maps are of the complete study area, and the second set centred around Ponders End in Enfield which saw enormous changes over this period.

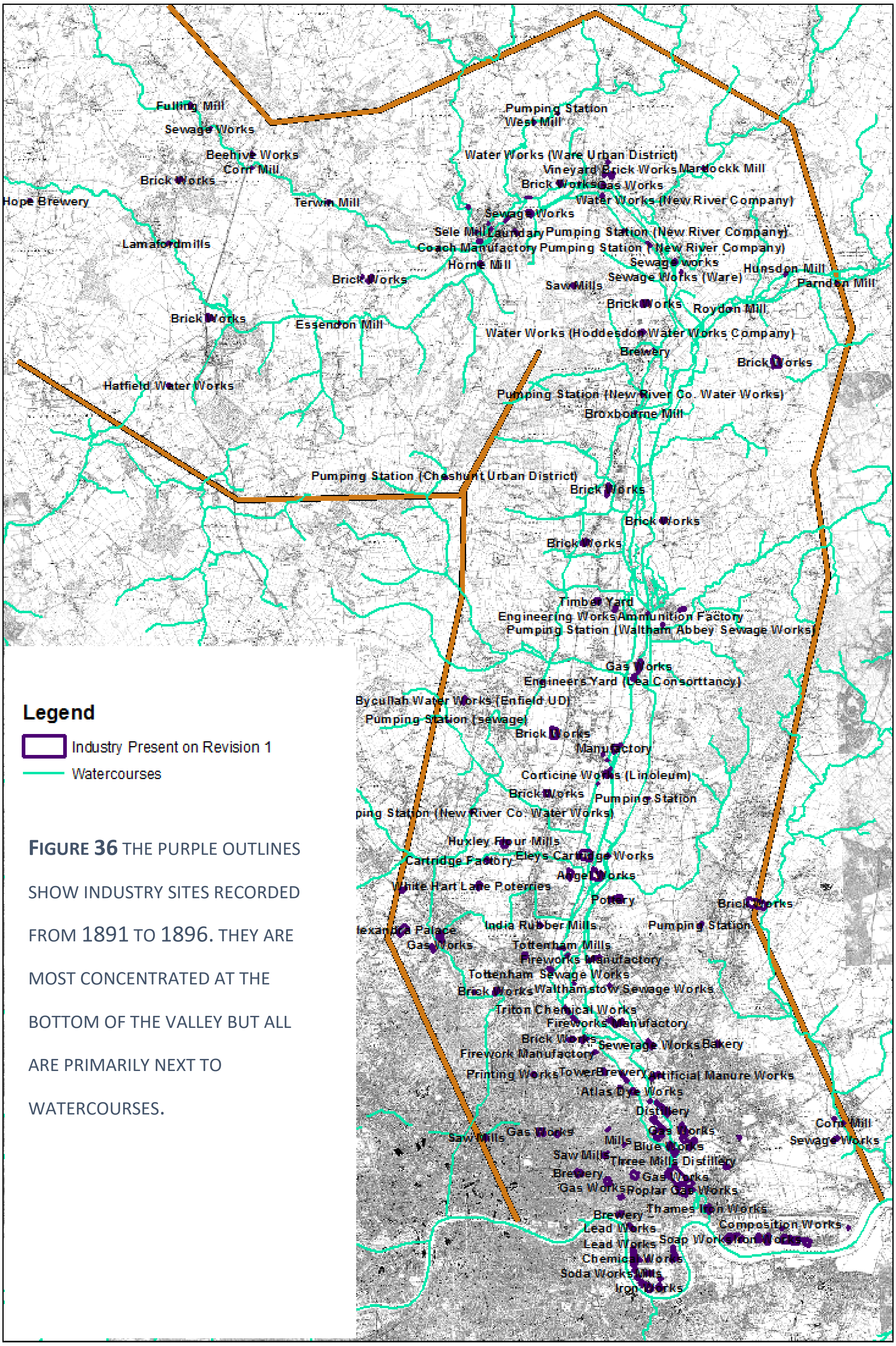


FIGURE 36 THE PURPLE OUTLINES SHOW INDUSTRY SITES RECORDED FROM 1891 TO 1896. THEY ARE MOST CONCENTRATED AT THE BOTTOM OF THE VALLEY BUT ALL ARE PRIMARILY NEXT TO WATERCOURSES.

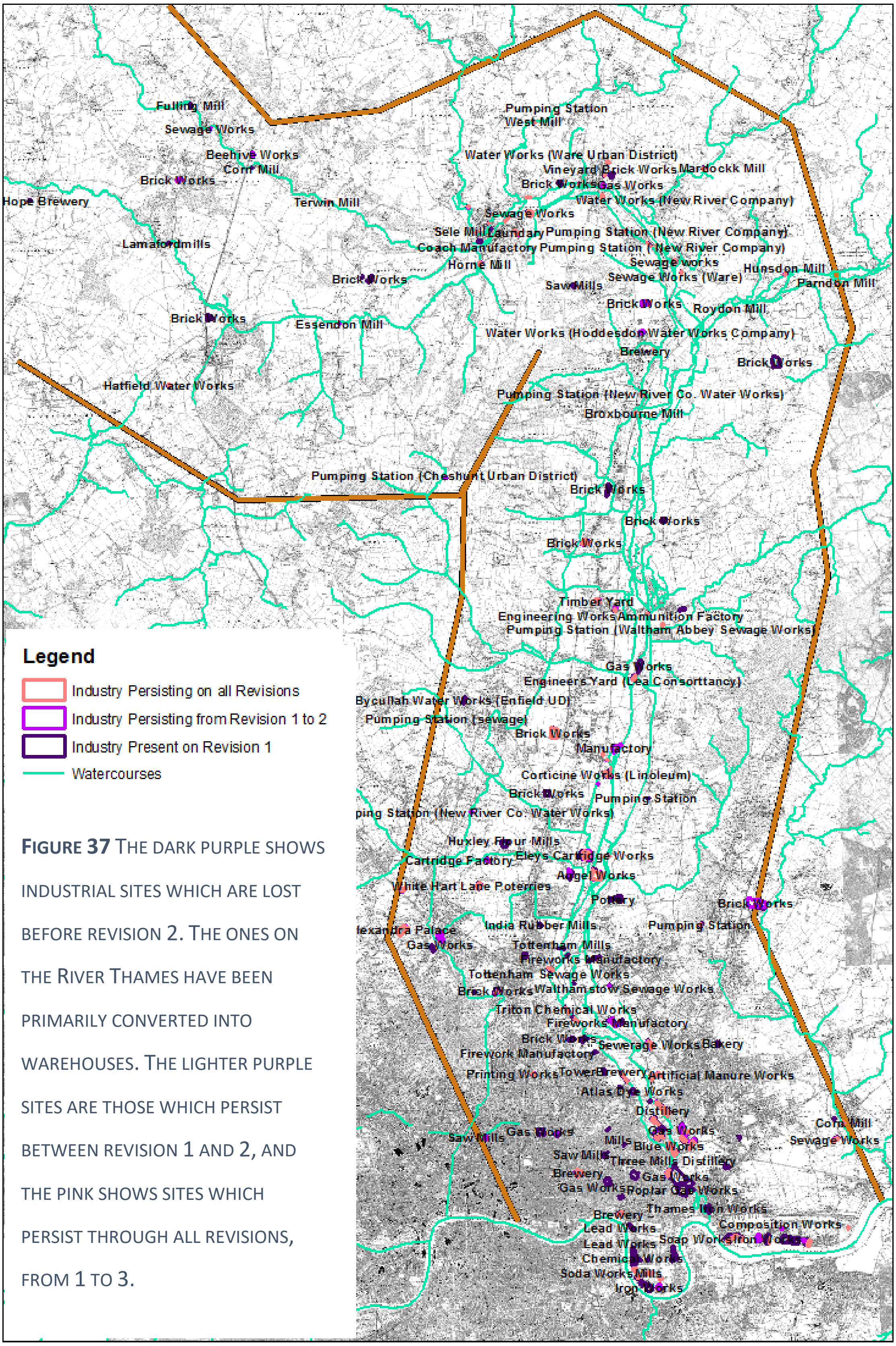


FIGURE 37 THE DARK PURPLE SHOWS INDUSTRIAL SITES WHICH ARE LOST BEFORE REVISION 2. THE ONES ON THE RIVER THAMES HAVE BEEN PRIMARILY CONVERTED INTO WAREHOUSES. THE LIGHTER PURPLE SITES ARE THOSE WHICH PERSIST BETWEEN REVISION 1 AND 2, AND THE PINK SHOWS SITES WHICH PERSIST THROUGH ALL REVISIONS, FROM 1 TO 3.

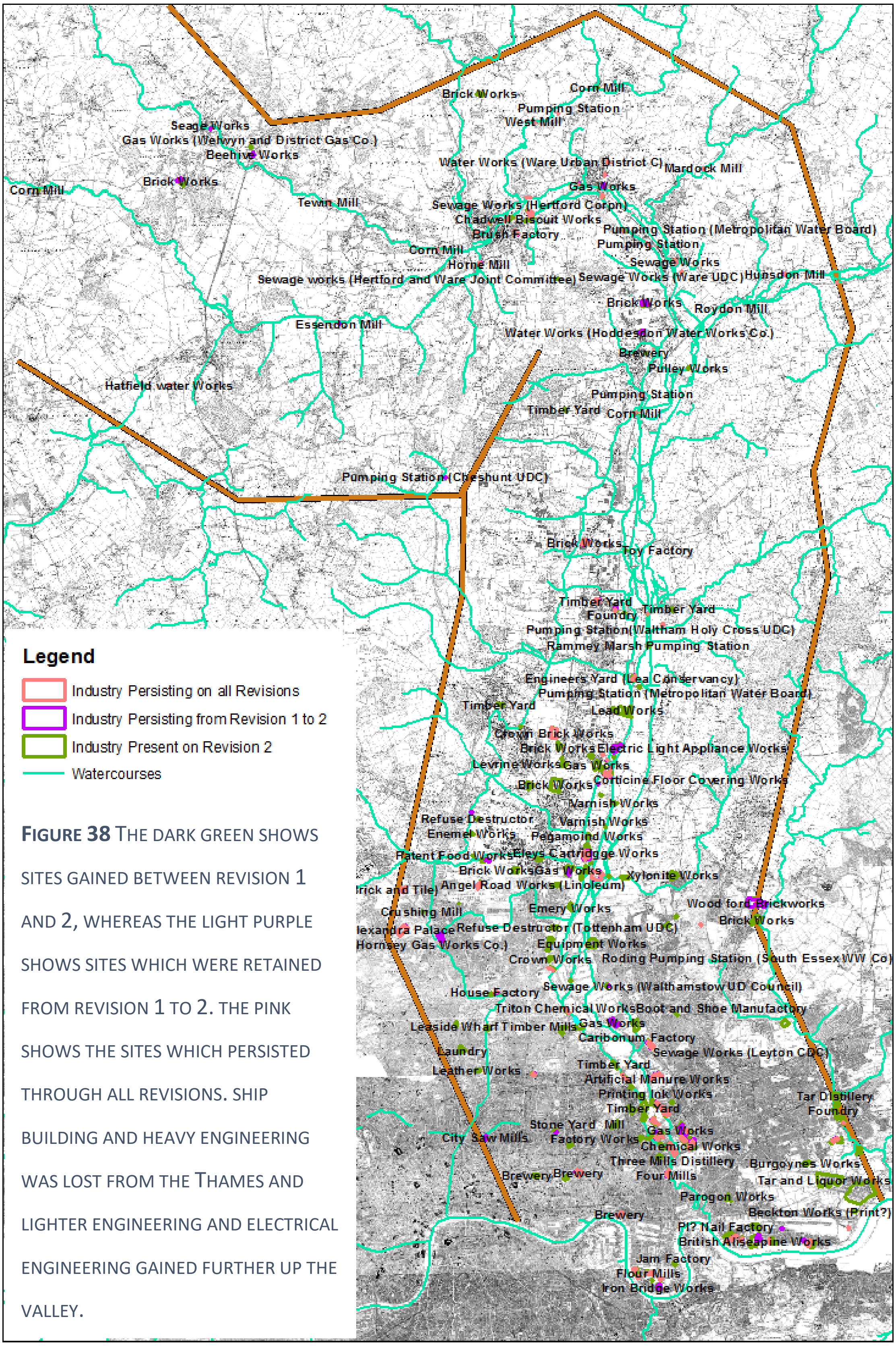


Figure 38 The dark green shows sites gained between revision 1 and 2, whereas the light purple shows sites which were retained from revision 1 to 2. The pink shows the sites which persisted through all revisions. Ship building and heavy engineering was lost from the Thames and lighter engineering and electrical engineering gained further up the valley.

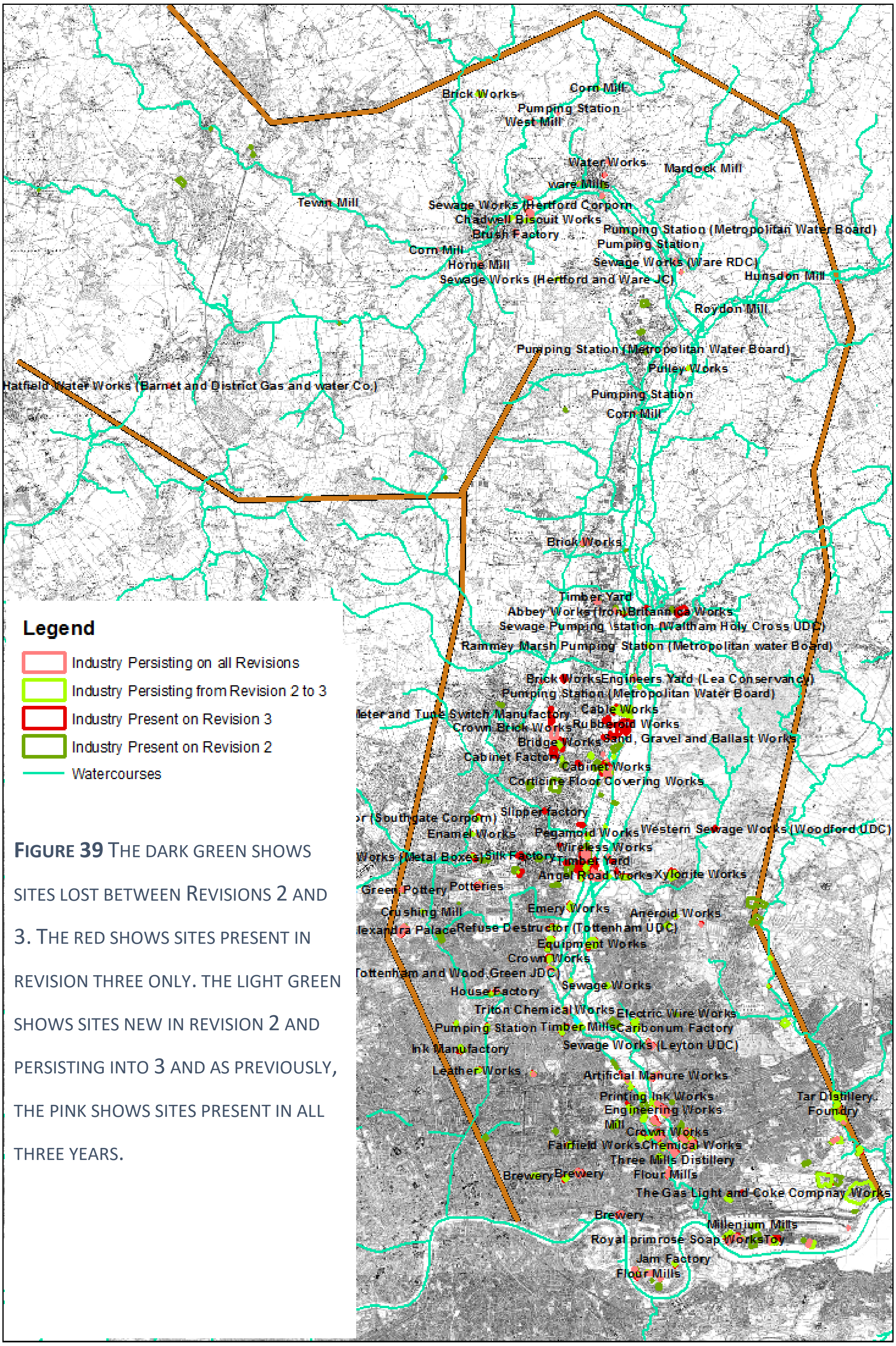


FIGURE 39 THE DARK GREEN SHOWS SITES LOST BETWEEN REVISIONS 2 AND 3. THE RED SHOWS SITES PRESENT IN REVISION THREE ONLY. THE LIGHT GREEN SHOWS SITES NEW IN REVISION 2 AND PERSISTING INTO 3 AND AS PREVIOUSLY, THE PINK SHOWS SITES PRESENT IN ALL THREE YEARS.

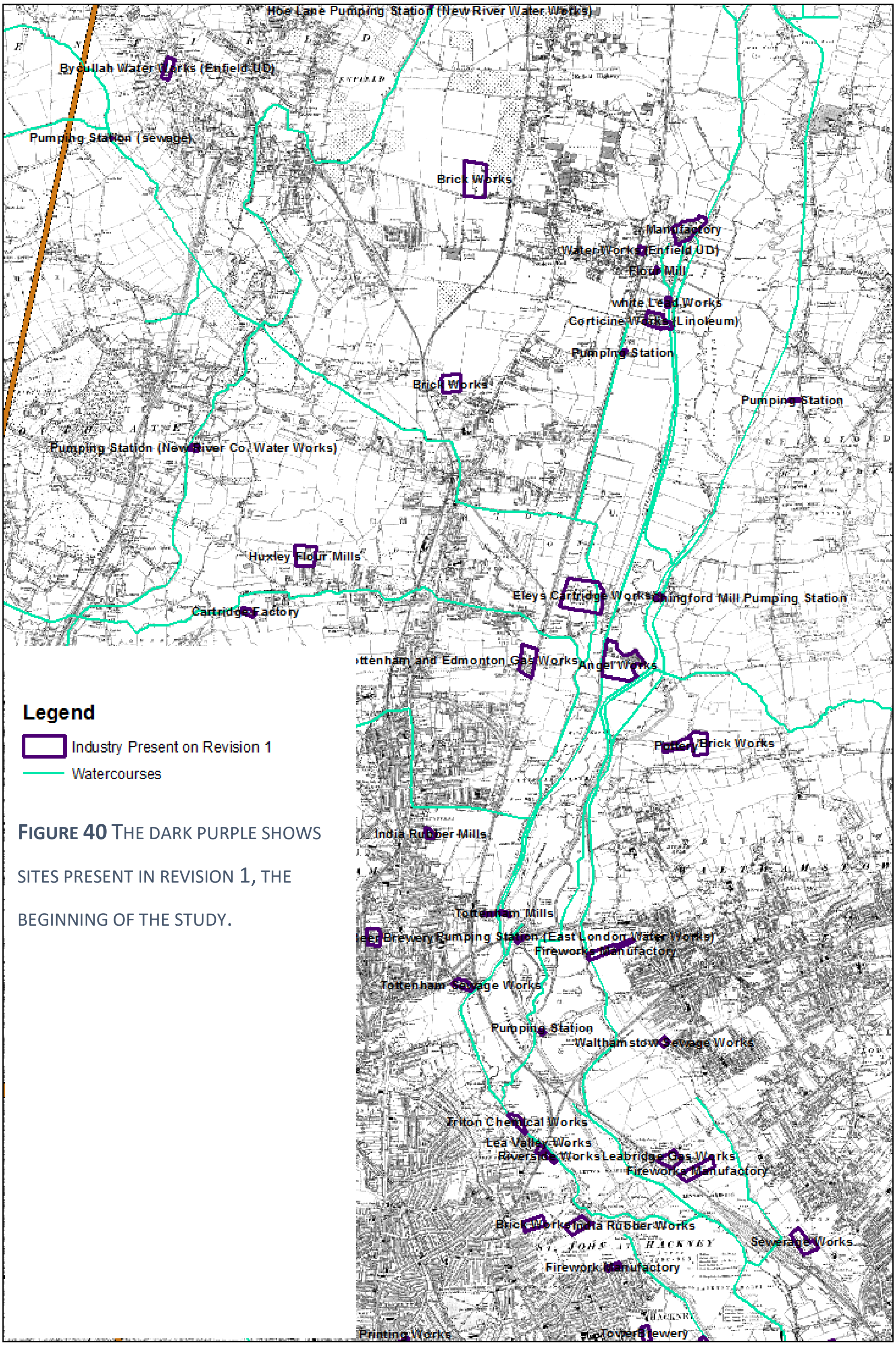


FIGURE 40 THE DARK PURPLE SHOWS SITES PRESENT IN REVISION 1, THE BEGINNING OF THE STUDY.

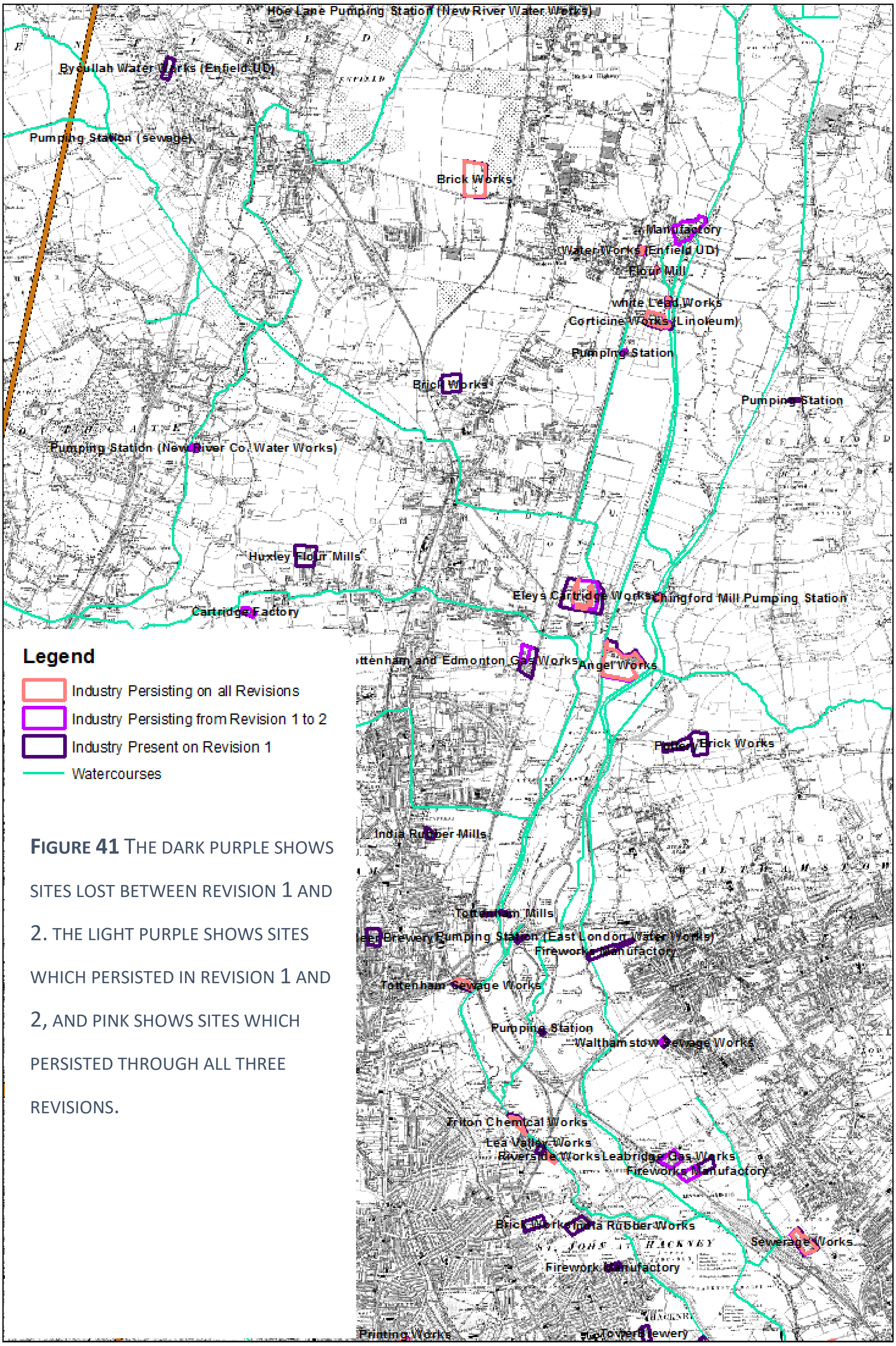


Figure 41 The dark purple shows sites lost between revision 1 and 2. The light purple shows sites which persisted in revision 1 and 2, and pink shows sites which persisted through all three revisions.

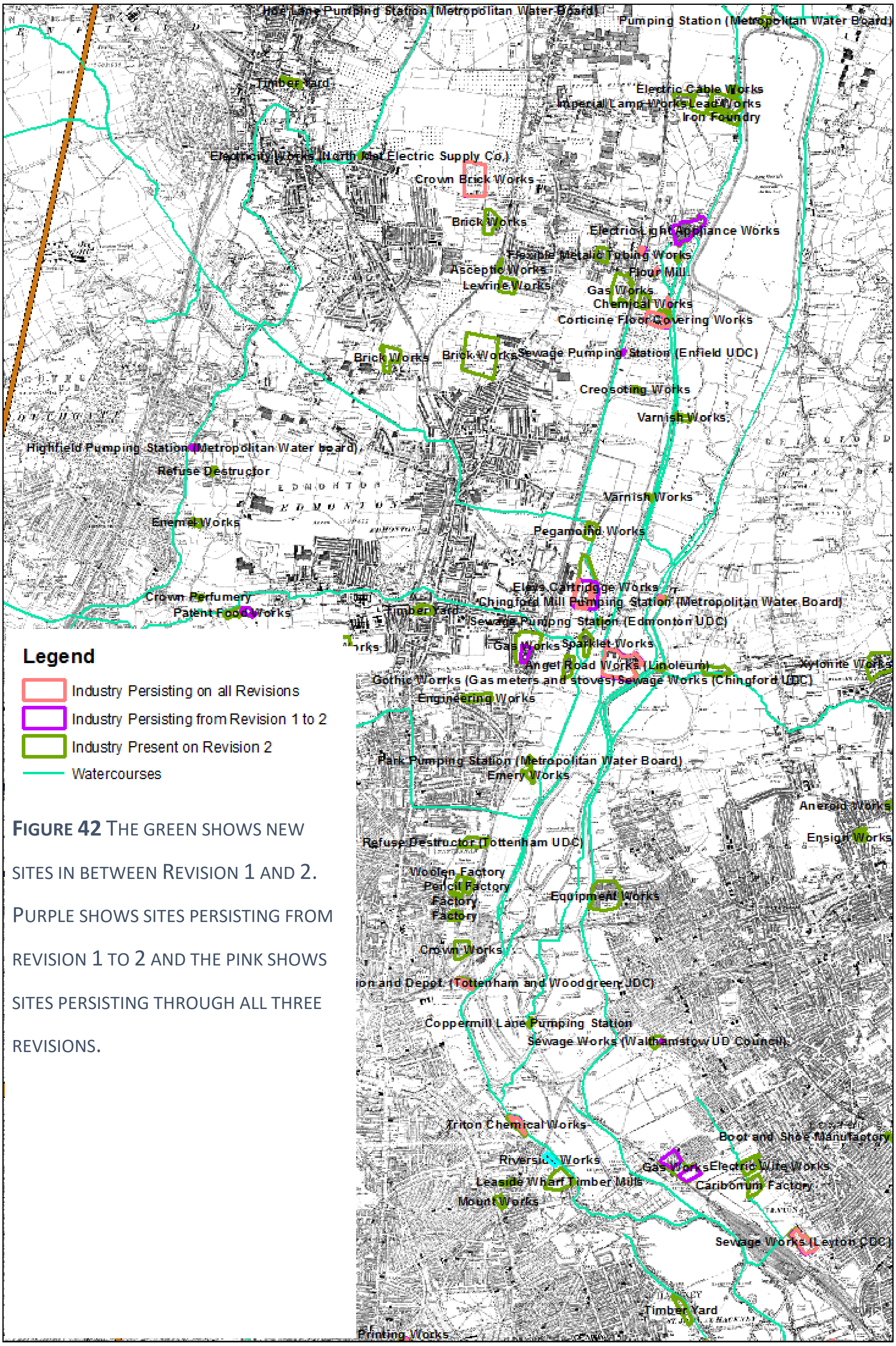


FIGURE 42 THE GREEN SHOWS NEW SITES IN BETWEEN REVISION 1 AND 2. PURPLE SHOWS SITES PERSISTING FROM REVISION 1 TO 2 AND THE PINK SHOWS SITES PERSISTING THROUGH ALL THREE REVISIONS.

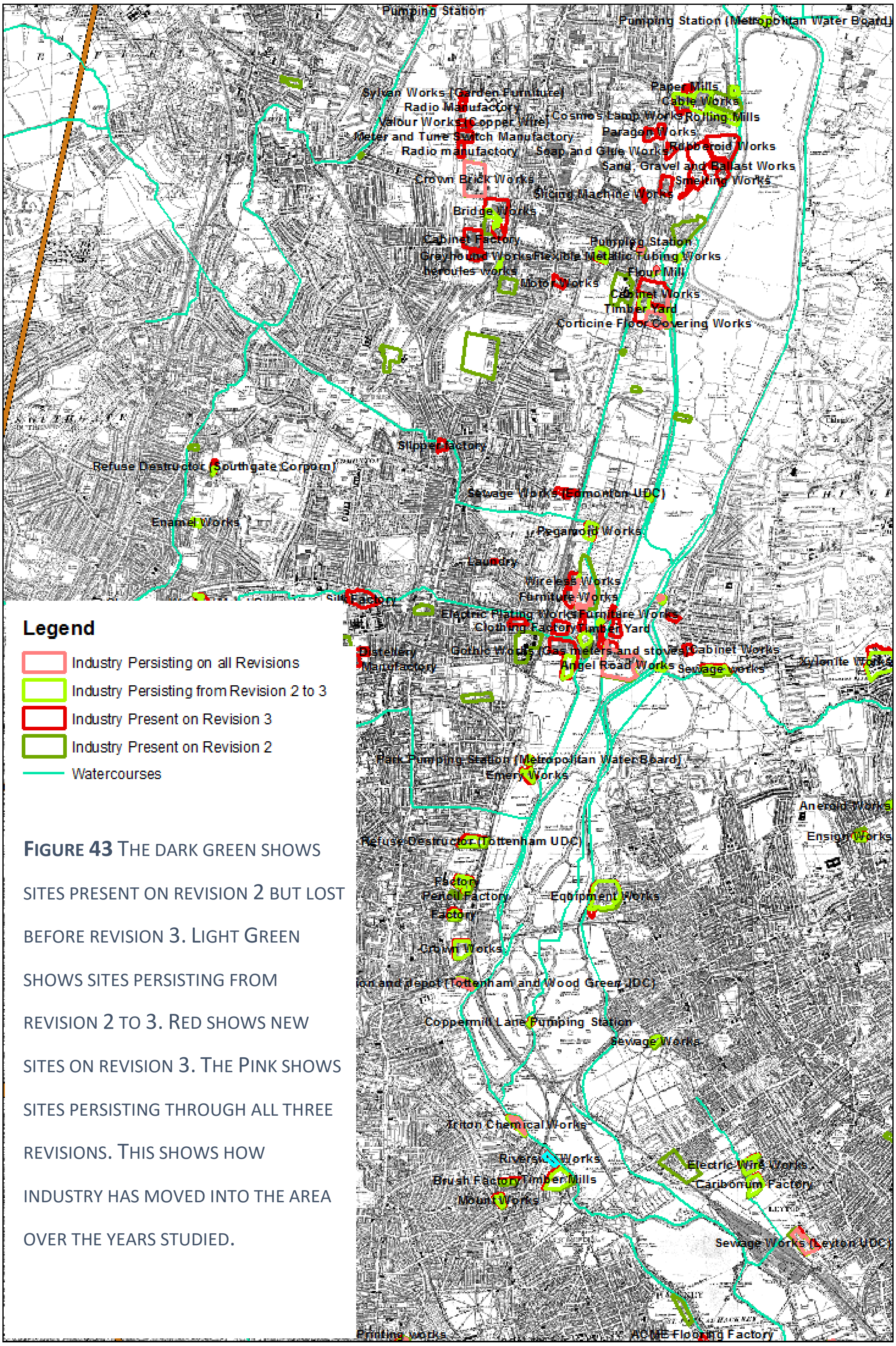


Figure 43 The dark green shows sites present on revision 2 but lost before revision 3. Light green shows sites persisting from revision 2 to 3. Red shows new sites on revision 3. The pink shows sites persisting through all three revisions. This shows how industry has moved into the area over the years studied.

These maps demonstrate propensity for change over this when industry migrated up the valley but generally maintained links to water. The maps showing Enfield demonstrate how industry moved into areas by the Lea and tended to cluster but, by revision 3, small groups were beginning to locate along roadways too, suggesting the linkage to water was breaking. At Ponders End, the reservoir fed Brimsdown Power Station, which made its first industrial electrical connection in 1906 to the Ediswann Factory. Many businesses maintained self-generating potential even after connection to public supply.[374]

The most obvious changes, visible in the 1930s were losses of large established sites beside the Thames and smaller sites newly establishing higher up the valley. These reflected changes in energy accessibility, with watermills closing and new factories producing foodstuffs and confectionary. Heavy engineering, ship building, boat building and iron works closed around the Thames docks and electrical engineering workshops and scientific instrument manufacture moved further up the valley. There are indications by the third revision of these maps that water was becoming less important as industrial sites began migrating to railways and roads. An example is the engineering, radio and furniture works which moved to The Great Cambridge Road (A10), away from watercourses.

The RGS suggested that it took 150 years for industry to locate along watercourses responding to water transport and steam power. Therefore, it is not unsurprising that the influence of electricity becoming increasingly available was only starting to become apparent in the 1930s.[375] The final map (Figure 44) is a comparison of revision 3 to a comparable map showing industry present in 1948. Whilst a full analysis has not been carried out for industry types it does indicate further changes to industry sites between the 1930s and 1948.

[374] Personal communication with Jim Lewis.
[375] Manley, ‘Location of Industry’, p.511.

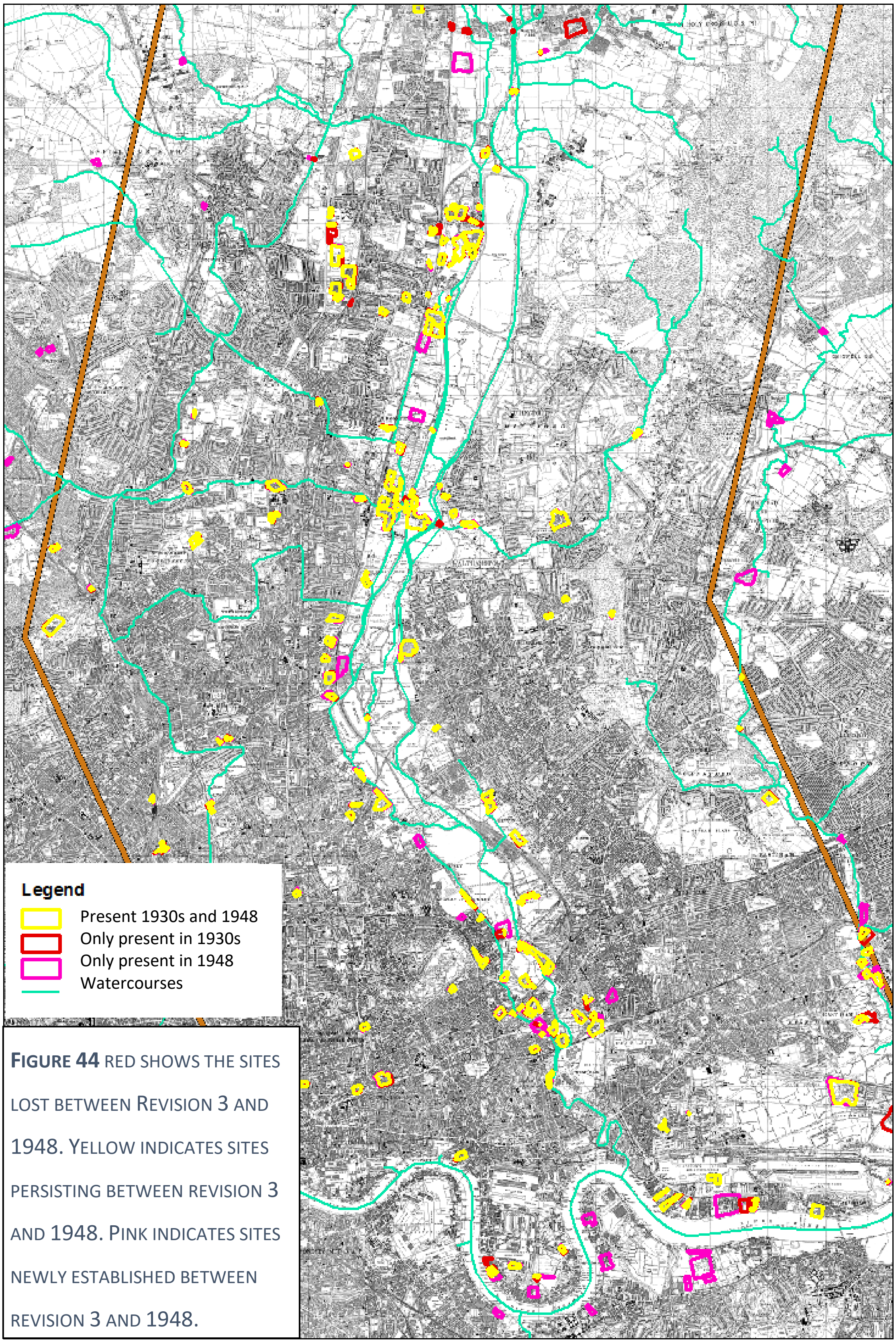


FIGURE 44 RED SHOWS THE SITES LOST BETWEEN REVISION 3 AND 1948. YELLOW INDICATES SITES PERSISTING BETWEEN REVISION 3 AND 1948. PINK INDICATES SITES NEWLY ESTABLISHED BETWEEN REVISION 3 AND 1948.

In 1948 thirteen new sites were located next to water, and just five were not. Whilst this was a visual count, it suggests over sixty percent of sites were locating next to water. The Census of Production for 1948 reported that nationally twenty-seven percent of industry was self-generating, sixty four percent was purchasing from public supply and nine percent had another supplier. This suggests that water was for a secondary purpose, that the Lea Valley had a high proportion of self-generating industry types in 1948, that sites in these locations were still financially attractive or perhaps that the owners were happy to maintain the *status quo*.

This prompted a second piece of work to consider the proportion of industry types with a high propensity to self-generate and their proximity to water across a larger area of the Lea Valley but considering only 1948. This study assigns the proportions of electricity from public supply, self-generation or other suppliers as reported in the 1948 Census of Production to determine whether industrial proximity to water could be predicted by its propensity to self-generate as reported in the 1948 Census of Production.

Industrial Locations and the Census of Production 1948

Whilst the first part of this study suggests linkage to water was beginning to break as electrification increased, large numbers of industries were still situated on watersides. For this reason, a fourth map was digitised representing industry in 1948, and its industrial activity on each site researched using a variety of sources.[376] The trade at the site in 1948 was then matched to the trade group on

[376] Sources included Edith's street maps, an online repository for streets, industry and all manner of features in and around greater London, the History Online website, and Grace's Guide, which contains information about Britain's industrial history. Where these were not useful other web searches were carried out for firms or local histories. The Edina Digi map series was also used and information given for the 1940s and 50s was used as a guide to industrial type where no other information was available. For example, the brickworks in Epping,

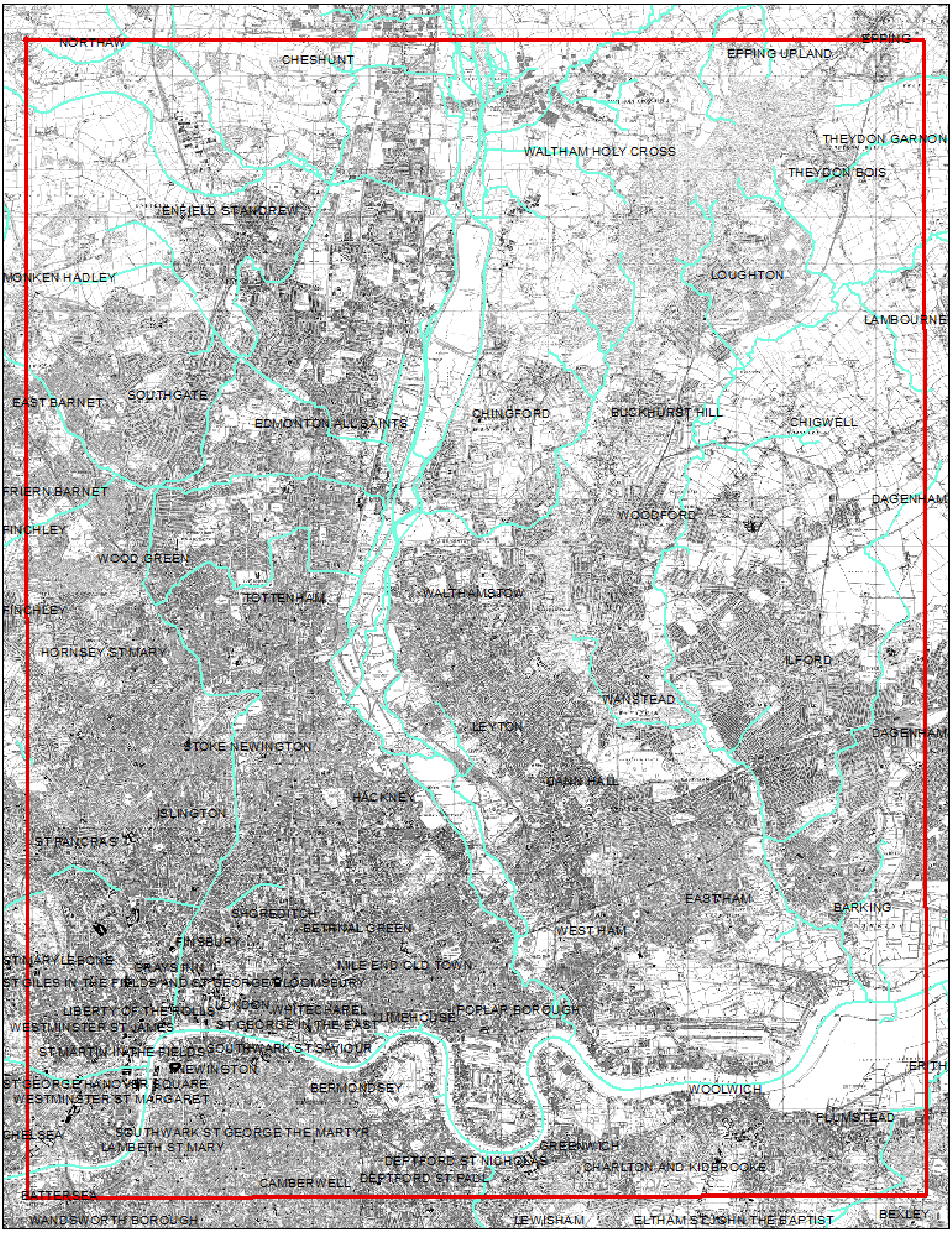
the Census of Production and electricity consumption and supply reported by that trade groups was allocated to that site.

The study area is shown in Figure 45 with red box showing the boundary.

---

which is marked on the maps as just a works in the third revision was checked; there are only very detailed maps for the 1930s and 1960s, where the site is a brickworks and engineering works respectively. After being unsuccessful in finding a name for the engineering works through the other sources, a larger scale map for the 1940s was found on Edina, on which the site in the 1940s is labelled as a brickwork, and this is the best information available.

FIGURE 45 MAP SHOWING THE 184-SQUARE MILE STUDY AREA.



This map also has a scale of 1:10 560 and is the 1st Imperial Edition, as the previous versions used for the first study were no longer produced. Within the 184-square mile area 241 industry sites were found in 1948. Whilst the survey period was 1948 to 1977 nationally, trade types attributed to each site were the trade types in 1948, verified by various sources.[377] Instead of relying on the calculated 'distance' algorithm, sites were individually visually checked to determine whether it was directly adjacent to a watercourse to ensure large sites, or wide rivers, did not skew the results.[378]

Of the 241 sites 214 have industry, trade, and energy statistics associated with them that directly correspond to the 1948 Census of Production.[379] This allowed them to be categorised as one of 159 trade groups rather than as one of 14 industry types making it more representative. This affords the opportunity to investigate whether the sites in the study area were located as their grouping in the Census of Production reported.[380]

---

[377] *Ibid*.

[378] As the algorithm works by using nearest features it takes the central point of those features. If a site is very large or a watercourse very wide this can significantly increase the resulting values and therefore suggest large distances, although proximity is the important factor. Another issue might be that a site is on a sewer or other watercourse which is not included in the water dataset, and therefore these might be missed. Whilst this is a good proxy for the nearest watercourse it is having water next to the site which is important for self-generation and so each was checked.

[379] Of the remaining 27, 5 are disused waterworks, 2 are refuse destructors, 4 are electricity generating stations, 6 are depots of some description and the remainder have been defined as leisure. 11 of these sites are situated directly next to water and have had industrial activity on the site before 1948. The electricity generating plants or power stations have been separated from the main data because they are all next to water, and the owners were either selling, and/or purchasing from the CEB, as well as potentially generating for their own use and/or for bulk sales. As a result, they are too different to include in a meaningful way and the volumes of electricity involved would skew any results. The two refuse destructors have been separated out because they were essentially very large furnaces constructed in 1903 in Tottenham and 1906 in Southgate. Neither of these were authorised electrical suppliers so were unlikely to need water for the processes involved in generation but there were some refuse destructors which did produce electricity. These particular ones both have small chimneys denoted on the maps, and whilst not directly next to water, both are only 250m away from the nearest watercourse, although there is a rail track between Tottenham's destructor and the River Lea, and a street lined with several houses separating Southgate's and the New River. As a result, these have also been excluded as they do not fit into any particular trade grouping.

[380] The caveats to this are firstly that the returns are not from all the businesses within a trade group, and secondly that in some cases whether self-generation took place onsite, or from a factory under the same owners or electricity came from another source which was not pubic supply was not disclosed as it was considered commercially sensitive. There are 24 cases in which purchasing from works under the same owner is combined with purchasing from public supply. In all other cases, I have only considered self-generated or purchased from public supply to ensure the data is not skewed by the different ways self-generation was reported.

The following graphs consider the spatial arrangement of industries in the Lea Valley in 1948. The first part of the graph (Figure 46) in orange and yellow, shows the total units of electricity consumed and self-generated by the trade groups not located next to water, and the second part, in blue and grey, those which are sited next to water.

The most obvious conclusion from Figure 46 is that the maximum number of units used by the second group (next to water) is three times that of the first: 4.5 million as compared to 1.5 million units. For self-generation the maximum values have a difference of 1.5 million units: 1.2 to 2.7 million units. However, the largest value for the trade groups not directly next to water is for a papermill, established in Ponders End at Brimsdown in 1910, and not situated directly next to water. The paper and board trade, to which this mill corresponds, as a rule, self-generated seventy-six percent of the electricity they consumed. This particular papermill was in very close proximity to Northmet's, Enfield power station, which provided commercial electricity close to the papermill from 1906. Therefore, this papermill may have purchased electricity from Northmet if they offered favourable rates. Self-generation would have required extensive pipework to provide enough water but because water was used in the paper making process it would likely have accessed water in some way. It is possible that other trades in the same area which would normally have been self-generating might have been purchasing from the same power station but, as shown earlier, it was still likely to be cheaper to self-generate than purchase electricity. Without examining each individual company it is only possible to speculate, as both options were possible at this location. No specific evidence on this mill has been found. The final observation from this graph is the abundance of water undertakings as a trade group which, as would be expected, are predominantly next to water, except for two pumping stations. Figure 47 shows the same profile but water undertakings have been removed because their primary purpose for being next to watercourses was to manage them.

FIGURE 46 TOTAL ELECTRICITY CONSUMED AND ESTIMATED ELECTRICITY GENERATED ON SITE.

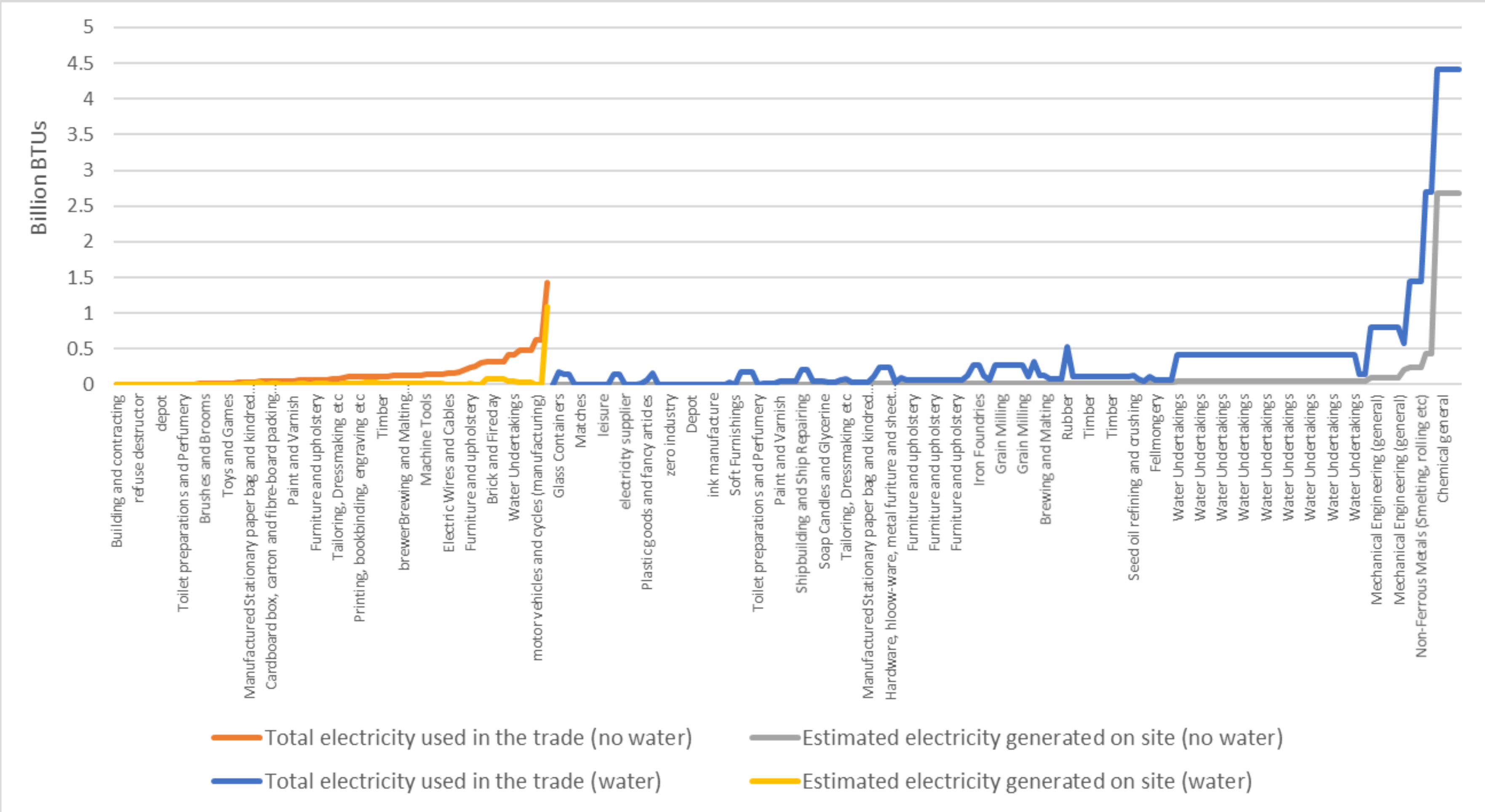


FIGURE 47 TRADE GROUP BY TOTAL ELECTRICITY USED AND ESTIMATED SELF-GENERATION WITHOUT WATER UNDERTAKINGS.

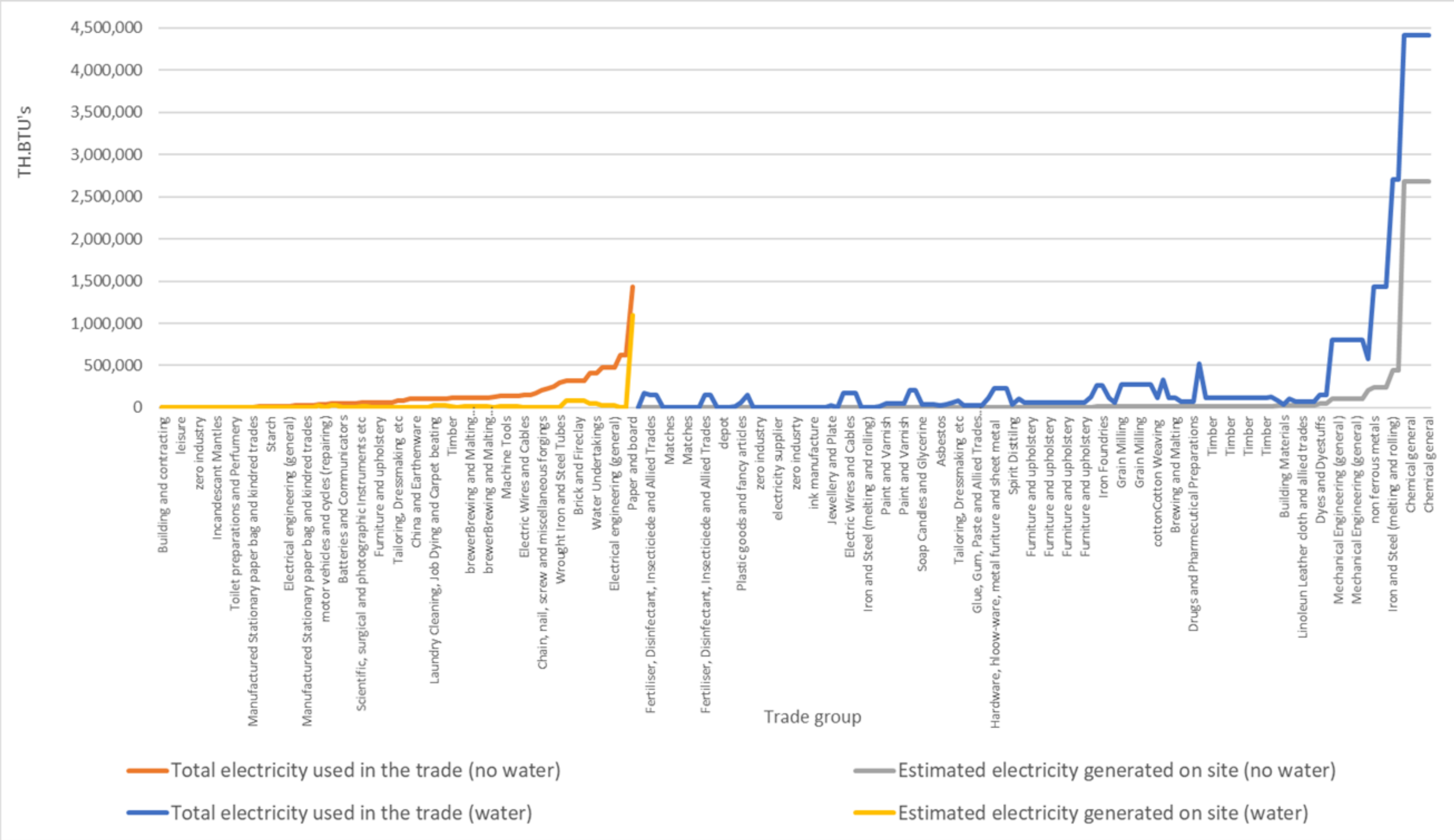


Figure 48 maintains the groupings, with the first showing sites not directly next to water and the second those that were. The data on the x axis is ordered by the distance to the nearest water watercourse for each grouping. This demonstrates, as expected, that the distance to water is reduced for the group directly next to it but it also demonstrates the problems of reliance on the algorithm, which would have produced an overlap between the two groups. There are ways to compensate but they were too time consuming for a case study of this nature.[381]

Figure 48 and 49 show the groupings in the same way, and the data for each group ordered by distance to the nearest watercourse. This shows that for trades not directly next to water the amount of electricity self-generated was generally very low, excepting the previously discussed papermill. The other four small peaks are all brickworks, most of which ran furnaces to dry the bricks. Generally, brickworks located because of the natural resources needed to make bricks and used diesel generators to provide the necessary electricity. The Census of Production shows they spent ninety-six pounds per year on fuels other than electricity for power, ten percent of the budget for publicly supplied electricity. However, self-generated power produced twenty six percent of the total electricity used suggesting self-generation was cost effective in terms of fuel but prone to all the difficulties of maintaining and investing in equipment. Whilst there were reliability issues and investment costs for twenty six percent of the electricity, the risks were less significant than for trades generating larger volumes of electricity, such as mills and chemical trades.[382]

[381] In order to compensate for this the water courses can be digitised in a different way and algorithms using the nearest edges of polygons used to calculate distance but there are so many watercourses it was impractical in this instance.
[382] 'The Brick Society' accessed via http://britishbricksoc.co.uk/, and verbal communication with ex construction workers.

FIGURE 48 TRADE GROUP BY TOTAL ELECTRICITY USED AND DISTANCE TO WATER.

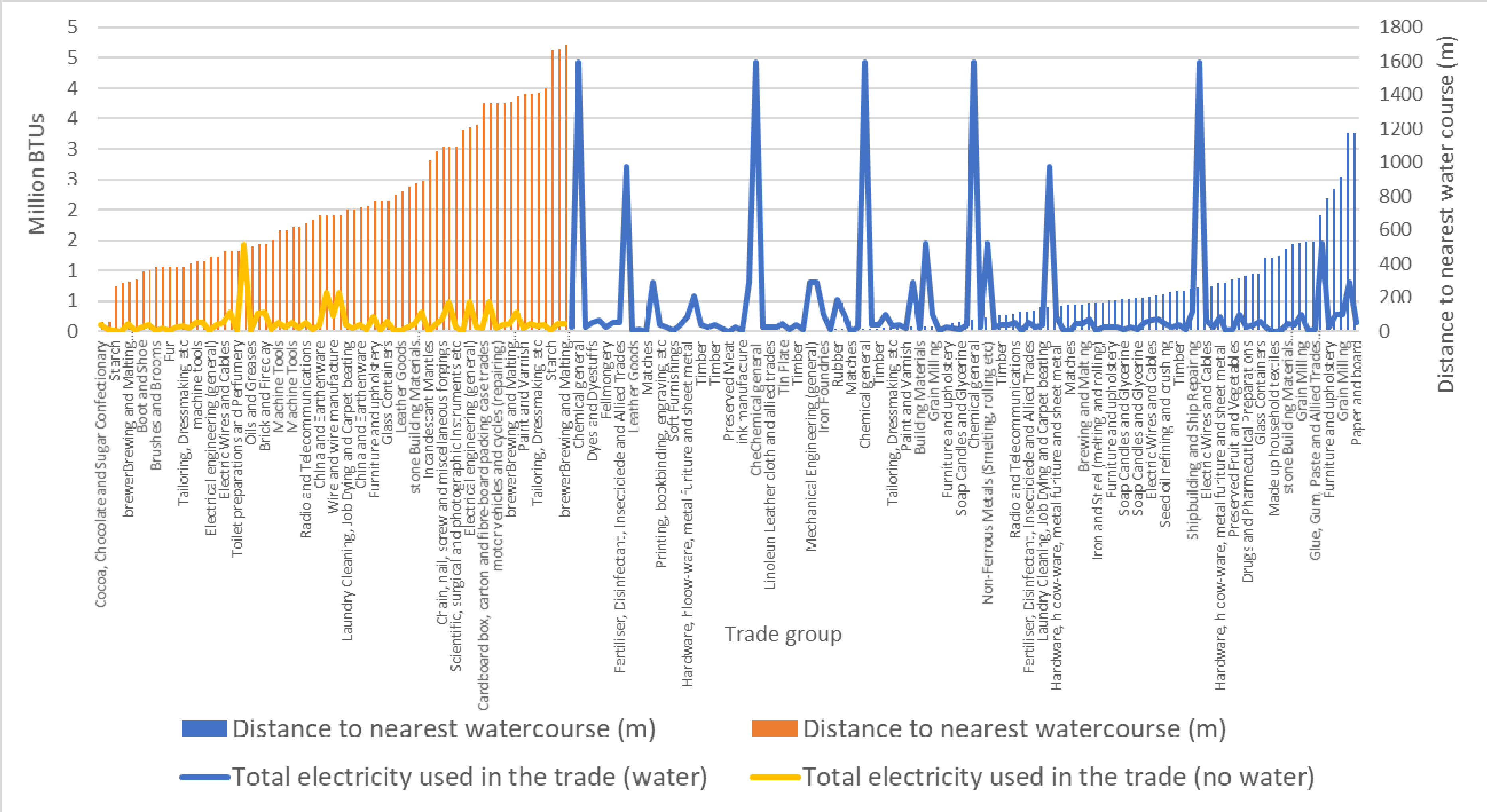
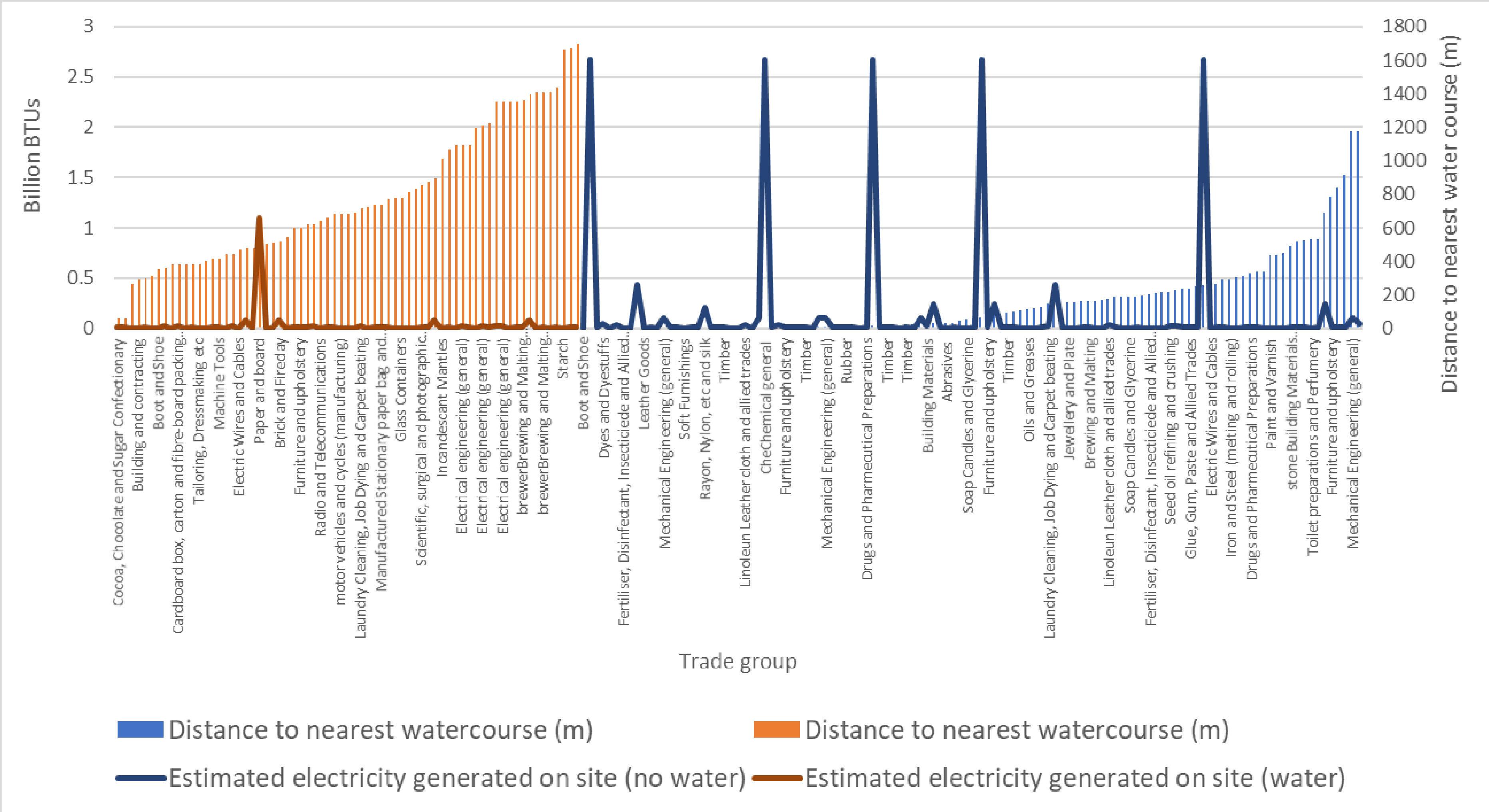


FIGURE 49 TRADE GROUP BY SELF-GENERATION AND DISTANCE TO WATER.



There is greater variation in the trades next to watercourses (Figure 50), with general chemical trades, metals, non-ferrous metals, furniture and a silk factory being the highest self-generators. In the graph below all the trade groups identified in the study area are arranged by proximity to water, as defined by the algorithm. Except for a lace paper factory and confectionary factory located next to each other, the shortest distances tend to be for the trades which were directly adjacent to water. At the other extreme, were large plots directly beside water but with buildings situated away from it, there was a mechanical engineering works and a dye works. These trades self-generated thirteen and thirty three percent of their total electricity usage, which is estimated at 101,090 and 49,952 thousand BTUs, respectively. Again, the other peaks include the papermill at Brimsdown and the brickworks. The furthest distance of any of these trades from water was 1.1 miles.

The next graph (Figure 51) demonstrates how much the 'other suppliers' of electricity were generating; these were not public suppliers but either private power stations or industries selling surplus electricity. They were providing less electricity than was being self-generated, with the maximum purchased being twenty-one percent for motor vehicles and cycles (repairing). This is perhaps to be expected because it involved cooperative working. This must have been considered sensitive information because the 1948 Census of Production was careful about what information could be released into the public domain regarding suppliers. However, it must have either have been a widespread practice or very little was known about it, which is why the 1948 census collected it. Given its small proportion, about nine percent of total electricity used in industry, it is perhaps not as important as the other categories, but the sensitivity of disclosure meant that in twenty-four trade types of 159 this measure was included with the public supply figure or placed into the onsite generation figures.[383]

[383] Census of Production, 1948

FIGURE 50 ESTIMATED ELECTRICITY GENERATED ONSITE AND DISTANCE TO WATER.

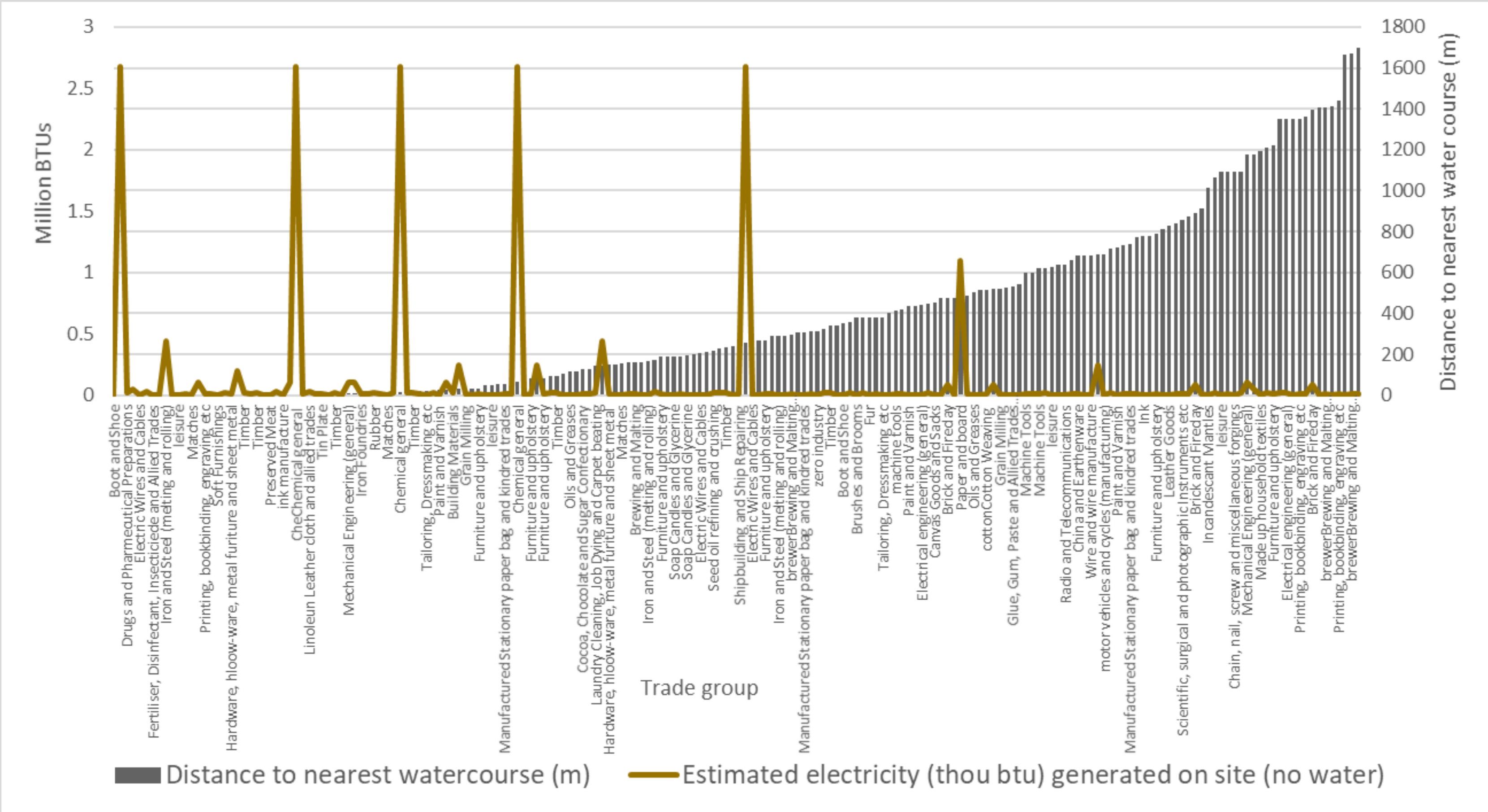
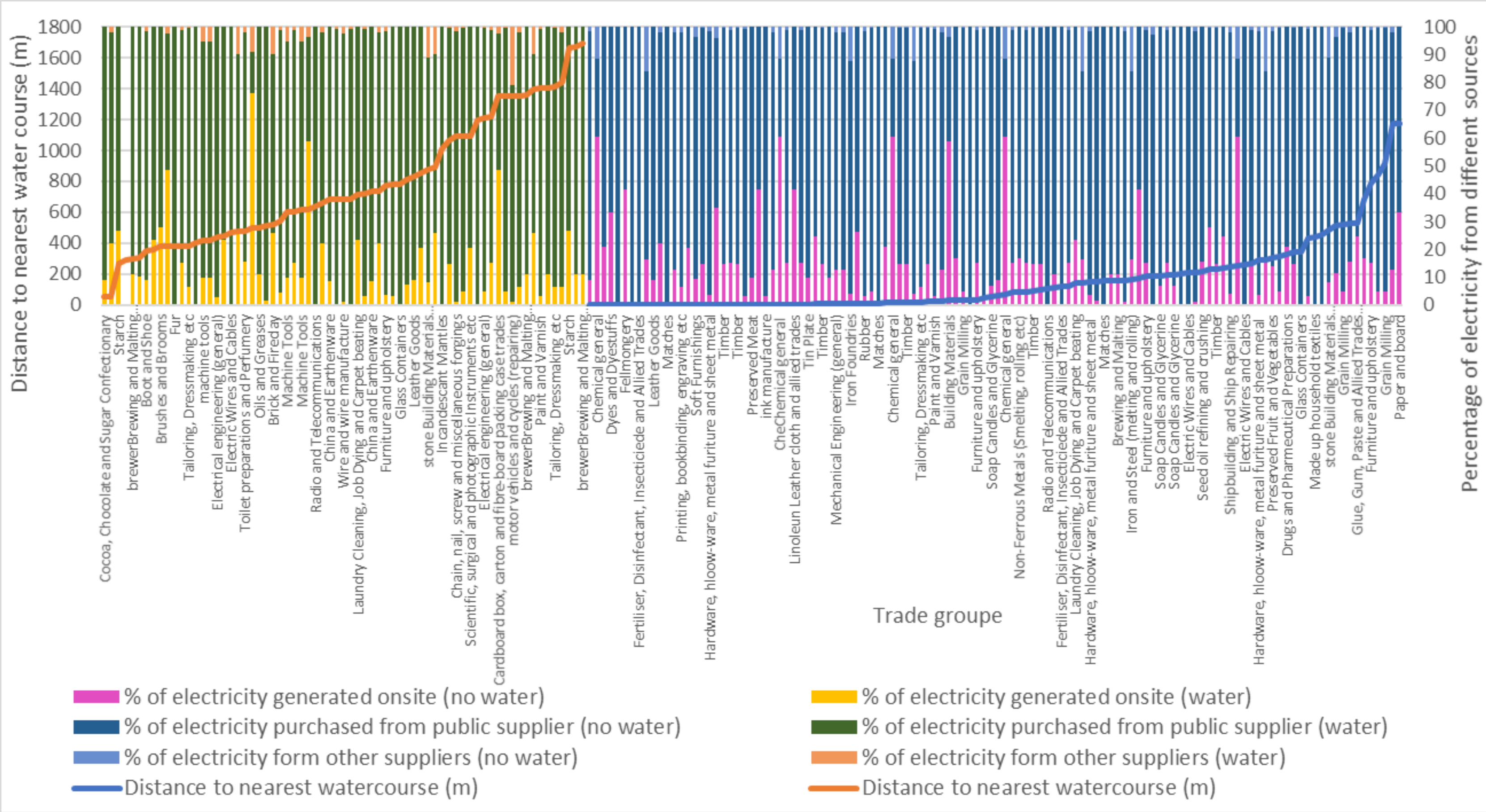


FIGURE 51 TRADE GROUP BY PERCENTAGE OF ALL ELECTRICITY SOURCES.



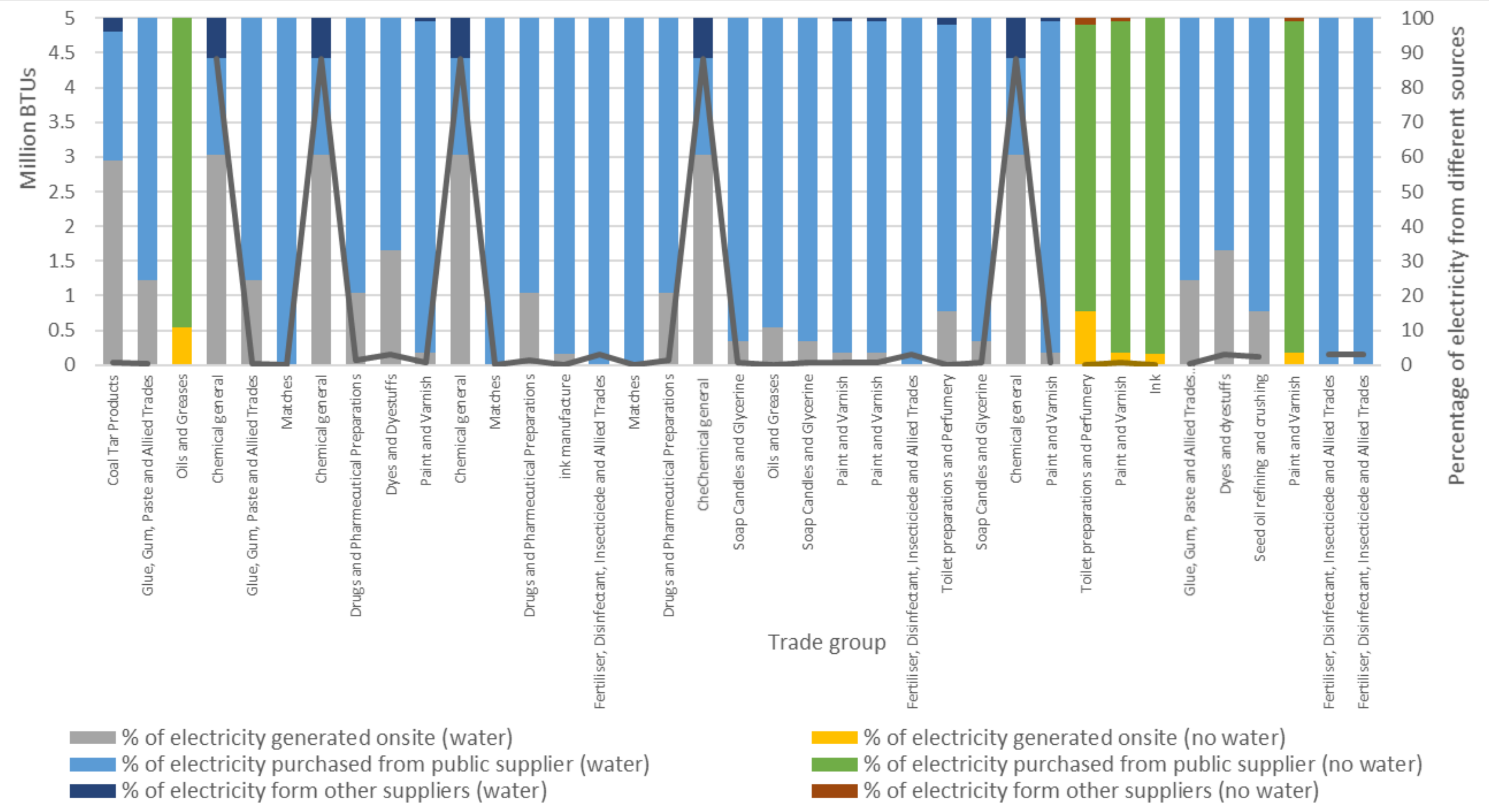
Behaviour of Industry Sectors

Using the first three revisions of the map, 1891-95, 1911-13, and 1932-43, industries can be seen to migrate up the Lea Valley. This is consistent with Smith's and Scott's findings, who both talk about fringe development.[384] It is also consistent with the Census of Production, where industries from the groups last to convert to purchasing electricity, rather than self-generating, and who were energy intensive, were likely to remain *in situ,* close to water. These include Mining and Quarrying, Chemical and Allied Trades, Metal Manufacture, Treatment of Mining Products, and Vehicles. Mining and Quarrying are not represented in the valley during this period but the other industry types are.

As intensive electricity users these industry types were more likely to invest in self-generation. However, the 1948 map gives an opportunity to consider this more carefully and be more specific in the groupings; for example, there are 37 sites hosting 13 different chemical trade groups shown in Figure 52. The predominantly green bars show sites not directly next to water, and as expected these are further from water; the coal and tar products site is next to the gas-works, and a sewer outflow. It is a very large site, hence the greater distance.

[384] Scott, *Triumph of the South*, throughout the work but examples on p.64, p.131 and p.200 and Smith, *The Industries of Greater London*, p.9 and p.117.

FIGURE 52 CHEMICAL TRADE GROUPS BY DISTANCE TO WATER AND ELECTRICITY CONSUMPTION.



This suggests that the persistence of an industry in a location is likely to be related to its investment in energy. Heavier industries and manufacturers who self-generated would have invested heavily in boilers, generators, dynamos, other equipment and personnel costs. This is supported through the Census of Production. For the chemical industries, most sites persisted from revision 2 of the county series maps (1911-22). Eighteen of the sites were either not labelled as industrial or even a map feature in the early 1890s when the first map revision was published. Of the other nineteen, fifteen sites hosted the same type of trade persistently from 1891.[385] This might be related to the necessity of water for chemical processing but it is known that large chemical plants tended to self-generate because it was likely to be cost effective. Martin reported that in Wembley 0.99d. was paid per unit of electricity purchased in 1956, compared to 0.65d. in Leeds but suggested it did not affect production in London because it was not the only factor, although this study suggests it was an important one.[386]

'The capital formation associated with electrical developments was considerable' which made it important to ensure that returns were made.[387] If this was true then depreciation of investment might be a better indicator of when industry was free to move rather than availability of electrical power, although this would be affected by technological changes within the trade itself and electricity supply. It is difficult to determine whether energy supply, and generation onsite was the last development block to be removed and was a 'lock-in' to waterside location, and, if it was, how it was overcome. New processes or machinery reducing the electricity needs might have been enough of an incentive for an industry to relocate as energy costs reduced. As public supply became cheaper

[385] The others include an electroplating works established in 1911-1913 (Rev. 2) on a site which used to host a nursery, a glue works and an oils and grease works, both of which were breweries for vinegar. There was also a linoleum factory which became a chemical works producing a number of different chemical products between revision 3 and the Imperial edition, so between 1932-43 and 1948. The linoleum factory went out of business, as did the breweries.
[386] Martin, *Greater London, An Industrial Geography,* p.140.
[387] Byatt, *The British Electrical Industry,* p.5.

through the Grid and self-generation was no longer a cheaper option this might also have had an effect. However, the costs shown in the 1948 Census of Production demonstrated that self-generation, still offered substantial savings to intensive electricity consumers depending on capital charges. According to the Census of Production total consumption of electricity by industry (excluding electricity undertakers and water undertakings) was 27,727,466 thousand BTUs, with a further 7,569,810 thousand BTUs estimated as self-generated, twenty-seven per cent. However, this was still a significant amount, accounting for a quarter of electricity consumed industrially.[388]

Recouping capital investment took a considerable time. Byatt suggested a rate of four percent depreciation over twenty years, just under the twenty-one-years before compulsory purchase was allowed under the 1882 Electric Lighting Act which would explain reluctance of investors after it passed into law. The compulsory period was doubled to forty-two years in the following Act of 1888, partly because of this investment period. This was financial 'interconnectedness', an investment that needed to reach at least break-even point, before changes to the rest of system could be undertaken, unless new systems or technologies could off-set any losses and provide alternative ways to profit. It is important to consider financial lock-in because electricity was nationalised in 1948, the same year as this census was taken. Thirty-six percent of industrial electricity was still being generated privately and only sixty-four percent was purchased from public supply through the grid, which had been trading for over fifteen years. However, fifteen years might be important, because it is five years less than the expected investment period for electrical generation.

Therefore the next stage would be to consider the same questions for the mid to late 1950s, as the generating plant installed by industries who were not persuaded to purchase from public supply, and of the Grid's reliability, would be reaching the end of their investment cycle in the mid to late

[388] The calculations are shown in Table 8 Costs of purchase and self-generation of electricity in 1948.

1950s and may have connected to public supply in this period, relocating independent of energy requirements.

Figure 53 shows the distribution of industry sites displayed by total electricity consumption of the corresponding trade group. The larger circles, showing site with higher consumption, are situated by watercourses, and are primarily located in three major groupings along the River Lea. Figure 54 shows the proportion of self-generated electricity, the differences between those sites next to water and the others further from water is more obvious. It shows how rivers attracted groups of industry sites, while away from the rivers the sites tended to be more isolated and only small quantities were self-generated.

FIGURE 53 LOCATION AND CONSUMPTION OF ELECTRICITY BY LOCATION.

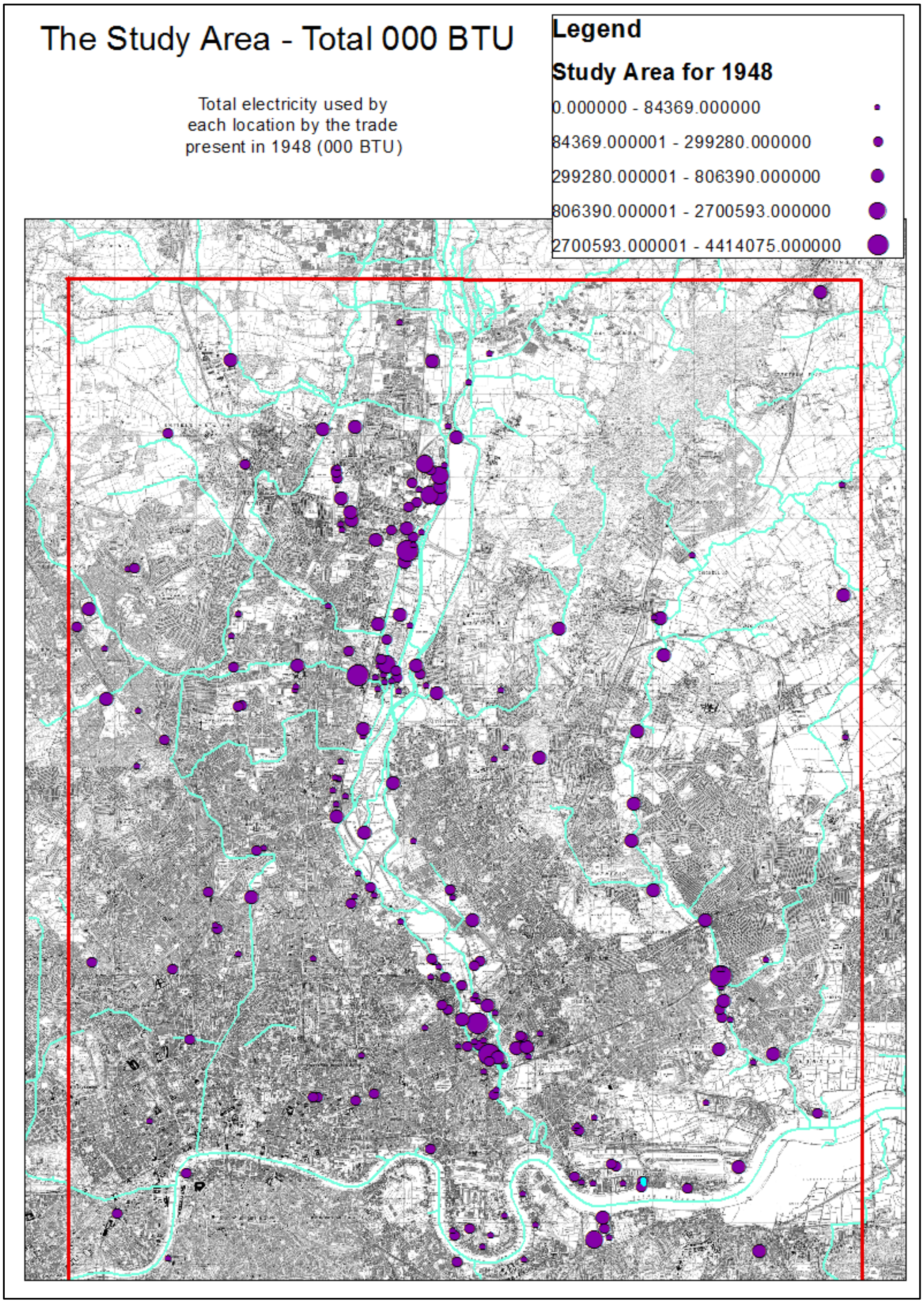
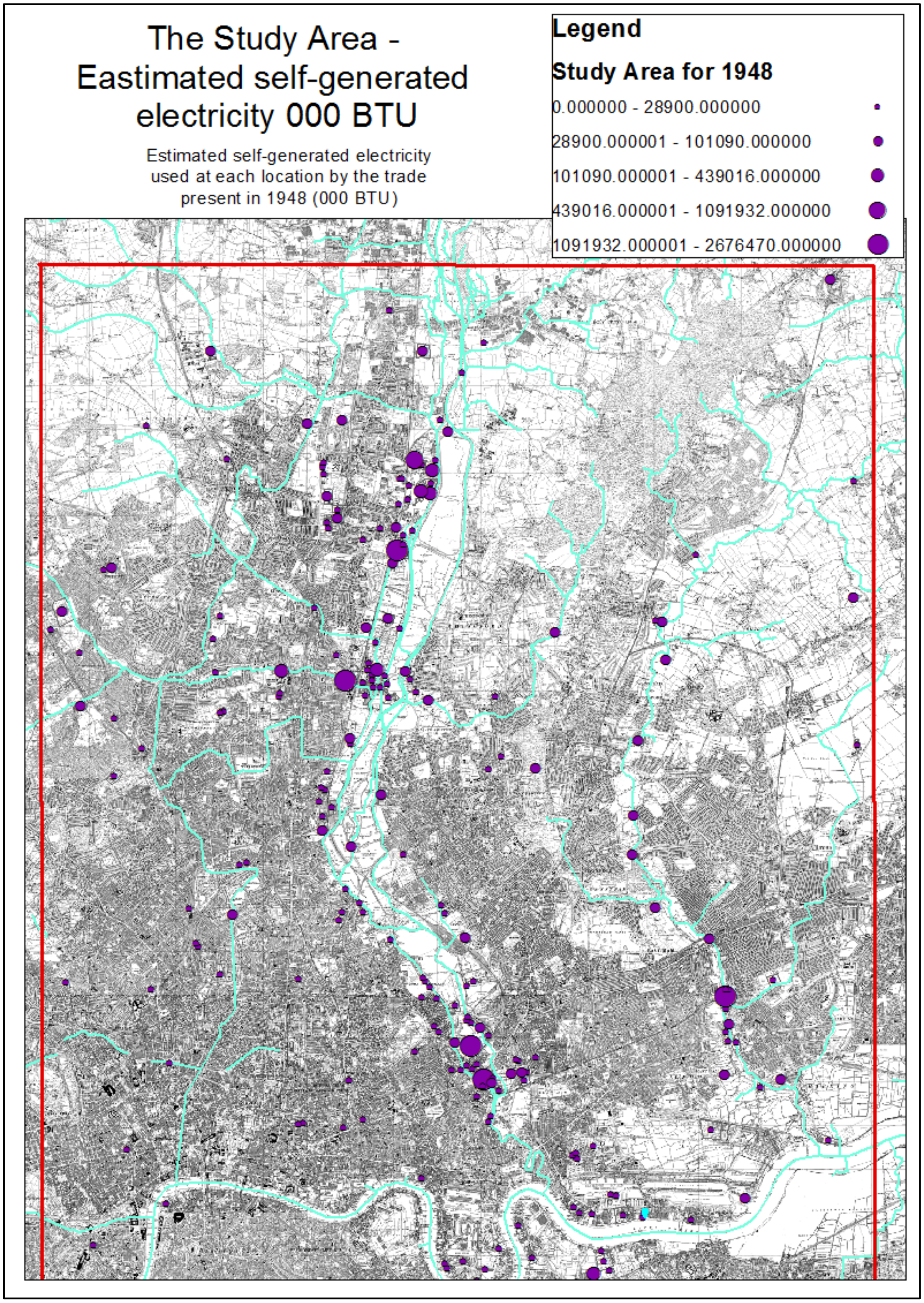


FIGURE 54 MAP OF SELF-GENERATED ELECTRICITY BY LOCATION.



Discussion and Conclusions

This case study set out to determine if the increasing use of electrical power, and the construction of the Grid, had provided a new 'freedom of location' as Manley, Smith and Matthews suggested.[389]

The RGS study in 1938 suggested it took 150 years for industry to establish along the network of canals and rivers which transported goods, and for producing steam power. Given this, perhaps the timescale for this work should be increased to obtain statistically significant results. Even after fifteen years of trading, in 1948, only thirty-seven percent of sites were located away from water, suggesting it was still important for processing, self-generation, transportation or more simply because sites had previously hosted industry and the necessary facilities were present. However, by revision 3 (1932-40) industry was beginning to cluster into groups, sometimes around water but also alongside main roads. These tended to be small sites comprising engineering or precision industries, like radio valve makers and workshops. Overall industry was more diverse by revision 3 (1932-40).

Larger sites of heavy engineering gave way to smaller workshops and factories where items could be made at faster rates, with interchangeable parts on production lines enabled more efficient working and mass production. Water mills were closed and food and clothing factories set up. Wrights flour mill, for example, introduced electricity replacing water wheels in 1909; whilst they did not explicitly state where the supply was from, they were located at Ponders End so are likely to have been supplied by

[389] Manley, 'Location of Industry', pp.511., and Smith, *The industries of greater London,* pp.176-177 and Matthews, *Electricity for Everybody* (1924 ed.), p.150.

NorthMet's Brimsdown power plant. However, they did not convert to a 'modern food factory' until 1963.[390]

Martin's work supports this, discussing changes in the valley in the twentieth century he reported: 'It is also noticeable that in the upper part of the Lea Valley, new industries moved into nuclei provided by the scattered early waterside industries, either moving alongside or actually taking over their buildings'.[391] Although a little after this case study period, in 1966, Martin noted that the 'The Lea Valley has net flows of wholesale deliveries outward to all of the 7 blocs [sections of outer London] and might appear the archetype of a primary processing area'.[392] He suggested that raw materials for the metals and engineering industry were shipped in from overseas, replacing the products which previously came up the river in the early 1900s.

Railway development cannot be ignored either, and a similar analysis of distance to railways using 1911 data is shown in Figure 55 following the same format as the analysis undertaken for water. Like the water analysis most industry was found within 250m of a rail line.[393] There are many water courses in the Lea Valley but does suggest that rail lines followed the general path of waterways. To be within 250m of both water and a rail line would suggest that the greatest distance between a watercourse and railway could only be 500m.

---

[390] The History of Wrights Flour accessed via http://www.wrightsflour.co.uk/our_history.aspx.
[391] Martin, *Greater London, an Industrial Geography*, p. 22.
[392] *Ibid.*, p.213.
[393] Distance is to a railway line, not necessarily a station at which freight could be loaded or unloaded.

Figure 55 Distance to rail lines by industry type.[394]

[394] See footnote 374 for key.

Row Labels	1			1 Total	2				2 Total	3			3 Total	Grand Total
	In Rev 1+2+3	In Next Rev	In Rev Only		In Rev 1+2+3	In Prev Rev	In Next Rev	In Rev Only		In Rev 1+2+3	In Prev Rev	In Rev Only		
250	**42**	**17**	**36**	**95**	**41**	**17**	**50**	**14**	**122**	**44**	**48**	**17**	**109**	**326**
2	3	1	2	6	2	2	5		9	4	1	2	7	22
3					1				1			1	1	2
4	2	1		3	2		3		5	3	1		4	12
6	8		10	18	11	1	6	1	19	9	6		15	52
7	10		4	14	8		7	1	16	6	6	1	13	43
8	1		1	2	1		2	1	4	2	2	2	6	12
9			1	1							1		1	2
10	3		3	6	2		5	2	9	2	6		8	23
11	2	3	5	10	2	4	3	2	11	2	5	2	9	30
12	3	1	1	5	2	1	2	1	6	3	3	2	8	19
13	9	9	7	25	8	9	7	3	27	10	5	1	16	68
14	1	2	2	5	2		10	3	15	3	12	6	21	41
500	**22**	**2**	**19**	**43**	**23**	**1**	**25**	**7**	**56**	**22**	**26**	**7**	**55**	**154**
2	3		5	8	1		5	1	7	1	4	3	8	23
3	1		2	3	1		4	2	7	2	4		6	16
4	1			1	1				1	3		1	4	6
6	3		2	5	5		5		10	2	5		7	22
7	3		2	5	3		1		4	3	1		4	13
8	1			1	1		2	1	4	1	5		6	11
9			1	1			1		1		1	1	2	4
10							1	1	2		1		1	3
11	3		2	5	3		1	1	5	2			2	12
12	2			2										2
13	5	2	5	12	6	1	3	1	11	6	4		10	33
14					2		2		4	2	1	2	5	9
750	**13**	**3**	**15**	**31**	**10**	**3**	**6**	**6**	**25**	**11**	**6**	**10**	**27**	**83**
2	2	1	3	6	1				1	2		4	6	13
3			2	2			2		2		2	1	3	7
4			1	1	1				1					2
6	2		1	3	1			1	2	1		1	2	7
7	5	1	5	11	2	1	1	1	5	2	1		3	19
9			1	1										1
10								3	3			4	4	7
11		1	1	2		1	1		2		1		1	5
12								1	1					1
13	3		1	4	3		2		5	4	2		6	15
14	1			1	2	1			3	2			2	6
1000	**3**		**2**	**5**	**3**		**3**		**6**	**3**	**3**	**2**	**8**	**19**
3			1	1										1
7							1		1					1
13	3			3	3		2		5	3	2	2	7	15
14			1	1							1		1	2
1250	**4**	**3**	**5**	**12**	**4**	**4**	**5**	**1**	**14**	**3**	**5**	**1**	**9**	**35**
6		1	2	3		2		1	3					6
7							1		1		1		1	2
10		1		1		1			1					2
11	1		1	2	1				1	1			1	4
13	3	1	2	6	3	1	4		8	2	4		6	20
14												1	1	1
1500	**2**	**1**	**2**	**5**	**2**	**1**	**1**		**4**	**2**	**1**	**1**	**4**	**13**
2						1			1					1
6			1	1										1
11	1		1	2	1				1	1			1	4
13	1			1	1		1		2	1	1		2	5
14		1		1								1	1	2
1750	**1**	**1**	**2**	**4**	**1**	**1**	**1**	**1**	**4**	**1**	**1**		**2**	**10**
10								1	1					1
11	1		2	3	1				1	1			1	5
13		1		1		1	1		2		1		1	4
2000	**1**	**1**	**1**	**3**	**1**	**1**			**2**	**1**		**1**	**2**	**7**
2												1	1	1
6	1			1	1				1	1			1	3
13		1		1		1			1					2
14			1	1										1
2250							**1**		**1**		**1**		**1**	**2**
13							1		1		1		1	2
2500			**1**	**1**				**1**	**1**					**2**
4			1	1										1
10								1	1					1
2750	**2**		**1**	**3**	**2**				**2**	**2**			**2**	**7**
4	1			1	1				1	1			1	3
10			1	1										1
13	1			1	1				1	1			1	3
3500							**1**		**1**		**1**		**1**	**2**
6							1		1		1		1	2
4000											**1**		**1**	**1**
11											1		1	1
4250							**1**		**1**					**1**
11							1		1					1
Grand Total	**90**	**28**	**84**	**202**	**87**	**28**	**94**	**30**	**239**	**89**	**93**	**39**	**221**	**662**

In his survey Martin reported that only thirteen of 107 firms consulted mainly used rail transport; mostly, because the firms did not feel it was reliable. The remaining firms used road transport. Like others who study industrial location, he suggested that location is based on transport and market forces; market forces from the proximity to the London market, particularly in the early 1900s, and the new towns later in the twentieth century. He suggested it was the influx of new firms moving into the valley rather than the movement of existing ones which changed industry and its locations there.[395]

Water transport is usually considered important: timber trade increased in the valley between 1891 and 1932 from two sites to nine in the 250m buffer zone and remained stable further out but with only one or two sites. 'Canals play an important role in redistributing the heaviest types of traffic through and across London, although it is easy enough to find factories on their banks that turn their backs to the waterway'.[396] This suggests that industries were using more road transportation but the sites remained on the waterside but was not necessarily reliant on the water.

By Revision 3 (1932-40), the mid 1930's industries began to migrate to roads such as The Great Cambridge Road (A10). Martin reported that a firm was considering a thirty-acre factory site on the road in 1937, although he does not report the outcome. There is no site seen on the 1948 map used in this study.[397] Over the longer term other locations should be studied, and this industrial relocation should be investigated further, specifically with respect to energy usage to consider the implications of future energy transitions.

The second part of this study, considering a snapshot of industry in 1948, demonstrated that 116 industry sites in the study area were situated directly next to water and sixty-seven were not,

---

[395] Martin, *Greater London, An Industrial Geography*, pp.29-35 and Smith, *The Industries of Greater London,* p.42.
[396] Martin, *Greater London, An Industrial Geography*, p.215.
[397] *Ibid*., p.34.

representing sixty-three and thirty-seven percent respectively. The average distance to water in 1948 was 159m for sites next to water, and 775m for those which were not. Assuming the distances have similar averages in the earlier years then the proportion directly next to water would be somewhere between the proportion of sites found in the 250m and 500m buffers. Therefore, in revision 1 (1981-86) between sixty-six and eighty-two percent would be next to water, for revision 2 (1911-22) between sixty-two and seventy-nine percent, and in revision 3 between sixty-two and seventy-seven percent. This demonstrates a reduction in the proportion of industry in the valley next to water over the period. The total reduction in sites next to water could be a small as three percent or as large as nineteen percent. Realistically, it is probably somewhere in-between but it indicates the beginnings of 'freedom' to leave the waterside. The time scales of the changes between revisions 1 and 2 (1891 and 1911) correspond to the beginnings of self-generation in the late nineteenth century and the introduction of public electricity supply. Revision 3 (1932-40) and the 1948 map show the changes in industrial locations when the Grid began to trade. Whilst this is just correlation it should be given further consideration.

The second part of the case study demonstrated that trades were situated in the Lea Valley did reflect the national profile, high self-generating trades close to water, and those with a propensity to purchase electricity were further away. However, although the results are indicative they are not statistically significant, probably because of the small numbers. Further study over a longer period, though, might provide more definitive answers.

4. Electricity and the Domestic Setting

Introduction

This chapter considers how the British domestic market responded to electricity as a new technology: how electricity was introduced and promoted to domestic consumers and the response of households and individuals. The Weir Report highlighted that British electricity consumption was small compared to other countries and made two suggestions; first, that all new housing should include an electricity supply and secondly, the accepted premise that suppliers should be able to make a return of twenty per cent from newly connected consumers within two years should be altered, placing more responsibility on the supplier rather than the consumer to increase connections. These measures were excluded from the 1926 Act but domestic consumption did increase as individuals and households adopted lighting, appliances and the lifestyles that electricity provided when it became accessible and affordable to them.

The general theme of this chapter shows how electricity expanded from primarily industrial use to the domestic setting. It also includes a case study of the South-West region, chosen because it complements other work undertaken by the larger project, 'The Power and the Water' which includes an exploration of energy infrastructure aesthetics, particularly in the Quantock Hills, the Bristol Channel and the River Severn.[398] The area was also chosen because it includes swathes of countryside alongside the cities of

[398] This work form part of a larger AHRC funded project to study how our 21st century sense of place, livelihood and community has been moulded by our links to the environmental processes of rivers, constructed watercourses, energy systems and infrastructure. Publications include: Skelton, 'Mastering North-East England's "River of Tine": Efforts to Manage a River's Flow, Functions and Form, 1529-c.1800', in Miglietti and Morgan, (Eds.), *Governing the Environment in the Early Modern World,* pp.76-96, Skelton, 'Stories of Life, Work and Nature Before and After the Clean-Up of North-East England's River Tyne, 1940-2015', in Holmes and Goodhall,

Bristol, Exeter and Bath. The South-West is not particularly representative of Britain, or even England, but it provides examples of urban and rural issues which had significant effects on when a supply of electricity became available. A mixture of authorised and unauthorised undertakers supplied the region owned by municipalities and individuals, showing the entrepreneurial spirit of the South-West alongside the limitations of supply in rural places. The South-West contrasts with the Lea Valley study with less industry but a thriving agricultural sector. It provides an ideal backdrop to consider how electricity spread through the domestic sector, considering supply infrastructures, marketing, consumption and how people accepted it into their homes and lives.

The South-West has a small electricity museum, managed by a group of retired electrical engineers who shared materials with the project which contributed to this chapter.[399] Other material is from personal communication obtained primarily in response to an article published in the Norfolk Women's Institute Magazine asking for people's electricity memories, but other correspondence too. Also included is information from the London Metropolitan Archives to ensure the first part of the chapter is more geographically diverse in considering the domestic market. The second part of the chapter focusses on the South-West and uses material from archives across the region, mostly applications for licenses to setup electrical supply companies submitted to the Quarter Sessions of their respective councils. These

(Eds.), *Telling Environmental Histories: Intersections of Memory, Narrative and Environment*, pp.53-177, Skelton, 'Regulating the Environment of the River Tyne's Estuary, 1530-1800', in Melo *et al*., (Eds.), *Environmental History in the Making: Volume II: Acting*, pp.241-262, Van Lieshout, 'Contested subterranean waterscapes: lead mining sough disputes in Derbyshire's Derwent Valley' in Francesco and Visentin, (Eds.), *Waterways and the Cultural Landscape,* 86-103 and further work to be completed.

[399] The Western Power Electricity Historical Society (WPEHS) is a Bristol based volunteer lead museum and archive which used to be known (at the time of working) as South West Electrical Historical Society (SWEHS) but recently rebranded as Western Power Electricity Historical Society.

include maps of, and information about, supply areas. Over time these applications increased in size and complexity as supply areas grew larger and additional information was required for licencing.

Figure 56 through to 59 show an early application for a licence known as an Electric Lighting Order from 1903, comprising a map and written application, which, if successful, was converted into the licence, and its equivalent from 1925. It should be noted that over the intervening twenty-year period the mains which were to be laid under licence were only extended by a few streets.[400] Whilst this was not the complete extent of the area where electricity was accessible it is indicative, and the extension applied for in 1925 demonstrates how more mains cable needed to be laid to reach more consumers. The maps also demonstrate how large an area a supplier controlled as a monopoly but how concentrated the population was in areas where mains cables were laid. Figure 57 and Figure 59 illustrate the increased amount of information required for licence applications that considered neighbouring properties included after 1909, as described in Chapter 2.

[400] Blue for 1903 and red for 1925 on the respective maps.

Figure 56 Example of a map from an electric supply licence application for Crediton circa 1903[401]

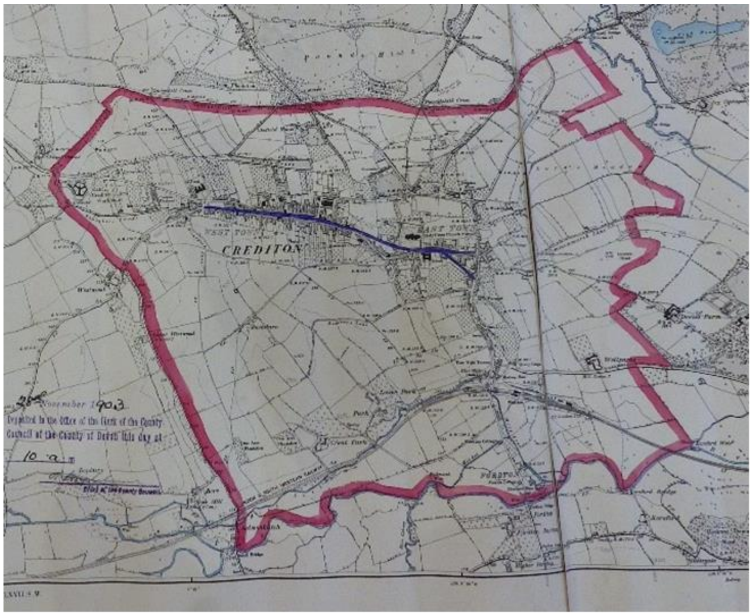
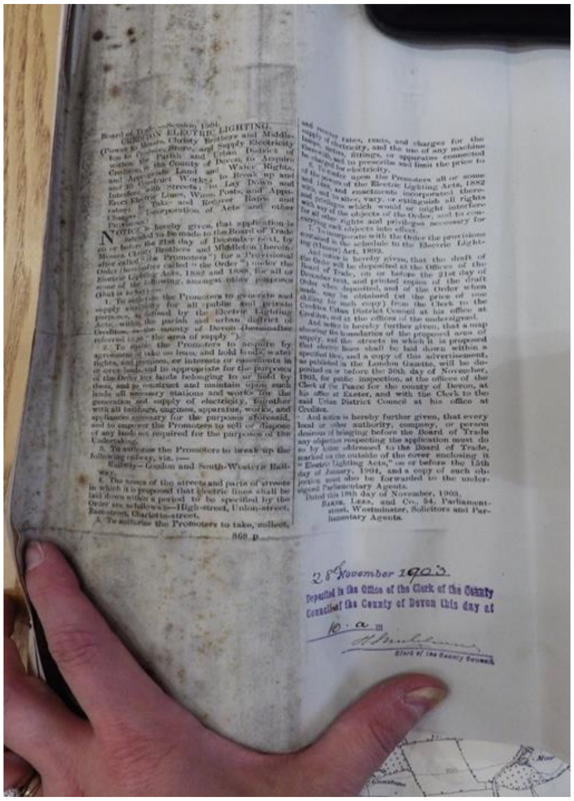


Figure 57 Example of an electric supply licence application for Crediton circa 1903[402]

[401] Source: Exeter, The South West Heritage Centre, ‘Crediton Electric Lighting Order 1903’, QS/DP/633.
[402] *Ibid*.



Board of Trade.—Session 1904.

CREDITON ELECTRIC LIGHTING.

(Power to Messrs. Christy Brothers and Middleton to Produce, Store, and Supply Electricity within the Parish and Urban District of Crediton, in the County of Devon, to Acquire and Appropriate Land and Water Rights, and to Construct Works; to Break up and Interfere with Streets; to Lay Down and Erect Electric Lines, Wires, Posts, and Apparatus; to Take and Recover Rates and other Charges; Incorporation of Acts and other Provisions.)

NOTICE is hereby given, that application is intended to be made to the Board of Trade on or before the 21st day of December next, by Messrs. Christy Brothers and Middleton (hereinafter called "the Promoters") for a Provisional Order (hereinafter called "the Order") under the Electric Lighting Acts, 1882 and 1888, for all or some of the following, amongst other purposes (that is to say):—

1. To authorise the Promoters to generate and supply electricity for all public and private purposes, as defined by the Electric Lighting Acts, within the parish and urban district of Crediton, in the county of Devon (hereinafter referred to as "the area of supply").

2. To enable the Promoters to acquire by agreement or take on lease and hold lands, water rights, and premises, or interests or easements in or over lands, and to appropriate for the purposes of the Order any lands belonging to or held by them, and to construct and maintain upon such lands all necessary stations and works for the generation and supply of electricity, together with all buildings, engines, apparatus, works, and appliances necessary for the purposes aforesaid, and to empower the Promoters to sell or dispose of any lands not required for the purposes of the Undertaking.

3. To authorise the Promoters to break up the following railway, viz.:—

Railway—London and South-Western Railway.

4. The names of the streets and parts of streets in which it is proposed that electric lines shall be laid down within a period to be specified by the Order are as follows:—High-street, Union-street, East-street, Charlotte-street.

5. To authorise the Promoters to take, collect, and recover rates, rents, and charges for the supply of electricity, and the use of any machine, lamps, meters, fittings, or apparatus connected therewith, and to prescribe and limit the price to be charged for electricity.

6. To confer upon the Promoters all or some of the powers of the Electric Lighting Acts, 1882 and 1888, and enactments incorporated therewith, and to alter, vary, or extinguish all rights and privileges which would or might interfere with any of the objects of the Order, and to confer all other rights and privileges necessary for carrying such objects into effect.

7. To incorporate with the Order the provisions contained in the schedule to the Electric Lighting (Clauses) Act, 1899.

And notice is hereby given, that the draft of the Order will be deposited at the Offices of the Board of Trade, on or before the 21st day of December next, and printed copies of the draft Order when deposited, and of the Order when made, may be obtained (at the price of one shilling for each copy) from the Clerk to the Crediton Urban District Council at his office at Crediton, and at the offices of the undersigned.

And notice is hereby further given, that a map showing the boundaries of the proposed area of supply, and the streets in which it is proposed that electric lines shall be laid down within a specified time, and a copy of this advertisement, as published in the London Gazette, will be deposited on or before the 30th day of November, 1903, for public inspection, at the offices of the Clerk of the Peace for the county of Devon, at his office at Exeter, and with the Clerk to the said Urban District Council at his office at Crediton.

And notice is hereby further given, that every local or other authority, company, or person desirous of bringing before the Board of Trade any objection respecting the application must do so by letter addressed to the Board of Trade, marked on the outside of the cover enclosing it "Electric Lighting Acts," on or before the 15th day of January, 1904, and a copy of such objection must also be forwarded to the undersigned Parliamentary Agents.

Dated this 18th day of November, 1903.

BAKER, LEES, and Co., 54, Parliament-street, Westminster, Solicitors and Parliamentary Agents.

868 p

28th November 1903

Deposited in the Office of the Clerk of the County Council of the County of Devon this day at 10 . a m

[illegible]

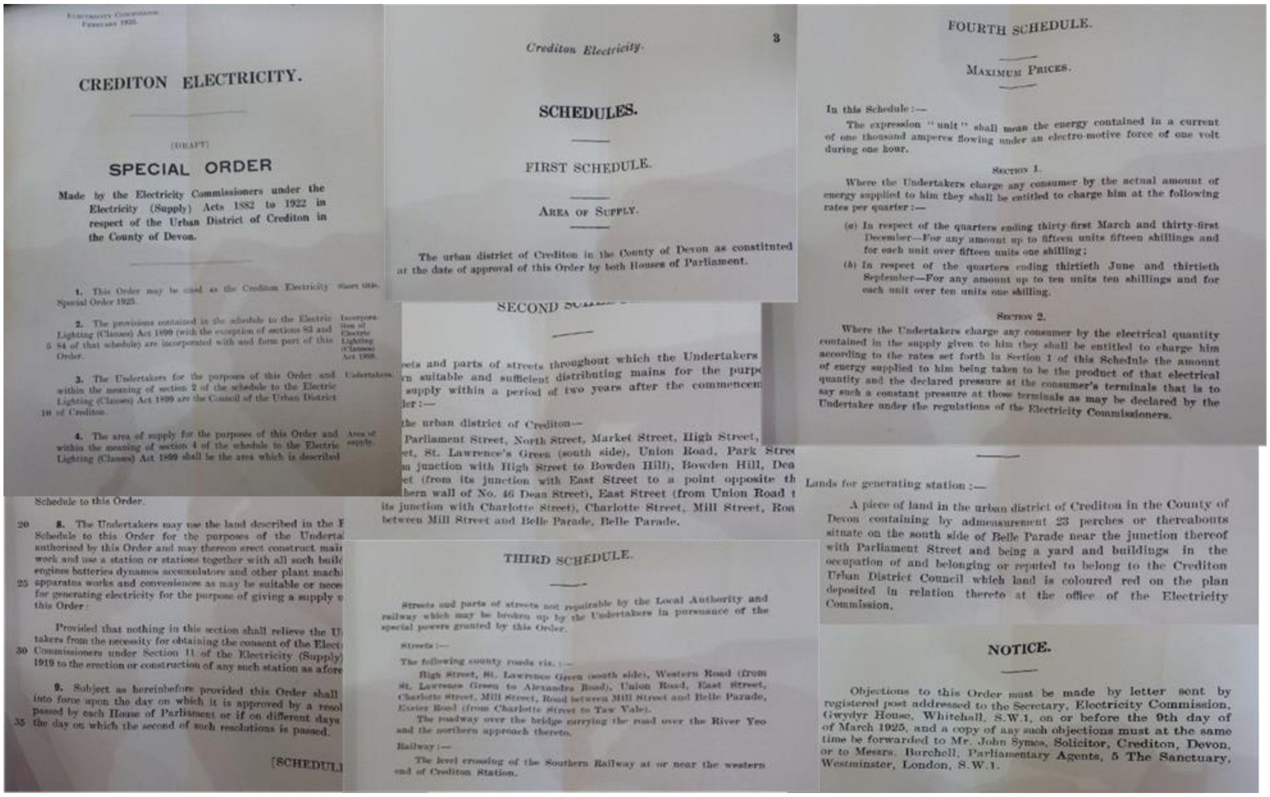
Clerk of the County Council

FIGURE 58 EXAMPLE OF A MAP FROM AN ELECTRIC SUPPLY LICENCE APPLICATION FOR CREDITON CIRCA 1925[403]

FIGURE 59 EXAMPLE OF AN ELECTRIC SUPPLY LICENCE APPLICATION FOR CREDITON CIRCA 1925[404]

---

[403] Source: Exeter, The South West Heritage Centre, 'Crediton Electric Lighting Special Order', QS/DP/714.
[404] Ibid.



Electricity Commission
February 1925

CREDITON ELECTRICITY.

[DRAFT]

SPECIAL ORDER

Made by the Electricity Commissioners under the Electricity (Supply) Acts 1882 to 1922 in respect of the Urban District of Crediton in the County of Devon.

1. This Order may be cited as the Crediton Electricity Special Order 1925. Short title.

2. The provisions contained in the schedule to the Electric Lighting (Clauses) Act 1899 (with the exception of sections 83 and 84 of that schedule) are incorporated with and form part of this Order. Incorporation of Electric Lighting (Clauses) Act 1899.

3. The Undertakers for the purposes of this Order and within the meaning of section 2 of the schedule to the Electric Lighting (Clauses) Act 1899 are the Council of the Urban District of Crediton. Undertakers.

4. The area of supply for the purposes of this Order and within the meaning of section 4 of the schedule to the Electric Lighting (Clauses) Act 1899 shall be the area which is described Area of supply.

Schedule to this Order.

8. The Undertakers may use the land described in the F Schedule to this Order for the purposes of the Underta authorised by this Order and may thereon erect construct mai work and use a station or stations together with all such buil engines batteries dynamos accumulators and other plant mach apparatus works and conveniences as may be suitable or nece for generating electricity for the purpose of giving a supply u this Order:

Provided that nothing in this section shall relieve the U takers from the necessity for obtaining the consent of the Elect Commissioners under Section 11 of the Electricity (Supply) 1919 to the erection or construction of any such station as afore

9. Subject as hereinbefore provided this Order shall into force upon the day on which it is approved by a resol passed by each House of Parliament or if on different days the day on which the second of such resolutions is passed.

[SCHEDUL

Crediton Electricity. 3

SCHEDULES.

FIRST SCHEDULE.

AREA OF SUPPLY.

The urban district of Crediton in the County of Devon as constituted at the date of approval of this Order by both Houses of Parliament.

SECOND SC

eets and parts of streets throughout which the Undertakers n suitable and sufficient distributing mains for the purp supply within a period of two years after the commencem ler:—

the urban district of Crediton—

Parliament Street, North Street, Market Street, High Street, et, St. Lawrence's Green (south side), Union Road, Park Stre n junction with High Street to Bowden Hill), Bowden Hill, Dea et (from its junction with East Street to a point opposite th hern wall of No. 46 Dean Street), East Street (from Union Road t its junction with Charlotte Street), Charlotte Street, Mill Street, Ro between Mill Street and Belle Parade, Belle Parade.

THIRD SCHEDULE.

Streets and parts of streets not repairable by the Local Authority and railway which may be broken up by the Undertakers in pursuance of the special powers granted by this Order.

Streets:—

The following county roads viz.:—

High Street, St. Lawrence Green (south side), Western Road (from St. Lawrence Green to Alexandra Road), Union Road, East Street, Charlotte Street, Mill Street, Road between Mill Street and Belle Parade, Exeter Road (from Charlotte Street to Taw Vale).

The roadway over the bridge carrying the road over the River Yeo and the northern approach thereto.

Railway:—

The level crossing of the Southern Railway at or near the western end of Crediton Station.

FOURTH SCHEDULE.

MAXIMUM PRICES.

In this Schedule:—

The expression "unit" shall mean the energy contained in a current of one thousand amperes flowing under an electro-motive force of one volt during one hour.

SECTION 1.

Where the Undertakers charge any consumer by the actual amount of energy supplied to him they shall be entitled to charge him at the following rates per quarter:—

(a) In respect of the quarters ending thirty-first March and thirty-first December—For any amount up to fifteen units fifteen shillings and for each unit over fifteen units one shilling;

(b) In respect of the quarters ending thirtieth June and thirtieth September—For any amount up to ten units ten shillings and for each unit over ten units one shilling.

SECTION 2.

Where the Undertakers charge any consumer by the electrical quantity contained in the supply given to him they shall be entitled to charge him according to the rates set forth in Section 1 of this Schedule the amount of energy supplied to him being taken to be the product of that electrical quantity and the declared pressure at the consumer's terminals that is to say such a constant pressure at those terminals as may be declared by the Undertaker under the regulations of the Electricity Commissioners.

Lands for generating station:—

A piece of land in the urban district of Crediton in the County of Devon containing by admeasurement 23 perches or thereabouts situate on the south side of Belle Parade near the junction thereof with Parliament Street and being a yard and buildings in the occupation of and belonging or reputed to belong to the Crediton Urban District Council which land is coloured red on the plan deposited in relation thereto at the office of the Electricity Commission.

NOTICE.

Objections to this Order must be made by letter sent by registered post addressed to the Secretary, Electricity Commission, Gwydyr House, Whitehall, S.W.1, on or before the 9th day of of March 1925, and a copy of any such objections must at the same time be forwarded to Mr. John Symes, Solicitor, Crediton, Devon, or to Messrs. Burchell, Parliamentary Agents, 5 The Sanctuary, Westminster, London, S.W.1.

FIGURE 60 MAP FROM AN ELECTRIC SUPPLY LICENCE APPLICATION FOR CHUDLEIGH CIRCA. 1929[405]

Figure 60 shows the map from an application to supply Chudleigh c.1929 shows a larger area in which mains were laid in three heavily populated villages, leaving large swathes of countryside with no access to public electricity despite being an area with a licensed supplier. This demonstrates a large territory with mains only in the circles which provided mains in the primary streets in the most populated villages.

Novelty and Newness

Like all new technology, there was a novelty value associated with electricity from the 1850s. Newspapers from the South-West contained invitations to, and reports about, electricity lectures and

[405] Source: Exeter, The South West Heritage Centre, ‘Chudleigh Electricity (Extension) Special Order, 1928’, QS/DP/790.

demonstrations from this period.[406] Later, focus shifted from specialist lectures and demonstrations to larger public displays. For example, in March 1863 the Victoria Rooms hosted a ball to celebrate a royal marriage and several newspapers announced that electric light would be used on the auspicious occasion. The same organiser illuminated the Clifton Suspension Bridge at its opening a year later.[407] In 1878 Bristol Cathedral was first illuminated by electricity, prompting the comment that 'Although produced by a battery of low power, the light proved very effective, enabling small print to be read with little difficulty at a distance of about 100ft'.[408] Other installations included the Merchant Alliance Supply Stores (1883), the New Promenade Pier, Plymouth (1884), the Exeter Asylum (1885), Wills Factory, Bristol (1886), Torquay Theatre (1887) and the Dartmouth Training Ships (1888). Electric light was also used in 1882 in the boring of the Severn Tunnel.[409]

Electricity became embedded in industry through a combination of public supply and self-generation, as discussed earlier. As electric lighting became publicly available and supply companies were formed the novelty of domestic electrical lighting remained an attraction and luxury. A Bath hotel had electric lighting installed in 1891, and another two hotels had private installations in 1892. Further hotels 'switched on' in St Austell in the early 1890s. Yet electricity was still being used as a selling point in a hotel in Cornwall in 1925 (Figure 61), suggesting that there was still a novelty or luxury value associated with it. Other hotel advertisements included mentions of electric lights and lifts; like this advertisement were electric light was listed with hot and cold running water.

FIGURE 61 HOTEL ADVERTISEMENT[410]

[406] 'Cornwall Royal Institution', *The Cornwall Royal Gazette,* (Cornwall, 1840), p.4.
[407] 'Opening of the Clifton Suspension-Bridge', *Bristol Mercury* (Bristol, 1864), p.8.
[408] 'News of the Day', *Bristol Mercury* (Bristol, 1878), p.5.
[409] P. Lamb. 'Early Days of Electricity in the South West - Covering a period from 1850 – 1900' (Bristol, 2014), Shared via personal communication with SWEHS.
[410] 'Thos. Cook & Son, Ltd.', *The Times* (London, 1925), 44120, p.21.

It took decades before domestic electricity was considered a necessity rather than a luxury. In industry the need for war time munitions catalysed electrification in factories, large scale adoption of electricity from public supplies took many years. Domestic adoption was also a long-term process which began in earnest after the Weir Report had highlighted its potential to expand electricity market growth, complimenting the industrial load. Nearly 30 years later, in 1953, after nationalisation of the whole electricity supply industry, a conference was held to consider rural electricity because only about eighty-five percent of the population could access it. Targets were set to in order to reach almost the whole population over the following ten to fifteen years, meaning it was the late 1960s before everyone could access a supply.[411]

The New Domestic Market and Housing

Like industrial development the domestic market began with self-generation. The very wealthy installed personal electricity systems in large houses and on estates but it remained beyond the reach of the

[411] R.H. Abell and F.P. Meadows, 'Electrification of the Countryside' (A Paper read at the E.D.A. Rural Electrification Conference, Nottingham, 1962), p.3.

majority. Whilst businesses could calculate the costs and benefits of conversion to electricity, determining a financial value, decisions in peoples' homes are not made in such a calculated fashion. They take account of lifestyle, including time, quality of life and tradition which vary in individual homes. Persuading a household to invest in new technology was more perhaps more difficult than for business for these reasons and because electricity's demonstrable benefits were less tangible but were no less transformative to its functioning. However, as the country recovered domestic units consumed increased more rapidly in the late 1930s before consumption reduced over WW2 allowing maximum electricity for industry.

Figure 62 shows the number of units of electricity sold to domestic consumers (RHS). Recording of consumers changed in the early 1950s, from 'number of consumers' to 'number of households', and this corresponds with a slight reduction in numbers seen during that time. This suggests that the earlier consumer numbers included more than one consumer per household or, more likely, multiple meters in each household. Separate meters were installed for each type of electrical use, lighting, cooking, heating or water heaters, for example, because different rates were charged for different uses dependent on the supplier. Therefore, increases in consumer numbers do not directly equate to additional households becoming connected to supply, it simply represents additional connections. There is no definition of what defines a consumer in the earlier recorded statistics.

However, the numbers of recorded consumers, and therefore additional usage of electricity, increased from 1920 to the outbreak of WW2, where the numbers appear to plateau and then increase again. The number of domestic units (RHS) consumed rises almost exponentially despite the depression in the early 1930s due to the Depression. However, as the country recovered domestic units consumed increased more rapidly in the late 1930s before consumption reduced over WW2 allowing maximum electricity for industry.

FIGURE 62 TOTAL UNITS SOLD, THOUSANDS OF CONSUMERS AND PERCENTAGE SHARE OF ELECTRICITY FOR DOMESTIC USE [412]

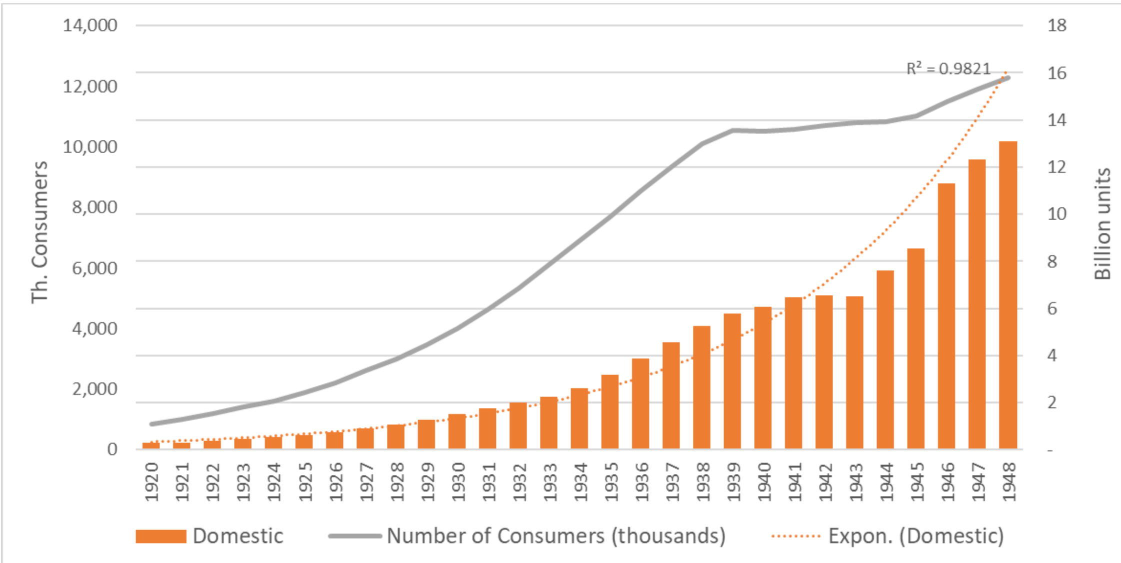
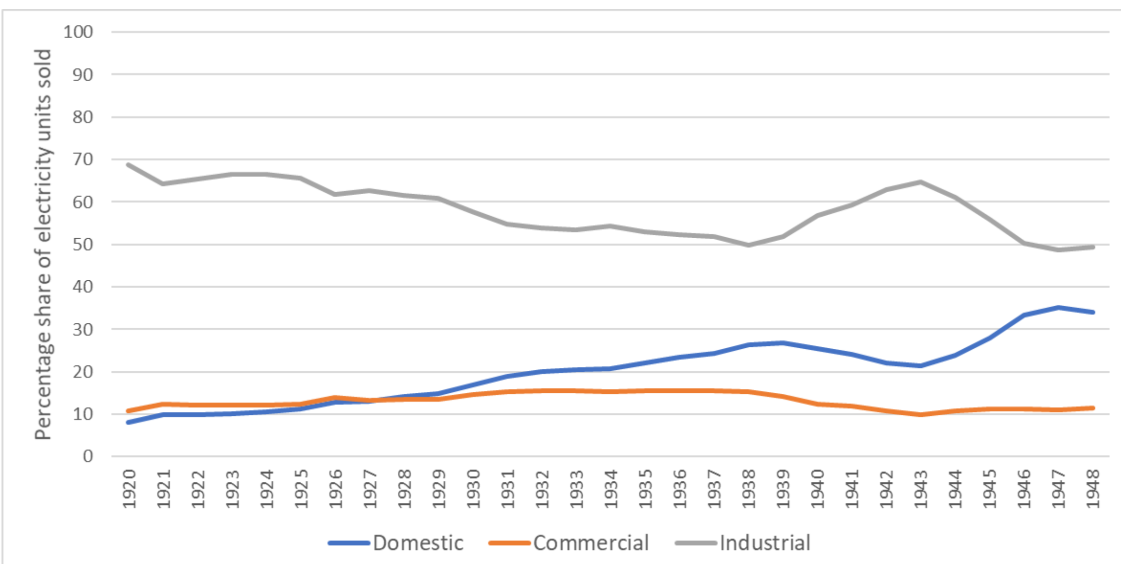


FIGURE 63 PERCENTAGE SHARE OF ELECTRICITY UNITS SOLD[413]



412 BEA, *Annual Report*, p.249.
413 *Ibid.*

However, as the country recovered domestic units consumed increased more rapidly in the late 1930s before consumption reduced over WW2 allowing maximum electricity for industry.

Figure 62 Total units sold, thousands of consumers and percentage share of electricity for domestic use

Figure 63 demonstrates that during WW2 industry was prioritised reducing the domestic percentage share. The beginnings of domestic recovery can be seen from 1946 to 1948, although the rapid growth rates before the war were not achieved before the change in recording consumer numbers is shown. During WW2 industrial consumption increased for war munitions productions and the press ran advertisements asking for reductions in domestic use. Some electricity supply companies used this as an opportunity to promote the 'all electric house', suggesting they would be available for everyone after the war.[414] Post-WW2 there was a huge public house building programme which had been less prominent before the war, although numbers of houses available for rental in the private sector significantly increased, particularly in late 1930s. As the domestic market involved electricity in people homes it is important to consider houses and how they adapted to incorporate electricity into everyday life.

Before 1919 housing policy was concentrated on slum clearances and, 'By 1917, authorities in England and Wales had built about 25,000 homes' and only 'in the final few years before the war [WW1] did these houses account for a remotely significant percentage of all houses built', about six percent of the total stock. The voluntary sector had 'about twice the stock, if predominantly in London'.[415] Rural housing, considered in a 1920 pamphlet showed fireplaces as the only energy source. No other form of utility was mentioned, and the pamphlet suggested that these workers cottages were 'based for

---

[414] London, LMA, 'All Electric House', LEB Scrapbook, LMA/4278/01/084, p.63.

[415] J. Morton, *Cheaper than Peabody: Local Authority Housing from 1890 to 1919*, (York, 1991), p.57.

practical convenience and are the result of practical experience. Theory, which too often provides for bathrooms and w.c.s' is ignored in view of the knowledge of the real requirements of the majority of workers in rural districts'.[416] This suggests that electricity as a commodity was unlikely to be prioritised in rural housing by Public Utility Housing Societies around this period, but there was underlying pressure on these types of organisations and on 'Municipal and State Enterprise' to create more housing.[417]

The owners of housing stock were important during electrification because they ultimately made decisions about the property. If the property was local authority owned then their policy towards electrification and whether they owned the electrical supply company in their area became important. One criticism of the quality of local authority housing was that, except for two short periods after each world war, it was often quite poor.[418] However, Merret suggested that 'council tenants generally occupy relatively recent purpose-built and self-contained dwellings, and typically do not suffer from lack of basic amenities', and that difficulties in council housing are often about 'dwelling type, construction standards, estate layouts, densities, building materials, repairs and maintenance, and so on'.[419] However, there is no mention of what 'basic amenities' includes. Much of the housebuilding after WW1 was undertaken in big cities, clearing slums to provide more sanitary conditions. However, these homes were still comparatively expensive and were occupied by the wealthier working classes, particularly in emerging suburbs where electric tramways made traveling easier. Morton reported that in 1895 forty-five percent of workers used the tram to get to work and noted that trams were often owned by the local authority, who determined the routes, suggesting that for Greater London, this was well

---

[416] V.A. Malcomson, 'Rural Housing and Public Utility Societies – A Few Suggestions Which May Contribute Something Towards the Solution of Rural Housing Problems', (London, 1920), p.5.
[417] *Ibid*, p.1.
[418] S. Merrett, *State housing in Britain* (London, 1979), p.199.
[419] *Ibid*., p.200.

planned.[420] However, no evidence has been seen during this work that suggests tramways, or other organisations, and electrical supply companies planned development together but rather they tended to co-exist in the same area with the same lack of 'joined-up thinking' that still persists today. In Stonehouse and Devonport, for example, the electric tramway and the electricity company were so uncoordinated that it caused significant problems for the supply of electricity across the area mostly because of lack of communication.[421] Standards governing new dwellings varied but in 1914 in Birmingham private landlords were found to be demolishing houses rather than improving them to meet new expected standards that even local authority housing did not meet. These included water supply and ventilated larder, filling in cellars and laying quarry tiles, rather than anything as modern as electricity.[422] Another scheme in Glasgow, around the same period, with 'no lavatories and no internal plasterwork' was later considered embarrassing to the authority but provided housing for the poor, displaced by slum clearances.[423] It would seem from this evidence, and other work, that public housing was unlikely to affect electrification prior to, or immediately after, WW1 either in terms of dwelling numbers or the types of amenities which were being considered.

'In 1976 32% (6,557,000 dwellings) of the housing stock in Britain was rented from local authorities or new towns', with the proportion being twenty-two percent in the South West and fifty-four percent in Glasgow. Of this total, just four percent were built before 1919, twenty-five percent between 1919 and 1943, and forty-eight percent between 1944 and 1965.[424] These figures suggest that there would have been little local authority influence regarding electricity installations although it varied between local

[420] Morton, *Cheaper than Peabody*, p.32.
[421] Luscombe and Buck, *Plymouth's Electrical Revolution,* pp.20-27.
[422] Morton*, Cheaper than Peabody*, p.51.
[423] *Ibid.,* p.28.
[424] Merret, *State Housing in Britain*, p.197.

authorities, their housing stock and decisions regarding energy infrastructure for newly built houses. Local authorities were aware of the potential for electricity though, and reports in *The Municipal Journal* around the mid-1920s mention 'The All Electric House' being considered by some authorities.[425] *The Times,* in 1925, discussed the difficulties for households of converting to electricity, citing costs of wiring, appliances, reluctance to lose the coal fire in the sitting room and difficulty getting rid of refuse without it. It suggested that such issues were beginning to be addressed and that small houses might become all-electric was possible.[426] However, a decade later, *The Times* reported an all-electric house built for £1,000 by the WEA to demonstrate that it was possible for the working class to get electricity into their homes.[427] This was an experimental period for local authorities regarding design and funding of housing for residents who needed it, within which electricity was a consideration.

Home ownership in the later 1930s, when the economy was thriving, saw private house building become more prolific producing a greater proportion of private landlords. However, despite the Grid trading from 1933 electricity distribution was still governed and delivered in the same way as the 1880s, with seemingly no changes to the electricity consumer. Electrical appliances were also supplied through the electrical supply companies for their areas and where larger appliances or meters needed to be wired in, the same company would be responsible. External suppliers and electricians could be used if the supply company approved them, restricting consumer choice. Locational choices for industry were affected by electricity accessibility and the same was true for domestic supply. Public electricity could

---

[425] 'All Electric House', *The Municipal Journal* (December, 1924), pp.1437-1439 and 'All Electric House Experiment' The Electrical Times (December, 1929), p.679.
[426] 'Electricity in The Home', The Times (London, 1925), 44136, p.11.
[427] 'Electricity in Working Class Homes.' *The Times* (London, 1935), 47061, p.7.

only be accessed where there were mains to be connected to. By 1938, just over ninety-seven percent of available public electricity came wholesale through the Grid system.[428]

It was after WW2 that local authority housing became more common and energy infrastructure, both external and internal to dwellings, and might have significantly affected people's fuel choices. Despite many urban areas having a supplier there were still many areas within their boundaries that had no supply because there were no mains close enough for connection. From WW1 to the early 1950s home ownership shifted from renting to mortgages. Pawley reports that in 1918 just ten percent of homes were owned by their occupants, whereas this reached fifty-five percent in 1971, although, as Figure 64 shows the rise in owner-occupation increases beyond 1951.[429]

---

[428] CEB, *Annual Report*, 11, p.13.
[429] M. Pawley, *Home ownership* (London, 1978), p.68.

FIGURE 64 DWELLING OWNERSHIP OVER TIME.[430]

A survey from 1935 recorded the number of wired households, finding that 53.6% of households had an electricity supply, totalling 6,073,706. This was the lowest of all the European countries compared;

[430] Source: National House Building Council, 'Homes Through the Decades – the making of the modern house', (NHBC Foundation, 2015), NF 62, p.12. Using Office for National Statistics Table 104 Dwelling stock and 'Tenure in England: 1914-99' in Research Paper 99/111 *A Century of Change: Trends in UK statistics since 1900*. House of Commons Library, 1999, p.12.

Austria was slightly higher 55.9% and Switzerland the highest at ninety-nine percent. France and Germany had 93.6% and 75.3% respectively. For Britain this meant that 4,137,934 homes were still without electricity.[431]

By 1935 the Grid was operating and the new standard of 240v, 50Hz, AC electricity had been promoted for a decade but there was still enormous diversity in public supply. Seventy-one percent of homes in the Lea Valley were connected to a supply, of which fifty-two percent had AC, and the rest DC.

TABLE 12 LEA VALLEY ELECTRICITY SUPPLY DIVERSITY[432]

Area Supplied	Percentage of wired households	Percentage with AC	Percentage with DC
Lea Valley	71	52	48
Poplar	99	0	100
Walthamstow	79	75	25
West Ham	56	100	0
Hackney	67	1	99

In Devon and Cornwall fifty-three and thirty-seven percent of households were connected to the public supply respectively. In Devon ninety-two percent of connections were AC and in Cornwall this reduced to eighty-five percent. Somerset was similar to Devon with ninety-two percent of the fifty-one percent of connected homes on AC. For comparison with a northern county, Cumberland had fifty-three percent of households connected with eighty-one percent on AC services. Across England 56.2% of households were connected, slightly higher than Great Britain as a whole (53.6%), with 83.3% on AC and 16.7% on

[431] 'Electrical and Radio Trades' Survey of Wired Houses' (London, 1935), p.2.
[432] *Ibid*.

DC, similar to the eighty-three percent and seventeen percent for the whole country.[433] This demonstrates how profiles of connection and standardisation still varied across the country as just over half of homes were connected but still depended on the same supply companies now within the wholesale market, purchasing from the Grid.

The survey reported that ‘During the last year, 680,906 [houses] were added – the largest increase since these surveys began … If the current rate of progress can be maintained, every home within reach of the mains will have a supply of electricity by the end of 1944’, as households without electricity wiring reduced from sixty-two percent in 1932 to forty-six percent in 1935.[434] However, this rate was not maintained because supply profitability diminished as homes became increasingly rural. Areas with less potential consumers in sparsely located dwellings increased the infrastructure necessary for connection, reducing return on any capital investment.

Carlson-Hyslop suggested that, ‘While demand management has been attempted by the electricity industry since well before the 1970s, these attempts only had a limited effect on the overall trend towards increasing demand, in part to do with how these promotions were adopted’.[435] Indeed, demand management and promotion of demand, alongside efficiency had been the underlying principle of electricity supply since its inception. However, choices made by individual consumers and choices dictated through their local authority housing were different. Work by Trentmann and Carlson-Hyslop showed how politically sensitive the principle of choice was, for tenants and home owners alike. To exercise choice between fuels the infrastructure to use them must be available, both internally and

[433] *Ibid.,* pp.4-21.
[434] *Ibid*., p.1.
[435] A. Carlson-Hyslop, ‘Past Management of Energy Demand: Promotion and Adoption of Electric Heating in Britain’, *Environment and History*, (2016), 22, 1, p.75.

externally.[436] However, for some occupants there was no choice over the fuels they used, particularly in London and large cities, where social housing was more common. By 1979, social housing was lowest in the South-West, twenty-two percent of housing stock, and highest in Glasgow at fifty-four percent. London boroughs had the highest proportion of council dwellings made up of flats, with 'Kensington and Chelsea, Camden, Hackney, and Southwark having ninety-six, ninety-five, ninety-three, and eighty-eight percent respectively', compared to 'Stoke, Hull. Leicester and Ipswich which had fourteen, nineteen, twenty and twenty-two percent respectively'.[437] Council tenants had little autonomy over fuel choices and this was further reduced in multiple occupancy in a building, such as flats.

In 1948, debate turned to rural electrification because more isolated populations were still unable to access electricity. Government-backed schemes were introduced after nationalisation to reach these communities and properties, aiming to complete connections by the late 1960s.

Domestic Electricity and Gas

Before WW1 electricity, even for lighting, was a luxury, available to those who could afford to pay for private generating plant for their properties. The first private home to be electrified, Cragside, belonged to Armstrong, an industrialist from the North East, who had electric lighting installed in 1878. The novelty prompted the local newspaper to report on the mechanism of generating electricity from the outflow of a Northumberland Lake. It explained how the current would be 'conveyed' through stout

---

[436] F. Trentmann and A. Carlsson-Hyslop, 'The Evolution of Energy Demand: Politics, Practices and Infrastructural Change, Public Housing in Britain 1920s-70s', *The Historic Journal* accessed via https://doi.org/10.1017/S0018246X17000255 (2017).
[437] Merret, *State Housing in Britain*, p.179.

copper wire the mile and half to the house.[438] It went on to describe in great detail the quality of lighting to view Armstrong's gallery, and how electricity would also be used for other domestic purposes. *The Graphic* reported on Cragside in 1881, after additional lighting was installed, and described the switches which controlled them.[439] Armstrong wrote to *Engineer Magazine* in 1881 to express his delight with his new incandescent lights, which were 'free from all the disagreeable attributes of the arc-light', continuing 'In short, nothing can be better than this light for domestic use'.[440]

Overbecks house in Devon was built in 1914 with a generating house for electricity. Figure 65 shows the electric lighting used during WW1 when the house was given over to the Red cross in tribute to the Overbeck's son, who was killed in action. The house was still self-generating in 1937 when the National Trust took it over.

---

[438] 'Sir William Armstrong and the Electric Light' *Newcastle Courant* (Newcastle-upon-Tyne, 1878), p.5.
[439] 'Swan's Electric Light at Cragside' *The Graphic* (1881), 592, p.16.
[440] Armstrong, 'Letters to the Editor' *Engineer Magazine* (January 21, 1881). Please note that a copy of the original letter was supplied by the National Trust.

FIGURE 65 OVERBECK HOUSE DURING WW1.[441]

At the turn of the nineteenth century, *Country Life* magazine suggested that ‘in every well-appointed country house the electric lighting is considered to be of scarcely less importance than the water supply, drainage and other necessaries’.[442] Correspondence with the National Trust during this project highlighted that even amongst people living in opulent housing, with considerable wealth, electricity was not universally installed, for reasons including safety, health and expense. A survey of infrastructure in 2,467 National Trust properties found 685 had electricity infrastructure remaining within them. Palmer and West wrote ‘Electricity was introduced into country houses far more enthusiastically than gas had been; by 1905, only 25 years after the birth of domestic electric lighting, at least 400 houses in

[441] Source: This information was supplied by the National Trust through correspondence with Overbeck house managers.
[442] Quoted in M. Dillon, *Artificial Sunshine: A Social History of Domestic Lighting* (London, 2002), p.178.

Britain had their own electricity generating plant'.[443] This does not mean the others never had electricity but does suggest it was not uniformly installed. This early period prior to WW1 saw electricity in the homes of people with significant financial resources.[444]

The domestic market for electricity was recognised and promoted by the Weir Committee in 1926. They believed that expanding domestic consumption would increase the scale of production which would, in turn, increase efficiency and reduce prices. A larger domestic market would also complement the industrial load, creating demand outside of normal working hours, further increasing efficiency and economy within the electricity supply industry. However, unlike America, in Britain there was serious competition from gas in the domestic fuel market. Gas prices in Britain were low compared to electricity prices. 'It has been said that the battle for Electric Light should not be fought on the ground of cheapness, but on the ground that as compared with gas it is a desirable luxury', Shiman, concluded, arguing that, rather than price differences, Americans responded to electricity as the superior product.[445] However, the domestic price differential was less in America and his work primarily considered public street lighting. Street lighting often provided the first contract for an electricity supply company, allowing them to establish themselves in an area where they could provide electricity to other premises within connective reach of the generating station.

Many British towns had an established coal-gas plant in the 1880s, piping gas directly into homes to provide lighting and other services. Competition from electricity provoked the gas industry to improve

---

[443] M. Palmer and I. West, 'Nineteenth-Century Technical Innovations in British Country Houses and their Estates', *Engineering, History and Heritage* (2013), 166, EH1, pp.36-44.
[444] This information was supplied by the National Trust through correspondence with house managers. The database of infrastructure was also provided by the national trust and is from a project they conducted with the University of Leicester.
[445] D.R. Shiman, 'Explaining the Collapse of the British Electrical Supply Industry in the 1880s; Gas versus Electric Lighting Prices', *Business and Economic History* (1993), 3, 1, pp.318-327.

its technology in the 1890s, and new burner and mantle technology improved gas lighting considerably. Correspondence in the press discussed the benefits of both gas and electric lighting, often influenced by writers employed in both industries. Such correspondence discussed the calculation of prices, including volumes of gas burned, light intensity and the validity of examples presented. Nevertheless, technical improvements in the delivery of gas for lighting and its increasing versatility were clear. Coal-gas began similarly to electricity, in that first, it was made 'safe' as its potential to provide artificial light was proven. Producing coal-gas for individual consumers was expensive and, as a result, a delivery system of pipes with a central production point was developed for towns. Costs became prohibitive in more rural areas leaving lighting there to be provided by oil lamps and candles, hence the term 'town-gas' sometimes used. Although already nearly a century old, the gas industry developed rapidly between 1885 and 1905 as electricity was obtaining a foothold in the energy market. Russell noted, however, that gas suffered from a lack of investment and support during WWI, the time when electricity was rapidly expanding as its benefits for large scale production were realised for industrial production.[446]

---

[446] T. Russell, 'The History and Operation of Gasworks', available through Research Gate (2013) accessed via https://www.researchgate.net/publication/236532402_The_History_and_Operation_of_Gasworks_Manufactured_Gas_Plants.

FIGURE 66 GAS AND ELECTRICITY MASCOTS.[447]

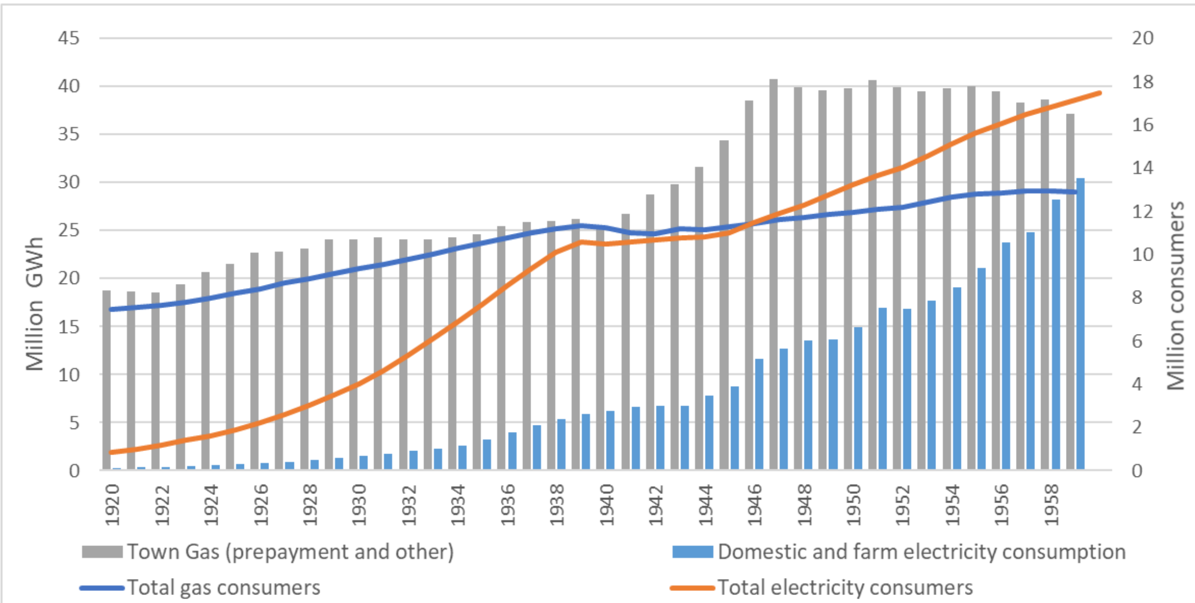
In 1933 The Gas, Light and Coke Company, from London, introduced a mascot, 'Mr Therm', closely followed by the British Electrical Development Association introducing theirs, 'I'm Electric', in 1936 (Figure 66). This was indicative of the fierce competition in the 1930s as the number of domestic electricity consumers increased, particularly in urban areas where coal-gas was operating.

Figure 67 shows gas consumption and numbers of gas and electricity consumers. Electricity consumers outnumbered gas consumers in the mid- 1940s and beyond, with electricity consumption continuing to rise through to the 1980s. Coal-gas consumption increased in the very late 1950s and 1960s, likely because of the Clean Air Act of 1956 which resulted in the conversion to gas fires over 10 years. It was not long after this that natural gas, recorded in official statistics from 1960, replaced coal-gas, recorded in the same statistical data until 1988. Figure 67 shows domestic consumption of town-gas, and

[447] Source: Alick Barnett.

domestic and farm consumption of electricity between 1920 and 1960, alongside number of consumers of gas and electricity. These are the most comparable domestic statistics, particularly because most farms were not connected until the 1950's and '60s.

FIGURE 67 GRAPH SHOWING GAS CONSUMPTION AND A COMPARISON OF GAS AND ELECTRICITY CONSUMERS.[448]



It is difficult to find information on the supply of gas and electricity to individual estates. However, as an example, a new estate in Woolwich included four 'all-electric houses' without grates for coal fires. It was reported that the council approached the local gas company to supply the estate but they would not provide gas unless they were guaranteed the lighting and cooking load. When this guarantee was not given, the gas company were the first to apply for exemption to supply the area in which electricity was being provided, a provision from earlier electricity legislation, meaning that tenants could not use gas

[448] Source: Department for Business, Energy and Industrial Strategy, 'Historic Electricity Data 1920 to 2013' accessed via https://www.gov.uk/government/statistical-data-sets/historical-electricity-data-1920-to-2011 and Department for Business, Energy and Industrial Strategy, 'Historic gas Data 1920 to 2013' accessed via https://www.gov.uk/government/statistical-data-sets/historical-gas-data-gas-production-and-consumption-and-fuel-input-1882-to-2011.

appliances: an example of infrastructure limiting choice. The council supplied the estate with electricity. This estate was reported as 'an experiment', and the rent and electricity combined cost 23s. 7d. per week making it beyond the reach of most ordinary workers.

The *Electrical Times* described the estate as being 'frankly, an experiment' but the 'Housing Progress' section of the *Municipal Journal* described the council as 'pioneering'. The tenants of the all-electric houses reported they were 'quite satisfied' with the electric cooking and the reduced cost of building houses without chimneys and associated needs was reported positively. The lack of reporting about the inclusion of electricity in house building and local authority policies regarding electricity perhaps suggests there were local understandings and arrangements, or, as I suspect, that it was carried out on an *ad hoc* basis. Electricity companies expanded into places where investment would yield a return, they would lay mains or connect new properties where profits could be made.[449] Fouquet reported 'Cheaper or better services were the key to the switch' when he considered fourteen energy transitions from 1500 onwards.[450] Electric lighting was considered brighter and cleaner but remained more expensive than gas and although they competed neither completely dominated. Electricity and gas both have their market but electricity is more pervasive, reaching all properties who want access through the Grid, whereas some rural communities rely on bottled gas where delivery infrastructure is not available.

In 1937 the estimated number of farms and agricultural holding connected to an electricity supply varied between 8,000 and 25,000 out of a potential 388,433; between two and 6.5%. Many of these were potential consumers because these rural locations were reliant on coal and oil for their energy needs because coal-gas did not reach them. This meant that there was less competition for electricity

---

[449] 'All Electric House', *The Municipal Journal* (December, 1924), pp.1437-1439 and 'All Electric House Experiment' *The Electrical Times* (December, 1929), p.679.
[450] R. Fouquet, 'The Slow Search for Solutions: Lessons from Historical Energy Transitions by Sector and Service', *Energy Policy*, (2010), 38,11, p.6591.

companies and, because electric lighting was generally cheaper than oil, the academic, Golding, suggested these potential consumers would be receptive to electricity for cooking and other purposes to enable access to electrical lighting. He also suggested that electricity would be welcomed to the domestic farm setting writing ‘Considering the service given, this charge cannot be considered excessive’.[451]

For the farm itself many different uses were considered including barn machinery, pumping, dairy machines, poultry rearing and crop treatments and machinery. What Golding recognised was that farmers, like earlier industrialists, needed to understand the benefits electricity provided to decide if they justified the cost. Installing wiring, whether paid for as an up-front capital cost or through hire-purchase arrangements, was a considerable expense and had to ultimately profit the farmer and supply company. Although similar arguments were made about all electricity installations, for rural farms and other properties the costs for distribution were higher making the arguments more extreme. Many rural consumers felt that they should pay the same for electricity as consumers in more populated areas; in the same way that stamps were not priced differently for mail deliveries although this essentially meant that rural consumers were subsidised by urban ones. Golding suggested it was a common misconception that the Grid would reduce the costs of wholesale electricity and provide ubiquitous electricity for the same unit price across the country. While the reduction in wholesale prices were expected to enable greater investment in distribution networks it was not expected to supply everyone, everywhere, for the same price. Understanding that the grid would supply standard services at the same price was an easy message to take from the press but even *The Times* stated ‘In many quarters recently there has been an unfortunate tendency to exaggerate the function and purpose of the Grid’ and considers that the

[451] E.W. Golding, *The Electrification of Agriculture and Rural Districts* (London, 1937), p.140.

common misconceptions were that the CEB owned to power stations and influenced distribution but neither were true.[452] It took two further decades, nationalisation of the whole electricity supply industry and further investment before real progress was made in distributing electricity to all rural areas.

A conference, at Mortonhampstead, in 1953, specifically addressed rural electrification and determined that despite two thirds of the countryside having an electricity supplier by 1939, most rural areas still could not access it. During WW2 there was a need to increase agricultural productivity as well as industrial productivity to provide food and munitions. Fewer people were available to work but more needed to be produced so productivity per worker had to be increased. As a result, increased efforts were made during WW2 to connect more farms and its successes were maintained beyond wartime.[453] Afterwards, in 1945, a Ministry of Agriculture report quoted by Brassley *et al*., stated 'the belief that electricity is a social service which should be provided by right to every citizen' but also accepted this would be costly, and suggested that some of the expense for supplying rural areas would need to be subsidised by the urban consumer.[454] The same problem Golding discussed in 1930, fifteen years earlier.

Ditt suggested that rural electrification began in the 1920s, but unauthorised suppliers, such as Lynton and Lynmouth were supplying hydroelectric power as an unauthorised supplier from 1890 in small rural areas and are often missed in data.[455]

He also suggested that for the 1920s and '30s we assume that total rural areas covered 81,000 square miles with a population of 9.4 million, statistics were as follows:

[452] 'National Grid Complete', *The Times* (London, 1934), 46619, p.34.
[453] K. Ditt, 'The Electrification of the Countryside; The Interests and Electrical Enterprises and the Rural Population in England, 1888-1939' in P. Brassley, J. Burchardt, and K. Sayer, (Eds), *Transforming the Countryside the Electrification of Rural Britain* (London, 2017), p.14.
[454] P. Brassley, J. Burchardt, and K. Sayer, (Eds), *Transforming the Countryside,* p.4.
[455] W. Gibson, 'The Electricity Works – Lynton and Lynmouth', Supplement to the Hist Elec News No.1, (1996), SWEHS accessed via http://emep.worldonline.co.uk/SWEHS/docs/news01su.html.

- In 1920, there were supplies to seven percent of rural areas and twenty-one percent of the population.
- In 1928, there were supplies to forty-two percent of rural areas and sixty seven percent of the population.
- In 1930, there were supplies to fifty-nine percent of rural areas and eighty-two percent of the population.
- In 1936, there were supplies to ninety percent of rural areas and eighty-five percent of the population.[456]

He compared this to figures for urban areas of eighty-nine per cent of areas and ninety-seven percent of the population as being connected into the grid by 1928, indicating that rural areas were lagging behind by 10 years.[457] However, these figures are indicative of the population who lived within area with a licensed electrical supplier which did note equate to being connected to a supply. 1969 is reported as the year in which the majority of all households had a connection to electricity. The household wiring survey reported 53.6% of total households connected in 1935 and work by Bowers reports sixty-five percent of total households connected in 1938 and support this argument.[458] These works do not compare rural and urban properties but the Mortonhampstead Agreement, resulting from the 1953 rural electrification conference set targets for eighty-five per cent of farms and a higher percentage of other households to be connected over the following ten to fifteen years demonstrating that this had definitely not achieved before this date.

---

[456] K. Ditt, 'The Electrification of the Countryside, p.29.

[457] *Ibid.*

[458] Elec. Radio Trades, 'Survey of Wired Houses, 1935', p.2. and Bowers, 'Electricity', p.294.

In 1960 Abell and Meadows reported that advances in technology and a new agreement to share post offices poles for electrical wires had reduced the capital costs to supply more rural areas. This meant that connections for isolated farms and buildings could be taken directly from high voltage lines rather than needing to go through a substation, the high voltage was reduced through a transformer on the pole and from which cables could directly supply the property. From this connection, the local electricity supply company or its approved electricians could wire the property as required. By 1960 additional planning requirements had to be fulfilled which could make connecting such properties a lengthier process but progress was made in rural areas albeit it slowly.

Marketing Domestic Electricity

Before the Weir Report

Bristol's electricity was supplied by the local authority from 1893. They reported just 1,893 consumers out of a total population of 320,000 by 1900, nearly three percent of households, although some consumers were likely to be industrial.[459] Over time electric lighting became more popular in homes which could afford it, and for public street lighting, but it was far from universally appreciated. In 1881 Robert Louis Stevenson wrote 'A Plea for Gas Lamps':

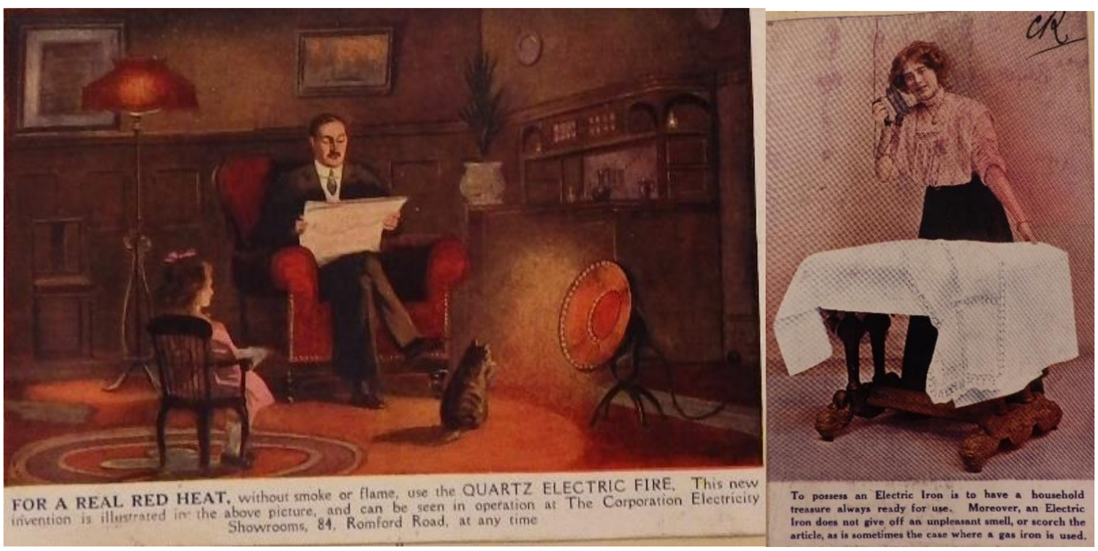
> A new sort of urban star now shines out nightly, horrible, unearthly, obnoxious to the human eye; a lamp for a nightmare! Such a light as this should shine only on murders and public

[459] Garcke, *Garcke's Manual*, 5, West Ham Entry. (Calculated using 4.6 as the average number of people per household to convert it to a proportion of the population in households) otherwise as reports this is 0.6% of the total population.

> crime, or along the corridors of lunatic asylums, a horror to heighten horror. To look at it only once is to fall in love with gas, which gives a warm domestic radiance fit to eat by.[460]

Romanticism for softer, gas lighting lingered and acceptance of electric lighting took time. However, even before the Weir Report was published there were indications that electrical engineers were already considering the domestic market. For example, West Ham, a leading electricity supply corporation, were actively marketing to domestic consumers before WWI; examples of their advertising from 1911 and 1912 are shown in Figure 68.

FIGURE 68 POSTCARDS ADVERTISING ELECTRICITY FOR THE HOME BY WEST HAM. SOURCE: WEST HAM SCRAPBOOK.[461]



By 1913/14 the Bristol Corporation had still only reached 4.6% of households and this only increased to 6.9% of households in 1918/19 although some would be industrial consumers. Whilst the war proved catalytic for industry it had little effect domestically except for reducing coal availability for fireplaces, stoves and indirectly for coal-gas and electricity. There were newspaper advertisements to reduce

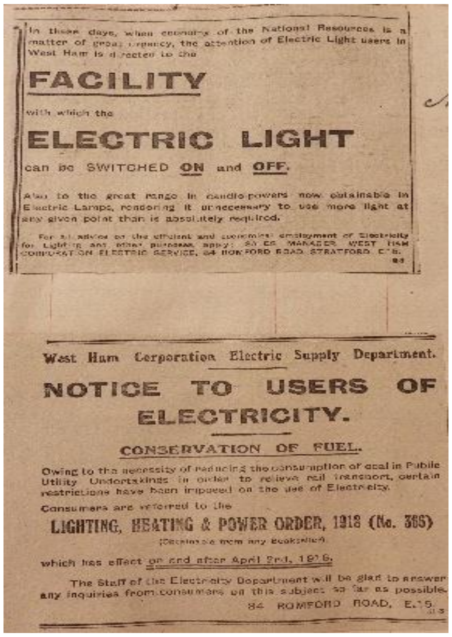
---

[460] R. Stevenson and M. Ridley, *Virginibus Puerisque: Familiar Studies of Men and Books* (London, 1963), pp.189-193.

[461] London, LMA, 'Scrapbook', LMA/4728/01/070/05, p.52 and p.41.

domestic use during WW1 to divert electricity to industrial munitions production. An example advertisement can be seen in Figure 69.

FIGURE 69 NEWSPAPER CUTTINGS TO SAVE ELECTRICITY FROM WW1 (*C.* 1818).[462]



In these days, when economy of the National Resources is a matter of great urgency, the attention of Electric Light users in West Ham is directed to the

FACILITY

with which the

ELECTRIC LIGHT

can be SWITCHED ON and OFF.

Also to the great range in candle-powers now obtainable in Electric Lamps, rendering it unnecessary to use more light at any given point than is absolutely required.

West Ham Corporation Electric Supply Department.

NOTICE TO USERS OF ELECTRICITY.

CONSERVATION OF FUEL.

Owing to the necessity of reducing the consumption of coal in Public Utility Undertakings in order to relieve rail transport, certain restrictions have been imposed on the use of Electricity.

Consumers are referred to the

LIGHTING, HEATING & POWER ORDER, 1918 (No. 365)

which has effect on and after April 2nd, 1918.

The Staff of the Electricity Department will be glad to answer any inquiries from consumers on this subject so far as possible.

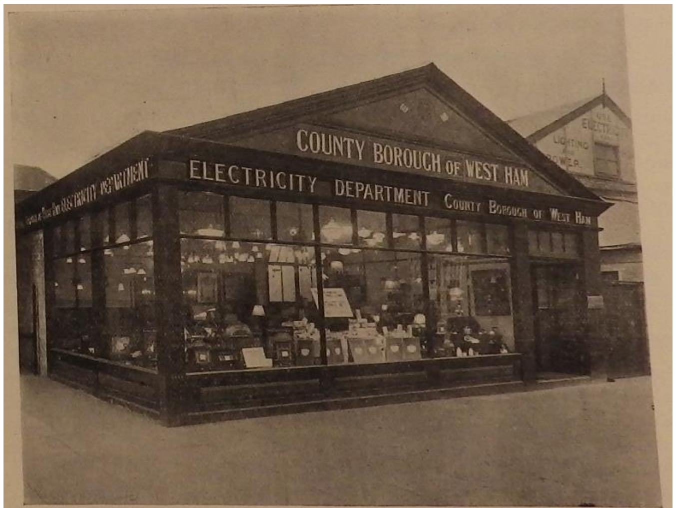
84 ROMFORD ROAD, E.15.

Some, more entrepreneurial electricity supply companies marketed electricity through showrooms which opened early in the period. For example, West Ham opened its first showroom in 1906 (Figure 70) and provided sales brochure '*Electricity, its advantages and uses in the home and business*' with a final page inviting people to address questions to the sales manager who would arrange representation to call at their convenience. Although not dated it included a photograph of their new, 1906, showroom. It promoted appliances, showing an electric kettle priced from 35s. and an electric hair dryer at 37s 6d. These were considerable costs, more than most working class and even middle-class consumers could afford.[463]

---

462 *Ibid*., p.33.
463 London, LMA, 'Scrapbook', LMA/4278/01/064, p.6.

FIGURE 70 SHOWROOMS OF WEST HAM ELECTRICITY 1906.[464]

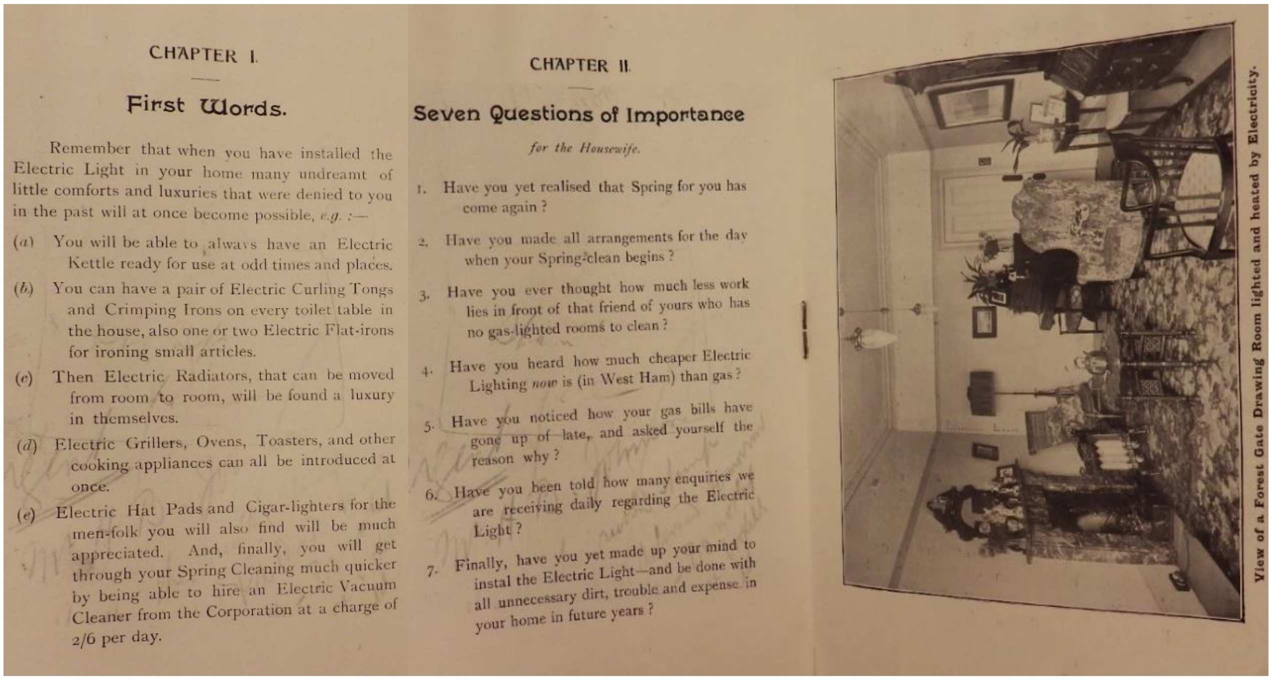


Exterior view of the new Showroom in Romford Road, Stratford, adjoining Head Offices of the Electricity Department.

In 1911 they advertised the benefits of electricity for spring cleaning (Figure 71) promoting the benefits of electric lighting, stating that it was cheaper than gas for lighting in West Ham. Although the aim was primarily to advertise electric lighting it also explained that once electric light was installed additional appliances such as kettles, irons and hair curlers could be used by plugging them into the light fixing.

[464] London, LMA, 'West Ham Electricity Uses in the Home and Business', LMA4278/01/064 p.1.

FIGURE 71 IDEAS FOR HOW ELECTRICITY CAN IMPROVE YOUR SPRING CLEANING.[465]



CHAPTER I.

First Words.

Remember that when you have installed the Electric Light in your home many undreamt of little comforts and luxuries that were denied to you in the past will at once become possible, *e.g.* :—

(*a*) You will be able to always have an Electric Kettle ready for use at odd times and places.

(*b*) You can have a pair of Electric Curling Tongs and Crimping Irons on every toilet table in the house, also one or two Electric Flat-irons for ironing small articles.

(*c*) Then Electric Radiators, that can be moved from room to room, will be found a luxury in themselves.

(*d*) Electric Grillers, Ovens, Toasters, and other cooking appliances can all be introduced at once.

(*e*) Electric Hat Pads and Cigar-lighters for the men-folk you will also find will be much appreciated. And, finally, you will get through your Spring Cleaning much quicker by being able to hire an Electric Vacuum Cleaner from the Corporation at a charge of 2/6 per day.

CHAPTER II.

Seven Questions of Importance

for the Housewife.

1. Have you yet realised that Spring for you has come again ?
2. Have you made all arrangements for the day when your Spring-clean begins ?
3. Have you ever thought how much less work lies in front of that friend of yours who has no gas-lighted rooms to clean ?
4. Have you heard how much cheaper Electric Lighting *now* is (in West Ham) than gas ?
5. Have you noticed how your gas bills have gone up of late, and asked yourself the reason why ?
6. Have you been told how many enquiries we are receiving daily regarding the Electric Light ?
7. Finally, have you yet made up your mind to instal the Electric Light—and be done with all unnecessary dirt, trouble and expense in your home in future years ?

View of a Forest Gate Drawing Room lighted and heated by Electricity.

After the Weir Report

In 1926 Snell gave a speech to the engineering section of The Association about the technical plans that he, Merz and Kennedy had created for the grid. He suggested that:

> Taking all factors into consideration and assuming the population at the end of the next twenty-five years would have grown to 50 million, and that the methods and extent of distribution had advanced and developed, and that a sensible reduction could be effected in the cost of appliances resulting from scientific and commercials improvement and greatly increased scale of manufacture, the total output for domestic requirements, including

[465] London, LMA, 'Scrapbook', LMA/4728/01/070/05, p.33. .

> residential premises, shops, offices and public places, might be estimated at not less than 20,000 million units with a maximum load of 8 million kilowatts.[466]

This was ambitious, required many conditions to be met and a great deal of progress was necessary over the twenty-five years. Whilst industry was introducing assembly lines and mass production, including manufacturing new domestic appliances, they were only useful for those who could access electricity and afford it and its associated products.

By the late 1920s into the '30s the electricity industry had become increasingly conscious of the need to educate, promote and sell the benefits of electricity to all potential consumers. This type of marketing did not become prolific until after construction began on the Grid, when selling electricity to housewives and their husbands began in earnest. Messages promoting electricity were endorsed by The Women's Electrical Association (WEA), The British Electrical Development Association (BEDA or EDA), the Incorporated Municipal Electrical Association (IMEA) and others, including electrical engineers, all people and institutions with their roots in the electricity industry.[467]

In 1934 Boltz's work *Everybody's Electricity* stated 'Electricity has been described as the wonder worker of to-day. By means of it we warm or cool ourselves, bath, cook, listen to entertainment, watch the time fly, travel, and talk to people thousands of miles away. Yet many of us hesitate to touch the most elementary electrical toy because we are ignorant of the principles involved'.[468] This 'hesitation' was the barrier proponents of electricity wanted to address through education, demystifying electricity, to make

---

[466] J. Snell, 'Speech before the Engineering Section of the Association', *The Engineer* (August, 1928), 99, p.167.
[467] Hannah, *Electricity before Nationalisation* and Luckin, *Questions of Power,* in particular provide information regarding these electricity advocates, along with organisations such as the Council for the Protection of Rural England (CPRE) and the people who resisted changes such as Williams-Ellis, Abercrombie, Hill and others, alongside information on propaganda from all sides of the arguments and their various campaigns.
[468] C.L. Boltz, *Everybody's Electricity* (London, 1934), preface.

it a less worrisome phenomenon and widen its appeal. In later editions of *The Electrical Handbook*, the WEA wrote 'The need for a handbook of this kind first became apparent in the early 1930s when electricity in the home had revealed a whole new subject for study'.[469] This handbook provided information about electric lighting, radiators and fires, water heating, cooking, and 'motor driven appliances for domestic use', including vacuum cleaners, floor polishers, fans, hair dryers and others. Workings, correct usage, maintenance, electrical current consumption and costs are explained through text and multiple diagrams. It also described electricity, circuits, measurements, technicalities about current, supply methods, house wiring, and information about various domestic tariffs. These guides were believed necessary by electricity advocates but like much of the information and advertising of this time it catered largely for the middle classes who were more able to determine access to electrical supply.[470]

In both editions of *Electricity for Everybody,* Matthews reviewed appliances and their design and uses like *Everybody's Electricity* and *The Electrical Handbook.* This genre mimics books which circulated when electric lighting first appeared for domestic use, such as Robert Hammond's *The Electric Light in our Homes.*[471] Such works sought to reassure people that electricity was safe and encourage more use, promoting its health benefits and for granting increased leisure time, and often suggesting electrical appliances reduced time spent on domestic chores, or replacing servants. This battle for hearts and minds is discussed in Luckin's *Questions of Power*, where he considered actors and institutions, how they were connected and used 'propaganda' to convey their messages. Other than individuals and members in the gas industry there is no substantial evidence that people objected to electricity itself but instead

[469] The Electrical Association for Women, *The E.A.W Electrical Handbook,* (London, 1965), p. xiii.
[470] *Ibid*.
[471] Matthews, *Electricity for Everybody*, pp.1-3 and R. Hammond, *The electric light in our homes* (London, 1884).

objected to the infrastructure which transmitted and distributed it, and the generation stations which produced it.[472] This will be discussed in Chapter 5.

From the 1930s new, well-lit, showrooms appeared in most towns, a place from which electrical supply companies explained, demonstrated, sold and hired electrical appliances to the public.

Figure 72 shows the Belfast showroom but others included Battersea Vestry, which opened a showroom in 1927, Shoreditch, in 1928, and Leytonstone, in 1934, and Islington Vestry, which opened one in 1936. In the South West, Bath opened in 1933, although they had smaller displays in their offices from 1911, and Plymouth, opened showrooms in 1931. Where rural areas were connected it was generally by larger companies holding licences over large supply areas, such as the West of England Supply Company, who supplied 248 towns and villages and had opened 23 showrooms by 1939.[473]

---

[472] Luckin, *Questions of Power*, discusses the propaganda around electricity and the organisations who promoted and opposed both electricity and its infrastructure.

[473] London, LMA, 'Brochures, Leyton Scrapbook', LMA/4278/01/116, p.129, Luscombe and Buck, *Plymouth's Electrical Revolution,* Lamb, 'Early Days of Electricity in the South West', and M.A.C. Horne, 'London Area Power Supply – A survey of London's Electric and Power stations', (2012) accessed via http://www.metadyne.co.uk/pdf_files/electricity.pdf.

FIGURE 72 BELFAST CORPORATION SHOWROOM.[474]

To encourage people to use electricity, supply companies, and other interested organisations, carried out appliance demonstrations, primarily of electric cookers, which were often well attended. Cookery demonstrations in Hackney, intended to encourage people to purchase or hire cookers, regularly attracted over 80 people, sometimes over 100 (Figure 73).[475]

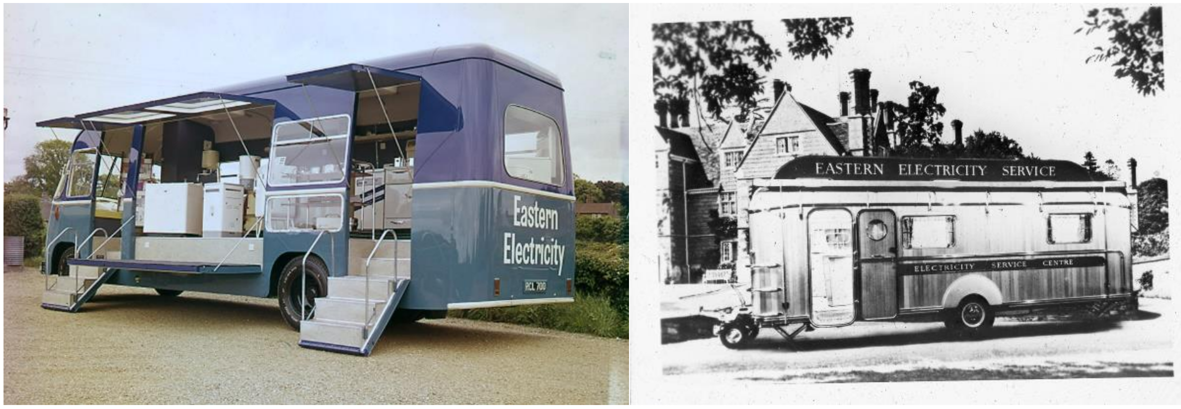
FIGURE 73 ELECTRIC COOKER DEMONSTRATION, 1932.[476]

[474] Source: A. Macartney.
[475] London, London Metropolitan Archive (LMA), 'Hackney Electrical Showroom Ledger', LMA/4278/01.
[476] Source: A. Macartney.

As well as using shop fronts for demonstrations, suppliers had travelling showrooms (Figure 74) which could be used to take demonstrations 'on tour' reaching the population living further from the main towns.[477]

[477] Source: A. Barnett.

FIGURE 74 TRAVELLING SHOWROOMS[478]



Showrooms offered opportunities for consumers to talk directly to electricity company staff, to organise connections, pay bills and to hire or purchase appliances. A ledger from Hackney's electricity showroom recorded connections, disconnections and changes to the tariffs, alongside the number and type of appliances sold or hired. It also recorded the numbers of consumers who visited the shop, alongside service information about wiring and appliance repairs, public demonstrations and attendances. Luckin discussed showrooms and described sales techniques in detail.[479] An ex-demonstrator for Eastern Electricity recalled the acronym they were taught, HELPS ME SELL:

- **H** for Health
- **E** for Efficiency
- **L** for Leisure
- **P** for Pleasure
- **S** for Status
- **M** for Modernity
- **E** for Economy

---

[478] *Ibid.*
[479] Luckin, *Questions of Power*, pp.23-73. He describes the show room experience.

- **SELL** for Selling and Distribution.[480]

The acronym was designed to remind staff of the main issues consumers wanted reassurance about regarding electricity and appliances. These reflected the issues addressed by authors and supply companies who wrote books and pamphlets to promote electricity and increase. Sales and demonstrations were not restricted to showrooms, if required, the product could be demonstrated in the consumer's home and help provided to support the consumer as requested. Door to door sales of vacuum cleaners began during this period and although new to Britain it followed the success of this approach in America. Scott reported that there was some opposition from the British and he wrote; ‘The average English householder dislikes very much to be hurried into a decision by “high pressure” sales methods, especially in his own home’.[481]

This was all part of a huge promotional effort which was beginning to reap rewards in the mid-1930s for suppliers as domestic electricity consumption rates began to significantly increase.

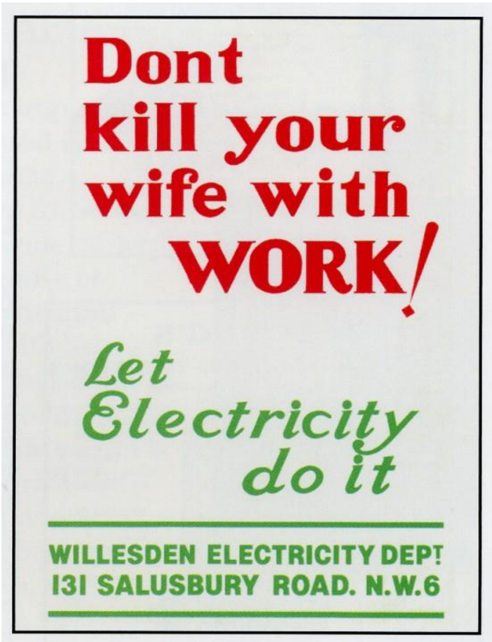
FIGURE 75 ADVERTISEMENTS FOR ELECTRICITY, PRIMARILY TARGETING WOMEN.[482]

[480] Personal communication with Mrs. Barnett who worked in the showrooms of Eastern Electricity.
[481] P. Scott, *The market makers: Creating mass markets for consumer durables in inter-war Britain* (Oxford, 2017), p234.
[482] Source: Display Board at the Museum of Science and Technology, Manchester, 2014.

There were many advertisements, particularly aimed at women for domestic products but some of the adverts tried to appeal to men, as shown in Figure 76 because they often had more financial power than women during this period.

FIGURE 76 EXAMPLE ADVERTISEMENT TARGETING MEN.[483]

[483] Source: A. Barnett.



Darling gave a lecture in 1930 considering changes to cooking apparatus and other appliances. He suggested that converting from almost exclusively coal fires to 'gas stoves, electric ovens and utensils and oil cookers' reduced labour, costs and made the kitchen 'a cleaner and brighter place than in the past'.[484] The benefits and disadvantages of different appliances were discussed but the complexity of the issues raised and the discussion it provoked amongst 'experts' suggests that choices made about fuel types and appliances, if, and when, electricity could be accessed were complicated and difficult.[485] Darling reported that 'Probably the commonest [apparatus] of all is the internally heated flat iron, which can now be procured for use with electricity, gas, or petrol'. He noted, 'Regarding other contrivances it may be stated in general that when an article employing one form of heating is introduced, an

[484] C.R. Darling, 'Modern Domestic Scientific Appliances', *Journal of the Royal Society of Arts* (1931), 79, 4078, pp.205-216.
[485] *Ibid.*, p.212.

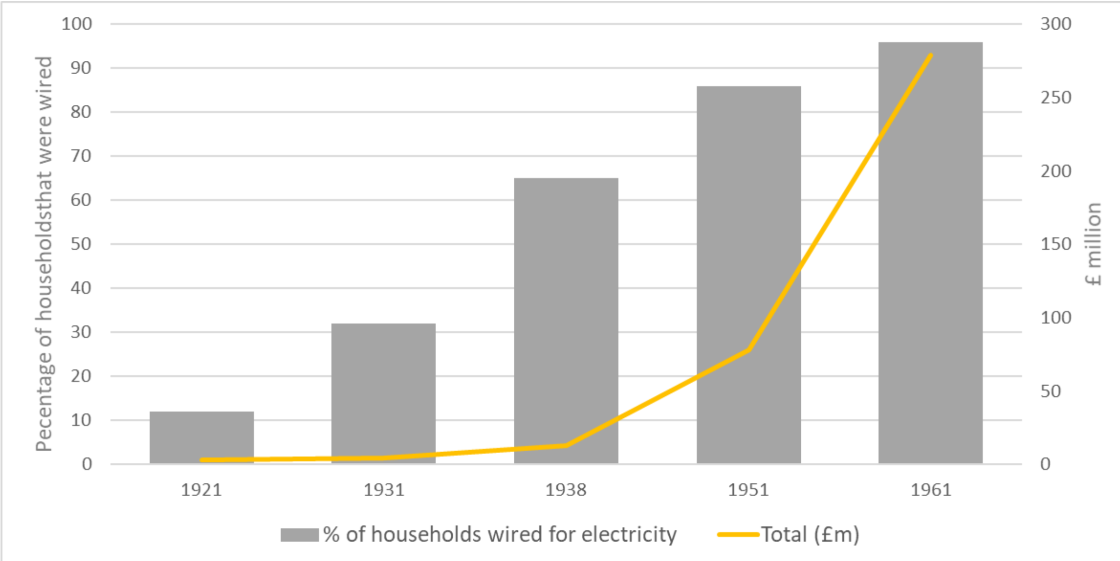
equivalent is usually forthcoming in which a rival form of heating is employed' and suggested that 'Much commendable enterprise is shown and the healthy rivalry is good for all concerned'.[486] This supports the idea that there was competition between suppliers of different fuel types to attract consumers, with improving appliance design used to attract custom. The earliest adopted and most popular electrical appliance was the clothes iron. Table 13 shows how ownership of appliances increased in Britain.

TABLE 13 PERCENTAGES OF WIRED HOUSEHOLDS IN BRITAIN OWNING VARIOUS APPLIANCES.[487]

Appliance	1938	1948	1963
Vacuum Cleaners	27%	40%	77%
Fires		64%	72%
Washing Machines	3%	4%	50%
Water heaters		14%	44%
Cookers	18%	19%	35%
Refrigerators	3%	2%	33%
Irons		86%	100%

FIGURE 77 PERCENTAGE OF HOUSEHOLDS WIRED FOR ELECTRICITY AND SPENDING ON ELECTRICAL APPLIANCES.[488]

[486] *Ibid.,* pp.205-216 and p.213.
[487] Bowers, 'Electricity', p.294.
[488] *Ibid.*



Studies of domestic fuel use are, and continue to be, either very small and detailed or large and general. However, there are a few studies which provide an insight into households which were wired and purchasing electrical products. Bowers shows the rate of change reported by the numbers and proportions of wired households. In the two sub-periods 1921-1931 and 1931-8 the rate of increase was between twelve and thirteen percent per year, before reducing dramatically during WW2 (Figure 77). Beginning from a low base this meant that in absolute terms the largest number of connections per year was made during the 1930s, around three quarters of a million per year. It was at this time that assisted wiring was introduced bringing new consumers into the market. Expenditure rate increase on appliances fell across the 1920s, probably reflecting slightly lower-income households becoming connected and reducing appliance prices. Expenditure rates did not increase rapidly until after WW2, when the increase in houses being wired approached 100% by the early 1960s.[489] Purchase tax, introduced in 1940 applied to electrical appliances and may also have contributed towards the slower rates of electrical

[489] *Ibid*.

development as there was a threefold increase in the number of families who had to pay tax from1938/39 to 1948/49.[490] Wartime coal conservation also reduced consumption rates.

More recent work by Scott and Walker examined household power in Britain in the 1930s as electricity demand grew rapidly, showing substitution amongst fuels helped by hire purchase schemes. Household coal-gas consumption began to decline in the 1930s as consumption of electricity increased but there was fierce competition between them. However, the costs of installing electricity within the house and purchasing units was still expensive, and appliances were still beyond the reach of many households. This required the supply companies to develop methods to capitalise on the increasing willingness of the domestic consumers to use electricity and find ways to provide the infrastructures necessary but still be profitable.[491]

Scott and Walker reported that between 1920 and 1938 electricity rose from five to almost twenty percent of fuel and lighting expenditure, with wired households increasing from seven to seventy-two percent. This is slightly higher than the sixty-five percent that Bowers reported over the same period, and the household wiring survey suggested 53.6% in 1935. Prices per unit of electricity were falling more slowly at this time and the growing domestic market helped to spread the load. This process was not uniform across Britain, with most loads in the high teens in the South West and only Bristol, a much larger undertaker, having a more efficient load of twenty-seven percent.[492]

Bowden and Offer considered the diffusion of domestic appliances in Britain and America. They addressed this by grouping electrical appliances as ‘time-using’ or ‘time saving’, roughly equating to

---

[490] T. Clark and A. Dilnot, *Long Term Trends in British Taxation and Spending* (London, 2002), p.5.
[491] P. Scott and J. Walker, ‘Power to the people: working-class demand for household power in 1930s Britain’, *Oxford Economic Papers* (2011), 63, 4, p.619.
[492] *Ibid.,* p.600, Bowers, ‘Electricity’, p.294, Elec. Radio Trades, ‘Survey of Wired Houses,1935’, p.2 and Garcke, *Garcke’s Manual*, 31-42, Entries for the Bristol Corporation.

entertainment or labour-saving appliances, respectively. They found that time-saving devices, vacuum cleaners and, particularly, more expensive items such as refrigerators and washing machines, were slower to diffuse than time-consuming ones, primarily radio and television. They also suggested that, compared to America, Britain lagged about 30 years behind for diffusion of time-saving appliances, fitting with the corresponding lag in incomes. However, the lag between the two countries of time-using appliances was only five to ten years, corresponding more closely to the lag seen in industrial take up of electricity, perhaps linked more to accessibility. They suggested this was partly because diffusion of these appliance types was about the status the owners wanted to portray, with time-using appliance ownership presenting a higher status than ownership of time-saving ones. [493]

Whilst they further explained that these time-using and time-saving categories are not as distinct as research might suggest, this demonstrated like other research by the same authors, that diffusion of electrical appliances into homes was a long-term process. Vacuum cleaners reached just over fifty percent of wired homes by 1954 but it was 1969 before refrigerators reached a similar proportion, by which time nearly ninety-eight percent of households were wired for electricity. Yet it was as early as 1933 that fifty-five percent of wired homes had a wireless and 1958 when a similar proportion had a black and white television.[494]

Bowden also considered regionality, particularly ownership of electric cookers. What is interesting about this paper is that it considers 1932 to 1938, the same period over which the Grid began trading. The electricity supply industry began changing as regions were connected to the Grid system, and regional

[493] Bowden and Offer, 'Household Appliances and Use of Time', pp.725-748. This contains a good discussion of potential economic models to explore uptake and normalisation of various electrical appliances.
[494] *Ibid.,* P.746. This presents percentages of appliances in wired homes from various sources, some for the UK and others for England and Wales. The values reported here are for the years in which ownership of the reported appliance reached over fifty percent.

Grid tariffs were introduced. The South-East was the first region to be connected and Bowen suggested that this region demonstrated that 'growth was dependent upon level of and growth of current household income levels and the above-national levels of new private housebuilding'.[495] In the North-West, a region later connected to the Grid, demand for cookers was explained by 'a judicious mixture of price and income considerations'.[496] In the regions connected to the Grid in between, the South-West and the Midlands, Bowden suggests this 'reflected price and substitution factors'.[497] This could suggest that, alongside other factors, market changes were important as Grid regions adjusted to the new tariffs. In the areas studied the proportion of wired houses was highest in the South-East with eighty-one percent in 1935, and the North West the lowest with forty-five percent. The Midlands, North-East and South-West were similar at fifty-nine, fifty-nine and sixty-one percent respectively.[498] Although overall Bowden suggested that gas prices were also a significant factor in people's cooker choices these would also have been regional because gas prices, similarly to electricity, were somewhat dependent on the underlying costs of coal.[499] This suggests that the proportion of households wired in any area and the accessibility of electrical supply influenced the way in which people made decisions about their purchases, as it became increasingly normalised.

The adoption of domestic electricity and its associated appliances has often led to the conclusion that women, particularly, gained leisure time. Cowan and Vaneck suggested this is not true and that

---

[495] S. Bowden, 'The Consumer durables revolution in England 1932–1938; A regional analysis', *Explorations in Economic History,* (1988), 25, 1, pp.42-59.
[496] *Ibid*.
[497] *Ibid*, p.58.
[498] The proportion of wired household is calculated from Elec. Radio Trades, 'Survey of Wired Houses,1935' using the towns as listed in Bowden in footnote 66, p.48 and using the proportion of wired houses, as reported in the survey, for the respective corporation or equivalent supplier for that town, named by Bowden, to create the regional totals.
[499] Bowden, 'The Consumer Durables Revolution', p.57.

appliances simply replaced servants for some and made housework more productive for others but housework remained, at least, as time consuming with less help from husbands and children.[500] Cowan, following long term trends, suggested that very little changed even after the introduction of electricity into homes because it simply raised the expected standards of cleanliness for the home and its occupants.[501] Given that people tended to purchase time-consuming appliances first, the idea of time saving appliances may have seemed more attractive later as new ways to spend leisure became available. The change was gradual, and appliances, particularly time-saving ones, took decades to be integrated into everyday life. Old habits, traditional ways and days of working also took decades to change. For example, Monday remained 'wash day' and increases for load on such days for washing machines were identified by electricity suppliers and the Grid; an engineer recalled, 'Heavy cloud or cold weather would always give us a heavy afternoon peak, but for some reason we were getting one on Mondays, even when it was fine. Then I realised what was happening. Monday was the universal wash day'.[502]

Although change was gradual, connecting homes to electricity continued. Energy available at the flick of a switch negated the need to tend coal fires allowing greater freedom for its occupants. Combined with other factors, this presented opportunity for greater equality between men and women within the home and outside of it, in workplaces and for leisure pursuits.

For the working classes, even electricity for lighting at home was still expensive because of the costs to become connected. Wiring a home was costly even if the supplier reduced unit costs, and for tenanted properties it was usually the landlord who decided on installation. Over time, prices slowly reduced but

---

[500] J. Vanek, 'Time spent in Housework', *Scientific American,* (1974), pp.116-120.

[501] R. Cowan, *More work for mother: The ironies of household technology from the open hearth to the microwave* (New York, 2003), p.89 and as a recurring theme.

[502] Cochrane, *Power to the people*, pp. 24-25.

it was the introduction of assisted wiring schemes that provided real progress for suppliers and consumers. These schemes enabled wiring installations for which payments were spread over time, added to electricity bills. Bowden, however, suggested that while these credit schemes helped to overcome market inertia 'the important consideration was the relative costs of using electricity against gas in the home'.[503] However, for consumers, it was the local electrical supplier who determined if, and when such schemes were available and the costs and terms of the scheme. Scott reported that 'The proportion of electrical undertakings operating assisted wiring schemes rose from a third in 1929 to eighty-four per cent in 1936, with repayment periods as long as ten or even fifteen years'.[504]

A previous employee of Lyme Regis Electrical Supply Company recalled, 'In Lyme Regis there was an assisted wiring scheme. For five shillings, you could get your house connected and get four lights'. He explained that his mother paid seven and sixpence to have an extra light on the stairs with a two-way switch.[505] In Bath, electricity was supplied by the local authority and assisted wiring was set up in 1928 in response to consumer demand. A scheme for private residences (but not new properties) rated up to £22 per annum was instigated and provided for between six and twelve lighting points. The consumer paid the net cost of installation and an additional ten percent. Ten percent was paid in advance, then spread over a further eleven quarterly payments. A two-way switch for the landing or bedroom, or a plug socket could be installed for an additional fee.[506] Whilst different schemes were offered by different supply companies the monopolistic nature of supply meant that consumers were limited to the

---

[503] Bowden, S., 'Credit facilities and the growth of consumer demand for electric appliances in the 1930s', *Business History* (1990), 32, pp.52-75.
[504] Scott, The Market Makers, p.194.
[505] M. R. Greene, 'Electric Lyme', Supplement to the Hist Elec News, (August 2003), SWEHS accessed via http://emep.worldonline.co.uk/SWEHS/docs/news24su.html.
[506] W.E. Eyles, 'Electricity in Bath, 1890-1974' Supplement to the Hist Elec News, (August 2006) SWEHS accessed via http://www.swehs.co.uk/tactive/prnt/S33.pdf.

supplier licensed for their area for such schemes. The Electricity Commissioners explored supply company sales in 1934, reporting that 479 of the 625 undertakings offered assisted wiring schemes, that one or more showrooms existed in 472 undertakings and 360 undertakings carried out house-to-house canvassing.[507]

Most people who shared their electricity memories during this work remembered their first experiences as being between the 1930s and ‘50s although those from rural areas at the time reported theirs in the 1950s or later. Figure 78 shows two images provided are from a farm just outside Bideford, where there had been an electricity supplier since 1923 but supply did not reach the farm. However, the farmer installed a generator outside, in the barn. The first image shows the family outside their home and a piece of string (visible within the ellipse) connected the generator to a bedroom, through the window to start it first thing in the morning and turn it off last thing at night to employ electric lighting in the house. The second photograph, from 1964 shows one of the children helping to dig the hole for the telegraph pole that would finally connect them to the public supply. It was remembered as a momentous occasion, providing perspective on how long it took for public supply to reach rural locations despite being within a licenced supply area. Connection was not guaranteed though, even three decades after the Grid was introduction distribution mains were still primarily limited to very urbanised areas

[507] Elec. Comms., *Annual Report*, 15, p.9.

FIGURE 78 STRING CONNECTION TO A GENERATOR.[508]

Trentmann and Carlson-Hyslop considered 'the evolution of energy demand by examining the interplay between provision and use in public housing in the middle of the twentieth century' as a way of exploring energy infrastructure and tenants use of utilities. In many ways their work at the individual estate and house scale reflects the wider process of adoption of electricity into homes and everyday life nationally. They demonstrate that tenants 'were neither passive nor always compliant in the transition from coal or coke to gas and electricity' and refer to the way in which 'fixed domestic technologies such as cookers and boilers were important mediators between people, practices and the fuels they used, and these exercised resilience to change'.[509] This echoes the national picture of change, where acceptance of this new technology was mediated through the pylons, wires and power stations affecting the whole environment in which people lived and worked. This was an intimate change in the way people functioned in the privacy of their homes. Electricity did not replace other energy sources but

[508] Source: M. Weaver, Tennacott Farm Dairy.
[509] Trentmann and Carlsson-Hyslop, 'The Evolution of Energy Demand in Britain', p.31-32.

found its place alongside them in a process of negotiation between homeowners, tenants, local and national government, experts and lobby groups. Whilst much of the twentieth century saw availability and accessibility of electricity negotiated, but debates continue, emerging in the late twentieth century over which fuels should be used to generate it, and their environmental impacts.

Entrepreneurs and Electrical Supply

Although everyday life in Britain is now reliant on electricity, alongside many other 'developed' countries, its introduction relied on the efforts of pioneering entrepreneurial individuals. Such individuals took financial and personal risks proving that public electric supply was a viable technological and commercial possibility. The South-West had a handful of such pioneers, enthusiasts Massingham and Heath, alongside professionals such as Preece, who after being employed by The Bristol Corporation went on to the highly prestigious role of chief electrician to the Post Office. Such entrepreneurs brought personal connections to, what they saw, as a new and exciting technology from its infancy, believing electricity would become essential for everyday life.

Massingham could be described as an 'electricity evangelist'.[510] He inherited, and ran, his family's boot and shoe shops. He was deeply inspired by a demonstration of electrical lighting at Bristol Cathedral in 1878. He later recalled, 'That caused me to become one of the early pioneers, owing to my ardent advocacy of a pure light for our homes, and my determination to bring about a system of house to

[510] Weightman, *Children of Light*, pp.118-127, uses evangelism terminology in his chapter entitled 'Electrical Messiahs'.

house lighting by means of electricity, in which I was successful, although at a considerable loss to myself'.[511]

With his enthusiasm for electricity he hired the same generating equipment used to light Bristol Cathedral and set up a demonstration in Taunton. After this proved successful he founded The Taunton Electric Light Company supplying electric street lighting from 1886, generated in his shop in Fire Street. The Castle Hotel became its first private customer in 1887. In 1888 he approached the Bath Corporation with a scheme for electric street lighting and agreed that he would apply for a licence which the corporation could take over after seven years, less time than the legal compulsory purchase period. To fulfil the contract he formed the Bath Electric Light Company began lighting the city in 1890. Just three lamps were placed opposite the junctions of incoming streets, and as the electric carbon arc lamps on 30ft standards were brighter than their gas predecessors they provided sufficient light. Electric lights were approximately twenty times brighter than their gas equivalents and must have made a considerable difference.[512] The Electric Lighting Committee of the council was formed in 1888 to oversee electricity and it took over this electric lighting in 1897 and by 1898 new lamps, bearing the city's coat of arms, replacing the first installation.

Lamb reported:

> Mr. Massingham, being a very persuasive man, coerced the Exeter City Council to give him permission to conduct a much larger demonstration in the form of an experimental system of supply to the central area of the City. Overhead wires on poles were then erected in High Street, Queen Street and St. Sidwells to supply 11 traders and street lamps using arc lamps.[513]

---

511 Massingham, *The Past and Future Developments of Electricity*, p.22.
512 J. Manco, 'The Hub of the Circus, A history of the streetscape of the circus' (Planning Services, Bath and North East Somerset Council, Bath, 2004), pp.27-35.
513 P. Lamb, 'Early Days of Electricity in Exeter', (Exeter,2014), p.1.

This Exeter demonstration resulted in Massingham forming the Exeter Electric Light Company after garnering local support in 1889 and which the local authority bought from him in 1896. Massingham also approached The Electric Lighting Committee for Bristol with a plan to deliver electric lighting but they were not persuaded. The Bristol Corporation, on the advice of electrical engineers waited before they provided a very successful supply from 1893, seven years after supplies began in the South-West.

The rapid expansion of the companies Massingham founded, required significant capital demand to meet demand increases, and by 1901 he was bankrupt and in poor health. However, he was a resilient man and later gave lectures on his experience as a pioneer of electricity and his vision for its future. He was the star guest at the Taunton Undertakings in 1935, celebrating fifty years from when he founded it.[514] *The Times* reported on this anniversary celebration, explaining that public lighting had been so successful that a 'deputation' from London visited to 'examine and report'. Afterwards, the previously unsuccessful attempts to light London's streets were rectified, were then lit by electric lighting too, suggesting that Massingham's work was successful and valued beyond the South-West.[515]

Once the viability of electrical supply had been proven, opportunist entrepreneurs with financial strength recognised its potential profitability. These were larger firms such as Christy Brothers and Company, from Chelmsford, founded in 1883 as consulting and contracting engineers. Christy was eighteen when he founded the company, encouraged by Crompton after serving his apprenticeship at Crompton's Works. Originally the company installed electrical systems for small towns which led them to Bude in 1908, after which they began taking large interests in many South-West electricity

[514] P. Lamb, 'The Massingham Family in the Bristol Area', Hist Elec Article, No.S20 (2002) accessed via http://www.swehs.co.uk/tactive/_S20-2.html., p.2.
[515] Electric Lighting Pioneer', *The Times* (London, 1935), 47246, p.16.

companies.[516] By 1934 this included Aldeborough, Burnham, Culm Valley, Holsworthy, Mid-Somerset and North-Somerset, and the West Devon Electric Supply Company, which meant they had interests in both generation and supply.

Lodge was an active member of SWEHS. He began working for Christy Brothers at the North Somerset Company in 1932. He was seconded to a travelling showroom, to attend shows and give appliance demonstrations, with most mornings dedicated to 'obtaining electrical contracts for wiring and installation work'.[517] Christy Brothers left a small green energy legacy at Mary Tavy, where they purchased the supply rights of the West Devon Mining and Power Company in 1932, which included a hydro-electric generating plant which remained in the generating plant. A second hydro-electric plant was installed on the same river in 1936, and a further one installed at Tavistock. The plant at Mary Tavy still serves 1700 houses for South West Water.[518]

When discussing the sales techniques they employed, Lodge explained that 'voltage and copper wire were in short supply' and that finding potential sales, 'where to go in and where to stay away was important local knowledge', and suggested;

> Engineers today tend to think of the rural development as that of the 50s and 60s, but it was the private companies who brought the first supplies to rural areas in the 1930s. The 'plums' of the big revenue earnings against capital expenditure had been picked off by the various city and town authorities. It was therefore left to the energetic private enterprises to develop and extend power lines under bulk purchase arrangements from the large city undertakings.[519]

---

[516] P. Lamb, and E. Lodge, 'Christy Brothers in the South West', Supplement to Hist Elec News No.15, (2000) accessed via http://emep.worldonline.co.uk/SWEHS/docs/news15su.html, p.1.
[517] *Ibid*, p.2.
[518] South West Water, 'Mary Tavy Power Station: Green Energy from Dartmoor' (South West Water, ref. 321010, 2012).
[519] Lamb and Lodge, 'Christy Brothers in the South West', p.2.

London-based Whitehall Securities, a national finance company also saw this potential working with Purves, who with his brother were consulting engineers based in Exeter. They had interests in several electrical supply companies and were instigators of electricity in the South-West from the turn of the 20th century. Purves was described by Grant as ‘a well-known figure in Devon and Somerset and had promoted electricity Special Orders in Teignmouth, South Molton, Bampton and elsewhere’.[520] Grant began his career at Siemens and the British Traction Co. and spent time as an international consultant. During WWI he worked for the Ministry of Munitions before returning to his previous employers. He then moved to Whitehall Securities as chief electrical engineer, and later, manager of the engineering department.[521] It was in this last role that Grant met Purves, in 1928, through the Electricity Commissioner, Snell. Their business relationship began as Whitehall Securities provided the finance for the amalgamation of electrical supply companies under the umbrella of The West of England Electrical Supply Company. [522] Grant described the inspection carried out in 1928, by Snell for the Electricity Commissioners to grant its initial permissions, reporting;

> The inspection disclosed that only 20 years ago the state of electricity supply in the area was absolutely pathetic. In nearly all the small towns the supply was direct current from a small and often antiquated generating plant … Units sold per head per annum were generally of the order of 20, and no attempt had been made to reach out into the country beyond… except in a very limited way.[523]

---

[520] S. Grant, ‘West of England Electricity’, Supplement to Hist Elec, Article, No S26, (2004) accessed via http://emep.worldonline.co.uk/SWEHS/docs/news26su.html.
[521] ‘Obituary Notice, 1950, Selwyn Grant OBE’, Institute for Electrical Engineering accessed via http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=5320467.
[522] Grant, ‘West of England Electricity’, p.1.
[523] *Ibid*, p.2.

The necessary negotiations for the amalgamation included the Exeter Corporation, who provided 'bulk supply' and deals made with Christy Brothers, who agreed to sell them specific companies in return for being the sole contractor to construct the new transmission system.[524] In 1929 the scheme's estimated cost of £900,000 which was approved by the chairman of Whitehall Securities because he saw that profits could be made in the long-term, and work began the following year.

To bolster their investment and increase demand they hired out electric cookers at a rate which included maintenance and service costs and offered a preferential cost per unit of electricity consumed for a normal sized cooker. Other incentives promoting demand included low rates (1d per unit) for water heating with thermal storage which was not very successful because it was still more expensive than solid fuel boilers.

For homes which chose assisted wiring schemes usually two possible tariffs were available, a slot meter or a two-part tariff. It was possible for consumers to swap between the two tariffs and as more money became less scarce the second scheme was favoured. WW2 slowed domestic development because consumption was discouraged in favour of industry and its aftermath brought material shortages but an increase in electrical units sold. Grant suggested, 'Partly this is due to the permanent increase in population, and partly due to the greater use of electricity owing to the fuel shortage'.[525] This suggests that there was a disconnect between fuel and electricity as increasing electricity usage meant using greater volumes of coal, one of the fuels which needed conserving. His final paragraph noted that, in 1948, demand for electricity was not yet satisfied.[526]

---

[524] Lamb and Lodge, 'Christy Brothers in the South West', p.1.
[525] Grant, 'West of England Electricity', p.7.
[526] *Ibid.*, p.8.

These were opportunities that entrepreneurs and financiers could exploit, either using the opportunity to commoditise new technology, or profiting from investment to deliver it as widely as possible when it proved successful. It should, however, be noted that Christy Brothers and Whitehall Securities were named by the Electricity Commissioners in their investigation of company ownership and structure in 1935, discussed earlier. Whilst not accused of anything outright, certain practices such as contract arrangements and relationships between supply companies and power companies under the same owners, were raised.

The Grid scheme's introduction to the South-West began in January 1930 with an article in local newspapers announcing its details. Under the title 'Electrifying the West' it reported that the scheme would cover 17,000 square miles, cost over £6 million and result in capital savings of precisely £1,383,506. The scheme incorporated the South West of England and South Wales and had six selected generating stations with a further two which would be constructed, one in Southampton and one in South Wales. A further eleven stations would be available for connection if needed, and five needed to be converted to meet the standard AC, 240v, 50hz supply to ensure that interconnectivity was sufficient to meet the needs of the area.[527]

By 1956, the South Western Electricity Board (SWEB) comprised Devon, Cornwall and Isles of Scilly, nearly the whole of Somerset, a small part of Dorset and the city and county borough of Bristol and a small part of Gloucester. There was major industrial activity in Bristol, Plymouth and Exeter, with light industry in a few small towns. *Garcke's Manual* still reported 'progress', indicating that this was still a developing industry, and in fact, stated for SWEB that 1956 was the year in which the most engineering construction was carried out at any time in its existence hitherto. There were 393 miles of mains cable

[527] 'Electrifying the West', *The Western Morning News and Mercury* (Bristol, Jan, 1930), pp.2-3.

and a further 211 miles of cabling, and an additional 1,119 transformers. Demand for electricity continued to increase with commercial supplies growing by twenty seven percent and domestic and farm supplies by thirteen percent.[528]

A standard tariff was in place across the South West region by this time too but, it was still extremely complex, consisting of different tariffs for domestic, farm, industrial and commercial premises. Properties were assessed depending on their size and numbers of rooms, the prices per unit of electricity were reduced as the number of rooms increased. For example, the domestic tariff was 6d. per unit for an assessed number of primary units. This was fifty units for private dwellings of up to four rooms, sixty units for five to eight rooms or ninety units for more than nine rooms. The same number of units for the same size dwellings would then be 2.5d., and then 1d. for all additional units used per quarter. For a prepayment meter the first sixty units, regardless of the dwelling's size, were charged at an additional 0.5d. per unit. Assessable rooms included cloakrooms, closets, WCs and even sheds or greenhouses, even a folding partition in a room would be assessed as two rooms. Rooms did not have to be wired or even used to be included. Farm tariffs were similar except it was based on the volume of demand for the farm, the activity electricity was used for and the farmhouse was charged separately on a domestic tariff.[529] The industrial and commercial tariff more complex because it was demand dependent, involved service charges, and varied by time of the year and the time of day.

Alternative tariffs were available, including flat rates where lighting was charged at 6d. per unit, power, cooking and heating at 2.5-3d. per unit, and thermostatically controlled water heating at 1d. per unit. Each different usage had to be separately metered, and these rates were only available where the

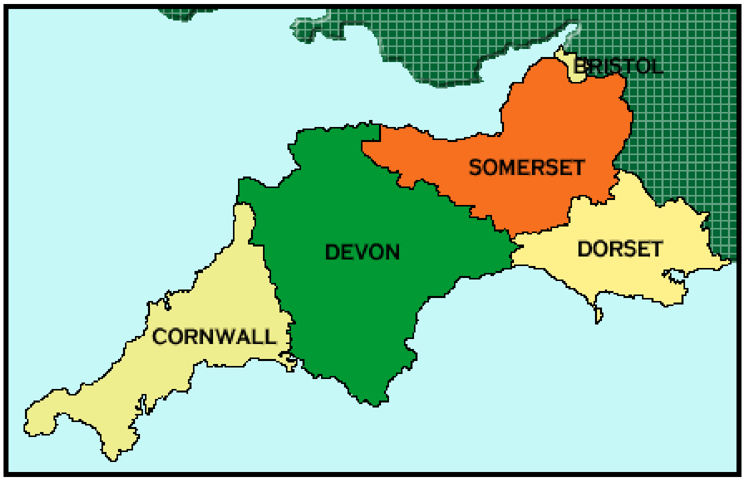
[528] Garcke, *Garcke's Manual*, 53, Entry for the South West Electricity Board (SWEB).
[529] *Ibid.*

property was supplied by municipal authorities before nationalisation. Whilst ownership might have been simplified and be entirely state owned, consumers still faced a bewildering set of costs and variables, although eventually, as electricity was finally standardised and accessible across the whole of the SWEB area, a standard tariff across properties and uses was adopted.[530]

[530] *Ibid.*

The South-West

FIGURE 79 COUNTIES OF CORNWALL, DEVON AND SOMERSET AND BRISTOL AREA



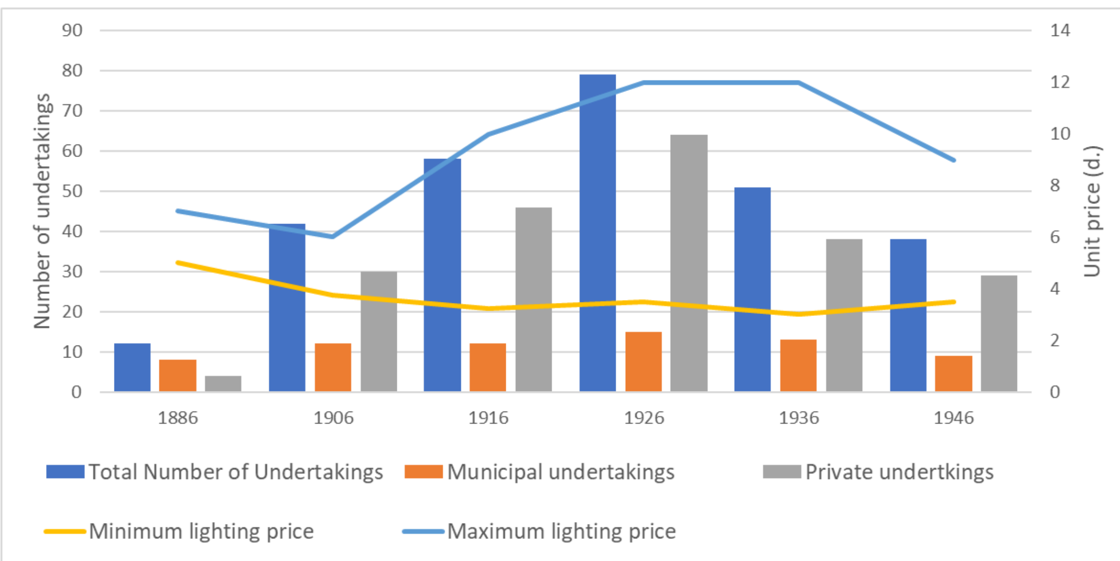
The final part of this chapter is a more systematic spatial and quantitative analysis of electrical development in the South-West which includes the counties of Cornwall, Somerset and Devon and the main conurbations of Bristol. The region includes some urban centres but remained rural in many parts. Electricity was supplied from the early 1880's by authorised and unauthorised suppliers.

Electricity Supply in the South West

There are two primary sources for this case study. Firstly, the electricity supply company entries from *Garcke's Manual,* which provide many variables including the units of electricity sold, consumer numbers and prices. Individual supply companies made voluntary returns to *Garcke's Manual* but did not necessarily submit all their information every year but over the period there are enough entries to make the data fairly robust. Over the sixty years it was published the information companies submitted evolved as the technology did. It provides a vast wealth of information for individual companies and national statistics over the period. Whilst there is no regional reporting in the manual, it is possible to create it which although time-consuming is straightforward, and can be analysed in GIS, as this study has done, collecting the available information for the companies in the South-West as described. The second source is from an unpublished paper supplied by Bloomfield who has also studied some of the supply companies in the South-West.

Figure 80 shows the growth and decline in the numbers of undertakers across the South West (LHS). It demonstrates the stability of local authority suppliers over the period, and it was the number of private companies which varied, supporting the idea that municipal suppliers were supplying their urban centres. Private suppliers were at their peak just before, and whilst the Grid was constructed whilst opportunity to profit from holding licenses was greatest. However, the reduction in supplier numbers was caused by smaller companies merging or being bought out, not closures.[531]

FIGURE 80 SUMMARY OF ELECTRICAL SUPPLY UNDERTAKERS IN THE SOUTH WEST.[532]



[531] Source: *Ibid*.
[532] Source: Garcke, *Garcke's Manual*, 1-46, Entries for Companies in the Devon, Cornwall, Somerset and Bristol.

Maximum and minimum lighting prices are included to show its variation across the region (RHS). Often the smaller operators charged 1s. or 12d. per unit of electric lighting, twice the price of some other suppliers. The highest prices were charged in the early 1920s because coal was scarce, and special orders, allowing undertakers to charge more than their first licences allowed, could be applied for to compensate for these scarcity issues and problems arising after WW1.

FIGURE 81 NUMBER OF CONSUMERS FOR ALL SUPPLIERS OVER TIME.[533]

---

[533] Source: *Ibid*.

Figure 81 shows number of suppliers in each of the years represented by the concentric circles, the size of each suppliers' block is proportional to the number of consumers each supplier had. This clearly demonstrates how the Bath Corporation (in the innermost ring) were the earliest established, but how the Bristol Corporation (dark green) had the most consumers dominating the other five rings. They supplied 120,893 consumers by 1946, almost a six-fold increase from the 20,234 consumers twenty years earlier. Growth rates slowed between 1936 and 1946 because of WW2 when domestic consumption was significantly curtailed to bolster industry. The Plymouth Corporation (pale green) was the next largest supplier after Bristol, followed by Exeter and Bath Corporations, having 49,761 and 34,187 consumers respectively. These suppliers were municipally owned and demonstrate the benefits of supplying urban centres, large populations living in a small area. The largest private company was The North Somerset Company which had 18,171 consumers reported in 1936 and not expanded further by 1946, likely because the population density was low, making new consumers too costly to reach, particularly with wartime conditions. The diagram demonstrates how the maximum number of suppliers were reached around 1926 and begin to reduce in 1936 and ’46.[534]

[534] Recording of consumers changed in the early 1950s, from ‘number of consumers’ to ‘number of households’, and this corresponds with a slight reduction in numbers seen during that time. This suggests that the earlier consumer numbers included more than one consumer per household or, more likely, multiple meters in each household. Separate meters were installed for each type of electrical use, lighting, cooking, heating or water heaters, for example, because different rates were charged for different uses dependent on the supplier. Therefore, increases in consumer numbers do not directly necessarily equate to additional households becoming connected to supply, it simply represents additional connections. There is no definition of what defines a consumer in the earlier recorded statistics but consumer numbers are recorded separately to connections which equate to each individual installation connection, (e.g. cookers, sockets, fires and meters).

Figure 82 Numbers of units generated, purchased and sold.[535]

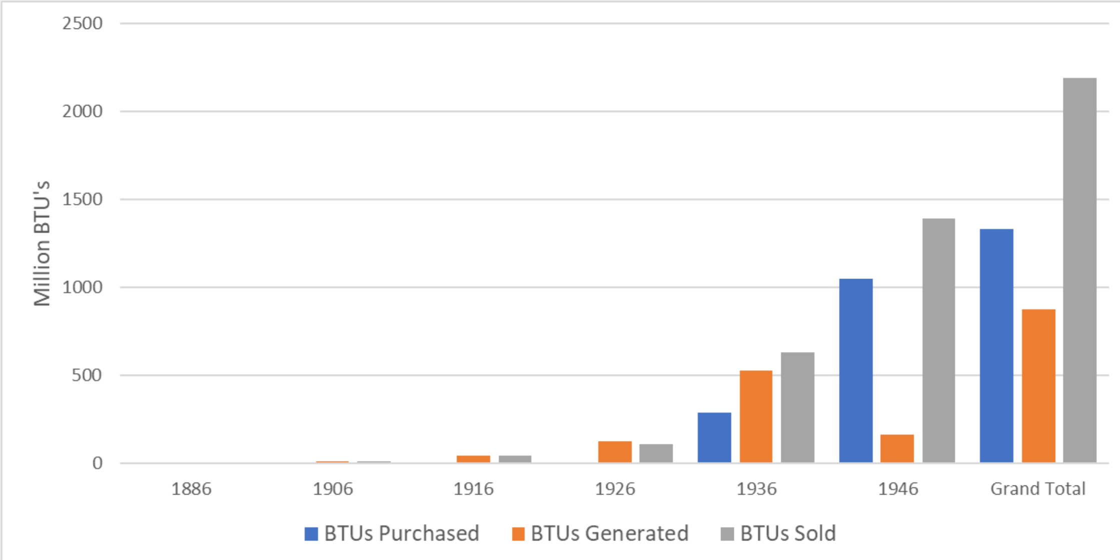


Figure 82 shows the changing pattern of generation, bulk supply and units sold to consumers. It shows that 'units purchased', by suppliers, only became important from 1936, as trading was becoming wholesale through the Grid and between suppliers. As explained in Chapter 2, suppliers could purchase units from the CEB and sell it on as bulk and cover their 'middleman' costs. The changeover to this wholesale market occurred between 1936 and 1946 for all undertakers and units purchased exceeded the number generated for non-selected stations. This was a crucial period when the Grid really affected organisation of generation and supply. Within the number of units generated in 1936 and 1946, some were sold to the CEB, others used within the power stations in which they were generated and the rest were sold to consumers.

[535] Source: *Ibid.*

FIGURE 83 AVERAGE PRICES FOR LIGHTING, POWER, HEATING AND COOKING.[536]

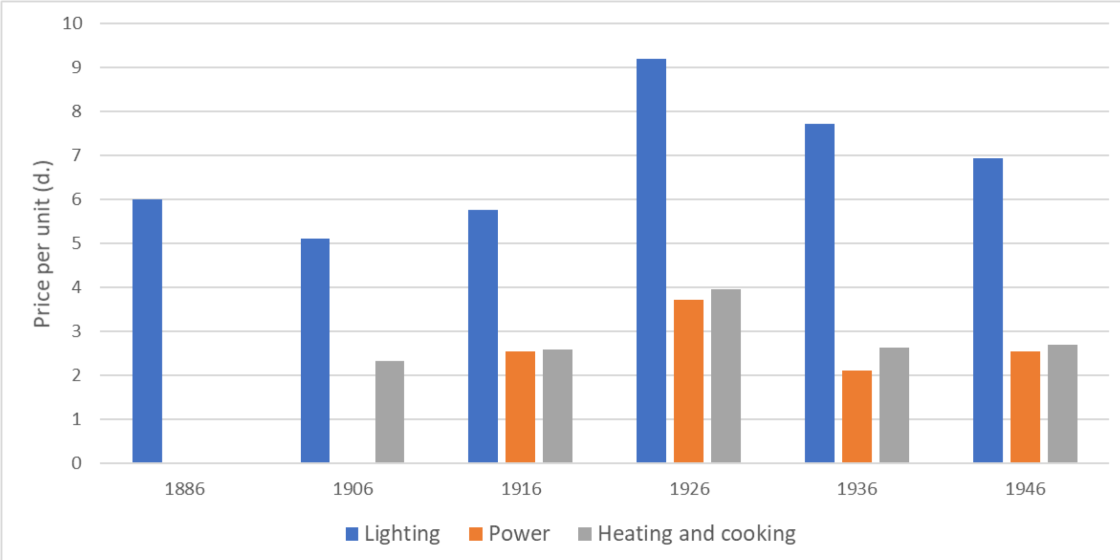


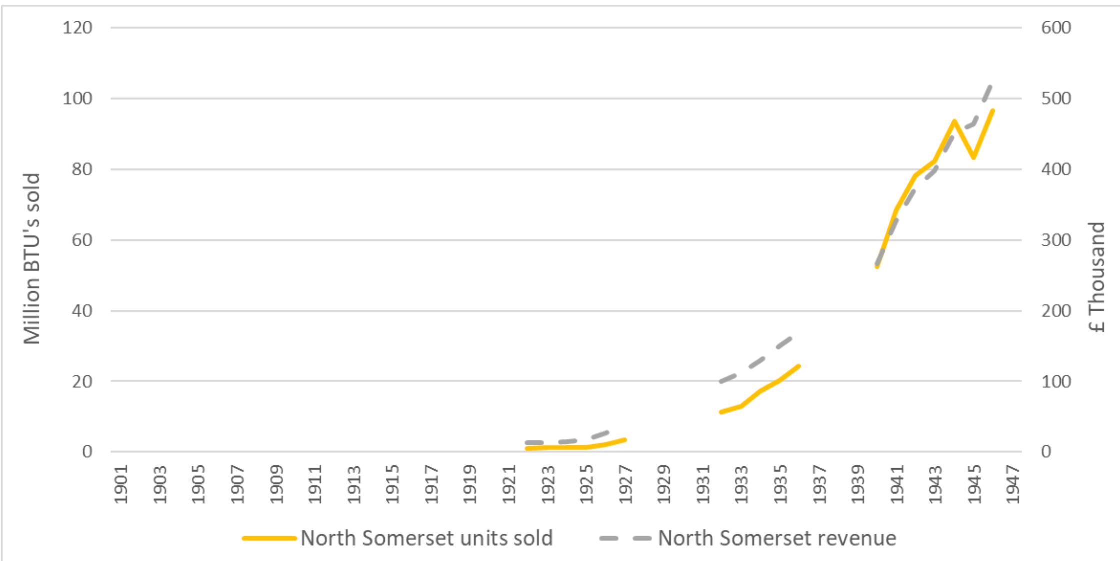
Figure 83 shows the average prices for the different uses. These increased in the 1920s because coal prices rose, but the accusation at the time was that the prices remained high for longer than necessary and savings from the Grid were not being passed on to consumers. However, permission was granted for suppliers to raise their maximum license prices to cover for the effects of WW1.

Figure 84 and 85 show average revenue per unit across all units sold. The solid lines show the revenue (RHS), and the dashed line the numbers of units sold (LHS). These are representative and for all suppliers the striking importance of the 1930s can be seen. The prices charged per unit varied to reflect how they affected the generating load. For example, lighting was more expensive per unit than power because power was preferential for load. These graphs also show how at the beginning of the period the cost/revenue per unit sold was favourable to the undertakers; it is not completely clear why except that in 1886 and 1906, most units sold were for the more expensive lighting. The graphs also demonstrate

[536] Source: *Ibid.*

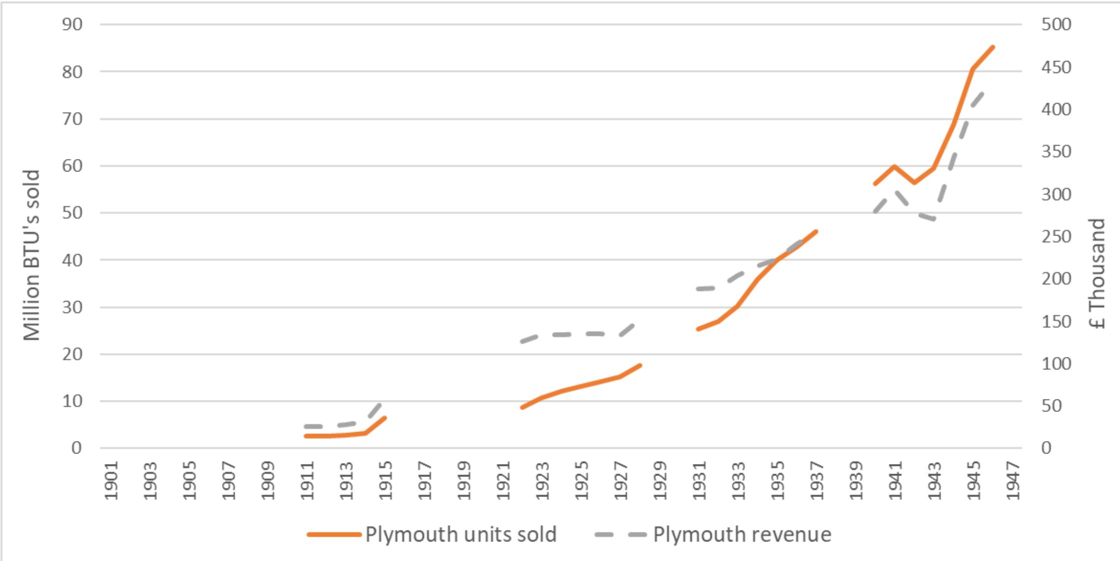
that cost/revenue was highest for all these undertakers between the early 1920s and late '30s. Later, as nationalisation approached, revenue received and number of units sold began to converge. Engineers and other people I have spoken to hold the opinion that in the later 1920s and '30s prices were kept artificially high after they were increased responding to coal shortages. Hannah also suggested that some companies were profiteering during this time.[537] The Electricity Commissioners also investigated the suppliers and whether they were making excess profits.[538]

FIGURE 84 UNITS SOLD AND REVENUE NORTH SOMERSET.[539]



[537] Hannah, Electricity before Nationalisation, pp.226-227.
[538] London, TNA, 'Memorandum by the Electricity Commissioners for the Committee on Electricity Distribution on the Control of Electricity Companies by Other Companies' POWE 13/95, pp. 7-14.
[539] Source: Garcke, *Garcke's Manual,* 1-46, Entries for North Somerset Supply Co.

FIGURE 85 UNITS SOLD AND REVENUE PLYMOUTH.[540]



Figures 86 to 88 show how gas, and coal prices changed over time amongst suppliers. The prices are not directly comparable because units for different fuel types provided different quantities of energy, however, they demonstrate how different fuels followed similar pricing patterns.[541] It must be remembered that the 1920 was a period of deflation and stagnation in growth which helps to explain the price increases between 1916 and 1926, as did the underlying coal prices which were also affected by strikes during this period.[542] There were slight rises, or stable prices between 1936 and 1946 in prices. Whilst coal and gas are cheaper per unit more fuel needs to be consumed to achieve the same results as

---

540 Source: Garcke, *Garcke's Manual,* 1-46, Entries for the Plymouth Corporation.

541 Gas and coal prices shown are per therm. for gas, and for coal the price for the volume of coal estimated to be required to generate 1 unit of electricity in that year. Sources: for gas prices, these are listed for the specific local authority area in Garcke's Manual. Coal Prices supplied by P. Warde.

542 In some companies there was a sliding scale of gas prices, with lighting prices being a little higher than gas for electricity, so an average has been taken. Electricity prices used are either the flat rate quoted by the tariff or derived by calculating the average between the top and bottom prices. The complex tariffs make this difficult but as close to a mean value between the highest and lowest values as possible has been calculated.

electricity to obtain the same brightness of lighting, or cooking heats, which were debated in the technical press.

FIGURE 86 GAS AND ELECTRICITY PRICES BRISTOL.[543]

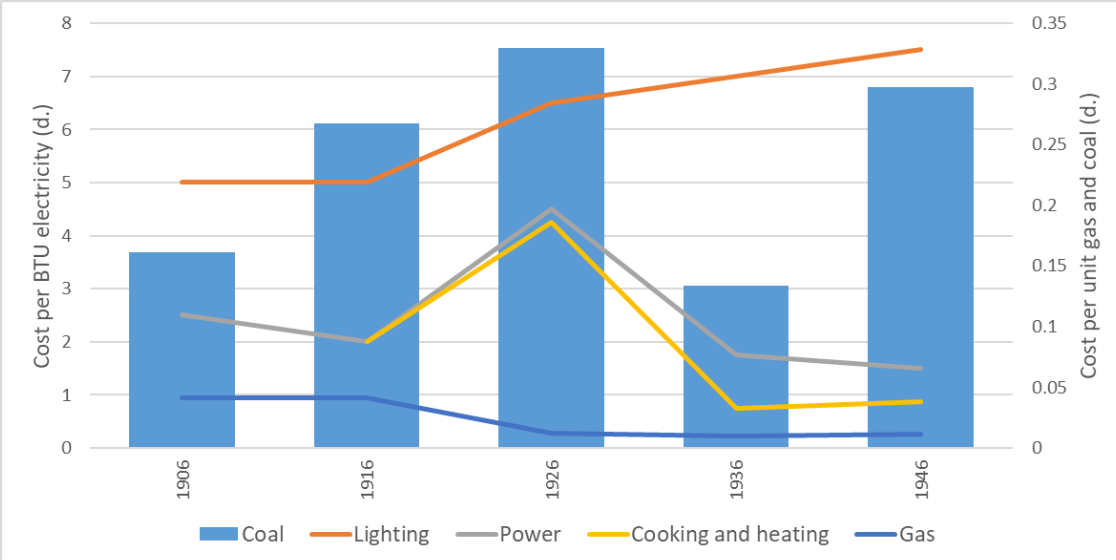
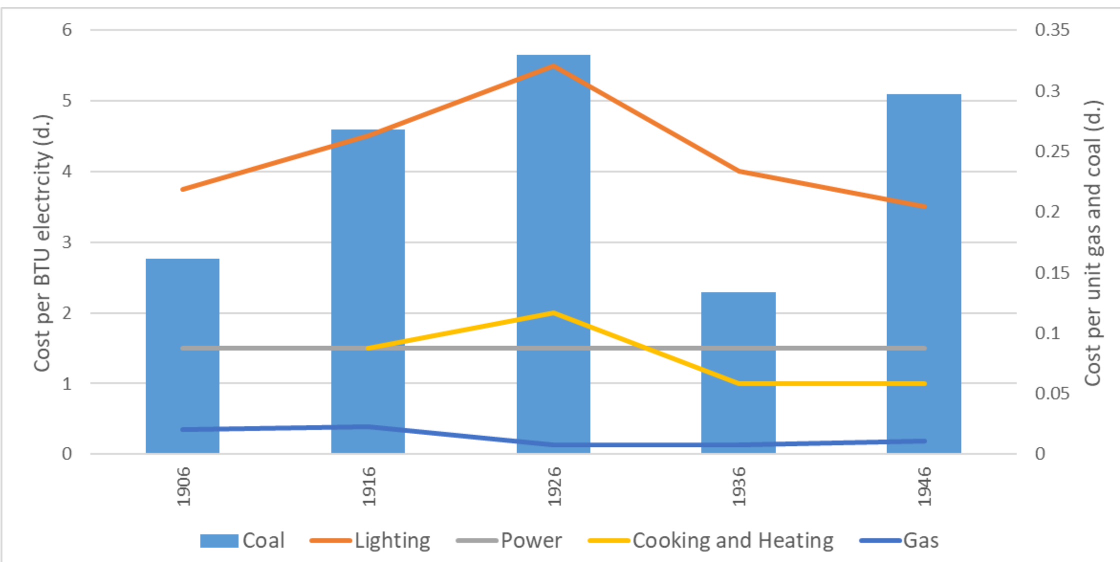


Figure 87 Gas and electricity prices Barnstaple.[544]



543 Source: Garcke, *Garcke's Manual,* 1-46, Entries for The Bristol Corporation.
544 Source: Garcke, *Garcke's Manual,* 1-46, Entries for The Barnstaple Corporation.

FIGURE 88 GAS AND ELECTRICITY PRICES EXETER.[545]

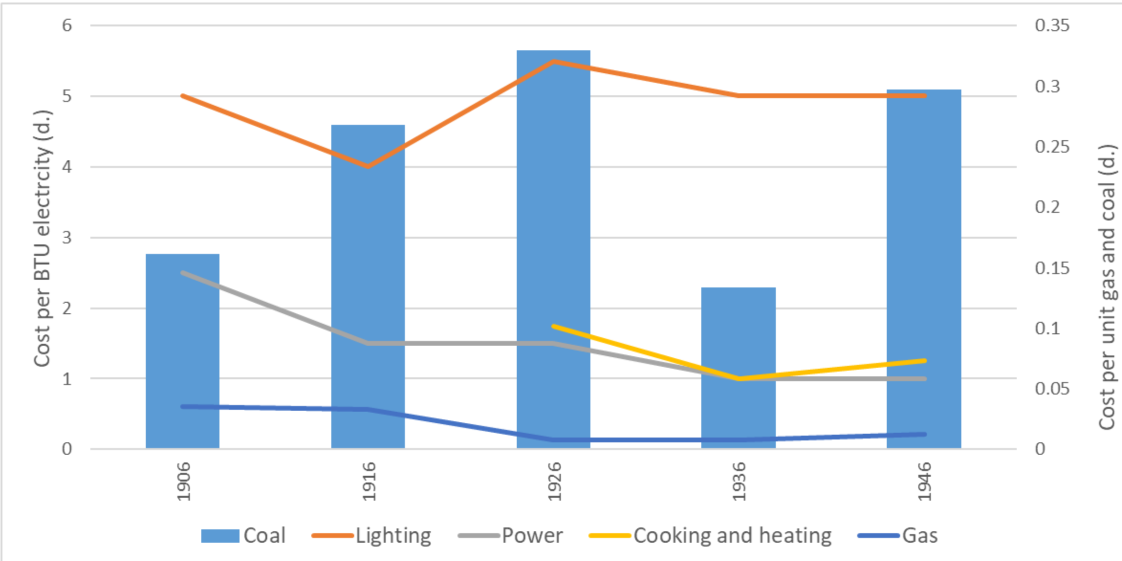


Figure 89 and Figure 90, using the same vertical axis values for comparability, show the prices charged for lighting, power, and cooking and heating. Although undertakings with selected stations charged slightly less in 1936 and 1946 compared to undertakings without selected stations it is likely to be because they supply more urban areas with high population densities making distribution cheaper. The highest price for lighting, 9d., was charged by North Somerset suppliers to 387,992 acres with a ratio of people to area of 0.35. The lowest price, 3.5d. was charged by Bristol and Taunton suppliers, people to area ratios of 7.63 and 0.58 respectively. Charging just slightly higher at 3.6d. was Plymouth, having a ratio of people per acre of 33.98. Power prices and heating and cooking charges were all between 1d. and 1.5d. except for North Somerset who charged 4d. This shows that the most rural undertaker, North Somerset, had the most expensive electricity for lighting, power heating and cooking but no correlation

545 Source: Garcke, *Garcke's Manual,*1-46, Entries for The Exeter Corporation.

is apparent between costs charged by the other undertakers and population densities within their territories (Table 14).

Figure 89 Prices for lighting, power, and heating and cooking for undertakings supplying the grid.[546]

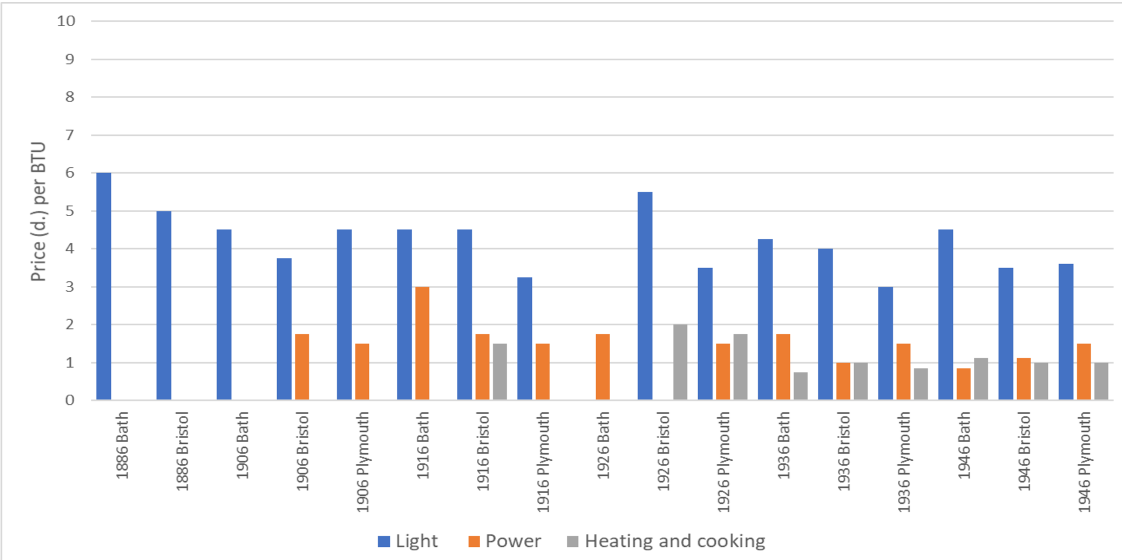
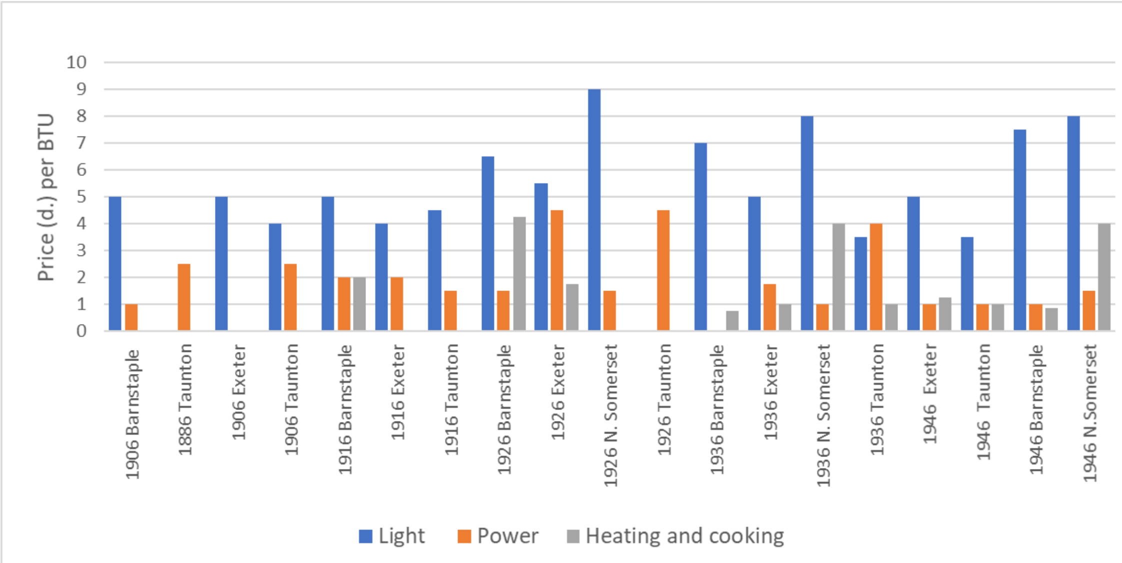


Figure 90 Prices for lighting, power, and Heating and cooking for undertakings not supplying the Grid.[547]

[546] Source: Source: Garcke, *Garcke's Manual*, 1-46, Entries for Companies in the Devon, Cornwall, Somerset and Bristol.
[547] Source: *Ibid.*



Consumers could do little about these differences because of the monopolistic nature of the electricity supply system: either purchasing from their local supplier or going without electricity. No-one I have spoken to during this work remembered electricity being available in the countryside before the 1940s. One recollection was of parents who built their own house and wired it ready for connection in 1936 but could not connect it to a supply until 1942. Another person reported that his mother, who was a nanny in London in 1929 worked in a house with electricity but returned to Norfolk to marry a farmer and could not be connected until 1958.

TABLE 14 POPULATION DENSITY AND PRICES 1946.[548]

Undertaker	Population	Acreage covered	People per Acre	Lighting Price (d)	Power Price (d)	Heating and cooking (d)
North Somerset	135,000	387,992	0.35	8	4	4
Taunton	42,039	73,109	0.58	3.5	1	1

548 Source: *Ibid.*

Exeter	80,500	26,000	3.10	5	1	1.25
Barnstaple	14,700	4,000	3.68	7.5	1.5	0.875
Bath	81,870	16,256	5.04	4.5	1.125	1.125
Bristol	489,393	63,987	7.65	3.5	1.5	1
Plymouth	206,400	6,075	33.98	3.6	1	1

Domestic electrification took tens of years and was, for many of these what today would be called a postcode lottery because of its monopolistic nature. It was clearly sought after, so accessibility and affordability mattered. Warburton wrote about the 'walk-over' surveys instigated to consider pole positions on the ground intended to make wayleave permissions easier to obtain to expand distribution networks but explained that 'Pole positions were irrelevant when a land owner desperately wanted a supply, but once supplied, the 33kV pole [distribution network] was unwanted'.[549]

It was after the CEB was succeeded by the BEA that real progress was made towards universal supply in rural areas resulting from the 1953 Mortonhampstead Agreement. It was estimated, at the time, that the South West Electricity Board (SWEB) had forty-two percent of the population in their area had no electricity access, including large areas of West Devon, Exmoor, Dartmoor, the Quantocks and Mendips.[550] Even before the Mortonhampstead agreement, SWEB had devised a specific scheme for rural consumers. Rather than requiring a twenty percent return on invested capital invested per property, usually expected for hire purchase schemes, they looked for this rate of return on whole

[549] G. Warburton, 'The History of SWEBs Electrification', HistElec Article, No. S17, (2001) accessed via http://emep.worldonline.co.uk/SWEHS/docs/news17su.html, p.4.
[550] Abell and Meadows, 'Electrification of the Countryside' and Warburton, 'The History of SWEB's Electrification', p.5.

schemes. In roughly five years this added distribution to 5,000 farms and 50,000 other rural properties and SWEB reached their rural connection target of eighty-five percent of farms and ninety-three percent of rural properties four years ahead of time.[551]

[551] Warburton, 'The History of SWEBs Electrification', p.4.

Mapping the Electrification of the South West

The South-West in 1912

Table 15 Electricity Suppliers c.1912.[552]

Local Authority Suppliers	Date Supply Began
Barnstaple	1903
Devonport	1901
Exeter	1889
Plymouth	1899
Torquay	1898
Private Company Suppliers	
Braunton (non-statutory supplier)	1909
Chagford (non-statutory supplier)	1891
Dartmouth	1902
Dawlish	1911
Exmouth	1905
Holsworthy	1910
Ilfracombe	1903
Lynton and Lynmouth (non-statutory supplier)	1890
Newton Abbott	1902
Paignton	1909
Topsham	1907

[552] Source: Adapted from Bloomfield, 'Notes for the Study of Regional and Local Electricity Systems in Britain' 2014.

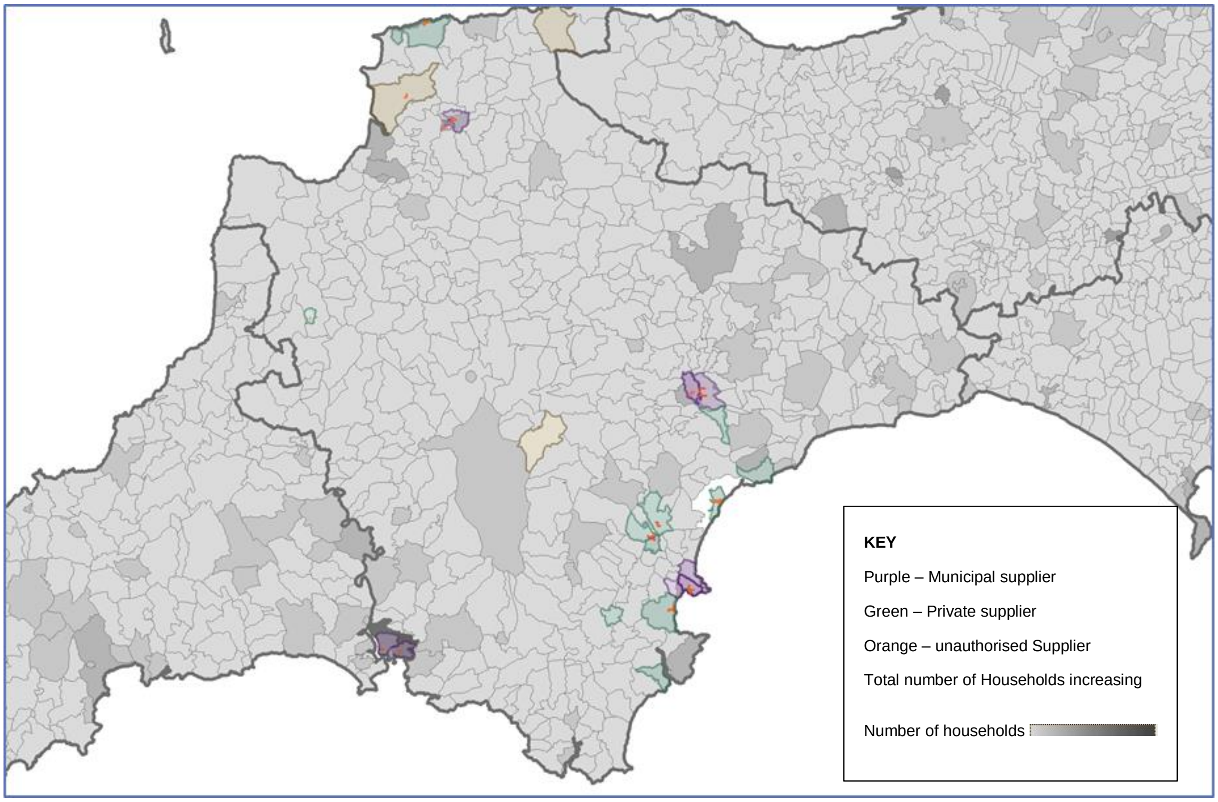
Totnes	1904

Although supply began in the 1880s the coverage of the companies was so sparse that I have chosen to begin mapping from 1912 when the following electrical supply companies were operating.[553]

Figure 91 shows the distribution of electrical supply companies *circa* 1912 with total household numbers. This demonstrates that the number of households with potential to be supplied was important because supply was generally provided where household densities were highest. The distribution of companies along the coasts is obvious and Figure 92 and 93 show this in greater detail.

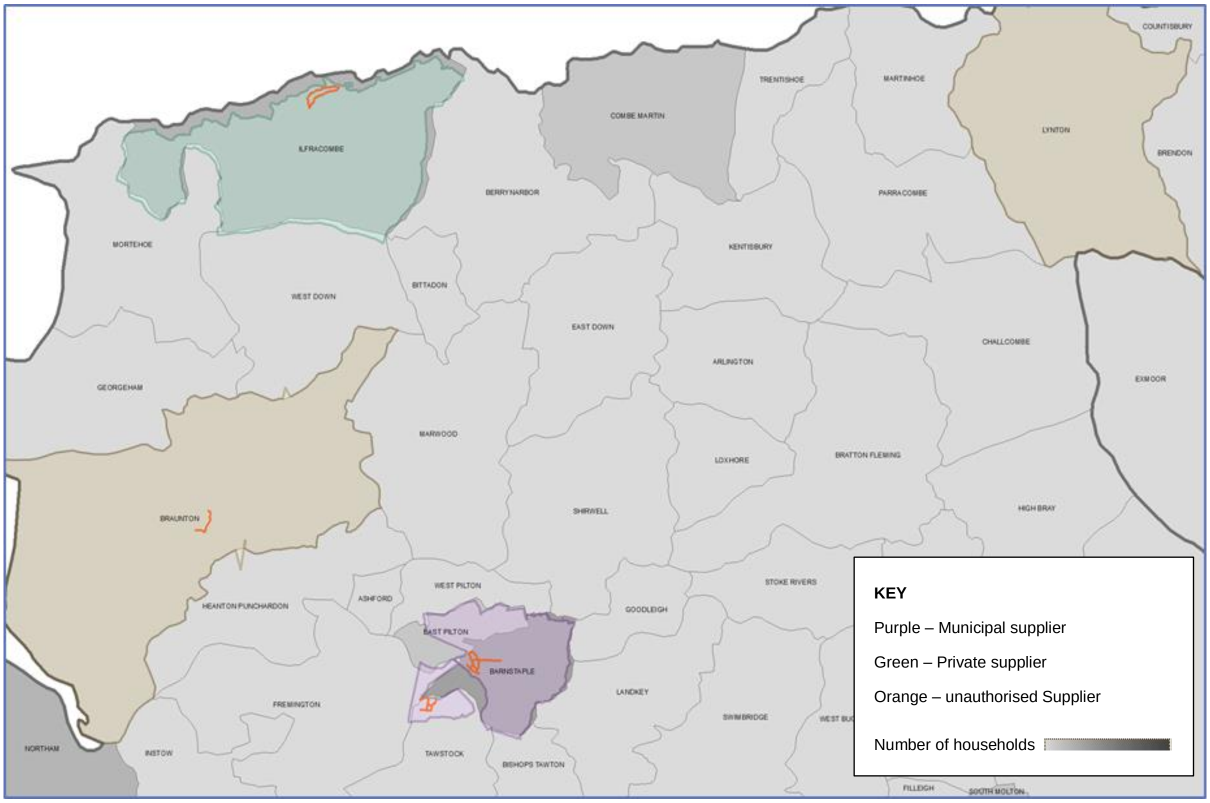
[553] Before presenting the results of the mapping it is important to explain the data sources that have been used. The maps are primarily of Devon, which had the greatest number of electrical supply companies in the region and is the largest of the counties studied. In Britain the country's administrative areas, moving from the smallest to largest extent, are parishes, unitary authorities and/or local authorities (historically sometimes called municipalities) and counties. The electricity company applications that were submitted to The Board of Trade before 1919, and post-1919 to the Electricity Commissioners, were primarily based on parish boundaries within the larger administrative area in which they would operate. In the late 1910s this began to cross county boundaries as some companies began to interconnect their supply. The census data on which the additional data depends was collected every ten years and aggregated results of this data are made available at different administrative geographies. For meaningful information, particularly at the early stages of development, this needs to be parish data as many companies were only supplying a single parish. Later, as territories became larger, unitary authority data can be used.

FIGURE 91 DISTRIBUTION OF ELECTRICAL SUPPLY COMPANIES C.1912.



The necessity of water for generation has been discussed and the larger the power stations the more water was necessary. Other logistical considerations included accommodation of heavy plant and transportation and storage of coal, the primary fuel source for this period. In the early period coal and water volumes for the small volumes of electricity generated for local distribution were not prohibitive to placing generating stations where it was convenient for distribution to consumers, reducing the need for lengthy mains cables. Distribution networks and generating stations became larger as consumers and their consumption increased from the 1920s. As Devon and the South-West had an abundance of rivers, locating generating stations less restricted than it might be in other parts of Britain.

Figure 92 Electrical supply companies in North Devon c 1912.



In North Devon there were two unauthorised suppliers, a municipal and a private company. It is difficult to determine why they located where they did. Ilfracombe had a high household density, as did Barnstaple, but other areas, such as Coombe Martin, had similar household densities but no supply.

In South-West Devon, well known for its tourism, a greater number of private companies provided supply suggesting that this it likely had potential to be profitable. The resort of Torquay, for example, brought high social status visitors and electricity might have been expected whilst visiting. For others without electricity in their homes it was a novelty that would enhance the holiday experience. Both public lighting and some hotels marketed electricity as an attraction; most consumers in this area, at this time were traders of some description.

Torquay's growth as a resort began with harbour development in the early nineteenth century and it remained a focal point, especially for tourists arriving by sea. During subsequent development the commercial heart of the town grew back from the harbour. It is not surprising that the streets in which electricity mains were laid surrounded the harbour area and hotel locations, as shown in

Figure 94. This further supports the idea that, at least in the South-West, supply was influenced by the main economic activity of the area, tourism, which promoted electricity to attract more visitors, preferably wealthy ones.

Another interesting area comprises the parishes of Devonport, East Stonehouse and Plymouth which were inextricably linked to Britain's naval history having a large dockyard in Plymouth. There was dense urban population making it an ideal target for early supplies of electrical power.

FIGURE 93 ELECTRICAL SUPPLY COMPANIES ON THE SOUTH WEST DEVON COAST C 1912.

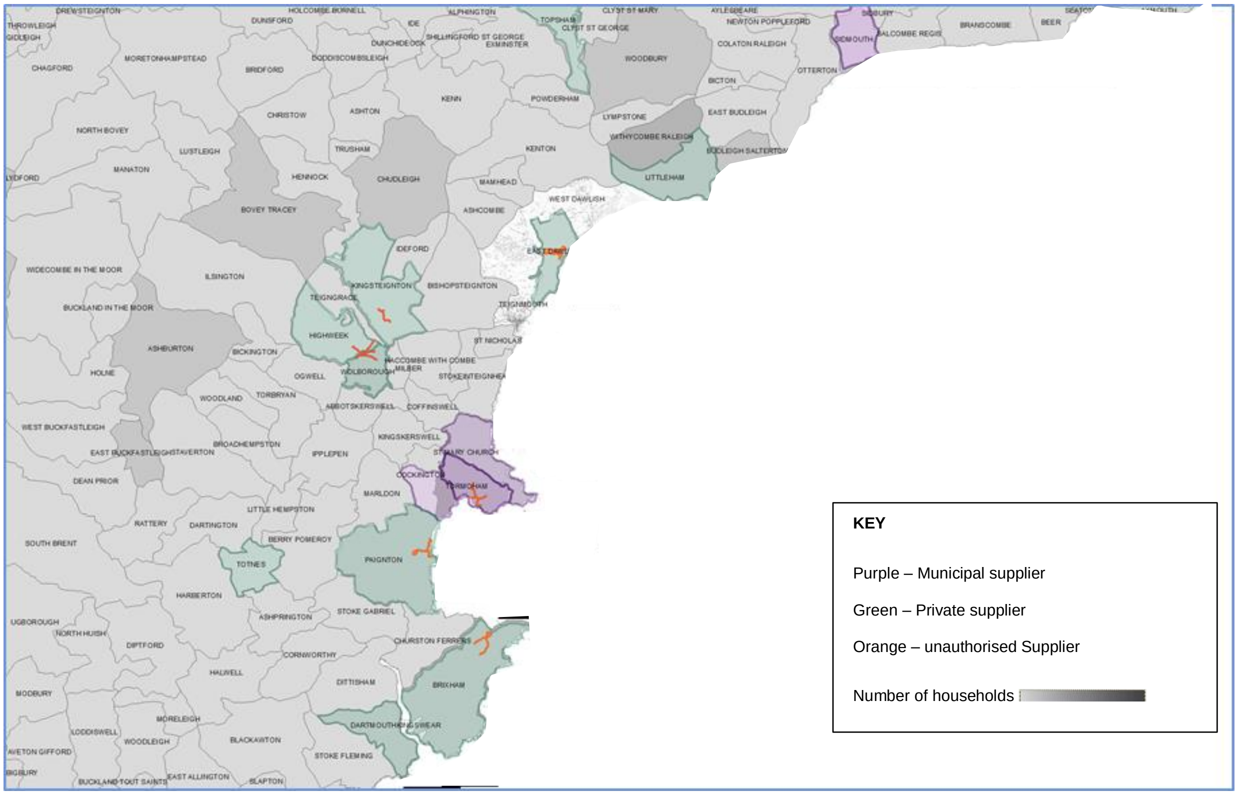
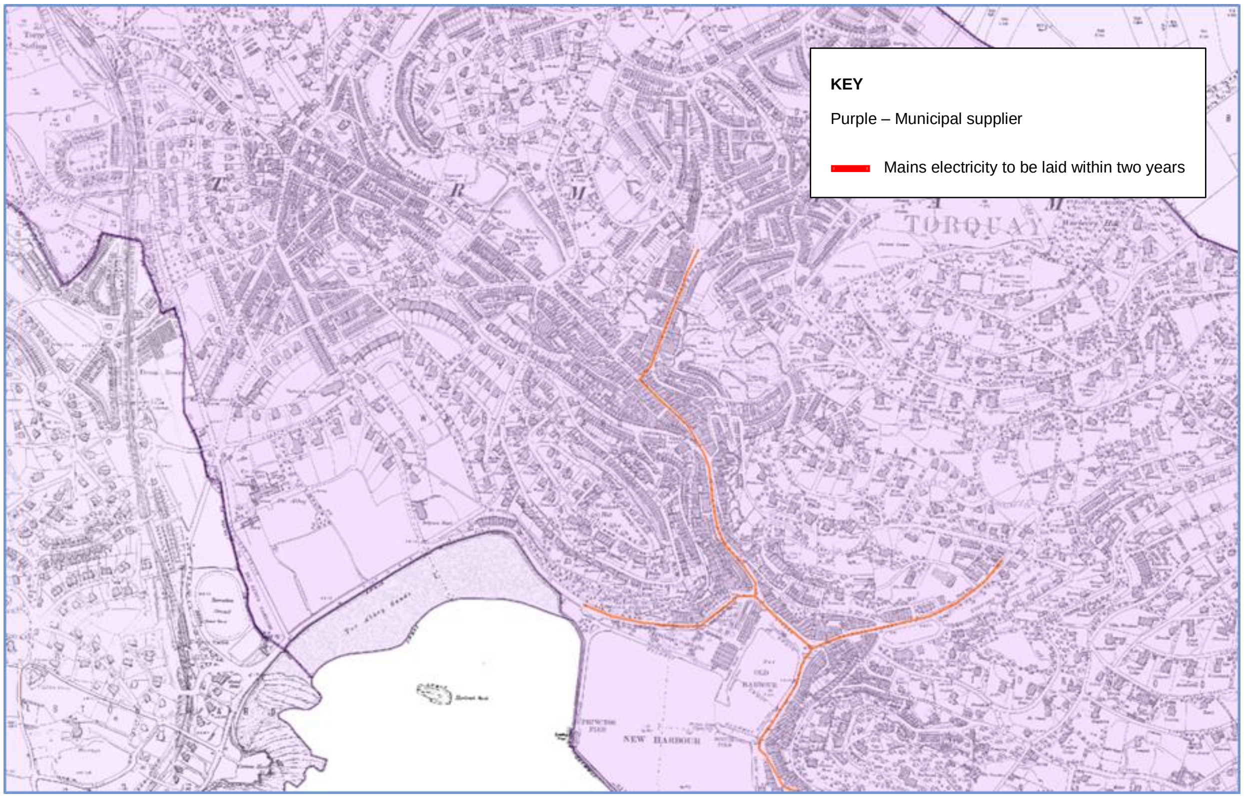


FIGURE 94 TORQUAY MAINS TO BE LAID AROUND THE HARBOUR.



As early as 1882 companies wanted to supply electricity to Plymouth but the council was unwilling to consider it until 1889. One interested company was the Devon and Cornwall Electric Supply Company (D&CESCo.), of which most of the directors were local men.[554] Initially, negotiations to for them to supply electricity to Devonport, East Stonehouse, and Compton Gifford appeared to be going well. However, despite national legislation that allowed for compensation if the commercial enterprise was bought out by the local authority, in this instance the authorities tried to veto this, fracturing the alliance of authorities. Although D&CESCo successfully applied for a license, no progress was made, and it was revoked. Eventually, the Plymouth Corporation bought the horse-drawn tramway, providing impetus for electricity supply for traction and the corporation decided to generate its own supply. After obtaining the necessary licence, an electric lighting sub-committee was set up and Flemming appointed

[554] Luscombe and Buck, *Plymouth's Electrical Revolution*, p.8.

as their electrical consulting expert.[555] Rider joined as their electrical engineer and they opened the Prince Rock Electricity Works in 1899, supplying the tramway and providing additional electricity.[556] Electricity cost 4.5d. per unit for private companies, which was ‘about double that of gas but would give about twenty times as much illumination’.[557]

Despite a difficult beginning the corporation expanded rapidly and, before opening officially, it had already decided to extend the tramway and build a substation. Just three months after opening additional demand for private lighting necessitated an extension and additional plant at the works. The electrical engineer was, by this time, responsible for all street lighting, including gas lamps. After this success Rider moved London County Council, as chief engineer and Okell, his successor, was promoted to chief electrical engineer, remaining there for 34 years.

East Stonehouse and Devonport worked together, sharing an electrical works built in Devonport which provided power for electric tramways. Unlike Plymouth, the tramway was the major consumer poor communication about their power requirements which made it difficult for the authority to plan and manage the load. The chief engineer, Furnace, frustrated by the lack of cooperation from The Devonport and District Tramways Company (D&DTCo.) and so he laid, what he thought were sufficient cables. However, within a month of operation D&DTCo. complained that the supply was inadequate and additional infrastructure was commissioned.[558] Although a joint venture by East Stonehouse and Devonport, East Stonehouse still had no public lighting in 1902. Eventually a threat from another company to apply for a new licence to provide public and private lighting in East Stonehouse provoked

[555] Bristol, Western Power Historical Electrical Society, ‘Works Committee Minutes 1891-94’, WDRO 1648/WS9, Min 1505.
[556] Luscombe and Buck, *Plymouth’s Electrical Revolution*, p.13.
[557] *Ibid*.
[395] *Ibid*., pp.14-16.

the Corporations into providing some public lighting. This delay was blamed on the tramways using so much load capacity but it is an example of the lack of joined-up thinking over services. Fewer than fifty lights were provided and the corporation were still recommending that incandescent gas lamps should be installed in 1907; and it should be noted that the corporation also owned the gas-works.[559] The Navy was forward-thinking regarding electricity, particularly in these early days and realising its potential in wartime. They installed a generating scheme in the dockyard and their main buildings were connected in 1904.[560]

A referendum in 1913 suggesting that residents of the three towns were in favour of amalgamating the electricity systems but the Devonport Corporation was not and spent thousands of pounds fighting the proposal.[561] Ballots were organized by Plymouth Corporation and ultimately led to a formal request to the local government board to amalgamate. An inquiry was held in January 1914 to establish the best organisation of services.[562] With the threat of war looming, some motivation was possibly military with a major witness to the enquiry, Major Penton said, 'In peacetime the organisation of the Three Towns into three distinct bodies does not affect us much, in wartime it is an entirely different question. You would have the fortress commander having to go to three different bodies'.[563] The effects of wartime in Plymouth and its environs saw consumers increase during this period and tramways running frequently, especially around the dockyard.[564]

[559] *Ibid*.
[560] Bristol, Western Power Historical Electrical Society, 'Agreement with Admiralty', *Devonport Minute Book*, 9 September 1904. WDRO 1814/49.
[561] Luscombe and Buck, *Plymouth's Electrical Revolution*, p.34.
[562] Plymouth City Council, 'Three towns Centenary Stone Panel', 'Three Towns or One?' and 'Plymouth's Great War – Teachers Notes' accessed via https://www.plymouth.gov.uk/boundarystone/threetownsamalgamationcentenarystone
[563] *Ibid.*
[564] Luscombe and Buck, *Plymouth's Electrical Revolution*, pp.34-35.

Despite calls to expand from 1917 wartime restrictions meant it was not possible for a further two years. Additional equipment arrived in 1921 but it was 1925 before the engineer reported that the changes were fully implemented. Plymouth's electricity works at Prince Rock were producing AC and supplying bulk to the Devonport and East Stonehouse electricity works, which became a sub-station converting AC to DC. This meant that changeover could be gradual, allowing consumers time to adjust because their electrical equipment ensuring compatibility with the new AC system. By the end of the 1930s only a few isolated consumers remained on DC but, to demonstrate the pace of change, Luscombe and Buck noted, 'in 1935 the principal streets of Devonport were still lit by gas, as indeed were most of the minor roads and back lanes of the city'.[565]

FIGURE 95 DEVONPORT, EAST STONEHOUSE AND PLYMOUTH.

[565] *Ibid.*, p.35.

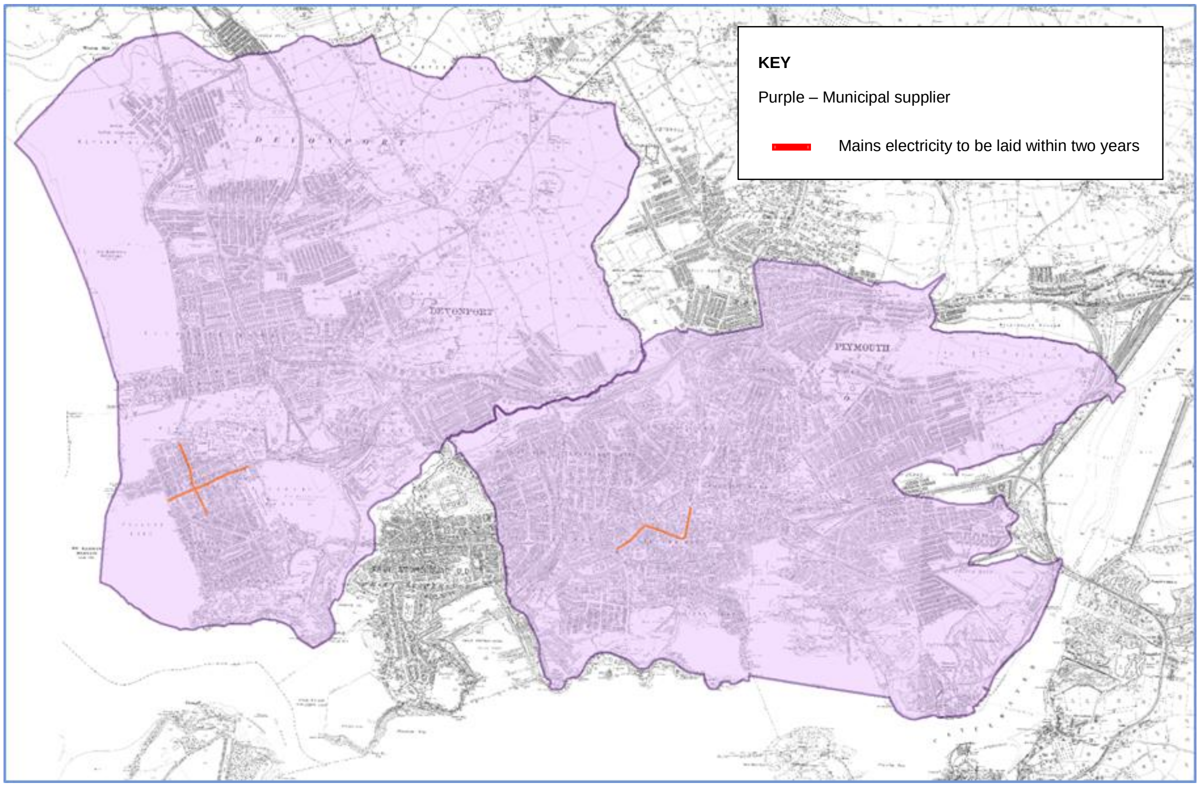
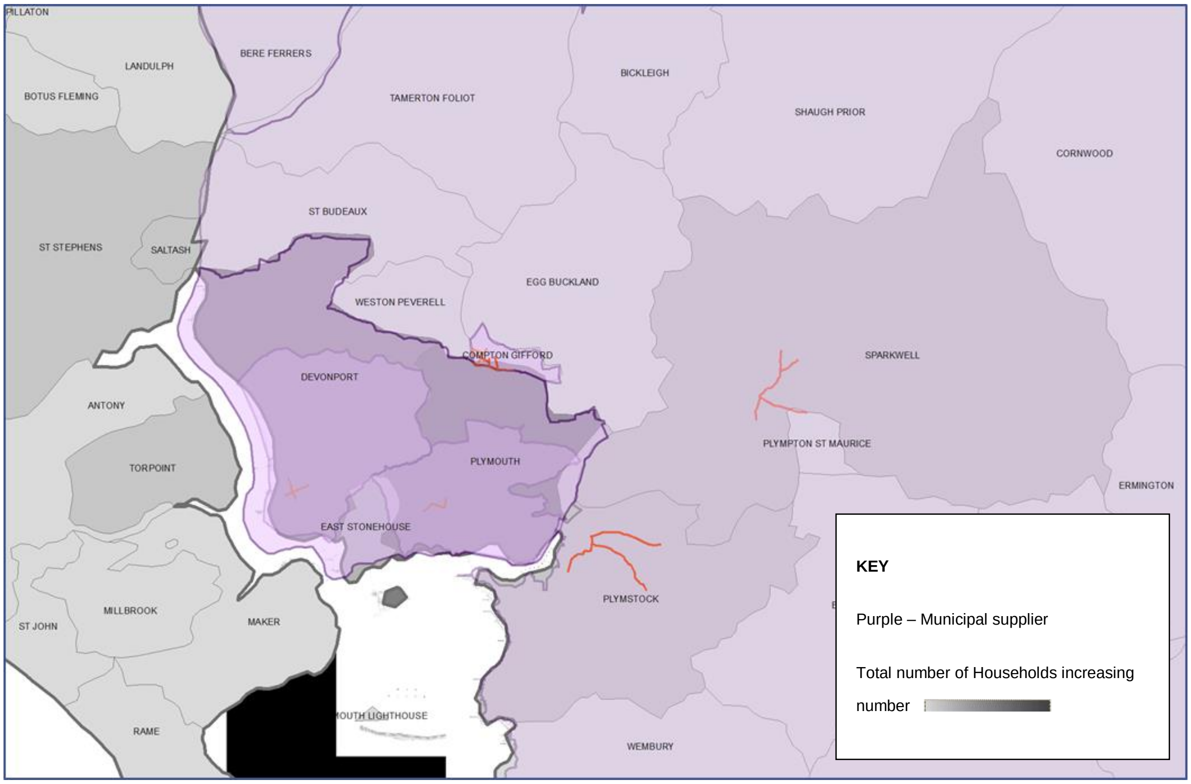


Figure 95 shows the expanded area this covered. East Stonehouse does not have a boundary because it s electricity was generated in Devonport. The background map shows this was a densely populated area, with populations of 112,030, 15,111 and 81,678 in Plymouth, East Stonehouse and Devonport respectively.

The extension of electricity supply to this area can be seen in Figure 96 which shows the total number of households and supply which expanded by 1932 to cover the whole of the adjacent areas through municipal suppliers. Whilst the areas all had a supply company, physical connection to electricity was not possible for everyone. The red lines on the map show the main distribution lines; the further from these lines the household, the less likely connection would be.

FIGURE 96 DEVONPORT, EAST STONEHOUSE AND PLYMOUTH C 1932 MAPPED WITH TOTAL NUMBER OF HOUSEHOLDS.



The South-West c.1926

After construction of the grid began in 1926, new companies emerged, and existing companies expanded looking to gain territory and distribution rights.

Table 17 gives details of suppliers, the year their application was submitted, the type of electricity they were supplying, and the capacity of the plant they owned.

TABLE 16 ELECTRICITY SUPPLIERS C.1926[566]

Local Authority Suppliers	Board of Trade or Electricity Commission session date (latest)	Supply Type	Generating Capacity kw
Barnstaple	1899	DC	1,050
Exeter	1923	AC/DC	5,800
Plymouth	1924	AC/DC	17,450
Sidmouth	1903	DC	174
Tiverton	1906	DC	152
Torquay	1924	AC/DC	10,225
Private Suppliers			
Bideford and District	1923	AC	200
Brixham Gas Co	1905	DC	200
Budleigh Salterton	1911	DC	66
Chudleigh	1922	DC	38
Dawlish	1926	DC	200
Electric Supply Co. Exmouth	1922	DC	515
Electric Supply Co. Totnes	1904	DC	164
Holsworthy Gas & Electric	1909	DC	45
Ilfracombe	1898	DC	330
Paignton	1907	DC	Bulk Supply from Torquay Corporation
Seaton and District	No record	DC	80

[566] Source: Adapted from Bloomfield, 'Notes for the Study of Regional and Local Electricity Systems in Britain' 2014.

Teignmouth	1924	DC	190
Urban ES Co Dartmouth	No record	DC	330

Between Figure 91 (1912) and Figure 97 (1926) the distribution areas increased, but not even half of the county had suppliers yet. The suppliers present in 1912 had expanded, and a few new ones established, but they were concentrated in the north of the county and the south-west coast, shown in greater detail in Figure 99 and Figure 100.

FIGURE 97 DISTRIBUTION OF ELECTRICAL SUPPLY COMPANIES C1926.

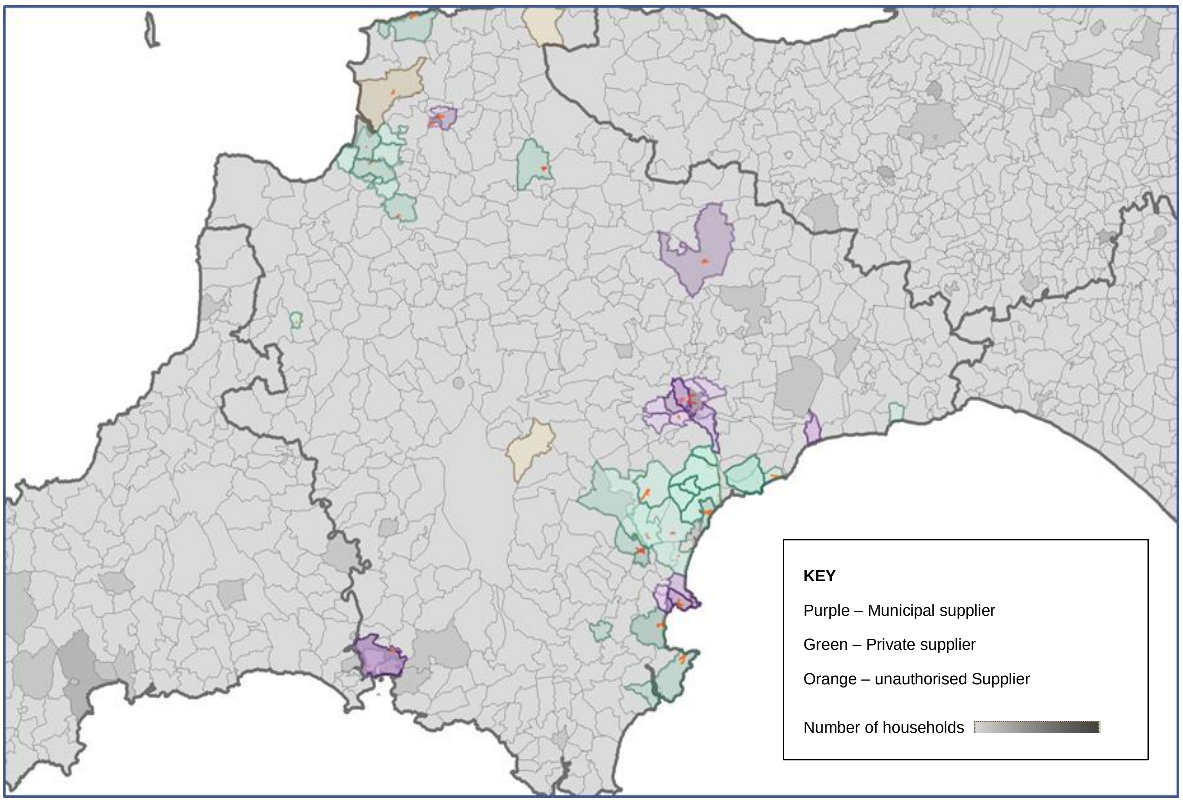


FIGURE 98 ELECTRICAL SUPPLY COMPANIES IN NORTH DEVON c1926.

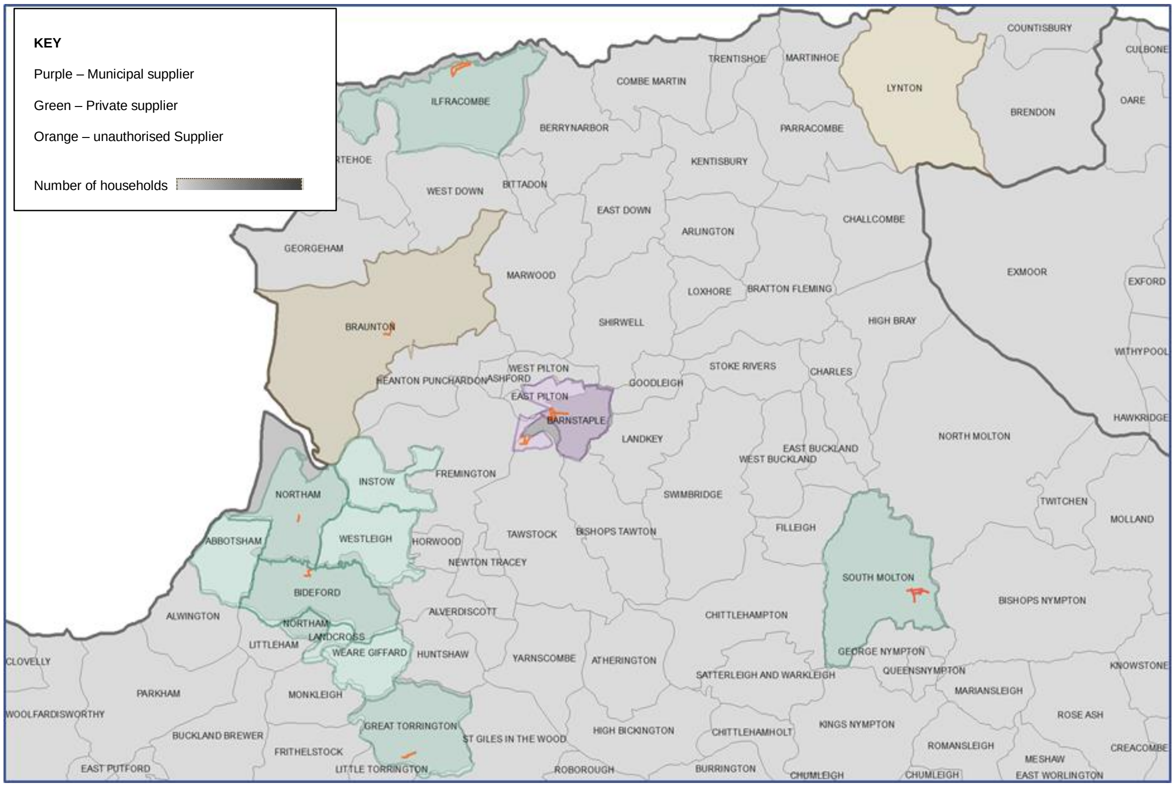
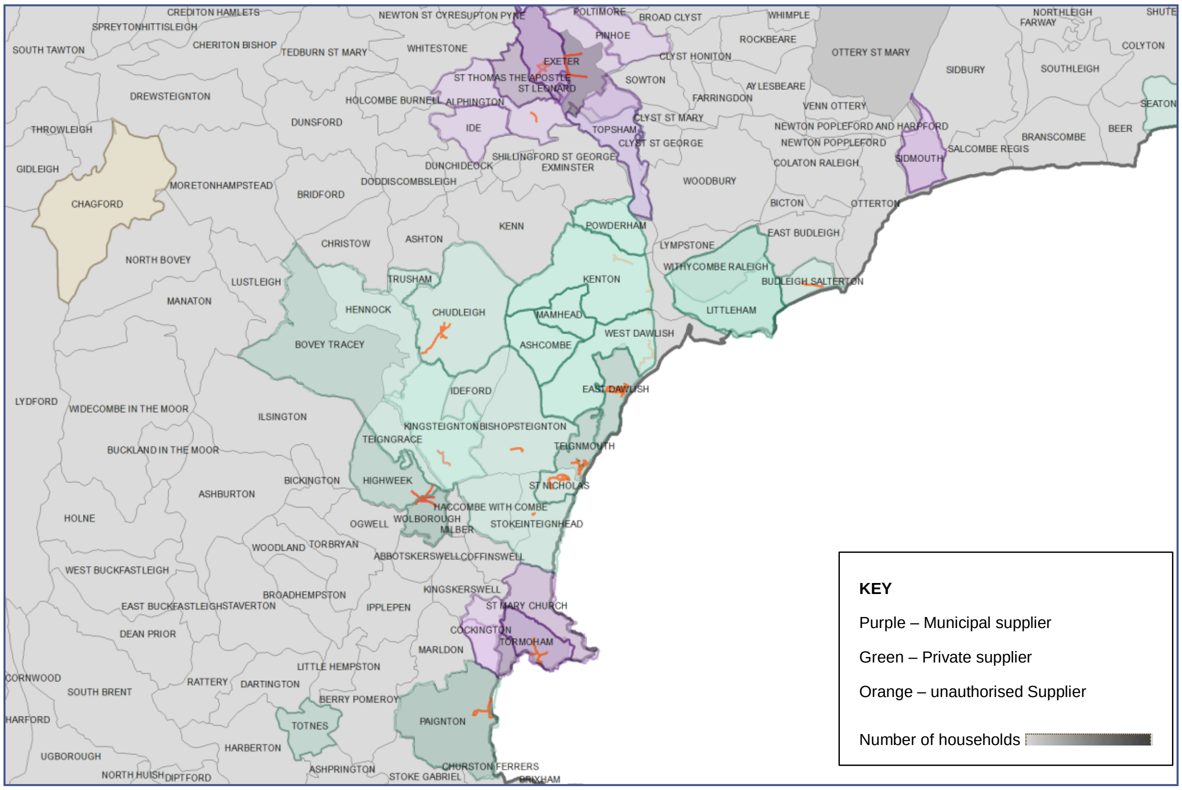
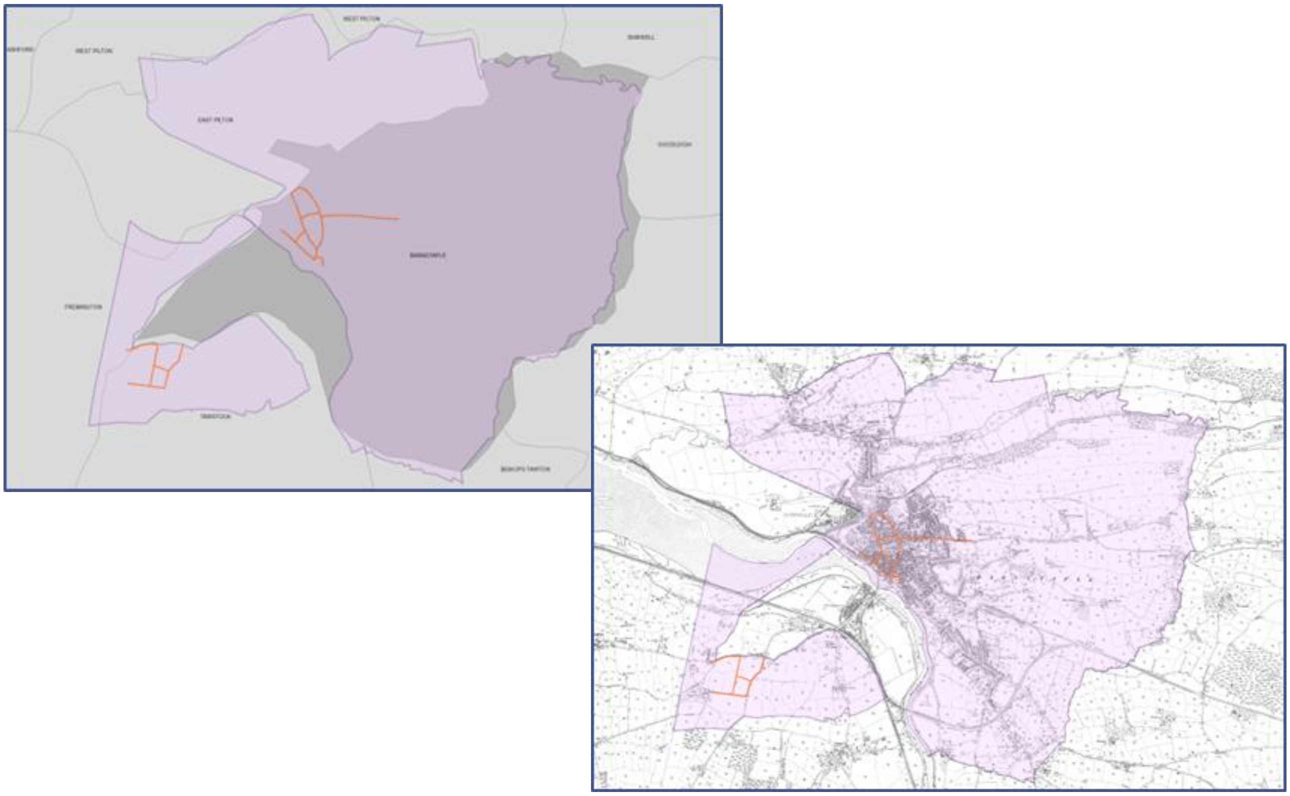


FIGURE 99 ELECTRICAL SUPPLY COMPANIES ON THE SOUTH WEST DEVON COAST c1926.



Excepting Torquay, Sidmouth and Exeter, run by their respective corporations, suppliers were privately or shareholder-owned companies which had grown since 1912, again concentrated in areas with higher household densities and/or tourism, which private companies favoured. The boundaries could be complex, not always relating to underlying standard geographies as Barnstaple shows (Figure 100).

FIGURE 100 BARNSTAPLE WITH TOTAL NUMBER OF HOUSEHOLDS C1926 AND BARNSTAPLE WITH ORDNANCE SURVEY MAP C1926.



In this case, the discrepancy between parish and electrical supply boundaries resulted from the river and railway which the corporation did not supply. This example demonstrates the complexities of both tracing and mapping the history of electricity supply because it was not uniform and, although governed by national legislation, each company was strongly influenced by the locality within which it worked.

The South-West 1932

Beyond the 1930s as supply areas increase in size and companies begin to merge and ownership changed and mapping them becomes increasingly difficult. By 1948 there were twenty-two separate undertakings in Devon; Five, individually owned, two owned by large national companies, and the rest owned by holding companies, suggesting that owning individual monopoly suppliers was potentially lucrative.[567]

TABLE 17 ELECTRICITY SUPPLIERS C. 1932.[568]

Local Authority Suppliers	Board of Trade or Electricity Commission session date (latest)	Supply Type	Generating Capacity kw

[567] P. Lamb, *Over 100 Years of Electric Supply in Devon*, (Bristol, 1995), p.2.
[568] Source: Adapted from Bloomfield, 'Notes for the Study of Regional and Local Electricity Systems in Britain' 2014.

Barnstaple	1899	DC	1,340
Exeter	1932	AC/DC	15,300
Plymouth	1924	AC/DC	34,850
Plympton St Mary	1924	AC	-
Sidmouth	1903	DC	174
Tiverton	1906	DC	558
Torquay	1929	AC/DC	22,725
Private Suppliers			
Bideford and District	1923	AC	1,335
Brixham Gas Co	1929	DC	440
Chudleigh	1922	DC	-
Culm Valley	1928	AC	18
Dawlish	1926	DC	-
East Devon	No record	AC	-
Exe Valley	No Record	AC/DC	539
Holsworthy Gas & Electric	1909	AC (conversion from DC)	-
Ilfracombe	1898	AC/DC (conversion from DC)	856
Lynton and Lynmouth	1928	AC	370
Paignton	1907	DC	-
Salcombe Gas and Electricity	1926	AC	104
Seaton and District	No record	AC (conversion from DC)	-
Teignmouth	1924	AC (conversion from DC)	-
Urban ES Co Dartmouth	1928	AC	-
West Devon	No record	AC	2,600

Changes Brought by the Grid

One aim of the Grid was to implement a national standard for supply. This case study, alongside the information in the previous chapter, shows this was not achieved during the CEB's management, although the intention was there. Distribution companies remained autonomous and often converted the electricity purchased from the Gird into the type of electricity previously distributed through its network avoiding the expense of converting networks to carry standard electricity.

Conversion could be more expensive for domestic consumers than it was for industrial ones, who were able to get financial assistance towards new equipment. However, if appliances were rented or on hire purchase agreements, suppliers may have offered financial help to maintain goodwill but no evidence has been found for this. The conversion from DC to AC between 1926 and 1932 occurred in just four of the undertakers in the South-West but new suppliers tended to favour AC, suggesting that they were guided by the new standard. Over the period capacity trebled for Exeter and doubled for Torquay and Plymouth, demonstrating consumption increases. However, although consumer numbers rose it was 1967 before ninety-three percent of households were connected in the SWEB area.[569]

Discussion and Conclusions

It took about forty years, after the Grid's introduction, for electricity in the South-West before more than ninety percent of its households were connected. Whilst initially electricity provided public lighting, tourism, traders and private consumers soon followed. There seems to have been two drivers for electricity: firstly tourism, marketing it as an attraction, and secondly and more importantly, population

[569] Warburton, 'The Story of SWEBS Electrification', p.6.

density. Tourist areas attracted private suppliers, while municipal corporations tended to favour main towns and cities. After WW1 legislation began encouraging interconnection, and eventually these efforts resulted in the Weir Report. It seems there was genuine desire from potential consumers for connection to benefit from the freedoms that electricity afforded domestic life. However, for many this was not realised until the 1930s and '40s in urban areas, and the 1950s and '60s in more rural ones. From the correspondence I received, Norfolk appears similar to the South-West, suggesting a twenty-year lag between urban and rural connection in Britain.

The Grid played a significant role. Between 1926 and 1932, the period between details of the Grid being released and connection of the South-West, companies continued to enter the market and individual supply territories grew larger as distribution rights were seen as lucrative opportunities. These were valuable commodities, Weir stated, 'To-day, distribution is a practical monopoly; under our proposals the commodity to be distributed will become available to the monopolist at a lower price, and, therefore his monopoly will become more valuable'.[570] Bloomfield suggested, 'Over the next decade [1926 to 1936] almost all of the empty areas of the map were covered by new or extended supply areas'.[571] Investment companies saw the opportunity and purchased licenses where they could. At nationalisation, there were twenty-two individual suppliers in Devon which were vested into SWEB in 1948. All but five were owned by companies outside of the area.

Regardless of national legislation, suppliers found ways to remain in business, continuing to distribute non-standard electricity where they chose to, and remaining autonomous in the maintenance of their distribution networks until nationalisation swept them away. Whilst the Grid provided national

[570] The Weir Report, p.14.
[571] Bloomfield, 'Notes for the Study of Regional and Local Electricity Systems in Britain – The South Western Electricity Board Area', p.6.

coordination, and standard supply at wholesale scale, consumers still faced a variable and complicated tariffs and uncertainty over its benefits. However, when the BEA took over operation of the Grid in 1948, the task was less about educating people regarding the benefits of electricity to encourage consumption but more about providing all consumers with a standardised supply, at a standard tariff through one national system.

5.The ‘GridIron’ and the Countryside

Introduction

Environmental history has developed into a subject for studying the extent of the damage that human activity has, and continues to have, on the planet.[572] Choices made in approaching various issues historically have had profound environmental consequences, whether obvious or hidden, explicit or implicit. Environmental history offers an opportunity to create a knowledge base from exploring these approaches and their consequences over time. For electricity this includes the impact it made, how and where impacts occurred and its eventual ubiquitous nature. From this, policy makers, lobbyists and wider society can begin to understand some of the fundamental shifts which have occurred in the environments where everyday life is centred around electrical power and determine if, and how, future decisions and behaviours should be affected.

As discussed earlier, processes within any environment are never isolated, and ensuring a holistic view is taken the ‘environment’ cannot be reduced to a narrower definition unless it is for a specific reason. Interdependence of relationships and feedback loops are fundamental to environmental interactions, whether natural or man-made. Reducing the environment to a few simple processes and ignoring the influence of wider environmental actions is often why changes in behaviour lead to both expected and

[572] S. Sörlin and P. Warde, *Nature's End,* pp.1-18.

unexpected consequences. The cascading effects of change can be widespread, lasting longer, spreading further and sometimes not meeting the intention behind the change.

Previous chapters demonstrated how influential planning the distribution of electricity and building national capacity were, but it is not possible to consider all of these in direct relationship to their environmental impact in one piece of work. Enormous long-term shifts have been created as energy transitions have occurred. This is shown by the RGS work on 150 years of industrial change and Fouquet's work on long term energy transitions.[573]

The results of this transition, Britain's electrification, on the environment affected the way people worked, commuted and interacted with the built environment which had consequences for the 'natural' environment. Many works consider societal changes but it is only Nye who directly attributes many of them to electrification, saying, 'In the United States electrification was not a "thing" that came from outside society and "had" an impact; rather it was an internal development shaped by its social context'.[574] This study suggests this was also true in Britain. Electrification and social changes were processes which were negotiated and normalised through supply and demand by people and institutions that were active or passive during the process. Whilst chapters 3 and 4 considered such changes within the workplace and home, this chapter will consider how this affected the 'natural' environment.

There is very little, if any, truly 'natural' environment left in Britain, by which I mean places unaffected by human activity. However, there are large areas of countryside and unpopulated areas, some of which now have protection. In fact, in 1926, as Grid construction began, the Council for the Protection of Rural

[573] Manley, 'Location of Industry' and R. Foquet, 'The Slow Search for Solutions: Lessons from Historical Energy Transitions by Sector and Service', *Energy Policy* (2010), 38, 6586–6596.
[574] Nye, *Electrifying America*, p.xi.

England (CPRE) was founded, and they, alongside other individuals and institutions, played a significant role in negotiating the type and placement of infrastructure necessary to generate and transmit electricity from the power station to consumers' premises. The aesthetic impacts of the Grid were hardest fought perhaps because of their obvious visibility but this chapter will also consider impacts on places and resources which were defended by people and organisations during the Grid's construction. I will also consider the direct environmental impacts of the volumes of resources used for its construction, and the volumes of fuel necessary for the Grid to meet growing electricity demand. Whilst there were, and remain, numerous consequences of electrification, only impacts directly relevant to the Grid are explored here.

This chapter considers how negotiation took place and how the people represented themselves or raised issues with the relevant authorities and made their views known. Debates over open spaces and air quality for example were difficult because they do not belong to anyone but are shared by everyone and needed individuals or organisations, such as the CPRE, to 'protect' them from increasing 'development'.[575] The need for 'protection' and to determine what 'development' was and if it was necessary was at the heart of many of these debates. The relationship between the Grid and the environment will be traced through challenges to, and responses from, the Grid's operators, primarily the CEB, and other authorities, following their changing approach over time, and considering the drivers behind these changes.

Defining the Grid

[575] Cronon, 'The Uses of Environmental History', p.8.

Defining ‘the Grid’ is not simple despite its seemingly tangible parameters. In Chapter 1 the difficulties of determining where the grid begins and ends were outlined. In this chapter, the focus is initially on the pylons and high voltage wires connecting the transmission system, constituting the Grid as a physical entity with less focus on the extremities of the system. Nevertheless, the locations and impacts of these extremities, generating stations, distributors and consumers are never far from the discussion because they were directly influenced by the Grid and will be discussed later in this chapter. A comment from the Grid’s current head of network strategy could have been made at any point in its history: ‘What we are really talking about is finding ways to make the way we generate and consume energy more interconnected’. The drive for more interconnectivity leading to ultimately greater efficiency still remains.[576] This has always been the overriding aim of the whole industry, which became concentrated within the grid as it was conceived, constructed and operated.

Planning the Grid

The network was called ‘The Gridiron’ by the Weir Committee in its technical plans to provide a physical structure to supply the country with cheap and abundant electricity.[577] The word ‘gridiron’ was typically used to refer to bars or beams forming a support network, for example supporting a ship in dock or scenery and lighting in a theatre. The report presented this new structure as a gridded network supporting the country by providing power where it was needed. The CEB was the board of directors introduced to manage its construction and operate it effectively. Despite its relationship to government

[576] P. Sheppard, P ‘Smart Thinking’, on National Grid Blog ‘Connecting’ accessed via http://nationalgridconnecting.com/towards-smart-energy-systems/.
[577] The Weir Report. This is mentioned six times in the covering letter to emphasise its importance, and then described on p.10 in the main report.

and the Electricity Commissioners, the CEB was constituted as an electricity supply undertaking. Like other suppliers it submitted entries to *Garcke's Manual* and was subject to the same controls. However, it was responsible for the Grid's construction and held powers to both generate and coordinate generation. As such, it was essentially a well-funded national power company. The board were able to act in the best interests of the Grid as a company, and although appointed by the Minister of Transport they were not directly accountable to parliament. Correspondence in the National Archives shows how little they were involved in decisions about regulatory issues because responsibility for these was deputised to the Electricity Commissioners through the Transport Minister. However, the CEB ensured compliance with any restrictions imposed, or extensions allowed to power stations they operated, by the Electricity Commissioners, or the Minister ensuring that generation and transmission were executed in the country's best interests.

The CEB's first task was to oversee the Grid's construction. A technical scheme for each newly delineated region was prepared by the Electricity Commissioners and sent to the CEB who published the plans. They ensured that interested parties, such as current suppliers in the area, the local authority, and any other interested parties understood the plans and allowed a minimum of one month for objections to be raised. If no objections were raised the plans could be adopted but where issues were raised, the Electricity Commissioners could undertake arbitration or a public enquiry could be undertaken. The CEB could choose to accept the scheme unchanged, with any recommended changes or make its own alterations. The CEB annual reports briefly discuss the kind of objections raised, primarily by undertakers, but the Electricity Commissioner reports contained greater detail because of their roles as arbitrators. For Wales and Scotland proper use was made of the available water power with the CEB agreeing to purchase specific quantities of hydro-electricity from them to be transmitted through the Grid.

The published plans included routes for high voltage cables and identified the power stations selected to generate power for the Grid and any plans to construct new ones. In South-East England concerns were raised regarding ‘temporary measures’ which supply undertakings felt were particularly advantageous to the selected stations.[578] The term ‘temporary measures’ is misleading because it referred to parts of the Grid which were actually constructed early. Any power station changes or extensions required permission from the electricity commissioners and where permission was applied for building work or new bulk arrangements, rather than providing permission to the existing supplier, if an appropriate part of the Grid infrastructure could be constructed early, it was. When the rest of the scheme was completed in areas containing temporary measures everything was connected into the national scheme which avoided duplication of work and materials in anticipation of the Grid’s subsequent arrival.

By 1932, 1,360 miles of primary lines, 596 miles of secondary lines and ninety-four miles of underground cables were placed into schemes ahead of time. The CEB reported:

> The Board have continued their policy of so arranging their construction programme that supplies of electricity may be available in advance of the completion of the grid, for authorised undertakers whose generating stations have become insufficient to meet their consumers’ demands or who have desired to open up new territory. As a result of the advance supplies, given or arranged during the year, authorised undertakers have again been able to avoid large outlays on extensions to their generating stations which would not be of service when the grid is in full operation.[579]

It was also noted that implementing temporary measures provided valuable experience for the CEB engineers who would be operating the completed Grid.

---

[578] CEB, *Annual Report*, 1, pp.27-28.
[579] CEB, *Annual report*, 4, p.4.

This was the first sign of 'environmental' concern shown by the CEB. The board tried to avoid duplication and unnecessary works, not to conserve resources *per se* but to minimise effort and financial investment. This was an example of the CEB's planning strategies producing a sound, if unintentional, environmental policy. They prevented wasting of materials and environmental damage from construction which brought only short-term benefits. Through coordination of available resources and advanced planning, business aims and environmental protection coincided, fortuitously rather than through deliberate design or intention. It is possible that there was still some concern about material shortages (resulting from WW1) but these are not recorded as important regarding 'temporary measures'.

In 1929, Marshall and Wright (deputy chief engineer for the Grid), electrical engineers, wrote about how decisions were made regarding technology and materials for the component parts and construction of the Grid, and its rigorous testing.[580] The durability of materials for construction were considered carefully, including the operation and reliability of components operating in various weather conditions and other specific circumstances under which it would operate, for example next to seawater or where towers were taller at river crossings. The CEB encouraged research, establishing their own small research laboratory at Leatherhead. Most research for the Grid and its materials was undertaken by a partnership of the Grid component manufacturers themselves. This collaborative partnership included the CEB and other industry bodies which funded the British Electrical and Allied Industries Research Association (ERA). The National Physical Laboratory carried out additional tests and wrote extensively on continuity and preservation of supply.[581]

---

[580] J. Wright and C. W. Marshall, 'The Construction of the "Grid" Transmission System in Great Britain', *Journal of the Institution of Electrical Engineers* (1929), 67, 390, pp.685-722.
[581] BEA, *Annual Report*, 3, p.27.

Whilst the CEB oversaw the construction of the whole Grid, it was consulting engineering firms that had direct responsibility for individual regions. These firms included Kennedy and Donkin, and Merz and McLellan, from which Merz and Kennedy contributed to the Grid's initial technical design. They worked alongside other firms, meeting with Page (first chief engineer for the Grid), and Wright, fortnightly to discuss and coordinate design, specifications and technical matters.[582]

After five years of progress the CEB stated; 'Of the entire transmission system of approximately 4,000 miles, inclusive of cables, only 212.5 miles of towers and 3.5 miles of cables have still to be completed'.[583] As might be expected in an annual report they celebrated progress, reporting the completion of two scheme areas. The CEB, at this time, estimated the total cost of the completed transmission system to be in the region of £26.7 million, which transpired to be just £0.05 million less than it finally cost. In this year, the first phase of their task, the physical construction of the Grid, was reaching its conclusion and Grid operation in its entirety was looming. It was also this year that District and National Consultative Committees were decided upon as a mechanism to ensure that good relations between the CEB and the rest of the electricity supply system were maintained.[584]

The Grid took just six years to build and the transmission system cost £26.75 million. The whole system, including eighteen new power stations, five of which were hydro-power and standardisation costs, was estimated to cost £80 million. There were 4,000 miles of transmission lines, 2,894 of primary lines at 132KV and 1,106 miles of secondary lines at lower voltages (66KV and 11KV).[585] As part of the grid's

---

[582] Rowland, *Progress in Power*, p.81.
[583] CEB, *Annual Report*, 5, p.3.
[584] CEB, *Annual Report*, 5, pp.5-6.
[585] The Central Electricity Board, 'Construction of the National Grid' in British Commerce and Industry, The Post-War Transition, 1919-1934, With Special Contributions from Representative Industrial Groups and Leading Economic Authorities (1934), pp.187-198.

structure 66KV lines were included in an effort to accelerate development into new areas, although distribution to consumers was carried out by the existing suppliers.[586] There were roughly seven towers for every mile of cable, averaging seventy-five feet and weighing over three tons. Sixty rivers were crossed; Dagenham had the largest towers at the Thames crossing, where the pylons reached 478 feet and weighed 290 tons each. Over 150,000 tons of steel and 12,000 tons of aluminium were used. Huge quantities of copper for wires, porcelain for insulators, creating upwards of 200,000 strings and bushings alongside cement to anchor the towers into the ground, were used.[587]

Grid construction learned from the example of the telegraph system, consulting with Preece, (postmaster general) who had experience of implementing overhead cables. There were fears about electrical wires causing interference for telegraphs and initially there were restrictions preventing them being within six feet of telegraph lines. These were relaxed over time and there was greater cooperation between the physical networks.[588] Gutta-percha was used for wire insulation in earlier systems providing an extreme example of the repercussions of resource harvesting occurring at a distance from where it will be consumed.[589]

---

[586] CEB, *Annual Report*, 5, p.3.
[587] The Central Electricity Board*, British Commerce and Industry,* pp.189-190.
[588] CEB, *Annual Report*, 5, p.8.
[589] J. Tulley, 'A Victorian Disaster: Imperialism, The Telegraph, and Gutta-Percha', *Journal of World History* (2009), 20, 4, p.559. An environmental lesson which, with hindsight, should have been learned regarded the exploitation of natural resources through the experience of using Gutta-percha, a substance used to protect and insulate both electrical and telegraph cables. This was harvested in South East Asia but the dispersed nature of the trees required resulted in large areas of deforestation. Gutta-percha was primarily imported to Britain via West Ham, where there was a gutta-percha works located next to a cable works on the Thames. Whilst the gutta-percha works disappeared at the turn of the 20th century the cable works continued to produce telegraph and electrical cables. Tully wrote in 2009 of the dismal consequences of this industry, so essential to early cabling. 'The key to the success of the new system was a natural plastic, gutta-percha (almost forgotten today), which proved indispensable as insulation for the submarine cables…the 'gum' was obtained by profligate, inefficient and ultimately unsustainable methods of extraction which killed the trees in the process'. He describes this as an 'ecological disaster [that] adumbrated the galloping destruction of tropical rainforests so depressingly familiar to us today'.

Alongside the necessary physical materials there were transportation and energy resources necessary to erect pylons and connect high-tension wires. Similar requirements were necessary for lower voltage networks, except these poles tended to be wooden, and each company determined their source. Various insulators were needed for cables dependent on placement. For overhead wires air acts as an insulator and coolant whereas underground cables required special coatings and water to prevent overheating. This was partly why the costs for underground cables were up to twenty times the overhead costs.[590]

In their second annual report the CEB stated that: 'The board again record with special satisfaction that they have been able to place all their contracts with British Firms'.[591] Using only British companies provided welcome orders for manufacturers of electrical equipment after a difficult time for the industry and helped to secure overseas orders as the good reputation of their work on the Grid spread. Using home firms reduced the financial and environmental costs of importing components. However, some of the gains in saving materials from not importing components was negated by exports made by increasingly confident British firms.[592] 12,000 tons of aluminium for the Grid were processed in a factory in Scotland which used hydro-power to generate its power providing an environmental bonus.[593]

The use of domestic materials was also in keeping with the idea of the system being national. The Grid was conceived a decade after WW1 during a reconstruction programme. Using home-made products and creating employment for ex-servicemen were principles of great pride for the CEB, although they benefited from employment support grants which reduced labour costs. The Gird's construction had

[590] Cochrane, *Power to the People*, p.47.
[591] CEB, *Annual Report*, 2, p.10.
[592] Rowland, *Progress in Power*, p.83.
[593] The Central Electricity Board, 'British Commerce and Industry', p.193.

implications for industries that supplied it, electrical engineering and coal mining being the obvious ones, but also iron and steel manufacturers, cement and pottery makers, and construction companies. Over 240,000,000 man-hours of work were directly or indirectly created.[594]

In fact, constructing the Grid during recovery from WW1 but before the 1930s depression provided an ideal moment in time. 'A national emergency presented an opportunity which would never recur', reported Ballin, who suggested the Grid was about removing municipal control but that other interests viewed this as an opportunity.[595] Birchenough reported on a strong sense of 'realising [the] national importance' of electrical industries after the war, as did newspapers and writing of the time. It was considered a period of enormous change in which the feeling of 'pulling together' was central but went unsaid because it was obvious.[596] The need to vocalise unity was not necessary and uniting the country's electricity system was a part of that underlying cultural shift. It was about making things better for everyone. Although nothing is explicitly stated in the literature, nor written in the Weir Report or responses to it there was a book celebrating post-WW1 reconstruction, which stated;

> 'Leisure is not yet properly valued, because we still believe the false doctrine that it is the privilege of a class. So it was in a slave society. But now for the first time in human history we can distribute to all – not merely health and longer lives but spare energy and spare time to use it. That is the way in which, under a planned industry and agriculture, everyone will share more freedom'.[597]

This perhaps demonstrated the hopes of those who had won the war.

---

[445] *Ibid.*
[595] Ballin, *The Organisation of Electricity Supply*, pp.95-101. Quotes from p.99.
[596] Birchenough, 'British Electrical Industries after the War', p.362.
[597] The Central Electricity Board, 'British Commerce and Industry', p.314.

Aesthetics – Pylons, Wires and Substations

The CEB were aware of potentially contentious issues when construction began, and experience was sought from other European countries and America. The CEB chose to arrange the cables with large spaces between the wires because 'high-voltage transmission lines are very free from operation troubles in comparison with lower-voltage lines. The reasons for this immunity from faults are the stronger mechanical construction and the very large spacing of the lines, which eliminates trouble due to birds, branches and (in some cases) lightning'.[598] High voltage cables provide a great place for birds and finding lines heavy with starlings is not uncommon but there is an underlying level of collisions and electrocutions of birds on power cables with its own research literature. The forward thinking of the CEB meant that bird deaths were less of a problem than in other countries. However, this was another practical decision taken by the CEB to reduce the possibility of interruptions to supply which also produced a positive environmental outcome. In 1962 the CEGB suggested that bird collisions had become more prevalent within the last few years, being particularly difficult near 'rivers and large stretches of water, with swans being the main problem', although no indication for the rise in 'supply interruptions' by birds was suggested. 'An effective remedy has been to erect a P.V.C. insulated conductor as the centre phase of the line and, in certain cases, to increase the conductor spacing', these and various other devices were placed on wires to warn birds of their presence.[599] This was part of

[598] Wright and Marshall, 'Construction of the Grid', p.697.
[599] Abell and Meadows, 'Electricity Supply to the Countryside', p.15.

measures, introduced the CEGB, alongside creating bird sanctuaries and homes for migrating insects generated from old rotting poles as awareness of the environment increased.[600]

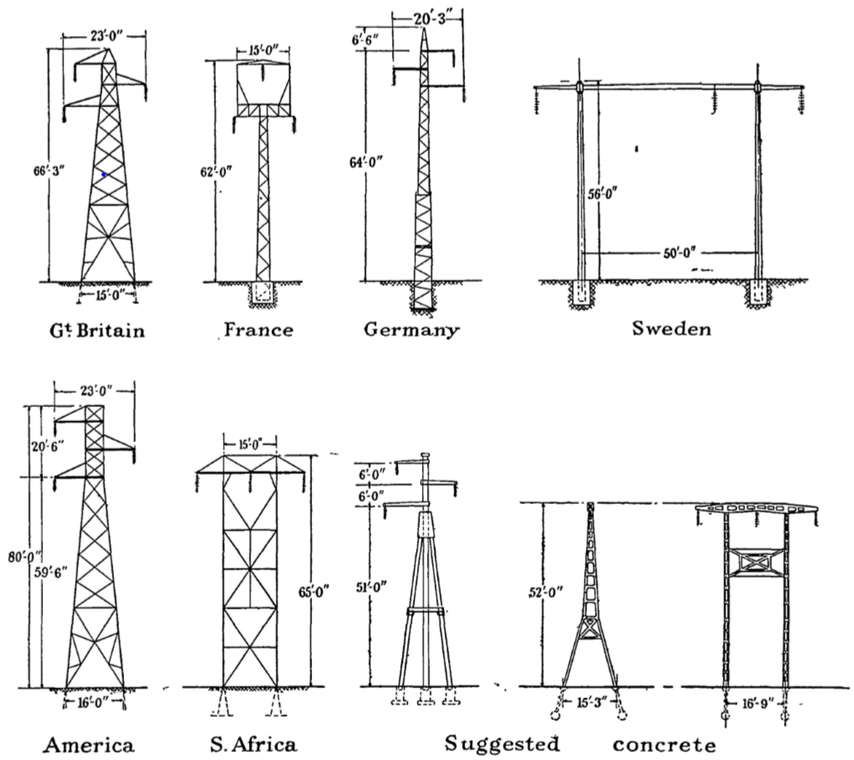
The CEB were conscious of the physical stature of the pylons. Cochrane reported, 'There was no way in which the power lines – especially the pylons could be made unobtrusive; but at least something could be done to prevent them being positively ugly'.[601] A design was needed and Wright and Marshall noted, 'An examination of existing transmission systems will show that there is nothing approaching uniformity of opinion as to what constitutes the best outline design to be adopted for towers'.[602] An easy decision was that steel was far superior to the wooden or partly steel structures used to support high-voltage lines previously. 'Aesthetic considerations played a considerable part in the choice of wide based towers for the grid, and this consideration was also instrumental in eliminating the horizontal arrangement of conductors'.[603] The choices were made from a range of different types of pylons which were available in different countries for single and double circuits see (Figure 101 and 102). The CEB's solution came in the form of architect, Bloomfield. He is often misrepresented as designing the pylons, whereas he was used as a consultant and chose from a series of designs with the CEB, although this myth followed him for many years.[604&605] The CEB were looking for a universally acceptable aesthetic and choosing a traditional architect was probably deliberate. Pylon-like structures had been proposed for war memorials in the early 1920s, and this tentative linkage may have made them less objectional

---

[600] Cochrane, *Power to the People*, p.48.
[601] *Ibid.*, p.18.
[602] Wright and Marshall, 'Construction of the Grid', p.692.
[603] *Ibid.*
[604] CEB Annual Report, 1, p.16.
[605] J. Purdon, 'Electric Cinema, Pylon Poetry', *Amodern, A journal on Media, Culture, and Poetics* (2013), 2, pp.1-18. His final choice, to which he made some alterations, was based on a design by American firm Miliken Brothers. Purdon suggests that this was classical in its design, even to the use of the word 'pylon'. However, the word used by those implementing them was 'towers' while the media coverage used the word 'pylon'. It is likely, though, that the influence was there given Bloomfield's traditional roots.

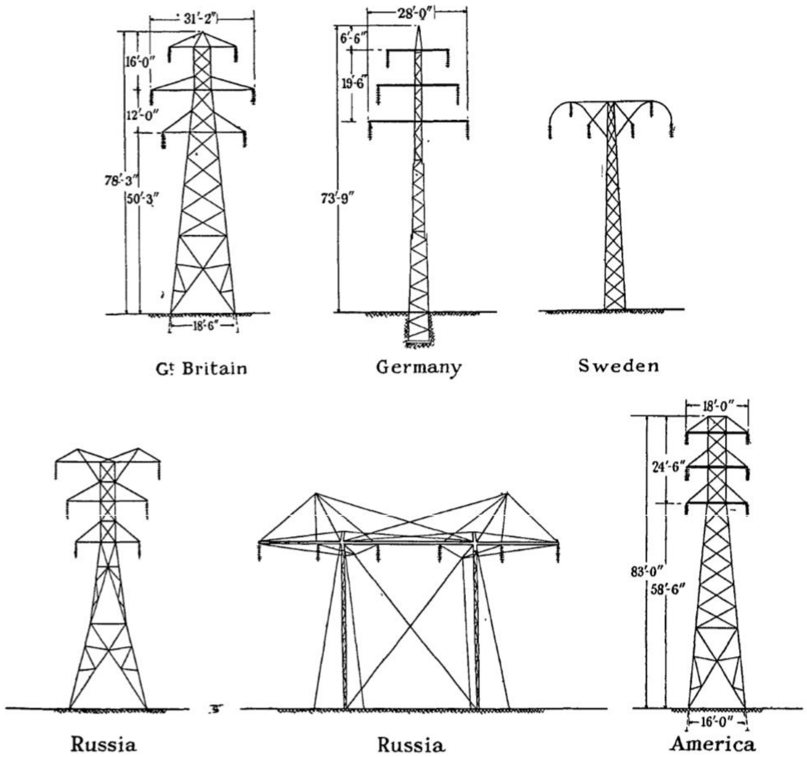
structures. However, there is no real evidence for this, and the term 'towers' was maintained by Bloomfield and the CEB in their work.[606]

Figure 101 Examples of single circuit pylons.[607]



[606] *Ibid.,* p.3. describes Bloomfield defending the design in articles in *The Times,* referring to them as 'towers' and 'masts', as do the CEB reports and Wright and Marshall in 'Construction of the Grid'.
[607] Source: Wright and Marshall, 'Construction of the Grid', p.693.

Figure 102 Examples of double circuit pylons.[608]



The choice of design was made primarily aesthetically, although economic and practical needs for the towers were also met. However, as the CEB predicted, there was controversy, primarily because some people objected to the damage 'the march of the pylons' caused to the English countryside.[609]

The CEB's wider battle regarding extent and form of transmission lines was played out quite publicly, simply because pylons and wires were visible to many people. The debate soon became about more

[608] Source: Wright and Marshall, 'Construction of the Grid', p.694.
[609] Luckin, *Questions of Power,* p.156. 'March of the Pylons' is a common term used frequently in the press and other writings and is discussed further by Luckin.

than pylons and for some it became symbolic of a movement to retain England's Englishness. Battles over transmission lines and pylons were fought at local enquiries called to hear objections to regional schemes that could not be overruled by the minister of transport for being 'frivolous'.[610] These enquiries were reported by the press and directly involved those who objected to specific schemes directly. Yet, there were recurring faces at these events, particularly Williams-Ellis and Abercrombie amongst others from the CPRE. They and their fellow advocates are discussed by Luckin in his study of the rhetoric surrounding electricity and its development in the interwar years.[611] However, the individuals from the CPRE were concerned about the erosion of the countryside generally, which included but was not limited to the Grid.

In reissuing his famous book, *England and the Octopus* forty-five years after its first publication Williams-Ellis wrote a new preface, which began, 'This is an angry book, written by an angry young man nearly half a century ago' and continued, 'Now I am in my ninety-second year and still angry because many of the follies and abuses I then tilted are still with us'.[612] His objections were not just to the Grid but a reaction to the 'short-sighted' approach being taken in a time of rapid change.[613] He objected to roads, signs, garages and electricity, imposing their associated infrastructure and changing the face of the landscape. Other concerns included outward 'sprawling' of towns and lack of forethought and appropriateness of such changes. For example, he complained that workers' 'residences' are 'monstrously roofed with pale pink tiles, and that in the midst of quarries producing the best slates in

[610] London, TNA, 'Consent to Overhead lines', POWE 13/70.
[611] Luckin, *Questions of Power,* pp.157-168.
[612] C. Williams-Ellis and P. Abercrombie, *England and the Octopus* (Glasgow, 1975), p.1.
[613] *Ibid*., p.24.

the world'.[614] He and others did not resent the development of the Grid *per se* but were ready and willing to fight the march of the pylons under the banner of preserving England and amenity.[615]

The language used in these debates was almost romanticised, including 'rural beauty', 'dignity of a landscape' and 'tradition', and suggested that pylons were 'disfigurement', 'spoiling', 'ugly' and even 'evil'.[616] In fact, the debate was primarily about maintaining the *status quo*, particularly in areas considered as 'inspirational', such as the Lake District. The suggestion that pylons would not even be noticeable after a year, was answered with, 'But was it a good thing to blind their senses to what was evil or ugly and was it not better to keep things beautiful and get what inspiration they could from them?'.[617] The objections were about degradation of the view rather than protection of the environment as it would now be recognised. There was no mention of damage to plants or wildlife, yet the language used provoked a sense of finality if pylons were sited in such 'inspiring and beautiful places'. Purder, reviewed poems written in response to pylons in the 1930s and concluded that there were 'two ways of approaching infrastructural technology, the prophetic and the prosthetic'.[618] The prosthetic relating to disfigurement and the prophetic being the concerns raised regarding the changes, particularly industrialisation, pylons would pre-empt.[619] This may underlie the sense of unease, that

[614] *Ibid.,* p.143.

[615] Luckin, *Questions of power*, considers the writings of Williams-Ellis, Abercrombie, Cornish and Trevelyan as preservationist in his book but Octavia Hill was also influential, particularly in the battle to preserve amenity spaces which were open to everyone.

[616] 'Preserving the Beauties of England'. *The Manchester Guardian* (Manchester, September, 1929), p.15, 'Pylons and Cheap Electricity: Keswick Committee's Statement', *The Manchester Guardian* (Manchester, November, 1929), p.12 and 'Those Pylons Again', *The Manchester Guardian* (Manchester, April, 1930), p.10.

[617] 'Pylons in the Lake District: Difference of Opinion in Debate', *The Manchester Guardian* (Manchester, November, 1929), p.4.

[618] Purdon, 'Electric Cinema, Pylon Poetry', p.10.

[619] *Ibid.*, pp.5-10.

nothing would be the same again, seen in some objectors to the Grid. People who perhaps realised damage was being done but were lacking the understanding or language to frame their concerns.

Matless, reviewed preservationism and modernism from 1926 to 1939, and suggested that much of the CPRE writing was about expressing ‘a notion of tradition itself as a version of modernism’, which again supports the idea that people wanted to retain what already existed, familiarity.[620] However, debates over pylons were not really about electricity, which was mostly welcomed, but about how much people were prepared to ‘pay’ for it. It was not necessarily a financial cost, although one report from Keswick suggested that the ‘opposition to the pylons was largely confined to a few people, some living away from the district who could easily afford to pay what price was asked for electricity’. It continued, the ‘aim of the Electricity Commissioners was to provide for the poor as well as for the rich’ and that insisting on underground cables would ‘kill the scheme at birth’.[621]

Many skirmishes were fought out in the press. *The Times* reported opposition to pylons in places of ‘natural beauty’, including the Lake District, Kent and the South Downs. Articles reported ‘obscured views’, and how ‘they are ruining what one might almost call the sacred beauty of this district’.[622] There were plenty of objections, letters and articles about the ruination of the countryside in local and national papers, particularly in the early 1930s. Objections included that the ‘open countryside’ would be ‘subdued to this machinery of transmission and urbanised’, and ‘these huge structures striding across the countryside cannot fail to disfigure and to create an alien feature in the landscape’ or that

---

[620] D. Matless, ‘Ages of English Design: Preservation Modernism and Tales of Their History, 1926-1939’, *Journal of Design History* (1990), 2, p.203.
[621] ‘Pylons in the Lake District: Difference of Opinion in Debate’, *The Manchester Guardian* (Manchester, November, 1929), p.4.
[622] ‘Public Assistance Committees, The Rejected Principle of Co-option’, *The Manchester Guardian*, (Manchester, October, 1929), p.2.

‘amenities would be spoiled by the appearance of the pylons’.[623] One writer suggested that overhead cables and pylons were outdated, and other countries were placing cables underground, and/or raised safety as an issue. However, the subject was introduced as ‘the proposed desecration of Northern Lakeland’, suggesting that aesthetics had a significant role in his objections.[624] The main objections, though, included terms such as ‘desecration’, ‘ugliness’ and ‘eyesore’. These were raised particularly in rural areas, Lakeland, Keswick, Dorset and Kent in particular, with pylons causing more concern than cables. Cables were objected to on health grounds in the 1880s and 90s and was similarly played out in the press, with objections including there being too many cables, they were being ‘fixed with great rapidity’ and the perceived high voltages they carried. In one local enquiry for example, St Georges Vestry were looking to absolve themselves of any responsibility for accidents which might occur.[625] Again, in earlier and later debates advocates for electricity, countered such arguments, saying ‘the great sources of danger in electric light wires are bad material, inexperienced workmen, neglect of rules and imperfect inspection. Cheap work in electric light equipment is not only nasty, but very dangerous’.[626]

There were those who did not find pylons offensive or, at least, were happy to defend them. A journalist visiting the Shannon Scheme in the Irish Free State reported that he did not consider ‘the cables and the supporting pylons a disfigurement to the landscape’. The CEB made some concessions and moved transmission lines on occasion but refused to spend additional funds on underground cables when they could avoid it. The CEB met with the newly formed CPRE and The National Trust to discuss the best

---

[623] ‘Pylons in the Park’, *The Manchester Guardian*, (Manchester, March, 1932), p.18. and ‘The Keswick Pylons’, *The Manchester Guardian* (Manchester, February, 1932), p.16 and ‘Malvern Electricity Pylons’, *The Times* (London, 1950), 51806, p.2.
[624] ‘A Lesson from Germany’, *The Manchester Guardian* (Manchester, November, 1929), p.22.
[625] ‘Overhead Electric-Lighting Wires’. *The Times* (London, 1888), 32579, p.5 and p.10.
[626] ‘The Dangers of Electricity’, *The Times* (London, 1889), 32812, p.10.

approaches and find ways of working together.[627] Perhaps one of the most extreme reactions reported was that of Austin, who moved to Paris to escape his view of the pylons. He admitted the move had been a long-time dream but stated, 'I should not have gone [to Paris] yet had it not been for these 'things' [pylons]'. The journalist reporting this case suggested, 'There are those who object to every new thing that is reared up, just as there are people who object to the pulling down of every old thing. The destruction of a windmill excites as fanatic opposition as the erection of a pylon. Yet what is a pylon but a kind of modern windmill – a source of power!'. He concluded, 'The pylon's greatest fault is its newness'.[628] This argument continues today when new routes for pylons are suggested or renewable energy infrastructures are proposed.

Brown, a Spectator journalist wrote, 'We cannot eat our cake and have it too. Either we are an industrial nation, dependent on cheap power and modern equipment, or we must reduce our population to Elizabethan numbers and give up hoping to be the workshop of the world'.[629] Like other journalists he likened objections to pylons to objections against windmills a century earlier and there are similarities to arguments on both sides of the debate in current disputes over wind turbines.[630] This idea that 'The wiseman does not tilt at windmills – one may not like it but the world moves on' was made by Bloomfield when he defended the Grid and his chosen tower design, and was often used as the counter argument in opposition to the Grid and its pylons.[631]

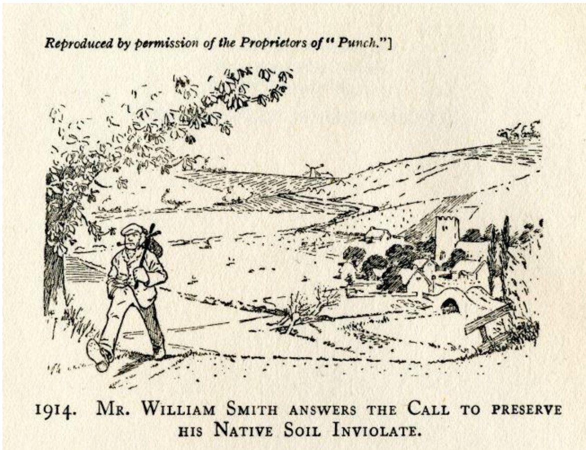
Electrification took decades and in the 1930s the benefits of electricity still had not reached the majority of the population despite the Grid taking only six years to construct. Perhaps this magnified the sense of

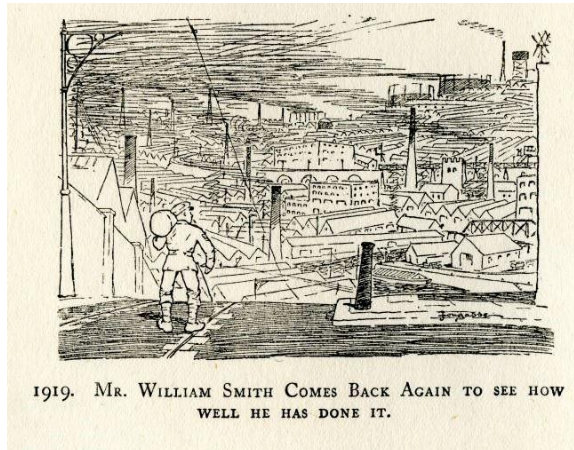
---

[627] 'Amenities of The Countryside', *The Times* (London, 1928), 45024, p.10.
[628] 'Pylons', *The Manchester Guardian*, (Manchester, April, 1931), p.8.
[629] 'Our five-year plan', *The Spectator* (London, October, 1930), p.10.
[630] L. Barton, 'Windfarm wars: are they a majestic man-made wonder – or a blight on the countryside?', *The Guardian*, (London, April, 2005), p.18.
[631] 'Pylons on The Downs', *The Times* (London, 1929), 45349, p.12.

rapid change because the infrastructure appeared with no tangible benefits for most people. A Punch cartoon from 1919 (Figure 103) illustrated that sense of rapid change, linked it to WW1 and national identity.

Figure 103 Mr Smith goes to war.[632]





Objections to pylons tended to be raised in places it was considered desirable to live and therefore tended towards wealthier residents. That is not dismiss them because they played a valuable role in negotiations over the construction and placement of Grid components and no doubt represented the views of some of the public but often did so from a privileged position. Duncan and Duncan suggested that 'members of certain communities can mobilise enough economic and cultural capital to create landscapes that have the power to incorporate and assimilate some identities while excluding or erasing others'. They continue, 'Not merely a backdrop for social action, landscapes play an active role in the performance of elite social identities and the framing of social life and values within a community'.[633] This perhaps suggests that communities who opposed the towers and cables either had the economic and cultural capital to do so or were making their values and social identity known as whole

[632] Source: *Punch Magazine,* 1919.
[633] J.S. Duncan and N.G. Duncan, 'The Anesthetisation of the Politics of Landscape Preservation', *Annals of the Association of American Geographers* (2001), 91, 2, p.387.

communities. Whilst the small beginnings of more equality and upwards mobility were appearing there are very few examples of 'Mr Smith' protesting the changes.

Debates about the Grid and landscape have never completely subsided. Negotiations continued when new gridlines were required for the 275kV 'supergrid' implemented after WW2. Similar debates and disputes raged over infrastructure in the Malverns, Lakelands and Surrey, where a joint committee of the Surrey Amenity Committee and the Kent branch of the CPRE joined forces to ensure the minimal loss of amenities.[634] The amenity argument was about minimising the loss of features or specific places. A wayleave officer remarked at the time, 'I wish objectors would realise that electricity is an amenity too - and if people want a supply, we've got to put the lines somewhere'.[635] Similar issues arose around distribution networks as they became increasingly dense. Perhaps surprisingly the wooden poles in the network caused more disquiet than the steel pylons, which were even considered 'harmonious' within the landscape by some of the people consulted.[636]

High voltage transmission and distribution networks both suffered from what we would now term NIMBYISM (not in my back yard). Cochrane reported that when wayleave officers asked landowners for permission to site pylons, they were more likely to acquiesce when they felt they would benefit from electricity themselves. When informed this was not the case it could be more problematic.[637] The Electricity Commissioners concluded in their final report for 1947-48;

---

[634] There are several articles in *The Times* including 'Pylons in Kent And Surrey', *The Times* (London, 1954), 53066, p.5, 'Malvern Electricity Pylons', *The Times* (London, 1950), 51806, p.2, 'Super-Grid for Britain', *The Times* (London, 1950), 51751, p.4 and 'Pylons on Malvern Hills', *The Times* (London, 1950), 51794, p.3.
[635] Cochrane, *Power to the People*, p.44.
[636] Matless, 'Ages of English Design', pp.204-205.
[637] Cochrane, *Power to the People*, p.18.

In the earlier years there was considerable opposition from local authorities and landowners to the reaction of overhead lines and this opposition was for a while intensified when the Central Electricity Board commenced the erection of the National Grid System. As however the importance of the availability of a supply of electricity as a factor in rural life and the development became to be realised there was a steady decline in the number in the number of cases in which objections were raised, concurrently with a striking increase in the number of applications for consent.[638]

They reported 1930-31 and 1931-32 as the most difficult years, in which compulsory powers applied for represented thirty-two percent (421) and twenty-nine percent (643) of total wayleave applications, while after WW2 less than one percent of applications necessitated compulsory purchase.[639]

In practice, the important factors were not *objections* but obtaining *permissions* from landowners to place structures on, or across, their land. For farmers, or others working the land, the additional difficulty of working around the structure was unwelcome. Whilst some landowners refused the wayleaves, particularly where pylons were considered 'eyesores' or disfigurements, not all of them objected. Many of the locations which resisted pylon installations later received Area of Outstanding Natural Beauty (ANOB) status, such as the Lake District and the Malvern Hills. Where wayleaves were agreed between the landowner and the CEB, or by suppliers for distribution networks, 'compensation commensurate to the inconvenience caused, either as a lump sum, or rental payment was made'.[640] For the first 132kV Grid many wayleave officers were ex-servicemen, 'with several admirals and generals in their ranks; the sort of people, the CEB hoped, who could talk man-to-man with the many large landowners of that time'. 'Wayleaving isn't an art, it's a penance' was the comment of another wayleave

[638] Elec. Comms., *Annual Report*, 20, pp.10-11.
[639] *Ibid.*, p.11.
[640] R. Poole and P.M. Poole, The Valuation of Pipeline Easements and Wayleaves (London, 1962), p.21.

officer, while an undertaking manager reported, ‘Every year the lack of adequate powers to obtain wayleaves grows more irksome’.[641] These were views in 1926, and the method for obtaining permission remained similar throughout the CEB’s management and beyond. An application was made to the local authority and Minister of Transport (through the Electricity Commissioners) and whilst engaging the local authority and getting the correct administration in place was time consuming, routes were not scrutinised unless specific objections were made. When the Grid was nationalised the new Town and Country Planning Act of 1947 was introduced applications were required to pass through a planning process. As National Parks, Sites of Special Scientific Interest (SSSI), ANOB’s and wildlife reserves gained legal status and protection, it became increasingly difficult to obtain wayleaves through them.

Pylon construction and erection methods also developed over time. Depending on the subsoil in which they would stand; excavated earth, ordinary concrete bases or concrete balls were possible methods which would secure their foundations. The concrete ball method was newly imported from America to Britain, where a hole was drilled for each leg before exploding a charge of dynamite within it, inserting the tower leg stubs and filling the cavities with cement. After testing, it was described as ‘simple, accurate and economical’.[642]

[641] Cochrane, *Power to the People*, p.43.
[642] Wright and Marshall, ‘Construction of the Grid’, p.692.

Figure 104 Using horse power to install roadside cables and erecting a pole for bulk supply.[643]

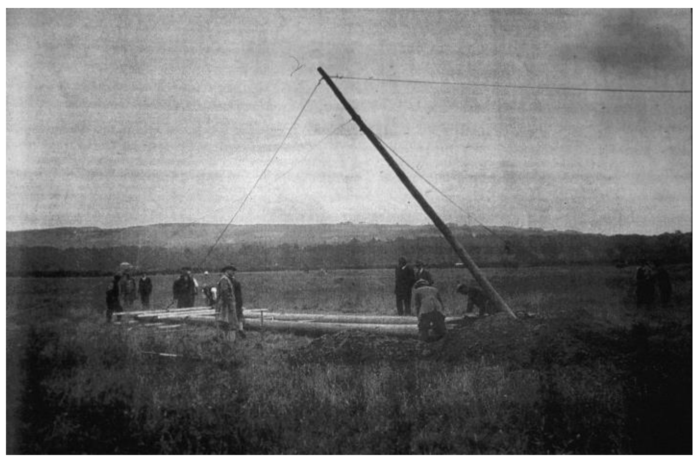


Figure 104 shows how horse drawn carts were used to pull poles into position and how pole sites next to roads were beneficial allowing easy vehicle and equipment access for installation and maintenance. Particularly noticeable is the number of men needed for the process.

[643] Source: A. Barnett and A. Macartney.

Vehicles and the fuel to power them have also changed. Electric vehicles were common enough to include vehicle charging on supply tariffs in the 1920s and were often used by electricity companies. Petrol driven machinery such as the 1931 pole boring machine shown in Figure 105 was also used. These photographs show how powered vehicles substituted for manpower; even with the photographer only three men were present with the petrol borer rather than six with the horse and cart.

Figure 105 Ipswich Corporation Electric Supply electric van, c. 1923 and a petrol hole boring machine, c. 1931.[644]

After WW2 vehicles and processes became more mechanised shown by the ex-army vehicle shown in Figure 106 It is clear from the size of the vehicle that it wields more power and has tyres and wheels

[644] Source: A. Barnett and A. Macartney.

which create more immediate damage than earlier, lighter vehicles but it further reduced required manpower.

Figure 106 An ex-army vehicle for hole boring.[645]

These changes demonstrate two things. Firstly, they show that electrification began when horses and carts were common but was still not complete when heavy petrol vehicles were used post WW2. Secondly, it shows how transportation, hydraulics and more reliable engines have increased potential environmental impact with less manpower. Much of this development has been facilitated through improved engineering enabled by electricity. Beyond the lifetime of the CEB technology continued developing, and by the 1980s vehicles for digging, lifting and cable works, looked very similar to those being used today (Figure 107).

---

[645] Source: A. Barnett.

Figure 107 c.1980 machinery for holes and hydraulics.[646]

Despite battles over aesthetics less than three percent of wayleaves for the Grid (594 out of 21,026) needed compulsory orders, and many issues were resolved easily.[647] In fact, as the Grid matured and generating stations reduced in number but increased in size it became substations that were more noticeable. When the Grid was initially constructed there were just 273 substations but numbers grew rapidly and now, there are thousands. Initially, some generating stations were effectively converted to substations transforming electricity to lower voltages before distribution. Smaller substations were located on streets and their appearance has altered over time attempting to be sympathetic to their surroundings. The following set of figures demonstrate how they changed over time and attempted to 'blend-in'.

[646] Source: *Ibid*.

[647] G.E. Moore, 'Completion of the Electric Grid', *Fortnightly Review* (1933), 3, p.466-467.

Figure 108 Street substations from 1920 and 1924.[648]

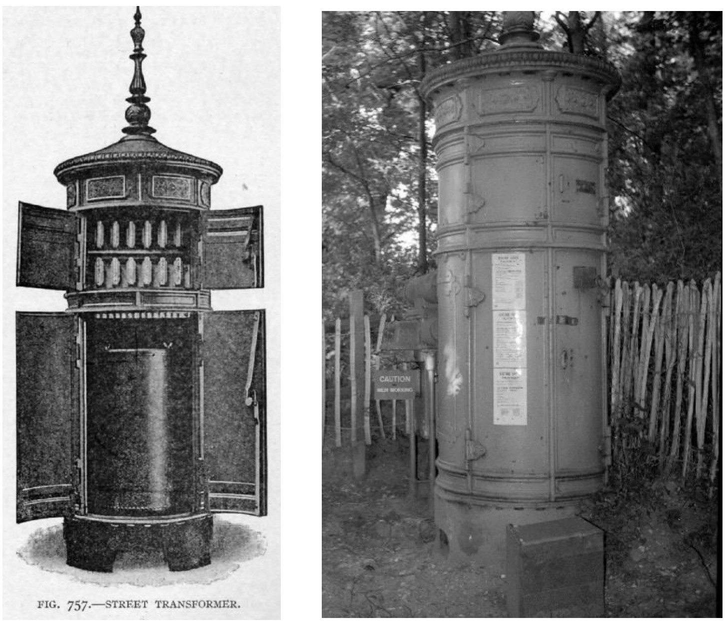
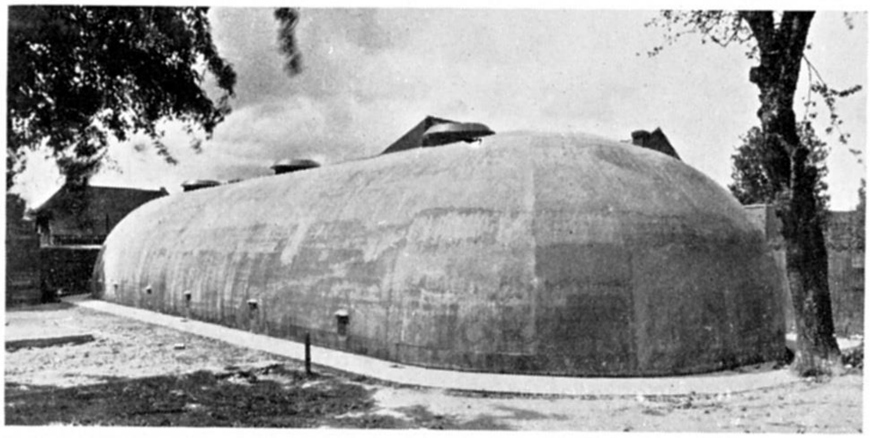


Figure 108 shows substations from 1920 and 1924 respectively. The substation shown in Figure 109, from 1938, is from Bentley Priory, home of Fighter Command, and was very acceptable for its time and place but would likely raise objections now. The protection afforded by its reinforced shell made it difficult for anyone to break into or damage during wartime.

[648] Source: A. Barnett.

Figure 109 Substation for wartime.[649]



The new bomb-resisting substation recently completed at Watford.

Essentially, the same question has been asked since the introduction of electricity, and was focussed by the Grid: How much would people 'pay' for underground cables, unobstructed views and cleaner emissions? After the 1970s it became how much were/are people prepared to pay to protect the environment? This was presented as 'The Dilemma' at the beginning of *England and the Octopus* and was met with the suggestion:

> It is quite possible, perhaps probable, that there will be a great reaction and revulsion against the doings and omissions of the last few generations, and that we, or our children, having regained consciousness, will view with consternation the wreckage wrought in our delirium.[650]

Matless pointed out that Abercrombie himself suggested, 'The pylon, a new arrival, has given rise to more heat and illogical discussion than any other one feature'. Matless further remarked: 'To say that a

[649] Source: *Ibid.*
[650] Williams Ellis and Abercrombie, *England and the Octopus*, p.viii.

pylon, because it is a good seemly straightforward piece of engineering is therefore a suitable addition to any scene, is as bad as condemning it wholesale'.[651] Duncan and Duncan suggested that 'its [landscape] consequences are more far reaching than may at first appear', proposing that these debates are important and consideration should be given to their origins and participants.[652] It should be remembered that alongside these active individuals there were many unrecorded or passive voices, and by choosing not to enter this debate they were either happy that their voices were represented or were uninspired or unable to actively engage in the negotiation. Landscape changed as additional infrastructure was, and continues, to be added. Debate is continually provoked and negotiation remains a dynamic process, which values and exogenous pressures affect too.

Air Quality and Generating Stations

Public electricity supply was established when there was already disquiet, and academic writing, about air quality, resulting from domestic coal fires, industry's steam engines and furnaces. While aesthetic issues surrounding the Grid were primarily visual, smoke invades all senses; it smells, tastes, and can be seen and felt. It is generally accepted as gritty and dirty. In contrast to factories with tall chimneys, shorter house chimneys did not funnel smoke high into the air for dispersal.[653] Smoke and it origins in

---

[651] Matless, 'Ages of English Design', p.205.
[652] Duncan and Duncan, 'The Anesthetisation of the Politics of Landscape Preservation', p.387.
[653] S. Mosley, *The Chimney of the World: A History of Smoke Pollution in Victorian and Edwardian Manchester* (Cambridge, 2001), S. Mosley, 'A Network of Trust: Measuring and Monitoring Air Pollution in British Cities, 1912-1960' *Environment and History* (2009), 15, 3, pp.273-302 and P. Brimblecombe and C. Bowler, 'The History of Air Pollution in York, England', *Journal of the Air & Waste Management Association* (1992), 42, 12, pp.1562-1566. Alongside Luckin, *Questions of Power* and Sheail, *Power in Trust.*

the nineteenth century were discussed by Mosley in relation to ‘a variety of serious problems, including the destruction of vegetation; loss of sunlight; the defacement of monumental architecture; and rising rates of respiratory diseases among urbanites’.[654]

In the very early twentieth century electricity generation was included in this debate because power stations were central to the communities they supplied resulting in marginal spatial displacement of smoke pollution. Initially, coal burning power stations provided electric lighting for streets, retailers, other businesses, and a few domestic premises. The shift away from domestic coal fires was slow and negligible at this time with domestic electric heating not recognised until the 1920s.[655] However, the nuisance of power stations was described by Hinton as ‘real and widespread’. This was not just about smoke, which he documented, but also ‘the vibration was so severe that it stopped clocks on the walls of the houses in the neighbourhood’.[656]

Complaints about chimney smoke, noise and vibration from engines, and cable placement were made about many electrical suppliers. For example, a group of residents in Manchester sought to prevent smoke and vibration nuisance from the Metropolitan Electric Supply Company. They obtained an injunction against the company for vibration, although it was suspended for three months enabling the company to complete ‘remedial works’ but they were unsuccessful in preventing smoke nuisance.[657] Station owners do seem to have been held to account, the Morning Standard reported police ensuring further action was taken because, despite twenty summonses, the company had not followed earlier

---

[654] Mosley, 'A Network of Trust’, p.275.
[655] BEAMA, The Electrical Industry of Great Britain, p.178.
[656] Hinton, *Heavy Current,* p.33.
[657] ‘Electric Lighting Works’, *Berrow's Worcester Journal* (Worcester, May, 1894) p.6.

restrictions placed against them by the courts.[658] Legal sections of newspapers often reported litigation but details were scant.

Some authors noted that electricity represented a displacement of pollution, shifting it from homes to generating stations. A Liverpool correspondent wrote, ‘While electric lighting was making its debut at international and other exhibitions, we may have felt it only courteous to the debutant to do our best to ignore the hideous array of smoke belching stove pipes which generally occupy the rather too obvious background of the spectacle’. As electricity became increasingly normalised, rather than a novelty, the realities of the plant and infrastructure which provided it became less easily forgiven. The same correspondent pleaded for the prevention of ‘the pollution of the atmosphere and surroundings of these homes’, which reduced their letting and rateable values. He did though, admit the reality of the situation, remarking, ‘But electric lighting is now an accepted fact, and the public has a right to insist that the municipal and private installations which are being laid down regardless of the expense, may be a model of all that is best and least offensive, instead of exactly the contrary, as is often the case at present’.[659]

Electrical engineers found this difficult. ‘We should be the last to seek to justify or extenuate a smoke nuisance which is caused by negligent stoking’, reported *The Engineer* in 1905, ‘but where the accused parties [the generating station] are able to show that they use the very best mechanical stokers, and how they take the utmost precaution, ought they to be held liable?’.[660]

The difficulty was that ‘nuisance’ was not really defined or quantified but rather described by the people who felt they were suffering from it. When the CEB began operating generating stations, the quantities

---

[658] ‘Police Intelligence’ *The Standard* (London, 1898), 23084, p.2.
[659] ‘Electric Lighting Smoke Nuisance’, *Liverpool Mercury* (Liverpool, September,1899), p.4.
[660] ‘Smoke Nuisance’, *The Engineer* (November, 1905), p.470.

of electricity generated and size of the stations grew, creating fewer, but more concentrated centres of smoke pollution. As a result, despite increasing efficiency the total volume of coal burnt was also increasing and chimney effluent raised serious concerns amongst local residents.

Under the 1909 Act, residents within 300 yards of a proposed generating station had to be consulted, and pre-emptive action taken, or enquiries made to address concerns. It was not until controversy in London concerning Battersea Power Station that any sort of atmospheric protection was included in licensing of generating stations and was the response to numerous complaints regarding the damage to buildings from smoke and sulphurous fumes. *The Times* and other newspapers included examples of complaints and lobbying carried out by the Smoke Abatement Society and other interested parties.[661] Battersea, was a large power station with a 360,000-kW capacity and complaints were anticipated resulting in the following stipulation included in its license to supply;

> The Company shall, in the construction and use of the said generating station, take the best known precautions for the due consumption of smoke and for preventing as far as reasonably practicable and the evolution of oxides of sulphur and generally preventing any nuisance arising from the generating station or from any operation threat.[662]

Consent was given to Battersea in 1927 as concerns continued to rise regarding emissions from domestic houses as well as power stations. Responding to a London County Council Public Control Committee report, the *Electric Times* suggested that electricity and gas suppliers should be 'given every incentive to cheapen their commodities', in order that people could stop using coal domestically for heating and cooking and convert to electricity and gas instead.[663]

---

[661] Further details can be found in Luckin, *Questions of Power,* and Sheail, *Power in Trust.*
[662] Sheail, *Power in Trust*, p.8.
[663] London, London Metropolitan Archive (LMA), 'Leyton Scrapbook', LMA/4278/01/116, p.149.

The argument was that where conversion occurred, small inefficient house fires would be replaced by large furnaces in generating stations. An open fire is about twenty-five percent efficient, whereas an electric or gas fire is almost 100% efficient but only heats a single space. As late as 1964 only thirteen percent of households had central heating.[664] Coal-fuelled power stations had reached thermal efficiencies of around twenty-seven percent at the time which, given distribution losses, meant there was probably little thermal efficiency gained over domestic coal grates. However, open coal fires can have an overall negative heating effect because it pulls cool air into the room. Electric heaters convert all the electricity they consume into heat but rely on convection for heat dissipation around the space but given the known draughts in British housing stock, all forms of heating had difficulties.[665] After WW2 housing began to be built to use central heating systems more effectively.[666] However, there was certainly irony in electricity, a fuel marketing itself as being clean and healthy for domestic consumers, being accused of polluting the air with soot and sulphur.[667]

Through the 1930s, debates raged with complaints, recorded in voluminous archives, often to the Ministry for Health, resulting in correspondence between power station owners and Electricity Commissioners. Part of the difficulty for the CEB and Electricity Commissioners was a lack of agreed parameters within which to work. The clause in the Battersea consent document, for example, stated that protection of air quality should be undertaken if there was a 'best known' method which could 'reasonably practicably' be used. It took further complaints and years of experimental work to

[664] J. Rudge, 'Coal fires, fresh air and the hardy British: A historical view of domestic energy efficiency and thermal comfort in Britain', *Energy Policy* (2012), 49, pp.7-8.
[665] Figures are taken from The Solid Fuel Technology Institute accessed via http://www.soliftec.com/efficiency.htm. Twenty-seven percent is the thermal efficiency of steam powered power stations across the 1930s, according to Garcke, *Garcke's Manual*, 47, p.46.
[666] Janet Rudge, 'Coal fires, fresh air and the hardy British', p.8.
[667] Sheail, *Power in Trust*, p.13.

determine what level of sulphur emissions could be considered appropriate and the effectiveness of different removal techniques and was repeated for Soot and other emissions but as one problem was solved, others came to the fore, such as wetness in the air.[668] Establishing what constituted a safe level of any emission and the efficacy of any remedies then required monitoring to ensure compliance. The introduction of monitoring and the responsible bodies from the early twentieth century are discussed in detail by Mosley. As he argued, it was the 1956 Clean Air Act which really focused this work, doubling the number of organisations and local authorities involved in reducing air pollution.

Having safe levels meant a qualitative nuisance could be quantitatively assessed to determine if a chimney's emissions required additional cleaning. These test results primarily assisted the organisations collecting them to reduce smoke related nuisance but the data they collected was also used to determine what acceptable emission levels might be.[669]

Investigations into nuisance could be enduring. For example, complaints resulting in investigations were made about Kirkstall Power Station in Leeds from 1930, when the station opened through to extensions added in the late 1940s. A letter to the Ministry of Health sought to 'respectfully draw your attention to the most unbearable nuisance we have suffered for the past thirteen years from the daily emission of large quantities of grit and fumes'.[670] This 1948 letter, signed by householders, residents and shopkeepers made five claims about difficulties they faced:

1. Grave danger to the health and happiness of our children and ourselves
2. Serious damage to food in our houses and shops

[668] London, TNA, 'General Smoke and Grit Nuisance: Policy', POWE 14/123.
[669] Mosley, 'A Network of Trust', pp.290-295.
[670] London, TNA, 'Kirkstall (Leeds) Generating Station Grit Nuisance: Proposed New Chimney', POWE 14/125.

3. Damage to property and greatly increased maintenance costs

4. Unnecessary damage to our furniture, furnishings and decorations

5. Damage to growing trees, shrubs, and plant life generally.[671]

This complaint went to the BEA, the successor of the CEB in 1948, and the Electricity Commissioners. This represented major change because the board now operated *and* owned the generating stations. This perhaps made such issues more urgent because there were no longer layers of organisations between station owners and local residents. Later in this correspondence it was noted that a story about Kirkstall generating station appeared in the local press two or three days a week adding pressure for action. After several months, consensus was reached that additional grit filtering and a higher chimney were needed. However, it was eventually decided that the central coal milling unit, where coal was ground into smaller pieces, improving combustion but creating soot, should also be closed and smaller milling units constructed within each boiler section but that took time. The investment in technology at power stations had to be balanced, because the plant in each boiler section, previously reliant on the central mill ranged from just a few years old to more than twenty. This provides an indication of the accounting and technical complexities, and the 'interconnectedness' even within powers stations, involved in such changes.[672]

Similar issues were raised regarding North Tees Power station. Complaints to the Department of Health prompted a series of emission tests to establish the size and volume of particles emitted. The completed report recommended that instead of mechanical particulate separators, electrostatic ones should be installed because the technology had improved. The CEGB, who were the operators when the

[671] *Ibid.*
[672] London, TNA, 'North Tees Generating Station: Smoke and Grit Nuisance', POWE 14/127.

investigation was undertaken in 1963, applied for permission for this change because they were compelled to comply with the 1956 Clean Air Act and mechanical separators did not remove enough grit to reach the clean air targets. Progress on technical and regulatory issues was slow and many other investigations occurred at Brimsdown in the Lea Valley, and Mexborough and Fulham power stations. For the BEA and CEGB the position was clear because they owned and coordinated the whole electrical supply system but the position for the CEB was less straightforward.

Pollution issues were almost a step removed from the CEB because the Electricity Commissioners investigated complaints through powers deputised by the Minister of Transport. In 1930 the Electricity Commissioners appointed a committee to report on 'The measures which have been taken in this country and in others to obviate the emissions of soot, ash, grit and gritty particles from the chimneys of electric power stations'.[673] The committee, almost entirely electrical engineers, appointed a technical sub-committee who visited power stations to gather evidence about practices in Britain, and at twenty power stations in Germany and France for comparison. The opening statement of their report, published in 1932, set the tone stating, 'It is evident … that power stations are receiving a greater share of the blame for grit nuisance than is their due'.[674] They suggested that earlier plants had fewer problems than later ones with 'forced draught to stoker fired boilers and the advent of the shorter chimney' because this enabled 'inferior' coal to be burned, and with increased burning rates, air and gas speeds were increased and coal was pulverised to increase process speed even further. For ash leaving chimneys, the difference between standard and pulverised coal was suggested to be ten percent of the twelve percent ash content, and as much as seventy percent of the twelve percent ash content respectively. Likewise

[673] London, TNA, 'Report on the measures which have been taken in this country and in others to obviate the emissions of soot, ash, grit and gritty particles from the chimneys of electric power stations', POWE 14/126, p.5.
[674] *Ibid.,* p.10.

grit through chimneys was 0.3 grains per cubic feet for solid fuel compared to 2.62 for pulverised.[675] The smaller the particles the better they combusted but power station design needed to adapt as it did at Kirkstall by enclosing the pulverising units within each boiler section, with a chimney, preventing pulverised coal dust from escaping and the associated pollution as it was moved around the site.

Although scientific in their approach to chimney emissions the knowledge base that engineers worked from was very different from what is now understood. The purpose of their work was to prevent nuisance which in this instance, was the grit which fell to earth resulting in dirt and other damage. Therefore, they suggested:

> The emissions from the chimneys of such a plant [pulverised fuel] cannot cause a nuisance if discharged into an air stream which can be depended upon under normal circumstances not to come to earth. It only remains necessary, therefore, to ascertain to what height a chimney must be taken to ensure emission into such an air stream, and the problem is solved.[676]

Therefore, their solution was that chimneys should be at least 2.5 times as tall as the tallest part of the surrounding land and buildings. This would mean that any gritty particles emitted would remain in an air stream and therefore not fall to the ground, eradicating the nuisance. They did not explain if they thought the particles would eventually fall to earth somewhere else, or whether they expected them to remain suspended *ad infinitum.* Other solutions included ensuring chimneys were as clean as possible preventing greater emissions when the plant exceeded normal capacity, and using new electrostatic particle removers, and for these to be considered when designing new plants.

---

[675] *Ibid.,* p.15.
[676] *Ibid.,* p.16.

Although the idea of eradicating air pollutants by literally leaving them up in the air may seem naïve today, the committee carried out significant experimental work and implemented greater uniformity and standardisation of flue gas testing. They recommended that new power stations should be designed to make routine testing easier to undertake. However, what to do with the extracted waste particulates was still a problem. 'The general practice is to dump it on a suitable site as close to the generation station as possible', which had obvious implications for its transportation and being blown around.[677] However some generating stations formed relationships with local firms that used it in industrial processes, which was encouraged; otherwise, it was expelled into water systems.

The final conclusions of the sub-committee included that full, detailed information about individual plants was needed to ensure maximum dust extraction was carried out. They added that further work was necessary to standardise methodology for emissions testing. However, as for many other issues of the time, they reported, 'the Sub-Committee are satisfied that it is impracticable to formulate any Regulations governing the emissions of dust from generating station chimneys, and they are convinced that if their recommendations are carried out the necessity for Regulations does not arise'.[678]

Although there was a desire to make processes efficient, and to reduce nuisance, regulation was slow to be implemented, partly perhaps because this would have meant additional 'red-tape' but also because there was still a lack of data in the 1930's and it took a further twenty or so years to put regulatory legislation in place, rather than working on a case by case basis.

A list of complaints about grit and smoke relating to power stations, held by the National Archives, includes a note suggesting that the Electricity Commissioners' files were not fully available. It reported

[677] *Ibid.*, p.24.
[678] *Ibid.,* p.32.

that before WW2 there were only six complaints, but between 1940 and '47 there were twenty-nine, twenty-three of which were explained by 'poor quality fuel'. The note suggested that after vesting (between 1948 and '54) there were eleven complaints because of 'poor quality fuel', a further eleven because of old plant which, but for WW2, would have been decommissioned, and nineteen (thirteen of which were between 1948 and '50) where 'remedial measures were being taken,' alongside comments that only two complaints since vesting were against 'modern power stations'. The complaints were made by local residents, abatement societies or other 'groups' such as the National Union of Railwaymen. There were also escalated complaints made through members of parliament, the local authority or in most cases the Ministry of Health, who referred complaints to the Electricity Commissioners. Repeated complaints about the same power station did not often come directly from the same complainant, for Croydon A power station, for example, local medical offices and a local resident complained the MP in 1948, followed by the War Office complaining in 1950. Complaints about Mexborough in 1946, 1948 and 1953 came from the Ministry of Health on behalf of Mexborough Council, Mexborough UDC and local residents respectively. Whilst it might suggest that local residents were behind each complaint, where local residents were the main complainant it is specifically recorded suggesting where they are not recorded, they were not the main complainant.

An example from 1938 records Viant, MP, asking a parliamentary question regarding reported nuisance at North Met's generating station in Willesden. The Minister for Transport promised to make enquiries. As a result, Damon and East from the Ministry of Health and an inspector for the Electricity Commissioners respectively, visited the power station because the local council wrote to the MP explaining they had no powers to intervene. Four generating stations were inspected, three of which passed with clean emissions, and the fourth, the origin of the complaint was reported as being, 'in a difficult position as regards space and it is felt that they are doing their best in the circumstances'. If the new proposed station, to replace it, was constructed, it would use the ‘most modern type of electrostatic precipitator plant’ and, it was decided that any action would be unsuccessful. The Minister of Health replied to Viant stating, ‘The general conclusions of the Inspectors were that none of the four Stations was at that time operating to the detriment of the neighbourhood but that there were a number of industrial chimneys in this district which gave evidence of being likely to contribute to atmospheric pollution far more than the Power Stations’. After this correspondence, further complaints were made by the National Union of Railwaymen to Willesden Council in 1945. Again, these were passed to the Minister for Health. East and Damon were again asked to inspect the station and to compare it with others in the area. This time they concluded that the nuisance was sporadic and more frequent cleaning would rectify it, and that problems were being caused by emissions from Neasdon Power Station. Neasdon was owned by London Passenger Transport and was not an authorised supplier. The Electricity Commissioners then wrote to the Minister of War Transport ‘with a view of urgent steps being taken to remedy the position’. The resolution included actions to reduce emissions by emptying grit hoppers more frequently and an improved flue. Complaints continued into 1946, although many problems were blamed on poor fuel quality. This was the reason given after a group of MPs and residents from Willesden and surrounding areas made a deputation to the Minister of Health, Fuel and Power and Electricity Commission, which included housewives claiming their curtains had been dissolved by sulphurous fumes in just three months.[679] As nationalisation of both the electricity and coal industries approached, there was uncertainty about what new policies might be implemented and from the 1st April 1948 these issues, still ongoing, became the problem of the new area boards and the BEA. However, it should be noted that people who had worked for the Electricity Commission were re-

---

[679] London, TNA, ‘Willesden generating station: emission of smoke and grit’, POWE 14/128.

deployed in the newly created BEA, as members of its area boards, or within the Ministry of Fuel and Power, continuing with much of the same work.[680]

The Willesden example shows that investigations still occurred during wartime and although there were some suspensions, leeway was also given regarding emissions to ensure continual supply. Experimental flue gas cleaning at Battersea and Fulham produced a distinctive white smoke and was suspended during WW2 because of fears it made them easy bombing targets. To ensure adequate electricity supply, some normal requirements for new stations or extensions were suspended, as legislation in WW1 had been. The suspensions of normal practice primarily affected how objections and complaints were handled. This was in part due to information restrictions preventing enemy knowledge of the electrical system which was essential for munition production. While information was restricted the electrical press relied upon the Electricity Commissioners to supply them with publishable information but more importantly, announcements of new generating stations or extensions were considered too sensitive to print. The 1909 Act stated that potential neighbours of a proposed generating station must be consulted and they were but during wartime they could be prosecuted if they passed this information on, although this was qualified to relate to deliberately providing information to the enemy.[681]

Discussions between the Ministry of Fuel and Power, Minister of Transport and the Censorship Office, amongst others, resulted in the CEB releasing a document explaining the ‘Procedure for securing the construction of new generating stations in England and Wales’ from 1945; despite the timing, it does not

---

[680] Elec. Comms., *Annual Report*, 23, p.40.
[681] London, TNA, ‘Procedure for dealing with applications to establish new generating stations’, POWE 14/13.

discuss war-time restrictions and requirements. It does, however, include the following statements regarding 'Selections of Site', stating;

> 'a site be such that at least the following essential requirements exist or can be easily provided;
>
> A sufficient area of vacant land with suitable subsoil for foundation
>
> Ample supplies of water of suitable qualities for condensing and boiler feed purposes respectively, preferably from a river which would also give access for water-borne coal
>
> Readily obtainable supplies of coal at appropriate prices
>
> Rail access for construction materials, coal plant and stores
>
> Good road access
>
> Facilities in the neighbourhood for the contractors' men during the period of construction, and for the operating staff thereafter; or, if not available locally, room on, or near, the site for the provision of housing accommodation'.[682]

The document also reported that two plans had been sent to the Royal Fine Art Commission, who had commented on the appearance of chimneys and emissions, effect on the skyline, external appearance of copings, windowsills and other features, building materials used and the planting of trees as a screen. They noted that whilst engineers and architects did not completely agree, it was part of an effort to make generating stations more aesthetically pleasing. As we have seen with pylons and sub-stations this was a continual concern for the electricity industry, particularly bodies charged with constructing the large infrastructure of the Grid and associated power stations.[683]

---

682 *Ibid.*
683 *Ibid*.

The Grid enabled large quantities of electricity to be transmitted with reduced losses which enabled the system to rely on fewer, larger generating stations, sited where they would have less impact on their direct neighbours and consumers. Until the Town and Country Planning Act of 1947, only people living within 300 yards of a station had to be consulted, and permission obtained from the local authority and Electricity Commissioners to build a power station. This meant that few people were directly consulted but the severity of complaints became increasingly vigorous as the scale of the 'nuisance' increased as power stations grew larger.

The list of site allocation considerations indicates the enormous volumes of resources necessary to construct large power stations besides the amounts of fuel and water generation on this scale required. As larger stations could be located further from consumers, because transmission had improved, they more dependent on transport access for particular resources including fuel and water; waterways impacts were potentially large and, water quality testing was undertaken to determine sulphur content and water temperature as it was returned to its original source after use. In fact, legislation was passed in 1951 to prevent river pollution, faster than for air pollution as the Clean Air Act passed in 1956. This was partly due to River Boards, who had authority to set parameters regarding discharges into their water, but those directly responsible for maintaining the quality of the air had no equivalent. Equally, the number of actors regarding rivers was lower because it was a more contained entity than air. The Alkali Inspectorate instigated in 1863 to monitor heavy chemical discharges was initially charged with monitoring air quality for generating stations.

Both major Acts regulating water and air pollution were passed after the CEBs tenure and electricity nationalisation. This is discussed in detail in Sheail's *Power in Trust,* which demonstrated how the BEA took up the environmental mantle. There was some internal resistance, within the supply industry to these concerns discussed by Self and Watson in their chapter entitled 'Non-productive Capital

Expenditure and Amenity Preservation’ which demonstrates how they felt these protections were ‘being virtually forced upon the industry by the requirements of outside interests and agencies’.[684] They reported that the BEA was prevented from building on some sites which meant additional expenditure was necessary to use less ideal sites and required additional transmission lines. They also suggested the imposition of reduced capacity made the production costs more expensive than necessary. The expense of tall, gas-washing chimneys caused further complaint by the authors who suggested that such ‘frills’ prevented investment for ‘safety and continuity of supply’.[685] The costs required to meet the ‘preservation of amenities and the standards required by public opinion’ were considered to result in additional costs for cables to make generating stations more palatable. Looking forward they expressed concerns about the additional expense that ‘preservation’ would cause as the cables moved further from dense populations. However, by this time, the opinion of a public now largely connected to the Grid was that further generation and connection should not come at any cost.[686]

The BEA was managing supply as many of these new measurable controls came into force and, as a result, they faced the challenges of adjustment. They were now benchmarked against new rules which had not existed for the CEB, many of which were not yet met by power stations. The late 1940s and ‘50s was a period of legislative change in which the electrical engineers were playing catch up, rather than politicians, to ensure the industry met new regulations. After WW2 the electricity supply industry found itself having to comply with more general reforms and wider regulation than just the Electricity Supply Acts. When the CEGB, took over management of electricity supply in 1957, they exploited this as an opportunity rather than considering it a burden using environmental issues to improve public relations.

---

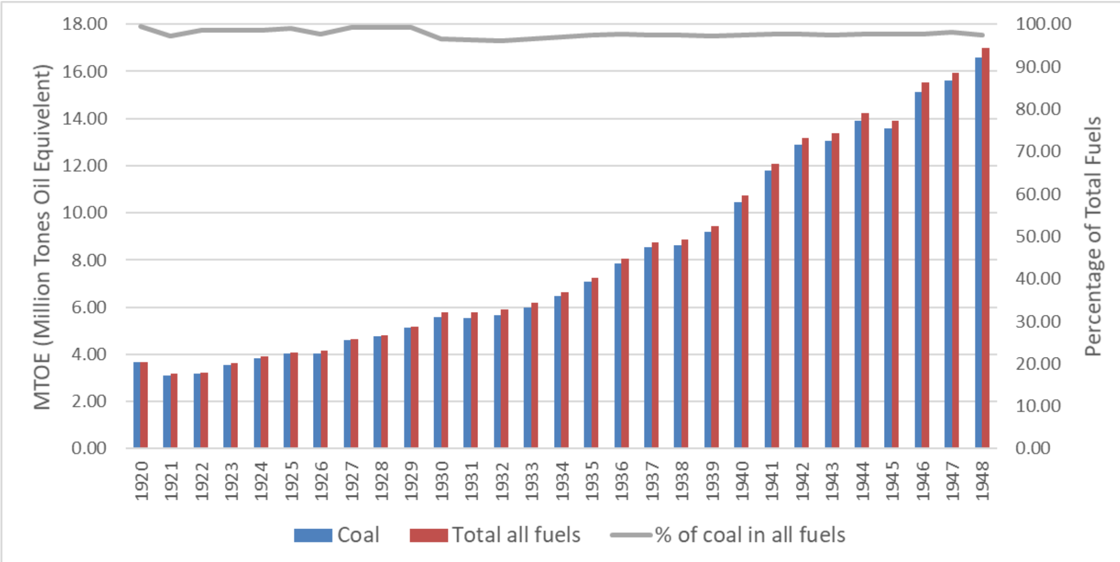
[684] Self and Watson, *Electricity Supply in Great Britain*, p.174.
[685] *Ibid.,* p.175.
[686] *Ibid.*

One of their advisers suggested, ‘We cannot help worsening the environment by power lines. Our job is to reduce the impact as far as possible, but we cannot hide them except at impossible cost, and I do not think we should pretend to be conservers, which we are not’.[687] Responding to this alongside other advice, they opened up some of their sites to show the public their efforts to minimise the environmental impact of generation and transmission. This was successful, as were their bird sanctuaries, migrating insect homes and fish lifts, shared with visitors, and they won many awards for environmental care. Like the CEB responded to concern for aesthetics when challenged by defenders of the ‘countryside’ as the Grid was constructed, their successors in the era of a conscious environmentalism learned to refine their behaviour and perhaps, above all, their communication strategy, to keep step.[688]

It would be fair to suggest the CEGB could not realistically portray themselves as conservers regarding the landscape, especially as, to a large extent, beauty is in the eye of the beholder but fuel and resources were a different matter. The Grid, as an enabler of power transmission and consumption, was essential for conservation of fuel because it increased efficiency and increased electricity consumption fulfilling its purpose. This had countervailing impacts: increasing the efficiency of fuel use but the ‘rebound effect’ of expanding total use and therefore total coal consumption, shown in Figure 110.

Figure 110 Coal as a proportion of total fuels used for the generation of electricity.[689]

[687] Sheail, *Power in Trust,* p.123.
[688] Cochrane, *Power to the People,* pp.43-56 and Sheail, *Power in Trust,* p.119-126.
[689] Source: DECC data, 1920-2013.



Coal was the most important resource for the grid because generation was almost entirely coal dependent with no more than four percent hydropower. Unlike America, with wide, fast flowing rivers providing much of their electricity, Britain relied on coal because it was the abundant fuel source of the time. The Grid allowed the numbers, sizes and locations of generating stations to change by transmitting their electricity produced from increasing volumes of coal, for distribution to consumers to meet demand.

Resources through the Grid

The main resources required before and after Grid construction were coal and water. The Electricity Commissioners wrote in their final report, 'whereas in 1922/23 there was only one station with a total installed capacity of over 100,000kw., the actual figure being 106,750kw., in 1947/48 there were 21 stations with an installed capacity of over 150,000kw., the largest having a capacity of 541,500kw.'.[690]

Indirectly, the electricity network had a major impact on coal mining, its associated infrastructure and communities, supplanting steam engines and domestic fires as electricity generation became a major coal customer. Mining and its associated processes provided employment for whole communities. It was determined that locating generating stations close to coalfields to reduce transport costs was beneficial, which, like many efficiency decisions, had environmental benefit by reducing environmental impacts of multiple coal transport journey's. Work was also undertaken to consider where existing selected stations for the Grid could be extended, and some riverside sites were identified that the CEB considered close enough to coal and water to be idea for expanding generation when they began their work from 1926.[691] Changes in the coal industry resulted from the increasing efficiency and growing consumption facilitated by the Grid, as well as increasing environmental awareness over the period. This is beyond the scope of this work but it is an area in which there is available data and potential for further work.

[690] Elec. Comms. Annual Report, 23, p.9.
[691] CEB, Annual Report, 2, p.10.

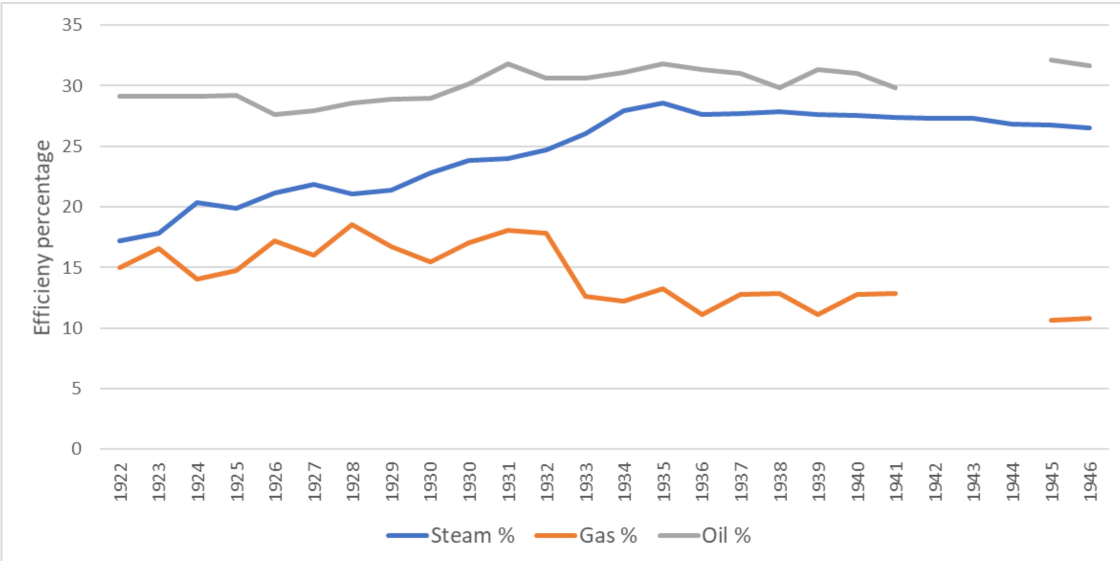
Table 18 Statistics during the CEB period.[692]

	1921-22	1931-32	1941-42	1947-48
Coal and coke consumed (tons)	5,362529	8,736,134	20,179,275	26,147,636
Average fuel consumption per unit generated (steam Stations) (lbs.)	3.24	1.78	1.41	1.41
Approximate % of spare plant	83 (estimated)	82	19 (estimated	12

Table 19 shows the percentage of spare plant reduced from an estimated eighty-three percent to just twelve percent. This is an example of waste reduction because small generating plants, as discussed in Chapter 3 required spare capacity to meet peak demand, and in case of mechanical failure. The interconnectivity of the Grid meant it was no longer necessary for all power stations to carry additional capacity because the whole system had flexible capacity to meet peak demand and connected stations could compensate if any generating station failed. The table also shows volumes of coal consumed between 1921-22 and 1947-48 increased five-fold, whilst the volume of coal per unit generated more than halved. Alongside reduced fuel input per unit generated, thermal efficiencies also improved over this period.

[692] Source: Electricity Comms. *Annual Report*, 23, p.6.

Figure 111 Highest thermal efficiency for any generation station.[693]



As expected there is a reduction in the volume of fuel required per unit of electricity generated over time for coal and oil. Figure 111 shows the increase in thermal efficiency of steam plant over the 1920s and '30s to become almost as efficient as oil, which remained stable, while the efficiency of gas declined.

---

[693] Source: Garcke, *Garcke's Manual*, 34, 37 and 47, p.46. Note, Year end up before 1930 is Mar. 31st, year after 1930 is Dec. 31st, hence two values for 1930. From 1935 the values are for units sent from the power station, before 1935 they are total units generated.

The electricity commissioners reported in 1948 that;

> As a measure of the growth of efficiency and the reduction in costs, the average fuel consumption fell from 3.24 lbs per unit generated in 1921-22 to 1.41 lbs in 1947-48. While the average cost of coal after falling from the higher level of 35s. per ton in 1921-22 to 15s 9d. per ton in 1931-32 again rose to practically three times the latter figure in 1947-48'. In terms of working costs per unit this was 0.903d in 1947-48 compared to 1.726 in 1921-22 and average revenue per unit of 1.123d and 2.482d respectively, making the cost to revenue 80.41% and 69.54% in the corresponding years.[694]

In terms of profit per unit, 1921-22 was more lucrative than the later years, corresponding with license changes to increase maximum price to compensate for increased coal costs after WW1.

Figure 112 Graph to show units available and lost: source BEA statistics annual report.[695]

[694] Elec. Comms. *Annual Report*, 1948, p. 14.
[695] Source: BEA, *Annual Report,* 1, p.249.

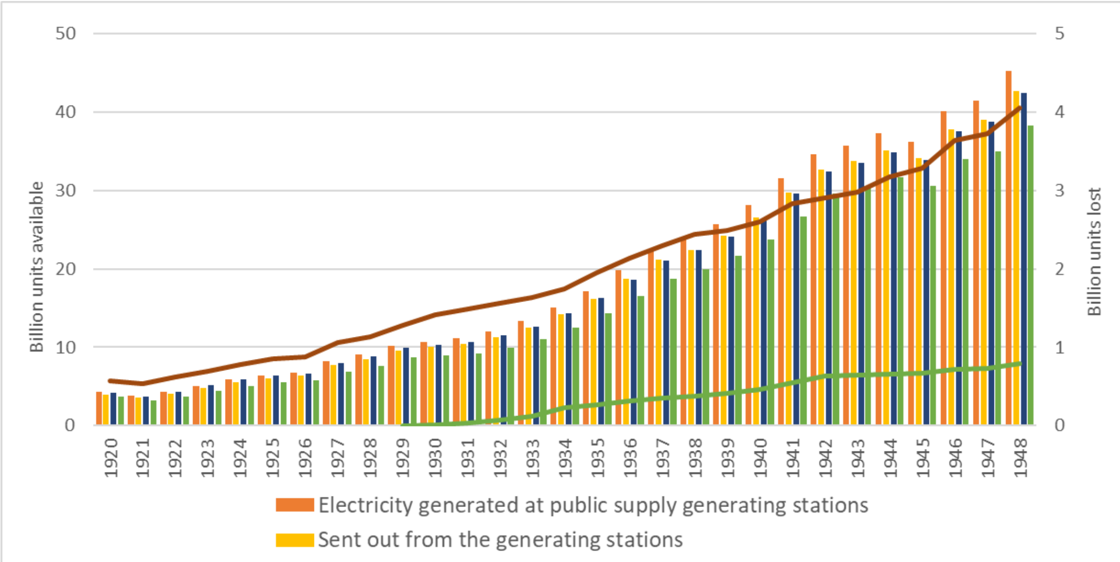
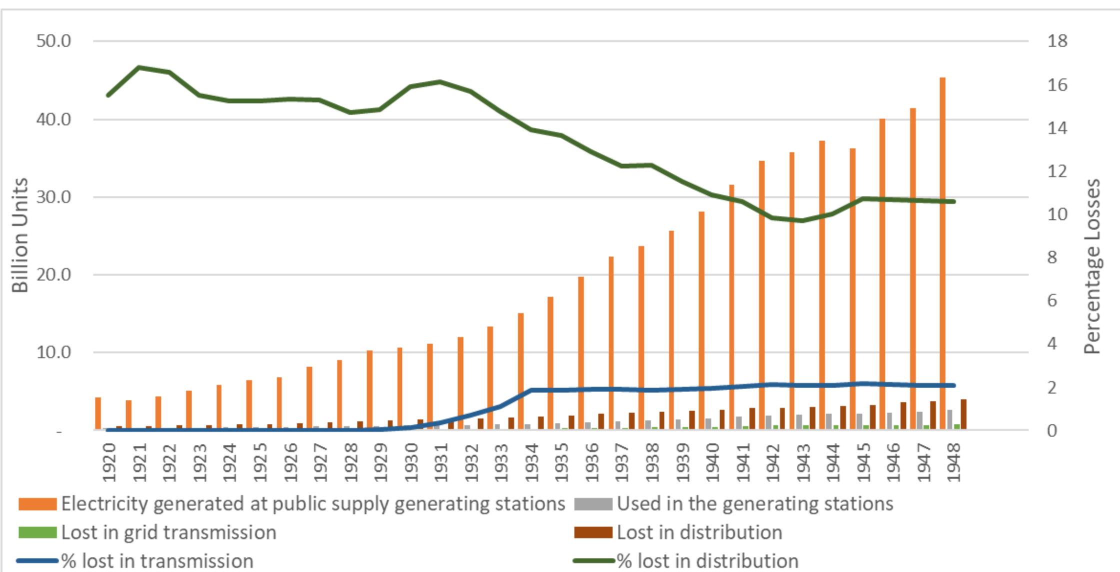


Figure 113 Graph to show total electricity generated and percentage losses in transmission and distribution[696]



[696] Source: *Ibid.*

The purpose of the Grid was to transmit high volumes of high voltage electricity to where it was demanded with as few losses as possible facilitating an efficient system. Figure 112 shows the numbers of units available in the system from generation and at various points beyond. Power stations used electricity internally and there were inevitable losses through transmission and distribution networks. The graph shows distribution losses through the suppliers' distribution networks were greater than losses from the Grid's transmission system (RHS). Figure 113 shows how the proportion of transmission losses reduced over time reaching a plateau of approximately two percent (RHS) as the Grid became fully operational. This was still proportionally lower than losses from the distribution system, which settled to approximately ten percent in the early 1940s.

These graphs support Cohen who suggested that electrical engineers acted as conservationists in her work on America's electricity system. This was because of their enormous efforts to extract the maximum energy from primary fuels and provide it for consumption with as few losses as possible but not because they were inherently conservationists. Motivation included long term profitability, the desire to perfect engineering for its own sake or to reduce the amount of coal necessary but the result was conservation of a sort. As Cohen pointed out, though, 'The irony for modern environmentalists, and for the industry itself, is that interconnected power systems offered the opportunity to use energy resources more efficiently, but only if consumers used more and more power'.[697] The only way to increase efficiency was to make the system bigger; that meant more consumers, higher demand and ultimately more coal. Whilst this all seems rather self-defeating, had the increase in demand happened more organically within the earlier parochial system, retaining small local power stations, wastage of machinery and fuels would have been much higher.

---

[697] Julie Cohen, 'Biography of a Technology', p.390.

The availability of coal to meet demand has been calculated periodically through history. As electricity became a public commodity 'The coal question in England' was asked in *Science* in 1885, providing an echo of Jevons' 1865 book and concluded that the exhaustion of coal was theoretical. This was determined because the increasing costs associated as coal become increasingly scarce would ultimately cause demand to cease. The article concluded that coal supplied at three million tons per annual extraction would theoretically last until 2145, and suggested that one of four options would eventually be needed:

- 'A new source of energy must be found,
- A larger percentage of the coal must be utilised,
- Coal would need to be imported, or
- England must give up her manufacturers'.[698]

Each recommendation has been implemented to some extent but only the 'larger percentage of the coal being utilised' was implemented by the CEB. Decline in manufacturing, and importation of coal has occurred as the economy has shifted from a secondary to tertiary sector base. The others have been implemented since the 1960s and significant advances have been made with renewable fuels in the last few decades.

The CEB – Unintentional Conservationists

[698] 'The Coal Question in England', *Science* (1885), 5, 108, pp.175.

The mantra of the environmentalist movement, since accepting global warming as mainstream science in the 1970s has been, in various forms, 'Reduce, Reuse, Recycle', and was essentially what electricity engineers did, although not always in the way the spirit of the slogan intended. Engineers worked to improve efficiency, of component parts and the whole system. Improvements reduced the coal necessary to generate a unit of electricity, reused and recycled resources and products within the system and, ultimately, reduced the overall coal volumes necessary to meet increasing demand.

Waste heat, which would otherwise be lost, was reused in some stations. Merz worked with the Preistman collieries building a new bank of coke ovens, to test his ideas for recycling waste heat. Merz realised that as coal was converted into coke, much of the heat and gas produced could be captured for further use and piped off waste gasses which were used to generate electricity used within the works, with any surplus fed into the common network. It was a successful trial and Merz formed The Waste Heat and Gas Electricity Generating Stations Company Limited, building similar stations in the North East.[699] Other companies did similar things, reusing maximum heat and/or combining self-generation with industrial production requirements, again efficiency and economy being the main drivers.[700]

It is difficult to determine how long the CEB expected the Grid to be in service but its testing considered how its materials and structures would last over decades. It is likely that the plans were long term because steam power was the only comparable power source previously experienced, and many early electrical engineers had started as mechanical engineers previously working with steam. The slow adoption of electricity may well have reinforced this timescale. Assuming electricity was being considered as the main power source for the foreseeable future the most obvious question would have

[699] Rowland, *Progress in Power*, p.34.
[700] This is discussed particularly with reference to textile factories in Chapter 3.

been how to fuel it. While the CEB controlled the Grid this question was not addressed by the electrical supply industry who knew that coal was abundant.[701] However, poor coal quality or reduced availability resulting from exogenous pressures of war or labour disputes were issues they addressed. There was no reason to conserve coal as a resource. Its availability with respect to the industrial revolution and steam power had been discussed by Jevons and revisited later in *Science*. Rather, it was about increasing efficiency, producing more from less, which in turn reduced costs.[702] Although coal shortages were not considered as a threat, the CEB purchased water power where it was available and there were some gas and oil generating stations but they were very much the minority, but the drive for efficiency extended to these too.

---

[702] W. Jevons, *The Coal Question: An Enquiry Concerning the Progress of the Nation, and the Probable Exhaustion of our Coal-Mines*, (London, 1865), pp.34-36.

6.Conclusions

The ‘environment’ in this work comprised the surroundings in which people worked and lived, and the ‘natural’ environment or countryside. This is because as electricity became universally available through the Grid, it affected every part of the environment, and underpinned changes in lifestyles and working methods, homes and workplaces through its infrastructure reaching across the country. Whilst supply began in the 1880s, it was the 1960s before almost all premises were wired and using electrical appliances, taking about eighty years to become fully integrated into British life. The Grid played an enormous role in this process, constructed after forty-five years of parochial development and imposed across public and private enterprise creating a controlled wholesale electricity market. With hindsight the five years of work by the Electricity Commissioners producing much of the evidence demonstrating Britain’s electricity shortcomings was very important for this process, providing quantitative evidence that real change was necessary and, importantly, urgent. The Weir Committee highlighted the potential of the domestic market to complement increased industrial consumption which had been necessary for munitions production during WW1. Encouraging domestic consumption would contribute to the upscaling of the system which would in turn improve efficiency and reduce costs, promoting further demand in a perpetual feedback loop until market saturation. This would help Britain increase productivity to prevent it falling further behind international competitors such as America and Germany, and this finally convinced Parliament that a national scale supply system was necessary. After the 1926 Act invoking the Grid was passed, public and private companies and lobby groups and appliance manufacturers began to ‘educate’ potential consumers by selling electricity through the promotion of its uses and benefits.

Trentmann and Carlson-Hyslop demonstrated negotiation between tenants and landlords over energy infrastructure in individual homes and raise the idea of 'consumption by proxy' which describes how the infrastructure provided in the home dictates what can be consumed. The eighty-year process of negotiation between consumers, suppliers, politicians, experts and wider society to embed electricity into Britain was similar but at the national scale. Electricity supply was available depending on where mains were laid and the license holder for the area in which you lived and worked. The type of electricity supplied, who was authorised to sell appliances and carry out electrical installations and connections was also dictated by the same licensed companies.[703] The negotiation process started at this local level between residents, consumers and suppliers but as governance became more national so did the negotiation. Individuals, communities and institutions responded to the circumstances electricity brought, sharing their opinions, whether positive or negative to influence change.

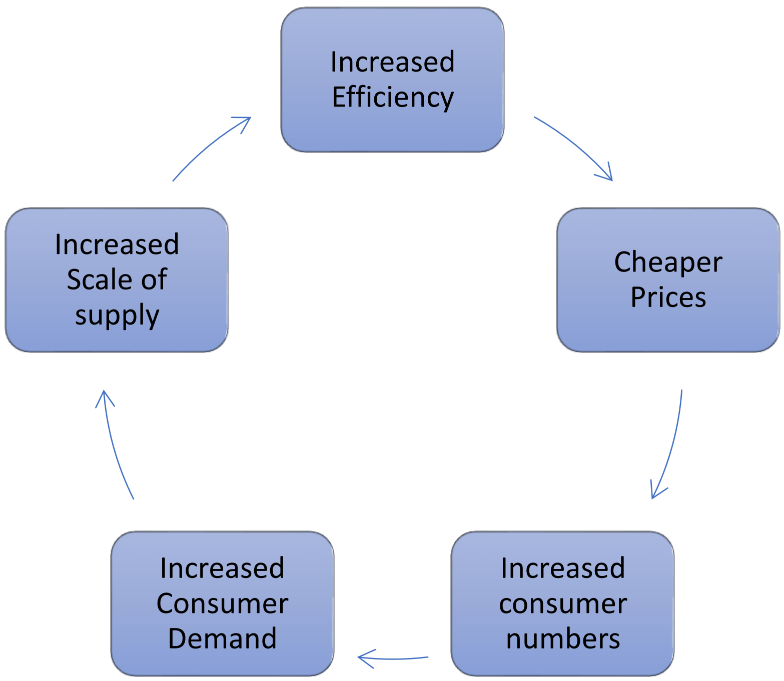
The process began with scientists who understood electricity's enormous potential when it was a scientific curiosity, followed by entrepreneurs who realised its potential profits. Responses to electricity supply ranged from enthusiastic acceptance through apathy to ardent opposition. The difficulty, as with all manmade, rather than natural systems is when to stop the expansion of the system. Is market saturation a natural end point, or will demand continue to rise as new devices are invented? Unlike the feedback loops in natural systems, electricity requires manmade management systems to determine if it is a limitless power source, or at what level electricity production is stopped and we have to limit our usage.

The political will to make electricity available to everyone became more explicit from 1926, when accessibility of supply became more political than technical as other nations were using electricity to

[703] Trentmann and Carlson-Hyslop, 'The Evolution of Energy Demand', p.5.

improve productivity. This was the aim of the Grid and was based on the simple principle that increased scale would provide efficiencies and reduce prices, thus increasing demand further increasing the scale of production.

FIGURE 114 CYCLE OF INCREASED SCALE AND EFFICIENCY OF SUPPLY TO REDUCE PRICES AND INCREASE DEMAND.

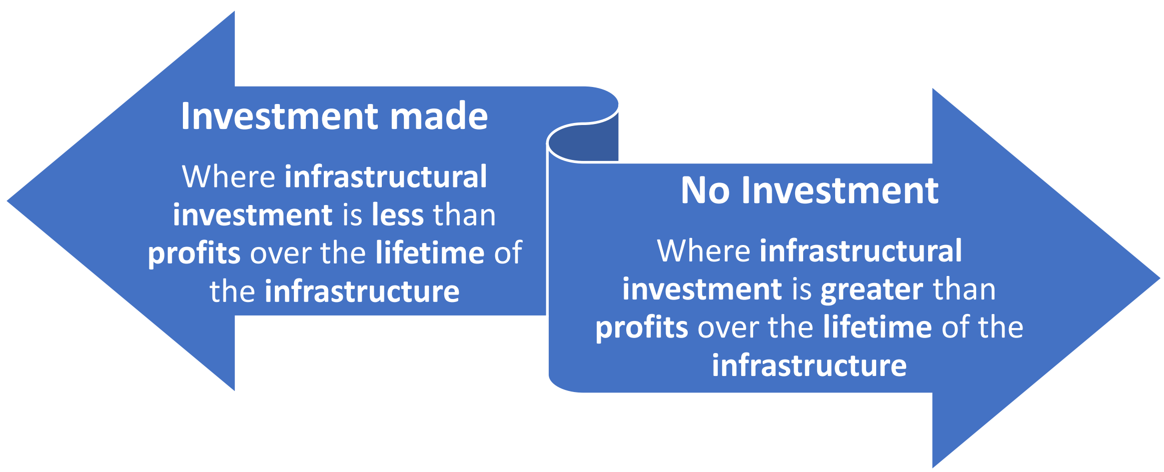


The Grid increased efficiency, and demand increased, but this was not achieved easily, partly because of decisions taken in the early years of the industry creating a disparate system. Suppliers who controlled distribution remained autonomous. Competition came from other fuels and the Grid itself was only linked gradually and in a piecemeal fashion, and wariness towards this new technology remained.

These issues are reflected in many new technological systems; the closest contemporary equivalent would be internet access through broadband technology, in which parallels exist regarding availability and accessibility of connection to the national network, particularly in rural locations, where there is disparity between urban and rural access to these services. The idea of universal services for communication, water and energy and associated costs based on consumption rather than location, is engrained deeply in Britain. Where the accessibility, or costs, of services occurs they are termed 'postcode lotteries' and are regularly complained about. As a marketable commodity electricity was like other networked services and profitability determined availability even under local authority control.

In 1948, nationalisation meant public control of the whole industry which combined with additional government subsidies eventually provided universally available electricity in the late 1960s. The following chart shows when and where new technology is likely to be available:

FIGURE 115 THE BASIC DECISION-MAKING CRITERIA FOR INVESTING IN A NEW TECHNOLOGY IN A NEW AREA.



The difficulties outlined in Chapter 2 when legislation made it difficult for the CEB to close small inefficient power stations to rationalise distribution meant that consumers experienced very little change up to, and beyond nationalisation when prices still differed widely geographically and numerous tariffs persisted within supply areas, and services remained patchy in rural locations. The 1926 legislation tried to improve distribution through manipulating a wholesale market, rather than exhorting direct control. Despite not achieving this outcome, the CEB management of the Grid, did significantly increase efficiency of generation and transmission to meet the continuously growing demand, and inadvertently limited its environmental impact.

The system, including the Grid continues to be negotiated although the process of electrification is arguably complete. National Grid PLC have owned and operated the Grid's transmission system since privatisation in 1990 taking over from the CEGB. In 2016, the latest available year for statistics just 11.3% of electricity was coal fuelled. The majority (40.1%) was from natural gas and renewables (hydropower, wind and solar power) contributed 7.3%.[704] New fuel types and increased self-generation through community schemes, solar panels and individually installed wind turbines all selling excess electricity back to the Grid are growing in number. The Grid's owners, generators, distributors, politicians and consumers are still negotiating the future of the Grid and electricity supply and sources. Under their 'Future Energy Scenarios' National Grid PLC state,

> 'We are in the midst of an energy revolution. The economic landscape, developments in technology, evolving business models and consumer behaviour are changing at an unprecedented rate creating more opportunities than ever for our industry'.[705]

Any of the bodies, public or private, which have operated the Grid or indeed been involved in any part of the electricity industry could have made this statement at any time.

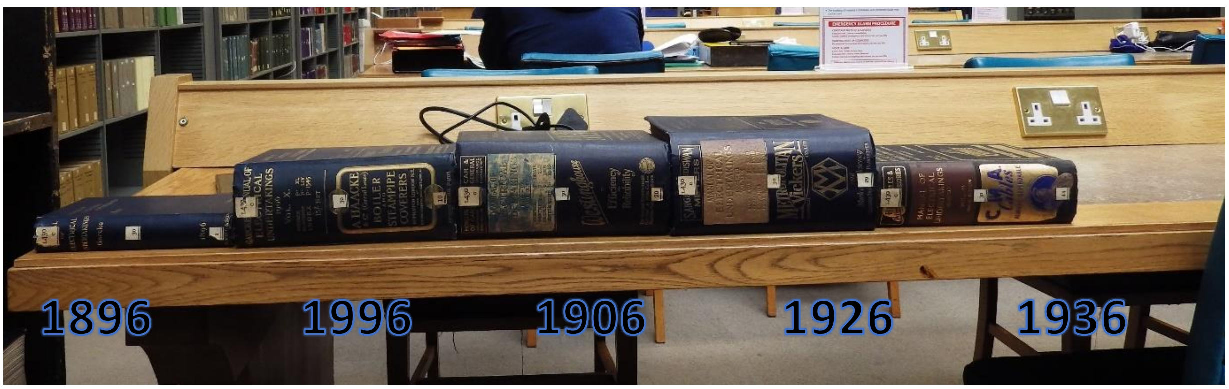
The history of the electricity industry can be represented by the size of the volumes of *Garcke's Manual* from 1896 to 1936 (Figure 116). The period before the Grid saw rapid growth and development, the

---

[704] DECC data, 1920 to 2013. The rest is from nuclear power (25%), other fuels (15.3%) and oil (1%)
[705] National Grid PLC, 'Future Energy Scenarios' (Warwick, 2017), 4031152, p.1.

1926 Act provided a more planned approach using a full evidence base to plan and be proactive in the supply of electricity, rather than reactive. Although the Grid and associated legislation did not solve all the issues it sought to address it did improve efficiency, provide greater accessibility, and began the slow journey to national standardisation.

FIGURE 116 *GARCKE'S MANUAL* OF ELECTRICAL UNDERTAKINGS FROM 1896 AT TEN-YEAR INTERVALS. SOURCE: OWN IMAGE.



When this study began, determining the environmental impact of the National Grid seemed a simple proposition. The Grid was and remains a set of pylons and wires that form part of a wider energy system but it soon became clear that the Grid's impacts extended well beyond its physical presence. The technological development from open fires through closed furnaces, steam engines and turbines converting fuel into increasingly convenient forms of power is a long-term process within wider energy transitions.[706]

[706] Energy Transitions are widely accepted and used as a framework to think about long term energy processes and change. Most of the literature used in this work refer to energy transitions which are largely accredited to works by Smil.

Movement towards ever increasing efficiency in energy systems has been a subject of interest to both natural and physical scientists, who suggest that there is a tendency for systems to move towards 'maximum efficiency'.[707] The Grid demonstrates this for electricity supply, and human energy systems, striving to maximise efficiency. Whilst resource availability is important, it has not been a limiting factor in this debate. Indeed, if anything increased efficiency has simply led to increased use of resources. The nineteenth century economist W.S. Jevons wrote of coal 'It is wholly a confusion of ideas to suppose that the economical use of fuel is equivalent to a diminished consumption. The very contrary is the truth'.[708] The CEB did not make a conscious decision to conserve coal but by making the system increasingly efficient, coal's 'shelf life' was extended and therefore provided a paradoxical justification for increasing the volume of use. More recently it has the potentially irreparable environmental damage caused through the created dependence on electricity which has led to a search for even greater efficiency and development of alternative, environmentally benign primary fuels. Even as fuels are changing to utilise more renewable energy and the phasing out of coal plants by 2025 is planned, debates remain over the Grid's capacity to meet demand in the future, and fuel mixes.[709] Both National Grid and the electricity regulator, Ofgem, carry out regular capacity checks and suggest the supply margins are narrowing with time making the future of the Grid still challenging and uncertain. There are also localised energy schemes generating electricity emerging which raise issues around the usefulness

---

707 For further information see H. T. Odum, *Environment Power and society – For the twenty first century* (New York, 2007), E.P. Odum, *Ecology and our endangered life support systems* (Stanford, 1989) and E. Sciubba, 'What did Lotka really say? A critical reassessment of the "maximum power principle"', *Ecological Modelling* (2011), 42, pp.1347-1353.
558 W. Jevons, *The Coal Question*, p.124.
709 Department for Business, Energy and Industrial Strategy, 'Implementing the end of unabated coal by 2015 Government response to unabated coal closure consultation', (BEIS, London, Jan 2018), p.8.

of interconnection, and how to finance the national system if communities choose to go ‘off-Grid’ making this history important when the immediate future of electricity supply is considered.

Brimblecombe suggested that we have excused the behaviour of earlier societies damaging the environment and that this is ‘because the magnitude of the changes they wrought were usually small and many people currently see an innocence in their actions’.[710] This ‘unintentional conservation by the CEB is almost the opposite. They had no legislative framework or models of good practice framework, or even a language in which to consider the environment but their actions often had positive effects despite the unforeseen fossil fuel damage. Whilst understanding how human interactions affect the environment is now more advanced than when the Grid was first operating the ‘best available’ options for them to introduce were just that, the best available at the time. The best available options for reducing the ‘nuisance’ that electricity brought were used when deemed necessary, on a case by case basis, which began creating an evidence base of problems and solutions. Forward planning, reduced duplication of effort and materials, and the desire to use British components and firms, reduced the environmental impact of the Grid’s construction because the ‘best available’ options were implemented.

Another reason for excusing earlier generations is perhaps that, despite their actions causing permanent landscape changes, such as the Broads created by peat-digging in Norfolk or soughs in Derbyshire from lead mining, there were localised effects. However, over the past century we have developed ways to increase the energy available to us anytime, anywhere, facilitating much larger scale impacts. Where once an electricity pole was erected with a horse, cart and six men, a single individual in a vehicle can accomplish the same task in less time, although this has, of course, brought many benefits as well as damage.

---

[710] P. Brimblecombe, *The Big Smoke: A History of Air Pollution in London Since Medieval Times* (London, 1987), p.1.

During this work, a conversation was recalled of an elderly family member in the mid-1960s, who stated that the best invention during her lifetime had been 'the plaited wick' because it did not need to be repeatedly snuffed and relit. For her, this introduced a source of constant light and perhaps an electric light is not that dissimilar, except in brightness. Like the aesthetics of landscape, technological progress is not perceived in the same way by everyone, perspective and personal experience are important, not just quantitative assessment.

Each chapter of this work has shown how, in varied ways, the Grid played a vital role in Britain's energy history and has arguably impacted every environment in which people live and work. It enabled industrial changes, including new working methods and reduced physically demanding work, substituting electricity for manpower which contributed towards a new era for women, at work and home. These changes inevitably altered family dynamics, and alongside increasing gender equality, electricity in the home changed lifestyles as new appliances were introduced for leisure and domestic chores. These changes are still ongoing as new devices and technologies, dependent on electrical power continue to affect society. Industrial and domestic consumers eventually embraced electrical technology but refused to accept it at any cost, protesting against it, or finding alternative routes and methods of production if necessary. As a technology, electricity provided impetus to pioneers who demonstrated its viability, engineers who refined it, and managers and politicians who negotiated its place in society with lobbyists, institutions and individuals, with different interests and agendas.

All historians believe their subjects are pivotal but in this instance I would suggest that the reason it has been difficult to isolate the environmental impacts of the Grid is because of its fundamental role providing electricity which is pervasive in, and affects, all aspects of everyday life. It is difficult to devise counterfactuals. Would a decentralised system inevitably have become more interconnected? How large would the additional costs of generation and capital investment been without it?

Alongside its impacts on the landscape, and its impacts on everyday life, the Grid has altered the relationship between people and their energy source. The Grid has bridged the gap between the primary fuel and the consumer. This made it revolutionary, providing a simple but powerful intermediary separating the consumer from the resource they were actually consuming. The pylons, poles and wires altered the external landscape but enabled the internal spaces to be rearranged and provides universal power accessibility. Electricity generation moved from being centred close to its consumers, as the first power stations were, to the periphery transmitting power back into them. As the Grid became operational, primary fuels and generation became hidden from view and the Grid facilitated transmission of electricity directly into communities where it reached into homes and workplaces, remaining mostly invisible. Internally, sockets and switches, and the 'life' electricity supplies to appliances, provide the interface between people and electrical power, removing the downstream processes from sight.

Summers has considered this process of how 'in the case of consumption, people's dependence on the manipulation of nature became increasingly hidden from view'.[711] The Grid does this, almost hiding in plain sight, no longer really noticed. Yet it is constantly transmitting electricity, a colourless, odourless energy form, around the national network, making lives cleaner, easier and healthier regardless of location. Although, sometimes this has been at the expense of the minority living in close proximity to the power stations. As early as 1953, before some places even had an electrical connection, *The Times Electrical Supplement* talked about 'Immense Strides', noting;

[711] Summers, *Consuming Nature*, p.7.

> It is 20 years since *The Times* published its first supplement providing a survey of the electricity industry in Britain in the early years of the grid. In the interval the grid has ceased to be a novelty: the efficient performance of its function is taken for granted.[712]

Electricity has become so embedded into everyday life over the three to four generations who have embraced it. Reliance is tacit, and unless there was a problem, the need to engage with it consciously is practically non-existent.

This physical distance the Grid affords has also created a knowledge gap; the linkage between the primary fuel and the electricity has been lost because consumers are physically removed from the downstream processes. For most people, what was once a direct relationship between people, fuel and energy has been complicated by distance, and reliance on experts to provide for people's everyday energy needs. This meant that encouraging people to reduce their energy consumption to reduce coal use in war-time or to prevent damaging environmental impacts from primary fuels relied on people understanding the link between electricity and coal. Like the posters encouraging energy conservation because of coal shortages in WW2 stating plainly, 'electricity comes from coal', people still need to be reminded that consuming electricity means consuming a primary fuel source, whatever it might be. However, where people are interested and want to express their views, the ways to engage in negotiation have increased through increased media types, and the ability to choose your electrical supplier based on price, fuel mix and their ethics is now also possible but how accessible this is to all consumers is still debated.

---

[712] R.J. Gordon, The rise and fall of American growth: The U.S. standard of living since the Civil War (New Jersey, 2016), p.3.
[712] Cochrane, *Power to the People*, p.15 showing the first page of *The Times Electrical Supplement* from 1953.

This work shows that the impacts and influence of the Grid are far-reaching, and ongoing, over both time and space. Given the enormous reliance on it for all aspects of life, its lack of visibility in much of Britain's written history seems puzzling. Converting established parochial electricity suppliers into a nationally coordinated utility began with the Grid which the CEB used to consolidate generation and transmission and made it more efficient whilst reducing its environmental impact, albeit unintentionally. The Grid remains a robust, integrated and efficient infrastructure which would be recognisable to the electrical engineers advocating for national interconnection at the turn of the twentieth century and continues to provide power to the people.

Bibliography

1. Primary Sources

Archival

Bristol, Western Power Historical Electrical Society, 'Taunton Minutes - Entry for Jun 11, 1935' (ARC-4, --- *Sub-records Cabinet A1* Minutes 1893-1947, Reports 1884 - 1911 Consents & Orders 1912-47).

Bristol, Western Power Historical Electrical Society, 'Works Committee Minutes 1891-94', WDRO 1648/WS9.

Bristol, Western Power Historical Electrical Society, 'Agreement with Admiralty – entry for Sep 09, 1904', Devonport Minute Book. WDRO 1814/49.

Cambridge, Churchill College, Lord Hinton of Bankside, 1961, 'The British Electricity Transmission System', HINT 3/5.

Cornwall, Cornwall Records Office, CC/8/3/4124 to 149, QSPDE/3/4, QSPDE/6/3, QSPDE/6/5, QSPDE/6/6, QSPDE/6/7, QSPDE/15/3, QSPDE/15/4.

Exeter, The South West Heritage Centre, 'Electricity Orders used in Mapping the South West', QS/DP/581, QS/DP/585, QS/DP/462, QS/DP/575, QS/DP/580, QS/DP/581, QS/DP/632, QS/DP/682, QS/DP/680, QS/DP/452, QS/DP/683, QS/DP/714, QS/DP/775, QS/DP/823, QS/DP/704, QS/DP/761, QS/DP/760, QS/DP/858, QS/DP/713, QS/DP/717, QS/DP/754, QS/DP/814, QS/DP/841, QS/DP/842, QS/DP/693, QS/DP/698, QS/DP/699, QS/DP/705, QS/DP/763, QS/DP/764, QS/DP/690, QS/DP/691, QS/DP/706, QS/DP/708, QS/DP/730, QS/DP/792, QS/DP/702, QS/DP/762, QS/DP/633, QS/DP/790.

Exeter, The South West Heritage Centre, 'Crediton Electric Lighting Order 1903', QS/DP/633, 'Crediton Electric Lighting Special Order', QS/DP/714 and 'Chudleigh Electricity (Extension) Special Order, 1928', QS/DP/790.

London, LMA, 'All Electric House', *LEB scrap book*, LMA/4278/01/084.

London, LMA, 'Scrapbook', LMA/4728/01/070/05.

London, LMA, 'Scrapbook', LMA/4278/01/064.

London, LMA, 'West Ham Electricity Uses in the Home and Business', LMA4278/01/064.

London, LMA, 'Hackney Electrical Showroom Ledger', LMA/4278/01.

London, LMA, ‘Leyton Scrapbook’, LMA/4278/01/116. London, The Institute of Engineering and Technology Archive (ITE) ‘Charles Merz, Letter from Charles Merz to his Father’, UK0108 NAEST 014/1, 1902-1911.

London, The National Archives (TNA) ‘Electricity Commission Report into Distribution of Electricity’, POWE 13/95.

London, TNA, ‘Correspondence with Association for Electric Power Companies’, POWE 38/5.

London, TNA, ‘Notes Submitted by the Electricity Commission’, POWE 13/95.London, TNA, ‘Memorandum by the Electricity Commissioners for the Committee on Electricity Distribution on the Control of Electricity Companies by Other Companies’, POWE 13/95.

London, TNA, ‘Consent to Overhead lines’, POWE 13/70.

London, TNA, ‘General Smoke and Grit Nuisance: Policy’, POWE 14/123.

London, TNA, ‘Kirkstall (Leeds) Generating Station Grit Nuisance: Proposed New Chimney’, POWE 14/125.

London, TNA, ‘North Tees Generating Station: Smoke and Grit Nuisance’, POWE 14/127.

London, TNA, ‘Report on the Measures which have Been Taken in this Country and in Others to Obviate the Emissions of Soot, Ash, Grit and Gritty Particles from the Chimneys of Electric Power Stations’, POWE 14/126

London, TNA, ‘Willesden Generating Station: Emission of Smoke and Grit’, POWE 14/128.

London, TNA, ‘Ocker-Hill Smoke and Grit Nuisance’, POWE 14/131.

London, TNA, ‘Procedure for Dealing with Applications to Establish New Generating Stations’, POWE 14/13.

London, TNA, ‘Report of the Cabinet Meeting Held February 1937’, CAB/24/268.

London, TNA, ‘Report of the Cabinet Meeting Held, July 1946’, CAB/129/11,

London, London Metropolitan Archive (LMA), ‘The West Ham Electrical Bulletin, 1914’, LMA/4278/01/064.

Manchester, Museum of Science and Industry Archive, (MOSI Archive) Un catalogued, NESCo. records, Gloucester Electric Supply Company Minutes.

Somerset, Somerset Records Office, Q/RUP/438, Q/RUP/506, Q/RUP/438, Q/RUP/547, Q/RUP/558, Q/RUP/565, Q/RUP/578, Q/RUP/610, Q/RUP/614, Q/RUP/628, Q/RUP/630, Q/RUP/633, Q/RUP/671, A\BWG/4/54/1.

Printed Primary Sources

Board of Trade, *Final report on the first census of production of the United Kingdom (1907): General report.* (H.M. Stationery Office, London, 1907).

Board of Trade, *Final report on the second census of production of the United Kingdom (1912): General report.* (H.M. Stationery Office, London, 1912).

Board of Trade, *Final report on the third census of production of the United Kingdom (1924): Part V: General report.* (H.M. Stationery Office, London, 1924).

Board of Trade, *Final report on the fourth census of production of the United Kingdom (1930): Part V: General report.* (H.M. Stationery Office, London, 1935).

Board of Trade, *Final report on the fifth census of production of the United Kingdom (1948): General report.* (H.M. Stationery Office, London, 1948).

British Electricity Authority, 'British Electricity Authority Annual Report and Accounts' (9 vols. H.M. Stationery Office, London 1949 to 1958).

Central Electricity Board, 'Central Electricity Board Annual Report and Accounts' (20 vols. Whitehead Morris Ltd., London, 1927 to 1947).

Electricity Commissioners, 'Electricity Commissioner Annual Reports' (23 vols. H.M. Stationery Office, London, 1921 – 1948).

Garcke, E., *Garcke's Manual of Electrical Undertakings*, (Vols. 1-57, London, 1896-1960). The entry for each undertaking is used for reference, page numbers are supplied if quotations are from comments provided in the manuals.

'Report of the Committee appointed to review the National Problem of the Supply of Electrical Energy, Ministry of Transport – Including the Technical Scheme by John Snell and Charles Merz 1926: Includes Additional Reports from the committee to review the national problem of Electricity Supply' (H.M. Stationery Office, London, 1926).

'Report of the Committee appointed by the Board of Trade to consider the question of Electric Power Supply', (H.M. Stationery Office, London, 1918).

Acts of Parliament

'The Electric Lighting Act 1882' (H.M. Stationery Office, London, 1882).

'The Electric Lighting Act 1888' (H.M. Stationery Office, London, 1888).

'The Electric Lighting Act 1909' (H.M. Stationery Office, London, 1909).

'The Electricity (Supply) Act 1919' (H.M. Stationery Office, London, 1919).

'The Electricity (Supply) Act 1922' (H.M. Stationery Office, London, 1922).

'The Electricity (Supply) Act 1926' (H.M. Stationery Office, London, 1926).

'The Electricity (Supply) Act 1935' (H.M. Stationery Office, London, 1935).

'The Electricity Act 1947' (H.M. Stationery Office, London, 1947).

Newspaper articles

'A Lesson from Germany', *The Manchester Guardian* (Manchester, Nov 12, 1929).

'Amenities of the Countryside', *The Times* (London, Oct 15, 1928) 45024.

'Big Electricity Breakdown', *The Times* (London, Jul 30, 1934) 46819.

Bramwell, F., 'Something more than the Electric Lighting Bill' *The Times* (London, Jul 21, 1882) 30565.

'Cheaper Electricity for Industry', *The Times* (London, Sep 27, 1921) 42836.

'Coal Peace Urgent', *The Times* (London, Apr 18, 1921) 42697.

'Cornwall Royal Institution', *The Cornwall Royal Gazette,* (Cornwall, Nov 13, 1840) 3926.

'Electricity in the Home', *The Times* (London, Dec 04, 1925) 44136.

'Electrifying the West', *The Western Morning News* (Bristol, Jan 15, 1930).

'Electricity in Working Class Homes', *The Times* (London, May 11, 1935) 47061.

'Electricity v. Burglars', *The Times* (London, Aug 23, 1882) 30593.

'Electric Lighting in the Metropolis', *The Times* (London, Apr 09, 1889) 32668.

'Electric Lighting Pioneer', *The Times* (London, England, Dec 13, 1935) 47246.

‘Electric Lighting Smoke Nuisance’, *Liverpool Mercury* (Liverpool, Sep 15,1899).

‘Electric Lighting Works’, *Berrow's Worcester Journal* (Worcester, May 05, 1894).

‘Electric Power Supply and Transmission’, *The Times* (London, Sep 03, 1901) 36550.

‘Investment Notes’, *The Economist* (London, Nov 26, 1932) 4657.

‘Malvern Electricity Pylons’, *The Times* (London, Sep 26, 1950) 51806.

Marshall, E., ‘Mr. Edison on the War: Science in the Battlefield’, *The Observer* (London, Dec 10, 1916).

‘Midland Institute of Mining Societies and Institutions’, *The Times* (London, Dec 04, 1907) 38507.

Moulton, J.F., ‘The Electric Lighting Bill’, *The Times* (London, Aug 07, 1882) 30579.

‘National Grid Complete’, *The Times* (London, Dec 05, 1934) 46619.

‘News of the Day’, *Bristol Mercury* (Bristol, Nov 29, 1878) 9529.

‘Opening of the Clifton Suspension-Bridge’, *Bristol Mercury* (Bristol, Nov 19, 1864) 3894.

‘Our five-year plan’, *The Spectator* (London, Oct 25, 1930).

‘Overhead Electric-Lighting Wires’, *The Times* (London, Dec 26, 1888) 32579.

‘Overhead Electric Wires’, *The Times* (London, Nov 02, 1883) 30967.

‘Preserving the Beauties of England’, *The Manchester Guardian* (Manchester, Sep 23, 1929).

‘Prices and Production’, *The Times* (London, Sep 09, 1920) 42511.

‘Public Assistance Committees, The Rejected Principle of Co-option’, *The Manchester Guardian* (Manchester, Oct 29, 1929).

‘Pylons’, *The Manchester Guardian* (Manchester, Apr 10, 1931).

‘Pylons and Cheap Electricity: Keswick Committee's Statement’, *The Manchester Guardian* (Manchester, Nov 01, 1929).

‘Pylons in Kent And Surrey’, *The Times* (London, Oct 19, 1954) 53066.

‘Pylons in the Lake District: Difference of Opinion in Debate’, *The Manchester Guardian* (Manchester, Nov 08, 1929).

‘Pylons in the Park’, *The Manchester Guardian* (Manchester, Mar 08, 1932).

‘Pylons on Malvern Hills’, *The Times* (London, Sep 12, (1950) 51794.

‘Pylons on The Downs’, *The Times* (London, Nov 01, 1929) 45349.

‘Sir William Armstrong and the Electric Light’, *Newcastle Courant* (Newcastle-upon-Tyne, Nov 22, 1878) 10639.

‘State Coal and Electricity’, *The Times* (London, Oct 09,1924) 43778.

‘Super-Grid for Britain’, *The Times* (London, Jul 24, 1950) 51751.

‘The Dangers of Electricity’, *The Times* (London, Sep 24, 1889) 32812.

‘The Electric Power Bills -The Association’, *The Times* (London, Feb 21, 1900) 36071.

‘The Electricity Bill’, *The Spectator* (London, Apr 03, 1926).

‘The Government Electric Lighting Bill’, *The Times* (London, Apr 14, 1882) 30418.

‘The Keswick Pylons’, *The Manchester Guardian* (Manchester, Feb 15, 1932).

‘Thos. Cook & Son, Ltd.’, *The Times* (London, Nov 16, 1925) 44120.

‘Those Pylons Again’, *The Manchester Guardian* (Manchester, Apr 10, 1930).

Weir, W., ‘The Handicaps of Industry, *The Times* (London, Apr 16, 1924) 43628.

White, A., ‘To the Editor of The Times’, *The Times* (London, Aug 07, 1882) 30574.

Books

Baldwin, S., O*ur Inheritance* (Hodder and Stoughton Ltd., London, 1928).

British Electrical Allied Manufacturers' Association (BEAMA), Economic Statistical Department., *The Electrical Industry of Great Britain: Organization, Efficiency in Production and World Competitive Position* (BEAMA Publication Department, London, 1929).

Boltz, C.L., *Everybody’s Electricity* (George C. Harrap and Co. Ltd., London, 1934).

Dalton, J., *The Electricity Supply Act, 1926 Annotated and Explained, with an Introduction* (London, 1927).

Electrical Association for Women (EAW), *The EAW Electrical Handbook (*8th Edn., English Universities Press Ltd., London, 1965).

Garcke, E., (Ed.) *Garcke’s Manual of Electrical Undertakings* (50 vols. P.S. King, London, 1886-1953).

Garcke, E., *The Progress of Electrical Enterprise; Reprints of Articles from the Engineering Supplement of The Times on the British Electrical Industries* (Electrical Press Ltd., London, 1907).

Hammond, R., *The Electric Light in Our Homes* (Warne, London, 1884).

Haslam, A., *Electricity in Factories and Workshops. Its Cost and Convenience. A Handy Book for Power Producers and Power Users* (London, 1909).

Massingham, H.G., *The Past and Future Developments of Electricity and its Bearing on World Peace* (Hutchinson & Co. Ltd., London, 1935).

Parsons, R.H., *Early Days of the Power Station Industry* (The University Press Cambridge, Cambridge, 1939).

Stevenson, R. and Ridley, M., *Virginibus Puerisque: Familiar Studies of Men and Books* (Everyman's Library, London, 1963).

Matthews, R.B., *Electricity for Everybody: A Popular Handbook Dealing with the Uses of Electricity in Home and Business* (1st Edn., Electrical Press, London, 1909).

Matthews, R.B., *Electricity for Everybody: A Handbook for Central Station Engineers and All Users of Electricity* (3rd Edn., Electrical Press, London, 1924).

Chapters

The Central Electricity Board (CEB), ‘Construction of the National Grid’ in *British Commerce and Industry, The Post-War Transition, 1919-1934. With Special Contributions from Representative Industrial Groups and Leading Economic Authorities* (Russell-Square Press Ltd., London, 1934) pp. 187-198.

Articles

Armstrong, ‘Letters to the Editor’, *Engineer Magazine* (January 21, 1881). Please note, a copy of the original letter was supplied by the National Trust.

Benedict, C., ‘Conservation of Our Resources’, *Register of Kentucky State Historical Society,* 8, 39 (1915), 57-61.

Birchenough, H., ‘Industries After the War’, *Journal of the Royal Society of Arts*, 66, 3432 (1918) 644-645.

Birchenough, H., ‘Industries After the War. II.—Engineering’, *Journal of the Royal Society of Arts*, 66, 3433 (1918) 658-660.

Birchenough, H., ‘Industries After the War. III.—Electrical’, *Journal of the Royal Society of Arts*, 66, 3434 (1918) 672-673.

Birchenough, H., ‘Industries After the War. IV.—Textiles’, *Journal of the Royal Society of Arts*, 66, 3432 (1918), 781-784.

Brown-Lyman, C., ‘Lamps and Lighting’, *The Art World,* 116, 2 (1917) 185-188.

Burns, C.D., ‘The Readjustment of Industry in the United Kingdom’, *Annals of the American Academy of Political and Social Science,* 22 (1919) 52-82.

Campbell, W.W., ‘Science and Civilization’, *Science,* 5, 1077 (1915) 227-28.

Cook, C., ‘The Modern Home’, *The Art Amateur,* 64, 1 (1884) 16-19.

Darling, C.R., ‘Modern Domestic Scientific Appliances’, *Journal of the Royal Society of Arts,* 79, 4078 (1931) 205-216.

Edison, T.A., ‘The Success of the Electric Light’, *The North American Review,* 7, 287 (1880) 295-300.

Faraday, M., ‘Experimental Researches in Electricity’, *Philosophical Transactions of the Royal Society of London,* 23, 2 (1850) 188.

Fawcett, C.B., ‘Natural Divisions of England’, *The Geographical Journal,* 5, 2 (1917) 124-135.

Gridley, A. and Human, A., ‘Electric Power Supply During the Great War’, *Journal of the Institution of Electrical Engineers*, 57, 282 (1919) 406-415.

Gridley, A. and Human, A., ‘Electric Power Supply During the Great War’, *Journal of the Institution of Electrical Engineers*, 57, 285 (1919) 541-546.

Hyndman, H.M., ‘The Coming Revolution in England’, *The North American Review,* 18, 311 (1882) 299-322.

Kennedy, J.M. and Noakes, J.M., ‘Analysis of the Costs of Electricity Supply and Distribution in Great Britain, with some Suggestions as to the Causes of and Remedies for the Slow Rate of Development’, *Journal of the Institution of Electrical Engineers,* 3, 440 (1932) 97-113.

Manley, G., ‘Memorandum on the Geographical Factors Relevant to the Location of Industry’, *The Geographical Journal*, 92, 6 (1938) 499-526.

Marshall, C.W., ‘The Metering Arrangements for the "Grid" Transmission System in Great Britain’, *Journal of the Institution of Electrical Engineers,* 5, 95 (1930) 1497-1503.

Master, F.H., ‘British Electricity Supply - Past and Present’, *Saturday Review of Politics, Literature, Science and Art*, 134, 3502 (1922) 899.

Moore, G.E., ’Completion of the Electric Grid’, *Fortnightly Review,* 3, (1933) 436-472.

Rowland, H.A., ‘On the General Equations of Electro-Magnetic Action and to the Theory of the Magnetic Rotation of the Plane of Polarization of Light’, *American Journal of Mathematics,* 26, 1 (1880) 89-96.

Scott, C., ‘Long Distance Transmission for Lighting and Power’, *Transactions of the American Institute of Electrical Engineers,* IX, 1 (1892) 425-444.

Snell, J., ‘Speech Before the Engineering Section of the Association’, *The Engineer,* 99 (Aug 13, 1928) 167.

Source, J.M., ‘Historical Notes on Gas Illumination’, *Science,* 1, 2 (1880) 275-277.

Tawney, R.H., ‘The British Coal Industry and the Question of Nationalization’, *The Quarterly Journal of Economics,* 35, 1 (1920) 61-107.

Upton, F.P., ‘Electricity as Power’, *Science,* 1, 1 (1880) 5.

Williams, E.T., ‘The Electricity Supply of Great Britain’, *Journal of the Institution of Electrical Engineers,* 131, 260 (1916) 581-587.

Williams, C.W., ‘Prize Essay on the Prevention of the Smoke Nuisance’, *The Journal of the Society of Arts,* 35, (1856) i-iv.

Wright, J. and Marshall, C.W., ‘The Construction of the "Grid" System in Great Britain’, *Institute of Electrical Engineers Journal,* 9, 390 (1929) 685-722.

Articles not attributed to authors

‘All Electric House’, *The Municipal Journal* (Dec, 1924) 1437-1439.

‘All Electric House Experiment’, *The Electrical Times* (Dec, 1929) 679.

‘Britain will Begin Transmission of Commercial Television in September’, *The Electrical Engineer,* 78, 8 (1955) 743-743.

‘From Superstition to Humbug’, *Science,* 2, 41 (1883) 637-639.

‘Furniture Viewed by Electricity’, *The Art Amateur,* 6, 6 (1882) 128.

‘Notes on the Electrical Conference’, *Science,* 4, 86 (1884) 313-316.

‘Obituary of George Westinghouse’, *The Engineer,* 117 (1914) 315-16.

‘Recent Government Reports’, *Science,* 5, 110 (1885) 220-221.

‘Sir Andrew Duncan Obituary’, *The Engineer,* 193 (Apr 4, 1952) 474.

‘Smoke Nuisance’, *The Engineer* (Nov 10, 1905) 470.

‘Swan's Electric Light at Cragside’, *The Graphic*, 592 (April 2, 1881) 16.

‘The All-Electric House’, *The Engineer* (Dec 11, 1925) 789.

‘The Coal Question in England’, *Science,* 5, 108 (1885) 175-176.

‘The Commercial Situation’, *The Engineer* (Jun, 1902), 610.

‘The Conservation of Electricity’, *Science,* 2, 52 (1881) 304.

‘The Determination of the Ohm’, *Science,* 3, 48 (1884) 10-11.

‘The International Conference for the Determination of the Electrical Units’, *Science,* 1, 4 (1883) 87-89.

‘The National Conference of Electricians’, *Science,* 4, 80 (1884) 127.

‘The World's Progress in Trade and Industry’, *Journal of the Statistical Society of London,* 45, 1 (1883) 82-114.

’Visual Telegraphy’, *Science,* 1, 2 (1880) 14-15.

‘Water Jets as a Source of Electricity’, *Science,* 1, 7 (1880) 84.

‘What Is Electricity?’, *Science,* 4, 84 (1884) 232-234.

Pamphlets and Reports

Abell, R.H. and Meadows, F.P., ‘Electrification of the Countryside’ (*A Paper read at the E.D.A. Rural Electrification Conference*, Nottingham, 1962).

Arnold, L., ‘Our Inheritance in the Earth’ (LSE Selected Pamphlets, London, 1883).

Bazalgette, J.W., ‘Report Upon Metropolitan Railway and Other Schemes: Session 1879’ (Bristol Selected Pamphlets, Bristol, 1879).

Bramwell, F., ‘State Monopoly or Private Enterprise? An Address Delivered at the Second Annual Meeting of the Liberty and Property Defence League’ (Bristol Selected Pamphlets, Bristol, 1884).

Central Electricity Board, ‘The Grid, Electricity Supply in Great Britain’ (booklet published by the CEB, London, 1946).

‘Electrical and Radio Trades’ Survey of Wired Houses’ (The Broadcaster and Electrical Trades, London, 1935).

Malcomson, V.A., ‘Rural Housing and Public Utility Societies – A Few Suggestions Which May Contribute Something Towards the Solution of Rural Housing Problems’ (John Murray, London, 1920).

National Grid PLC., ‘Future Energy Scenarios’, 4031152 (National Grid PLC., Warwick, 2017).

Russell, F.A.R., ‘London Fogs’ (LSE Selected Pamphlets, London, 1880).

Scudamore, F.I., ‘Report by Mr. Scudamore on the Re-organization of the Telegraph System of the United Kingdom’ (H.M. Stationery Office, 1871).

‘Electrical and Radio Trades’ Survey of Wired Houses’ (The Broadcaster and Electrical Trades, London, 1935).

Websites

‘Electric Lighting Act 1882’, HC Deb 15 July 1882 vol 272 cc565-632, accessed via http://hansard.millbanksystems.com/commons/1882/jul/15/committee#S3V0272P0_18820715_HOC_35.

‘Second Reading Electric Lighting Act 1888’, HL Deb 01 March 1887 vol 311 c856, accessed via http://hansard.millbanksystems.com/lords/1887/mar/01/second-reading#column_855.

‘Government and Coal Industry’ HC Deb 07 December 1927 vol 211 c.1245, accessed via http://hansard.millbanksystems.com/commons/1927/dec/07/government-and-coal-industry#column_1425

‘Electricity (Supply) Bill’, HL Deb 24 November 1926 vol 65 cc787-839, accessed via http://hansard.millbanksystems.com/lords/1926/nov/24/electricity-supply-bill#column_820.

‘Electricity Bill’ HC Deb 04 February 1947 vol 432 cc1585-701, accessed via http://hansard.millbanksystems.com/commons/1947/feb/04/electricity-bill#column_1600.

2. Secondary Sources

Books

Aldcroft, D., (Ed.), *The Development of British Industry and Foreign Competition, 1875-1914: Studies in Industrial Enterprise* (vol.12, Allen & Unwin, London,1968).

Anthony, S., *Public Relations and the Making of Modern Britain – Stephen Tallents and the Birth of a Progressive Media Profession* (Manchester University Press, Manchester, 2012).

Appleyard, R., *History of the Institution of Electrical Engineers 1871-1931* (The Institution of Electrical Engineers, London, 1939).

Ashworth, W., *An Economic History of England, 1870-1939* (Methuen, London, 1960).

Ballin, H.H., *The Organisation of Electricity Supply in Great Britain* (Electrical Press Ltd., London, 1946).

Bolton, D., *Costs and Tariffs in Electricity Supply* (Chapman & Hall, London, 1938).

Brassley, P., Burchardt, J. and Sayer, K., *Transforming the Countryside: The Electrification of Rural Britain* (Rural Worlds series, Routledge, London, 2017).

Brimblecombe, P., *The Big Smoke: A History of Air Pollution in London Since Medieval Times* (Methuen, London, 1987).

Broadberry, S.N., *The Productivity Race: British Manufacturing in International Perspective, 1850-1990* (Cambridge University Press, Cambridge, 1997).

Broadberry, S.N., *Market Services and the Productivity Race 1850-2000 – British Performance in International Perspective* (Cambridge University Press, Cambridge, 2006).

Byatt, I.C.R., *The British Electric Industry 1875 to 1914 – The Economic Returns to a New Industry* (Clarendon Press, Oxford, 1979).

Chick, M., *Electricity and Energy Policy in Britain, France, and the United States Since 1945* (Edward Elgar Publishing, Cheltenham, 2007).

Cochrane, R., *Power to the People – The Story of the National Grid 1935-1985* (Newnes Books, London, 1985).

Cowan, R., *More Work for Mother: The Ironies of Household Technology from the Open Hearth to the Microwave* (Basic Books, New York, 2003).

Daunton, M., *Wealth and Welfare – An Economic and Social History of Britain 1851 to 1951* (Oxford University Press, Oxford, 2007).

Deane, P., *The First Industrial Revolution* (Cambridge University Press, Cambridge, 1965).

Dike, J. and Lamb, P., *Torquay's Electricity History 1877-1948* (The South Western Electrical Historical Society, Bristol, 2012).

Dillon, M., *Artificial Sunshine: A Social History of Domestic Lighting* (National Trust, London, 2002).

Dormois, J. and Dintenfass, M., (Ed's.) *The British Industrial Decline* (Routledge, London, 1999).

Garside, W.R., *The Durham Miners – 1919 to 1960* (George Allen and Unwin Ltd., London, 1971).

Gill, C., *Plymouth, A new History – 1603 to the Present Day* (David and Charles, Newton Abbott, Devon, 1993).

Gledhill, D. and Lamb, P., *Electricity in Taunton 1809-1948* (The Somerset Industrial Archaeological Society, Bristol, 1986).

Glynn, I., *Elegance in Science: The Beauty of Simplicity* (Oxford University Press, Oxford, 2010).

Golding, E.W., *The Electrification of Agriculture and Rural Districts* (Electrical Engineering series, The English Universities Press, London, 1937).

Gordon, L., *The Public Corporation in Great Britain* (Oxford University Press, Toronto, 1938).

Gordon, R.J., *The Rise and Fall of American Growth: The U.S. Standard of Living Since the Civil War* (Princeton University Press, New Jersey, 2016).

Gould, J.M., *Output and Productivity in the Electric and Gas Utilities 1899 – 1942* (National Bureau of Economic Research, New York, 1946).

Hannah, L., *Electricity Before Nationalisation – A Study of the Development of the Electricity Supply Industry in Britain to 1948* (The Macmillan Press Limited, London, 1979).

Hannah, L., *Engineers, Managers and Politicians – The First Fifteen Years of Nationalised Electricity Supply in Great Britain* (The Johns Hopkins University Press, Baltimore, 1982).

Haslam, A., *Electricity in Factories and Workshops. Its Cost and Convenience. A Handy Book for Power Producers and Power Users* (London, 1909).

Hecht, G., *The Radiance of France – Nuclear Power and National Identity After World War II* (The MIT Press, Massachusetts, 1998).

Hennessey, R.A.S., *Factories* (Batsford, London, 1969).

Hennessey, R.A.S., *The Electric Revolution* (Oriel Press Ltd., Newcastle-upon-Tyne, 1972).

Hinton, C., *Heavy Current Electricity in the United Kingdom – History and Development* (Pergamon Press, Oxford, 1979).

Hughes, T.P., *Networks of Power – Electrification in Western Society 1880-1930* (John Hopkins University Press, Baltimore, 1983).

Jevons, W., *The Coal Question: An Enquiry Concerning the Progress of the Nation, and the Probable Exhaustion of Our Coal-Mines* (Macmillan, London, 1865).

Jones, C.F., *Routes of Power – Energy and Modern America* (Harvard University Press, Massachusetts, 2014).

Kander, A., Malanima, P. and Warde, P., *Power to the People: Energy in Europe Over the Last Five Centuries* (Princeton University Press, New Jersey, 2013).

Kindleberger, C., *Economic Development inEngland and France 1850 to 1950* (Harvard University Press, Massachusetts, 1964).

King, A. and Crewe I., *The Blunders of our Government* (One World Publications, London, 2014).

Lamb, P., *Electricity in Bristol* (Bristol Branch of the Historical Association, Bristol, 1981).

Lewis, J., *London's Lea Valley: Britain's Best Kept Secret* (Phillmore and Co. Ltd., Chichester, 1999).

Lewis, J., *London's Lea Valley: More Secrets Revealed* (Phillmore and Co. Ltd., Chichester, 1999).

Lewis, J., *Regeneration and Innovation: Invention and Reinvention in the Lea Valley* (Libri Publishing, Oxfordshire, 2011).

Lewis, J., *Weapons, Wireless and World Wars: The Vital Role of the Lea Valley* (Libri Publishing, Oxfordshire, 2010).

Lincoln, G., *The Public Corporation in Great Britain* (Oxford University Press, Oxford, 1938).

Luckin, B., *Questions of Power* (Manchester University Press, Manchester, 1990).

Luscombe, E. and Buck, C., *Plymouth's Electrical Revolution* (The South West Electrical Historical Society, Bristol, 2014).

Marchant, J., (Ed.) *Post War Britain* (Eyre & Spottiswoode, London, 1945).

Marr, A., *The Making of Modern Britain* (Macmillan, London, 2009).

Martin, J.E., *Greater London: An Industrial Geography* (G. Bell and Sons Ltd., London, 1966).

Melosi, M.V., *Coping with Abundance – Energy and Environment in Industrial America* (Temple University Press, Philadelphia, 1987).

Merrett, S., *State Housing in Britain* (Routledge and Kegan Paul, London, 1979).

Milward, R., *Private and Public Enterprise in Europe – Energy, Telecommunications and Transport 1830 – 1990* (Cambridge University Press, Cambridge, 2005).

Mosley, S., *The Chimney of the World: A History of Smoke Pollution in Victorian and Edwardian Manchester* (White Horse, Cambridge, 2001).

Morton, J., *Cheaper than Peabody: Local Authority Housing from 1890 to 1919* (Joseph Rowntree Foundation, York, 1991).

Nye, D.E., *Electrifying America – Social Meanings of a New Technology 1880-1940* (The MIT Press, Massachusetts, 1990).

Nye, D.E., *Consuming Power – A Social History of American Energies* (The MIT Press, Massachusetts, 1998).

Odum, E.P., *Ecology and Our Endangered Life Support Systems* (Sinauer Associates Inc., Stanford, 1989).

Odum, H.T., *Environment Power and Society* (John Wiley and Sons Inc., New York, 1971).

Odum, H.T., *Environment Power and Society – For the Twenty First Century* (Columbia University Press, New York, 2007).

Pawley, M., *Home Ownership* (Architectural Press, London, 1978).

Poole, R. and Poole, P.M., *The Valuation of Pipeline Easements and Wayleaves* (The Estates Gazette Ltd., London, 1962).

Pritchard, S.B., *Confluence – The Nature of Technology and the Remaking of the Rhone* (Harvard University Press, Massachusetts, 2011).

Ridding, A., *S.Z. de Ferranti Pioneer of Electric Power* (A Science Museum Booklet, H.M. Stationery Office, London, 1964).

Ritzer, G., *Enchanting a Disenchanted World, Revolutionizing the Means of Consumption* (Pine Forge Press, California, 1999).

Rowland, J., *Progress in Power – The Contribution of Charles Merz and his Associates to Sixty Years of Electrical Development 1899-1959* (Newman Neame Ltd., London, 1960).

Schewe, P., *The Grid: A Journey Through the Heart of Our Electrified World* (Joseph Henry Press, Washington DC, 2007).

Scott, P., *The Market Makers: Creating Mass Markets for Consumer Durables in Inter-War Britain* (Oxford University Press, Oxford 2017).

Scott, P., *Triumph of the South: A Regional Economic History of Early Twentieth Century Britain* (Ashgate Pub., Aldershot, 2007).

Self, H. and Watson, E.M., *Electricity Supply in Great Britain – Its Development and Organisation* (National Board Series, George Allen and Unwin Ltd., London, 1952).

Sheail, J., *Power in Trust* (Clarendon Press, Oxford, 1991).

Sheail, J., *An Environmental History of Twentieth Century Britain* (Hampshire: Palgrave Macmillan, 2002).

Skelton, L., T*yne After Tyne: An Environmental History of a River's Battle for Protection, 1529-2015* (The White Horse Press, Winwick, Cambridgeshire, 2017).

Smith, D.H., *The Industries of Greater London – Being a Survey of the Recent Industrialisation of the Northern and Western Sectors of Greater London* (P.S. King & Son Ltd., London, 1933).

Smith, H., *The New Survey of London Life and Labour* (P. S. King & Son Ltd., London, 1930).

Somers, G.E., Cushman, E.L. and Weinberg, N., (Ed's.) *Adjusting to Technological Change* (Harper and Row, New York, 1963).

Sörlin, S. and Warde, P., *Nature's End: History and the Environment* (Palgrave Macmillan, Basingstoke, 2011).

Stiel, W. and Rodger, A., *Textile Electrification: A Treatise on the Application of Electricity in Textile Factories* (Authorized translation by A. F. Rodger, with six plates and 650 other illustrations, G. Routledge, London, 1933).

Summers, G., *Consuming Nature: Environmentalism in the Fox River Valley, 1850-1950* (University Press of Kansas, Kansas, 2006).

Thompson, A., *The Dynamics of the Industrial Revolution* (Edward Arnold Ltd., London, 1973).

Tivy, J. and O'Hare, G., *Human Impact on the Ecosystem – Conceptual Frameworks in Geography* (Oliver & Boyd, Edinburgh, 1981).

Trentmann, F., *Empire of Things: How We Became a World of Consumers, from the Fifteenth Century to the Twenty-first* (Allen Lane, London, 2016).

Tuma, E.H., *Economic History and the Social Sciences – Problems of Methodology* (University of California Press, California, 1971).

Tuve, G.L., *Energy Environment Populations and Food – Our Four Interdependent Crises* (John Wiley and Sons Inc., New York, 1976).

Van der Vleuten, E. and Kaijser, A., (Ed's.) *Networking Europe – Transnational Infrastructures and the Shaping of Europe 1850 - 2000* (Science History Publications, Massachusetts, 2006).

Van Vliet, B., Chappells, H. and Shove, E., *Infrastructures of Consumption – Environmental Innovation in the Utility Industries* (Earthscan Publications Ltd, London, 2005).

Vries, L. and Van Amstel, I., *Victorian Inventions* (Murray, London, 1971).

Weightman, G., *Children of Light, How Electricity Changed Britain Forever* (Atlantic Books, London, 2011).

White, G., (Ed.) *Natural Hazards – Local National Global* (Oxford University Press, Oxford, 1974).

White, R., *The Organic Machine* (Hill and Wang, New York, 1995).

Williams, T., (Ed.) *A History of Technology – Vol. VI The Twentieth Century c.1900 to c.1950* (Clarendon Press, Oxford, 1978).

Williams-Ellis, C. and Abercrombie, P., *England and the Octopus* (New ed. with a new preface by the author; and a contemporary introduction by Lewis Mumford, Portmeirion, Glasgow, 1975).

Wilson, J.F., *Ferrante and the British Electrical Industry – 1864-1930* (Manchester University Press, Manchester, 1988).

Winther, T., *The Impact of Electricity – Development, Desire and Dilemmas* (Berghahn Books, New York, 2011).

Wrigley, E., *Energy and the English Industrial Revolution* (Cambridge University Press, Cambridge, 2010).

Chapters

Atkinson, A.B., 'Distribution of Income and Wealth in Britain over the Twentieth Century' in Halsey, A. and Webb, J., (Eds.) *Twentieth-Century British Social Trends* (3rd ed., Palgrave, London, 2000) 348-384.

Bowers, B., 'Electricity' in Williams, T.I., (Ed.) *A History of Technology, Volume VI, The Twentieth Century, c.1900 to 1950* (Part 1, Clarendon Press, 1978) 284-297.

Ditt, K., 'The Electrification of the Countryside; The Interests and Electrical Enterprises and the Rural Population in England, 1888-1939' in Brassley, P., Burchardt, J. and Sayer, K., (Eds) *Transforming the Countryside the Electrification of Rural Britain* (Rural Worlds series, Routledge, London, 2017) 15-37.

Hall, P., 'The Geography of High Technology: An Anglo-American Comparison' in Brotche, J., Hall, P. and Newton, P., (Eds.) *The Spatial Impact of Technological Change* (Croom Helm, London, 1987) 141-156.

Hewings, G.J.D. and O'Huallachain, B., 'Industrial Factors' in Hamilton, F., and Linge, G., (Eds) *Spatial Analysis, Industry and the Industrial Environment: Progress in Research and*

Applications. Vol.3, Regional Economics and Industrial Systems (Wiley, Chichester, 1983) 41-57.

Hughes, T.P., ‘The Evolution of Large Technological Systems’ in Weibe, B.E., Hughes, T.P. and Pinch, T.J., (Eds) *The Social Construction of Technological Systems; New Directions in the Sociology and History of Technology* (The MIT Press, Massachusetts, 2001) 51-82.

Jones, C.F., ‘The Electrification of America’ in Jones, C.F., *Routes of Power,* (Harvard University Press, Massachusetts, 2014) 195-226.

Skelton, L., 'Mastering North-East England's "River of Tine": Efforts to Manage a River's Flow, Functions and Form, 1529-c.1800', in Miglietti, S. and Morgan, J., (Eds.), *Governing the Environment in the Early Modern World* (Routledge, London, 2017) 76-96.

Skelton, L., 'Stories of Life, Work and Nature Before and After the Clean-Up of North-East England's River Tyne, 1940-2015', in Holmes, K. and Goodhall, H., (Eds.), *Telling Environmental Histories: Intersections of Memory, Narrative and Environment* (Palgrave, London 2017) 153-177.

Skelton, L., 'Regulating the Environment of the River Tyne's Estuary, 1530-1800', in Joanaz de Melo. C., *et al.*, (Eds.), *Environmental History in the Making: Volume II: Acting* (Springer, Berlin, 2017) 241-262.

Van Lieshout, C., ‘Contested subterranean waterscapes: lead mining sough disputes in Derbyshire's Derwent Valley’ in Francesco, V. and Visentin, F., (Eds.), *Waterways and the Cultural Landscape* (Routledge, London, 2018) 86-103.

Warde., P., ‘The Environment’ in Coates, P., Moon, D. and Warde, P. (Eds.), *Local Places, Global Processes*, (Windgather Press, Oxford, 2016).

Articles

Barton, L., ‘Windfarm Wars: Are They a Majestic Man-Made Wonder – Or A Blight on the Countryside?’, *The Guardian* (London, April 12, 2005) 18.

Bevanger, K., ‘Biological and Conservation Aspects of Bird Mortality Caused by Electricity Power Lines: A Review’, *Biological Conservation,* 86 (1998) 67-76.

Bowden, S., ‘The Consumer Durables Revolution in England 1932–1938; A Regional Analysis’, *Explorations in Economic History,* 25, 1 (1988) 42-59.

Bowden, S., ‘Credit Facilities and the Growth of Consumer Demand for Electric Appliances in the 1930s’, *Business History,* 32 (1990) 32, 52-75.

Bowden, S. and Offer, A., ‘Household Appliances and the Use of Time: The United States and Britain’, *The Economic History Review,* 52, 3 (1999) 552-562.

Brimblecombe, P. and Bowler, C., 'The History of Air Pollution in York, England', *Journal of the Air and Waste Management Association,* 42, 12 (1992) 1562-1566.

Carlson-Hyslop, A., 'Past Management of Energy Demand: Promotion and Adoption of Electric Heating in Britain', *Environment and History*, 22, 1 (2016) 75-102.

Cronon, W., 'ASEH Presidential Address, The Uses of Environmental History'. *Environmental History Review*, 17, 3 (1993) 1-22.

Devine, W., 'From Shafts to Wires: Historical Perspective on Electrification', *The Journal of Economic History,* 43, 2 (1983) 347-372.

Duncan, J.S. and Duncan, N.G., 'The Anesthetisation of the Politics of Landscape Preservation', *Annals of the Association of American Geographers*, 91, 2 (2001) 387-409.

Fath, B.D., Patten, B.C. and Choi, J.S., 'Complementarity of Ecological Goal Functions', *Journal of Theoretical Biology,* 7 (2001) 493-506.

Foquet, R., 'Long Run Demand for Energy Services: Income and Price Elasticities Over 200 Years', *Review of Environmental Economics and Policy,* 1, 2 (2014) 186-20.

Foquet, R., 'The Slow Search for Solutions: Lessons from Historical Energy Transitions by Sector and Service', *Energy Policy,* 38 (2010) 6586–6596.

Foreman-Peck, J.S. and Hammond, C.J., 'Variable Costs and the Visible Hand: The Re-Regulation of Electricity Supply 1932-37', *Economical,* 3, 253 (1997)15-30.

Grove, J. W., 'British Public Corporations: Some Recent Developments', *The Journal of Politics,* 1, 4 (1956) 651-677.

Hughes, T.P., 'Managing Change - Regional Power Systems 1910-30', *Business and Economic History,* 62 (1977) 52-68.

Jones, E., 'The Cardiff Electricity Undertaking 1891-1941 Western Centre: Chairman's Address', *Journal of the Institution of Electrical Engineers,* 89, 14 (1942) 94-97.

Kaghan, W.N. and Bowker, G.C., 'Out of Machine Age? Complexity, Sociotechnical Systems and Actor Network Theory', *Journal of Engineering and Technological Management* 12 (2001) 253-269.

Kellett, J., 'Municipal Socialism, Enterprise and Trading in the Victorian City', *Urban History*, 5 (1978) 36-45.

Manley, G., 'Memorandum on the Geographical Factors Relevant to the Location of Industry', *The Geographical Journal*, 92, 6 (1938) 499-526.

Matless, D., 'Ages of English Design: Preservation, Modernism and Tales of Their History, 1926-1939', *Journal of Design History,* 2 (1990) 203-212.

Melling, C.T., ‘Nationalisation of Electricity Supply 1947, Reasons and Problems’, *Engineering Science and Education Journal* (1998) 11-17.

Mosley, S., 'A Network of Trust: Measuring and Monitoring Air Pollution in British Cities, 1912-1960’ *Environment and History*, 15, 3 (2009) 273-302.

Odum, E.P., ‘The Emergence of Ecology as a New Integrative Discipline’, *Science,* 195, 4284 (1977) 1289-1293.

Owen, E.L., ‘Four Generations of Electrical Engineers’, *IEEE Industry Applications Magazine,* 1, 2 (1998) 6-15.

Palmer, M. and West, I. ‘Nineteenth-Century Technical Innovations in British Country Houses and their Estates’, *Engineering, History and Heritage,* 166, EH1 (2013) 36-44.

Pattee, B.C., ‘Network Integration of Ecological Extremal Principles: Exergy, Emergy, Power, Ascendancy, and Indirect Effects’, *Ecological Modelling*, 79 (1995) 75-84.

Perry, C.R., ‘Frank Ives Scudamore and the Post Office Telegraphs’, *The North American Conference on British Studies,* 82, 4 (1980) 350-367.

Preetum, D. and Pollit, M.G., ’The Restructuring and Privatisation of Electricity Distribution and Supply Businesses in England and Wales: A Social Cost–Benefit Analysis’, *Fiscal Studies,* 8, 1 (2001) 107-146.

Pursell, C., ‘Domesticating Modernity: The Electrical Association for Women 1924-86’, *The British Journal for the History of Science,* 32, 112 (1999) 47-67.

Rose, K. and McDonald, J.F., ‘Economics of Electricity Self Generation by Industrial Firms’, *The Energy Journal*, 12, 2 (1991) 47-66.

Rose, N. and Joskow, P., ‘The Diffusion of New Technologies: Evidence from the Electric Utility Industry’, *The RAND Journal of Economics,* 21, 3 (1990) 354.

Rudge, J., ‘Coal Fires, Fresh Air and the Hardy British: A Historical View of Domestic Energy Efficiency and Thermal Comfort in Britain’, *Energy Policy*, 49 (2012) 6-11.

Sayers, D. P. and Hill, E., ‘Twenty Years of Electricity Distribution Under Public Control’, *Proceedings of the Institute of the Electrical Engineers,* 5, 9 (1969) 1527-1543.

Sciubba, E., ‘What Did Lotka Really Say? A Critical Reassessment of the “Maximum Power Principle”’, *Ecological Modelling,* 42 (2011) 1347-1353.

Shiman, D.R., ‘Explaining the Collapse of the British Electrical Supply Industry in the 1880s; Gas versus Electric Lighting Prices’, *Business and Economic History,* 3, 1 (1993) 318-327.

Shove, E. and Southerton, D., ‘Defrosting the Freezer: From Novelty to Convenience – Normalisation’, *Journal of Material Culture,* 5, 3 (2000) 301-319.

Snow. A, ‘Ferranti and Merz: Power Transmission System Design Engineers’, *Engineering Science and Education Journal, History of Technology* (1998) 10.

Townroe, P.M., ‘Locational Choice and the Individual Firm’, *Regional Studies*, 3, 1 (1969) 15-24.

Spear, B., ‘Sebastian de Ferranti – Electrical Engineering Pioneer and Enthusiastic Patentee’, *World Patent Information,* 14 (2013) 230-234.

Trousset, S., ‘Current Trends in Science and Technology Policy Research: An Examination of Published Works from 2010 – 2012’, *The Policy Studies Journal*, 42 (2014) S87-S117.

Tulley, J., ‘A Victorian Disaster: Imperialism, The Telegraph, and Gutta-Percha’, *Journal of World History*, 20, 4 (2009) 559-579.

Vanek, J., ‘Time Spent in Housework’, *Scientific American,* (1974) 116-120.

Websites

Baldwin, S., ‘Leader’s Speech’, Conservative Party Conference, 1926, accessed via http://www.britishpoliticalspeech.org/speech-archive.htm?speech=87.

Department for Business, Energy and Industrial Strategy, ’Historic Electricity Data 1920 to 2013’, accessed via https://www.gov.uk/government/statistical-data-sets/historical-electricity-data-1920-to-2011.

Department for Business, Energy and Industrial Strategy, ’Historic Gas Data 1920 to 2013’, accessed via https://www.gov.uk/government/statistical-data-sets/historical-gas-data-gas-production-and-consumption-and-fuel-input-1882-to-2011.

European Commission Definitions, 2017, accessed via http://ec.europa.eu/health/scientific_committees/opinions_layman/en/electromagnetic-fields/glossary/abc/alternating-current.htm.

National Grid, ‘Glossary of Terms’, accessed via http://www2.nationalgrid.com/WorkArea/DownloadAsset.aspx?id=36706.

‘Obituary Notice, 1950, Selwyn Grant OBE’, Institute for Electrical Engineering, accessed via http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=5320467.

Oosthoek, J., ‘What is Environmental History’ Podcast 1 on Environmental History Resources accessed via https://www.eh-resources.org/podcast-1.

Purdon, J., ‘Electric Cinema, Pylon Poetry’, *Amodern, A journal on Media, Culture, and Poetics*, 2 (2013) accessed via http://amodern.net/article/electric-cinema-pylon-poetry.

Sheppard, P., ‘Smart Thinking’, *Connecting* accessed via http://nationalgridconnecting.com/towards-smart-energy-systems.

‘The Brick Society Web Pages’, accessed via http://britishbricksoc.co.uk.

Warde, P., ‘Environmental History: Definitions, Methods and Challenges’ Podcast 23 on Environmental History Resources, accessed via https://www.eh-resources.org/podcast-23.

Pamphlets and Reports

Clark, T. and Dilnot, A., ‘Long Term Trends in British Taxation and Spending’ (Briefing Note No. 25, Institute for Fiscal Studies, London, 2002).

Cossons, N., ‘Historic Infrastructure’, in *Conservation Bulletin, A Bulletin of The Historic Environment, Attitudes to Infrastructure* (English Heritage, London, 2011).

Department for Business, Energy and Industrial Strategy, ‘Implementing the End of Unabated Coal by 2025. Government Response to Unabated Coal Closure Consultation’ (BEIS, London, Jan 2018).

Electricity Networks Strategy Group, ‘Our Electricity Transmission Network: A Vision for 2020. A Report by the Electricity Networks Strategy Group’ (Department of Energy and Climate, 2009).

Frontier Economics Limited., ‘Competition and Entry in the GB Electricity Retail Market – A Report Prepared for Energy UK’ (Frontier Economics Ltd., London, 2011).

Hoggett, R., ‘GB Electricity Demand – Realising the Resource’ (Sustainability First, 2012).

Manco, J., ‘The Hub of the Circus, A History of the Streetscape of the Circus’ (Planning Services, Bath and North East Somerset Council, Bath, 2004).

National House Building Council, ‘Homes Through the Decades – the Making of the Modern House’, NF 62 (NHBC Foundation, 2015). Using Office for National Statistics Table 104 Dwelling stock and ‘Tenure in England: 1914-99’ in Research Paper 99/111 *A Century of Change: Trends in UK statistics since 1900*. House of Commons Library, 1999.

Robinson, C., ‘The Results of UK Electricity Privatisation’ (Published by Surrey Energy Economics Centre, 1992).

Simmonds, G., ‘Regulation of the UK Electricity Industry’ (Desktop published by Jan Marchant, The University of Bath, 2002).

Smith, C., (Ed.) ‘Attitudes to Infrastructure Conservation’ (Bulletin of English Heritage 4, 2010).

Smith, T. and Carr, B., 'Guide to the Industrial Archaeology of Hertfordshire and the Lea Valley' (Association for Industrial Architecture, 2004).

South West Water, 'Mary Tavy Power Station: Green Energy from Dartmoor' (South West Water, ref. 321010, 2012).

Thomas, S., 'Wholesale Electricity Market in Britain – 1990-2001' (The Public Services International Research Unit, University of Greenwich, 2001).

Upham, P. *et al*., 'Public Attitudes to Environmental Change: A Selective Review of Theory and Practice' (Research Councils and Living with Environmental Change, 2009).

Warburton, G., 'The History of SWEBs Electrification', (HistElec Article, S17, p. 4, 2001) accessed via http://emep.worldonline.co.uk/SWEHS/docs/news17su.html.

Unpublished

Bloomfield, G.T., 'Notes for the Study of Regional and Local Electricity Systems in Britain – The South Western Electricity Board Area', (University of Guelph, 2014).

Carlsson-Hyslop, A. and Pearson P.J.G., 'How Did the Electrical Development Association Attempt to Mould Domestic Electricity Demand in Britain 1945-1964?', Working Paper 2013/01 (2013).

De Neuman, A.M., 'Some Economic Aspects of Nationalisation', Self-Published.

Eyles, W.E., 'Electricity in Bath, 1890-1974', Supplement to the HistElec News (Aug 2006) SWEHS accessed via http://www.swehs.co.uk/tactive/prnt/S33.pdf.

Gibson. W., 'The Electricity Works – Lynton and Lynmouth', Supplement to the HistElec News No.1, (1996), SWEHS accessed via http://emep.worldonline.co.uk/SWEHS/docs/news01su.html.

Grant, S., 'West of England Electricity', Supplement to HistElec Article, No S26, (2004) accessed via http://emep.worldonline.co.uk/SWEHS/docs/news26su.html.

Greene, M.R., 'Electric Lyme', Supplement to the HistElec News, (Aug 2003), SWEHS accessed via http://emep.worldonline.co.uk/SWEHS/docs/news24su.html.

Hare, T., 'London Municipal Reform: A Reprint with Additions of Several Papers Thereon', Earl Grey Pamphlets Collection, University of Durham (1882).

Horne, M.A.C., 'London Area Power Supply – A survey of London's Electric and Power stations' (2012) accessed via http://www.metadyne.co.uk/pdf_files/electricity.pdf.

Ireland: IEE Chairman address Dublin Electric Revolution in Ireland presentation, power point presentation (2000). Shared via personal communication.

Lamb. P., 'Early Days of Electricity in Exeter', (SWEHS, Bristol, 2014). Shared via personal communication.

Lamb. P., 'Early Days of Electricity in the South West (Covering a period from 1850 - 1900)', (SWEHS, Bristol, 2014). Shared via personal communication with SWEHS.

Lamb, P., 'Over 100 Years of Electric Supply in Devon', (SWEHS, Bristol, 1995). Shared via personal communication with SWEHS.

Lamb, P., 'The Massingham Family in the Bristol Area', HistElec Article, No. S20 (2002) accessed via http://www.swehs.co.uk/tactive/_S20-2.html.

Lamb, P. and Lodge, E., 'Christy Brothers in the South West', Supplement to Histelec News No.15, (2000) accessed via http://emep.worldonline.co.uk/SWEHS/docs/news15su.html.

Plymouth City Council, 'Three Towns Centenary Stone Panel', 'Three Towns or One?' and 'Plymouth's Great War – Teachers Notes', accessed via https://www.plymouth.gov.uk/boundarystone/threetownsamalgamationcentenarystone.

Russell, T., 'The History and Operation of Gasworks', available through Research Gate (2013) accessed via https://www.researchgate.net/publication/236532402_The_History_and_Operation_of_Gasworks_Manufactured_Gas_Plants.

Trentmann, F. and Carlsson-Hyslop, A., 'The Evolution of Energy Demand: Politics, Practices and Infrastructural Change, Public Housing in Britain 1920s-70s' (2017) accessed via http://www.cambridge.org, *The Historic Journal*, https://doi.org/10.1017/S0018246X17000255.

Warburton, G., 'The History of SWEBs Electrification', HistElec Article, No.S17, (2001) accessed via http://emep.worldonline.co.uk/SWEHS/docs/news17su.html.

Western Power Electrical Historical Society, 'Newsletters' and 'articles' available through http://www.wpehs.org.uk.

Theses

Byatt, I.C.R., 'The British Electrical Industry 1875 to 1914' (PhD Thesis, Oxford University, 1962).

Cohn, J., 'Expansion for Conservation: The Growth of America's Power Grid Through the Twentieth Century' (PhD Thesis, University of Houston, 2010).

Hankin, E., 'Buying Modernity? The Consumer Experience of Domestic Electricity in the Era of the Grid' (PhD Thesis, University of Manchester, 2012).

O'Brien, S., 'Representing the Shannon Scheme: Electrical Technology Modernisation and National Identity in the Irish Free State 1924-32' (PhD Thesis, University of Brighton, 2012).