Security of Supply: The Role of the State in Britain's Emerging National Electricity Network, 1914-1956

Paul Michael Coleman

Submitted in accordance with the requirements for the degree of Doctor of Philosophy

The University of Leeds
School of Philosophy, Religion and History of Science

September 2018

The candidate confirms that the work submitted is his own and that appropriate credit has been given where reference has been made to the work of others.

Acknowledgements

Firstly, I would like to thank my supervisors Professor Graeme Gooday and Dr Alice Cliff, whose support, encouragement, feedback and patience has been invaluable throughout all stages of writing this thesis. I would also like to thank Anne Hanley, Laura Chilton, Annie Jamieson and Clare Coleman for their patience in proof-reading and putting up with my typographical and grammatical oddities. Special thanks are due to the AHRC and the Museum of Science and Industry for funding this research. Thanks are also due to the White Rose College of Arts and Humanities for their support over the last four years. I would also like to thank to my friends and family particularly Clare and of course Tiffany for their support over the last four years and especially the last two months. Finally, I would like to thank my examiners, Professor Karen Sayer and Dr Sally Horrocks for their time and their invaluable feedback and insights in arriving at this corrected version of the thesis.

Abstract

This thesis explores how energy security has been a key feature of British government policy in electrification since the First World War, in contrast to accounts that characterise electrification as if simply a means to achieve greater economic efficiency in energy supply. For Britain this focus on energy security has historically meant reliance on coal: since the end of the nineteenth century, new high-efficiency technologies of electricity generation and network distribution had offered a means of reducing the tonnage of coal needed to produce power. Economic histories of electricity supply in Britain, such as Hannah's *Electricity Before Nationalisation*, as well as more recent work such Hausman Hertner's *Global Electrification: Multinational Enterprise and International Finance in the History of Light and Power, 1878-2007*, have focused almost exclusively on such efficiency-centred arguments to explain the widespread electrification of the UK in the first half of the twentieth century. These works, however, do not consider the additional security benefits that were secured in ubiquitous electricity supply, whether in terms of the strategic preservation of coal stocks for future use, or of the potential risks of becoming overly reliant on a fallible coal supply for electrical production, or of the breakdown of electricity power supply for a variety of reasons. I show that the development of a National Electricity Supply, between 1914 and 1956, was part of a deliberate move by the State (of any and all political affiliations) to fulfil their top priority of security of energy supply for British industry, Ironically, however, the success of this move to widen electrical usage also had the unintended effect of significantly increasing the UK's dependence on coal and therefore vulnerability to any interruption in the localised supply of coal to the power stations. Hence, establishment of a plan for a National Grid of electricity supply from 1926, the year of the General Strike, was also a vital strategic move to attain national security, enabling the multi-routed distribution of electricity around the entire country's industries to minimise any disruption to power supplies from the four security threats of enemy attack, industrial action by coal or power-station workers, political (terrorist/revolutionary) sabotage or accidental damage. Not only did the distributed infrastructure of electrical energy supply became part of the national defences to deal with airborne attacks first encountered in the First World War, it also became an essential part of preparedness for future conflict, in what Edgerton has dubbed the 'Warfare State'. Throughout the thesis I explore the tension between Hannah's and Hughes's arguments for economic efficiency, and the agenda of security of supply which was less efficient but limited the nation's vulnerability. I show that, both in peace and war, security of supply was the overridingly important factor in the development of Britain's National Grid.

Contents

List of Figures

List of Abbreviations

A.R.P	Air Raid Precaution
AC	Alternating Current
AEI	Associated Electrical Industries
Board of Trade Unit	A unit of energy equal to the work done by a power of 1000 watts operating for one hour
CEB	Central Electricity Board, 1919-1952
CEGB	Central Electricity Generating Board, 1952 – 1990
Cwt	Hundredweight – unit of 100lb Not commonly used in Britain
DC	Direct Current
DORA	Defence of the Realm Act
EAW	Electrical Association for Women
EC	Electricity Commissioners
EDA	Electrical Development Association
ERA	Electrical and Allied Industries Research Association
FOSM	Flag Officer Submarines
GCHQ	Government Communications Headquarters
GRT	Gross Registered Tonnage
IEE	Institution of Electrical Engineers
IRA	Irish Republican Army
Kva	Kilovolt amps
Kw	Kilowatts
LGB	Local Government Board
M.O.W	Ministry of Works
MEW	Ministry of Economic Warfare
MFGB	Miners Federation of Great Britain
Mw	Megawatts
NESCo	Newcastle-upon-Tyne Electric Supply Company
NIAB	National Institute of Agriculture and Botany
OFGEM	Office of Gas and Electricity Markets
RAF	Royal Air Force
s.m.d	Simultaneous Maximum Demand
Therm	Unit of measurement for Gas
TUC	Trades Union Congress

Key Terms

Baseload: The minimum value of the load that an electricity or gas supply is required to deliver, typically met (in a Grid system) by the continuous operation of the most efficient stations, without the intermittent and varying contribution of less efficient ones.[1]

Peak load: The greatest load required to be provided, carried, etc.; especially the maximum power demand on a particular generating system. Also: a period during which such a maximum occurs.[2]

Board of Trade Unit: The commercial unit of electrical energy, equivalent to one kilowatt-hour of current. The Board of Trade Unit is the commercial standard for purposes of public supply and is measured by the product at the rate of doing work into the hours divided by 1,000: hence 1 B.T.U. = 1,000-Watt hours.[3]

Energy Security: The safety of energy supplies, power networks, fossil fuel reserves, etc.; the safeguarding of these, esp. by a government.[4]

[1] 'base, n.1'. OED Online. July 2018. Oxford University Press. http://www.oed.com/view/Entry/15848?redirectedFrom=Base+Load (accessed September 21, 2018).
[2] 'peak load, n.'. OED Online. July 2018. Oxford University Press. http://www.oed.com/view/Entry/261018?redirectedFrom=Peak+Load& (accessed September 21, 2018).
[3] 'board, n.'. OED Online. July 2018. Oxford University Press. http://www.oed.com/view/Entry/20731?redirectedFrom=Board+of+Trade+Unit (accessed September 24, 2018).
[4] 'energy, n.'. OED Online. July 2018. Oxford University Press. http://www.oed.com/view/Entry/62088?redirectedFrom=Energy+Security (accessed September 21, 2018).

Security of Supply: The Role of the State in Britain's Emerging National Electricity Network, 1914-1956

1.1. Introduction.

It has become something of a cliché to point out the extent to which we have become dependent on electricity supply as a universal utility in modern life: constant access to a secure source of electricity is something which we now take for granted.[1] Yet with the phased elimination of fossil fuels from British electrical power generation, there are growing concerns about the ability of the country to meet its energy requirements in electrical supply. A 2016 report in *The Guardian* newspaper predicted an energy deficit in Britain for the winter of 2017-18, which the writer argued had been created by the closure of several large coal fired power stations, coupled with a lack of any significant new construction. The journalist claimed that the only means of avoiding this deficit would be to keep a significant number of old, inefficient power stations in reserve, as well as importing electricity from the continent. Both options would, however, increase the price of electricity for consumers.[2] This tension between economic efficiency and security of supply of electricity began during the First World War, as British industry came to rely on access to electrical power. Today, this issue is best exemplified by the need to import electricity. Britain has been a net importer of electrical energy, via undersea connections to the European continent, since 1986 when the first interconnection with France was established.[3] However, rising demand for electricity across Europe, combined

---

[1] Bahman Zohuri, *Application Of Compact Heat Exchangers For Combined Cycle Driven Efficiency In Next Generation Nuclear Power Plants* (Cham: Springer International Publishing, 2016), p.17.
[2] Fiona Harvey, 'Engineers Warn Of Looming UK Energy Gap', *The Guardian*, 2016 <https://www.theguardian.com/environment/2016/jan/26/engineers-warn-of-looming-uk-energy-gap> [Accessed 8 August 2017].
[3] Paul Bolton, *Energy Imports And Exports* (London: House of Commons Library, 2018), pp. 1-11 <http://www.parliament.uk/commons-library | intranet.parliament.uk/commons-library> [Accessed 20 October 2018].

with the closure of nuclear power stations in France and Germany, may mean that there is insufficient capacity to meet further British demand. The historical and political conditions for meeting expectations for a secure supply of electricity are the central issues in this thesis. Historical consideration of this issue of security of electrical supply is timely, given that it is currently the subject of debate among policy organisations. For example, in a recent paper from the Centre for Policy Studies, Tony Lodge and Daniel Mahoney identify the financial and political issues at stake in maintaining security of electricity supply.[4] They express concerns over the lack of investment in gas-fired electrical generation for a planned increase in interconnections between Britain and continental Europe. Furthermore, they identify a conflict of interest in relation to the National Grid: its current status as a private company, they argue, motivates it to prioritize purchasing cheap electricity from abroad, rather than encouraging investment in more secure forms of domestic generation.[5] Lodge and Mahoney point out that both the Office of Gas and Electricity Markets (OFGEM) and the House of Commons Energy and Climate Change Select Committee have recently called for the creation of an independent system operator to replace the National Grid in operating the energy transmission network. Essentially, their argument is that because the continued development of the electrical supply industry in Britain cannot be left entirely in the hands of private business, the UK government needs to legislate to encourage investment in domestic electrical supply.[6]

The situation described by Lodge and Mahoney is strikingly similar to high-level concerns expressed at the end of the First World War about the consequences of a privately owned and managed electrical supply industry. Then, as now, the consensus among the major political parties was that some form of change was needed. The creation of the National Grid in 1926

---

[4] Tony Lodge and Daniel Mahoney, *The Hidden Wiring: How Electricity Imports Threaten Britain's Energy Security/* (London: Centre for Policy Studies, 2017), pp. 1-16 <https://www.cps.org.uk/files/reports/original/171024092454-TheHiddenWiring.pdf> [Accessed 10 August 2018].
This is a free market think tank with strong historical links to the Conservative Party.
[5] National Grid plc was founded in 1990.
[6] Furthermore, they also argue that the increased dependence on imported electricity is a significant risk to the security of electrical supply in Britain unless Britain deregulates its energy markets and encourages investment in gas-fuelled power stations in order to ensure security of energy supply for the post-Brexit era.

and the eventual nationalisation of the electrical supply industry in 1948 were spurred by just the type of concerns articulated in Lodge and Mahoney's paper. Namely that private industry and investors could not be trusted to develop electrical infrastructure in the best interests of the nation but would instead only invest in the areas which promised the greatest private profit. However, there is one key contrast to bear in mind. While Lodge and Mahoney suggest that governments should make it easier and more profitable for domestic investors in electrical supply, they seem unaware that during the 1920s, 1930s and 1940s a very different solution was adopted. Far from being treated as a private concern, this was a state matter. Successive governments, irrespective of political affiliation, played an active role in the organisation and development of a national electricity supply; this culminated in the state ownership and control of the industry and the elimination of private investment in electrical supply by the time of the public launch of the full nationwide nationalised Grid in 1948.

My primary research question in this thesis focuses on the comparative significance of efficiency versus security of supply in the development of the British National Grid between 1914 and 1956. I ask how this balance changes between peace and war and argue that while issues of economic efficiency do become more important, they are still overshadowed by security concerns. I argue that national security and energy security are best seen as ideals, with multiple potential definitions, which are impossible to obtain. Instead, it is better to think in terms of degrees of security, with different factors taking priority, depending on the economic and political circumstances. I also consider the influence of the British armed forces on the development of electrical infrastructure. I argue that the development of electrical systems for the military was closely linked to the development of the Grid system and that military considerations had a significant influence on electrical infrastructure in Britain.

I contend that such political concerns about national energy security, and the means to secure it, offer a markedly different account of British electrification to previous historical accounts. The generally accepted views put forward by Thomas Hughes, Leslie Hannah and more recently by Hausman *et al.*, have argued that economic and technical efficiency alone motivated the creation of the National Grid. [7] Instead, I argue that national security in the form of energy security was the primary driving force behind this strong state management of the early British electrical supply industry. However, due to the interconnected nature of all these aspects of energy security, it is almost impossible to separate them. Security of supply and economic efficiency are in tension with each other, greater security tends to come at the cost of efficiency; however, security of supply also requires a certain degree of economic efficiency, which in turn is not possible without a certain degree of security.

Since the 1970s discussions on energy security have focussed almost exclusively on the availability of oil, particularly for military purposes. Yet recent works such as Peter Shulman's *Coal & Empire* have demonstrated that governments have been aware of the importance of energy security at least since the development of ocean-going steamers.[8] However, this limited focus on the importance of energy security for military forces means that the requirement for energy security for civil infrastructure and industry has been largely ignored. Yet as this thesis demonstrates both are important to national security and, as is demonstrated in chapter three, both are required in order to support military operations.

By the outbreak of the First World War the British military had largely ceased to rely on coal for fuel as the bulk of the Royal Navy had been converted to utilise oil. Yet coal was still considered to be vital to the future of Britain. Not only was it a key trading resource, but it was also the primary source of fuel for much of Britain's transport infrastructure. Furthermore, it was still the primary source of energy for heating and cooking in British homes, either burnt directly or as town gas. Finally, it was essential more much of Britain's heavy industry, either powering steam engines, directly driving machinery, or being used to generate electrical

---

[7] Thomas P Hughes, *Networks Of Power* (Baltimore: The Johns Hopkins University Press, 1983).
Leslie Hannah, *Electricity Before Nationalisation* (London: Macmillan, 1979).
William. Hausman, Peter Hertner and Mira Wilkins, *Global Electrification: Multinational Enterprise And International Finance In The History Of Light And Power, 1878-2007.* (New York: Cambridge University Press, 2008).
[8] Peter A Shulman, *Coal & Empire: The Birth Of Energy Security In Industrial America* (Baltimore, Maryland: Johns Hopkins University Press, 2015).

power in the factory. As such the management of Britain's finite coal resources was of critical importance for the security of the country, politically, economically and militarily.

In 1945 US Navy Secretary James Forrestal claimed that

> The question of national security is not merely a question of the Army and Navy. We have to take into account our whole potential for war, our mines, industry, manpower, research, and all the activities that go into normal civilian life.[9]

As this quote demonstrates, as a concept national security can include a range of factors, which may change over time and depend on the circumstances. For constitutional lawyer Robert Post, national security, in its widest international sense, could include anything with the potential to have an impact on the defence of a country. Peacetime conceptions of security can be very different to those held during wartime. In the case of electricity, this is best exemplified by the conflict between security of supply and economy of supply. In peacetime, economy is often more important, whereas during times of conflict security becomes more important.

I argue that national security provided a strong rationale for successive British governments to expand state control or influence in certain key industries, particularly those relating to energy security such as coal mining, and the generation of electricity, as these had a profound impact on all areas of modern life and society. Yet for much of the period of this thesis, national security is equated with military security. A keyword search on the *British Newspaper Archives* for the term 'national security' between 1919 and 1950 brings up over three hundred hits relating to national security. However, most of these focus on military strength, either warning against further cuts to spending, or claiming that reducing military spending was the only way to ensure national security.[10]

---

[9] Cited in: Robert Post, 'National Security And The Amended Freedom Of Information Act', *The Yale Law Journal*, 85.3 (1976) https://doi.org/10.2307/795448, p.410.
[10] For example, 'Our Waning Air Power', The Times, 22nd April 1922, p.13.
And, 'Armaments And World Peace', Courier and Argus, 24th July 1923, p.5.
Some of these commentators claimed that reducing military spending would boost national security as the country would not be pulled into an arms race with foreign powers.

While National Security did not appear a discrete academic concept until Arnold Wolfers 1952 paper, *National Security' as an ambiguous symbol,* the different aspects of National Security; energy security, economic security, political security and military security are all in evidence, albeit indirectly, in the records of parliamentary debates and cabinet meetings. [11] I show that British electrical engineers and politicians believed that the development of a national electrical system offered a means of ensuring secure supplies of electricity for industry as well as helping to preserve Britain's strategic coal reserves. Yet, as we see demonstrated in this thesis, the increasing reliance on centrally generated electrical power in all areas of national life became a matter of great concern for successive British Governments.

Due to the growing importance of electricity in everyday life and the importance of electricity to the military, and in the economic and political security of the state, the development of electricity could not be safely left to the vagaries of the free market. While the Liberal, Conservative and Labour parties of the period had differing views as to the ownership of individual power stations, I show that they all agreed that the state should have a central role in managing the generation and distribution of electricity on a national basis. Contrary to claims made by Leslie Hannah and, more recently, by John Sheail, that the National Grid was not intended to facilitate inter-regional transfers of power, I argue that the National Grid was intended from the start to enable the transfer of significant quantities of power between Grid regions and that this intention was fundamental to the design and construction of the Grid network.[12]

By focusing on the period between 1914 and 1956, I demonstrate that as British industry, transportation and defensive systems became more reliant on electrical generation and distribution systems, there was an increasing diversification of energy sources. While coal

---

[11] Arnold Wolfers, ''National Security' As An Ambiguous Symbol', *Political Science Quarterly*, 67.4 (1952), 481-502 <https://doi.org/10.2307/2145138>.
[12] John Sheail, 'Power To The People: Power Stations And The National Grid.', in *Transforming The Countryside: The Electrification Of Rural Britain.* (Oxford: Routledge, 2017), 38-50, (p.39.)

remained king, the use of hydro, nuclear, natural gas and heavy oil for electrical generation meant that the risk of disruption from interruption of any single fuel source was at least somewhat reduced.

The 1956 end date is significant not only due to the opening of Britain's first nuclear power station at Calder Hall, but also because of the passage of the 1956 Clean Air Act in response to the high level of deaths resulting from the London smogs of the early 1950s. Furthermore, the Suez crisis of October 1956 threatened access to the oil supplies needed for oil fired power plants such as Bankside in London; while, as we see in chapter seven, electrical generation was not dependent on access to oil, oil was rapidly becoming more important to British industry and transport services as well as to military operations. Daniel Yergin notes that while British control over the canal could not be justified on the basis of the defence of India, it gained a new role as the 'highway not of empire, but of oil'. By 1955 over half of the canal's traffic consisted of oil and petroleum, with two thirds of Europe's oil passing through it.[13] While oil was only one of the fuels used for electrical generation in Britain, it was also vital for transportation and for the military. As such any threat to oil supplies was a strategic risk, which could not be tolerated by the British Government. The importance of the Suez Canal was for the transport of oil soon diminished due to the rapidly increasing size of tankers, but at the time it constituted a clear and present danger to Britain's energy security.

One of the most important features of this period are the economic downturns experienced in the 1920's and 30s and again immediately following the Second World War. Traditional histories of the period such as A.J.P. Taylor's *'English History, 1914-1945'* have focussed on the spending cuts and economic retrenchment of the period, highlighting the reduced spending and high levels of unemployment experienced by British Industry.[14] However, as is noted by David Edgerton, spending on the military and related industries in the 1920s and 30s only

---

[13] Daniel Yergin, *The Prize: The Epic Quest For Oil, Money And Power* (New York: Simon & Schuster, 1991), p.480.
[14] Alan J. P Taylor, *English History: 1914-1945.* (Oxford: Clarendon Press, 1988), p.450.

appears to be reduced when viewed in relation to the elevated levels of spending occasioned by the First and Second World Wars.[15] While the precise figures are not available for the entire period, this thesis shows that government spending on electrical infrastructure, either directly or in the form of loans, was consistently high throughout both wars and throughout the inter-war period; thereby emphasising the importance developing a secure supply of electrical power to the British state, both in peace and war.

As a whole this thesis explores the different ways in which the development of an integrated National Electrical Network served to enhance energy security within Britain. This network thereby enabed the preservation of strategic energy resources (coal) and ensuring secure supplies of power for industrial and domestic use as well as for civil and military defence. To a lesser extent the development of the national grid also helped to ensure the political security of the State, providing significant employment during the depression. This is emphasised by the IRA attacks on the Grid in January 1939, discussed in chapter six, which were carried out with the aim of destabilising the British Government. The development of the grid also enhanced the economic security of the country, by providing sufficient orders to electrical manufactures and associated industries during the depression to ensure that they remained in business. I argue that for twentieth century Britain, energy security, in the form of electricity from the National Grid is central to all aspects of National Security. Without a secure supply of energy industry was unable to function at full capacity, potentially leading to a loss of jobs and a potential increase in social unrest. Furthermore, without the support of the industrial base the military services could lose the ability to function effectively in the defence of the country. This is particularly highlighted by the concerns of the RAF over rail electrification which are discussed in chapter four.

Building on David Edgerton's Warfare State thesis, I show that the development of the National Grid was both a product of the experience of the First World War and also a vital

[15] David Edgerton, Warfare State (Cambridge: Cambridge University Press, 2006), p.21.

factor in enabling the rapid expansion of industry that took place in the mid to late 1930s and into the Second World War. Figure 1.1 shows the changing pattern of electrical usage in Britain between 1921 and 1948 and demonstrates a continuous growth in electrical consumption throughout the period. For much of the period covered, electrical usage for industry and domestic purposes increased at approximately the same rate. However, between 1938 and 1945, these rates diverged, with a massive increase in industrial usage of electricity and a relative decrease in the use of domestic electricity (despite an initial decline at the outbreak of war, domestic electrical use continued to rise, albeit at a lower rate than industrial use). I show that inter-war governments viewed the creation of a secure supply of electricity as being vital to the post-war reconstruction of the country, as well as being essential to the ongoing military, political and economic security of the British state. Throughout the inter-war period, electrical policy in Britain favoured the replacement of inefficient smaller power stations with a smaller number of stations with a larger generating capacity. Figure 1.2 shows the decreasing number of generating stations in Britain between 1924 and 1948 contrasted with the increasing generating capacity of the country as a whole. Despite the missing figures between 1938 and 1943, we can see the general trend was for an increase in generating capacity which, particularly after 1929, was matched by a continuous decrease in the overall number of generating stations. Thereby indicating that the newly constructed stations were significantly more powerful than those they replaced. The development of the first stage of the National Grid, between 1926 and 1935, is estimated to have cost a minimum of £20 million and a maximum of £50 million.[16] In *Warfare State*, David Edgerton shows that during the inter-war period Britain spent a similar amount refitting the battleships and battle cruisers of the Royal

[16] Hannah, *Electricity Before Nationalisation*, p.121.
The Higher figure includes indirect costs, such as loans made to undertakers to construct or update power stations and transmission cables

Navy, which were perceived as being the main stay of Britain's military strength. [17] Edgerton makes a direct comparison between battleships and power stations, noting that:

> The core of the Royal Navy, […] was its fleet of battleships. […]. Their engines – usually steam turbines fed by oil-fired boilers – were as powerful as many electric power stations: British battleships were driven by 30 and 100 megawatts of power.[18]

In many respects battleships and power stations had a lot in common: both involved a significant investment in time, money and materials, and both produced a significant amount of power. Battersea power station, constructed between 1929 and 1935, cost a total of £2,141,550 with an output in 1935 of 243 megawatts. Battersea was only one of approximately 20 new power stations which were constructed in Britain during the inter-war period, with many more existing power stations receiving significant costly upgrades. Due to the fragmented nature of the records it is difficult to assess precisely how much was spent on constructing new stations or upgrading existing generating plant during this period. However, based on known costs, such as the cost of an entirely new power station like Battersea A, it is likely to have been a significant amount.

Having set out the motivation for this thesis in relation to current policy debates, and the research questions it addresses, in the following sections I provide an outline of the different archival sources used to support my argument and the methods of research used to interrogate these different sources. Finally, this Introduction ends with a synopsis of my chapters, showing how each one supports my overall thesis argument.

---

[17] Edgerton, *Warfare State*, p.27-30.
[18] Edgerton, *Warfare State*, p.26.

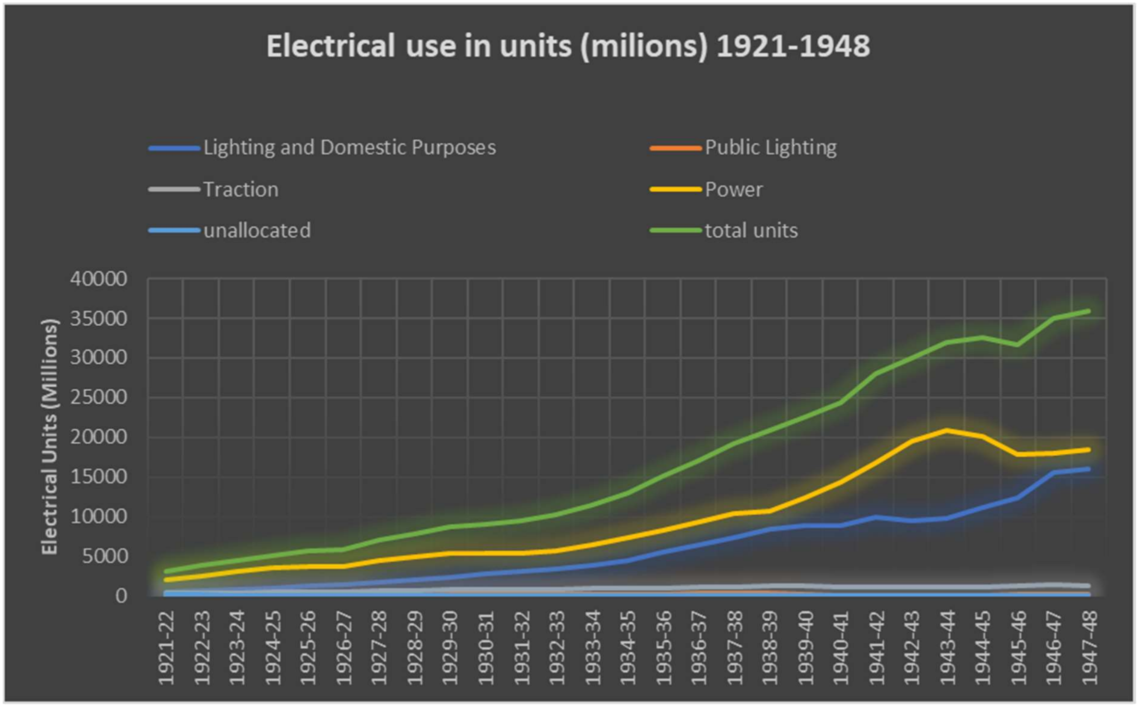


Figure 1.1. Electrical Generation in Britain, 1921-1948. Data taken from the annual returns of Engineering and Financial Statistics relating to Authorised Undertakings in Great Britain between 1920 and 1948. These were compiled on behalf of the Electricity Commissioners in order to provide comparative statistics in a readily accessible form to assist in carrying out their duties. See Appendices 1 for a more complete explanation and table of statistics.

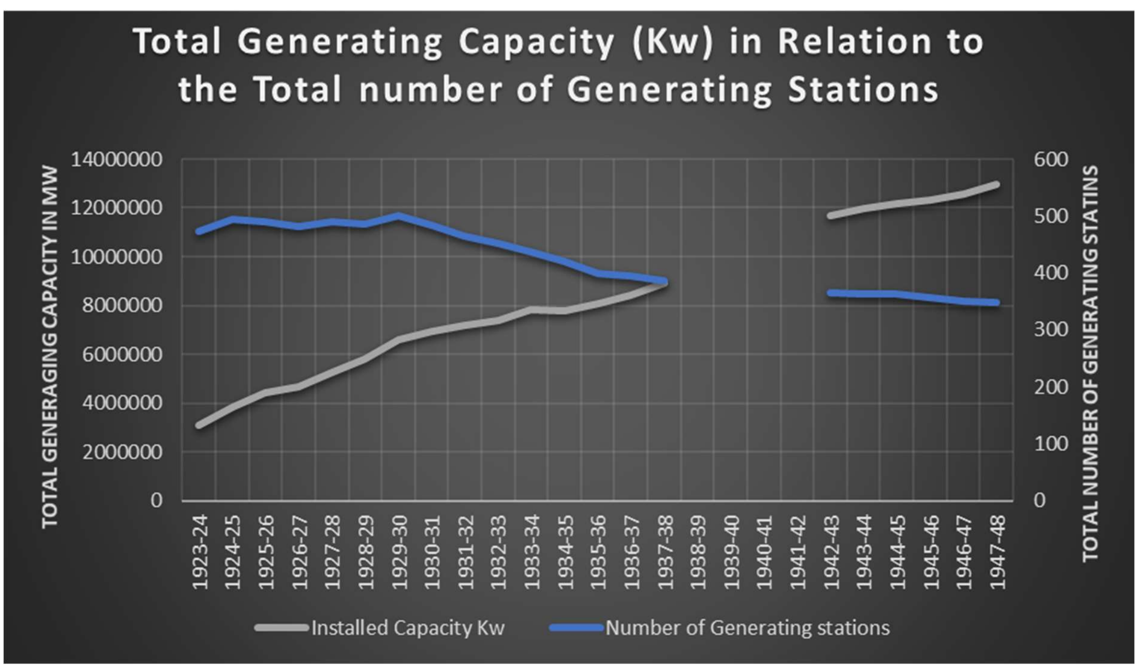


Figure 1.2. Installed capacity Kw vs number of generating stations 1923-1948. Data taken from the annual returns of Engineering and Financial Statistics relating to Authorised Undertakings in Great Britain between 1920 and 1948. These were compiled on behalf of the Electricity Commissioners in order to provide comparative statistics in a readily accessible form to assist in carrying out their duties. See Appendices 1 for a more complete explanation and table of statistics.

1.2. Methodology and Sources.

This thesis makes extensive use of the Electricity Council Archives held at the Museum of Science and Industry in Manchester. I have particularly focused on the archives of the Electrical Development Association, documenting the arguments used to convince the general public to adopt electricity in everyday life and examining the way in which these arguments supported official government policy. In addition, I have made extensive use of the annual reports of the Central Electricity Board and the Electricity Commissioners as well as the order books for the National Grid, with a particular focus on the overall generating capacity of Britain in comparison to the level of demand for electricity throughout the country as a whole. The order books for the Grid document the spending on equipment and materials for each Grid region and demonstrate the way in which orders were spread across the electrical manufacturing industry. However, the use of the data tables and statistics presented in these reports as well as in other official records is at times problematic. As is suggested by B. R. Mitchell in *British Historical Statistics*, there are three main problems in the use of statistics. The first of these is the changes in definitions or data being collected over the course of a series, this is particularly an issue in relation to the records of electrical generation in Britain which are included in the Annual reports of the Central Electricity Board. The second problem raised by Mitchell relates to the efficiency with which the initial data collection took place, raising concerns as to the reliability of the data gathered as it could not be assumed that those collecting the data used the same standards and systems of measurement. This is less of a problem for electrical generation and fuel consumption as the record keeping was carried out as part of the everyday business of the generating stations and as such can largely be ignored for the purposes of this study. The final concern raised by Mitchell is that often records have been collected as a by-product of another, often, administrative purpose, and therefore people or companies may have tried to avoid being included. Again, this is less of a problem when dealing with the records of the Central Electricity Board and the associated electrical manufacturers and providers as the data was recorded explicitly for the use of the Central Electricity Board.[19]

This thesis also utilises a variety of sources from the National Archives, particularly Cabinet documents, documents from the Ministry of Fuel and Power, and the Ministry of Transport. These are supported by hitherto largely unexamined documents from the Air Ministry, Admiralty and the Ministry of Munitions, relating to electrical supply. I used keyword and date restricted searches for key events and themes following up on any related documents or documents which were referenced in other sources, including secondary literature. However, as is noted by John Tosh, this approach can be problematic as some of the most useful sources in this thesis were found by going through apparently unconnected files rather than in the more obviously connected documents.[20] A further challenge when working with some of the archival documents is dealing with multiple drafts and copies of documents, often contained within the same file, as important information is often not contained within the final draft, but may well be hidden in the marginalia of early drafts. As John Sheail notes, only a tiny fraction of the paperwork generated by the British Government is kept in the archives, with over 95 per cent being destroyed.[21] Often the most revealing sections of these documents are the handwritten notes in the margins indicating changes to be made and often revealing the unspoken and otherwise unrecorded priorities of the politicians, civil servants, military officers and engineers involved.[22] However, accessing these side notes is complicated by the use of pencil on most documents, much of which is now faded and difficult to read, this is also the

---

[19] B. R Mitchell, *British Historical Statistics* (Cambridge: Cambridge University Press, 1988), p.viii.
[20] Tosh argues that it is difficult for a researcher to tell in advance which sources are going to be the most relevant to the research being undertaken and that 'the most improbable sources are sometimes found to be illuminating, while the obvious ones may lead the historian into too close an identification with the concerns of the organisation that produced them.
John Tosh and Sean Lang, *The Pursuit Of History: J. Tosh And S. Lang, The Pursuit Of History: Aims, Methods And New Directions In The Study Of Modern History.*, 4th edn (Harlow: Pearson Longman, 2008), p.89.
[21] John Sheail, *An Environmental History Of Twentieth-Century Britain* (Houndmills, Basingstoke, Hampshire: Palgrave, 2002), p.7.
[22] Rodney LOWE, 'Plumbing New Depths: Contemporary Historians And The Public Record Office', *Twentieth Century British History*, 8.2 (1997), 239-265 <https://doi.org/10.1093/tcbh/8.2.239>.

case with many of the carbon copies of documents contained within the files. As such in many cases my choice of source materials was limited by legibility.

Finally, this thesis makes considerable use of national and local newspapers available through the *British Newspaper Archive* and the *Gale Newsvault* as well as Contemporary industry journals such as the *Journal of the Institution of Electrical Engineers,* and the *Electrical Times*. These journals trace ongoing developments within the industry and demonstrate the involvement of electrical engineers in debates over the future of the industry. In making use of the Ferranti corporate archives, particularly letters, I discovered that many of the boxes are only archived at box level, arranged alphabetically and by date. As such using letters and other correspondence either to individuals or companies required an item by item search through all the boxes in the right date range for each chapter.

I began by searching by date for key milestones in the development of electrical power in Britain, such as the 1926 Electricity Supply Act. I then conducted a page by page search for up to two weeks on either side of the relevant date. This allows me to deal with one issue with digitised collections identified by James Mussell: While searching for key words and terms allows the researcher instant access to articles containing that information. However, that information alone does not show how it fits within the paper as a whole.[23] Searching on a page by page basis enabled me to build up a picture of the editorial opinion on the importance of the topic to the editorial team and owners of the paper or journal. This is indicated by its location within the paper and whether the article is spread out over multiple connected columns and pages or distributed throughout the paper. A further indication of the importance of the topic, is whether the discussion continues in subsequent issues. One final issue to be raised is that newspapers and journals tend not to publish responses which adopt a different stance One of the key points with the development of electrical power in Britain is the

[23] James Mussell, *The Nineteenth-Century Press In The Digital Age* (London: Palgrave Macmillan, 2014), p.56-61.

consistency of the support for electrical development. As with politicians and engineers, the main area of disagreement was over the ownership of generating stations and not over the need for some form of national reorganisation.

1.3. Thesis Plan.

Chapter Two: Literature Review.

In this chapter I examine the relevant literature from national and international histories of electrical development, environmental histories, business and economic histories of the period as well as studies on energy security and national security.

Chapter Three: The Great War: A First Experiment in the National Coordination of Electricity Supply.

In Chapter three I focus on the use and development of electrical supply during the First World War, beginning with a brief examination of the state of electrical supply prior to the outbreak of the war. The chapter seeks to explain the expansion of electrical usage during the war, showing how and why industrial users came to rely on centrally generated electricity, as well as the lessons which were taken from this by politicians on both sides of Parliament. The chapter also includes a section on the military use and development of electricity on the Western Front, demonstrating the parallels to the development of the civilian power supply network and some of the ways in which lessons from the western front influenced subsequent electrical development in Britain.

Chapter Four: 1919-1924, The Politics of Power.

Chapter four focuses on the passage of the 1919 Electricity (Supply) Act, demonstrating the importance of electricity to all the major political parties during the 1919 General Election, although the lack of consensus within Lloyd George's Coalition Party made it difficult to pass controversial legislation, such as the Electricity (Supply) Bill. Next, I examine the interplay between coal mining and electrical development, which intensified during this period. Finally, I consider the continued interest of the military, particularly the British Army and Air Force, in the development of electricity in Britain, and the ways in which this influenced the development of civilian networks.

Chapter Five: 1926-1935, Building the Grid.

This chapter focuses on the passage of the 1926 Electricity (Supply) Act and the construction of the National Grid. Beginning with an examination of the Weir Report, which formed the basis of the 1926 Act, we then examine the 1926 General Strike, and its impact on electrical supply, particularly the way in which, despite its minimal disruption, it demonstrated the growing importance of electricity to everyday life in Britain. The next section of the chapter focuses on the construction of the National Gridiron including the influence of the RAF on the shape of the National Grid, particularly in relation to the siting of pylons, but also in terms of RAF interest in the design and construction of power stations. This chapter also includes a case study of the construction of Battersea power station, which I argue demonstrates the intended purpose of the National Grid and the primacy of military and security considerations over economic, environmental and social concerns. This chapter also examines the importance of the National Grid in supporting British industry during the late 1920s and early 1930s, providing in excess of 200,000 jobs, spread across several sectors.

Chapter Six: 1935-1945, The Grid at War.

In this chapter I examine the operation of the National Grid system during the Second World War, including the preparations of the Central Electricity Board. I also consider the importance of electricity to the development of the Chain Home Network radar system. This is followed by an examination of the changes to electrical demand occasioned by the war and the ways in which the electrical authorities worked to meet this demand, including the challenges of predicting wartime requirements and the rationing of labour and materials. Next, this chapter analyses the role of the Electrical Development Association in influencing the behaviour of domestic consumers, and particularly the way in which they connected the use of electricity in the home with the production of munitions. Finally, I examine the damage caused to the Grid and British power stations not only by enemy action but also by the British defence network, and the way in which this inspired an operation against the German electrical supply, which has since been acknowledged as one of the most cost-effective operations of the war and credited with causing significant damage to continental electrical networks.

Chapter Severn: 1946-1956, The Perfect Storm.

This chapter scrutinizes the state of the electrical supply industry in the years immediately after the Second World War. I examine the reasons for the coal shortage in 1946, its impact on electrical supply and consider these factors in relation to the surprisingly high level of industrial and domestic electrical use during the late 1940s. This is complemented by a study of the severe winter of 1946/7 and its impact on coal supplies and electrical use and generation. The next section of this chapter focuses on the passage of the 1947/8 Electricity Supply Act which resulted in the complete nationalisation of the industry, and also considers the development of a national fuel and energy policy alongside potential plans to control the use of domestic electrical appliances. Finally, I examine the development of alternative or complementary sources of power, including oil and nuclear generating plants, as a means of supplementing coal generation.

2. Literature Review.

In examining the significance of national security in the development of the British National Grid, this thesis works across several historiographical boundaries. By combining aspects of economic, political, social, business, military and environmental histories, I show that the availability of electrical power through the National Grid was central to the development of modern Britain and was vital in enabling the government to ensure the political, economic and military security of the State.

I begin by giving an overview of the standard electrical histories of Britain and the National Grid as well as more general histories of electrical development, David Edgerton's writings on the concept of the Warfare State, and a selection of literature relating to concepts of national security and energy security. This is followed by a brief examination of the relevant literature on environmental and business histories for early to mid-twentieth century Britain and the ways in which these are linked to both energy supply and national security.

2.1. Electrical Histories.

When exploring the development of electrical networks, historians such as Thomas Hughes and Leslie Hannah have tended to focus on issues relating to economic and technological efficiency. Even recent texts such as Julie Cohn's *The Grid, Biography of an American Technology*, have focused primarily on the technologies and strategies used to control the grid and have been strangely silent on the vulnerability of electrical supplies to disruption, either by direct attack or through accidental damage.[1] I argue that this is at least in part for the same reason that the results of Operation Outward, which is discussed in chapter six, were

[1] Julie A. Cohn, *The Grid: Biography Of An American Technology.* (Cambridge MA: MIT Press, 2017).

suppressed. In an age where concern over terror attacks is high, it may be considered undesirable to highlight the vulnerability of electrical infrastructure to disruption, or the potential consequences of a successful attack being carried out. It is also important to note that unlike Britain, until the onset of the Cold War, the United States did not face any external threat to the supply of electricity.

2.1.1. Infrastructure and Generation.

This lack of external threat was also apparent in David Nye's 1995 *Electrifying America, Social Meanings of a New Technology*. Nye argues that electrification is not an abstract process which was simply imposed on the United States but is instead the result of a series of choices made by the American population. While economic and technological considerations do play a part in the decision-making process, they were not the only factors influencing decisions. Instead Nye claims that American culture was the primary driving force behind the development of electricity supply in the USA, in particular a distrust in state or municipal organisations owning and administering utilities due to perceptions of corruption.[2]

There is, however, one key similarity between electrification in the USA and Britain. For both countries rural electrification was not profitable due to the immense cost of the infrastructure needed to connect remote communities or farmsteads to electrical networks.[3] According to Nye, in the United States rural electrification only became a realistic possibility with the creation of the Tennessee Valley Authority (TVA) and Rural Electrification Administration (REA) in 1935 as part of the New Deal Program.[4] As was the case with the development of the National Grid in Britain, these programs were linked to increased employment during the depression and this became a key feature in promoting the work of both the TVA and the REA during the inter-war period. While the TVA program was intended to provide an integrated approach to resource management, it faced a great deal of opposition from private business,

---

[2] David E Nye, *Electrifying America: Social Meanings Of A New Technology, 1880-1940.* (Cambridge, Mass.: MIT Press, 1992), pp.7-8.
[3] This point is further developed in Sayer *et al., Transforming the Countryside* and is discussed latter in this chapter.
[4] Nye, *Electrifying America*, p.307.

particularly in relation to electrical generation and transmission. As a result of this opposition the Authority's remit was eventually restricted to flood control and dam construction, demonstrating that the key factor involved was the provision of jobs. In contrast, while the REA did provide a significant amount of work in the construction of new power lines and the development of electrical cooperatives, it was primarily intended to provide loans and grants for powerline construction. Rather than generating their own power the cooperatives would instead buy in bulk from the nearest distributor. In some ways this system was similar to that set up by the Central Electricity Board in Britain; however, it did not contain the same level of price controls or standardisation of systems. It was intended to enable the extension of electricity into rural areas but not as part of an integrated supply network, but rather one which was dominated by the interests of private industry.

One major omission from Nye's work is any in depth analysis of electrical generation in the USA during this period. While hydro generation is mentioned in several chapters, Nye does not discuss the importance of coal to US energy production, despite figures showing that between 1906 and 1920 coal provided almost three-quarters of energy for heating, lighting, cooking and power in the United States.[5] Due to his focus on the uses and changing cultural meanings of electricity, Nye's text serves to complement Thomas Hughes existing work on the technological aspects of electrification in the United States.

In *Powering up Canada*, Ruth Sandwell takes a long view of energy usage in Canada since the 1600s.[6] Sandwell and the other contributors highlight the changes in energy usage in Canada noting that many communities continued to make use of wood and other easily obtainable fuels as the vast distances and often difficult terrain made the establishment of gas or electrical networks impractical and prohibitively expensive. In Chapter 8 on Coal in Canada,

[5] Bureau of the Census, *Historical Statistics Of The United States, Colonial Times To 1957.* (Washington D.C.: U.S. Department of Commerce, 1960), p.355.
[6] Ruth Sandwell, *Powering Up Canada: A History Of Power, Fuel And Energy From 1600.* (Montreal: McGill-Queen's University Press, 2016).

Andrew Watson notes the importance of coal to energy use in urban areas of Canada, however, he does not mention the use of coal for electrical generation.[7] In chapter nine Matthew Evendon and Jonathan Peyton note that hydroelectric power rather than coal has been the primary source of electric power in Canada since the late nineteenth century.[8] However, they do note that as with coal resources, not all areas of Canada, such as Saskatchewan, had access to significant hydro resources, and as a result coal burning turbines tended to be more important in those regions lacking easy access to coal.[9] Most significant for this thesis was the impact of the Second World War on electrical development, particularly hydroelectric, which, according to Evendon and Peyton, increased by 40 percent over the course of the war.[10]

From these accounts of the development of electrical power in the United States and Canada it quickly becomes obvious that the situation in Britain was in many ways unique. Unlike the United States and Canada, Britain was almost entirely reliant on coal for the Generation of electricity. Furthermore, Britain lacked any significant or easily exploitable hydro-resources. These issues were compounded by highly fragmented and localised organisation of electrical supply in British towns and cities, a situation which was seemingly not as prevalent in towns and cities in North America. However, neither of these accounts comprehensively discuss the development of electrical power systems to a comparable extent as Leslie Hannah's *1979 Electricity before Nationalisation*.

Hannah provides a comprehensive account of the development of electrical generation, transmission and distribution in Britain in the decades prior to the nationalisation of the electricity supply industry in January 1948. One of the major foci of Hannah's work is on the ownership of electricity supply undertakings. In particular, he examines the differences

---

[7] Andrew Watson, 'Coal In Canada', in *Powering Up Canada: A History Of Power, Fuel And Energy From 1600.* (Montreal: McGill-Queen's University Press, 2016), pp.213-250.
[8] Mathew Evenden and Jonathan Payton, 'Hydroelectricity', in *Powering Up Canada: A History Of Power, Fuel And Energy From 1600.* (Montreal: McGill-Queen's University Press, 2016), 251-273, (p.252).
[9] Evenden and Payton, *'Hydroelectricity.'*, p.255.
[10] Evenden and Payton, *'Hydroelectricity.'*, p.259.

between privately and publicly (municipally) owned companies and the way in which pre-1914 legislation prevented large scale organisation and interconnection. He points to the Newcastle-upon-Tyne Electric Supply Company (NESCo) as an example of the successful development of an integrated, privately owned power system, comparing British cities to places such as Detroit, Boston, Hamburg, and Paris where

> In circumstances similar to Britain, the objections of small companies and municipalities had in those cities been overcome by shrewd businessmen and accommodating politicians, who recognised that the enormous potential savings left ample room for a negotiated compromise which could satisfy the vested interests as well as produce electricity cheaply.[11]

Indeed, this appears to reflect Hannah's later interpretation of the 1926 Electricity (Supply) Act. Hannah describes the First World War and the associated involvement of government in the electrical supply industry as having been disruptive to the development of the industry. Yet he provides little evidence to back up these claims.[12] While Hannah excels at describing the complex political manoeuvrings required to pass the inter-war electrical legislation, he does not provide a convincing reason for politicians from all parties to compromise, in order to achieve this result. Conflict, beyond between those with private business interests in electrical supply, and those in favour of greater involvement by the state, appears to be largely ignored in Hannah's account. Even the 1926 General Strike is merely noted as a disruption to political life and no attempt is made to examine its impact on the contemporaneous passage of the Electricity (Supply) Bill. [13] This is despite arguing that, once the Central Electricity Board began trading, it 'became responsible for ensuring the 'security of supply' and the economic generation of electricity in Britain. Hannah also claims that due to the passage of the 1926 Electricity Supply Act the CEB

---

[11]Hannah, *Electricity before Nationalisation*, p.52.
NESCo was founded in 1889 by John Theodore Merz (father of Charles Merz.) Renamed the North Eastern Electric Supply Co. in 1932.
[12] A large number of the relevant documents did not become available until the early 1990s. Although this is likely a result of the continued classification of many of the papers relating to wartime electrical development.
[13] Hannah, *Electricity before Nationalisation*, p. 97.

had the authority to ensure the standardisation and interconnection of electrical supply in Britain.[14] However, Hannah does not explain what is meant by 'security of supply' nor whether there was any potential tension between providing a secure supply and an economical supply of electrical power. Hannah also points to the development of hydropower resources, particularly in southern Scotland, to take advantage of the National Grid. Yet, these hydroelectric stations are only discussed in relation to their ability to reduce overall generation costs, rather than as a means of economising on coal usage or of diversifying sources of supply.[15]

Hannah dedicates two central chapters to the work of the Electrical Development Association (EDA) and the Central Electricity Board (CEB) in encouraging the uptake of electricity by industrial and domestic users. However, he does not connect the advertising materials of the EDA with the development of the Grid, seemingly ignoring the obvious connections made in the advertising materials to coal use and 'the national good'.[16] Instead he focuses almost entirely on the increase in the overall numbers of consumers and what they used electricity for. Yet, as I show, a close analysis of the EDA advertising during the Second World War, demonstrates clear links between electrical advertising and security of supply. EDA advertisements encouraged responsible use of electricity as a means of saving coal showing that cooking and heating by electricity made better use of coal than burning it directly in the hearth. They also directly linked electrical use to industrial, and particularly to munitions, production, encouraging users to think about the amount of electricity they were using and suggesting ways in which they could economise to help ensure the availability of electrical supplies for munitions production. This advertising, as will be demonstrated in later chapters, also highlights the ongoing conflict between security and economy of supply, and the tension

---

[14] Hannah, *Electricity before Nationalisation*, p.122.
[15] Hannah, *Electricity before Nationalisation*, pp.129-131.
Although he does note concerns over the future of coal if cheap oil imports became available.
[16] "YA1985.78, Collection Of Material Relating To Electricity Supply In Manchester" (Manchester, 1919), Science and Industry Museum Archive Centre, Manchester Corporation.

between the image of electricity as a clean, healthy form of energy and the polluting reality of generation by city centre power stations.

When dealing with the Second World War, Hannah provides a comprehensive account of the Grid activities during the war. He particularly notes the competition between the Central Electricity Board and munitions factories for labour and materials, and the eventual consequences for electrical generation after the war. Again, when discussing the issue of the winter of 1946/7, Hannah does not seem to draw any direct links between these events and the eventual nationalisation of the industry. Instead he seems to view the nationalisation Bill as being a natural and recognisable development of two decades worth of discussion and compromise on the reorganisation of the electrical supply industry.[17] Overall, Hannah provides a comprehensive description of the development of the electrical supply industry in Britain culminating in the nationalisation of the industry in 1948. However, he does not provide any convincing reasons for the creation and development of the National Grid and Central Electricity Board by any of the inter-war or wartime governments, instead merely documenting events.

In *Networks of Power: Electrification in Western Society, 1880-1930*, Thomas Hughes uses a series of case studies of electrical development in Western Society to highlight five stages in the development of technological networks. These are: invention and development; technology transfer; system growth; and momentum. Hughes places the British experience of electrification into a wider global context, showing some of the ways in which the British experience differed from other Western nations, most notably the USA, France and Germany. He positions the First World War as having halted the early momentum of electrical development in Britain and pushing it in a new direction. Hughes describes this final stage of 'system history' as being characterised the 'rise of financiers and consulting engineers' to positions of authority, who played a leading role in the development of planned regional

[17] Hannah, *Electricity before Nationalisation*, p.349.

systems. The main difficulties in the development of these systems were the provision of funding and circumventing the legislative and political barriers to development.[18]

This thesis focuses on this final stage of Hughes' argument. Hughes argues that the First World War only temporarily altered the development of electricity in the Western World. He claims that engineers, managers and politicians, who had previously been committed to small scale development, 'acknowledged the primacy of output when personal and national survival seemed to depend on it.'[19] Hughes also argues that the governments of Germany, the USA, and Britain all attempted to maintain wartime controls over electrical generation and supply. He claims that these efforts failed as a result of conservative reactions to change, combined with a range of other contributing factors.[20] In contrast to this, I show that, at least in the case of Britain, this wartime interest and control was maintained to a surprising degree, and one which, insofar as I have been able to ascertain, was not matched by any other Western nation during this period. Like Hannah, Hughes pays a great deal of attention to the promises made in the Weir Report as well as in the 1926 Electricity (Supply) Bill. However, Hughes does not examine the motivations of the politicians and engineers involved in preparing the report or the first draft of the Bill, beyond noting that it gained the support of Labour MPs who saw it as a first step towards nationalisation.[21]

In *The Evolution of Large Technological Systems,* Hughes claims that the First World War altered the development of electrical power systems in Britain. He argues that the First World War caused politicians, engineers and economists to reassess the political and economic values of the country and to question whether the 'efficiency achieved during the war was not a prerequisite for industrial recovery in peacetime'. Hughes claims that as a result of this wartime experience, the need for technological change in the provision of electrical power was prioritised

---

[18] Hughes, *Networks of Power*, pp.15-17.
[19] Hughes, *Networks of Power*, p.285.
[20] Hughes, *Networks of Power*, p. 286.
[21] Hughes, *Networks of Power*, pp.355-356.

over the tradition of local government autonomy. [22] Yet despite crediting the First World War with altering the momentum of British electrical development, Hughes does not describe the problems highlighted by the war or explain how they would be solved by this development. Neither does he explore the tensions between the quest for greater efficiency and economy, and the cost of establishing a national supply network during a period of economic and political uncertainty.

In *Technology, Power and Space—the means and ends of geographies of technology*, Steve Hinchcliffe provides an effective counter to Hughes' technological determinism.[23] Hinchcliffe draws attention to the 'ontological and representational issues' encountered when considering issues related to 'geographies of technology and techno-scientific knowledge' and examines the consequences of rejecting technological and social determinism.[24] Hinchcliffe identifies the rejection of technological determinism as a key unifying feature of science and technology studies and claims that there was nothing inherent in the nature of electricity that would lead to centralised production and distribution of electricity supplies.[25]

Hinchcliffe demonstrates this point by examining the development of electrical supply in Denmark, a country in which the development of electricity supply has taken a very different form to that of most of Europe or North America. He highlights the way in which the Danish system has developed 'from the bottom up' with utilities combining and merging in ways which served to maintain the 'mixed and local character of the system'. He explains the differences in electrification between Britain and Denmark in terms of the political and educational character of the country.[26] However, this on its own is not enough to explain the differences in the process of electrification. Hinchcliffe goes on to demonstrate that electricity

---

[22] Thomas Hughes, 'The Evolution Of Technological Systems', in *The Social Construction Of Technological Systems* (Cambridge, Mass.: MIT Press, 2012), 45-76, (p.73.)
[23] Steve Hinchliffe, 'Technology, Power, And Space—The Means And Ends Of Geographies Of Technology', *Environment And Planning D: Society And Space*, 14.6 (1996), 659-682 <https://doi.org/10.1068/d140659>.
[24] Hinchcliffe, '*Technology, Power and Space'*, p.659.
[25] Hinchcliffe, '*Technology, Power and Space'*, p.662.
[26] Hinchcliffe, '*Technology, Power and Space'*, p.663.

was not a 'neutral means of providing energy' and that it was embedded in the socio-political organisation of the country as well as of the individuals, organisations and social groups involved.[27] However, it is important to note that for Hinchcliffe, the development of electricity within any particular country is contingent on circumstances. An alteration to any of the variables, be it the actors involved or sequence of events such as the First World War and the General Strike, can have a profound impact on the development of electrical supply. This thesis explores the way in which the social, economic and political circumstances influenced the development of electrical supply in Britain in a way which has not been replicated within any other country.

One text which does deal effectively with the impact of the First World War is Gordon Woodward's 1996 thesis *Electric Power System Evolution in Merseyside and North Wales: The Technical History of a Region's Electrification, 1879-1948.*[28] Woodward begins with a description of electric power systems worldwide between 1879 and 1948, comparing developments in Britain to those in France, Germany and the United States of America, essentially arguing that while Britain had capable engineers, prior to World War One, the country lacked the 'political will' needed to 'implement the large scale electrical developments needed to minimise costs.'[29] He claims that while national security was threatened there was a 'will to change', as was demonstrated by the increased spending on naval armament in 1909, this did not extend to the electrical industry, 'on which much of the country's industry was beginning to depend.'[30] Woodward describes the period between 1914 and 1926 as being a period of revolution, claiming that the First World War 'established the pre-eminence of electricity as the motive power for industry both in Europe and the United States'.[31] He further claims that the war demonstrated the importance of the electrical supply industry to Britain

[27] Steve Hinchcliffe, 'Technology, Power and Space', p.665.
[28] Gordon Woodward, 'Electric Power System Evolution In Merseyside And North Wales: The Technical History Of A Region's Electrification, 1879-1948.' (unpublished Doctoral Thesis, University of Manchester, 1996).
[29] Woodward, 'Electric Power System Evolution', p.8.
[30] Woodward, 'Electric Power System Evolution', p.8.
[31] Woodward, 'Electric Power System Evolution', p.9.

showing that over the course of the First World War the demand for electrical power increased by almost the same amount as the previous thirty-two years. He does, however, note the difficulties brought about by the need to conserve coal supplies, as well as the difficulties in acquiring the needed generating plant during the war. Woodward also points out that during the First World War the development of electrical supplies was focussed on supplying the immediate industrial demands of the war at the expense of later development in electricity for domestic purposes.[32]

One interesting point is the idea that while the Electricity Commissioners appointed under the 1919 Electricity (Supply) Act were unable to enforce development on national lines, they were able to prevent developments and expenditure which would have been contrary to the national interest. While Woodward claims that the return to peacetime conditions after the war served to dampen any enthusiasm for government sponsored technology, my thesis shows that successive British Governments maintained a high level of enthusiasm for the development of electricity supply on a national basis. However, at least in the early years of the post-war period, I show that this enthusiasm was held in check by a lack of political stability. Woodward also shows that the development of the National Grid in the late 1920s and early 1930s served to stimulate the British economy, providing orders for British electrical manufacturers.[33] However, he does not consider the impact on industry more generally, which as I show in chapter five, was more significant than has previously been acknowledged.

In the next section Woodward comments that the complete interconnection of the National Grid, which was achieved in 1938, played a significant role in the ability of the grid system to

---

[32] Woodward, 'Electric Power System Evolution', p.10.
See John Leon Baker, "Planning The Future Of The Electricity Supply Industry 1935-48" (unpublished Doctoral Thesis, University of Birmingham, 1991). For a discussion on the plans to develop and extend the Mational Grid during this period.
[33] Woodward, 'Electric Power System Evolution', p.16.

meet the demands imposed on it by the Second World War.[34] Woodward also examines the importance of the standardisation of generation, claiming that

> The savings possible with the Grid system could not [have] been achieved on the same scale had there not been a commitment to standardisation of frequency. Economies in the production costs of transformers, motors and meters gave benefits to supply authorities and consumers. National defence was simplified by the adoption of a national standard frequency.[35]

This claim is supported by the previously unseen evidence I present in chapters three and four which lays out the interest of the military in the development of national standards for electrical generation and distribution.

The remaining chapters of Woodward's thesis focus first on the consulting engineers involved in the development of electricity supply in the North West of Britain, and then on case studies on specific locations within the region. These chapters provide detailed breakdowns of the generating and distribution equipment installed at each site and track the changes and adaptions made as new technological methods became available. One point illustrated in these chapters is the level of small-scale hydropower resources being exploited in the North West region. However, much of this was used as a reserve for the steam plant due to the unreliability of the water sources.[36] In his conclusion Woodward reiterates the significance of hydropower developments in the North Wales region, particularly linking these developments to aluminium production.[37] He also emphasises the importance of the First World War in establishing the 'pre-eminence of electricity as the motive power for industry' and for highlighting the weaknesses of the existing supply system. Despite having examined both hydropower and waste reclamation as alternatives to coal, his thesis does not directly examine the importance of a reliable and economical fuel supply, or of the advantages of using multiple

[34] Woodward, 'Electric Power System Evolution', p.27.
[35] Woodward, 'Electric Power System Evolution', p.28.
[36] Woodward, 'Electric Power System Evolution', p.73.
[37] Woodward, 'Electric Power System Evolution', pp.273-274.

sources of generation. Furthermore, despite having mentioned the importance of standardisation for national defence, this theme is not explored in his thesis.

Andreas Marklund's and Mogens Rudiger's 2017 *Historicizing Infrastructure* highlights the significance of national infrastructure in everyday life and demonstrates the way in which infrastructure becomes part of the background to life. They show how infrastructure can come to have different meanings to different groups of users.[38] Thus for electrical infrastructure, such as the National Grid, it is possible for the state to view the National Grid as being about security of supply and the management of energy resources, whereas for the individual companies making up the industry, as well as individual domestic and industrial users, the economic and technological efficiencies noted by Hughes and Hannah become more important. Of equal interest is Elizabeth Bruton's contribution on *The Cable Wars: Military and State Surveillance of the British Telegraph Cable Network during World War One*. The degree of redundancy, noted by Bruton, in the British telegraph network, enabled the continuous operation of the network, even while under enemy attack.[39] This is in many ways similar to the layout of the British electrical grid, which provided sufficient redundancy to ensure minimal disruption, even in the event of damage by enemy action. This principle of network redundancy is most often attributed to the development ARPANET to ensure secure communications in the event of a nuclear war. However, as I show in this thesis, has its origins in the development of the British National Grid.[40]

2.1.2. Electrification and Gender.

Another aspect of electrical history is the role of women within the development of electrical power and particularly the way in which electrical distributors have often viewed women as being the primary users of domestic electricity. This topic has been covered extensively by

[38] Andreas Marklund and Mogens Rüdiger, *Historicizing Infrastructure* (Aalborg: Aalborg University Press, 2017), p.15.

[39] Elizabeth Bruton, 'The Cable Wars: Military and State Surveillance of The British Telegraph Cable Network During World War One.', in *Historicizing Infrastructure.* (Aalborg: Aalborg University Press, 2017), 159-182, (p.161).

[40] For more on the development of ARPANET see Stephen Lukasik, "Why The Arpanet Was Built", *IEEE Annals Of The History Of Computing*, 33.3 (2011), 4-21 <https://doi.org/10.1109/mahc.2010.11>.

Ruth Schartz Cowan in *More Work for Mother: The Ironies of Household Technology from the Open Hearth to the Microwave*, and *A Social History of American Technology*.[41] While focusing on the United States, Cowan effectively demonstrates the ways in which electrical technologies were advertised to female users and the discrepancy between the promised emancipation of women from the drudgery of housework and the reality in which access to electrical appliances created more work for women. The time spent on individual tasks did indeed go down, however, the number of tasks to be carried out increased significantly.

This theme is also picked up in Elizabeth Sprenger and Pauline Webb's article, *Persuading the Housewife to Use Electricity? An Interpretation of Material in the Electricity Council Archives*.[42] Sprenger and Webb show the way in which the Electrical Development Association attempted to shape electrical use, at times trying to convince people to use more electricity and at other times trying to persuade people to use less electricity.[43] They show the close cooperation of the EDA with the Electrical Association for Women, and the way in which electricity was marketed to the domestic consumer and in particular to women. While pointing out that the advertising of electricity to women was an important factor in the increase of domestic electrical use during the inter-war period, Sprenger and Webb nonetheless do not consider other explanations for this increase. In examining the effectiveness of the EDA and EAW Sprenger and Webb consider three areas: changing perceptions of electricity; the liberation of women from housework; and the needs and means of consumers. They suggest that, as a result of the First World War, a large number of women had gained experience with the use of electricity in the workplace, however, there is no indication as to whether this wartime experience had any measurable impact on the medium-longer term uptake of electricity for

[41] Ruth Schwartz Cowan, *More Work for Mother* ([New York, NY]: Basic Books, 1983).
Ruth Schwartz Cowan, *A Social History of American Technology* (New York: Oxford Univ. Press, 1997).
[42] Elizabeth Sprenger and Pauline Webb, 'Persuading the Housewife to Use Electricity? An Interpretation of Material In The Electricity Council Archives', *The British Journal For The History Of Science*, 26.1 (1993), pp.55-65. <https://doi.org/10.1017/s0007087400030132>.
[43] Sprenger and Webb, 'Persuading the Housewife to Use Electricity.', p.57.

domestic purposes. They then highlight the differing approaches of the EDA and EAW, with the EAW focusing on educating women on electrical matters, while the EDA focused on selling a 'modern technology' which promised cleaner, healthier homes thanks to the wonders of electricity. [44] However, once again there is no indication as to the overall effectiveness of this approach in convincing women to use electricity. Their next section on removing the drudgery from housework is structured in a similar way, highlighting the differences between the approach taken by the EDA and the EAW, noting that the EAW approach was based on detailed surveys and reports, whereas the EDA advertisements

> Extol the joys of electrical housecraft to the point of beyond credulity, then and now. […] Electrical housework seems to take place in a fantasy land where women resplendent in their best clothes, languidly operate appliances.[45]

They also show how EDA advertising suggested that electrical appliances could go some way to replacing the labour of the now scarce servant. Sprenger and Webb cite a 1935 EAW report by Elsie Edwards, which showed that in an all-electric home housework took significantly less time to complete than in non-electric homes. Nevertheless, they also point out that later research has shown that while electrical appliances reduced the time and effort required for each task, changes in standards meant that these tasks were now performed more regularly.[46] Finally, Sprenger and Webb note that both the EAW and the EDA struggled to reach outside of the middle classes, although prominent members of the EAW were at least instrumental in enabling the provision of electricity to working class homes.[47] In their conclusion Sprenger and Webb suggest that while the EAW only played a minor role in the history of the British electrical industry, it deserves greater credit from historians for its work. However, they are

[44] Sprenger and Webb, 'Persuading the Housewife to Use Electricity.', pp.61-62.
[45] Sprenger and Webb, 'Persuading the Housewife to Use Electricity.', p.62.
[46] Sprenger and Webb, 'Persuading the Housewife to Use Electricity.', p.63.
[47] Sprenger and Webb, 'Persuading the Housewife to Use Electricity.', p.64.

unable to show the effectiveness of either the EDA or EAW in increasing the consumption of electricity by domestic users.

This theme of the spread of domestic electrification is explored in more depth in Emily Hankin's 2012 thesis, *Buying Modernity? The Consumer Experience of Domestic Electricity in the Era of the Grid.*[48] Hankin focuses on the gulf between the ideal of domestic electricity as advertised by the EDA and the EAW and the reality as experienced by British housewives. She aligns the development of the National Grid and the increasing standardisation of electricity supplies in Britain with the increasing use of electricity within the home. Hankin mentions the impact of fuel shortages on electricity supply particularly in relation to the shortages of coal during the Second World War and again during the shortages in 1946/7. She also notes that power cuts served to contradict the claims by the electrical authorities that electricity was 'an efficient source of power for the home.'[49]

In chapter three, Hankin discusses the way in which cleanliness was linked to the use of electricity within the British home, focusing on the sale and use of electric irons and vacuum cleaners. Interestingly, despite commenting on the cleanliness of electric irons in comparison to flat irons, this is not linked to the idea of electricity as a clean fuel which was a key feature of many of the EDA pamphlets throughout the inter-war period.[50] This theme is also absent from chapter four in which Hankin focuses on the introduction of the gas/electric cooker and the refrigerator. Hankin concludes that by the 1960s the demand for domestic electrical appliances had largely stabilised in part due to the increasing availability of a reliable supply of electricity on a common standard. She notes that the difficulties occasioned in reaching this point were due to the diverse age and nature of housing in Britain, and that there were significant variations in the demand for electricity in different regions.[51] Despite having

[48] Emily Hankin, 'Buying Modernity? The Consumer Experience of Domestic Electricity In The Era of The Grid.' (unpublished Doctorate, University of Manchester, 2012).
[49] Hankin, 'Buying Modernity?', pp.73-74.
[50] Hankin, 'Buying Modernity?', pp.81-88.
[51] Hankin, 'Buying Modernity?', pp.201-202.

mentioned the disparity between the electrification of urban and rural regions in the introduction, this theme was not explored in the thesis beyond noting that rural regions were more likely to use electricity for industrial purposes. However, the theme of rural electrification is discussed in more detail in Paul Brassley, Jeremy Burchardt and Karen Sayer's *Transforming the Countryside: The Electrification of Rural Britain.*[52]

2.1.3. Rural Electrification.

Transforming the Countryside, as an edited volume, examines all aspects of the electrification of rural Britain. Brassley, Burchardt and Sayer point out that as a source of power, electricity is highly flexible as it can be used for lighting, heating and motive power and, at the point of use, is clean and safe and could be viewed as the 'closest thing there was to an ideal modern source of power.'[53] Through the different chapters, the authors explore the reasons for the slow progress of rural electrification in Britain, looking at the technical, economic and legislative challenges to electrification.[54] They then explore the impact of electrification on the lives of individuals and communities involved, before finally comparing the process of rural electrification in Britain to the experiences of rural communities in Canada and Sweden. They show that by the outbreak of the Second World War the electrification of rural Britain was largely complete, at least for those living in communities of over five hundred people.[55] They argue that the central problem in the provision of electricity to rural communities was the high cost of supply, often dictated by the length of the connection needed. As such, it was often only economical to connect communities with sufficient potential customers to justify the costs. They also show that for much of Britain, the speed with which a community was connected was also influenced by other factors, such as the proximity to existing power lines.[56]

---

[52] Paul William Brassley, Jeremy Burchardt and Karen Sayer, *Transforming the Countryside: The Electrification of Rural Britain.* (Oxon: Routledge, 2017).
[53] Brassley, Burchardt and Sayer, *Transforming the Countryside*, p.2.
[54] Slow in comparison to the electrification of metropolitan regions.
[55] Brassley, Burchardt and Sayer, *Transforming the Countryside,* p.221.
[56] Brassley, Burchardt and Sayer, *Transforming the Countryside*, p.225.

Brassley, Burchardt and Sayer go on to claim that the most significant development for rural electrification was the success of the National Grid and the subsequent reduction in the cost of generating electricity. However, due to the distances involved and the relatively small number of potential customers, most electrical undertakings still felt unable to justify the costs of supply to the 'more isolated settlements and dwellings, including most farms.'[57] It was not until the nationalisation of the industry in 1947 that it became feasible to extend supply to the more isolated communities and farms, although as, was mentioned earlier in the volume, the final community was not connected in Britain until 2004.[58] They also consider the problem of creating demand for electricity in rural areas, noting that lighting alone did not offer the prospect of creating the kind of balanced load sought by electrical undertakers. This was compounded by the problem that while there were many jobs for which electrification was ideal, these often tended to create high loads for short periods of time, which was equally problematic for electrical undertakers. However, developments in food standards, particularly in regard to dairy products did lead to an increase in demand in the mid-1930s due to the need to sterilise milk and to store it at a constant 'cool temperature'.[59] Finally, electricity was not yet essential to farm work or daily life on the farm. Much work was able to be carried out using draft horses and mechanical engines, which many farm labourers were familiar with, while electricity was still less well understood.[60]

Overall Brassley, Burchardt and Sayer conclude that when affordable electricity finally arrived in rural Britain it was welcomed by farmers since it proved beneficial to farm production as well as for the personal lives of farm workers. One broader issue not pursued in this collection is the implication for electrification of successive governments' plans to make inter-war Britain self-sufficient in food production. This is empathised in chapter five of this thesis in the

[57] Brassley, Burchardt and Sayer, *Transforming the Countryside*, p.226.
[58] See footnote 154 on page 25.
[59] Brassley, Burchardt and Sayer, *Transforming the Countryside*, p.228.
[60] Brassley, Burchardt and Sayer, *Transforming the Countryside*, pp.228-231.

discussion about emissions from power stations and the threat to arable land. Dominic Berry claims that science and technology were crucial ‘driving forces behind bigger yields’ in British agriculture during the 1920s and 1930s.[61] Further, Richard Howarth points out that growth had ‘been achieved by plant and animal scientists, chemists, and geneticists simultaneously with a mechanical revolution […] and now an electronic revolution.’[62] As Berry suggests, this approach to agriculture in Britain fits within Edgerton’s warfare state thesis and would provide an additional incentive for increased funding for rural electrification in the post war period.

In *Rural Electrification in the British Empire* Ute Hasenöhrl examines the inequalities in electrification which have resulted from the process by which British colonies underwent electrification during the late nineteenth and early twentieth centuries, particularly in reference to rural regions throughout the British Empire.[63] She shows that the development of infrastructure throughout the Empire was undertaken in a highly piecemeal fashion.[64] She notes that much of the work carried out on electrification in British colonies has either focussed on economic questions or the techno-politics of energy infrastructure and argues that thus far the cultural dimensions of energy infrastructure have received little attention. She shows that while companies such as General Electric and British Westinghouse deliberately sought to develop markets in the colonies, they did not always secure that market in the face of competition from American and German companies.[65] Hasenöhrl claims that the electrification of the British Empire was a ‘tenacious and highly uneven process’, the approach taken differed between regions and over time.[66] One commonality, however, was the lack of investment in rural areas.[67] In analysing the electrification of India, Hasenöhrl points out that

---

[61] Dominic Berry, ‘Genetics, Statistics, And Regulation At The National Institute Of Agricultural Botany, 1919-1969.’ (unpublished Doctoral Thesis, University of Leeds, 2014), p.199.
[62] Richard W Howarth, *Farming For Farmers? A Critique Of Agricultural Support Policy,* (London: Institute of Economic Affairs, 1985), pp.43-44.
[63] Ute Hasenöhrl, ‘Rural Electrification In The British Empire’, *History Of Retailing And Consumption*, 4.1 (2018), pp.10-27 <https://doi.org/10.1080/2373518x.2018.1436220>.
[64] Hasenöhrl, ‘Rural Electrification In The British Empire’, p.11.
[65] Hasenöhrl, ‘Rural Electrification In The British Empire’’, p.14.
[66] Hasenöhrl, ‘Rural Electrification In The British Empire’’, p.15.
[67] Hasenöhrl, ‘Rural Electrification In The British Empire’’, pp.15-16.

the first buildings to receive electric light and power were places such as the Governor's mansion, telegraph stations and railway stations. She points out that in addition to the practical benefits, electricity also served as a 'visual manifestation of imperial might' claiming that electricity was not regarded as being an essential service by the colonial administrators. As was the case in Britain, most power stations were privately owned and profit orientated, as such operators were largely uninterested in extending services to the general public. Hasenöhrl argues that the British policy of discouraging the development of industry in the colonies served to exacerbate this problem.[68] The development of industries in the colonies during the inter-war period is not discussed in this paper, as such it is unclear what impact, if any, this had on electrification in the colonies during this period.

One important point raised by Hasenöhrl is the diversity of fuels used throughout the colonies, with a greater reliance on hydropower and less on coal than had occurred in Britain. However, many of these sites, as was the case in Scotland, were located in remote areas and did not have easy access to potential customers.[69] During the inter-war period Hasenöhrl argues that colonial powers such as Britain took a more 'proactive approach to the development of their colonies', but that much of the intended work on infrastructure such as electrical networks was never carried out due to financial problems. She points out that Britain did not make any significant commitment to colonial development until the passage of the Colonial Development and Welfare Act in 1940. However, she does not connect this increased spending on development to the Second World War and the need to construct munitions factories close to natural resources and out of range of potential attacks by Axis forces. As I show in chapter six, the provision of generating plant for India was a priority and resulted in changes to the way in which large scale electrical plant was ordered. Indeed, Hasenöhrl suggests that electrification was downgraded in importance due to the priority given to mining operations.[70]

[68] Hasenöhrl, 'Rural Electrification In The British Empire'', p.16.
[69] Hasenöhrl, 'Rural Electrification In The British Empire'', p.17.
[70] Hasenöhrl, 'Rural Electrification In The British Empire'', pp.17-18.

Hasenöhrl shows that electrification on a national basis did not take place until the end of the colonial period as former colonies gained independence. Nevertheless, she notes that these projects were often driven by visions of 'modernisation and instant prosperity' and as such did not correspond to the 'actual needs or capacities of the country.'[71] I argue that the colonial electrification projects described by Hasenöhrl can be better understood through the lens of the warfare state, particularly in light of the increased industrialisation in the colonies following the end of the First World War. Increased industrialisation in overseas colonies would have reduced the risk of aerial attack by other European powers in the event of a future war. However, this in no way negates the issue of colonial exploitation by Britain, as any developments in industry or infrastructure carried out in this period were primarily for the benefit of Britain and British Imperial interests.

Another key point raised by Hasenöhrl relates to how large-scale electrical projects in former colonies such India were developed as an expression of national identity and modernity. This is reflected in Sorcha O'Brien's 2017 publication, *Powering the Nation: Images of the Shannon Scheme and Electricity in Ireland*.[72] O'Brien shows that for Ireland in the 1920s the development of the Shannon hydro-electric scheme was as much about national identity and creating the image of Ireland as a modern State as it was about the production of cheap electrical power. A process which, as O'Brien points out, was complicated by the many conflicting meanings of what it meant to be Irish and what it meant to be modern.[73] This is later reflected in chapter six on the advertising campaign run by the newly established Electricity Supply Board (ESB). O'Brien shows that the ESB was remarkably quick to set up a publicity department in order to 'familiarise the Irish public with the Shannon Scheme itself, and with the idea of electrical power, with a view to becoming subscribers themselves.'

[71] Hasenöhrl, 'Rural Electrification In The British Empire'', p.19.
[72] Sorcha O'Brien, *Powering The Nation: Images Of The Shannon Scheme And Electricity In Ireland* (Newbridge: Irish Academic Press, 2017).
[73] O'Brien, *Powering The Nation, pp.*1-40.

However, O'Brien notes that unlike similar campaigns run by the EDA in Britain during this period, the Irish public were largely unfamiliar with electrical technologies.[74]

2.2. Inter-war Britain.

The initial establishment and construction of the construction of the National Grid took place during the inter-war years. Yet standard histories of Britain during this period pay scant attention to the political, economic or social effects of this major national undertaking. This also holds true of the economic histories of the United Kingdom during this period.

2.2.1. Political and Social Histories.

In English History 1914-1946, A.J.P. Taylor gives a comprehensive account of the social and cultural history of Britain during this period. Taylor's approach is explicitly socialist, which is apparent in his treatment of figures such Lloyd George this perspective of Taylor's might also account for his description of the way in which control over electrical power was 'curiously tacked on' to the Ministry of Transport due to the 'mistaken belief that the railways would soon be electrified.'[75] Taylor later mentions electricity in Britain only to highlight the 'chaotic state' of British industry, particularly the modern industries producing motor cars and electrical equipment.[76]

While discussing the impact of the depression on British industry, Taylor notes that employment in the electrical industry multiplied by three, however, he does not connect this increase in such employment to the ongoing work of constructing the National Grid.[77] Nor does he discuss the increase in electrical consumers from three quarters of a million in 1920 to nine million in 1938. Taylor suggests that this was purely down to the government encouraging citizens to 'put Britain first' and invest in British business and to consume British goods.[78] However, this does not account for the investment in electrical supplies and manufacture

---

[74] O'Brien, *Powering The Nation, pp.*127-128.
[75] Alan J. P Taylor, *English History: 1914-1945.* (Oxford: Clarendon Press, 1988).
[76] Taylor, *English History*, p.183.
[77] Taylor, *English History*, p.305.
[78] Taylor, English History, p.343.

beginning during the First World War and accelerated by the passage of the 1926 Electricity (Supply) Act.

In his conclusion Taylor claims that the Second World War 'unlike the First', stimulated the growth of new industries enabling Britain to take 'the decisive jump industrially' into the twentieth century.[79] However, this thesis shows that the First World War arguably had a greater influence on the development of industry and particularly the electrical supply and manufacturing industry, than was assumed by Taylor.

In Martin Pugh's *We Danced all Night: A Social History of Britain Between the Wars*, Pugh paints a compelling picture of life in Britain, which challenges the traditional narrative of dour cost-cutting, unemployment and breadlines.[80] He shows how accounts of the depression tended to be concentrated in regional industrial areas, particularly coal mining and ship building which had suffered a severe decline as a result of the First World War and the subsequent loss of markets to international competition. He notes that the 'new industries' benefited from the creation of the National Grid which enabled them to be located outside of the traditional manufacturing centres.[81]

Similarly, when discussing the inter-war boom in housing construction Pugh notes that it coincided with the passage of the 1926 Electricity (Supply) Act and the development of the National Grid, pointing out that the number of houses wired for electricity had increased from two percent in 1910 to seventy-five percent in 1939.[82] However, he does not connect this increase to the development of the new electrical manufacturing industries. Finally, while Pugh does acknowledge the importance of electrical power to the economy and points out that in 1919 the government had been concerned that strikes amongst 'electricity, coal and

[79] Taylor, *English History*, p.600.
[80] Martin Pugh, *We Danced All Night: A Social History Of Britain Between The Wars.* (London: Vintage, 2009).
[81] Pugh, *We Danced All Night*. Location 1941.
[82] Pugh, *We Danced All Night.*Location 1942.

railway worker could paralyse the entire economy'.[83] However, this point remains undeveloped and is not mentioned in relation to his discussion of the 1926 general strike.

The main theme in relation to electricity throughout this book is the idea that electricity was considered dangerous and mysterious and something to be mastered, with accounts of barbers who were unable to master their new electric clippers or housewives who were afraid their radio would catch fire so threw water over it.[84] By contrast I show that the demand for electricity for domestic purposes rose steadily throughout the period covered in this thesis. By the outbreak of the Second World War the use of electrical appliances such as wireless sets, heaters and ovens, was well established in Britain. So well established that the Government was forced to implement electrical rationing in an attempt to reduce the domestic demand for electricity.[85]

2.2.2. Economic Histories.

In discussions of the British economy during the inter-war period mentions of electricity are equally scarce. In *The Inter-War Economy: Britain 1919-1939*, Derek Aldcroft points out that investment in electrical supply increased almost continuously, with capital expenditure increasing from '£9 million in 1920 to £45 million in 1932'. However, he provides no reason for this increase in investment beyond suggesting that the Government desired to maintain investment during a time of recession.[86] He later shows the degree to which investment in plant and machinery increased, particularly during the late 1920s and again just prior to the outbreak of World War Two.[87] While the later peak is self-explanatory, the earlier peak is best explained by the construction of the National Grid during this period. Later in the book Aldcroft notes the significant improvements in electrical generation which were brought about by the development of the National Grid, highlighting the cost of construction and the increase

[83] Pugh, *We Danced All Night.*Location 418.
[84] Pugh, *We Danced All Night.*Location 865, Location 4458.
[85] See also, Leslie T. Newman, "The Electrification Of Rural England And Wales" (unpublished Masters Thesis, University of Reading, 1991).
[86] Derek Howard Aldcroft, *The Inter-War Economy: Britain, 1919-1939.* (London: The Bodley Head, 1965).
[87]Aldcroft, *The Inter-War Economy*, p.62.

in the number of consumers served by electrical power as a result.[88] Likewise in *The British Economy Between the Wars*, Aldcroft notes that the State, both in terms of local and national Government, was becoming increasingly involved in the organisation of industry, particularly in relation to gas, water and electricity.[89] However, he does not offer any explanation for the increasing state involvement in these industries, beyond speculation that some form of protectionism may have been involved.

2.3. Business Histories.

The role of British electrical manufacturers was central to the development of the British electrical system. Yet, the ownership of some of these companies was at times problematic, often involving multinational companies and foreign ownership. Two of the most important companies for this thesis are Metropolitan Vickers, which was part owned by US interests, and Ferranti, which, at this time, was wholly family owned.

2.3.1. The Problem of Ownership.

While most company histories do not consider the importance of ownership, Hausman, Hertner and Wilkins' 2008 book, *Global Electrification: Multinational Enterprise and International Finance in the History of Light and Power, 1878-2007,* concentrates exclusively on issues of finance, and is particularly strongly focused on the experience of American finance companies. They largely ignore the role of national governments in the development of electrical infrastructure and in creating the space needed for investment to take place.[90] Hausman *et al.* also appear to view the focus on domestic development, of countries such as Britain, as damaging to the development of electrical networks on a global scale. They note the importance of warfare in changing the pattern of government involvement in the electrical supply industry. However, as with Hannah and Hughes, they describe the First World War as

---

[88] Aldcroft, *The Inter-War Economy*, pp.191-198.
[89] Derek Howard Aldcroft, *The British Economy Between The Wars.* (Oxford: Philip Allan, 1983), pp.53-57.
[90] William. Hausman, Peter Hertner and Mira Wilkins, *Global Electrification: Multinational Enterprise And International Finance In The History Of Light And Power, 1878-2007.* (New York: Cambridge University Press, 2008).

being primarily disruptive to the development of electricity. They argue that that national governments, particularly in Russia and Britain, were spurred by the First World War to play an increasing role in the development of electrical infrastructure, noting that:

> At the war's end, many governments, backed by electrical engineers and industrial leaders, were convinced that electrification was too important to be left to the private market (domestic or foreign) or to local governments. The need to look at electrification from a regional or national level, its importance as a vital economic resource, and its insatiable demand for funding would make electrification a continuing object of state interest long after the last shells were fired.[91]

However, Hausman *et al.* fail to develop this theme further. There is also no discussion of the development of the British National Grid; the remainder of the chapter instead focuses on investments made in countries such as Chile and Argentina and in Central America. While the pattern of British investment in foreign undertakings is important, particularly in terms of tax revenue, it only made up a small percentage of British investment in electrical infrastructure, both in terms of private investment and investment by the state. It is also significant that despite mentioning the increasing role of the state in the British electrical industry, they do not examine the financing of the National Grid itself beyond noting that 'The British increased domestic investments at the expense of international ones.'[92] The lack of interest in the British experience of electrification displayed by Hausman *et al.* can be explained if we consider Britain in the same light as Russia. Following the end of First World War, the new Soviet State quickly seized control of all electrical utilities, effectively ending any outside influence. The situation in Britain, while not as extreme as the Soviet Union, was similar. While ownership of utilities was not affected, the state, through the Central Electricity Board, took control of, and provided much of the finance for, new development and expansion within the industry. While foreign investment companies may have had a stake in some utility companies, the choices available were limited. Power stations could only be extended with the permission of the

---

[91] Hausman, Hertner, and Wilkins, *Global Electrification*, p.130.
[92] Hausman, Hertner, and Wilkins, *Global Electrification*, p.201.

Central Electricity Board and they could only purchase materials and equipment from British suppliers. Furthermore, once an undertaking was connected to the Grid they could only sell or purchase electricity to the National Grid at prices fixed by the CEB. Any company unable to produce electricity at the price required and at the requisite voltage and frequency was unable to sell electricity to the Grid. Foreign investors were therefore unable to have any substantial influence on the development of the British electrical network after the First World War. Nevertheless, there was some concern related to issues of security due to Italian involvement in rural power stations just prior to the Second World War. Hausman *et al.* point out that:

> In 1938 the British Ministry of Transport worried about strategic information on electricity supplies and munitions factories being passed on to the German General Staff through the BUI's [British and International Utilities Ltd] Italian management.[93]

However, while they do note that the rural utility companies concerned only represented a small percentage of British electrical output, they fail to appreciate the point made by Brassley *et al.* that in Britain many rural areas were not connected to the National Grid until after the Second World War.[94] Indeed, by 1938 only seven percent of farms in Britain were connected to mains electricity.[95]

In general, while Hausman *et al.* demonstrate some awareness of the security concerns of the state in relation to electrical supply, this is never properly developed. They also ignore the ways in which the security concerns of the British Government over foreign ownership of electrical utilities were an important factor in the development of the National Grid. This element also helps to explain the insistence of the Central Electricity Board that only British firms could provide the equipment and machinery necessary to construct the Grid, even when

[93] Hausman, Hertner, and Wilkins, *Global Electrification*, p.209.

[94] The final village to receive a mains connection to the National Grid was Abergeirw in Gwynedd, which received its connection in December 2008**.**
'BBC NEWS | Wales | North West Wales | Electricity Switch-On For Village', *News.bbc.co.uk*, 2008 <http://news.bbc.co.uk/1/hi/wales/north_west/7790280.stm> [Accessed 24 July 2018].

[95] Paul Brassley, Jeremy Burchardt and Karen Sayer, *Transforming The Countryside: The Electrification Of Rural Britain.* (London: Routledge, 2017), 1-12, (p.6).

the use of a foreign supplier would have been quicker or more cost effective. This strategy reduced reliance on equipment which may have become unavailable in a time of war. It also provided jobs for a large number of workers during a period of high unemployment, in addition to creating large orders to key industries, described by David Edgerton as being vital in enabling Britain to 'produce for modern war'.[96]

The issue of foreign ownership is explored more thoroughly in Robert Jones and Oliver Marriott's *Anatomy of a Merger* which explores the complicated history and organisation of the General Electric Company, Associated Electrical Industries and English Electric. The authors cover the series of mergers between the different companies and track the changes in ownership, particularly in relation to the parent companies in the United States. They show that G.E.C, A.E.I, and English Electric were part of an international ring of electrical manufacturers all of which had some degree of interest in the others and which worked together to control the markets and ensure that all were able to remain in business and provide employment in a period of otherwise high unemployment.[97] However, this does not take into account the influx of orders within Britain brought about by the creation of the National Grid. One thing, however, that is clear from this account, is that while American companies did maintain a strong interest in and influence over the major British Electrical firms, control for the most part remained in British hands, at least in part due to the concerns about foreign involvement in an industry deemed vital to industrial development.

2.3.2. Reserved Occupations.

One theme which is picked up in chapter three and again in chapter six is of the status of power station workers during times of war. During both the First and Second World Wars power station employees were recognised as being in reserved occupations and as such

[96] David Edgerton, *The Rise And Fall Of The British Nation.* ([London]: Allen Lane, 2018), p.146.
[97] Jones and Marriot, *Anatomy of a Merger*, p.171.

exempt from military service. Indeed, as we see in chapter two, munitions producers were warned not to try and recruit skilled workers from power stations.

One text which deals with some of the issues surrounding recruitment and reserved occupations is Juliette Pattinson's *'Shirker', 'Scrimjacks' and 'Scrimshanks'?: British Civilian Masculinity and Reserved Occupations, 1914-45*.[98] Pattinson examines the idea of masculinity as it relates to non-military service in Britain during the First and Second World Wars. She explores the changing conceptions of what it meant to be masculine and notes the ways in which men in reserved occupations were often considered to be 'lesser men'.[99] Pattinson then goes on to discuss how the industrialised nature of warfare in the first half of the twentieth century made it necessary for a significant body of men to remain employed in mines and factories in order to keep up with the demand for munitions and other products required for the prosecution of the war. One of the main focuses of Pattinsons paper is on the application of the lessons learned by the British Government during the First World War and on conscription and reserved occupations during the Second World War.[100] While she does not directly reference the supply of electricity, this was one of the key industries which, like the mining industry, was subject to significant losses due to men volunteering for service on the front lines during the First World War. Pattinson demonstrates the way in which the state recognised the importance of skilled workers, particularly related to munitions production and took steps to ensure that they would not be subject to conscription. The point at which men would be called up varied on their age and occupation, and for jobs which were deemed more essential to the State, there was a lower age above which they could not be conscripted. One of the key changes prior to the outbreak of the Second World War was the creation of a list of nearly 300 reserved occupations from which men would, at least not initially, be accepted into

---

[98] Juliette Pattinson, ''Shirkers', 'Scrimjacks' And 'Scrimshanks'?: British Civilian Masculinity And Reserved Occupations, 1914-45', *Gender & History*, 28.3 (2016), 709-727 <https://doi.org/10.1111/1468-0424.12246>. 709-27.

[99] Pattinson, '''Shirkers', 'Scrimjacks' and 'Scrimshanks'?', p.710.

[100] Pattinson, '''Shirkers', 'Scrimjacks' and 'Scrimshanks'?', p.711.

the armed forces.[101] This list included those working for utilities, such as water, gas and electricity. Pattinson notes that as the Second World War progressed, men were gradually released from reserved occupations to meet urgent military needs, but only as long as they volunteered for service with the Royal Air Force. However, the list of jobs from which men could volunteer for service did not include heavy industry or electrical production. By the end of 1941 the increasing numbers of women working in munitions production and other vital industries resulted in more men being released for military service. Pattinson shows how the entry of women into the workforce brought an end to the system of reserved occupations. She also shows that despite the increased numbers of women employed in wartime industry, men still comprised over sixty percent of the workforce, particularly in heavy industries and that women were generally only seen as being employed for the duration of the war and as such did not receive as comprehensive a training as the men they were either working alongside or replacing.[102] There has been little work done on the employment of women within electrical generation. As is shown in chapter five, the major issues with construction of new power stations and pylons were more related to shortages in unskilled personnel for construction than to a shortage of engineers within the power stations themselves. Pattinson shows that the labour lessons of the First World War contributed to the deployment of labour in the Second World war, particularly in relation to key industries such as mining and munitions work. I build on this point to show that in addition to labour issues, the experience of the First World War directly influenced the management of electrical supply during the Second World War.

2.4. Nuclear Power.

With the end of the Second World War the focus quickly shifted from weapons development and munitions production to rebuilding and redevelopment. While today it is almost

[101] Pattinson, '‘Shirkers’, ‘Scrimjacks’ and ‘Scrimshanks’?', p.716.
[102] Pattinson, '‘Shirkers’, ‘Scrimjacks’ and ‘Scrimshanks’?', pp.721-722.

undisputed that the original focus of Calder Hall was the development of weapons grade plutonium, this was not the image that was presented to the British public, which instead focused on the development of atomic energy for civilian power generation. However, in this thesis I argue that the development of nuclear energy and the decreased reliance on coal for electrical generation was in fact equally as important. This viewpoint was first articulated by R.F. Pocock in *Nuclear Power: Its Development in the United Kingdom.*[103] Pocock, an engineer working in civil nuclear power, argues that between 1945 and 1952 the British nuclear programme was 'purely military', but that from 1953 onwards 'the commercial generation of power was increasingly significant.'[104] Pocock suggests that the harsh winter and fuel crisis of 1947/8 served to highlight the potential value of nuclear energy as a supplement to more traditional sources of power.[105] He claims that 'nuclear energy was seen as a valuable means of conserving conventional fuel stocks regardless, at that time, of its relative cost.[106] This clearly highlights the importance of ensuring security of energy supply and indicates that nuclear energy was, at this point, intended to supplement rather than replace traditional fuel sources. This point is emphasised in chapter three where Pocock shows that 92 percent of Britain's energy needs were met by coal, with the remaining 8 percent presumably being met by a combination of oil, gas and hydropower. However, by 1948 the demand for coal exceeded the production capabilities of the industry and supply was only maintained by drawing down on the nations stockpiled reserves and by the early 1950s Britain, once a major exporter of coal, was now forced to begin limited imports of coal to make up the deficit.[107] He compares the fuel situation in Britain to that of the United States, pointing out that whereas Britain had few suitable sites for hydro-electric developments, no access to indigenous oil, and had recently begun to import coal, the USA 'enjoyed the benefits of cheap coal, indigenous oil and

---

[103] Rowland F Pocock, *Nuclear Power: Its Development In The United Kingdom.* (Old Woking: Unwin Brothers, 1977).
[104] Pocock, *Nuclear Power*, p.19.
[105] Pocock, *Nuclear Power*, p.21.
[106] Pocock, *Nuclear Power*, p.25.
[107] Pocock, *Nuclear Power*, pp.45-46.

significant hydro-electric generating capacity.'[108] He claims that the aim of the British nuclear program was to 'to provide for the expansion of electricity supplies to meet anticipated increases in demand without a corresponding increase in coal consumption' and that the 'economic cost of providing this nuclear capacity was not really a factor in the Ministry's decision to initiate the programme.'[109] However, it does need to be re-iterated that all of the early Magnox reactors, including Calder Hall, were primarily designed with the enrichment of plutonium as their primary purpose, with the generation of electrical power a secondary by product. It is also important to note that according to Pocock much of the environmental concern expressed in relation to the construction of nuclear power stations in Britain was related to the idea of 'visual amenity; and was very similar in nature to the debates surrounding the construction of conventional coal fired power stations such as Battersea and Bankside.'[110] While nuclear power did not have the problem of smoke emissions as was the case with conventional power stations, it is significant for this thesis that the main areas of concern for campaigners against both conventional and nuclear power stations was the visual amenity of the area including the design of the buildings and the layout of the overhead transmission lines.

Writing in 2011 Martin Theaker argued that the development of nuclear power went through a military phase before becoming a predominantly commercial concern. He further argues that the non-martial aspects of nuclear technology have been largely ignored in mainstream histories and as such his thesis focuses exclusively on the development of nuclear power in a 'civil context'.[111] Theaker's second chapter focuses on the development of nuclear power in Britain during the late 1940s and early 1950s. He argues that one of the main problems in the development of nuclear power in Britain lay in the relationship between the state and the

[108] Pocock, *Nuclear Power*, p.47.
[109] Pocock, *Nuclear Power*, p.48.
[110] Pocock, *Nuclear Power*, p.221.
[111] Martin Theaker, 'Power Politics: Britain And Atomic Energy, 1945-62.' (Unpublished Masters, University of Birmingham, 2011), pp.2-3.

scientific community - particularly in light of the changing political regimes and international relations in relation to nuclear technology.[112] He claims that the atomic bombings in Japan had 'set the agenda for the future of weapons technology and international politics' resulting in increased government interest in science in relation to issues of 'national security and consequently, international position.'[113] However, I argue that this takes too narrow a viewpoint on national security and ignores the importance of energy supply to the ongoing security of the country.

Theaker also examines the introduction of nuclear power as a replacement or supplement for coal. He argues that during the early 1950s the Ministry of Fuel and Power had begun prioritising coal the use of coal for the generation of electricity in order to avoid a repeat of the winter of 1946/7, claiming that this process was made easier by the conversion of other industries, most notably the railways, to use oil based fuels.[114] However, as I demonstrate in this thesis, the conversion of the railways from coal to oil was incomplete and was highly vulnerable to fluctuations in the price of oil. Theaker shows that the British Government in the mid to late 1950s had accepted the idea that Britain was unlikely to be able to meet its energy requirements from coal alone. He argues that Britain was the ideal location for the development of a civilian nuclear programme in part due to the relatively secure supply of uranium achieved by Britain through the Combined Development Agency (CDA) as well as through the supplies from British Commonwealth countries.[115] As such the development of nuclear energy for electrical generation was highly attractive to the British Government as it offered a high level of energy security, which had previously only been provided by coal. However, there is nothing in this discussion about the ongoing environmental issues in Britain

[112] Theaker, 'power Politics', p.18.
[113] Theaker, 'power Politics', p.18.
[114] Theaker, 'Power Politics', p.18.
[115] Theaker, 'Power Politics', pp.28-29.
The Combined Development Agency (CDA) was established in 1943 by Britain and the United States in order to ensure adequate supplies of uranium for weapons development. For a more detailed discussion see Marian Radetzki, *Uranium: A Strategic Source Of Energy* (London: Routledge, 1980).

at this time - in particular the issues about pollution from coal fires which reached their height in the London Smogs of the 1950s.

Graham Walker's 2014 thesis, *UK Power Networks: The Political Discourse of British Nuclear Energy,* focuses on the importance of environmental and ecological issues in the development of Britain's nuclear power stations. He examines the origins of British nuclear power to show why Britain chose to develop the Magnox type reactors. He claims that for much of the early period of nuclear development the focus was on weapons development. He also argues that it was not until the mid-1960s that nuclear came to be seen as an alternative to coal. In chapter three Walker claims that the British government did not take any serious interest in the development of nuclear power for electrical generation until 1955 and that the interest was brought about by a combination of factors. Firstly the 'looming "energy gap" between supply and demand which coal alone could not bridge', and secondly the idea that nuclear power was vital to maintain Britain's status as a 'leading industrial nation.'[116] Walker points out in light of the ongoing problems with coal supplies, 'predictions of the potential for improvements in coal concurrent with nuclear developments are notable by their absence.' [117] From this it is evident that nuclear energy was coming to be viewed as a solution to Britain's dependence on coal. Walker goes on to point out that coal was to remain the dominant fuel for electrical generation in Britain until the development and exploitation of North Sea oil and gas in the 1970s.[118] Walker notes that the expected shortfall of coal predicted in 1955 did not occur and indeed the efficiency of coal plants outpaced developments in nuclear reactors. However, nuclear power remained a useful supplement to coal and was viewed as a means of limiting the political power of the Mining Unions.[119] Walker essentially shows that it is impossible to link the development of nuclear power in Britain to any one causal factor. National prestige,

---

[116] Graham Walker, 'UK Power Networks: The Political Discourse Of British Nuclear Energy.' (unpublished Doctoral Thesis, University of ESSEX, 2019), pp.68-69.
[117] Walker, 'UK Power Networks', p.70.
[118] Walker, 'UK Power Networks', p.71.
[119] Walker, 'UK Power Networks', pp.88-89.

politics, economics, military development and environmental issues all come into play at different times and with varying degrees of importance depending on national and international events. Thus, for the early years of nuclear development, covered in chapter seven, the key factors driving the development of nuclear energy were its military applications, the perceived shortage of coal and the difficulties in obtaining a secure supply of oil. I argue that of these factors, the difficulties in obtaining sufficient coal to meet energy demands was a crucial factor in the development of the British nuclear program.

2.5. Warfare State.

David Edgerton's Warfare State thesis has been developed and refined over the course of several books: *England and the Aeroplane*, *Warfare State*, *Britain's War Machine* and *The Rise and Fall of the British Nation*. All provide a counter to the traditional views of Britain during the inter-war period as being one of unpreparedness, retrenchment and pacifism. Instead, Edgerton shows that, throughout the inter-war period, the British State continued to invest a significant proportion of its available funds in the military. The armed forces also continued to invest heavily in new technology, contrary to traditional accounts which describe the British armed forces of the 1930s as reliant on out of date technology and as failing to embrace new designs and ideas.

2.5.1. England and the Aeroplane.

In *England and the Aeroplane*, Edgerton shows that, far from the commonly presented image of small struggling firms kept alive through being drip fed orders for obsolete aircraft, the British aviation industry was in fact highly industrialised and soon recovered and expanded during the mid-1920s.[120] He demonstrates that the ordering policy of the Air Ministry was deliberately designed to spread the available work across the entire industry.[121] This, as I will

[120] David Edgerton, *England And The Aeroplane: Militarism, Modernity And Machines.*, 2nd edn (London: Penguin, 2013), pp.34-38.
[121] Edgerton, *England and the Aeroplane*, pp.43-47.

show, was very similar to the way in which the CEB spread the orders for the National Grid across the entirety of the British electrical manufacturing industry.

Edgerton further points out that the use of airships and aeroplanes as bombers in the First World War raised concerns that 'Britain [was] no longer an island' and was now vulnerable to attack from the air. He concludes that this did not imply a fear of the aeroplane but was merely a product of English faith in technology.[122] However, when coupled with the increasing dependence on electricity, and as I will show in chapter three, it is evident that there was a growing concern about the vulnerability of British industry to disruption by aerial assault. *England and the Aeroplane* contains little information about the extent to which the aircraft manufacturing industry relied on electricity to operate. However, even assuming that aircraft construction continued to largely rely on 'traditional methods', the production of modern materials such as aluminium, required for production of the Spitfire, would not have been possible without ready access to a secure supply of electrical power. Likewise, it appears that the expansion of the industry in the late 1930s and into the Second World War, particularly the creation of shadow factories, would not have been achievable without access to centrally generated electricity.

2.5.2. Warfare State.

In *Warfare State* Edgerton expands on the thesis outlined in *England and the Aeroplane*, showing how the portrayal of Britain as a 'Keynesian-welfare state', which failed to transform its economy during the inter-war period, is a misleading depiction of the British state. Of particular relevance to this thesis is the conception of 'the expert state' in inter-war Britain. As Edgerton points out, this is at odds with the accepted view of senior civil servants being a product of 'Victorian Liberalism'.[123] However, Edgerton shows that this was not the case and that the civil service was also home to 'expert classes'. He further shows that the number of

[122] Edgerton, *England and the Aeroplane*, pp.69-74.
[123] Edgerton, *Warfare State*, p.108.

technical experts at senior levels of the civil service may have been underestimated, and many received highly competitive wages.[124] This is supported by both Leslie Hannah and Thomas Hughes, who have demonstrated that the senior administrators of the Central Electricity Board were drawn from the industry and selected due to their expertise as managers, financiers and above all as engineers. In addition to this, Hannah notes that the wages paid to board members were set to be competitive with private industry, the President in particular being paid more than the Minister of Transport.[125] This provided a clear indication of the importance placed on the development of electrical supply. Every single member of the CEB could be considered an expert in some aspect of the electrical supply industry.

Edgerton shows that histories of post-war reconstruction have largely ignored the role of the Warfare State, instead focusing on the creation of new ministries such as the Ministry of Supply, Ministry of Fuel and Power and the Ministry of Production.[126] He further argues that 'The warfare state, which dominated industry in wartime, does not appear and indeed appears not to exist.'[127] The same is true of histories of the electrical supply industry which have ignored both the continued military interest in power stations and the implications of new weapons, such as the atomic bomb, on the geographical location of new power stations.

2.5.3. Britain's War Machine.

In *Britain's War Machine: Weapons, Resources and Experts in the Second World War*, Edgerton continues to challenge what has become the accepted story of Britain as a 'plucky underdog.' He shows that far from the popular image of Britain as a beleaguered island standing alone against Nazi tyranny, it was instead secure at the centre of a global imperial production system, with strong allies and a well-equipped and military.[128] Edgerton also points out that prior to the Second World War Britain was 'Not only self-sufficient in energy, but was the

[124] Edgerton, *Warfare State*, pp.111-112.
[125] Hannah, *Electricity before Nationalisation*.
[126] Edgerton, *Warfare State*, p.64.
[127] Edgerton, *Warfare State*, p.65.
[128] David Edgerton, *Britain's War Machine: Weapons, Resources And Experts In The Second World War.* (London: Allen Lane, 2011). 17.

world's leading exporter of coal, the world's most important source of energy. […]. It exported more coal than it imported oil in all its forms.'[129]As I show, the development of the National Grid was central in enabling Britain to make the best possible use of its coal reserves, and in enabling the wider distribution of manufacturing industry around the country.

Edgerton next examines the massive expansion of the ordnance factories during the 1930s and into the Second World War.[130] However, while the importance of electricity to production at Metropolitan-Vickers is made in the introduction, the importance of electricity to industrial expansion or to defence is never fully developed. Furthermore, while Edgerton does comment on the development of communications infrastructure, there is no discussion of the considerable wartime extensions made to the National Grid to enable the transfer of power from under-utilised power stations or to enable the establishment of shadow factories during the Second World War. [131]

In discussing the development of radar during the mid-late 1930s, Edgerton particularly notes the dependence on 'high-power, high frequency radio transmission and reception.'[132] However, he does not consider the requirement for a secure supply of electricity in order to enable the operation of radar systems. While, as I demonstrate in chapter five, it would have been possible to run radar sites using petrol or diesel generators, this would have required a significant amount of oil, which would then have been unavailable for defensive or offensive operations, but instead dedicated to operating static defences. Edgerton again notes that, despite being a net exporter of energy, Britain was the world's largest importer of petroleum products and by the end of the war oil imports for all uses had doubled. [133]

[129] Edgerton, *Britain's War Machine*, p.17.
[130] Edgerton, *Britain's War Machine*, p.29.
[131] Edgerton, *Britain's War Machine*, p.199.
[132] Edgerton, *Britain's War Machine*, pp.39-41.
[133] Edgerton, *Britain's War Machine*, p.181.

2.5.4. The Rise and Fall of the British Nation.

Finally, in *The Rise and Fall of the British Nation: A Twentieth Century History*, Edgerton takes a longer view of the twentieth century, and the warfare state in Britain, placing this development into the wider context of the British Empire and global trade. He shows that many of the actions commonly attributed to the Labour Party of 1945, such as national healthcare and social support, had their origins with the Conservative Party of the 1920s, and were later expanded on by the Labour Government after the Second World War.[134] As I show in chapter four, the same is also true of the National Grid and the generation and supply of electricity, which was brought in by Stanley Baldwin's Conservative Government, and only brought fully under national control and ownership by the Labour party in 1945. Thus, the welfare state is perhaps better viewed as being a part of the warfare state.

Edgerton's use of 'anti-histories' is also highly significant, accounting for the disappearance of the idea of Britain as a strong and capable world power from the generally accepted histories.[135] The restoration of this narrative to the electrification of Britain during this period brings a new coherence to the development of the National Grid, lending structure to Thomas Hughes' account, and providing a clear motive for state involvement in electrical supply. As was the case with *Britain's War Machine*, Edgerton shows that for much of the twentieth century British wealth and prosperity was based almost entirely on the utilisation and exploitation of coal. Electrically powered refrigeration technology enabled the state to import much of the foodstuffs required to feed the nation, freeing up a greater percentage of the workforce for the factories, rather than being tied to the land.[136]

The importance of coal to the British economy throughout the first half of the Twentieth Century cannot be understated, and it is interesting to note that the consumption of coal

---

[134] Edgerton, *The Rise and Fall of the British Nation*, p.xxvii.
[135] 'Anti-history is a history of opposition to things which the commentator values, leading to the disappearance from history of what such histories intend to promote.'
Edgerton, *The Rise and Fall of the British Nation*, p.xxviii.
[136] Edgerton, *The Rise and Fall of the British Nation*, p.78.

within the United Kingdom was roughly the same in 1950 as it had been in 1913. Edgerton notes that coal was the primary source of energy for British transportation, the generation of both gas and electricity, as well as being the primary fuel for heating and cooking throughout Britain.[137] However, despite noting that much of the coal was 'burnt raw', Edgerton does not fully consider the importance of the ever-increasing use of coal to generate electricity throughout this period. This increasing use of electricity led to an overall decrease in the amount of coal burnt directly in homes and factories. While the creation of the National Grid and the Central Electricity Board is mentioned, it is not linked to either the development of industry or to changes in coal usage.[138] The amount of coal being used in Britain between 1913 and 1950 did not appreciably decrease; it was instead being burnt under what a 1919 Electrical Development Association pamphlet described as 'scientific control in power stations.'[139] Edgerton notes the changes in coal production during the Second World War, pointing out that despite decreases in the amount of coal raised, the British economy was able to continue to function largely due to the decrease in the demand for coal from foreign sources.[140] However, this does not take into account the changes in the ways in which coal was used, nor the effects of the strict energy rationing imposed on the country during the war. As I show in chapter five, the rationing system resulted in greater domestic use of electricity as coal supplies for domestic heating and cooking were reduced.

When discussing the nationalisation of industry in 1945, Edgerton, while discussing the changes in ownership, does not comment on the way in which all energy sources in Britain came under the control of the Ministry of Fuel and Power. Nevertheless, Edgerton does note that the nationalisation of industries such as electrical generation, transferred power from the shareholders to the state. However, in order to get the requisite legislation through

---

137 Edgerton, *The Rise and Fall of the British Nation*, p.81.
138 Edgerton, *The Rise and Fall of the British Nation*, pp.181-184.
139 'EDA 16: Britain's Buried Treasure.' (Manchester, 1919), Science and Industry Museum, Electrical Development Association.
140 Edgerton, *The Rise and Fall of the British Nation*, p.94.

Parliament, the Labour Government had to ensure that the shareholders were adequately compensated, despite arguing that these shareholders had put profit ahead of the wellbeing of the state.[141]

This certainly appears to have been the case with the generation of electricity. While much of the smaller and older generating plant had been replaced prior to the Second World War, there was still a large amount of generating plant operating which had not been replaced or updated with more efficient boilers and turbines. This was in part due to the expense of replacing the equipment; as was mentioned earlier, the cost of the equipment and machinery needed for a large generating plant was comparable to that of a battleship.

When examining the development of energy supply and infrastructure after 1950, Edgerton claims that, following nationalisation, energy was now a national endeavour, with all aspects of energy supply under the control of the state.[142] Electrical usage continued to rise, with oil, natural gas, nuclear and hydro-power supplementing coal generation, although, 'In electricity supply coal remained King despite the best efforts of planners.'[143] However, Edgerton does not address the reasons for this diversification of energy supply, and in particular does not appear to consider the impact of the Second World War coal shortages or the winter of 1946/7 on British energy policy. As I demonstrate in chapter seven, both events had a significant influence on energy policy, with the diversification of fuel supplies being seen as a means of ensuring security of energy supply and reducing the dependence on coal.

The application of Edgerton's concept of the Warfare State to the historical explanation of the development of electrical supply in Britain provides a rationale for governmental moves towards national control and organisation that is missing from the traditional historical

[141] Edgerton, *The Rise and Fall of the British Nation*, p.124.
[142] Edgerton, *The Rise and Fall of the British Nation*, p.291.
[143] Edgerton, *The Rise and Fall of the British Nation*, p.292.

narratives. It is this, I argue, that links the control over energy supplies to the issue of national security.

2.6 Environmental Histories.

The impact of electrical generation and distribution on the environment is a recurrent theme in this thesis. Concerns relating to the siting of pylons and power stations generally focused on aesthetic objections or human health issues rather than on wider environmental ecosystem damage in the way that such issues might play out today.

In *Rural Conservation in Inter-War Britain*, John Sheail looks at the ways in which the inter-war generations in Britain sought to use and manage the rural environment of the country.[144] According to Sheail, one of the main sources of opposition to rural development came from groups who opposed development due to perceived risks to the amenity and recreational use of the land. The Oxford English Dictionary describes amenity as being, ‘pleasant or agreeable’, particularly in relation to human activity.[145] Electricity was, for many of the groups, a major threat to the aesthetic enjoyment of the countryside as it enabled the migration of industry from the towns and cities into rural areas.[146] As we will see in chapter three, this was one of the features of electrification that was to be most strongly emphasised by Lloyd George and Eric Geddes in the early 1920s. The preservation of amenity remained a key theme in all electrical developments throughout the inter-war period, however, as I show in this thesis, despite the importance of amenity issues to rural development, the need for electrical power and military requirements frequently overcame those objections.

More recently in, *An Environmental History of Twentieth Century Britain*, Sheail examines the changing understanding and importance of environmental concerns in Britain during the

[144] John Sheail, *Rural Conservation In Inter-War Britain* (Oxford: Clarendon Press, 1981).
[145] ‘Amenity’, *Oxford English Dictionary Online* (Oxford: Oxford University Press, 2019) <https://www.oed.com/view/Entry/6315?redirectedFrom=amenity#eid> [Accessed 25 August 2019].
[146] Sheail, *Rural Conservation in Inter-War Britain*, p.31.

twentieth century. Sheail shows that many of the environmental issues were closely related to concerns about the health and wellbeing of the population, particularly in relation to sanitation and air quality. In chapter two Sheail examines the development of Local and National planning policy, briefly noting the military case for the geographic distribution of industry in the late 1920s and 30s away from the South East of England on the basis of Trenchard's claim that 'the bomber will always get through'.[147] However, he does not connect this to Lloyd George's plans for the railways and electricity which had been explicitly linked to the re-distribution of the urban population and manufacturing centres.[148] He explores the dilemma over the development of more centralised government planning and shows that rather than shifting power completely away from local authorities, the 1947 Town and Country Planning Act enabled both to work together more closely to make the best possible use of national resources.[149] In chapter five Sheail turns to the issue of amenity, noting a strong connection to the rise of an affluent middle class. He later shows how amenity came to be such a problem, particularly for the development of nuclear power plants in the late 1950s. However, Sheail does not link amenity issues to the earlier construction of conventional power stations such as Battersea or Bankside, both of which had faced significant challenges over amenity which, as we will see in chapters four and six, were either dismissed or overridden.[150] For Sheail the main connection between electrical power and the environment appears to be related to air pollution. In chapter eight he shows that both the government and amenity interests were becoming more active in combating air pollution and no longer regarded it as an 'inevitable consequence of industrialisation.' However, there appeared to be no practical method by which factory emissions could be reduced and legislation was largely ineffective.[151] According to Sheail, it was not until the London smogs of the 1950s that legislation was

---

[147] For more information see Ross Mahoney, 'Trenchard's Doctrine: Organisational Culture, The 'Air Force Spirit' And The Foundation Of The Royal Air Force In The Interwar Years.', *British Journal For Military History*, 4.2 (2018). 143-177.
[148] Sheail, *Rural Conservation in Inter-War Britain*, p.29.
[149] Sheail, *An Environmental History of Twentieth Century Britain*, p.43.
[150] Sheail, *An Environmental History of Twentieth Century Britain*, pp.132-133.
[151] Sheail, *An Environmental History of Twentieth Century Britain*, p.246.

seriously put forward to tackle air pollution. Sheail notes that electricity quickly took a central role in the promotion of the 1956 Clean Air Bill, due to the improvements in generating efficiency and the work of electricity suppliers in reducing emissions from power stations such as Battersea, Fulham and Bankside.[152] Although, as is pointed out by Bill Luckin in *Questions of Power*, these measures were not wholly successful and often created further problems.

In *Questions of Power*, Bill Luckin argues that the growth of domestic electrical usage and the development of the National Grid in the inter-war period demonstrates the victory of triumphalism over conservatism. This was a conflict which, he argues, had been at the centre of debates about science and technology in Britain for much of the eighteenth, nineteenth and twentieth centuries. Previously this debate had been shaped by the adoption of steam power and the development of the railway network, which had been viewed by conservatives as being detrimental to traditional ways of life and disruptive of social order. According to Luckin, 'triumphalists' argued that electricity would revitalise industry, transportation and domestic life, leading to increased productivity as well as improved quality of life.[153] Luckin examines the way in which these two ideologies interacted in the battle over the future of electricity in Britain. He begins by identifying the main proponents of these ideological systems, most notably the unsurprisingly pro-electrical, Electrical Development Association (EDA) and the Electrical Association for Women (EAW). The other side of this debate consisted of the well-established gas and coal interests. He examines the arguments put forward by these groups as well as the target audience for their campaigns. The main target demographic was middle class to upper middle-class families, particularly women. The main reasoning being that these groups had adequate disposable income to afford the often-expensive appliances. The arguments advanced by the pro-electrical groups initially centred around cost, before focusing on the health benefits of using electricity over either coal or gas. It is notable that proponents

---

[152] Sheail, *An Environmental History of Twentieth Century Britain*, p.251.
[153] Bill Luckin, *Questions Of Power: Electricity And Environment In Inter-War Britain.* (Manchester: Manchester University Press, 1990), pp.9-15.

of increased electrical usage such as the EDA initially concentrated on attempting to educate the general public about the economic possibilities and limitations of electricity as well as introducing them to the basic facts of this 'new science'. Advertisements frequently compared electricity to its two closest competitors, coal and gas, arguing that electricity was cleaner, safer, less labour intensive and above all cheaper than its better-established rivals.[154]

Luckin also notes that the protests against the construction of the Grid where largely dismissed by the government. Following a battle over the erection of electrical pylons on the South Downs, Sussex, protestors claimed that 'the state preached one thing to its citizens while practicing another' and suggested that government ministers appeared willing to 'ride roughshod over informed local opinion' in order to construct the Grid.[155] This pattern was repeated, not always successfully, across the country and ultimately the Government proved willing to compromise with local groups and authorities in order to complete the Grid, even if this meant taking the more expensive option of burying cables. While detailing the conflict between the Government and local authorities, Luckin does not examine the government's or the Central Electricity Board's reasons for picking those routes for pylons, nor the extent to which they were willing to increase the cost of the project in order to secure the desired route.

In dealing with the construction of Battersea Power Station, Luckin focuses on the problems surrounding the construction of a superstation within the metropolis. Opponents were particularly interested in issues relating to noxious emissions, which were regarded as hazardous to health and, more importantly, damaging to property. He notes that Herbert Morrison, the Labour Minister of Transport, was concerned that if ground was given over the construction of the Battersea plant then it would make way for a 'rash of injunctions against power stations in every part of the country', a situation which could not be tolerated.[156] Having explored the conflict between the electrical authorities and protestors, Luckin has not

[154] Luckin, *Questions of Power*, pp.9-15.
[155] Luckin, *Questions of Power*, pp.95-98.
[156] Luckin, *Questions of Power*, pp.149-150.

questioned why the Government was so invested in constructing a new power station on the Battersea site, despite, as we will see in chapter four, strong objections to the construction on the basis of amenity. As well as the argument that rather than providing for cleaner air and improved health, as was promised by electricity, the construction of Battersea power station threatened to increase pollution and health risks for the local area.

Lynda Nead's 2017 *'As Snug as a Bug in a Rug': post-war housing, homes and coal fires*, looks at the cultural and economic importance attached to the open coal fire in British houses during the inter-war period.[157] Nead argues that despite the limitations and inconveniences of coal fires they were symbolic of comfort and family life. She further argues that while these associations had existed prior to the First World War, they had been strengthened by wartime propaganda.[158] However, she notes that despite of the aesthetic appeal of the coal fire, there was a growing realisation and acknowledgement that not only were coal fire places contributing to the pollution of urban environments, but that it was also becoming a more expensive option than using gas or electricity.[159] She also points out that, due to the symbolic importance of the fireplace, it was more difficult for the authorities to regulate smoke from domestic dwellings than it was to regulate the emissions from factories and power stations.[160] However, Nead also notes that this infatuation with the comfort of the coal fire was highly gendered and that women tended to be more open to the idea of gas or electric heating as this would, at least in theory, reduce the amount of cleaning required.[161]

While the issues of amenity and air pollution were clearly of great importance to inter-war governments, the requirement for an economic and secure supply of electricity was of greater importance to national security. The threat to the environment from smoke or other forms of air pollution was viewed through the lens of its impact on the health and wellbeing of the

[157] Lynda Nead, ''As Snug As A Bug In A Rug': Post-War Housing, Homes And Coal Fires.', *Science Museum Group Journal*, 9.9 (2018) <https://doi.org/10.15180/180902>.
[158] Nead, ''As Snug As A Bug in a Rug'', p.3.
[159] Nead, ''As Snug As A Bug in a Rug'', p.4.
[160] Nead, ''As Snug As A Bug in a Rug'', p.12.
[161] Nead, ''As Snug As A Bug in a Rug'', p.14.

urban population, and, as was demonstrated by Luckin, electricity was seen as being part of the solution to that problem. Although, as Petra Dolata notes, it is only recently that environmental concerns have been construed as threats to national security, and this is with the exception of the Trump regime in the USA.[162]

2.7. National Security.

Writing in 1952, towards the end of the period covered in this thesis, Arnold Wolfers pointed out that the terms ‘national interest’ and ‘national security’ need to be carefully scrutinised as ‘they may not mean the same thing to different people’, although

> In a vague and general way ‘national interest’ does suggest a direction of policy which can be distinguished from several others which may present themselves as alternatives. It indicates that the policy is designed to promote demands which are ascribed to the nation rather than individuals, sub-national groups or mankind as a whole. It emphasises that the policy subordinates’ other interests to those of the nation. But beyond this, it has very little meaning.[163]

Wolfers claims that by the 1950s national interest had become synonymous with national security rather than welfare, largely ascribing this change to the impact of the Cold War.[164] However, he then goes on to explain that while common conceptions of security have focused on the ability of a state to deter or withstand attack, there is not one obvious means by which this can be achieved. Wolfers also notes that this concept of national security, especially if based on maintaining a nation’s values, may eventually become self-defeating as the measures implemented to ensure security are contrary to the values being defended.[165] The creation of the National Grid in 1926 by the Conservative Party can be viewed in this light. A large number of politicians on both sides of Parliament saw the development of a national electrical infrastructure as being vital for the development of British industry, to the extent that they passed legislation which, while leaving power stations and undertakings in private ownership,

---

[162] Petra Dolata, ‘The End Of The Security Paradigm Under Obama - Trump And Energy Security: Revival Of An Old Concept?’, *Journal Of Military And Strategic Studies*, 17.3 (2017), pp.92-106.
[163] Wolfers, 'National Security', p.481.
[164] Wolfers, 'National Security', p.482.
[165] Wolfers, 'National Security', pp.493-494.

effectively placed them under state control, in what a number of Conservative and Labour politicians saw as being a move towards nationalisation.

Moreover as Barry Buzzan argued in 1983, national security is deliberately maintained as a 'weakly conceptualised, ambiguously defined, but politically powerful concept' which if invoked provides 'considerable leverage over domestic affairs.'[166] By invoking the idea of national security, politicians are often able to pass measures which would appear to conflict with the economic or political situation of the country, or which, on the surface, appear to conflict with the ideology of the party or government.

More recently, David Baldwin notes that efforts to define security are often

> more concerned with redefining the policy agendas of nation-states than with the concept of security itself. [This] often takes the form of proposals for giving high priority to such issues as human rights, economics, […], in addition to the traditional concern with security from external military threats.[167]

As with Wolfer, Baldwin notes that these proposals are normally buttressed by normative arguments about which values should be protected and empirical arguments about the nature and magnitude of the threat. Baldwin then seeks to identify the 'common conceptual distinctions, which underlay different conceptions of security.'[168] One particularly important point is that concepts of security have often been more closely associated with military force than with other issues, and that for a large part of the twentieth century, discussions of national security have begun and ended with the military.[169] This is particularly relevant to discussions on energy security as some of the first clear indications of the importance ascribed to electrical power by the British state was its inclusion in Defence Regulations just prior to the

---

[166] Barry Buzan, *People, States, And Fear: The National Security Problem In International Relations.* (Chapel Hill: University of North Carolina Press, 1983), pp.4-9.
[167] David A. Baldwin, 'The Concept Of Security', *Review Of International Studies*, 23.1 (1997), 5-26 https://doi.org/10.1017/s0260210597000053, (p.5).
[168] Baldwin, 'The Concept of Security.', p.5.
[169] Baldwin, 'The Concept of Security.', p.9.

First World War, as well as the interest displayed by the British Army in the operation of civilian power stations in 1919.

Where Wolfers characterises security as being the 'absence of threats to acquired values', Baldwin modifies this to there being a 'low probability of damage to acquired values' thereby states or governments enact policies which deter or mitigate the possibility of damage. With this in mind, Baldwin argues that security can now 'be defined in terms of two specifications: Security for whom? And Security for which values?'[170] However, for Baldwin the answer to these questions is dependent on the research question(s) being asked. There is also the question of how much security is enough? While recognising that absolute security is an impossibility, Baldwin then asks what degree of security is enough, and further suggests that this is not a question that can or should be avoided. The next question raised by Baldwin regards the nature of the threat to be protected against, noting that people citing national security concerns rarely mention whether this refers to ideological, economic or military threats, or to some combination of the three.[171] The final three qualifying points relate to the means by which security is secured, the cost of securing security and the time period over which it takes place. Of these three, the concept of cost is particularly important. Baldwin points out that 'the pursuit of security always involves costs, i.e. the sacrifice of other goals that could have been pursued with the resources devoted to security.'[172] I would argue that this can also involve sacrificing values or freedoms in the name of security, as in the case of the Conservative Party and the National Grid, which involved some degree of sacrifice of the principles of free trade which were central to the Party.

However, Baldwin notes that while all these specifications are useful, they are not always all needed, and much will depend on the research question being answered.

---

[170] Baldwin, 'The Concept of Security.', p.13.
[171] Baldwin, 'The Concept of Security.', pp.5-26.
[172] Baldwin, 'The Concept of Security.', p.16

Baldwin then looks at the value of security, noting that security is often not the only thing valued by different groups and that the ‘pursuit of security necessitates the sacrifice of other values.’[173] After considering three different approaches to this problem, he concludes that:

Security is only one of many policy objectives competing for scarce resources, and subject to the law of diminishing returns. Thus, the value of an increment of national security to a country will vary from one country to another and one historical context to another, depending on not only how much security is needed, but also on how much security the country already has.[174] Clearly, it is important to historicise the concept of national security. This is certainly the case with the development of a national electrical supply in Britain during the inter-war period. As if often noted, the 1920s and 1930s are well known as periods of economic retrenchment, with massive cuts being made to budgets yet, despite this, spending on the National Grid appears to have been comparable to that on the military. This is perhaps not surprising due to the perceived threat from foreign industry during the 1920s and 1930s. A threat which politicians and engineers, such as Lloyd George, Charles Merz and Sebastian Ferranti, claimed would be reduced by the development of a cheap supply of electricity.

2.8. Energy Security.

In 2011, Aleh Cherp and Jessica Jewell argued that, while energy security has been a practical concern for almost a century, it has only emerged as a distinct area of academic study over the last few decades. [175] They claim that the limited ability of energy security studies to influence energy policy can be explained by an understanding of the ‘historic roots’ of energy security ideas.[176] They argue that we need to develop a unified field of energy security studies. They note that, historically, concepts of energy security have tended to centre around the supply of

---

[173] Baldwin, 'The Concept of Security.', p.18.
[174] Baldwin, 'The Concept of Security.', pp.19-20.
[175] Aleh Cherp and Jessica Jewell, ‘The Three Perspectives On Energy Security: Intellectual History, Disciplinary Roots And The Potential For Integration.’, *Current Opinion In Environmental Sustainability*, 3.4 (2011), 202-212 <https://doi.org/10.1016/j.cosust.2011.07.001>.
[176] Cherp and Jewell, 'The Three Perspectives of Energy Security.', p.202.

fuels to the military, highlighting the conversion of the Royal Navy from coal to oil in the early to mid-twentieth century, with the attendant, and much debated, risk to the Navy if the oil fields fell under enemy control. Cherp and Jewell claim that after the Second World War

> Developed nations became dependent on motorized vehicles fuelled by oil products, not just for passenger transport but also for food production, health care, manufacturing, heating, and electricity generation.[177]

Yet this claim overplays the importance of oil to the British economy, which even in the 1950s and 1960s was still highly dependent on coal as its primary energy source. Cherp and Jewell later claim that for the first three quarters of the twentieth century the most 'politically prominent problem of energy security was protecting oil supplies for the modern armies and economies.' However, the paper predominantly focuses on the 1970s and on US foreign policy, particularly towards the Middle East. This focus on oil also indicates that, as Baldwin noted, the primary focus was on military security. This ignores the importance of electrical power to the modern state, and as a result relegates fuels such as coal, and even nuclear energy, to a subordinate role. Yet as I show in chapter seven, at least in terms of electrical generation in Britain, oil along with nuclear power was merely a supplementary fuel source to coal. When discussing issues of energy security, Cherp and Jewell note the complexity of modern technological systems and their vulnerability to disruption by terrorist activity, accident or technical failure.[178] Again, this focus is primarily on the later part of the twentieth century, and as this thesis demonstrates, these issues were also under consideration during the earlier part of the century. The National Grid was at least partially developed in order to combat these issues, and as I show in chapter six, was successful in doing so. While this paper is certainly of great value to both historians of energy security and current policymakers, the case presented

[177] Cherp and Jewell, 'The Three Perspectives of Energy Security.', p.202.
[178] Cherp and Jewell, 'The Three Perspectives of Energy Security.', p.205.

would be strengthened by inclusion of the coal industry and a more comprehensive approach with less of a focus on direct military applications.

In 2011 Christian Winzer noted that although 'Energy Security is one of the main targets of energy policy the term has never been clearly defined.'[179] He points out that one commonality between the competing definitions of energy security is that 'they all include the idea of avoiding sudden changes in the availability of energy relative to demand.'[180] This is followed by an examination of what he describes as the three main groups of authors. The first of these groups describes energy security as being the 'continuity of energy commodity supplies', a definition which Winzer argues is central to all three groups. He notes that this concept is also used in technical analysis, where it is often referred to in terms of reliability and the ability of a system to adapt to changes in the demand and availability of energy supplies.[181] As we see in this thesis, the National Grid proved to be highly adaptable to changes in demand during the Second World War, the key weakness being the supply of fuel for the power stations. Winzer's second group defines energy security in terms of 'the physical availability of supplies to satisfy demand at a given price.' He suggests that this implies that security is only threatened if 'the scarcity of energy leads to prices above a certain threshold.' Winzer notes that this is more imprecise and can be difficult to measure, pointing out that 'continuity and price levels that are considered insecure by one country could be completely sufficient for another country.'[182] However, I argue that the point at which a country deems energy supplies to be insecure is dependent on a wide range of factors and, as such, can vary over time and due to national circumstances. Therefore, continuity and price levels that a country deems insufficient during times of peace may be deemed sufficient during time of war or other forms of national emergency. Winzer's third group extend the scope of impact measure to include the impact on

---

[179] Christian Winzer, *Conceptualizing Energy Security*, Cambridge Working Paper In Economics (Cambridge: Electric Policy Research Group, 2011), p.1.
[180] Winzer, Conceptualizing Energy Security, p.4.
[181] Winzer, Conceptualizing Energy Security, p.4.
[182] Winzer, Conceptualizing Energy Security, p.5.

the economy and environment. In this model, disruption to energy supplies extends to the wider economy and to domestic households, taking into account the loss of production in industry as well as the impact on the lives of the population brought about by disruptions to energy supply.[183] Winzer also points out that in many cases security of supply is not explicitly defined by authors, but that it is possible to draw conclusions about the implicit definitions of security of supply in their work. He notes that many authors treat the different risk factors as separate categories, distinguishing between technological risks, natural risks and geopolitical risks. He further notes that where energy security is discussed in this way it is often as a small part of a much wider ranging discussion.[184] This is certainly the case with most discussion on energy security that take place within the British Parliament in the period covered by this thesis. Winzer concludes by claiming that the common concept behind all of the definitions of energy security studied is 'the absence of protection from or adaptability to threats that are caused by or have an impact on the energy supply chain.'[185] This certainly fits with the issues which I argue the development of a national electrical supply was intended to combat, ensuring the best use of British coal reserves for the future and to ensure a secure supply of electricity to British industry.

More recently in *Coal & Empire* Peter Shulman examines the importance of coal to the United States of America during the mid-nineteenth to early twentieth century.[186] Shulman extends discussions over energy security and national security to the development of coal resources by the United States of America during the nineteenth century. By connecting the development of steam powered ships and the need to ensure secure supplies of high-quality coal, Shulman shows that energy security is intrinsically linked to national security and particularly to foreign policy in setting up global coaling stations and trade agreements to ensure adequate supplies

---

[183] Winzer, Conceptualizing Energy Security, p.6.
[184] Winzer, Conceptualizing Energy Security, pp.7-8.
[185] Winzer, Conceptualizing Energy Security, p.24.
[186] Peter A Shulman, *Coal & Empire: The Birth Of Energy Security In Industrial America* (Baltimore, Maryland: Johns Hopkins University Press, 2015).

of coal for the United States Navy. Shulman also analyses the work undertaken by the US Navy to scientifically assess the quality of coal throughout the continental United States. This is one of the few occasions in the text in which the energy needs of organisations and businesses outside of the military are discussed, in this case the railways. Shulman notes that the United States Navy employed Walter Johnson, a Professor at the University of Pennsylvania, to identify the best coal for naval use. He argues that this project was ‘designed to utilize the needs of national defence to launch research that might yield a broader social and economic benefit.’[187] However, Shulman does not follow through to assess the impact of the research on any of these other institutions.

Later in the book, Shulman demonstrates the ways in which American businessmen and engineers such as Harrington Emmerson viewed the coal reserves discovered in the Pacific Basin and particularly in Alaska as being vital to the future development of American commerce and industry. However, this theme is again not developed with attention being switched back to the significance of these reserves for the United States Navy.[188] In the concluding chapters Shulman shows how the ‘rhetoric of energy for national defence had slipped beyond the control of the designated defenders of the nation’. He shows that Americans conceived of fuel as being vital for national security at least in part because of the economic and social activities which it enabled to take place. Particularly in terms of trade and communication, this was as true for coal in the nineteenth century as it was for oil in the twentieth century.[189] Shulman argues that for the United States, energy security came to be conflated with national security as a direct result of the expansion of American interests beyond the continental United States. It is about energy independence and whether the US Navy should rely solely on domestic fuels, with the attendant difficulties of transport and higher costs, or whether they should risk relying on local markets.[190] However, this is still a

[187] Shulman, Coal & Empire, p.47.
[188] Shulman, Coal & Empire, pp.180-183.
[189] Shulman, Coal & Empire, p.217.
[190] Shulman, Coal & Empire, pp.226-227.

narrow conception of energy security. It does not consider the energy requirements of the domestic industries or the ways in which domestic industry served to underpin and enable military operations. As was pointed out by Yates Stirling in his 1917 *Fundamentals of Naval Service*,

> Men have been known to starve and yet fight and again advance to battle, but history has been silent upon the act of a warship, without coal and oil, or without ammunition, doing such heroic acts of duty.[191]

While Shulman comprehensively deals with the supply of coal to the US Navy and merchant marine, he does not account for the factories producing the goods to be traded overseas, or those supplying the munitions and ammunition required for the armed forces to function. Both of which he has already suggested are vital to national security.[192] Shulman's final point, delivered almost as an afterthought is that 'national interest' is a 'contested concept whose significance changes overtime.'[193] This concept is central to any discussion on energy security and national security and is further explored by Abdelrahman Azzuni and Christian Breyer in their 2017 paper, *Definitions And Dimensions Of Energy Security: A Literature Review.*

Azzuni and Breyer argue that energy security has thus far not had any fixed definition, further noting that the number of potential definitions provided has increased in recent years.[194] They finally provide their own definition of energy security as 'the feature (measure, situation, or a status) in which a related system functions optimally and sustainably in all its dimensions, freely from any threats.'[195] However, this appears to an unobtainable ideal. Instead, as is the case with definitions of national security, it appears to be more productive to think in terms of degrees of energy security. Interestingly, Abdelrahman *et al.* note that electricity was not included in studies on energy security prior to 2007, when Rutherford *et al.* published a paper

---

[191] Yates Stirling, *Fundamentals Of Naval Service* (Philadelphia: J.B. Lippincott Co, 1917), p.217.
[192] Shulman, Coal & Empire, p.217.
[193] Shulman, Coal & Empire, p.228.
[194] Abdelrahman Azzuni and Christian Breyer, 'Definitions And Dimensions Of Energy Security: A Literature Review', *Wiley Interdisciplinary Reviews: Energy And Environment*, 7.1 (2017), 1-34 https://doi.org/10.1002/wene.268, (p.4).
[195]Azzuni and Breyer, 'Definitions and Dimensions of Energy Security.', p.5.

on *'Linking Consumer Energy Efficiency with Security of Supply'*.[196] However, as I show in this thesis, concerns over energy security, particularly relating to the use of coal and electricity, can be traced back to Britain's experience during the First World War.

2.9. Summary.

In this thesis, I connect these broad areas of research, reassessing the motives for state interest in the development of a nationally coordinated electricity supply. I argue that, between 1914 and 1956, successive British governments viewed the creation of a nationally coordinated electrical supply network as being in the national interest and vital to national security. However, the meaning of national security varied depending on whether the country was at war. During wartime, the need for security of supply was the dominant factor, whereas during peacetime, economy of supply was the most important factor. The tension between these two considerations plays out throughout the different chapters of this thesis. Moreover, I show that the development of a nationally coordinated electrical supply is a logical and, indeed, necessary part of David Edgerton's Warfare State. I argue that the development of the National Grid was crucial in enabling the most efficient use of Britain's mineral resources and ensuring a secure and economic energy supply. Unlike town gas, which was entirely dependent on coal, electricity could not only be generated using different fuels, but could also be transmitted long distances, enabling supply to be shared between neighbouring towns and regions. This interconnection meant that not only could undertakers combine their most efficient plant, only running older plant during times of peak demand, but also that, when needed, vital services and factories could be supplied from neighbouring regions in the event of damage to the local power station. Yet on the outbreak of the First World War the situation in Britain was very different. The supply of electricity was split between private and municipal companies serving small regions; each to their own specification and standard. Legislation

[196] J.P. Rutherford, E.W. Scharpf and C.G. Carrington, 'Linking Consumer Energy Efficiency With Security Of Supply', *Energy Policy*, 35.5 (2007), 3025-3035 <https://doi.org/10.1016/j.enpol.2006.10.031>.

designed to prevent the formation of a monopoly restricted companies from serving larger areas, which limited the size and capacity of generating plants. It was by no means obvious that within a period of fifty years electrical supply in Britain would go from being highly fragmented and primarily providing electrical light, to being a nationally owned, interconnected industry, serving as the primary source of power for industrial and domestic use. The following chapter explores the provision of electrical power in Britain during the First World War and the way in which the experience of electrical use and management during the War shaped the development of electrical policy for the next fifty years.

3. The Great War: A First Experiment in the National Coordination of Electricity Supply.

Before the Ministry of Munitions had been many months in existence it became obvious that electric power supply was bound to play a large and increasingly important part in munitions production, […].

-HISTORY OF THE ELECTRIC POWER SUPPLY DEPARTMENT OF THE MINISTRY OF MUNITIONS-[1]

3.1. Introduction.

Prior to the First World War electrical supply in Britain had been organised along parish and municipal boundaries. There was a mix of Active Current and Direct Current generating stations, operating at a wide range of different voltages and frequencies. The existing electrical legislation largely prevented companies from expanding their areas of supply or connecting with neighbouring regions. Furthermore, many factories supplied their own power, either using steam plant to directly drive machinery, or generating their own electricity on site rather than accepting supply from a central generating station.[2]

In May 1913, the British government had commenced alterations and extensions to the state-run explosive works at Crombie, near Rosyth Dockyard, in Scotland. In keeping with the

[1] MUN 5/377/1380/1 'Work of Electric Power Supply Department from June 1915 To November 1918.' (London, 1919), The National Archives (TNA), Ministry of Munitions, pp. 1-15.
[2] For a more complete account of the state of electrical supply in Britain pre 1914 see:
Graeme Gooday, *Domesticating Electricity: Technology, Uncertainty And Gender, 1880–1914.* (London: Routledge, 2008).
Leslie Hannah, *Electricity Before Nationalisation: A Study Of The Development Of The Electricity Supply Industry In Britain To 1948.* (London: Macmillan, 1979).
Thomas P Hughes, *Networks Of Power: Electrification In Western Society, 1880-1930.* (Baltimore: The Johns Hopkins University Press, 1983).

existing model of localised generation, alternations at Crombie included the installation of an electrical generating station on the site.[3] By the end of the First World War, the Ministry of Munitions reported that not only had the Crombie works had been forced to take a supply of electricity from the local undertakers, but that its own generating plant was now outdated, incapable of further expansion and should be scrapped. Instead, the Crombie works would now operate entirely on centrally generated electricity. Government-owned ordinance works were not alone in switching to centrally-generated electricity: By November 1918, almost 95% of munitions factories in Britain received their power from central generating stations and it was unlikely that any of the factories converted during the war abandoned centrally generated electric power when returning to peacetime production. The First World War, therefore, exposed the pre-war lack of standardisation of electrical generation and supply around the country, and revealed inefficiencies inherent in a model of localised generation.

The official records of the work of the Electric Supply Department of the Ministry of Munitions shows that '103 Municipal and 33 Company owned power stations' were either extended or built over the course of the First World War. Table 3.1 shows the increase in capacity of the 327 municipal and 230 privately owned companies in existence between June 1914 and October 1918.

	Kw installed June 1914.	Kw installed or on order in October 1918	Increased by
Municipal undertakings	712,000 Kw	1,490,000 Kw	778,000 Kw
Company owned Power stations	410,000 Kw	758,000 Kw	348,000 Kw

Table 3.1. (Figures taken from MUN 5/377/1350) The Total Kw either installed or on order in Britain had doubled between 1914 and 1918. The Largest increase was in municipal owned stations in cities such as Manchester, Sheffield and Birmingham.

By the end of the War generating plant capacity in Britain had almost doubled compared to 1914 levels. The Ministry of Munitions report showed that '[T]he additional plant installed or

[3] 'Electricity In Explosive Works', *The Electrician*, LXXI.1824 (1913). 153.

ordered during the War, therefore, aggregated 1,127,000 Kw, […]. Almost exactly equal to the total plant capacity existing when the war broke out.'[4]

In this chapter, I examine the reasons behind this significant increase in electrical usage by British industry and explore the ways in which the First World War impacted on the generation and use of electricity in Britain. I focus on the way in which use of electricity helped to alleviate the losses in coal production as large numbers of miners joined the armed forces. I also examine the increasing use of electricity by the armed forces, particularly the British Army on the Western Front and the parallels with civilian electrical networks. Finally, I show how the experience of more centralised control, under the Ministry of Munitions, as well as operational experience of interconnection between local power stations, informed the work of wartime committees charged with investigating the future of the electrical supply industry in Britain.

I argue that the increased energy requirements of the state during the First World War served as a catalyst for increased State involvement in the generation and transmission of electricity. The shortage of coal, combined with the conflicting manpower demands of industry and the military, forced the State to intervene in the organisation of the electrical supply industry. Thereby ensuring the best possible use of the available mineral and manpower resources and facilitating the continued operation of industry and supply of munitions to the Front Lines. During this period ensuring the provision of power to munitions factories took priority of economic factors with additional generating capacity being developed only in areas engaged on war work. Provision of new connections for domestic dwellings and non-war related work was prohibited and when required power supplies for public transport were diverted to maintain munitions production.

[4] MUN 5/377/1380/1 'Work of Electric Power Supply Department from June 1915 To November 1918.' (London, 1919), The National Archives (TNA), Ministry of Munitions.


BRITAIN'S MOTTO:—
"Business as Usual"
¶ You cannot do business without your Printer and Stationer.
¶ A Business House is judged by its Stationery.
¶ Therefore place your Orders now and help to support the Industries of South Wales.
The Tudor Printing Works
(WESTERN MAIL, LTD.).
have 200 highly-trained Artisans at your service who can produce
PRINTING OF ALL KINDS
at the shortest notice.
TELEPHONE 2535.
BRITAIN'S MOTTO:—
"Business as Usual"

Figure 3.1. Western Mail, 21 August 1914: p1, c4.

3.2. August 1914 – April 1915: 'Business as Usual' in the Transition from Peace to War.

When Britain entered the First World War in August 1914, most people assumed that the war would be over by Christmas. Lloyd George, as Chancellor of the Exchequer, famously told businessmen that it would be 'business as usual', a phrase which was soon picked up in advertising material across the country.[5] Indeed, the language used in these adverts indicates that by carrying on 'business as usual' people would be supporting British industry and doing their duty to their country. According to Leslie Hannah, during the first year of the war electricity undertakings across the country witnessed a decline in sales. A report in the *Daily Record* on 16 October 1914 commented that daily life in London had been severely affected by the outbreak of war, particularly noting:

[5] The Western Mail was initially published in the early to mid-1800s, it was conservative leaning but was priced to be affordable for working class readers. The Western Mail was regarded as the foremost paper in Wales. Western Daily Mail, 'Britain's Motto: 'Business As Usual', 1914. p. 1.

> The earlier closure of licensed premises, the lighting restrictions, the suspending of evening performances […] the tendency towards earlier shopping, and the general shortening of the evenings while the advancing season lengthen them, are but a few signs of the times in which we live.[6]

The editorial team of *The Electrician* journal also noted the use of the phrase ‘business as usual’, claiming that this was especially applicable to the electrical industry.[7] They completed a survey of ‘The principle electrical manufacturing films and supply houses’ and found ‘there [was] no occasion for uneasiness, nor [had] there been any unwonted falling-off in trade.’ The editor of *The Electrician* went on to suggest that if the war continued for any length of time staffing problems might become an issue, but that any loss of custom through lighting restrictions or closure of factories would likely be offset by gains from factories running on overtime or the establishment of new industries as a result of wartime demands.[8]

During the early months of the war electrical engineers were being actively encouraged to join the armed forces. In October 1914, a notice in *The Electrician* highlighted a call from the London Electrical Engineers Regiment for ‘members of the electrical professions to join a corps where their technical abilities [would] prove a valuable asset to their country.’[9] It should be noted that this was not the first opportunity for electrical engineers to serve directly with the armed forces. On 2 October a notice had been circulated calling for engineers to join the Engineer Units of the Royal Naval Division, looking specifically for men with ‘actual experience of constructional work’. When considered alongside the provisions in the Defence of the Realm Act (DORA) this likely indicates that at this stage of the war, the Royal Navy intended to construct their own power facilities at key bases and dockyards and there are indications that some generating equipment destined for civilian power stations was appropriated by the

---

[6] ‘Changing London’, Daily Record, 16th December 1914, p.4.
The Daily Record was a Conservative leaning daily paper published in Glasgow; it had a record of supporting the Scottish Unionist Party.
[7] The Electrician was published between 1861 and 1952 and was advertised as being a weekly illustrated journal of electrical engineering, industry and science. In addition to the practical aspects of electrical engineering the journal also devoted a significant amount of space to experimental and theoretical work.
[8] ‘Business As Usual’, *The Electrician*, LXXII.1891 (1914), p.779.
[9] ‘London Electrical Engineers Recruiting’, *The Electrician*, LXXIV.1899 (1914), p.2.

Admiralty. Provision for this was included in an early draft of the Defence of the Realm Act in November 1914 in which it was stated that:

> It shall be lawful for the competent naval or military authority […] to take possession of any buildings or other property including works for the supply of gas, electricity, or water, and of any sources of water supply.[10]

The Defence of the Realm Act also specified that naval or military authorities could require the preparation of any such buildings or facilities for destruction presumably to prevent its use by the enemy in the event of an invasion clearly demonstrating the importance attached to public utilities, including electricity supply, by the government for military use.[11] Indeed, the importance attached to utilities such as electric power stations had been previously demonstrated by their designation as 'prohibited places' in the Official Secrets Act of 1911 on the grounds that 'information with respect thereto, or the destruction or obstruction thereof, or interference therewith, would be useful to an enemy.'[12]

As had been predicted in *The Electrician*, revenue from many electrical undertakings, particularly in the south, did indeed fall during this period as lighting restrictions cut into the main load provider of many of Britain's power stations. However, despite this initial reduction in custom, electrical engineers continued to predict increasing loads and applications for new or extended plant continued throughout the later part of 1914. Figures in the *Garcke Manual of Electricity Undertaking's* show an increase in the generating capacity of the country during 1914. Table 3.2 shows the total plant capacity in England between 1912 and 1915.[13]

---

[10] 'Second Supplement To The London Gazette.', *London Gazette*, 1914, pp.6379-6383 <http://www.thegazette.co.uk/London/issue/28869/supplement/6379/data.htm> [Accessed 1 October 2016], p.6379

[11] 'Second Supplement to the London Gazette', p.6380.

[12] Official Secrets Act, 1911.1 & 2 GEO. 5. CH. 28. (London: Her Majesty's Stationary Office, 1911), 1-8, (p.5).

[13] The Garcke Manual was founded by Emile Garcke in 1896 and published by Electrical Press Ltd. The Garcke Manuals carried a range of advertisements as well as data concerning electrical generation in all British electrical undertakings. The manual was compiled as a private concern

Year	Number of Undertakings	Municipal Corporations	Number of undertakings	Private Companies	Total Number of Undertakings	Combined Totals
1912-13	204	696,673 kw	95	374,178 kw	299	1,070,851 kw
1913-14	193	736,236 kw	90	383,381 kw	283	1,119,617 kw
1914-15	198	910,882 kw	101	438,439 kw	299	1,349,321 kw

Table 3.2. (Table taken from the 1918 Garcke Manual)

While the overall increase in generating capacity in 1914 was not huge, there was nonetheless a clear increase of some 48,766 Kw from the previous year; there was also an increase in the number of power undertakings in operation, both in terms of municipal corporations and in terms of private companies. These figures were consistent with the recorded increases for 1912 and 1913 demonstrating that, contrary to claims by Hannah, the outbreak of the war did not adversely affect electrical development during this period. Notes in *The Electrician* indicate that while the 'power load' was already beginning to increase prior to 1914, there had also been a corresponding loss of the lighting load due to lighting restrictions.

> Although the supply of electrical energy for lighting is still an important item in the output of large electric supply stations in this country, recent years have witnessed an enormous development in what is known as the 'power load.' To meet the growing demands of manufacturers for electrical energy at a cheap rate, many undertakings have had to extend and modify their systems of supply very considerably.[14]

This increase in demand for industry was particularly noticeable in the Midlands and the North, as demonstrated by applications for plant and plant extensions reported in *The Electrician* on 31 October 1913, with extensions sought in Darlington, Grimsby, Leicester, Plymouth, Poplar (London), Salford, Southampton, and South Shields.[15] These applications can

[14] 'Interesting Features At Bradford.', *The Electrician*, LXX.1795 (1912), p.20.
[15] 'Extensions.', *The Electrician,* LXXII.1850 (1914), p.151.

be taken as representative of the requests for extensions at this time, with similar requests evident over several editions of the journal.

A similar pattern is perceptible for late 1914, with an entry for 16 October 1914 showing extensions requested for Bradford, London, Luton, Salford, Turton, in Lancashire, Walsall, and West Bromwich.[16] At the same time it was reported that arrangements had been made between the Electricity Council in Dover and the Admiralty for power to be supplied to 'war department buildings on the east side of Dover, to the new Marine Station and the Post Office.'[17] This contributed to an increase in electrical usage, as can be seen in table 3.3, which shows an increase in income and demand from private lighting, power and traction over the previous year.[18]

Usage	**1914**	**1913**	**Difference**
Private Lighting	£2544	£2418	+£126
Private Power	£1065	£403	+£662
Public Lighting	£618	£672	-£54
Traction	£1018	£935	+£83
Meter rents	£176	£172	+£4
Sundries	£115	£154	-£39
Total	£5539	£4756	+£782
Units sold	341,175	256,307	+84,868

Table 3.3. (Data taken from the Dover Express. 6 November 1914.)

While not necessarily representative of the entire country, these figures do bear out the prediction made earlier that year by the editors of *The Electrician,* that any shortfall in demand due to lighting restrictions would be compensated for by increased usage for war purposes. The city of Birmingham saw a significant increase in demand for electricity as a result of wartime production. Having been granted permission for the construction of a new powerhouse at Nechells in 1913 to account for predicted peacetime increases in demand, however, the city

[16] 'Extensions.', *The Electrician,* LXXIV.1900 (1914), p.60.
[17] 'General.', *The Electrician,* LXXIV.1900 (1914), p.60.
[18] 'Electricity Committee', Dover Express, 6th November 1914, p.4.

had witnessed a massive increase in demand due to munitions work. The *Birmingham Daily Mail* reported that:

> Since October last, applications for large supplies for power purposes have been received, which are required for the manufacture of war material. […], and there is no doubt that still greater demands will be made upon the undertaking in the near future. The existing stations will carry the department through the present winter, but they will not be capable of meeting the ordinary growth of the undertaking during the winter 1915-16 in addition to this abnormal demand.[19]

This national increase in industrial usage connected with munitions development was also evident in places such as Bradford, Barrow, Manchester and Sheffield where extensions to the existing networks had either been already planned or underway prior to the outbreak of the First World War. However, the rapid increase in industrial demand soon began to exceed the savings realised from street lighting and domestic users, and electrical suppliers across the country struggled to meet the demand. In Manchester plans for a new power station on Great Barton Street were considerably advanced by the end of 1914 with tenders being invited for plant equipment as well as approval to borrow £543,000 from the Local Government Board (LGB) in order to construct further additions to the cities generating capacity.[20] In November 1914, the town of Barrow had entered into an extended contract with Vickers, having agreed to supply 5,000,000 units per annum for a period of three years, demonstrating that Vickers were confident that the war was going to last long enough to make such a contract worthwhile[21]. In Bradford, a sum of £5,000 was authorised to carry out a series of mains extensions and renewals, due to increased industrial usage of electricity.[22] Meanwhile in Sheffield mains extensions costing £796 were approved to extend mains around the city while

[19] 'Demands For Electrical Power', Birmingham Mail, 31st December 1914, p.4.
The Birmingham Mail dates back to the 1870s serving the local region. There are no records of the political ideology of the paper's owners or editors.
[20] 'Extensions', *The Electrician*, LXXIV.1903 (1914), p.194.
'Extensions', *The Electrician*, LXXIV.1907 (1914), p.301.
[21] 'General', *The Electrician*, LXXIV.1902 (1914), p.160.
[22] 'Extensions', *The Electrician,* LXXIV.126 (1914), p.126.

permission was being sought to borrow £85,400 to purchase an additional plant for the Neepsend powerhouse.[23] Some of this expenditure was simply routine maintenance and renewal of equipment and cables, but much of it was related to increased wartime industrial usage.

By January 1915 the need for power in Birmingham resulting from wartime demand was so much in excess of anticipated growth that the Electricity Council elected to begin work on a temporary extension to the main power plant at a cost of £97,300 in anticipation of gaining sanction from the LGB. This was despite the anticipation that the work would not be cost effective. This temporary expedient was merely intended to provide cover until the new powerhouse was completed in the winter of 1916-17 and was solely a response to wartime demand.[24] The Council's pre-war plans, while more cost effective, could not be completed in time to provide the extra power demanded for munitions work – a demand which was considerably in excess of pre-war growth predictions.

3.2.1. Material Shortages.

New construction was still being approved across the country but shortages of materials, such as steel, needed for the construction of new power plants caused delays in some places. In his annual statement, the Mayor of Huddersfield noted that, while the electricity supply department had connected an additional 626 customers, the 'new 5,000 Kw turbo alternator, ordered at the beginning of the year, was being erected, but owing to the war it would be very much behind the specified date for completion.'[25]

By the end of 1914, there was a growing realisation that the war would not be over quickly, and the importance of restricting spending and the use of raw materials on non-essential work meant that the LGB were directed to refuse any applications that would not be of immediate benefit to the prosecution of the war effort. One project effected by this was the construction

---

[23] 'Extensions.', *The Electrician,* LXXIV.1908 (1914), p.335.
[24] 'Electricity Supply at Birmingham.', *The Electrician,* LXXIV.1914 (1915). p.479.
[25] 'General.', *The Electrician,* LXXIV.1906 (1914), pp.266-67.

of the new power station on Great Barton Street in Manchester for which, according to a report in *The Electrical Times*, the board, 'taking its cue from the Treasury – in accordance with the public policy of restriction on capital expenditure', refused funding in December 1914.[26] It should be noted that, insofar as it has been possible to ascertain, there was no official policy restricting capital expenditure in place during 1914, and nothing was mentioned in Parliament until May 1915.[27] The fight for the new station at Great Barton Street continued throughout the early part of 1915. With the Manchester Corporation Electricity Committee continuing to push both the Treasury and the LGB to approve the loan, arguing that they were receiving continuous demands for electric power from large firms in the area, many of whom were engaged in the production of war materials.[28] A shortage of funding and construction materials was not the only problem facing power undertakings at this time. There were early indications that coal shortages would also become a serious consideration.

3.2.2. Coal Power.

Unlike countries such as the United States or Germany which were able to make greater use of hydroelectric power, Britain was primarily reliant on coal-fired power stations for its supply of electricity. Demands were also being placed on coal supplies by the gas industry, railways, the Merchant Navy and the Admiralty, as well as by domestic users across the country, with many families still reliant on coal fires for heating and cooking. In addition, coal exports formed a major part of Britain's overseas trade. However, during the first six months of the war coal production declined as miners left to join the armed forces. On 29 October 1914, the *Yorkshire Post* reported labour shortages throughout the South Wales coalfields 'owing to the rush to the colours.'[29] On 18 November 1914, Sir Joseph Walton a Liberal MP and British coal owner,

---

[26] 'Manchester.', *The Electrical Times,* XLVII (1915), p.461.
[27] 'TREASURY AND SUBORDINATE DEPARTMENTS.' HC Deb 13 May 1915, Vol.71, cc1878-97.
[28] 'Manchester.', *The Electrician,* LXXIV.1922 (1914), p.829.
[29] 'The Revival Of Trade', Yorkshire Post and Leeds Intelligencer, 29th October 1914, p.7.
The Yorkshire Post was a conservative leaning paper published from 1754. It featured stories from around the world but with a special focus on news and events in Yorkshire.

reported that 16,000 Yorkshire coal miners had enlisted on that day alone.[30] Barry Supple notes that by the end of first year of the war approximately 250,000 miners had left to join the armed forces. Consequently, in 1914 a total of 265.7million tons of coal was raised, compared to 287.4 million tons in 1913.[31]

In addition to the loss of trained miners to the front lines, July 1914 saw the beginning of a series of disputes between miners, mine owners, and the government which were to resonate beyond the First World War, with significant implications for energy security and the continuity of British coal supplies. The source of the disputes during the war can be traced, I argue, back to increases in food costs (24 percent) and living costs (20 percent) between July 1914 and March 1915, with the Executive Committee of the MFGB calling for a 20 percent increase in national earnings, this call for a national wage was rejected by the miner owners, who felt that wages should be decided locally, in part due to fears that this would disproportionally effect mine owners in less profitable areas.

While this shortfall in coal supply was initially absorbed by reducing domestic supplies for cooking and heating, undertakings around the country, and particularly in the south began experiencing problems with coal deliveries. Problems were reported in Bexhill and Portsmouth, both because of difficulties in obtaining sea-borne coal and the high costs associated with rail-borne coal.[32] At this early stage of the war, these shortages only appeared to affect power stations in the south of the country, however, as the demand for coal increased power undertakings were too come under increasing pressure to economise on coal usage.

3.2.3. Balancing Demand.

In March 1915, a report in *The Electrician* confirmed that in general there had been a considerable loss in revenue due to the war. However, the primary cause of this loss of

---

[30] 'SELECT COMMITTEE APPOINTED.' HC Deb, 18 November 1914, Vol.68, C509.

[31] Barry Supple, *The History of The British Coal Industry, 1914-1946: The Political Economy of Decline.* (Oxford: Clarendon, 1987), pp.44-48.

[32] 'Coal Supply for Electricity Works.', *The Electrician*, LXXIV.1914 (1915), pp.542-43.

revenue did not appear to be due to lost custom, but rather resulting from increases in the cost of coal and an increase in wage bills, both of which had risen since the outbreak of the war. This resulted in many electrical undertakings being forced to increase prices. At the general meeting of The Newcastle upon Tyne Electric Supply Company, Sir J. H. Armstrong commented that:

> The demands upon [NesCo's] supply had been extremely heavy on account of the manufacture of war material, and that had all business remained normal it would have been impossible to meet the Government's requirements without having to cut down a considerable portion of the current supplied to the general consumer.

The loss in demand for electricity from sources such as lighting provided a buffer, which helped undertakings to absorb the initial increase in the industrial power load. Armstrong's report also suggests that, had engineering works been reliant on their own generating plant for power, they would almost certainly have been worse off. Due to Board of Trade restrictions, they would have experienced considerable difficulties in the extending generating plant to meet their expanded power requirements and would have been unable to meet the need for munitions. In contrast to which power companies 'owing to the flexibility of [their] plant [were] able to provide much more [flexibility] in this direction.'[33]

The first year of the War had seen an overall increase in demand for electricity, particularly in relation to power for industrial manufacturing purposes. In fact, an article in *The Electrician* noted that during the 1914 session there had been an increase in the number of private members bills relating to electricity, with 49 Provisional Electric Lighting Orders being granted by the Board of Trade and confirmed by Parliament.[34] However, due to rising wage bills and coal prices, many undertakings experienced an overall loss in revenue and it was becoming clear to many in the industry as well as in Government, that some form of change was required

---

[33] 'Electricity Supply and the War.', *The Electrician*, LXXIV.1922 (1915), p.802.
J.H. Armstrong was a member of the Armstrong Family and was the Chairman of NESco during this period. DX1188, 'North Eastern Electricity Board Including NESco Directors.' (Newcastle, 1948), Tyne and Wear Archives Centre.

[34] 'Electrical Legislation in 1914.', *The Electrician*, LXXIV.1910 (1914), pp.396-398.

in order to maintain electrical supplies and keep up with the increasing demands from industry. In the following section, I examine these changes and how they affected to the power supply industry, particularly in relation to labour issues and the increasing prices of coal and electrical plants.

3.3. April 1915 – July 1916: 'Victory as Usual'.

By March 1915, the British Government had accepted that 'business as usual' was no longer possible, and that it should instead become 'victory as usual.' This would require that members of the community be prepared to 'suffer all kinds of inconvenience and, if necessary, sacrifice.' Lloyd George argued that it was essential for the country to 'increase, and increase enormously, our output of munitions of war.'[35] This was brought to a head on 27 March 1915, when Field Marshal Sir John French, the British Commander in Chief, reinforced the need for shells in an interview with *The Times,* in which he called for more ammunition arguing that: 'The protraction of the war depends entirely on the supply of men and munitions. Should these be unsatisfactory the war will be accordingly prolonged.'[36]

However, following the failure of the British army at the Battle of Aubers Ridge on 9 May 1915, Colonel Charles Repington, a correspondent for *The Times*, sent a report indicating that the defeat was due to insufficient quantities of high explosive shells.[37] This event on its own was not enough to topple the Asquith Government, but it was very embarrassing, coming so closely on the heels of assurances, by both Asquith and Lloyd George, that there was no shortage of

---

[35] 'DEFENCE OF THE REALM (AMENDMENT) (No. 2) BILL.' HC Deb, 10 March 1915, Vol.70, cc1453-94.
David Lloyd George (1863-1945) was a British Liberal Politician. He was first elected to parliament in 1891. He served as Chancellor of the Exchequer till May 1915 when he was appointed Minister of Munitions. In June 1916 he replaced Lord Kitchener as Secretary of State for War. On becoming Prime Minster in December 1916, he quickly established a War Cabinet which was primarily conservative in composition. Throughout the war he favoured whichever policy he believed most likely to secure rapid victory and particularly favoured State control over labour and Industry.
Kenneth O. Morgan, ''George, David Lloyd, First Earl Lloyd-George Of Dwyfor (1863–1945), Prime Minister'.', *Oxford Dictionary Of National Biography* (Oxford: Oxford University Press, 2018) <https://doi.org/10.1093/ref:odnb/34570> [Accessed 6 October 2019].

[36] 'Length Of The War', The Times, 27th March 1915, p.8.

[37] Charles à Court Repington, 'Need For Shells', *The Times*, 14th May 1915, p.8.

munitions. This was followed on 15th May by the resignation of the popular First Sea Lord Admiral Fisher, after a disagreement with Winston Churchill over the Gallipoli campaign. This led Asquith to call for the resignation of his Ministers. Asquith then formed a new government in coalition with the Conservatives, with Lloyd George serving as the Minister of Munitions, an entirely new ministerial post. Andrew Suttie observes that it was a job which, if mishandled, had the potential to destroy his political career, but which instead paved the way to his becoming Prime Minister in 1916.[38]

3.3.1. Ministry of Munitions.

Soon after becoming Minister of Munitions, Lloyd George came to realise the important part to be played by electrical power in the production of munitions, and invited the then Captain McLellan, a consulting engineer with NESCo and partner to Charles Merz, to advise him on electrical issues.[39] McLellan, like Merz, was a strong proponent of the large-scale generation and distribution of electricity, having been involved with the 1913 proposals for interconnection in London. Soon after taking his position in July 1915, McLellan became occupied with the electrical requirements of Sheffield and Coventry, both of which needed large extensions to their electrical works in order to keep up with the power demands of local industry. While this work was ongoing, policies were being implemented whereby all electrical supply undertakings would submit their schemes for approval with priority being given to those areas where it would have immediate effect on the production of munitions or other vital materials. In fact, demand for electricity proved so great that ‘nothing except that required for war work could be put in hand’.[40]

---

[38] Andrew Suttie, *Rewriting The First World War: Lloyd George, Politics And Strategy 1914-1918.* (London: Palgrave Macmillan, 2005), p.61.

[39] William McLellan was a partner with Charles Merz in the Merz and McLellan consulting company, which specialised in the design of large power grids and power stations. In 1916 he was appointed by Geddes to ensure the supply of electricity for munitions plants. Eventually becoming Director of Electric Power Supply. ‘William Mclellan - Graces Guide’, *Gracesguide.co.uk*, 2019 <https://www.gracesguide.co.uk/William_McLellan> [Accessed 8 August 2019].

[40] MUN 5/377/1380/1 ‘Work of Electric Power Supply Department from June 1915 To November 1918.’ (London, 1919), The National Archives (TNA), Ministry of Munitions, pp.1-2.

3.3.2. Labour Shortages.

Demand for electricity continued to grow. As strain was placed on already overworked electrical plants in cities such as Manchester and Sheffield, it became more urgent to find means of allotting money and materials to those areas that would benefit the most from investment in power supply. One of the key cities in need of major upgrades and expansion to its electrical supply was Sheffield. In April 1915, an inquiry was held into the application by the Corporation for permission to borrow a total of £164,373 for extensions to the generating plant and mains. These extensions being necessary 'not for the ordinary expansion of the business, but largely in order that they might supply a much-needed assistance to the large armament works that were fully engaged on Government orders.' The Chairman of the Electricity Supply Committee also pointed out that many of the applications for power had come from firms that had 'discarded their own plant because the Corporation could supply them more satisfactorily and cheaply.' This report also gives the first indication of Government recognition of the value of the power supply as it mentions that the Corporation had been given permission to prevent men engaged at the electricity works from joining the military.[41] Problems with the availability of labour in electrical undertakings were by no means unique to Sheffield. Birmingham was also undergoing rapid expansion in production capability and had already lost 2,500 Corporation employees to military service. The Corporation had indicated that it was prepared to lose a further 1,062 to munitions work. The writer suggests that those municipal workers remaining in power stations may feel some hardship in being asked to serve in a way that was not obviously related to front line service. He further noted that the badges being issued to men 'willing to join the colours' but who were 'engaged on war services' were only available to those engaged in the production of war materials. He felt that a similar scheme was needed to encourage men engaged in maintaining essential public services, such as electrical supplies, to do so without shame or fear of recrimination.[42] Mr Touche (MP for

[41] 'Sheffield.', *The Electrician,* LXXV.1925 (1915), p.30.
[42] 'Municipal Employees and the War.', *The Electrician,* LXXV.1926 (1915), p.42.

Islington North) had also raised the labour issue in Parliament. Touche claimed that, because of the loss of trained electrical engineers from power stations in the London area to munitions work and military service, there was a risk 'of the power stations […] becoming insufficiently manned.'[43] By November 1915, due to the loss of trained staff, many power undertakings were unable to guarantee sufficient supplies of power to munitions factories, resulting in loss of production. Lloyd George issued a notice in *The Times*, pointing out that electrical undertakings were:

> Engaged upon work of vital importance and that the removal of their employees … may have the effect of prejudicing the output of munitions of war.' He ended by calling on the managers of munitions works to refrain 'from attracting labour from these essential undertakings.[44]

On 12 November, *The Electrician* responded to Lloyd George's words, adding its voice to the call for common sense in recruiting on the part of municipal Corporations.[45] This was followed in December 1915 by the Liverpool Branch of the Electrical Contractors Association which unanimously passed a resolution claiming

> That, in the opinion of this meeting of the Liverpool branch of the Electrical Contractors' Association it is advisable in the interests of the country that a certain number of women should be trained in various branches of electrical work to ensure that the country's commercial work shall not suffer through the war; […].[46]

While the employment records for companies like Metropolitan Vickers and Ferranti do show that a high proportion of their wartime manufacturing was undertaken by women, particularly in relation to the manufacture of thermionic valves, I have been unable to find any figures recording the number of women directly employed in power stations or electrical substations.

---

[43] 'WORKMEN'S BADGES.' HC Deb, 27 April 1915, Vol. 71, cc548-50.
George Touche (1865-1931) was a conservative MP for Islington North between 1910 and 1918. He was an accomplished businessman and a strong spokesman on financial matters.
John Richard Edwards, 'Touche [Formerly Touch], Sir George Alexander, First Baronet1861–1935).', *Oxford Dictionary Of National Biography.* (Oxford: Oxford University Press, 2004) <https://doi.org/10.1093/ref:odnb/47822> [Accessed 1 October 2019].
[44] 'Labour At Power And Light Works', The Times, 10th November 1915, p.5.
[45] 'Recruiting and Common Sense.', *The Electrician,* LXXVI.1956 (1915), 185.
[46] 'Women Electricians.', *The Electrician,* LXXVI.1959 (1915), 327.

3.3.3. The Coal Crisis.

The shortage of labour was not limited to the electrical supply industry. It also had serious implications for coal production; the high rate of enlistment amongst miners during 1914 had resulted in increasing coal prices. As early as April 1915, the editors for *The Electrician* commented on the lack of regulation of coal prices, particularly noting that the owners of the mines were able to 'benefit unduly' from increased prices. Meanwhile, rates of pay for miners remained unchanged, potentially leading to unrest.[47] On 14 May, *The Electrician* carried a report on a conference on coal supplies held at the Institution of Electrical Engineers, to consider a situation that, they claimed was:

> Without precedent and was one of grave importance to the welfare – he might almost say to the safety – of their country. Coal was essential to the manufacture of gas and hardly less so to the production of electricity. Winter made a much larger demand than summer, and large stores or coal should now be accumulating to meet again the heavy and inevitable call of winter, instead of which they had found it difficult and, in some cases, impossible, to procure what had been necessary from day to day. Their reserves had been steadily vanishing, and they were face to face with the prospect of the adequacy and the continuance of supply becoming impossible.[48]

The conference attendees concluded that, in order to ensure adequate provision of coal for home use, the Government needed to restrict the export of coal to any countries other than Britain's Allies, and ensure that coal prices be fixed by the state to prevent mine owners or transportation companies from making excessive profits.[49] On 18 June 1915, *The Electrician* carried a report on the deputation, which had presented the conference resolutions to nearly two-hundred members of Parliament. In relation to electricity, the deputation had pointed out that the generation and distribution of electricity had reached such a state of efficiency in its

---

[47] 'The Coal Position', *The Electrician,* LXXVI.1927 (1915), p.75.
[48] 'Conference on Coal Supplies', *The Electrician,* LXXV.1930 (1915), p.195.
[49] 'Conference on Coal Supplies', *The Electrician,* LXXV.1930 (1915), pp.195-198.

usage of coal that its use 'was of material advantage in saving the greatest asset of the nation at this time.' Moreover, they warned that:

> If the electrical supply had to be curtailed or stopped, there would be no electrical searchlights, and, in addition, the food supplies of London and the country would be in danger owing to the stoppage of refrigerating plant in the cold storage warehouses.[50]

Although the debates over coal prices and the subsequent legislation do not form an essential part of this thesis, they do highlight the point that the gas and electrical industries were dependant on the smooth running of coal mines, as well as emphasizing the increasing national dependence on electricity, particularly within major towns and cities. Any dispute between labourers and employers in the mines had a huge impact on the ability of the power companies to guarantee provision of electricity. Moreover, the warning about the danger to London's food supplies was, as we will discover, remarkable prescient. By July 1915, despite personal attempts by Lloyd George to mediate between the miners and mine owners, strikes broke out in South Wales forcing the Government to intervene and take control of the industry. As Barry Supple has argued, 'the need for coal had proved much greater than the need to assert the government's sovereignty.'[51] While these measures went some way towards alleviating problems faced by electricity undertakings, many still faced difficulties in obtaining sufficient coal supplies.

By December 1915, as a result of the coal and labour shortages, there were reports that some power stations were being forced to draw heavily upon their winter reserves and in at least one case, an undertaking was forced to purchase its own wagons in order to secure supplies of coal. *The Electrician* reported that in one of the largest manufacturing towns in Britain, coal reserves had fallen to 'unacceptable levels' with deliveries of coal being up to one thousand tons short of the amount being used. While not an immediate problem, it did mean that the

---

[50] 'Coal Supplies', *The Electrician,* LXXV.1935 (1915), p.403.
[51] Supple, *The History of the British Coal Industry*, pp.62-67.

electrical undertakings were forced to use coal reserves, which they had stockpiled for winter use. However, the problems now seemed to be more the result of difficulties with transport than with the mines themselves.[52] This was in part the result of the acquisition by the Admiralty of a significant number of colliers in order to keep the Fleet coaled up, leaving insufficient vessels to transport coal from the coalfields in Wales and northern England to those areas in the south and midlands where it was in demand. As a result, a significant number of utilities were now reliant on the railway to transport coal supplies, a system, which was already, overloaded moving men and munitions to the ports for transport to France.

3.3.4. Changing Priorities.

Throughout the period April 1915 – July 1916, the Ministry of Munitions continued to offer advice to The Board of Trade on electrical extensions, with Captain McLellan playing a key role in the process. One such example of this process in action, which highlights the importance of managing the distribution of electrical power for munitions production, took place in the town of Bootle in Merseyside. Which, having applied for sanction to borrow £8,000 to install an additional generating plant, was inspected by the then Captain McLellan. While he approved the loan and helped with the acquisition of two boilers, McLellan commented that those firms engaged in munitions production must receive priority in the allocation of current, suggesting that, if necessary, tramways and private consumers should be disconnected in order to maintain the supply.[53] This was put into practice when, due to a period of high demand overlapping with some essential maintenance carried out on two boilers at the Summer-lane power station, it was realised that the 'resources of the department would be unequal to the strain'. Consequently, Birmingham city officials decided temporarily to suspend current to the municipal tramways in order to maintain current for manufacturing purposes. This was partly due to problems with the delivery of plant and equipment for the temporary generating station. The station, which had been due to go online by August, was not predicted to be

---

[52] 'Coal Supplies for Electricity Works', *The Electrician,* LXXVI.1961 (1915). p.369.
[53] 'Bootle.', *The Electrician,* LXXV.1950 (1915), p.971.

complete for another three weeks.[54] The stoppage was reported in the *Birmingham Daily Mail*, where it was noted that there had been a 'complete stoppage of the Birmingham tram services … owing to a failure of electric power.'[55]

By mid-November 1915, the Mayor of Sheffield was able to announce that the amount of current supplied by the Corporation had increased dramatically over the preceding four years. The current supplied had increased from 16,902,360 units in 1912 to 44,874,342 in 1915, at the same time gross revenue had increased from £96,868 to £184,658.[56] While it is unclear how much of this was due to increased wartime demand, the scale of the increase since August 1914 indicates that much was due to increases in demand of electricity for munitions production. This situation was reflected in Manchester where the Electricity Committee reported that there had been an 'unprecedented increase in the consumption of electrical current, and the estimate made in the earlier part of the year as to the probable demands on the department ha[d] been nearly doubled.'[57]

3.3.5. A Change of Control.

The problems caused in the power industry by high coal prices and, above all, by labour shortages, resulted in the Ministry of Munitions assuming control of power stations in the same way as it had over other electrical firms and businesses. In late November 1915, *The Electrician* reported that the Minister of Munitions was intending to ask for powers which would enable the Ministry to 'take over as controlled establishments undertakings like electric power stations and other businesses essential to munitions work.'[58]

By the end of 1915, growth of electrical undertakings had slowed but not stopped, with 27 of 31 applications for provisional lighting orders granted by Parliament. Many of these were extensions to areas of supply rather than totally new undertakings, indicating that the focus

[54] 'Birmingham', *The Electrician,* LXXVI.1952 (1915), p.68.
[55] 'Stoppage Of The Birmingham Tram Service', Birmingham Mail, 12th October 1915, p.3.
[56] 'Sheffield', *The Electrician,* LXXVI.1957 (1915), p.255.
[57] 'Manchester', *The Electrician,* LXXVI.1958 (1915), pp.294-95.
[58] 'Amendment of Munitions Act', *The Electrician,* LXXVI.1958 (1915), p.293.

was on the expansion of existing supplies rather than on extending the provision of electricity into new areas. In a review of the year, [59] *The Electrician* noted that the war had resulted in a number of the more contentious Bills being dropped, further delaying schemes for the interconnection of undertakings in the London area.[60] However, areas such as Manchester had seen an increase in power consumption, with an increase of nearly five million units for the last quarter, compared with the usual amount in the December quarter of 1914, including a 24 percent increase in the power load.[61] This demonstrated that the permission for new generating plant was now focused in those areas with increased demand due to munitions production.

Early 1916 saw continued intensifications in electrical demand from industry resulting in increasing demands for extension to generating plant. However, as the system of control put in place by McLellan and the Ministry of Munitions came into force, manufacture of new electrical plant could only be carried out with approval from the Ministry of Munitions, enabling the prioritisation of new construction in the areas where it was likely to have the greatest impact on munitions production.

The growing importance of electricity to munitions production was emphasized in early February 1916. *The Electrician* published a report on an event, which the editors believed indicated a change in attitude about the importance of electrical works to the country. They focused on the case of a Munitions Tribunal in London where the officials sided with a municipal engineer in deciding that a sub-station attendant's work at the electricity undertaking constituted vital war work and was a more valuable use of his talents than any other form of work. The editors of *The Electrician* claimed that the decision was important for two reasons. Firstly, that the tribunal acknowledged that power stations fell within their

[59] 'Provisional Lighting Order', *The Electrician,* LXXVI.1963 (1915), p.460.
[60] 'Some Electrical Events of 1915', *The Electrician,* LXXVI.1963 (1915), pp.462-64.
[61] 'Manchester', *The Electrician,* LXXVI.1968 (1916), p.651.

jurisdiction; and secondly because it showed that electrical works were now considered to be of national importance from the viewpoint of munitions production.[62]

Possibly one of the most significant moves in relation to electrical supply occurred in May 1916. On 25 May, the Board of Trade urged undertakings to consider arrangements for interconnection and joint working of undertakings, including those supplying tramways and railways. Undertakings were encouraged to take full advantage of the powers conferred on them by the Electric Lighting Act of 1909, which permitted local authorities to give bulk supplies to neighbouring authorities.[63] Although the editor of *The Electrician* commented that the proposal was welcome, they doubted that the Board were aware of the many difficulties inherent in such a scheme due to the multitude of different voltages in use around the country.[64] However, it is evident that they believed this move towards interconnection was a promising development, which, where practical, had the potential to enable significant savings in coal usage.

The issue of coal economy in power generation was becoming more prevalent during 1915-1916, Smaller and less economic undertakings were encouraged to accept a bulk supply from more efficient neighbouring undertakings, only running their own generating plant during periods of peak demand and to enable maintenance and repairs to the more efficient generating plant. As will be seen later, considerable interest was generated in the possibility of linking areas of supply, particularly in Lancashire and Cheshire.

In mid-June 1916, an article in *The Electrician* noted that, broadly speaking, electricity undertakings in Britain could be divided into three classes. The first of these consisted of those undertakings which mainly served residential areas and relied heavily on the lighting load, these invariably suffered due to the implementation of wartime lighting restrictions and

[62] 'The Central Station as a Controlled Works', *The Electrician,* LXXVI.1969 (1916), p.657.
[63] William Eric Swale, *Forerunners Of The North Western Electricity Board* (Manchester: North Western Electricity Board, 1963), p.51.
[64] 'Linking-Up', *The Electrician,* LXXVII.1984 (1916), p.239.

because they did not qualify for priority in plant extensions or improvements. Secondly, they showed undertakings where the loss of the lighting load had been balanced by a corresponding increase in the power load as a result of munitions production, with Manchester and Leeds being given as prime examples. Finally, there were those undertakings, such as Barrow-in-Furness, where there was a very large increase in demand for power, and whose output had increased by 283 per cent since the outbreak of the war.[65] This period also saw continued extensions to the electrical undertakings in Sheffield, with a total of £107,000 being sanctioned by the Local Government Board for the extension of mains and for additional equipment for sub-station equipment and transformers.[66] According to the Historical Record of the Ministry of Munitions Electric Power Supply Department, 'the use of electric power grew so rapidly that in July 1916 it was decided to establish a separate Electric Power Supply Department.'[67] The duties and works of this department are examined in the next section, along with the reports of the main commissions into the future of electricity in Britain.

3.4 August 1916 – November 1918: Planning for the Future.

Although meeting the demands of the war remained the overriding factor in the allocation of resources, the Government had also begun realising the importance of preparing the country for the reestablishment of peacetime economy. The Board of Trade and the Ministry of Reconstruction established a series of committees and commissions to examine the state of British industry and its ability to compete in an open market. They concluded that an efficient and economical power supply was vital if British industry was to compete, and these conclusions formed the basis of the 1919 Electricity Supply Act.

The Electric Supply Department of the Ministry of Munitions had been established in July 1916 in reaction to the huge increase in demand for electric power, resulting from the dramatic

[65] 'Effect of the Power Load', *The Electrician,* LXXVII.1987 (1916), p.342.
[66] 'Sheffield', *The Electrician,* LXXVII.1981 (1916), p.366.
[67] MUN 5/377/1380/1 'Work of Electric Power Supply Department from June 1915 To November 1918.' (London, 1919), The National Archives (TNA), Ministry of Munitions, p.2.

expansion of the munitions industry since August 1914. Initially under the Directorship of Captain McLellan, the department had several primary functions. However, for the purpose of this chapter I intend to concentrate primarily on two of these. While many of the departments functions could be considered extensions of the duties already undertaken by McLellan and his staff, these two, I argue, were to have a strong influence over the future direction of the power supply industry in Britain. Firstly, the role of the Electrical Supply department was

> To advise other Departments of the Ministry of Munitions, the Air Ministry and some Departments of the Admiralty and War Office on all schemes where the installation of electric generating plant or the installation of motors, or the purchase of current from a Public Service Undertaking [was] concerned.

Secondly, they were to provide Service on Various Standing Committees.[68] Many of the topics of discussion in the various standing committees were already being played out within the electrical engineering community.

A paper given by Ernest T. Williams to the I.E.E in April 1916 on the future of electrical supply in Britain had provoked a great deal of discussion among electrical engineers around the country, leading to splits along 'partisan lines' between those who favoured nationalising the industry and those who favoured a more *laissez-faire* approach. Replying to comments and criticisms of his paper, Williams noted that:

> It [was] unfortunate that the term nationalisation ha[d] been mentioned, for in the paper, […], there is no proposal for the nationalisation of our electricity supply, to which I am opposed.

Williams went on to explain that electrical engineers were 'practically unanimous' in arguing that reform of the electrical supply industry was needed, and felt that this should be attained, firstly by co-operation, and secondly, by the coordination of control. He felt interconnection and centralisation should only be pursued in places where they could produce the best results,

---

[68] MUN 5/377/1380/1 'Work of Electric Power Supply Department from June 1915 To November 1918.' (London, 1919), The National Archives (TNA), Ministry of Munitions, pp.2-3.

further proposing that the existing controls over the industry held by the government should be taken over by a 'professional public Board' tasked with watching over the interests of the public as well as the interests of the supply undertakers. This quasi-government board would be somewhat similar to the Port of London Authority and would be intended to 'encourage private enterprise to the maximum extent.' Williams also pointed out that his paper had not recommended any immediate or drastic changes to the industry and that any plans for reform, new power stations, or for interconnection should be laid out so as to meet the estimated requirements in a years' time. He wrote that, 'The necessity and value of a transition period was insisted on both for economic and administrative reasons.' Finally, Williams argued that it would be 'foolish' to make the mistake of mistrusting those representatives of the industry serving on committees examining the future of the industry, remarking that:

> When we read the names of those who constitute the Committees dealing with this reform in electricity supply, we can be assured by their past and present achievements that they will only take such steps as they are satisfied will be steps of true progress, which includes the interests of the industry itself as well as those of the greater public.[69]

While not an advocate of nationalisation, Williams recognised the need for national coordination and seems to have accepted that those who had been appointed to serve on the committee would only recommend the nationalisation of the industry if they truly believed it to be in the best interests of the industry and its customers. The state was not explicitly mentioned; however, it would likely be counted as a significant customer. Despite its obvious link to the ongoing discussions and commissions on this topic, Williams paper and his explanatory letter in *The Electrician*, are strangely absent from Hannah's account of the topic.

---

[69] Ernest T. Williams, 'Electricity Supply', *The Electrician,* LXXVIII.2003 (1916), p.25.
Williams was a leading member of the Institution of Electrical Engineers; he was also employed by the Royal Navy as an electrical engineer in the Department of the Director of Naval Construction.

3.4.1. Interconnections.

A 1916 circular, issued by the Board of Trade encouraging interconnection, had reached a large and receptive audience, many of whom were eager, where possible, to implement schemes for interconnecting local power stations. In the discussion of William's paper at the Manchester branch of the I.E.E, on 18 April 1916, a suggestion had been made for a scheme for the interconnection of some of the primary supply undertakings in Lancashire and Cheshire. Subsequently, prior to the Board of Trade Announcement, the local municipal councils had formed a committee to investigate the possibilities of interconnection from an engineering viewpoint. After careful consideration of the proposal, the committee predicted that if it was carried forward, there would be significant savings in the use of coal and the monetary output of the undertakings concerned would be reduced by about £82,000.[70]

The National Electric Power Supply Joint Committee also been formed around the same time to consider questions relating interconnection and concluded its deliberations in September 1916. This was a joint venture by the Incorporated Municipal Electrical Association and the Incorporated Association of Electric Power Companies and was tasked with considering how the country should be divided into areas of supply, and how best to link existing generating equipment with a view to more economical operation and security of supply. They also considered how this should be financed, and how joint undertakings would arrange for any payments for the supply and exchange of current. The committee arrived at five conclusions, which mirror those of Williams, particularly noting that:

[70] 'The Interconnection of Lancashire and Cheshire Electricity Supply Systems', *The Electrician,* LXVIII.2004 (1916), pp.53-56.

> The question of linking up should be considered broadly from the national point of view and having in mind not only the saving of fuel but the interests of consumers in obtaining a cheap supply of electricity. [And that] while the generation of electricity as distinct from its distribution must be considered broadly and irrespective of the present areas of electricity supply undertakings, clearly all existing rights must be respected, and existing areas must not be interfered with as regards distribution.[71]

They were arguing for a national system of interconnection based of the needs of the local area and respecting the rights of existing companies and undertakings.

The two main committees considered in this chapter are The Ministry of Reconstruction Coal Conservation Sub-Committee, and the Electric Power Supply Committee of the Board of Trade. The reports of these two committees were both published prior to the end of the war and were to have a significant influence over the shape of the post-war power supply industry. The Coal Conservation Sub-Committee was chaired by Lord Haldane, a known reformer who had been criticised in the press for his open admiration of German manufacturing techniques.[72] In April 1917, the Haldane Committee issued an interim report, which was to form the basis for much of the later discussion on the reorganisation of power supply. The Committee recommended the centralisation of generation and distribution based on the establishment of large-scale generating plants with large areas of supply containing a number of different electrical requirements, under the control of a single regional authority. Overall, they argued, the system would be placed under the control of a single body of Electricity Commissioners. The report highlighted the need for any such reorganisation to be national in nature, which would almost certainly cause a degree of conflict with local municipal utilities, but they

[71] 'National Electric Power Supply Joint Committee', *The Electrician,* LXVIII.2004 (1916), pp.56-57.
[72] 1st Viscount Haldane was a Liberal Imperialist politician who had been dismissed from the Cabinet in 1915 due to his apparent German sympathies.
H. C. G. Matthew, 'Haldane, Richard Burdon, Viscount Haldane (1856–1928).', *Oxford Dictionary Of National Biography* (Oxford: Oxford University Press, 2011) <https://doi.org/10.1093/ref:odnb/33643> [Accessed 28 October 2019].

believed that, ultimately, there was ‘no conflict in this matter between the interests of the local community and those of the nation as a whole.’[73]

The Second of these two Commissions was chaired by Sir Archibald Williamson.[74] This committee concluded that the post-war success of British industry would depend on the provision of cheap and reliable supplies of electric power, and that the existing system of supply, which had been adopted in the infancy of the electrical supply industry was now insufficient and incompatible with the capabilities of the technology. Finally, the Williamson committee suggested that a comprehensive system for the generation and distribution of electricity was urgently required and should be established as soon as possible. The committee also recognised that the question needed to be considered primarily from a national viewpoint. They also stated that it had been conclusively proven that the organisation of the industry along municipal or local government lines was very rarely the most economical arrangement and that the need for standardisation of generating and distribution equipment across different areas was paramount. In general, the committee endorsed the findings of the Haldane commission that the

> Creation of one central authority to regulate generation and distribution of electricity in Great Britain and Ireland is urgent, and that in the national interest steps should immediately be taken to establish it.

To this end, they recommended the creation of a board of five Electricity Commissioners, who should have ‘engineering qualifications and business experience of the highest order’. In contrast to the ideas presented by Williams and by the Haldane Committee, this was a truly nationalistic scheme, the commissioners were to have the power to purchase undertakings

[73] Cmd.8800, ‘Ministry Of Reconstruction. Coal Conservation Sub-Committee. Interim Report On Electric Power Supply In Britain’ (London, 1918), The National Archives, Ministry of Reconstruction, pp.1-30.
[74] Archibald Williamson was a businessman and Liberal Politician, he served as Chairman of a number of Board of Trade and Home Office committees during the First World War and was a strong support of Lloyd George. Robert G. Greenhill, ‘Williamson, Archibald, First Baron Forres (1860–1931).’, *Oxford Dictionary Of National Biography.* (Oxford: Oxford University Press, 2004) <https://doi.org/10.1093/ref:odnb/48399> [Accessed 2 October 2019].

from public utility concerns and that all such concerns should take their power from one network rather than generating current for their own use. The commission also went into a great deal of detail as to the proposed organisation of the commissioners, and local electricity boards, including detailed breakdowns of their duties and responsibilities.[75]

As can be seen by these brief summaries of both committees, it was generally considered that the existing organisation and legislation of the electricity supply system was inadequate and had failed to keep pace with technological progress. Hannah and Hughes have both argued that the First World War had provided an opportunity for engineers to demonstrate the potential of electricity to benefit the country and having done so brought engineers such as Merz and McLellan into influential positions from which they could influence and direct policy. In addition to this I argue that the dramatic increase in the use of centrally generated electrical power for munitions production, highlighted the importance of controlling the generation and distribution of energy supplies for the good of the nation. However, the civilian experience of electricity during the war only forms part of the story. The British military made extensive use of electricity in both Britain and France, providing lighting and power to hospitals, airbases and headquarters buildings as well as workshops and searchlight facilities.

3.5: On the Front Lines: Increasing Use of Electricity.

The development and adaption of technological systems for military use has been well documented, particularly with regards to studies of transportation and communication systems. However, many of these systems, such as wireless telegraphy or searchlights, required electricity to operate. From early in the war, electrical engineers had been in demand by the Army and Royal Navy, with units such as the London Electrical Engineers Regiment and the Naval Engineers Division specifically recruiting electrical engineers from civilian power stations. In fact, during the first year of the war, the Institution of Electrical Engineers, the

[75] Cmd.9062, 'Electric Power Supply Committee. Report Of The Committee Appointed By The Board Of Trade To Consider The Question Of Electric Power Supply.' (London, 1918), The National Archives, Board of Trade, pp.1-18.

Institution of Mechanical Engineers and the Institution of Chemical Engineers had all encouraged members to join the armed forces. These groups even offered to train and house the men until the War Office was able to make use of their services. The experiences of these men in providing electrical services to the armed forces in many respects parallels those of their colleagues who remained in the civilian sector.

The work undertaken by these units was varied, with many tasked with operating searchlight batteries in defence of British ports and cities. Other units were involved with the construction and running of power stations at naval and military bases where it was considered neither practical nor desirable to connect to local undertakings. These units were also involved in operations on the Western Front, providing power and lighting for military hospitals, airbases, and headquarters. One such example of this work was the provision of electric lighting at Wellington Quarry in Arras, which provided shelter for over 24,000 British and Commonwealth troops prior to the battle. Stuart Doldern of the First Battalion London Scottish Regiment recalled that:

> We descended to a considerable depth by a shaft cut into the chalk, and at the bottom walked a long way in the bowls of the Earth. We were billeted in a huge cavern which opened out of the tunnel along which we had walked. […]. There was accommodation for at least four thousand men. Water was laid on, and the crowning feature of the whole place was the electric light, which dimly illuminated the caverns.[76]

This 'touch of civilisation', while not unique in the British trench system, was sufficiently unusual to be commented on by men such as Doldern. The association of electricity with civilisation is an important factor and may have had some influence on servicemen's attitudes to electricity in the post war period. A detailed report on the use of electric power in the field was produced by GCHQ France in 1919. Major General Liddell, who served as Deputy Engineer in Chief and then Chief Engineer in the Third Army, noted that:

[76] A. Stuart Dolden, *Cannon Fodder* (London: Blandford, 1988), p.149.

> The use of Field installations of Electric Light was not originally contemplated. Demands have gradually arisen for the lighting of casualty clearing stations, workshops in forward areas, dug-outs, and headquarters of formations and camps, recreation establishments, etc., as a natural corollary to the introduction of stationary warfare.[77]

In essence, electricity was used on the front lines for the same purposes as it was in towns and cities across Britain. Where possible a supply was taken from the French domestic network, but for the most part units relied on local generation due to the vulnerability of fixed power stations and transmission cables to enemy action. The similarity to civilian generation was not restricted to the use of electricity, it also extended to the problems of generation and supply experienced by the civilian undertakers.

3.5.1. The Coal Problem.

As was the case in Britain, the engineering companies tasked with providing electrical power also had trouble securing adequate supplies of coal and other fuel supplies. Colonel Brook, the Deputy Director of Supplies noted that:

> The coal shortage at times was very serious. In October 1916 troops were actually at the station with transport waiting for the coal, but the trains in many instances did not turn up till several hours after the expected time, and we had no reserve with which to carry on.[78]

While some of the supply issues were clearly related to disruption of transport links by enemy action, in the report Brooke also pointed out that:

> So long as the mine owners were allowed to fix their prices it was extremely difficult to deal with them and obtain what we wanted, but when the government took over the mines our position was much easier.[79]

These concerns clearly demonstrate the importance of secure energy supplies not only for the production of munitions, but also to the Army in France. While the Army was not as reliant on fixed power stations as civil industry in Britain, any disruption of supplies could have severe

[77] W.O. letter 121/France/3376. In MUN 4/6349, TNA.
[78] W.O. Letter 232/France/3376 Remarks of Colonel H. Brooke, TNA.
[79] W.O. Letter 232/France/3376 Remarks of Colonel H. Brooke, TNA.

consequences particularly for regions reliant on electricity to run pumps. A letter from General Haig dated October 1915 also highlights some of the problems caused due to the use of overhead high-tension cables on or near the front lines, detailing fatalities resulting from damage to high tension cables from shelling;[80] a problem which was not common for electrical engineers working on the Home Front. Although, as we will see in the following chapter, fear of aerial attack on power stations and the associated high-tension network did have a strong influence on the development of the Grid network. Furthermore, the experiences of military personnel were considered when making decisions on the future of electrical generation and distribution in Britain.

3.6. Ministry of Reconstruction: Preparing for Peace and War.

In 1917 the Coalition Government set up a new Ministry of Reconstruction under the leadership of Christopher Addison, the former Minister of Munitions, and long-term supporter of Lloyd George.[81] The new ministry conducted a series of questionnaires for officials working in the government ministries, particularly in areas which had seen major changes as the result of wartime requirements and regulations.

Charles McLellan, the Director of Electric Power Supply for the Ministry of Munitions gave in-depth responses to many of the questions on the Ministry of Reconstruction questionnaire, outlining the functions of his department in which had broad controls over not only the distribution of electrical supplies to 'all works engaged on the production of munitions' but also manufacture of 'all generating plant and electric motors for home use and export.' McLellan claimed that:

---

[80] MUN 4/6349, 'Letter from General Haig', 25th October 1915, (London, 1915) The National Archives, Ministry of Munitions.

[81] Addison was a Liberal politician who had trained as a doctor prior to entering politics in 1910. Throughout his political career he consistently supported measures to improve public health and welfare. Addison's plans for post war reconstruction formed the basis for much of the Coalition governments post war legislation.
Kenneth O. Morgan, 'Addison, Christopher, First Viscount Addison (1869–1951).', *Oxford Dictionary Of National Biography* (Oxford: Oxford University Press, 2004) <https://doi.org/10.1093/ref:odnb/30342> [Accessed 28 October 2019].

> The importance from a War point of view of centralising the production of electric power is recognised by all modern Engineers. The Electric Power Department has made special efforts permanently to assist this, but in all this time has been the controlling factor, and it has frequently been impossible to do other than extend existing uneconomical and wrongly situated power stations.[82]

McLellan was one of the main partners along with Charles Merz in running the North Eastern Electric Supply Company, which was the main supplier of electricity to a large region surrounding Newcastle. As such, he was already convinced of the value of centralised generation. However, due to the wartime constraints on men and materials it had largely only been possible to carry out extensions to existing plant. While it does seem that he had attempted to put measures in place that would lead to a more enduring solution, much of the planned new plant was still incomplete at the end of the war.

Continuing the questionnaire, McLellan pointed out the ways in which the Defence of the Realm Act had been used to commandeer electrical plant, earmarked for civilian usage or export, for installation in power stations directly supplying munitions works. He had at times invoked the DORA regulations to secure way-leaves for transmission cables as well as to arrange for undertakers to supply power to areas outside of their usual area of supply if the local undertaking did not have the required capacity.[83] McLennan's actions show the needs of the state overriding the normal business operations of the supply companies, not only deciding which companies would receive additional plant, but also which companies would receive business from electrical undertakings.

One of the questions put to McLellan was whether electrical manufactures had been 'upset by their diversion to war work' and how quickly would they be able to return to normal operations. While historians such as Leslie Hannah and Thomas Hughes have since claimed

---

[82] MUN 5/188/1380/1, 'Director of Electric Power Supply Replies to Reconstruction Department Questionnaire, 28th June 1917', (London 1919) The National Archives, Ministry of Munitions.
[83] MUN 5/188/1380/1, (London 1919) The National Archives, Ministry of Munitions.

that the First World War had significantly disrupted the electrical manufacturing industry, at the time McLellan argued that:

> The Electrical Manufacturing industries have not as a whole been upset by the diversion to war work; on the contrary, the output of their normal products has been greatly accelerated, and as a number of orders for civil work have been diverted to war purposes, there should be no serious difficulty in re-establishing the normal industrial conditions immediately after the cessation of hostilities.[84]

McLellan later went on to talk about the growing importance of electricity to industry as a whole noting that:

> All the new factories erected, without exception, during the war have been driven electrically, and as a consequence the importance of electric power supply to the country is now more fully appreciated.[85]

However, he did also lament the lack of any systematic development and the enforced reliance on older and less efficient generating plant concentrated in small undertakings. McLellan went on to argue that:

> Anything which promises to result in the economical production of electric power should be supported by the State, and the electric power supply of the country should be more effectively controlled by the State than it is at the present.[86]

While McLellan had served in the Ministry of Munitions for most of the war, he was still a private businessman and a senior engineer and partner at one of Britain's most successful private electricity supply companies, consequently the fact that he supported greater state intervention in the industry is significant. As a result of his experience he was able to offer some explanation of the reluctance of some engineers to accept interconnection and centralised generation, pointing out that, while

[84] MUN 5/188/1380/1, (London 1919) The National Archives, Ministry of Munitions.
[85] MUN 5/188/1380/1, (London 1919) The National Archives, Ministry of Munitions.
[86] MUN 5/188/1380/1, (London 1919) The National Archives, Ministry of Munitions.

> The national importance of centralised electric power production [was] in theory universally admitted – it [was] almost equally generally damned in peacetime by every engineer who operates a small generating station, as he realises that the centralisation of power production must carry with it a diminution of his own personal authority.[87]

Ultimately McLellan argued that the only way to overcome the resistance of both the small power station engineers and the financial barriers to the development of a centralised network was through greater involvement by the state.

3.7. Conclusion: World War One as an Experiment in Electrical Nationalisation.

Prior to the First World War, electrical supply in Britain had been inefficiently organised along parish and municipal boundaries, with little in the way of standardisation. However, as I have shown in this chapter, this changed with the First World War dramatically increasing the use of centrally generated electricity by British industry. Contrary to accepted histories of electricity, which regard the war as adversely impacting the electrical supply system, I have shown that the First World War had a positive effect on the development of the electricity in Britain. Indeed, by the end of the war, generating capacity in Britain had almost doubled, and 95 percent of munitions factories in Britain received their power from central generating stations. Spurred on by the shortage of coal, companies were encouraged to accept supplies of electricity from local generating stations, rather than continuing to run their own generating plant.

Vital to the production of munitions, electricity was placed under the control of the newly formed Ministry of Munitions in 1916, in what was arguably the first nationally supported experiment in interconnection. Power station owners were encouraged to link with other local stations, enabling less efficient plant to be shut down outside of peak hours, thereby introducing further saving to coal supplies. More importantly however, the experience of the

[87] MUN 5/188/1380/1, (London 1919) The National Archives, Ministry of Munitions.

First World War led to significant changes to the legislative regulation of the electrical supply industry. Wartime committees had concluded that, due to the inefficiencies in the existing system of control, the supply of electricity needed to be reorganised on a national basis, in order to ensure both economy in the use of coal and security of electrical supply in the future - although they were unable to agree as to what form this reorganisation should take.

In parallel to the development of the civilian power supply network, the military, and particularly the British Army, had also come to rely on access to electrical power. The conditions for the Army engineers were similar to those prevalent in the civilian sector in Britain, with multiple generating standards being used. At the end of the war, the British Army issued a report on the use of electricity on the Western Front, which included suggestions for the development of civilian power networks, many of which were adopted in future legislation. This report and the subsequent legislation will be explored in the following chapter.

4. The Post War Years: 1919-1924, The Politics of Power.

Agricultural prosperity, improved transportation, industrial power, increased wages, and improved conditions of labour, and the health of the people are inseparably bound up in the development of electricity under Public Control.[1]

4.1. Introduction.

In the build up to the General Election of 1919, Prime Minister Lloyd George identified the development of electrical power during the Great War as having been one of the key factors in the recent victory over Germany. Furthermore, as the epigraph above indicates, the development of a publicly controlled electrical supply was, at least by some, seen as key to improvements in all areas of national life. As established in the preceding chapter, electrical usage had almost doubled over the course of the First World War, mainly as a result of increased munitions production: by the end of 1918 almost 95 percent of munitions factories in Britain accepted power from centrally located generating stations. This was a sharp contrast to the pre-war era, in which most factories had generated their own power. The utilisation of centralised generating stations had not only enabled greater economy in the use of coal but had also reduced the time and expense necessary to construct a new factory, as well as leading to reductions in the required workforce. All of which were vital in the face of the unprecedented demands on manpower and materials experienced by British industry during the war. In order to meet the greatly increased wartime demand, the Board of Trade and the Ministry of Munitions had not only forbidden electricity suppliers from taking on any new

[1] 'Electricity Supply in Greater London', *The Electrician*, LXXXII (1919), pp.19-20.

domestic customers but had also required them to gain authorisation to connect new industrial customers. This level of state involvement in the day-to-day operation of both private and municipal utilities was entirely new in Britain.

Not only had the experience of the electricity supply industry during the First World War demonstrated the potential of this industry for British industrial development, but also served to highlight many of the issues inherent in the pre-war organisation of that same industry: most notably, the way in which pre-war legislation, aimed at preventing the development of a monopoly, had resulted in an inefficient hodgepodge of power supply companies, each supplying a limited area on a wide range of voltages and frequencies. This in turn had led to higher costs for electrical appliances as manufacturers could not make standardised models.

Despite wartime encouragement from the Board of Trade and the Ministry of Munitions, interconnection between neighbouring supply companies had been limited, mainly due to incompatibility between the systems employed by different companies.[2] Thomas Hughes has argued that the First World War did away with some of the economic and political factors which had previously prevented the full utilization of existing electrical technologies, breaking a 'conservative crust that had restrained adjustments in the course and velocity [,]' of the development of electrical power systems. In this chapter, I expand on this argument by investigating the central position of electrification in post-war politics. Where Hughes claims that electrification was inevitable due to the inherent technical superiority and efficiency of the system,[3] I instead argue that the British state, galvanised by the experience of the First World War, pursued electrification as a means of enhancing national security: economically, politically, and militarily.

---

[2] Prior to the war the choice between DC and AC as well as the voltage and frequency of supply was left to the discretion of the chief engineer of the undertaking. As such he would tend to specify whichever format, he was most familiar with as being the most suitable.

[3] Hughes, *Networks of Power,* p.286.

I show that Wartime reports into electrical supply systems were unanimous in calling for the reorganisation of the industry on a national basis as well as on the need for standardisation of equipment and voltages. This latter requirement was mirrored by reports from the Army, which called for the standardisation of electrical equipment within military and civilian sectors of the state.[4] Furthermore, the reports of the Haldane and Williamson committees during the Great War had highlighted the importance of electricity in enabling British industry to be competitive with countries such as Germany and the United States of America, which had access to a cheap and abundant source of electricity in the form of hydro-electric power. Yet, despite a general consensus among politicians on the importance of electric power for Britain's future, as well as the requirement for a complete reorganisation of the industry, there was little agreement as to what form this reorganisation should take, nor how closely the state should be involved in the management of the industry. This lack of consensus is broadly reflective of the state of British politics in this period and, in particular, of Lloyd George's peacetime Coalition Government, which comprised of a primarily Liberal cabinet at odds with the predominantly Unionist and Conservative MPs who made up the majority of the party.

In this chapter, I extend Keith Grieves' analysis of the Coalition politics on the development transport to encompass electricity supply. [5] I show that while disagreements over the desired level of state involvement in utilities such as transport and electricity remained a point of contention between the different political ideologies, the development of electricity remained a priority for successive governments, regardless of political persuasion. However, I also argue that despite the strong interest in and support for electrification, the successive governments elected during this period lacked the political stability required to pass the necessary legislation, and as a result were unable to fully implement the proposals made by the Williamson and Haldane Committees.

---

[4] 'Ministry of War Transport, Subcommittee on Protection of Vital Services', MT 50/2. TNA.

[5] Keith Grieves, *Sir Eric Geddes, Business and Government in War and Peace.* (Manchester: Manchester University Press, 1989).

I examine the importance of electrification to the preservation and economical use of Britain's coal reserves and its connections to national security. I show that the preservation of Britain's 'strategic' coal supplies was one of the most important and prominent reasons given in both of the key wartime reports for encouraging the widespread adoption of electricity in Britain, as well as for the proposals to interconnect and rationalise generation into the most economic power stations. This concern over the preservation and use of Britain's coal stocks is central to the development of the National Grid and closely linked to the ongoing miner's disputes.

During the First World War disputes between mine owners and workers had led to the coal mines coming, at least temporarily, under the control of the state.[6] Following the end of the war, the miners' unions displayed a strong preference for maintained state control over the mines and for the full nationalisation of the industry. Unsurprisingly, this received little support from the mine owners, who demanded the return of the mines to private control, including control over wages and working hours. The mine owners argued that they needed to reduce wages in order to maintain profitability; meanwhile, the miners, while recognising the need for mines to make money, objected to any profits being made at their expense. Due to the existence of a continued high demand for coal from foreign sources, coupled with a shortage of coal for domestic use, the government had little choice but to retain control over the coal industry in an attempt to prevent a political crisis. However, as with other key industries, such as the railways, the Coalition Government lacked the political support needed to argue for nationalisation of the industry.[7]

Finally, I continue to examine the largely unexplored parallels between civilian and military interests in electrification, most notably the interest in standardisation. One key element of military interest in electrification was displayed by the Army in training military personnel to operate civilian power stations in the 'event of a national emergency'. Although, there is no

---

[6] For a complete discussion see, Barry Supple, *The History of The British Coal Industry, 1914-1946: The Political Economy Of Decline.* (Oxford: Clarendon, 1987), pp.41-116.
[7] Supple, *The History of the British Coal Industry*, pp.121-122.

evidence that this was ever implemented, it does indicate the importance placed on the security of civilian electrical supplies by the armed forces. I demonstrate the ways in which military interests informed and influenced the development of civilian electrical supply systems in Britain. However, as with civilian engineers, military engineers and technicians often differed in their opinions over the best systems to use. In the case of the Army and Air Force engineers, this debate centred around the choice between overhead and buried transmission cables and the potential vulnerability of electrical supply networks to enemy action.

Overall this chapter focuses on the attempt by the Lloyd George Government to establish a nationally co-ordinated, but not nationally owned electrical supply system. For the Lloyd George government electrical power was at the centre of their plans for industrial development, the development of industry, improvements to transport infrastructure and to the everyday life of the British population. Above all else the development of a nationally co-ordinated electrical supply, fully integrated with transport infrastructure would help to ensure the energy security of the country, particularly considering the ongoing disruption in the mining industry.

4.2. The Politics of Power Supply.

The speed and scale of the allied victory in November 1918 took Britain by surprise. As recently as the spring of 1918, Lord Northcliffe had gloomily predicted that the current generation 'would not live to see the end of [the] war'.[8] This was followed in July by General Wilson, who had served as an unofficial military advisor to Lloyd George and as the Chief of the General Staff from February 1918, suggesting that the decisive battle of the war would not take place until at least 1919.[9] Yet in spite of this pessimistic outlook on the part of the media and the

[8] Taylor, *English History, 1914-1945, p.*108.
[9] Keith Jeffery, 'Wilson, Sir Henry Hughes, Baronet (1864–1922).', *Oxford Dictionary Of National Biography* (Oxford: Oxford University Press, 2004) <https://doi.org/10.1093/ref:odnb/36955> [Accessed 28 October 2019].
Taylor, *English History, 1914-1945, p.*108.

armed forces, Lloyd George had already begun to prepare the groundwork for a peacetime Coalition Government and the reconstruction and revitalisation of the country. Lloyd George and his supporters believed that the successful wartime management of industry by the state had demonstrated their superior ability to organise and run manufacturing and supply industries for the national good more efficiently than could be achieved by private enterprise. One of the key steps in this direction had been the creation of the Ministry of Reconstruction under Christopher Addison in July 1917.

4.2.1. Ministry of Reconstruction.

By August 1916 the Coalition Government, headed by Lloyd George, had already realised the necessity of preparing the country for the re-establishment of a peacetime economy. As such the Board of Trade and the Ministry of Reconstruction had commissioned a series of reports to examine the state of British industry and its ability to compete with rival companies based in the United States of America or Europe.

The reports of the Haldane Committee and of the Williamson Committee focused on the importance of electricity to the nation, both recommending the reorganisation of the electrical supply industry on a national basis. In the previous chapter, I argued that the reports of these committees highlighted the restrictions placed on the electrical supply industry by pre-war legislation, which had severely limited the area of supply, thus rendering the generation and distribution of electricity uneconomical.

I further demonstrated that the development of electricity supply networks was closely linked to the need to preserve and make economical use of coal stocks, and that pro-electrical activists believed that significant economies of scale in coal usage could be achieved by the establishment of large centralised and interconnected generating stations.

Both the Williamson and Haldane committees had agreed that it was in the national interest that steps should be taken ‘to create a central authority to regulate [the] generation and distribution of electricity in Great Britain and Ireland.'[10] As I argued in the previous chapter, the creation of the board of 'Electricity Commissioners' was to become one of the key components of the 1919 Electricity Supply Bill and one of the few clauses to remain almost entirely unchanged throughout the passage of the Bill through Parliament.

4.2.2. The 1918 General Election.

Of the three major parties running for election in late 1918, only the Coalition Government under Lloyd George explicitly linked control over electricity to employment and industrial revival. The Coalition Manifesto which was published in all the major newspapers argued that:

> Active measures will be needed to secure employment for the workers of the country. Industry will rightly claim to be liberated at the earliest possible moment from Government control. By the development and control in the best interests of the state of the economical production of power and light, of the railways and the means of communications, […], output will be increased, new markets opened up, and greater economies, effected in industrial production.'[11]

Meanwhile, the Labour Manifesto, despite demanding the 'immediate nationalisation and democratic control of vital public services, such as mines, railways, shipping, armaments and electric power; […]', merely claimed that this would improve the position of labour in terms of pay and conditions and did not link state control of electricity to economic or industrial revival. In contrast to this, electricity was entirely absent from the Liberal Manifesto which instead focussed on free trade and the establishment of what Asquith described as a 'national minimum', arguing that:

> We ought not to be content until every British citizen […] has in possession or within reach a standard of existence – physical, intellectual, moral, social – which makes life worth living, and not only does not block, but opens the road to its best and highest possibilities.'[12]

[10] RECO 1/884, 'Report Of The Board Of Trade Committee On Electric Power Supply' (London, 1919), The National Archives, Ministry of Reconstruction, pp.1-18.
[11] Fred W. S Craig, *British General Election Manifestos, 1900-1974.* (London: Macmillan, 1975), p.30.
[12] Craig, *British General Election Manifestos,* pp.33-34.

However, unlike his opponents, and particularly Lloyd George, Asquith could not offer any concrete, practical proposals as to how this should be achieved. Furthermore, he appeared unwilling to commit a future government to any course of action which would interfere with the principles of free trade, including the maintaining of government control over vital industries and services such as electricity supply. In contrast to this non-committal approach, Lloyd George had an answer: continued state involvement in, and control of, key industries. The election result delivered an overwhelming majority for the Coalition Party, that should have enabled legislation such as the 1919 Electricity (Supply) Bill to be passed almost without opposition. Yet, as will be seen, the passage of this Bill and the related Ministry of Transport Bill were strongly opposed by Conservative elements of the Coalition Party.

4.2.3. Electrical development and the Railways.

Two of the key promises contained in the Coalition Manifesto of 1918 had been the revitalisation of British industry, and full employment. While unemployment figures for 1919 and 1920 had averaged about the same as in the immediate pre-war period, figures for 1921-22 demonstrated a dramatic increase in levels of unemployment.[13] One possible means of alleviating unemployment, suggested by Sir Allan Smith (a key spokesman on trade and industrial matters) and discussed by the Cabinet in 1923, was railway electrification. [14] By early 1923, various uncoordinated railway electrification schemes were underway across the country. Smith suggested that placing immediate orders for all the equipment needed for electrification and reconditioning of the railways would create much valuable work for people who would otherwise have been on the dole over the winter period. While the government did not have the power (in peacetime) to force railway companies to carry out electrification works on the lines, it was willing and able to offer incentives to them to electrify main lines. A Ministry of Transport report to the Cabinet noted that employment opportunities would

---

[13] James Denman and Paul McDonald, ‘Unemployment Statistics From 1881 To The Present Day.’, *Labour Market Trends*, 104 (1996), pp.5-18.
[14] Terence Rodgers, ‘Smith, Sir Allan Macgregor (1871–1941).’, *Oxford Dictionary Of National Biography* (Oxford: Oxford University Press, 2004) <https://doi.org/10.1093/ref:odnb/48196> [Accessed 28 October 2019].

extend beyond the obvious ones immediately connected to the railway companies, arguing that:

> The relief of unemployment is in many instances much greater than is apparent from the cost to the scheme to the Railway Company as further capital has to be found for plant for the production of power and for transmission lines and possibly substations. There is further the great advantage that the manufacture of all this plant does not involve the displacement of labour; it enables skilled men to be employed at their own jobs and in their localities.[15]

These were precisely the effects of electrification which had been promised by Lloyd George in the 1918 Manifesto, but which the government now found itself unable to deliver due to defeats on key sections of both the 1919 Electricity (Supply) Act and the 1919 Ministry of Transport Act.

In the case of the Electricity (Supply) Act, opposition to the Bill meant that key sections which would have given the Electricity Commissioners powers to force co-operation from the supply companies were dropped, with the government intending to re-introduce them as a new Bill the following year. The Ministry of Transport Act was curtailed in a similar manner: the decision taken, after much Parliamentary opposition, not to nationalise the railways, meant that the government was unable to force the electrification of the railway system through on a standardised national basis. In both cases, the reliance on voluntary co-operation on the part of electrical power and railway companies, meant that Government proposals for nationally planned and organised systems of power and transport were left at the mercy of private enterprise, for whom, this form of national organisation held no appeal. This is an issue which, as will be seen in the following chapter, was to be picked up in 1925 in the report of the Weir Committee.

The development of a centrally organised national electricity network was central to Lloyd George's plans for Britain. As was argued by Bill Luckin in *Questions of Power*, electrical

[15] 'MT 6/3172, Relief Of Unemployment, Electrification Of Railways, Proposals By Sir Allan Smith, (London, 1923), The National Archives, Ministry of Transport, 31 August 1923, pp.1-6.

enthusiasts viewed electricity as offering the possibility of a cheap supply of power for industry and transport, as well improving health in towns and cities by reducing the amount of smoke and soot in the air.[16] However, while the idea that increased use of electricity would reduce pollution played a central role in inter-war electrical advertising, it was only a secondary consideration for the state. Wartime experience had also suggested that increased use of electricity for power and lighting was one means of reducing coal consumption. One ton of coal burnt in a power station could be used to supply power to multiple factories, each of which would have originally required their own boilers and generating plant as well as their own supply of coal. While countries such as the United States of America, Canada, Germany and Italy had access to vast hydro-power resources, Britain was forced to rely on burning coal to provide power for industry. There were significant hydro-power sources available in Scotland, but they were largely inaccessible, and where developed, they were tied to specific industries, particularly aluminium production. Consequently, electricity in Britain was not only more expensive but also at greater risk of disruption due to fuel shortages or industrial action.

4.2.4. Alternatives to Coal?

The high costs of coal and the search for alternative fuels was a regular topic in *The Electrician*, with engineers from around the British Empire contributing to the ongoing discussion and suggesting alternatives which would enable the reduction of coal exports to the colonies. A.M. Beale of Ottawa, Canada, was a typical example.[17] In January 1919 he argued that the key to industrial revival was access to a cheap and reliable source of motive power.

British supremacy during the nineteenth century had been based on ready access to an abundant source of coal, which had 'placed large quantities of power at her disposal'. [18] Beale

---

[16] Luckin, *Questions of Power*, p.11.

[17] Beale was the Author of a 1915 report on 'Small Water-powers in Western Canada and discussion on sources of power for the farm.

[18] Prior to the First World War, France had imported one third of its coal requirements, with the loss of French coal fields to German advances early in the war it was forced to increase imports from Britain. However, between 1910 and 1919 France also increased its hydro-electric generating capacity by 450,000 horsepower. Meanwhile, Italy which had limited low quality coal reserves, mainly imported from Britain, almost doubled its hydro-electric capacity from 515,000 horsepower prior to the war to 1,200,000 horsepower by 1919 with a further 500,000 Horsepower planned**. '**Power – Canada's Opportunity', A. M. Beale, 'Power - Canada's Opportunity.', *The Electrician*, LXXXII (1919, p.12.

argued that centrally-generated electricity was the best means of realising the value of this coal and of preserving vital coal stocks for future generations. He went on to compare Britain to countries such as France and Italy which, due to shortages of coal during the war, had begun to develop hydro-electric schemes, which promised to supply a great deal of their electrical needs. Beale further commented on the investigations taking place across the British Empire into the most efficient means of generating electricity within each region. While later studies indicated a lack of suitable locations for hydro-electric stations within Britain itself, the possibility of developing hydro-electricity in the colonies during this period seemed to offer a means of eliminating or reducing the need for Britain to supply those colonies with vital coal resources.[19] The development of hydro-resources in places such as Canada and India were also hugely significant to firms such as Ferranti and Metropolitan Vickers. Both firms had expertise in the area from earlier projects and the development of colonial hydropower offered the promise of significant overseas orders.

In January 1919, Lloyd George announced that the Government intended to nationalise railway and electricity supply services and to appoint Sir Eric Geddes as Minister of Transport to oversee the reorganisation of the railways and electricity industry for transportation and power purposes.[20] This was to be a priority and the necessary Bills were to be introduced to Parliament and passed into law as swiftly as possible. These two Bills were closely linked; clause 44 of the Electricity (Supply) Bill made provision for the transfer of the powers and duties of the Board of Trade, in relation to electricity, to 'be transferred to the Minister of

[19] A. M. Beale, 'Power - Canada's Opportunity', *The Electrician*, LXXXII (1919), pp.12-13.
[20] Eric Campbell Geddes was a Conservative politician and businessman with a background in the railway industry. During the First World War he made a name for himself revitalising munitions production and transportation, eventually being promoted to Inspector General of transportation. He went on to serve as Civilian Lord of the Admiralty with the rank of Vice Admiral and was placed in charge British Shipbuilding. In 1917 he returned to civilian life and was appointed as First Lord of the Admiralty, reorganising the Admiralty. Lloyd George regarded him as one of the most able and remarkable men in government.
Keith Grieves, 'Geddes, Sir Eric Campbell (1875–1937), Politician and Businessman.', *Oxford Dictionary Of National Biography* (Oxford: Oxford University Press, 2015) <https://doi.org/10.1093/ref:odnb/33360> [Accessed 28 October 2019].

Ways and Communications' in the event of that post being established by an Act of Parliament.

4.2.5. Legislation, 1919-1922.

Two Acts of Parliament, the 1919 Electricity (Supply) Act and the 1919 Ministry of Transport Act best demonstrate the aims of the Lloyd George administration and its vision for the future of Britain. However, these two pieces of legislation also highlight the division between Lloyd George and the primarily Unionist and Conservative MPs sitting in the House of Commons. They also demonstrate the extent to which private interests in electrical supply companies, the railways, and coal mining, worked to reduce government influence in these industries, influence which had expanded considerably during the First World War. As was noted in the previous chapter, while many engineers recognised the 'national importance of centralised' electrical generation it was also a challenge to the authority of those engineers as they would no longer be free to set their own standards.[21]

In February 1919 Geddes argued that the Great War had altered the conception of the duties of Government claiming that:

> The events of the past four years have shown that a national emergency demands more from Government Departments than the regulatory and restrictive functions which have hitherto been the main feature of their activities. The emergency which gave birth to this new idea of the function of Government, […], has come to an end; but another has arisen which requires the adoption of drastic changes in the methods and functions of Government Departments. The war against Germany is over; the war against obsolete and inefficient industrial and social conditions is just commencing.[22]

This illustrates the changed view of the role of Government shared by men such as Lloyd George and Eric Geddes. However, this view was not shared by a large portion of Coalition

[21] 'MUN 5/188/1380/1, Director of Electric Power Supply Replies to Reconstruction Department Questionnaire', 28th June 1917, TNA.
[22] F/18/3/9, Memorandum on the Proposed Formation of a Ministry of Ways and Communications, by Geddes, dated 9 February 1919, Lloyd George Papers.

MPs, particularly those coming from a Conservative background. Writing in 1989, Keith Grieves points out that Geddes had confided in Lloyd George that:

> If this Government is going to carry through the program to which we are committed, the House of Commons has got to be held up to the bit. It professes, in theory, its desire to cut 'red tape', to facilitate business, to abolish vested interests and to go ahead, but 90% of the Members seem to stick at the theory and are reluctant to put it into practice. I would prefer an out-and-out Tory to a Tory giving lip-service to progress and throwing out grappling hooks all the time to prevent anything being changed.[23]

It was this type of obstruction from representatives of vested interests in mining, transportation and electrical concerns which prevented Lloyd George and Geddes from carrying through their plans for the country at this time. As I have already argued, this also demonstrates the split between Lloyd George and the predominantly Conservative Coalition MPs who made up the bulk of the Coalition Party. Grieves argues, and I agree, that this was at least in part because the Ministry of Transport was 'required to view transport – the railways – as a financial problem, with the idea of a 'Supreme Co-ordinating Authority' dismissed as impractical.'[24] I argue that the same was also true of electricity, particularly once it had been brought under the control of the Ministry of Transport.[25]

In 1920 Geddes attempted to re-introduce the clauses granting compulsory powers to the Electricity Commissioners which had been dropped from the 1919 Electricity (supply) Act. However, he again met with resistance from the vested interests represented in Parliament and the amendments were rejected. The first successful attempt to amend the 1919 Electricity (Supply) Act was not passed until August 1922and dealt mainly with financial considerations.[26] This did, however, include some limitations on electricity pricings, with the maximum permissible price to be set by the Electricity Commissioners and any loss incurred by an

---

[23] Grieves, *Sir Eric Geddes, p.*79.
[24] Grieves, *Sir Eric Geddes, p.*80.
[25] Section 39 of the 1919 Electricity (Supply) Act, 'All powers and duties of the Board of Trade under this Act […] be transferred to the Minister of Transport, and accordingly references to the Board of Trade […] shall be Constructed as references to the Minister of Transport.'
[26] 1920 (67) Electricity (Supply). A Bill to amend the Electricity (Supply) Act, 1919.

authorised undertaker to be paid out of a joint sinking fund open to all electrical undertakers within the district.[27]

In November 1920, Geddes penned a memorandum to the Cabinet in which he highlighted the problems encountered by both the original 1919 Electricity (Supply) Bill and his proposed amendments. He again proposed at least temporarily dropping any references to compulsory powers claiming that 'a more general tendency among owners of Electricity Undertakings to put forward schemes on an agreed basis than I had anticipated has been made […]'. However, he went on to inform the Cabinet that he believed that there would come a point in time whereby there would be a 'residuum of areas for which it [would] not be possible by mutual agreement among those concerned, to constitute satisfactory bodies to administer the supply of electricity.'[28] Thereby articulating his belief that voluntary co-operation was insufficient in itself to ensure the creation of the desired system. Furthermore, to ensure the creation of a national system of electricity supply, some degree of coercion would eventually be required. Geddes' claim that there had been a greater level of co-operation than was expected appears to be borne out in the Parliamentary records, with issues relating to electricity supply being debated hundreds of times a year as various districts put forwards plans for the organisation and linking of electrical concerns, many of which gained the approval of Parliament. This is possibly a result of concern among electrical suppliers that failure to co-operate on a voluntary basis would lead to government intervention and coercion.

4.2.6. The 1919 Electricity (Supply) Act.

The 1919 Electricity (Supply) Act drew heavily on the conclusions of the Haldane Committee, which, as noted by Leslie Hannah, was strongly influenced by Charles Merz. Hannah notes that, despite Merz being a member of the Individualist Society, his experience with electrical supply

[27] 1921 (65) Electricity (supply). A Bill to amend the Electricity (Supply) Act, 1919. Clause 18, sections 1-2.
[28] "CAB 24/115/23, 'Electricity Supply Bill, Memorandum By The Minister Of Transport, 10 November 1920'" (London, 1920), The National Archives, Cabinet Papers.

had led him to believe that some degree of government control was desirable, and indeed required, in order to ensure the most efficient development of electricity in Britain.[29]

As proposed in May 1919, the Electricity (Supply) Bill provided for the appointment of five Electricity Commissioners who were to control electricity supply. The Commissioners were also to have powers to appoint an advisory committee as well as to undertake and promote research into new methods of electricity generation and supply. This section was to be one of the few clauses in the original Bill to survive, almost unchanged.

The country was to be divided up into districts, each under the control of a District Electricity Board which was to have compulsory powers to acquire any generating stations and transmission lines. The Council of the Institution of Electrical Engineers commented that the proposal to appoint Electricity Commissioners was 'universally welcomed'. However, the council did caution against the Commissioners attempting to impose a rigid system across the entire country, due to the wide variety of local conditions. This desire for the individualised treatment of each area of supply was echoed by bodies such as the Junior Institution of Engineers, which held a special meeting on the 27 January 1919 to consider the question of a national electricity supply. They concluded that, in order to carry forward any reform of electricity supply, it was first necessary to 'establish a spirit of trust … between the parties and conditions framed to meet the local needs of each district.' This group also appeared to favour the development of electricity supply by private industries, citing a remark by a Mr. W. L. Heckins (of Cammell, Laird & Co) who had commented that the Government should establish the conditions under which superstations should be established but having done so should 'leave the actual work to be carried out by private enterprise.'[30] The main area of opposition to the Bill was in the proposed compulsory purchase powers, as the terms offered were felt to be

---

[29] Hannah, *Electricity Before Nationalization*, pp.62-64.
[30] 'National Electricity Supply', *The Electrician*, LXXXII (1919), pp.170-171.

inadequate and municipal authorities resented losing powers granted under previous legislation.[31]

The final key point of dissention was the proposal to place electricity supply under the authority of the proposed Ministry of Ways and Communications (later the Ministry of Transport). The IEE Council recommended that electricity supply should remain under the authority of the Board of Trade. When the Bill left the Commons in November 1919 it retained almost all of the contentious clauses which were then strongly opposed in the House of Lords. In order to ensure the swift passage of the Bill, the Government then removed all references to compulsory powers, intending to re-introduce them in the next session. The Electricity (Supply) Bill was finally enacted on 23rd December 1919.[32] As enacted the Bill could be described as a paper tiger. It authorised the commissioners to establish a nationally co-ordinated network but left them powerless to enforce their recommendations.

4.2.7. The 1919 Ministry of Transport Act.

In the Ministry of Transport Bill, the Government attempted to bring the different transport systems in the country together under one co-ordinated authority. As originally proposed the Bill would have given the Minister authority over roads, railways, canals and coastal shipping and would additionally have included taking control over the nation's electricity supplies from the Board of Trade.

One of the key arguments for linking electricity with the railways was the belief that, if fully electrified, the railways would swiftly become the largest single consumer of electricity in the country, potentially accounting for up to twenty percent of the total electrical usage. Further, if electricity was closely connected to the railway networks, it would be easier to gain permission for pylon construction, as railway companies already held many of the necessary permissions for the construction of overhead wiring. This clause was firmly opposed by both municipal and private electrical undertakers who feared that electrical generation for light and

---

[31] 'Municipalities And Electricity Supply', *The Electrician*, LXXXII (1919), p.159.
[32] 'Electricity (Supply)Bill', *Garcke Manual Of Electrical Undertakings*, XXIII (1920), pp.22-24.

power would become secondary to the demands of the railways. On 19 November 1919 Mr Thompson, arguing against the transfer of electricity supply to the Ministry of Transport, highlighted these concerns, particularly noting the importance of meeting the needs of an entire community as opposed to just one segment of it:

> The Home Secretary said, 'You have in the Ministry of Transport already railway electricians skilled in the development of electricity as required by railways.' That is a very strong argument against putting the Electricity Commissioners under the Ministry of Transport, because the traders, undertakers and municipalities will feel that in the development of this big scheme the interests of railway electrical development will naturally predominate rather than the development of electricity in the interest of the whole community. We were told that in future 10 or 20 percent of the electrical power may be taken by the railway companies. But whether it be 20 percent, or a much larger figure, it is essential that the community as a whole should feel that its electrical development will take place on lines not in the interests of any one section of the community, but in the interests of the traders as a whole.[33]

Despite this strength of feeling, within both the electrical supply industry and Parliament, against placing electrical supply under the control of the Ministry of Transport, control passed from the Board of Trade to the Ministry of Transport on 23rd January 1920. This is one of the strongest pieces of evidence in favour of claiming that the development of electricity was guided by national security interests. Placing electrical development under the authority of the Ministry of transport would mean that electrical development would, at least in theory, be less hampered by economic concerns and subject to a lesser degree of Parliamentary oversight than it had been under the Board of Trade.

4.2.8. Political wrangling, 1922 and onwards.

Talk of electricity receded during the General Election of 1922 and it was not mentioned as a topic of importance in any of the party manifestos, being overshadowed by more pressing

---

[33] 'Electricity (Supply) Bill' HC Deb 20 November 1919 vol. 121 cc1208-81.
Trevelyan Thomson was the Liberal MP for Middlesbrough. Born into a Quaker family he resigned from the society during the First World War and encouraged recruitment. In 1917 he enlisted in the Royal Engineers reaching the rank of Sergeant by the end of the war. He was not a supporter of Lloyd George who he did not believe was reliable due to his coalition with the conservatives.

concerns such as the 'Irish Problem' and the ongoing peace process in Europe. However, it did reappear in the Labour Manifesto for 1923 when the Party, under the leadership of Ramsay MacDonald, promised:

> [the] Establishment of a National System of Electrical Power Supply, the development of Transport by road, rail and canal, and the improvement of national resources by Land Drainage, Reclamation, Afforestation, Town Planning, and Housing Schemes.[34]

However, MacDonald's government lacked the majority needed to carry forward any of its proposed reforms. It is again mentioned in the 1923 Manifesto promises of the Liberal Party, in relation to coal power, but does not feature in either the Labour or Conservative election promises for that year.

An important and interesting contrast with the various electricity supply Acts and their amendments during this period are the government's dealings with the gas industry. In introducing the Gas Regulation Bill to the House Lords for its second reading, the Marquise of London-Derry, proposed that gas companies should no longer be held to such high standards as they had been in the past, and should instead be able to, 'supply such gas as [could] most economically be produced and [was] found in practice best to meet the requirements of their consumers.'[35]

This was almost completely the opposite of the move towards standardisation within the electrical industry at this time and could be interpreted as allowing gas companies to produce lower quality, cheaper gas. While the initial reduction in cost would tempt consumers to use gas rather than electricity, the longer-term results would have encouraged customers to

---

[34] Craig, *British General Election Manifestos, 1900-74*, p.48.
Ramsay MacDonald (1866-1937) became the leader of the Labour Party in 1911, he maintained an anti-war stance throughout the First World War.
David Marquand, 'Macdonald, (James) Ramsay (1866–1937), Prime Minister.', *Oxford Dictionary Of National Biography* (Oxford: Oxford University Press, 2015) <https://doi.org/10.1093/ref:odnb/34704> [Accessed 28 October 2019].
[35] The Under Secretary of State for Air.
'Gas regulation Bill', HL Deb 08 July 1920, Vol.41 cc73-80.

switch from gas to electricity for heat, light, and power. However, the same debate also suggests that the primary reason for these legislative changes was to make the most 'economical use of that precious asset, coal.'[36] It is also significant that this Bill proposed that users should be charged for the thermal units received, indicating that gas was now being considered as primarily useful for heating and cooking, rather than as a means of providing light or power.[37] This is again indicative of importance being placed on ensuring the most efficient and economic use of the nation's fossil fuel resource in order to secure continued supply in the future.

4.3. Military Interest in Electrical Supply.

Following the conclusion of hostilities in 1918, all three branches of the armed forces in Britain began a series of investigations and reports into the conduct of the war, examining different aspects of warfare and what, if any, changes needed to be made in order to make the best use of the new technologies developed or adopted during the war. For this thesis, the most prominent of these is the 1919 report from GCHQ France, on the use of *Electrical Power in the Field*. While the RAF was certainly interested in electrical development, much of its time was spent attempting to justify its continued existence as an independent fighting force, and particularly in combating the attempts by the Royal Navy to regain control over carrier-borne aircraft and airships. Although, as will be explored in the following chapter, the RAF was keen to exploit the potential vulnerability of power stations to aerial attack in order to preserve its independence. Finally, the Royal Navy was already highly experienced in the use of electricity aboard its ships and was able to transfer much of this knowledge and experience to shore-based power. However, it primarily relied on DC-based systems and as such had limited interest in the development of a national electricity supply in Britain.

[36] 'Gas regulation Bill' HL Deb 08 July 1920, Vol.41, cc73-80.
[37] 'Gas regulation Bill' HL Deb 08 July 1920, Vol.41, cc73-80.

4.3.1. On the Ground, the British Army and Electricity.

For the Army, electrification and the development of an electrical supply system offered a wide range of possibilities, from lighting, heating and cooking to providing power for pumps, communications systems, workshops and hospitals to name but a few. As was argued in the previous chapter, the electrical organisation of the Army pre-war closely mirrored contemporary civilian supply systems. The 1919 GCHQ France report detailed the use of electricity by the British army in France between 1914 and 1919 and made recommendations for the future development of electrical equipment for the Army as well as for the development of civilian power supplies. The report, which drew directly on the experiences of officers involved in the generation and distribution of electricity to the Army, highlighted the problems experienced due to the variety of equipment and standards that existed within the Army during the war.

The report was prefaced by a letter from Arnold B. Gridley, in which he highlighted some key points. Firstly, he pointed out that the commission considered it probable that the electrical requirements of the Army would increase both in peace and war. Secondly, he urged coordination between all departments (presumably both civil and military) and recommended the ‘standardisation of all electrical machinery.’ Thirdly, the report recommended the use of alternating current rather than direct current. Points four through six were directed solely at military requirements. However, point seven recommended that Army personal undertake training in operating civilian power stations. This last point is particularly interesting as it would have enabled the government to make use of the Army in order to break strikes by electrical workers, such as the one threatened in 1918. The final point made by Gridley was that the National Scheme under consideration at the time should ‘have some consideration from the military point of view.’ While it is not immediately apparent what was meant by the ‘military point of view’, this indicates that military requirements had a more significant role in the development of the post-war electrical system in Britain than has been previously acknowledged.[38]

The commission further recommended that, in the event of future hostilities, the engineering staff of power stations should 'automatically acquire military rank.' This would not only bring the engineers under military discipline but also prevent munitions factories and other manufacturers from head hunting experienced engineering staff from the power stations, as had occurred during the First World War. As had been noted by Gridley, this section of the report further recommended that 'with a view to being able to operate the stations in the event of a national emergency, a number of officers and men should be trained in power-stations.'[39] As I suggested earlier in the chapter, it is likely that this was, at least in part, a response to the threats of strikes by power station workers in late 1918. During this strike the government and the Admiralty had considered the possibility of using Naval Artificers and Stokers to run the power stations around London and ensure the supply of electricity to the capital; while this was not required on this occasion, it did offer a means of continuing a basic level of electrical provision, as we will see in the following chapter.

The commission's report identified two main areas of operations on the Western Front, both of which had very different electrical requirements. The first was the Lines of Communication; the conditions in this area could be broadly likened to peacetime in Britain. However, the urgency of the demand meant that it was rarely possible to adopt the most economical systems. The second area was known as the Army Area, for which the primary requirement was for the rapid delivery of highly robust and mobile generating stations. Many of the same issues facing power undertakings in Britain were repeated in France, one of the most important being the question of overhead versus buried cables. This problem was particularly

---

[38] MUN 4/6349, 'Letter from A.B. Gridley to Mr. Piggott', 1 May 1919: (London, 1919) The National Archives, Ministry of Munitions, pp.1-3.

[39] MUN 4/6349, 'Report from GCHQ France on the Use of Electrical Power in the Field,' 29 January 1919 (London, 1919) The National Archives, Ministry of Munitions, p.21.

relevant to the Army Areas, where the key objection to fixed networks was the lack of mobility inherent in such a system.[40] Further issues included the possibility of overhead lines interfering with the work of the Signal Corps as well as a certain degree of danger to troops from the overhead lines. These issues were also apparent in early power networks in Britain, where it was not uncommon to find power and telegraph/telephone cables sharing utility poles. Finally, there was the apparent issue of the higher manpower requirements needed to erect and maintain the overhead wires. These issues were set against the economy of materials, fuel and manpower that would be gained by supplying electricity from a single central station, set back some distance from the lines, as against the numerous local stations used in most sectors.[41] However, regarding the risk of electrocution, the report also indicated that the experiences of the French and American troops, stemming from the familiarity of their civilian populations with high tension overhead cables, had largely eliminated the danger from contact with these wires. The report further theorised that a similar degree of familiarity could be assumed of the British population, assuming that the schemes being developed in Britain went ahead.[42]

A further parallel between the systems used by the Army in France and those employed in Britain was the division of the electrical works into different areas of supply, each of which operated using different equipment and standards. The commission recommended that in future the supply of electricity should be entirely co-ordinated under one central authority. This suggestion was remarkably similar to recommendations regarding the future of civilian systems in Britain. The commission further recommended that there seemed to be no general reason, ‘why electric cables, instruments, lamp holders or switches purchased by the war department should differ from those purchased by other Government Departments.’[43] This

[40] This was as opposed to portable DC based generators.
[41] MUN 4/6349, ‘Report from GCHQ France on the use of Electrical Power in the Field’, 29 January 1919, (London 1919) The National Archives, Ministry of Munitions, p.6.
[42] MUN 4/6349, (London 1919) The National Archives, Ministry of Munitions, p.7.
[43] MUN 4/6349, (London 1919) The National Archives, Ministry of Munitions, pp.19-20.

would not only ensure compatibility across branches of the armed forces but also between military and civilian equipment, thereby making it easier for new recruits to operate military equipment or, conversely, for military engineers to take over the operation of civilian power stations and workshops.

While the design and development of power supply networks in Britain was technically outside of the remit of the committee, they did examine the proposals being made for the establishment of superpower stations. The commission noted that, if the supply of electrical energy was extended as planned, then the country would be:

> Completely dependent on a relatively small number of generating stations and their continued running. It [was] therefore essential that these should be so constructed that their vital centres […] shall be protected from aerial attack, and the boilers, generators and steam connections so disposed that damage may to a large extent be localised.[44]

As will be seen in the following chapter, the vulnerability of power stations to aerial attack was a concern which was shared by the RAF. A further element of concern to both the Army, and later the RAF, was the choice between overhead or buried transmission cables.

4.3.2. Overhead Versus Buried Cables.

As mentioned earlier, the Army was especially concerned over the potential vulnerability of high-tension cables to enemy action, particularly shell fire. Some experts suggested that a minimum of twenty feet of chalk or thirty feet of clay was necessary to adequately protect cables from enemy fire. As was the case in civilian power supply, opinion was divided as to whether the Army should adopt high tension AC generation and distribution, or continue to develop more localised, low voltage DC networks. While many officers acknowledged that high tension AC equipment could be more efficient and economical in its use of fuel and manpower than the DC equipment, others expressed reservations over the vulnerability of immobile central stations and the connected high-tension cables to enemy action. However, officers,

[44] MUN 4/6349, 'Report from GCHQ France on the use of Electrical Power in the Field', 29 January 1919, (London, 1919) The National Archives, Ministry of Munitions, p.21.

who had gained experience in operating high-tension AC systems on the front line, disagreed. Major B.C. Lockhart-Jervis, who had been responsible for all electrical work in the First Army Area, claimed that he had been able to construct a mile of high-tension cable per day, with a team of 35 men and a single man allotted per mile for maintenance. He believed that this was more than adequate even under the worst conditions. With regards to damage from enemy fire, his experience indicated that it was easy to repair and that the system was more reliable and economical in manpower and fuel than the use of independent sets.[45] I argue that this experience, alongside the lower cost of overhead cables in comparison to buried cables, played a role in the decision to use overhead cables to connect the Chain Home Radar Stations to the power supply in the late 1930s. However, as will be discussed in the following chapter, the RAF believed that buried cables were preferable to overhead transmission lines, as they would not interfere with flying operations.

4.3.3. Standardisation and Civilian Connections.

One of the main concerns raised by the commission in 1919 was the lack of standardisation of the electrical equipment of the Army. The report indicates that much of the electrical equipment initially deployed was left over from the Boer war and utilized DC power. This equipment was intended to supply the electrical needs of the British Expeditionary Force but proved unable to cope with the increased demands placed on it by the rapid expansion of the British Army over the course of the war. Because of this, as well as difficulties in obtaining new plant and supplies through official channels, many battalions had opted to purchase equipment directly from firms in Britain. As had been the case with civilian networks, this resulted in the engineer-in-charge specifying the equipment according to personal preference. This frequently led to difficulties in acquiring spare parts as well as in coordinating supply with neighbouring units. This approach also made it harder for units to utilize existing French supplies, as much of the equipment was incompatible.

---

[45] MUN 4/6349, (London, 1919) The National Archives, Ministry of Munitions, p.58.

One key complaint from numerous army officers involved in the 1919 commission was the cost of purchasing power from the established French networks. While the German and French forces were able to requisition power and supplies, the British were required to negotiate with the French power companies, with their requirements being met only at great cost. Therefore, the need for portable high voltage generating sets was strongly emphasised. However, military bases in Britain were strongly encouraged to purchase power from local suppliers rather than establishing their own generating and distribution systems. While a number of military power stations were established for isolated camps and major ports, most military facilities continued to take supply from local sources. As had been the case in France, there appear to have been a number of disputes over the scale of the rates to be paid, particularly when rising coal prices forced supply companies to increase prices, as each new contract had to be authorised by the treasury.[46]

4.3.4. Electrical Use in the Royal Navy.

One theme which has not been explored so far is the interest of the Admiralty and Royal Navy in the development of electrical power. After all, many of the newer systems, such as wireless communications, were very power hungry. However, for the most part, the Royal Navy appeared to be content to purchase electricity for its shore-based facilities from local electrical undertakings. By the 1920s, all major Royal Naval warships operated a DC-based ring mains system, with larger warships operating at 220 volts DC, while smaller warships operated a similar 110-volt DC system. DC-based systems continued to be used aboard ship until after the Second World War, when the increases in electrical demand by on-board systems meant that DC-based systems were unable to keep pace with the growing demand for electrical power. The late 1940s saw the commissioning of a new series of warships supplied with a three-phase

[46] T 161/101/6, 'War Office and Admiralty Agreement with Dover Corporation', January 1921, (London 1921) The National Archives, Treasury Files.

AC power supply and this system was to gradually supplant the DC-based systems as older ships were refitted or decommissioned.[47]

While ships continued to use DC-based power systems, naval bases such as Dover often relied on supplies from local undertakings, only generating their own power when the local supply was insufficient to meet requirements. However, it would appear likely that in the event of a local power failure, naval dockyards would be able to remain at least partially operational, even if this meant using the engines aboard a docked warship as generators, an option which, as we seen in chapter five and chapter seven, was demonstrated using submarines in 1926 and again in 1947. However, this may not have been the case for all naval facilities; the Bandeath Naval depot in Scotland was totally reliant on the local supplier for electricity from 1919 until at least 1943.[48]

4.3.5. Naval Power and Coal.

One area in which naval energy policies certainly overlap with domestic and industrial concerns was over the use of coal; shortly before the outbreak of the First World War the Royal Navy had begun the process of converting the main fleet from coal- to oil-fired boilers. Oil had significant strategic advantages over coal, such as the ability to carry out underway replenishment, as well as the potential to reduce crew size, as oil-fired ships required fewer stokers.[49] What is not mentioned in this is the significant reduction in demand for coal brought about by this change, which consequently reduced the vulnerability of the Royal Navy to strike action by miners. It would also free up more of the high-grade steaming coal from Welsh mines for export or use on the railways and by coal-fired merchant vessels. Furthermore, oil was easier to store and did not degrade in the same manner as coal stockpiles which required constant rotation due to the loss of calorific value.

[47] John M. Mayber, *Electrical Supply in Warships: A Brief History.* (London: Ministry of Defence).
[48] ADM 1/15737, 'Contracts R.N.A. Bandeath, Supply Of Electricity', (London), The National Archives, Admiralty.
[49] Erik J. Dahl, 'Naval Innovation, From Coal to Oil.', *Joint Force Quarterly*, 27 (2001), 5-56, (p.52).

One theme that is explored throughout this chapter is the importance of Britain's coal stocks, and the need to make the most economical use of them in order to ensure the country's continued independence from reliance on foreign fuels. Indeed, a large number of experiments were carried out during the inter-war years into methods to extract heavy fuel oil from coal.

4.4. Conclusion: Political Intrigue and the Politics of Power.

In Chapter four, I have shown that the development of some form of nationally controlled and coordinated supply of electricity was seen by most politicians and engineers as being in the 'national interest', particularly as a means of utilising and preserving British coal reserves. However, the development of the British electrical network was hindered by political instability, which prevent the passage of the required legislation. It is interesting to note that, at the same time, the rival gas industry was de-regulated, with manufacturers being permitted to produce lower quality gas, a factor which may have contributed to the increased use of domestic electricity during this period. Although this also meant gas suppliers were now able to use lower quality coal in gas production, it lowered costs and increased the supplies of high-quality coal available to other users, including the electrical supply industry. In general, the development of electrical supply was seen as a means of increasing the economic use of coal. The same is true of proposals to electrify the rail networks, as this would have increased the base load on power stations, leading to more economic production of electricity.

These issues were again mirrored by the British armed forces, which had maintained a strong interest in the development of the civilian electrical supply network. The Army and Air Force had been primarily interested in the design and layout of the electrical infrastructure, particularly in the use of overhead cables. The Army had also expressed significant interest in the standardisation of the electrical supply, as this would mean that military equipment would be compatible with the civilian power network. It also decreased the need for training as civilian electrical engineers would not need to be retrained to work military equipment, furthermore, military engineers would also be able to operate civilian generating stations during emergencies. Finally, the pre-war decision by the Admiralty to adopt oil over coal for naval warships reduced the reliance of the Royal Navy on coal supplies and as such was in part responsible for the fall in demand for high grade coal in the 1920s.

5. 'Really an Amazing Production': Building the National Grid, 1926-1935.

5.1. Introduction.

This chapter examines the planning and construction of the National Grid. It highlights the way in which energy security was the primary driving force behind the passage of the 1926 Electricity (Supply) Act, as well as the layout of the Grid network. It also emphasises the importance of the building the Grid to British industry in this period. I show that the construction of the Grid helped to ensure political and economic security by ensuring that key industries remained operational and offering employment to British Communities. This chapter also demonstrates the importance of energy supply over issues of amenity, particularly in relation to the construction of Battersea Power Station.

In November 1926, the *Hull Daily Mail* hailed the 1926 Electricity (Supply) Bill as being the 'Dawn of the Electricity Age', promising 'light, heat and comfort … for the many, not the few.'[1] Other newspapers, such as the *Dundee Courier* had noted that the Electricity (Supply) Bill was 'really an amazing production to be sponsored by a Conservative Government, above all a Conservative Government put into power to defeat socialism.'[2] Indeed, at the time many people expressed surprise that it had been left to a Conservative Government to pass a Bill of this nature. In July 1925, Phillip Cunliffe-Lister, the President of the Board of Trade, had

[1] 'Dawn Of The Electricity Age', *Hull Daily Mail*, 26 November 1926, p.11.
[2] 'The Electricity Bill', *Dundee Courier*, 5 November 1926, p.6.
The Dundee Courier was established in 1816 as a Conservative leaning paper, however, by the 1900s the paper had adopted a more independent stance.

asserted that 'electricity … is so inefficient today in this country that it has always been amazing to me that the Labour Government did not attempt to nationalise it.'[3]

One explanation for the apparent failure of the Labour Party to nationalise the electrical supply companies is the short-lived nature of the 1923 Labour Government, which was formed as a minority Government following a hung Parliament and lasted a mere ten months. In addition to this, the Labour Manifesto for 1923 had not included any references to electricity, nor indeed had it included any plans for the nationalisation of industry.[4] However, the identification of electrical power with socialism and the 1926 Electricity (Supply) Bill as a socialist measure was not uncommon; connections between electricity and socialism dated back to November 1920 when Lenin had famously described Communism as being 'Soviet power plus the electrification of the whole country'.[5]

So why was such a Bill even considered, let alone passed, by a Conservative Government? I argue that one key factor in the decision-making process was the 1926 General Strike, which had revealed not only the importance of electricity to the country, but also the vulnerability of the country to any disruption to electrical supply as a result of industrial action. While the vast majority of power stations had remained online throughout the strike, the small number that joined the strike had caused severe problems in London, cutting off power to food-storage sites, transportation services, dockyards and hospitals. I argue that following this event, the construction of an interconnected national electricity system was in part intended to ensure a continuous supply of electricity in the event of regional disruptions to power supplies, whether by industrial action, military attack or a simple accident. I further argue that the 1926 Electricity (Supply) Act was not intended as a means of nationalisation, but instead was a means of bringing the supply of electricity under state control, while still allowing the private

[3] CAB 27/281. 'Report Proceedings and Memoranda Of The Cabinet Committee On Electrical Development.' (London, 1926), The National Archives, Cabinet Documents.
[4] Craig. *British General Election Manifestos*m pp.47-49.
[5] Vladimir Lenin, *Lenin's Collected Works*, 4th edn, Vol. 31, (Moscow: Progress Publishers, 1965), pp.408-426.

ownership of generating plant and distribution networks. This system enabled the state to direct the shape and organisation of the industry on a regional and even national scale, while keeping the actual running and management of the individual power stations in the hands of private and municipal owners, much as had occurred with the control of the coal industry during wartime; as such it was not as socialist as contemporary commentators appeared to believe. Finally, I suggest that the development of a national electrical supply was intended to show that this kind of national infrastructure project was not merely the preserve of the Soviets, but could be undertaken, with greater efficiency under capitalism.

Battersea Power Station was one of the first new power stations to be commissioned after the 1926 Electricity (Supply) Act was passed. At the time, the decision to construct a new 'super-station' at Battersea was hugely controversial, attracting opposition from across the political and social spectrum. Yet, despite this widespread opposition, construction went ahead, with the power station becoming operational in 1933. Many of the objections to the construction related to the urban location, with critics arguing that the sulphur emissions from the new station would damage the fabric of the city and put the health of the local population at risk. The objectors claimed that the power station could just as easily and cheaply be sited closer to the pitheads with the electricity being transmitted wherever it was required. I argue that the construction of the new station at Battersea, rather than a more remote location, demonstrates that the National Grid was intended to ensure continuity of supply even if a local station was off-line, by enabling the transfer of power from other regions.

The construction of Battersea Power Station and the overall implementation of the 1926 Electricity (Supply) Act also demonstrates the commitment of the state to supporting the British electrical manufacturing industries. Following the Great War, politicians such as Lloyd George identified the electrical industry as being crucial to the continued development of the country. When planning the Grid, the Electricity Commissioners had insisted that all equipment should be sourced from British firms such as Ferranti and Metropolitan Vickers, both of whom received large orders for the Grid; Metropolitan Vickers was also one of the companies responsible for providing the turbines and generators for Battersea Power Station. The development of the Grid also helped to support other key industries, particularly steel manufacture and the shipping industries which were involved in producing pylons for the Grid and, of course, colliers to transport coal from the mines in Wales and the north of England to power stations, such as Battersea, in the south.

Beginning with an examination of the deliberations of the Weir Committee, I then move on to consider the role of the General Strike in enabling the Conservative government under Stanley Baldwin to pass the Electricity (Supply) Act. Following this, I explore the construction of the National Grid, focusing especially on the construction of Battersea Power Station to highlight the broader purpose of the Grid system. Finally, I show that the 1926 Electricity (Supply) Act and the construction of the National Grid form an extension of David Edgerton's concept of the 'Warfare State', not only ensuring a safe and secure supply of electricity for industry, transport, food storage and defence, but also providing sufficient orders to electrical manufacturers to enable them to remain in business.

5.2. The Weir Committee.

By 1925, the organisation of the electricity supply system was again under consideration by the Conservative government under the premiership of Stanley Baldwin. In 1924 Baldwin appointed Lord Weir to chair a Committee to 'Review the National Problem of the Supply of Electrical Energy.' The Committee reported back to the Cabinet in May 1925, concluding that, despite the advances made by the Electricity Commissioners over their five years of service, progress had been hampered by their lack of effective powers to coerce undertakings to work together.[6] The Weir report drew heavily on the conclusions of the 1918 Williamson

[6] CAB 24/173/56, 'Report Of The Committee Appointed To Review The National Problem Of The Supply Of Electrical Energy.' (London, 1925), The National Archives, Cabinet Documents.

Committee, endorsing and emphasising almost all the points made in 1918, as well as noting the losses which had been occasioned by the failure to fully implement the proposals of the Williamson Committee at the time.[7] Importantly they point out that while the Williamson committee had indicated the importance of interconnecting the different grid regions,

> The seven years which have elapsed since the Williamson Committee reported have produced almost complete evidence that this further degree of inter-connection between the areas is a *sine quo non*[*] to any really effective electrical system in a heavily populated and industrial country, such as is represent by the areas between roughly, the Clyde and the Tay on the North, and the Severn and the Thames on the South.[8]

This further strengthens the claim that the Grid was always intended to allow for the transfer of electrical power between regions and accounts for the siting of new stations such as Battersea in locations that would enable easy connection to the National Grid.

However, the Weir Committee stopped short of recommending full nationalisation and public ownership. Instead, it suggested that, as the Gridiron was completed, it would enable the owners of less efficient stations to purchase energy at a lower cost than they could generate themselves, naturally leading to the closure of inefficient plant. The report also makes clear that the adoption of a National Gridiron system along the lines proposed would impact positively on plans for the electrification of the railway network. The committee further noted that the proposed layout of the Gridiron would, as a result of the wayleaves necessary, largely conform to that of the railways. They further anticipated that this would enable the railways to take their supply directly from the Grid rather than expending capital on the construction of their own generating stations. This, it was argued, would also enable significant reductions in the cost of the generation of electricity as the committee believed that demand from the railways might account for up to twenty percent of the total national demand.[9] The Weir

[7] CAB 24/173/56, (London, 1925), The National Archives, Cabinet Documents, p.3.
* An Essential Condition.
[8] CAB 24/173/56, (London, 1925), The National Archives, Cabinet Documents, p.8.
[9] CAB24/173/56, (London, 1925), The National Archives, Cabinet Documents, p.20.

report was also strongly endorsed by the military, particularly the Royal Air Force. While the different branches of the armed forces had each developed an interest in developing the electrical resources of the country, they had in many places come to rely on access to electricity generated by civilian power stations. This obviously had important implications for national defence, particularly from aerial attack, but also effected the both Army and, to a lesser extent, the Royal Navy.

5.2.1. Not for Publication.

In July 1925, the Committee of the Cabinet issued an interim report on the actions which should be taken in response to the report of the Weir Committee. Foremost amongst the conclusions drawn by the Committee was that the report 'should not at present be published.' They accepted the technical basis for the Weir Committee's findings; however, the Committee warned the government not to exaggerate the potential benefits likely to be produced. The members of the Electrical Development Committee argued that, while the scheme would, as was suggest by the Weir Committee, directly provide a great deal of work, it would not on its own eliminate the problem of unemployment. They further pointed out that the provision of a cheap supply of electricity would not in itself serve to restore any industry as, 'the cost of power [was only] a very small percentage of the total cost of manufacture.' There was, however, some concern that, as proposed, the scheme did not contain sufficient safeguards to ensure that savings would be passed on to consumers and not be turned into profits for the undertakings. The Electrical Development Committee then recommended that the Committee of Imperial Defence and the Committee of Supply and Transport should be 'invited to report on the defence aspects of the Weir scheme.' This again emphasises the importance of electrification to the military as well as to transportation and communications.[10]

The decision not to publish the Weir Report is corroborated in *The Times* on 21 November 1925, when the paper reported on the annual dinner of the British Electrical and Allied

[10] CAB 27/281,'Report' (London, 1925), The National Archives, Cabinet Documents, pp.1-3.

Manufacturers' Association. Lord Weir commented that he had been asked to report to the Government on the development of electricity in the country, but that the Government;

> had not yet published the report, and he had no authority to disclose its contents. He did not know why it should not be published. His next difficulty was that he did not know to what extent the Government would adopt the report or when they would adopt it.[11]

Before going on to talk about his own 'personal views regarding the development of our power resources.' Lord Weir argued that coal was the main energy asset of Britain and that the real problem facing the country was how best to conserve and convert these resources into electrical energy. This point seems to be the most important factor in all the discussions and debates about energy, the interest of the state in the development of electricity is more closely related to retaining control over the country's energy resources, in particular, over the use of coal.

The coal shortage experienced during the First World War had highlighted the potential utility of electricity in controlling the distribution of energy in Britain. Wartime legislation had enabled the Government to control where and how energy was allocated, by approving or rejecting requests for connections. By prioritizing coal deliveries to power stations over domestic and industrial users, the Government had been able to ensure that energy was consumed to benefit the state.

On 16 June 1925, Colonel Ashley, the Minister of Transport, had pointed out that if the proposals made by the Williamson Committee in 1918 been adopted in their entirety, it was likely that no further legislation would have been required. He had also pointed out that, apart from the gas interests, there was general agreement 'that industry and transport would benefit greatly by increased electrical development.'[12] Ashley also noted that the committee's proposal to reduce the number of operational power stations, from 438 operational in 1925,

---

[11] 'Development Of Electricity', *The Times*, 21st November 1925, p. 14.
[12] Colonel Wilfred William Ashley was a conservative politician who served as Minister of Transport between 1924 and 1929.

to a total of 53, would lead to a significant reduction in the amount of coal required for power generation, as older and less efficient machinery was removed from use. He went on to conclude that it was neither possible nor desirable to nationalise the generating stations. In part this was because of the increased political opposition to nationalisation. However, the primary reason was because power companies were now more prosperous than they had been in 1918, likely in part a result of the work carried out by the Electricity Commissioners and the Electrical Development Association, over the intervening years. This would have increased the costs of buying out the private and municipal undertakings.[13]

A great deal of the discussion amongst committee members at this point centred on around concerns that the gas industry might be forced into competition with state-controlled electricity. While Mr Milne claimed to be happy competing against private enterprise, he was not prepared to face competition from what, Winston Churchill described as 'the unlimited resources of the state'. Lord Balfour likened the proposed Gridiron system to the railways, and argued that while the railways had not received government funding,

> If the state could have foreseen in the days of George Stephenson all that was going to happen in railway development, […] they would probably have made a different organisation, […]. The thing we are all wanting in electricity is this Gridiron and a universal system in which electricity should only be produced at the very best stations. From a national point of view, so far as electricity is concerned, that is all that anyone wants.[14]

The general viewpoint of the Electrical Development Committee appears to be that, even though electrical suppliers would be able to provide electricity for light, heating and cooking, this would not imply that the gas industry was in competition with the state. Rather the state was merely ensuring the most efficient organisation of the industry and hoping to miss the years of wasted development that they argued would occur if the industry was left to develop

---

[13] CAB 27/281, 'Report, Proceedings And Memoranda Of The Cabinet Committee On Electrical Development.' (London, 1925), The National Archives, Cabinet Documents.
[14] CAB 27/281, (London, 1925), The National Archives, Cabinet Documents.

on its own. Much of the argument by Mr Milne on behalf of the gas industry appears to rest on the basis that people should not adopt electricity because it was more expensive than gas at that point in time.[15] However, while it was hoped that the proposed Gridiron would help to reduce the cost of electricity to users, this was not the only, or indeed primary reason for proposing this scheme.

The most obvious reason for the high level of interest from the Conservative Government in constructing a national Gridiron, was the benefits to industry which would arise from access to cheap electricity. In many respects, it seems clear that the main interest of the government in developing a Grid system was to provide motive power for industry. This is supported by the statement of Sir Douglas Hogg, the chairman of the Electrical Development Committee, who summarised the relative positions of gas and electricity:

> So far as heating was concerned, gas is more efficient than electricity; with regard to lighting, there is little or nothing to choose between the two; as regards mechanical power, electricity is more efficient than gas.[16]

In this same meeting Sir John Snell went on to confirm that the desired level of electrical usage could likely be achieved without substantially increasing the domestic use of electricity for heating and cooking, and that the

> Estimate of 500 units per head for the whole country was based on the consumption in the industrial districts of 700 units per head and the consumption in the remainder of the country of only 200 units per head.[17]

This again emphasised the importance of electrical development for industrial purposes, rather than domestic use and suggests that the scheme was intended to enable an uninterrupted supply of electricity to vital industrial districts.

---

[15] CAB 27/281, (London, 1925), The National Archives, Cabinet Documents. [13281].
[16] CAB 27/281, (London, 1925), The National Archives, Cabinet Documents.
Sir Douglas Hogg was a Conservative MP with a background as a lawyer, he was later to become Chancellor of the Exchequer.
[17] CAB 27/281, (London, 1925), The National Archives, Cabinet Documents.

At a meeting of the Electrical Development Committee on 23 June 1925, Sir John Snell had been asked to describe the Weir Committee's scheme and to explain how it would benefit British industry.[18] In reply, he had explained the desirability of concentrating electrical generation in a smaller number of large stations, situated close to the coal fields and principal waterways. Snell then identified three types of station that would be required for the proposed scheme. The first type of station was those stations already in operation, but which had potential for further expansion. The second type of station was those which were currently under construction, but which had significant potential for future expansion and development. Finally, and most significantly, Snell identified a set of

> Future capital stations […] not yet in existence, which will be required in strategic positions in order to supply the various loads in denser parts of the country. And then in order to inter-connect them for three purposes, one for security, and secondly to prevent undue investment in spare plant, which is necessary if stations are independent of one another, and thirdly to traverse parts of the country which might not otherwise be fed with electricity at all.[19]

This was the first occasion on which security had been explicitly mentioned as a reason for the interconnection of generating stations. While it is unclear who or what the security is for, it is reasonable to assume that it was intended to protect against the loss of generation at any single power station, whether by military action, natural disaster or industrial action, from disrupting the supply of electricity for industry, transportation or communications.

5.2.2. The Military and the Weir Committee.

As has already been intimated, the Air Ministry largely endorsed the findings of the Weir Committee, both in terms of the development of a Gridiron system, on the basis that

[18] Sir John Snell was a consulting engineer and was appointed President of the Institute of Electrical Engineer in 1914.During the First World War he served on various committees advising the government on electrical matters.
[19] CAB 27/281, (London, 1925), The National Archives, Cabinet Documents. [13290], p.4.

> [I]n the event of a main station being seriously damaged, the sector normally dependent on that station can be adequately supplied with power from some other undamaged and interconnected station.[20]

As we shall see later in this chapter, this spoke directly to the fears of senior RAF officers as to the vulnerability of generating stations and promised to provide for continued electrical provision, even in the event of a successful attack on a generating station. In order to significantly affect the capacity of the Grid to generate and distribute electricity, it would be necessary for the attacker to simultaneously disrupt generation at multiple, geologically diverse power stations.

With regards to the location of new main generating stations, the Air Ministry also approved of the decision to locate most stations in the north of the country as this was at less risk of aerial attack than other regions of the country. In the First World War the only aerial craft which had been able to reach this region were Zeppelins, which had caused minimal disruption due to difficulties in bombing from the high altitudes at which they were forced to fly.[21] While acknowledging that the design and functionality of the Grid would require the construction of some power stations in the South of England. The Air Ministry suggested that, if possible, the Ministry of Transport should reduce the number of large power stations to be constructed in the south, particularly around the London area.[22] The concentration of main power stations in the north of England also made sense from the perspective of the Admiralty. Much of the coal for power stations in London was shipped by sea and would require protection from enemy naval forces in the event of a future war. This would significantly increase the demand for escort units such as destroyers which were also needed to ensure the protection of the battlefleet from submarines. If the creation of coastal convoys proved to be problematic, coal

---

[20] AIR 5/612, 'Defence Aspects of Electrical Development.' (London, 1925), The National Archives, Air Ministry.
[21] For a more complete discussion on First World War Air Raids see: Joseph Morris, *The German Air Raids On Great Britain, 1914-1918* (Darlington, East Sussex: Naval and Military Press, 1993).
[22] Air 5/612, (London, 1925), The National Archives, Air Ministry, pp.2-3.

supplies would again have to be transported by rail, as had happened in the Great War, placing a significant demand on the rail networks.

However, despite the general acceptance of the Weir Report by the government and the armed forces, it is uncertain whether any legislation would have passed through Parliament in the face of opposition from special interest groups within the electricity supply industry and the gas industry, without some form of external pressure. This came in May 1926 in the form of the General Strike, an event which for nine days brought Britain to a standstill and revealed the extent to which the country was already becoming dependent on access to electricity.

5.3. The 1926 General Strike.

The General Strike of 1926 lasted for nine days between 3 and 13 May. It was initiated by the General Council of the Trades Union Congress (TUC), to force the government to intervene in the ongoing dispute between the coal miners and mine owners over pay and working conditions. Keith Laybourn argues that it was the only occasion on which 'the vast majority of the organised working class have given their industrial, financial and moral support to a group of workers for more than a day.'[23] According to Laybourn, the huge support for the miners was an anomaly in a period which had seen a general reduction in the number of working days lost to industrial conflict. Indeed, Wrigley argues that, as a result of wartime experiences of cooperation between employers and workers, a significant number of trade unionists preferred to attempt to settle differences with employers without either industrial action or appealing to Whitehall.[24]

One aspect of the General Strike which has received a great deal of attention from historians is the interest and support for the strike shown by the Communist Party and in particular from

[23] Keith Laybourn, *The General Strike Of 1926* (Manchester: Manchester University Press, 1993), p.11.
[24] Chris Wrigley, 'Trade Unionists, Employers And The Cause Of Industrial Unity And Peace, 1916-21.', in *On The Move: Essays In Labour And Transport History Presented To Philip Bagwell.* (London: Hambledon, 1991), 155-180, (p.155).

the Soviet Union. Intercepts of communications and donations of money intended for the strikers indicate that the Soviet Union was actively, if covertly, attempting to aid the strikers, although it is unclear to what extent they expected the strike to have any lasting effect on Britain beyond a short-term disruption to the government. As a result of Lenin's 1921 speech, electricity was already closely associated with the Soviet Union in the minds of the British public and as we have already seen, the 1926 Electricity (Supply) Act was repeatedly criticised as being socialist in nature.[25]

However, traditional histories of the General Strike have largely ignored the role of power station employees, in part because the General Council of the TUC had attempted to stipulate that power stations could provide electricity for lighting and domestic use but could not supply electricity for business or industry. In practice, this system proved to be unworkable, as it was impossible to separate electricity for power from electricity for lighting and domestic purposes. This was compounded by the TUC allowing individual unions to decide whether they would supply power and for what purposes. As a result, there was no unified action and many of London's power stations remained operational.

This was partly enabled by the employment of naval ratings and volunteers from the universities, who helped maintain at least a basic level of service, during the strike. The use of naval ratings was a controversial step and one which required Parliament to give a great deal of additional authority to the Home Secretary. The use of naval ratings also shows that Parliament now recognised the importance of electrical supply, as military personnel could only be used to break a strike in industries which were deemed to be vital to the operation of the state. It is interesting to note that there was no attempt made to use the armed forces to operate the mines, possibly due to the time of year, as there had been time to build up sufficient coal stocks for power stations and gas works. Furthermore, the loss of the industrial

[25] 'The Electricity Bill, A Growing Revolt.', *Dundee Courier*, 5th November 1926, p.6.

power demand during the strike would have significantly reduced the electrical power needed and thereby reduced the amount of coal required for each power station involved.

5.3.1. Origins of the Strike.

Due to the importance of coal to the British economy, it is unsurprising that coal disputes form a key theme in British politics throughout this period. The dispute between the coal miners and mine owners mediated by Lloyd George during the early 1920s was never fully settled, and certainly not to the satisfaction of the miners. The strength of the disagreement between the miners and mine owners is indicated in the *Report of the Court of Enquiry Concerning the Coal Mining Dispute*, published in 1925. In summarising the differences between the two groups the writer noted that:

> It was obvious that the Mining Association could not be asked to abandon views which they entertained any more than the Miners' Federation could be asked to abandon views which they entertained.

The bulk of the problems between the two groups can be summed up in two main points: pay and hours. As was discussed in chapter three, in order to settle the dispute during the Great War, Lloyd George had met almost all the demands of the miners, increasing pay and reducing working hours, however, this had at best provided a temporary respite. The Mining Association believed that this had raised the price of coal making it uncompetitive both at home and abroad. In contrast to this the Miners' Federation were asking for the maintenance of the shorter working day and an increase in pay in line with the cost of living, with neither group willing to compromise on these points.[26]

In examining the causes of the dispute, the 1925 Court of Enquiry concluded that much of the trouble was related to the condition of the industry, which, in common with others '[was] experiencing a period of acute depression.' Neither the miners nor mine owners disputed this point, which was backed up by statistics. These showed a reduction in the amount of coal used

[26] Cmd, 2478. 'Report By A Court Of Enquiry Concerning The Coal Industry Dispute.' (London, 1926), The National Archives, pp.7-8.

by heavy industry, with the figures for 1924 showing a decrease of almost four million tons over the figures from 1913. This was attributed to a variety of causes, the increased substitution of oil for coal in shipping, particularly in the Royal Navy, the growth of hydroelectricity, and finally a conspicuous increase in coal production in countries which had previously been net importers of coal from Britain. Of these three points, the development of hydroelectricity in Britain had been minimal and therefore of little consequence. However, countries such as Italy, which had been unable to import coal from Britain during the war, had made great progress in this direction, and had reduced their imports of coal from British mines. The decrease in foreign demand was almost certainly the most important in terms of tonnage, with exports falling from over 73 million tons in 1913, to below 60 million tons in 1924. The decline in coal used by industry can likely be traced to increased electrical consumption as more industries switched to centrally generated electricity rather than utilizing steam power or generating their own electricity.

The court later questioned whether the coal mining industry was one

> Whose fate, from a national point of view can be left to be determined by the unmitigated operation of purely economic forces. It is a basic industry whose product is indispensable for our industrial, commercial and domestic life. […] a drastic restriction of its activities would be fraught with grave consequences.

However, they concluded that this question fell outside the remit of the court.[27] In general they concluded that the ongoing dispute was the fault of neither party, but rather an unavoidable consequence of the Great War, and was unable to offer any firm recommendations as to how to proceed, leaving the issue unresolved with dire consequences in 1926.

It is interesting that this court of enquiry issued its report at approximately the same time as the Weir Report was under consideration by the Cabinet. Economy of coal usage was a key

[27] Cmd. 2478, (London, 1926), The National Archives, pp.7-8.

feature in this report as well as in the deliberations of the Electrical Development Committee and would have been a key factor in the decision to develop the National Grid.

5.3.2. Electrical power during the General Strike.

When the strike finally took place on 3 May 1926, it had only a limited impact on the supply of electricity within Britain, with most of the disruption taking place in the London area. This was in part due to the confused stance taken by the General Council, which had attempted to limit the supply of electricity to lighting only. However, at the beginning of the strike the General Council had promised that all hospitals would be able to carry on their work without any interference. The situation was further complicated by the fact that different trade unions had already provided a wide range of instructions to their members. Some bodies such as the Electrical Trade Union had given instructions that all members, except those whose work involved the supply of electricity to hospitals, should cease working. One result of this confusion and disunity within the movement was that three major London hospitals were forced to operate without electricity, severely limiting the services which could be provided. On 8 May, the *Northern Whig* reported that:

> Three important London hospitals are still without electric current, owing to the Stepney Power Station cutting off the supply. […] The work of these hospitals becomes more and more hampered by the loss of electrical power, and all X-rays has had to be stopped. […] The action of the Stepney Power Station shows the incompetence of the Trades Union Congress, who promised in a manifesto issued at the beginning of the strike to allow all hospitals to carry on their work without interference of any kind.[28]

While this appears to show a degree of disunity within the trade unions, it may highlight a more basic problem: that it was very difficult, if not impossible, to control the way in which someone receiving a supply of electricity would make use of it. In practice, it would have been easier for strikers simply to stop generating power, than to attempt to control where the power went and how it was used.

---

[28] 'Hospitals Hampered.', *The Northern Whig*, 8th May 1926, p. 7.
The Northern Whig was a weekly Liberal paper established in 1832 in Belfast.

In an effort to maintain at least a minimal supply of electricity for vital services, the government turned to a combination of gentleman volunteers, particularly undergraduates from Cambridge and Oxford universities, working alongside naval stokers, and a few strike breakers. One Cambridge undergraduate later recounted that 'We arrived safely at the power station, where the gates opened and closed behind us like a prison. In all there were about 50 of us up there, 20 volunteers, 20 of the permanent staff and 10 or 12 seamen to help with the stoking.'[29]

The use of the military to break the strike had been authorised by the Home Secretary under the Emergency Powers Act 1920. On 30 April 1926, the Prime Minister declared a state of emergency. Regulation 4 of the Emergency Powers Act gave the Premier the authority to designate a service of being of vital importance to the state, and on 5th May the Home Secretary, Sir W. Joynson-Hicks informed Parliament that

> I have directed that the supply of electricity is a vital necessity. I have directed that the maintenance of the electrical and mechanical plant and machinery of the Port of London is a vital necessity. I have further directed that the transport of motor spirit is a vital necessity, and that the continuance of the railway service is a vital necessity.[30]

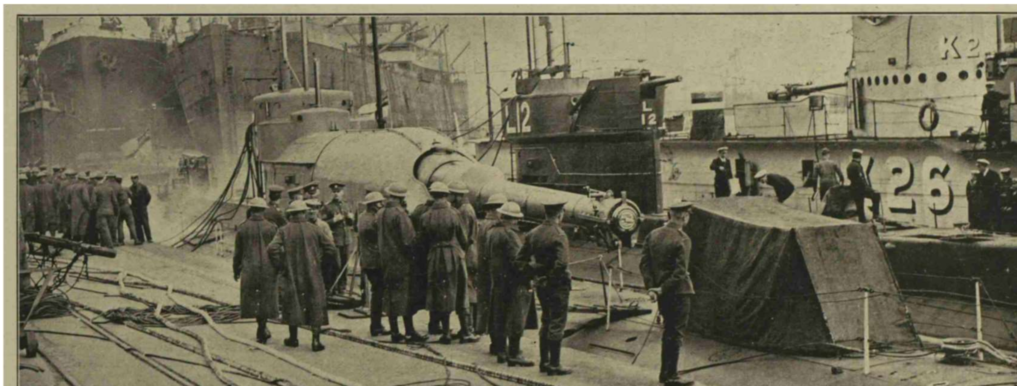
This declaration meant that the government was now able to call upon the military to ensure the continued supply of electricity and other vital services. On 6 May *The Scotsman* reported that Regulation 24 gave the government 'power to call upon the forces of the crown to assist in maintaining vital services.' Before going on to explain that only a small number of the naval personal and volunteers available had been employed.[31] However, the same report also noted that, as a result of the reduced electricity available there was now a danger of large amounts of meat in the Port of London warehouses going bad. In order to combat this problem and to

---

[29] Julian Symons, *The General Strike* (London: The Cresset Press, 1957), pp.80-81.
[30] 'Emergency Powers, Home Secretary's statement,' HC Deb 05 May 1926 vol 195 cc291-408.
Sir W. Joynson-Hicks was a conservative politician with a reputation of being well informed on technical matters. He became Home Secretary in November 1924 having previously held several junior ministerial positions.
[31] 'Emergency Powers Home Secretary's Statement.', *The Scotsman,* 6th May 1926, p.5.

provide power to the docks, the Royal Navy made use of three submarines to provide power to the Royal Victoria Dock, the Royal Albert Dock and the King George V dock (Figure 5.1).

As a result of the implementation of Regulation 24 and disjointed action of strikers in relation to power stations, the general strike had only a limited impact on the supply of electricity in Britain. Electrical workers around the country continued to supply electricity to vital services as had been promised by the Trade Unions Congress at the outbreak of the strike. However, those areas which did experience power shortages because of the strike served to further demonstrate to the government the importance of electricity to the country and undoubtedly played a part in the decision to coordinate and interconnect the supply of electricity across the entire country. While the 1926 Electricity (Supply) Bill had been introduced to Parliament prior to the General Strike and was already being debated in committee. I argue that the strike helped to focus the debate and arguments in favour of an interconnected network of power stations.



SUBMARINES (INCLUDING ONE WITH A BIG GUN) CONVEYING A SUPPLY OF ELECTRICITY BY MEANS OF CABLES AT THE ROYAL ALBERT DOCKS
A SCENE ON THE LAST DAY OF THE GENERAL STRIKE, SHOWING SOLDIERS ON ESCORT DUTY.

Figure 5.1. *'HMS M3 Supplying Power to The London Docks', Illustrated London News, 15th May 1926, p. 5.*

The Illustrated London News was a Primarily Conservative leaning newspaper established in 1842 and published on a weekly basis until the 1970s. It regularly carried features on scientific discoveries.

5.4. Building the Grid.

The 1926 Electricity (Supply) Act required the Electricity Commissioners to prepare schemes for different areas of the country. They were to provide for; the use of selected stations to generate electricity for the Board, the erection or purchase of main transmission lines, the standardisation of frequencies, as well as for any necessary temporary arrangements regarding the generation and supply of electricity while work was being carried out.[32] However, in recognition of the possibility that these schemes would require periodic alteration or extension, protective provisions were put in place.

> Any such scheme may from time to time be altered or extended by a subsequent scheme, but it is subject to protective provisions in favour of railway companies, canals, in-land navigation, dock or harbour undertakers and the owners of private generating stations.[33]

These protective provisions demonstrate the importance of both national security and private industry to the Conservative Government. One example of this, with regard to private industry, was that once a power station had been designated as a 'selected station' it could not

> Cease to be such without the consent of the owners thereof, and the Board must make arrangements with the latter for the operation, extensions or alterations of the station required by the Act or by the relevant scheme.[34]

This meant that once a power station was accepted as a designated station, it became almost impossible for the Electricity Board to stop purchasing electricity from it, thereby ensuring that so long as the owner of the station could continue to produce electricity below the set price, they would continue to make a profit. It is also likely that this restriction on the powers of the electrical authorities was a ploy to secure the cooperation of those with vested interests in both private and municipal power undertakings in passing the required legislation. In terms of

---

[32] Richard Home Studholme, *Electricity Law And Practice. A Handbook On The Application And Effect Of The Electricity Supply Acts. 1882 To 1935.* (London: Sir I. Pitman & Sons, 1935), pp.32-33.
[33] Studholme, *Electricity Law and Practice*, p.33.
[34] Studholme, *Electricity Law and Practice*, p.33.

national security, this demonstrates that transportation, was given a high priority. It would not be possible to alter an existing scheme in anyway which would protect the interests the railways, canal systems and other inland water ways.

5.4.1. Legislation.

Numerous historians and commentators, including Bill Luckin, Leslie Hannah and Graeme Gooday, have emphasized the complexity of the legislation relating to electricity and electrical supply during the first half century of electrical power supply. Indeed, the problems raised by this complexity was one of the key concerns put forward during the Great War by the Williamson Committee in favour of the complete reorganisation of the electricity supply industry under a simplified legislative framework. In the introduction to R.H Studholme's *Electricity Law and Practice*, published in 1935, the author notes:

> The existing law as to the supply of electricity is to be found in a series of Acts, orders and regulations dating from 1847 to the present day … the Acts have never been consolidated, and their interpretation involves much cross reference. To the majority of present or would be consumers of electricity they are a complete mystery.[35]

Studholme was one of many lawyers eager to try and explain the workings of the electricity supply legislation. While his book dealt expansively with all the legislation from 1847 to 1935, others, such as Rimmer and Allen's annotated version of the 1926 Electricity (Supply) Act, focused exclusively on the 1926 Act and provided a wealth of knowledge explaining the different clauses of the Act and how they would work in practical terms. The men, both practising Barristers, were concerned with the legal and legislative changes to the established system of electrical supply and their books would have primarily been intended for use by other lawyers, including those working in-house in private electrical generation and supply undertakings. In the preface to the publication they noted that the 1926 Electricity (Supply) Act:

[35] Studholme, *Electricity Law and Practice*, p.Vii.

> [Brought] into operation a National Policy in regard to the generation and high-tension transmission of electricity in this country without the Nationalisation of the industry and [marked] a step-in legislative reform which [could not] be overlooked by anyone interested in political and social progress.[36]

In many respects, this is one of the most important aspects of the Act, the provision of a national policy to coordinate the generation and distribution of electricity across the entire country while still supporting private industry. The Act allowed those private suppliers of electricity, whose plant met agreed standards, to supply power to the National Gridiron at prices set by the Central Electricity Board. As such, provided the suppliers where able to generate power below the purchase price set by the Board, they would be guaranteed to make a profit. This would ensure the availability of cheap electricity throughout the country while minimising the cost to the state. This is supported by R.H. Studholme in *Electricity Law and Practice*. As with Rimmer and Allen's volume, this book was intended to enable legal practitioners to easily locate and understand the vast quantities of legislation relating to electricity supply with the author noting that 'the first and last object of [the] book [was] utility.'[37] Studholme noted that, the 1926 Act was intended to enable the 'provision of cheaper and more abundant supplies of electricity'. He further noted that the Central Electricity Board, created by the Act, were responsible for the construction of main transmission lines 'between selected generating stations, the owners of which [were] obliged to sell the whole of their output to the Board at cost price.'[38] This electricity was then resold in bulk to authorised undertakers at prices set in accordance with the Act. This meant that only those undertakers whose generating plant met the standards laid down in the 1926 Act could supply electricity to the Gridiron. Conversely however, this also put into place controls over the price at which

[36] Edward Johnson Rimmer and George Read Allen, *The Electricity-Supply-Act, 1926, Explained And Annotated, With The Text Of The Electricity Supply Acts, 1919 & 1922, As Amended* (London: Solicitors' Law Stationery Society, 1927).
[37] Studholme, *Electricity Law and Practice*, p.Vii.
[38] Studholme, *Electricity Law and Practice*, p.5.

undertakers could sell electricity, and therefore mean that undertakers had to be able to provide and maintain their distribution infrastructure within those pricing constraints.

Some of the most important effects of the 1926 Act are those that relate to the issue of standardisation. Electrical enthusiast, particularly those, such as Merz and McLellan and Ferranti, who were interested in AC based systems, had long argued that the standardisation of supply, was a requirement to enable the supply of cheap electricity. They argued that this standardisation would benefit suppliers, manufactures and consumers alike. Studholme noted that the standardisation of frequency would be necessary to enable the full utilisation of the Electricity Boards supplies. The cost of any necessary alterations to generating plant would be met by the Board rather than by the owners of the plant and would be recovered from revenue generated by the sale of electricity to authorised undertakers.[39]

However, in the same way that the construction, extension, or alteration of a power station takes several years to complete, it also took several years to map out the requirements of the different regions and plan the program of construction. So despite being authorised in 1926, construction of the Grid did not properly begin for another two years with the erection of the first of the new pylons, near the village of Bonnyfield just outside Edinburgh, taking place in July 1928.[40] The extended construction period for new stations also accounts for the increase in the number of independent power stations during this period when a simple reading of the legislation would appear to indicate that the numbers should be decreasing. This may also at least partially explain the reluctance of private and municipal electricity suppliers to support the construction of a national power supply network and accounts for the way in which large sections of the 1926 Act dealt with issues relating to property and compensation. Rimmer and Allen explained that the regulations relating to the purchase of electricity undertakings by local authorities had remained largely unchanged by the 1926 Act, with the addition of 'Provision

---

[39] Studholme. *Electricity Law and Practice*, p.83.
[40] *Electricity Supply In Great Britain* (London: Electricity Council, 1973).

[being] made for the payment of a sum representing the capital properly expended upon plant or other assets rendered unsuitable for use by the reason of a company taking a supply in bulk from the Board instead of generating themselves.'[41]

This addition to the previous legislation was intended to encourage electrical undertakers to purchase a bulk supply of electricity from the Board, despite any recent investment in new and up to date machinery which would not be needed if the undertaker was to simply serve as a distributor of electricity rather than generating their own supply.

4.4.2. Pylons and Environmental Concerns.

As with all the previous electricity supply Acts, gaining the required permissions for the construction of the new pylons proved to be one of the most contentious aspects of the Act. Bill Luckin has noted that the construction of the pylons and power lines proved to be highly divisive, particularly in environmentally sensitive areas such as the Lake District and the South Downs.[42] In general, the Electricity Board had been able to persuade landowners to grant permission to construct the pylons, arguing that the completion of the network was in the 'national interest' and should not be delayed, however, this did not work in the Lake District or the South Downs. Instead the Ministry of Transport launched a Public Enquiry, which was intended to give all those interested a chance to air their grievances, hoping that any problems could be addressed, thereby enabling the construction of the Grid to proceed as rapidly as possible. The opposition to the pylons was comprised of a mixture of private landowners, municipal councils and environmentalists, with strong support from major national newspapers such as *The Times*. As with many other 'environmental' protests against electrical development during this period, the main issue was amenity and primarily focused on the aesthetic impact to the countryside. While the protestors did win concessions from the CEB in some parts of the country, for the most part the planned routes for the pylons went ahead

---

[41] Rimmer *et al.*, *The Electricity (Supply) Act, 1926: Explained and Annotated, p.*45.
[42] Luckin, *Questions of Power,* pp.94-117.

unchanged. However, while environmental concerns were only to have a limited influence on the shape of the Grid, military concerns proved to be much more influential.

5.4.3. Military Interest in Electrical Development.

The armed forces had maintained an interest in the development of electricity throughout the mid-1920s. A report, published in 1926, of the Committee of the Privy Council for Scientific and Industrial Research for the year 1925-26, noted that the electrical industry received a great deal of assistance from Government research establishments, particularly the Service Departments. All these departments spent 'large sums of money on electrical research, the majority of the results of which [were] available to industry.'[43] This clearly indicated that the State was maintaining a significant interest in the development of electrical technologies. This interest was shared by the military and particularly by the Royal Air Force.

By the mid-1920s, the Royal Air Force had developed a significant interest in the development of the country's electrical supplies, in part based on the desire of senior officers to justify the continued existence of the RAF as an independent service. By identifying the potential vulnerability of power stations and power lines to aerial attack and setting itself up as an expert on their design from a defensive perspective, the RAF was able to secure a place for itself that could not be readily assumed by either the Army or the Royal Navy. It also did not escape notice that this expertise could be used in reverse to attack enemy power stations in time of war, potentially crippling an adversary's munitions industries and transportation systems. However, as we will see in Chapter Six, while the RAF did in fact maintain dossiers on European power stations, carrying out a successful attack proved to be beyond the capabilities of the unescorted high-level bombers employed by the RAF at the outbreak of the Second World War. Indeed, Air Chief Marshal Harris described power infrastructure as a *panacea* target, which was not worth attacking. A viewpoint which was only enhanced following rapid

[43] Cmd. 2782, 'Report Of The Committee Of The Privy Council For Scientific And Industrial Research For The Year 1925-26.' (London, 1926), The National Archives.

recovery of German power infrastructure following the successful Dam busters raid on the Möhne and Dortmund dams in the Ruhr Valley following which Harris commented that:

> For years we have been told that the destruction of the Möhne Dam alone would be a vital blow to Germany. Both the Möhne and Eder dams were destroyed, and I have seen nothing either in the present circumstances of Germany or in M.E.W. reports, to show the effort was worthwhile except as a spectacular operation.[44]

However, in the meantime, the development of a national power network also created potential problems for the RAF, particularly in relation to flying training as such the air force also established a role for itself in planning the layout of pylon networks.

The RAF made extensive use of the rail network to transport parts and munitions around the country and were concerned that the proposals to electrify the rail network would render the system vulnerable to attack. The matter was considered so vital that it had been personally taken up by Air Chief Marshall Sir Hugh Trenchard in May 1924. The result of his enquiries was a meeting between Trenchard, John Snell, Maurice Hankey, J.R. Brooke, and Major General Ashmore, at the Offices for the Committee of Imperial Defence. They agreed that defence needed to be considered in the design of new power stations but could not take precedence over commercial concerns.[45] While the reason for this is not explicitly laid out it appears likely that some of the defensive ideas suggested, such as steel bulkheads dividing the interior of a generating plant, would have rendered the plant uneconomical to run.[46]

Responding to the RAF's fear over the potential vulnerability of the railways once they were electrified, Sir John Snell suggested that while he believed railway electrification to be inevitable in the long term, it was unlikely to be carried through as rapidly as it been in other countries, as Britain had 'an abundance of coal and a lack of water power, whereas in other

---

[44] Air 20/3239, 'Letter From Sir Arthur Harris To Air Marshal Norman Bottomley.' (London, 1944), The National Archives, Air Ministry.
[45] MT 50/2, 'Ministry Of War Transport, Sub Committee On Protection Of Vital Services,' 5 June 1924.' (London, 1924), The National Archives, Ministry of Transport, p.1.
[46] MT 50/2, (London, 1924), The National Archives, Ministry of Transport, p.2.

countries the converse was the case.'[47] However, Mr Brooks noted that the lack of standardisation on the electrified sections of main line track might lead to a lack of locomotives as the different standards would make it impossible to redistribute engines and rolling stock as had been done under government control during the Great War. He went on to suggest that he would like the support of the Air Ministry in convincing the Southern Railway to adopt the 1500 Volt system, which had been agreed to by the other railways groups, thereby illustrating the importance of military influence in the planning and organisation of national infrastructure.

As was discussed in the previous chapter, the Army had raised concerns about the potential vulnerability of overhead cables to damage from enemy action. However, opinion had been divided with some officers, suggesting that the overhead cables were easier and cheaper to maintain and repair quickly in the event of damage. In contrast to this, the Royal Air Force suffered from no such division, believing that in addition to being vulnerable to enemy attack, overhead cables also posed a risk to friendly aircraft. In August 1924, the Air Council sent a letter to the Committee of Imperial Defence stating their preference for the use of buried cables as 'an underground cable would no doubt be destroyed by a direct hit, but it would be immune from the risk of damage by blast or splinter.' The Air Ministry pointed out that as more aerial defences, such as searchlights, came to rely on electric power, it was imperative that they ensure the protection of those supplies. A further argument put forward by the Air Ministry against the use of overhead cables was the potential risk to the pilots of aircraft attempting to make an emergency landing.[48] Later correspondence appears to confirm that this was the most important factor in the RAF opposition, suggesting that any new power lines should be erected alongside roads, canals, railways and other natural ground obstacles, which

[47] MT 50/2, (London, 1924), The National Archives, Ministry of Transport, p.3.
[48] MT 50/2, (London, 1924), The National Archives, Ministry of Transport, pp.1-3.

pilots in difficulty instinctively avoid.[49] At a conference between the Air Ministry and the Ministry of Transport, ministers agreed:

> That during the next six months the Ministry of Transport would submit to the Air Ministry for their observations all proposals for the erection of overhead cables other than those … which definitely follow natural obstacles.[50]

It is possible that the positioning of many power lines alongside, roads, canals and railways may simply be a result of the Ministry of Transport already possessing the necessary wayleaves to establish electrical cables and pylons in those locations. Nonetheless, the support of the RAF in these decisions would have strengthened the case for selecting those routes.

5.4.4. Battersea Power Station: A Case Study.

As planned, the Grid was to be made up of almost 3,000 miles of overhead cables operating at a standard frequency of 50 cycles per second, with a pressure of 132,000 volts. Figure 5.4 (p.172) shows the proposed layout of the main transmission scheme but does not show the secondary lines which where to serve the distribution areas. While the selected stations where intended to mainly provide a supply to their own areas, they could also, when necessary, send power to anywhere else connected to the Grid. Potentially taking over the load from a damaged station while repairs were carried out. A key example of this policy in action is the construction of Battersea Power Station during the late 1920s.

Approval for the construction of the new power station on the Battersea site had initially been granted in 1927 with construction due to begin in 1929. In April 1929 Lord Jessel noted that, on 16 March 1927, *The Times* newspaper had published notice that consent had been granted for the London Power Company to construct a new power station at Battersea on the condition that:

---

[49] MT 50/2, (London, 1924), The National Archives, Ministry of Transport, p.3.
[50] MT 50/2, (London, 1924), The National Archives, Ministry of Transport, p.2.

> 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 the evolution of oxides and sulphur and generally for preventing any nuisance arising from the generating station or from any operations thereat.[51]

However, Battersea was not the first inner city power station to be affected by the requirement to limit smoke emissions. The Barton Street Power Station in Manchester was a key case which influenced the development of the station at Battersea. Barton Street power station had begun generation in 1923 and catered for nearly all the electrical load of south-east Lancashire. However, due to the low height of the chimneys (121 ft.) the dispersal of the waste emissions in all weather conditions was not guaranteed. A local farmer took the Manchester Corporation to court claiming that the emissions from the power station had reduced the value of his property. While this was initially dismissed, the judgment was later overturned by the House of Lords who stipulated that in future undertakers who ‘rely on statutory powers to excuse a nuisance [had] to prove, not that the nuisance [was] inevitable, but that it could not have been avoided by any reasonable expedience known to science.’[52]

This judgment had a profound impact on the design of Battersea Power Station, particularly in terms of the height of the chimneys and the proposed methods of scrubbing sulphur from the emissions. Bowler and Brimblecombe have argued that the case of Barton Power Station had served to illustrate the potential problems involved by situating a large power station within an urban environment and was likely responsible for stipulations placed on the London Power Company when constructing Battersea.[53]

[51] ‘PROPOSED POWER STATION AT BATTERSEA’, HL Deb 25 April 1929 vol.74 cc210-26.
News In Advertisements’, *The Times*, ‘16th March1927, p.13.
[52] Farnworth 1930, Cited in Catherine Bowler and Peter Brimblecombe, ‘Battersea Power Station And Environmental Issues 1929–1989’, *Atmospheric Environment. Part B. Urban Atmosphere*, 25.1 (1991), 143-151 <https://doi.org/10.1016/0957-1272(91)90048-j>.
[53] Bowler and Peter Brimblecombe, ‘Battersea Power Station And Environmental Issues’, p.144.

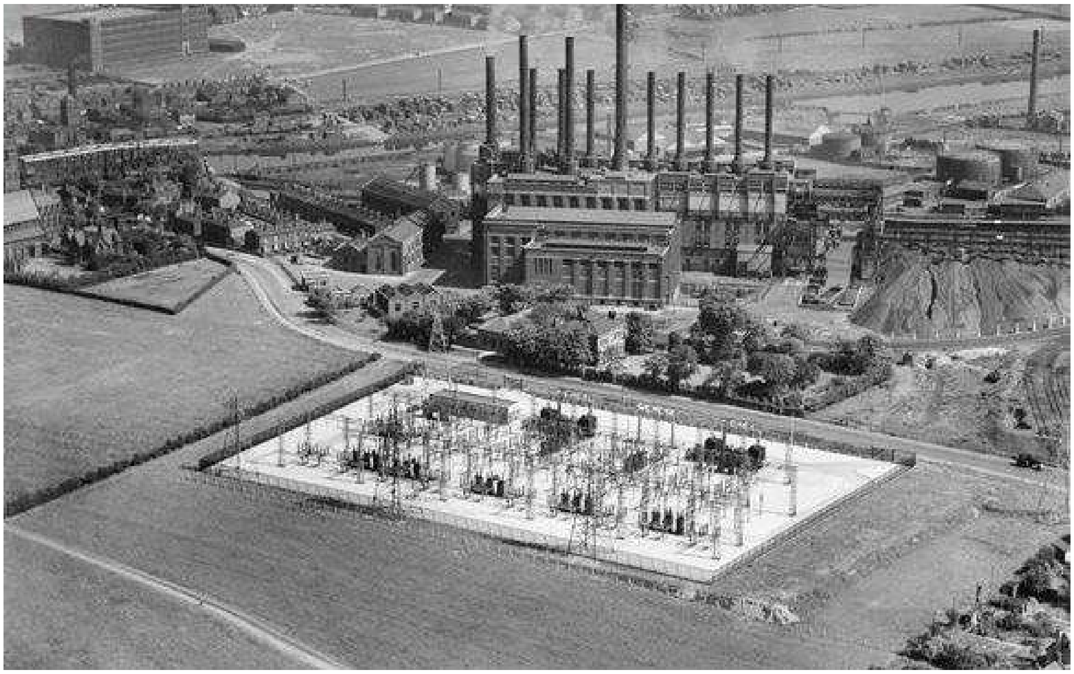


Figure 5.2: Barton Power Station, 1933. Britain from Above, EPW041532. Note the height of the chimneys and the proximity to local farmland.

Figure 5.3: Battersea A Power Station, C1930, 'Battersea Power Station – 50 Years of Service – A Short History' CEGB Public Relations, 1983, MSI Archive Centre. Note the proximity to the river and railway.

This case also indicates a further reason to site power stations such as Battersea in urban areas. The Great War had not only revealed the weaknesses of the pre-war electricity supply; it had also revealed the extent to which Britain was now dependent on imported foodstuff to feed the population. As discussed by Dominic Berry, The National Institute of Agriculture and Botany (NIAB) had been established in 1919 to develop new hybrid crop varieties to help enable the country to become more self-sufficient in terms of food supply.[54] The potential for power station emissions to cause damage to crops, as had been the case in Manchester, may have mitigated against the use of more rural sites due to the potential risk to crops. However, another key factor could also have been the lack of existing infrastructure in rural regions, which, as is shown by Brassley *et al*. would have made construction less economically viable due to the increased capital costs.[55]

Bowler and Brimblecombe have argued that Battersea was located in this position, despite the opposition from prominent scientists such as Henry Tizard, as well as from the King and other members of high society, because it had been:

> Designed as an integral part of the Grid System and, unlike earlier local sub-stations, was to take advantage of the Grid. The site on the industrial bank of the Thames was chosen to be convenient for the supply of coal and water, but also close to the west end of London, the intended area of supply.[56]

In the 1927 the Annual Report of the Central Electricity Board, the board identified the basis on which power stations would become selected stations. The decision was based on the five points outlined below.

Basis of Selection of Generating Stations:

(i) The cost of coal delivered to the station;
(ii) The abundance of water for condensing purposes;
(iii) Technical characteristics of the station such as type and size of the plant units, steam pressure, etc.;
(iv) Proximity to load;
(v) The possibility of the site for the further expansion of the station.[57]

The proposed station on the Battersea site more than fulfilled the five criteria listed above.

Due to its location, Battersea was in a good position receive shipments of coal both by

[54] Dominic Berry, 'Genetics, Statistics, And Regulation At The National Institute Of Agricultural Botany, 1919-1969.' (unpublished PhD, University of Leeds, 2014), p.51.
[55] Brassley and others, 'Transforming the Countryside', pp.222-223.
[56] Bowler and Brimblecombe, Battersea Power Station and Environmental Issues, p.143.
[57] 'First Annual Report Of The Central Electricity Board' (Manchester, 1928), Science and Industry Museum, Electricity Council Archives, p.3

river/coastal traffic and by rail, and this same riverside location also provided an ample supply of water for condensing purposes. In terms of technical characteristics, Battersea was to be a new station and was designed to run the largest electrical generating plant installed in a British power station. In 1928, *The Yorkshire Post* noted that two generating sets ‘each rated at 67,200 Kilowatts (90,000 horsepower) [had] been ordered from the Metropolitan-Vickers Electrical Company and the British Thomson-Houston Company for the Battersea power station of the London Power Company.’[58] Quite apart from the large size of the generating sets, these orders, presumably along with accompanying equipment, provided significant orders for two major electrical manufacturers during a period of economic recession.

Battersea was also very close to its intended area of supply, the west end of London, although it was this very proximity that led to many of the objections to the location due to fears of the emissions causing damage to buildings, artwork and the health of the local population. Finally, the site was intended to allow for further expansion, the power station was to be built in two halves, with the first section planned to come into operation in 1933. The importance of sites allowing for expansion did limit the possibilities in terms of city centre locations. This was a contributing to the expansion of rural sites in the 1950s and 1960s.

Most importantly, Battersea formed a part of the scheme of supply put forward for the Central England Electricity Scheme, which had been received by the Electricity Commissioners in March 1928. The scheme allowed for the interconnection and standardisation of electric power throughout central England and was predicted to cost more than had initially been allowed for. However, due to the importance of the area to the overall plan for the Grid, the CEB increased the money set aside for this work from £2,061,400 to £4,336,700 with work scheduled to begin in 1930.

[58] ‘Power Plants, New Size Records Being Established.’, *Yorkshire Post and Leeds Intelligencer*, 13th December 1928, p.4.

> After reviewing all the circumstances in light of the requirements both of the area and of the National Scheme, the Board came to the conclusion that in spite of the heavy increase in the anticipated expenditure on standardisation, it was necessary that the work should not be delayed.[59]

As can be seen in figures 5.4 - 5.6, Battersea power station was to hold a key place at the centre of this scheme, able to both transmit and receive power from the National Grid. Without the completion of Battersea, it would not have been possible to link the London area with the Central England Scheme. This would have weakened the interconnections between regions, restricting the amount of power that could be transferred into and out of London.

Bill Luckin has highlighted the controversy over Battersea's location and notes the responses to a letter published in *The Times* on 9th April 1929.[60] This letter, which had been signed by several dignitaries including the Mayors of Chelsea and Westminster, the President of the Royal Institute of British Architects, as well as representatives from several preservationist and voluntary organisations, outlined the size of the proposed power station and danger posed by its emissions to 'the whole of 'historic' and 'institutional' London, including the Houses of Parliament, the National Gallery and Whitehall.' The letter went on to question why the Electricity Commissioners had not followed the German practice of locating power stations away from urban areas and closer to the coalfields, suggesting that, due to the discovery of a significant coalfield in the area, a location in east Kent would be ideal for the construction of a new power station. Luckin noted that the editorial team of *The Times* was supportive of the letter. This position was further reinforced by support from Reginald Blunt, a local historian and the secretary of The Chelsea Society, which he had founded in 1927 in order to preserve the area for the public benefit.

---

[59] 'First Annual Report of The Central Electricity Board' (Manchester, 1928), Science and Industry Museum, Electricity Council Archives, p.11.

[60] C. B. Clapcott and others, 'Power Stations In Cities', *The Times*, 9th April 1929, p.17.
The Times is daily paper based in London and has been in publication since 1785. The paper has strong conservative leanings and has often been viewed as representing the views of the British government.

Eventually, having been greatly disturbed by correspondence in *The Times,* King George V also became involved in the debate instructing his private secretary to write to the Minister of Health, Neville Chamberlain, in which he questioned

> Why should it not be possible to follow the example of foreign countries where power stations are erected at a considerable distance from the towns which they serve, and in surroundings where they do the least damage?[61]

Herein lies the central point connecting the design and purpose of the National Grid with the decision to build a large power station on the Battersea site. The first report of the Central Electricity Board contains a technical description of the proposed Grid system. The report also makes clear that the National Grid was intended to serve a different function to similar systems on the continent and in the United States of America. Those systems were intended to transmit power between localised generating sources and the distribution areas where the power was required; in other words, they were designed to transmit 'large blocks of power over long distances in one direction only.' In contrast to this the British scheme was intended to provide for

> A system of interconnection which performs the two-fold function of an elongated busbar, with all the attendant advantages from the point of view of economical production, and a source from which the Electricity Supply Industry can draw all the bulk supply it requires.[62]

Battersea had been intended from the start to form a key link or node in this new network. Spreading major power stations throughout the country, interconnected by means of the Gridiron, enabled the Electricity Commissioners to ensure the continuous supply of electricity to vital services, even if a single power station was damaged by strike action, military activity or even by an industrial accident. Furthermore, the construction of the National Grid also enabled the Government to support British industry, providing employment for thousands of

---

[61] POWE 12/140, 'Captain A. M. L. Harding To Neville Chamberlain.' 12 April 1929.' (London, 1929), The National Archives, Ministry of Power.

[62] 'First Annual Report of The Central Electricity Board' (Manchester, 1928), Science and Industry Museum, Electricity Council Archives, p.14.

people across the country as well as securing the future of British electrical manufacturers, although as had been noted by the Electrical Development Committee in 1925, it is important not to overestimate the amount of additional work which was created by the construction of the National Grid.

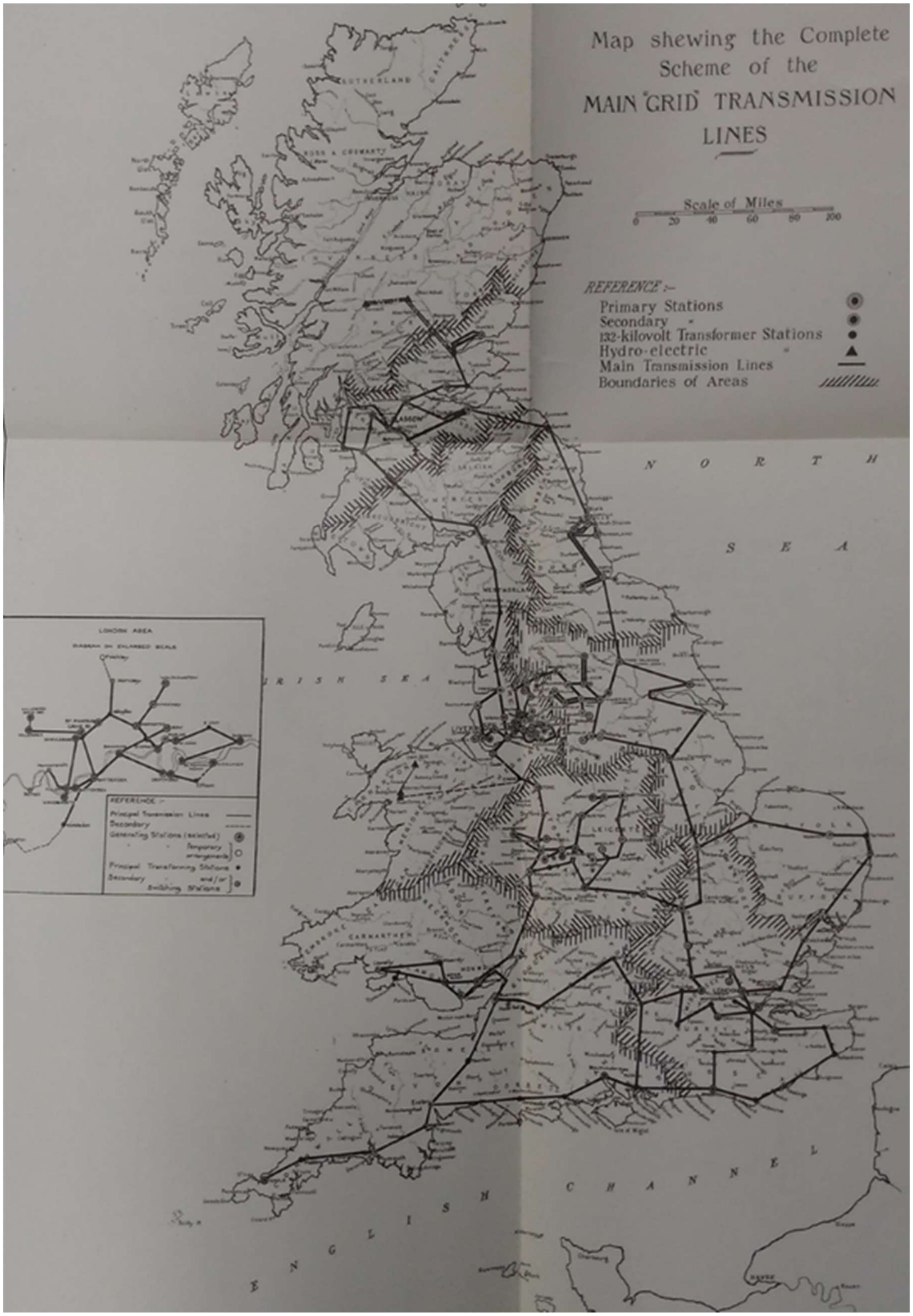


Figure 5.4. Map showing the proposed outline of the National Grid, excluding secondary lines. The smaller insert shows the connections to London. MSI Archives.

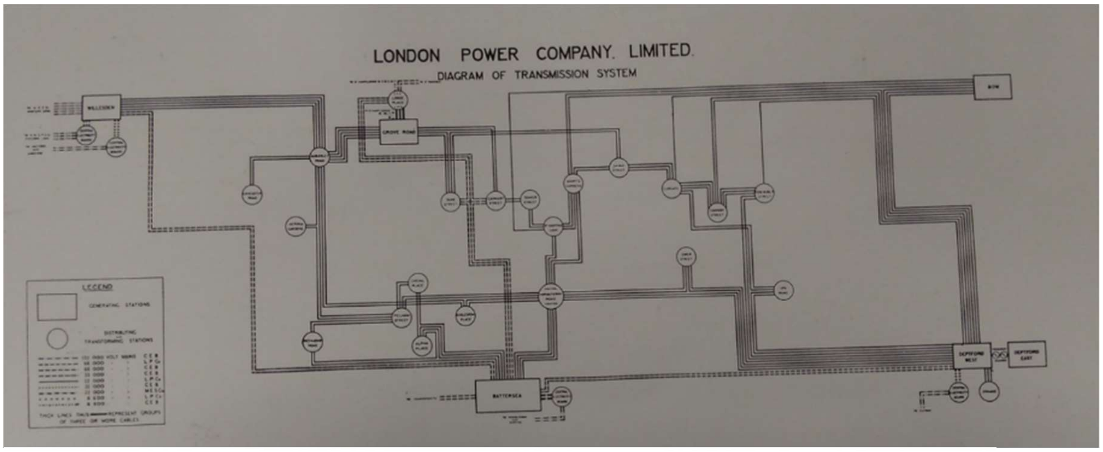


Figure 5.5. Enlarged diagram of the London area showing the locations of the power stations in relation to the Thames, MSI Archives.

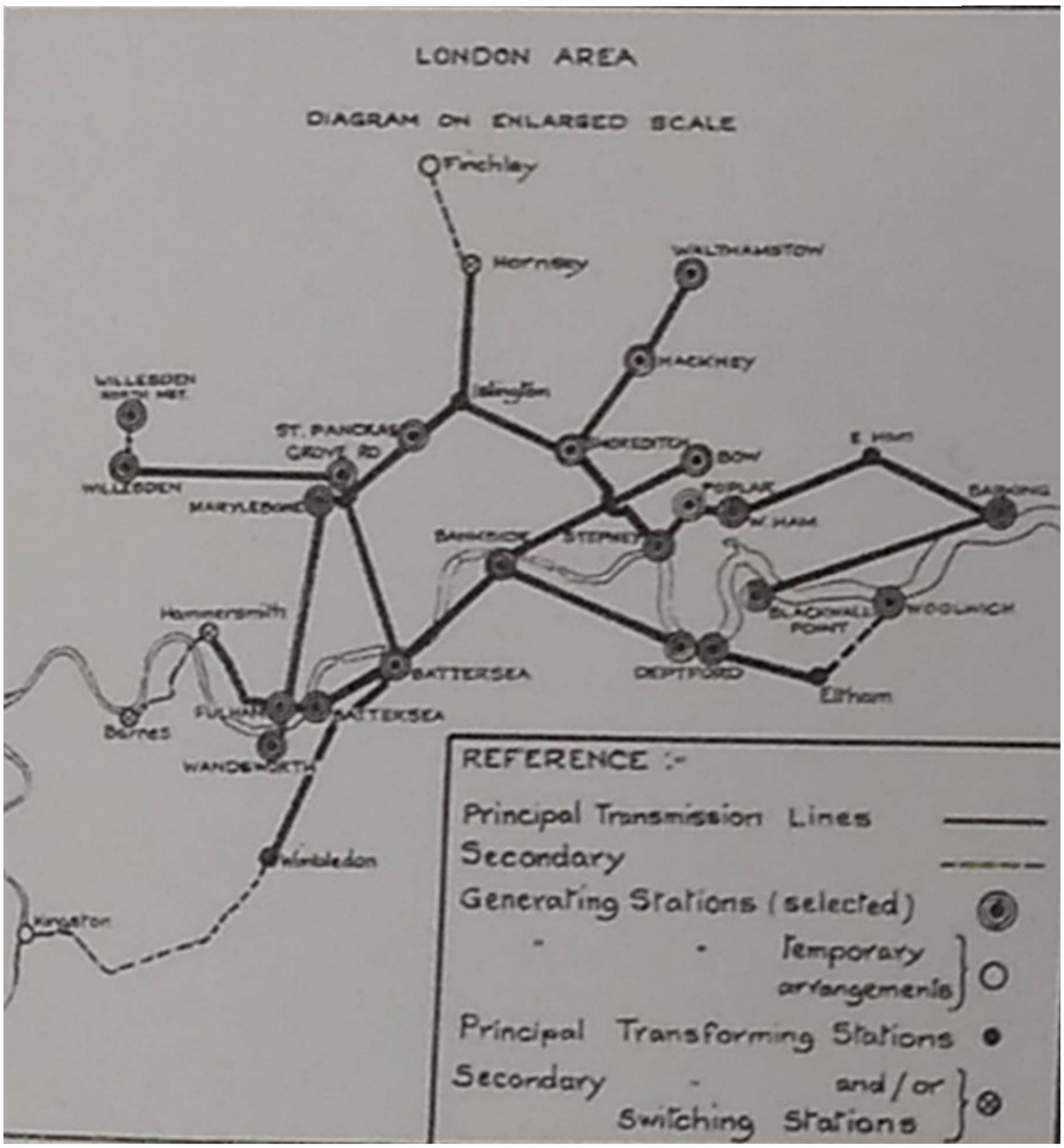


Figure 5.6. Diagram of the London Power Company network showing the connections to the National Grid, MSI Archives.

5.5. The Impact of the Grid's Construction on Industry and Employment.

The 1926 Electricity (Supply) Act not only ensured that industry was able to benefit from supplies of cheap electricity, but also the survival of British electrical manufacturers such as Ferranti and Metropolitan Vickers (Metrovic), both of whom supplied equipment to the National Grid and to the British military. In addition, both companies also manufactured electrical goods, such as fires, cookers and radios for the domestic market; therefore, they played a role in increasing the domestic demand for electricity that was vital to balance the industrial load and reduce the price of electricity overall.

In 1928, the first orders for the National Grid were placed with companies around Britain. One of the first sections of the Grid to be constructed was in Scotland. Three firms Ferranti and Metropolitan Vickers based in Manchester, along with the English Electric Company, based in Birmingham, received a total of £310,000 worth of orders. Of this Ferranti received £130,000 and Metropolitan Vickers £120,000 respectively. A report in the *Leeds Mercury* quoted a statement from a Ferranti official as saying that 'it will mean greatly increased employment in the district.' The paper went on to comment that 'these two great firms, like most others locally engaged in electrical engineering, have been successful in keeping their workers continuously employed.'[63] This suggests that electrical firms, such as Ferranti and Metropolitan Vickers, were unusual in their ability to maintain high levels of employment. This indicates a high level of investment within the electrical manufacturing industry, although it is also possible that this merely reflects the diverse nature of manufacturing carried out by both firms. However, it is clear that the construction of the National Grid brought about a significant increase in orders for both firms, both directly from the Central Electricity Board, as well as

[63] 'Big Electricity Scheme.', *Leeds Mercury*, 1st March 1928, p. 2.
The Leeds Mercury was first published in 1718, by the mid-1800s it was owned by Edward Baines as well-known reformist. However, the paper was purchased by the Conservative Newspaper Company in 1923.

from private and municipal power companies, taking advantage of the loan arrangements, which had been implemented as part of the 1926 Electricity (Supply) Act.

Beginning in 1928 Ferranti Ltd. began to experience higher levels of growth and reported profits of £54,616, up from £35,982 the previous year and by 1929 profits had risen to £66,976. [64] These levels of growth did fall in the early 1930s, as in October 1931 the Chairman, announced a profit of only £60,688 compared to £68,748 for the previous year. However, the Central Electricity Board arguably demonstrated its confidence in the Ferranti Company by 'placing with them the whole of its requirements for its largest transformers.'[65] This suggests that the Central Electricity Board's policy of only buying equipment from British firms had indeed served to bolster the industry during periods of financial hardship. John Wilson shows that by the end of 1930, Ferranti Ltd. had received almost thirty-two percent of the £1.5 million orders for 66 kV and 132 kV transformers, and that by the end of 1932 was in receipt of over £780,000 worth of orders from the Central Electricity Board as well as numerous power stations.[66]

As has already been mentioned, orders for the National Grid were not the only source of income for Ferranti or Metropolitan Vickers. Production of domestic electrical equipment, ranging from radios to electric meters, also provided a significant source of income as well as helping to increase the demand for electricity from domestic users. In 1933, the Ferranti Company went as far as making explicit links between their domestic products such as radios and their work providing transformers for the National Grid, building on what John Wilson in his history of the company has described as the company's reputation for quality.[67] Newspaper advertisements for Ferranti radios argued that it was comforting that 'should you buy a

---

[64] Ferranti Ltd', *The Yorkshire Post and Leeds Intelligencer*, '19th October 1928, p.18.
[65] 'Ferranti Ltd. Turnover Well Maintained: Stronger Position.', *The Yorkshire Post and Leeds Intelligencer,* 6th October 1928, p.14.
[66] John F Wilson, *Ferranti A History: Building a Family Business, 1882-1975.* (Lancaster: Carnegie Pub, 2003), pp.209-210.
[67] Wilson, *Ferranti A History*, p.215.

Ferranti radio set, to know that it was built by the same engineers who safeguard your electric current supply.'[68]

Interestingly, by this point Ferranti radio sets were almost exclusively designed to make of use of high voltage AC power with many of the models containing warnings that use with DC based electrical systems would damage the set. During this same period (1926-1933) the company also published a book *The True Way to Radio*, which was intended, not only to encourage amateur radio builders to use Ferranti components, but also to convince them that it was desirable to make use of mains electricity. However, the book also contained the warning that:

> Contact with the terminals or connections to a dry battery giving 120 or 150 volts can be unpleasant, but not very dangerous, owing to the limited power, but with apparatus connected to the Electricity Supply Mains, there may be the whole Power Station behind it, and contact can be dangerous to life.[69]

While warning of the potential dangers of mains electricity, the book also gave detailed instructions of how to mitigate the risks involved with building your own radio set, as well as the tools and metering systems, also supplied by the company, which would be needed to safely construct the device and achieve the best possible results.

Radio sets, while nearly ubiquitous by this time, did not use much current and did little to balance the industrial load. However, another device, which became common place in British households during this period was the electric heater. Many houses, particularly new builds, only had a single fireplace in the front room and possibly in the bedroom above; further, the high price of coal may have served to discourage families from lighting fires in all but the coldest weather. Electric fires were sold on the basis that they could provide instant heat when and where it was needed, without the attendant waste or mess inherent in traditional fireplaces. Ferranti had begun mass production of electric fires in 1927 following personal

---

[68] 'Ferranti, Electrical Engineers To The 20th Century.', *Portsmouth Evening News,* 23rd September 1933, p.5. The Portsmouth Evening News was a Daily newspaper with a liberal leaning first published in 1877.
[69] *The True Road To Radio.*, 6th edn (Manchester: Ferranti, 1935), p.202.

experiments to improve on the design of a Dutch heater which he had been using to treat rheumatism. His experiments resulted in a product that, as Corley points out, was to be described as 'the first fire of aesthetic merit'.[70] However, despite this success Ferranti struggled to compete with cheap imports as well as appliances produced by more specialist firms within Britain. This was in part due to the focus on producing high quality, well-engineered goods, which were significantly more expensive than those produced by the competition.[71]

Ferranti was not alone in producing products for both the domestic and industrial markets. Associated Electrical Industries (AEI), of which Metropolitan Vickers was a part, also made an explicit link between the production of electronic switchgear and domestic appliances. The AEI in-house journal regularly encouraged employees to purchase electrical products, pointing out that in doing so they not only helped provide work within the domestic appliance sectors, but also increased the demand for electricity and thus supported their colleagues in the transformer department by ensuring continued orders from the Central Electricity Board. This pressure on employees to increase their electrical usage appears to have been common within the electrical manufacturing industry, and is even depicted in an EDA pamphlet, *The Awakening of Peterkin*, published in 1921.[72] This pressure on employees to increase their own use of electricity and the consistent reminder about the links between domestic and industrial usage of electricity demonstrates the close links between all areas of the electrical industry, particularly firms such as Ferranti and Metropolitan Vickers, which benefited from the increase in domestic users as well as from the increases in orders for the National Gridiron.

5.5.1. Completing the Grid.

In September 1933, the final pylon, out of a total of 26,265 that made up the National Grid, was completed. Newspapers reported that 'the scheme has meant employment, directly or

---

[70] Thomas Anthony Buchanan Corley, *Domestic Electrical Appliances* (London: Cox & Wyman Ltd, 1966).
[71] Wilson, *Ferranti A History*, p.215.
[72] EDA 16, 'The Awakening Of Peterkin.' (Manchester, 1921), Science and Industry, Electrical Development Association.

indirectly, for 200,000 workers. Stimulus has been given to many British industries, including the iron, steel, coal, aluminium, and pottery.' The list of materials used included: 170,000 tons of steel; 12,000 tons of aluminium; 500,000 tons of cement; and 200,000 insulators; and 'the tonnage of coal represented by steel, cement, insulators, and the electrical engineering and cable-making industries is in excess of 800,000 tons.'[73] These were significant figures, the amount of aluminium used in the construction of the Grid accounted for almost one third of the industry's yearly output.

Possibly one of the more surprising industries to benefit from the construction of the National Grid and the construction of new power stations such as Battersea was shipbuilding. Between 1932 and 1935 the London Power Company ordered six new colliers to transport coal to power stations in London. These vessels were ordered from two shipyards, S.P. Austin & Co. based in Sunderland, and the Burntisland Shipbuilding Company, based in Fife. Possibly the best known of these ships was the SS *Ferranti,* launched in October 1932, and which survived the Second World War only to be lost in a collision with an American Liberty Ship in 1955.[74]

The orders for these colliers contributed to keeping these yards in business during this period. This is certainly true in the case of S.P. Austin & Company. Grace's Guide records that due to the Depression, the company only built two colliers in 1932. These were the *SS Tyndall* and the *SS John Hopkinson*, with a further vessel, the *SS Colonel Crompton* being launched in 1933, and all three were constructed for the London Power Company.[75] The same was true of the Burntisland Shipyard in Fife, which also constructed three colliers for the London Power Company during this period and was to construct three Loch class frigates, several Merchant

---

[73] 'Last Of 26,265 Pylons.', *Western Daily News,* 5th September 1933, p.7.
[74] Iain Sommerville and James Anderson, 'Ships Built By The Burntisland Shipbuilding Company Ltd: Arranged By Date Of Launch', *Burntisland.Net*, 2008 <https://www.burntisland.net/ships-list-anderson.htm> [Accessed 29 October 2017].
[75] 'S. P. Austin And Son - Graces Guide', *Gracesguide.co.uk*, 2019 <https://www.gracesguide.co.uk/S._P._Austin_and_Son> [Accessed 29 October 2017].
It is particularly interesting that so many of these colliers where named for electrical engineers, and possibly indicates that coal was becoming closely associated with electrical power.

Aircraft Carriers, and sixty merchant hulls during the Second World War.[76] It is unclear whether or not the construction of these ships and others like them was included in the figures for materials used and men employed reported in the newspapers. If not, it is possible that the figures shown under-report the impact of the Grid project on employment in Britain. In any case, the construction of the National Grid served to provide orders for companies which may well have been forced to close and enabled others, such as Ferranti, to maintain a higher level of employment than was normal for this period.

5.6. Conclusion: Electrical Security.

This chapter has focussed on the passage of the 1926 Electricity (Supply) Act and the construction of the National Grid. I have argued that the 1926 General Strike was key to the swift passage of the Act. While the strike itself had relatively little impact on the supply of electricity, it did reveal the extent to which the country, and particularly London, was becoming reliant on access to centrally generated electricity. It further revealed the potential for localised disruption to the supply of power to impact everyday life.

The Electricity (Supply) Act had stipulated that all the plant and machinery purchased for the Grid should come from British suppliers. This had two important effects, firstly, it provided work for British firms, at a time of high unemployment. Secondly, it ensured that the in the event of a future war, it would be possible to secure replacement parts for damaged Grid or power station components. This was key to ensuring security of supply for British Industry and as well see in the following chapter, the newly developed Chain Home Radar system. The construction of the Grid also helped to ensure economic and political stability during this period, by providing work for large numbers of British firms and their employees and reducing the risk of further strike action along the lines of the 1926 General Strike.

[76] 'Burntisland Shipbuilding Co - Graces Guide', *Gracesguide.co.uk*, 2019 <https://www.gracesguide.co.uk/Burntisland_Shipbuilding_Co> [Accessed 29 October 2019].

More importantly, the chapter clearly shows that the National Grid was intended from the start to ensure the security of electrical supply. By contrasting the interconnected nature of the Grid with the design of contemporary networks, it quickly becomes obvious that the Grid was intended to do more than simply transfer power from the point of generation to the point of use. Indeed, the first annual report of the Central Electricity Board clearly states that, in contrast to the systems used in the United States of America and Germany, the Grid was intended to serve as an 'elongated busbar' enabling power to be drawn from all connected power stations.

This chapter also demonstrated the increasing influence of the Royal Air Force on the layout of the Grid as well as on the design of individual power stations. While part of this appears to have been a political move, designed to demonstrate the importance of maintaining the RAF as an independent force; interest in other aspects of the Grid design, particularly the layout of the pylon networks, appears to have been motivated by operational concerns. It is particularly telling that military concerns over the positioning of high-tension cables had a more significant impact on the layout of the Grid than contemporary environmental concerns. The same is also true of the construction of Battersea Power Station. The importance of the Battersea location from a security of supply perspective overcame the environmental concerns raised by the local council as well as the King and other influential interest groups. However, the greatest test of the new grid system was still to come.

6. The Grid at War, 1935-1945.

6.1. Introduction.

On 6 February 1947, J. Hacking and J. D. Peattie presented their paper, titled *The British Grid System in War Time*, to a meeting of the Institution of Electrical Engineers. In this paper, they proceeded to describe the pre-war preparations of the Grid for war, and the actions taken by electrical undertakers, the Government, and the Central Electricity Board once war broke out. They also described changes in the load and generating plant capacity of the Grid and the operation of the Grid transmission system over the course of the war.[1] They concluded their paper by noting that:

> The experience during the 1914-18 war led in no small part to the planning and construction of the Grid. Designed for peace-time requirements, it proved its worth in the greater 1939-45 conflict, when the public supply of electricity was fundamental to the whole war effort.[2]

They noted that the success of the National Grid had been due to the personnel involved spread across 'every grade of the industry'. As with many other stories of British industry during the Second World War, the Grid is presented as part of a civilian system adapting itself to the needs of country during a time of war. However, while the Grid may have been primarily established for civilian, peacetime use, it is clear that the experience of the First World War had guided the construction of the Grid: not least in the degree of interconnection which enabled the Grid to provide an almost uninterrupted supply of power for industry, even in the event of damage to power stations or transmission lines by enemy action.

---

[1] J. Hacking and J.D. Peattie, 'The British Grid System In War Time', *Journal Of The Institution Of Electrical Engineers - Part II: Power Engineering*, 94.41 (1947), 463-476, (p.463).
Sir John Hacking was Appointed Chief Engineer of the Central Electricity Board in 1944 having previously served as Deputy. His early experience of electrical engineering had been gained with NESCo in 1908 and he had worked directly for Merz and McLellan. J.D. Peattie was a senior engineer with the CEB during the Second World War and a regular contributor to the IEE Journal.
[2] Hacking and Peattie, The British Grid System in War Time, p.476.

The Second World War was a war of machines, experts and, above all, of resources, the most important of which was energy. The management of energy was vital in enabling the production of the vast quantities of planes, tanks, ships and ammunition required to fight. For Britain, and indeed much of the world, the primary source of energy was coal. Oil use was increasing; however, this was primarily for transport, and, in Britain, was not used for electrical generation until the opening of Bankside B power station in 1947. As such the management of energy was a high priority for the government, especially when it came to providing power for the new war factories being established around the country. This was particularly the case in the west of the country where they would be less vulnerable to aerial attack, but where, due to the lack of modern industry in the region, there was insufficient local generating plant to meet the additional demand. The National Grid was vital in enabling the construction of these new factories in areas remote from the major population and transportation hubs by enabling the transfer of energy from one part of the country to another. However, it was not only factories that needed power.

Military historians have described the Chain Home Early Warning system as one of the pivotal inventions of the Second World War and it is often at least partially credited for winning the Battle of Britain.[3] However, one important aspect of radar development has been overlooked in both the technical and operational histories of the Chain Home system, that is the requirement for a secure supply of electricity.[4] While it was possible to run Chain Home stations using petrol or diesel generators, this would have been prohibitive in terms of fuel usage. All the sites had a backup diesel or petrol generator in case of any disruption to the main power supply, and several sites relied entirely on generators as they did not have access to either the National Grid or another local power station. A secure supply of electricity was

[3] Colin Dobinson, *Building Radar: Forging Britain's Early-Warning Chain, 1935-1945.* (London: Methuen, 2010). xv.
[4] See Raymond C Watson, *Radar Origins: Worldwide: History Of Its Evolution In 13 Nations Through World War II.* (Bloomington: Trafford Publishing, 2009).
David Zimmerman, *Britain's Shield: Radar And The Defeat Of The Luftwaffe.* (Stroud: Amberley, 2010).
Séan S Swords, *Technical History Of The Beginnings Of Radar.* (London, U.K.: P. Peregrinus on behalf of the Institution of Electrical Engineers, 1986).

vital to the existence and operation of the Chain Home Network and was one of the key requirements to be met when selecting a site. Without the Grid, it is likely that the early warning network would not have been able to provide the level of cover needed to warn of incoming attacks; the 2,720 Kw of electricity required would not have made an appreciable difference to munitions production but generating that much power using petrol or diesel generators would have been prohibitively expensive.

In the mid to late 1930s, the British Government had considered the possibility of supplementing imported oil by using coal oil. However, the process was expensive, energy intensive and would have required a significant quantity of coal that could have been better utilised for the generation of electric power. Providing sufficient quantities of coal for both purposes would have placed a great deal of strain on the coal mining industry and would likely have diverted manpower and resources from other tasks.[5]

While connecting the Chain Home Network to the National Grid placed only a minimal demand on the Grid system, the rapid increase in munitions production did threaten to outpace the construction of new generating capacity. Standard histories, such as Hacking and Peattie in 1947, show the National Grid succeeding in meeting the challenge of war, despite of a lack of resources and priority for materials and manpower. I show that while the National Grid and power generation may have initially struggled for the required resources, it was rapidly moved to the top of the priority lists both in terms of manpower and materials. Although this policy did not go unchallenged and did not entirely solve the problem of scarce resources, it demonstrates the commitment of the wartime government to the development of electrical supplies for national security.

However, this commitment to new construction on its own was insufficient to ensure the supply of electricity to all vital services. To provide for the increased industrial demand, it

---

[5] Edgerton, *Britain's War Machine, pp.*187-188.

became necessary to reduce the domestic usage of energy resources and particularly of electricity. As was the case in World War 1, the introduction of the blackout went some way towards meeting this demand in the early years of the war. However, the ever-increasing demands of the factories meant that new measures were needed as the construction of new generating plant was only just able to keep pace with demand. After the previous two decades working to convince the British public to use more electricity in the home, the Electrical Development Association was now faced with the challenge of reducing the consumption of electricity for domestic purposes. The EDA also co-operated with the Ministry of Food, releasing cookery guides for wartime meals, pointing out that cooking with electricity used less fuel and caused less shrinkage in meat than either gas or coal. These arguments, while not new, undoubtedly gained traction as a result of the war.

The Central Electricity Board had begun preparing the Grid for war in the late 1930s. It stockpiled spare parts for the Grid system and worked with the Treasury to provide the necessary funding for new construction, as well as ensuring that neither the CEB nor individual undertakers would be forced to pay for any additional plant that proved to be surplus to requirements at the end of the war. Once war broke out, it appeared that initial projections of wartime usage had overestimated demand, resulting in the CEB reducing the planned expansion for 1942. As war production expanded, so too did the requirements for electricity. The construction and repair of electrical plant was given a high priority in terms of manpower and materials. However, in order to meet the full requirements, it was necessary to cut safety margins and run older and less economical plant almost continuously, a decision which, as we will see in the following chapter, had disastrous consequences in the winter of 1946/47.

I begin this chapter by examining the previously undocumented links between the Chain Home Early Warning System and the National Grid, and the way in which use of the Grid to power the network helped to reduce fuel usage. I then examine the electrical requirements of Britain as a whole during the war, including the steps taken by the Central Electricity Board to meet the power requirements of the country, and to increase the degree of interconnection between regions. Furthermore, I examine the difficulties experienced by the Electricity Commissioners and the Central Electricity Board in predicting electrical requirements during the war; in particular, the increasing difficulties in securing manpower and materials, despite the high level of priority accorded to electrical infrastructure.

I then explore the role of the Electrical Development Association in reducing the use of electricity for heating and cooking. Next, I examine the ways in which EDA advertisements made close connections between use of electricity and munitions production, particularly noting the ways in which the EDA continued to promote the responsible use of electricity and the benefits of electric lighting, heating and cooking. I show that despite wanting to restrict civilian electrical usage, the authorities considered the domestic load to form an additional reserve of power which could be diverted to munitions production.

I investigate the operation of the Grid system during the war, including the establishment of the wartime reserve equipment during the late 1930s. I then demonstrate the resilience of the Grid to aerial attack and the speed with which repairs were carried out. I demonstrate the difficulties involved in attacking generating stations and examine an Air Ministry report on the *Comparative Vulnerability of Power Plants to Air Attack*, drawing comparisons to attacks on German electrical infrastructure. Finally, I focus on Operation Outward, a deliberate and sustained attack on German electrical infrastructure, carried out by the Women's Royal Naval Service (WRENS). This attack caused significant damage and disruption to the German power supply network and was subsequently classified.

Overall this chapter highlights the importance of energy security to the British state during wartime, particularly the importance of coal. I show that the National Grid was central in enabling the most efficient and economical use of Britain's energy resources. This is emphasized by the case study on Operation Outward which demonstrates the potential cost of disruptions to electrical supply.

6.2. Radar and Electricity.

The development of radar, by Watson Watt in the mid-1930s, has been described as one of the most important inventions of the twentieth century, revolutionising modern warfare, particularly in terms of aviation. The Chain Home Network, established around Britain's coastline provided an early warning of an incoming aerial attack, enabling defending fighters to be scrambled to intercept. Mainstream histories of the development of radar make little or no mention of the importance of electrical supply to the operation of the chain home network. While recent histories, such as Colin Dobinson's *Building Radar: Forging Britain's Early Warning Chain, 1935-1945*, discuss the importance of an integrated communications network, the need fora secure supply of electricity is overlooked.

In November 1935, Albert Rowe, writing about the work to be done to get the trial system online, commented:

> Transmitting sets must be installed at each of these points [Dunwich, Bawdsey, Clacton-on-Sea, Shoeburyness, Birchington, South Foreland, and Dungeness] and receiving sets at the second, fourth and sixth named; only the Orfordness sets now exist. Buildings must be erected, and the Grid system connected to them.[6]

Dobinson notes that Bawdsey would receive its power supply through the three-phase 230-volt lines in the January of 1936 and the other stations would be connected to the Grid by 20 May 1936 at the same time as they were scheduled to receive their towers huts and telephone connections.[7] Electrical power was a prerequisite for the sites to go online, yet even while

---

[6] Avia 7/4484, 'RDF Chain, Note By A. P. Rowe' (London, 1935), The National Archives, Civil Aviation Authority. Albert Rowe was educated at the Royal College of Science in London and worked for the Air Ministry as Assistant to the Director of Research. In 1935 Rowe Served as the Secretary to the Tizard Committee. He consulted with Watson Watt on the development of RDF and was later to take over from Watt as the superintendent of the Bawdsey research group. Bernard Lovell, 'Rowe, Albert Percival (1898–1976).', *Oxford Dictionary Of National Biography* (Oxford: Oxford University Press, 2004) <https://doi.org/10.1093/ref:odnb/51630> [Accessed 29 November 2019].

[7] Dobinson, *Building Radar*, p.122.

acknowledging this requirement, Dobinson appears to take the availability of electricity and the ability of the National Grid to provide the supply, for granted.

Based on documents from 1938, engineers believed that each operational site would add a maximum of 68 Kw load to the National Grid, although this would only be for a limited period each day with the usual load being approximately half that figure. The transmitters required power at 8Kva while the receiver only needed 1Kva. To supply the required power, most of the Chain Home sites had a direct connection to the 11 Kva lines of the National Grid. The availability of a connection to the Grid was high on the list of priorities when selecting potential sites for the stations.

In order to provide a backup to the Grid supplies, each site also had a backup power generator, consisting of a 9Kva petrol or diesel generator capable of handling a 60 Kw load. While it would theoretically have been possible to operate the Chain Home Network entirely on generators, this would have required a significant quantity of fuel. Based on a standard Mirrlees Diesel Generator of the period, each site would have required approximately 225 gallons of diesel a day to sustain twenty-four-hour operations.[8] Multiplying this by the total number of radar stations in operation by the end of the war indicates that operating the radar network only using diesel generators would have required the equivalent of a single 16,000 cwt tanker every day. While shipping losses to U-Boats were not as serious as has commonly been portrayed, had the Chain Home Network been reliant on diesel or petrol, the loss of a single large tanker could have potentially forced the Government to suspend military operations in order to ensure the continued operation of the Chain Home System. By the end of the war in Britain, there were more than 40 operation Chain Home Stations, as well as over 100 Chain Home Low stations and it is likely that many of them required more than the 68. kW maximum load of the early Chain Home stations.

---

[8] 'Mirrlees Diesel Engines, Power With Economy.' (Manchester), Science and Industry Museum, Trade Literature Collection.

6.2.1. Energy Management: Coal Verses Oil.

David Edgerton has described Britain in 1939 as a ‘world island’, the richest European power sitting at the centre of a vast network of trade, importing vital raw materials from around the globe, and exporting huge quantities of manufactured goods and coal.[9] Although manufactured goods were of the greatest monetary value, coal made up the bulk of British exports. Thanks to its coal reserves, Britain was able to supply not only its own energy requirements but was also the largest exporter of coal, exporting some 37 million tons in the year prior to the outbreak of war. At the same time, Britain was the world’s largest importer of oil, although the total quantity of oil imported and consumed was still significantly less than the amount of coal exported. At this point the British oil tanker fleet was the largest in the world. The two largest companies, Anglo-Saxon Petroleum and the British Tanker Company, between them operated over 180 large (12,000 ton) tankers. Table 6.1 shows the quantity of oil products imported into the United Kingdom in 1938 in comparison to 1944. The total quantity of imported oil products almost doubles during this period, although as Edgerton notes, this is only half of the story: British and Imperial forces abroad used almost the same quantity and were supplied directly from Persia and the Americas.[10]

Imports of oil products to the UK (all users including US Forces), millions of tons.		
	1938	1944
Motor Spirit	4.699	4.773
Aviation Spirit		4.751
Admiralty Oil	0.403	3.912
Gas Oil/Diesel	n/a	2.211
Total	11.618	20.344

Table 6.1. British Oil Imports, 1939 -1944.[11]

[9] Edgerton, *Britain's War Machine*, pp.14-15.
[10] Edgerton, *Britain's War Machine*, pp.182-184.
[11] Edgerton, *Britain's War Machine*, p.182.

The key oil imports, motor spirit (gasoline) and diesel, were both vital not only for road transport, but were also required by the armed forces, particularly the Army and the Royal Navy, as Edgerton comments:

> […] at the end of the war Britain was importing 20 million tons of petroleum-derived fuels […]. The forces dominated consumption. Although the level of motor spirit consumption was about the same as before the war, private motoring was severely cut back, and the balance was taken up by transport and the services.[12]

Edgerton notes that the British Army was, in contrast to popular opinion, one of the most advanced mechanised forces in the world with a heavier concentration of tanks and other mechanised transport than any comparable force. It required huge quantities of diesel and petrol in order to carry out offensive operations. Likewise, the Royal Navy was now largely comprised of steam-driven oil-powered vessels and was consuming approximately 4 million tons of fuel oil per year, roughly 10 times its peacetime requirements.[13] Additionally, many smaller combat vessels, such as submarines and motor torpedo boats and gunboats, relied on petrol or diesel rather than oil. If oil had also been needed to power the Chain Home early warning system, it would have dramatically reduced the fuel available for Army and Royal Navy offensive and defensive operations.

While the effectiveness of the Chain Home Network may be debateable, its existence prior to the war encouraged the creation of the fighter force needed to defend Britain. More importantly the establishment of the Chain Home Network would not have been possible without the existence of the National Grid, as even had electricity been available, it would likely have not been at the right voltage or frequency. The standardisation brought about by the National Grid was vital. Without the Grid's supply, radar stations would either have been forced to rely on diesel or petrol generators, or components would have had to have been designed to operate on a wide range of differing standards, thereby making the system

[12] Edgerton, *Britain's War Machine*, p.182.
[13] Edgerton, *Britain's War Machine*, p.182.

uneconomical. In any event, the strain placed on the Grid by the Chain Home Network was minimal, and ultimately had little impact on national power requirements. However, the same cannot be said of the munitions industry, for which the power requirements rose dramatically and quickly exceeded pre-war predictions.

6.3. National Electricity Requirments.

As can be seen from Figure 6.1 the amount of energy in the form of electricity used in Britain increased throughout the Second World War. While industry remained the single largest user of electrical power, domestic use also increased, despite the introduction of energy rationing in 1942. It is possible that this increase may reflect the re-homing of families bombed out during the Blitz and the replacement of their appliances with electrical appliances. It is also possible that some households chose to switch to electric cooking and heating due to the increasing restrictions on coal usage.

The rapid increase in industrial demand in the early years of the war is at least partially accounted for by the increase in the number of new war factories established during this period. These factories were predominantly established in the North West and South West of Britain often in areas which did not have sufficient generating capacity to meet the new demand. As can be seen from table 6.2, the margin of available plant for the entire country was under 1,000,000 Kilowatts in both years. Therefore, the Electricity Commissioners warned that 'In certain areas, in the western part of the country, the probable electrical demand under winter peak conditions will exceed the available plant capacity in the winters 1940 and 41.'[14] The Electricity Commissioners also noted that the list of available plant included

[14] CAB 21/1541, 'Electricity Commission. National Electricity Requirements. Additional Grid Connections,' 19 June 1940' (London, 1940), The National Archives, Cabinet Documents, p.1.

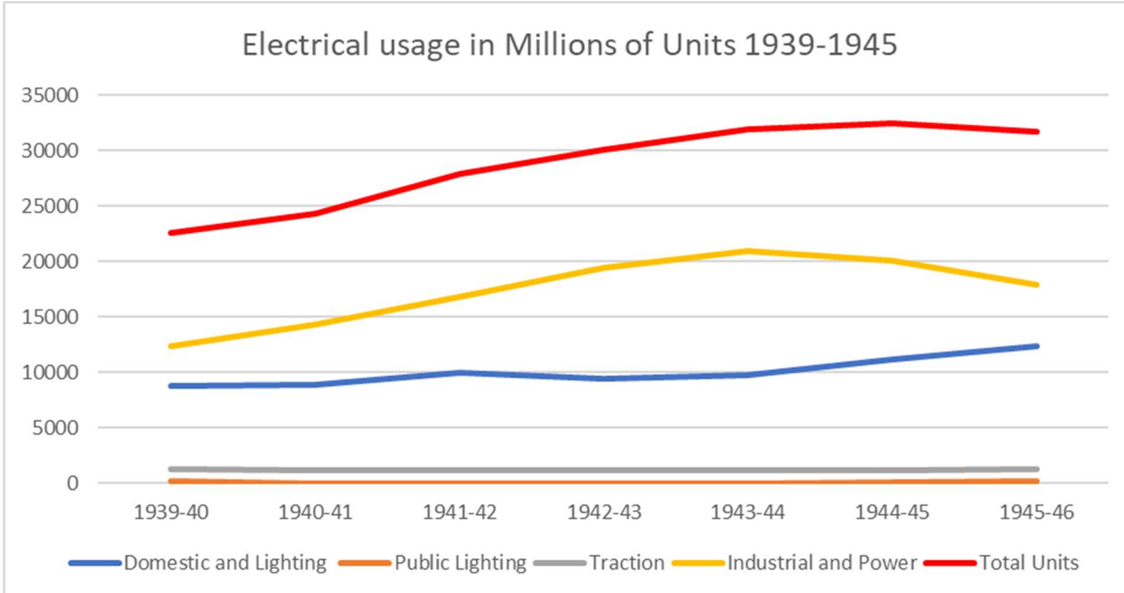


Figure 6.1. Wartime Electrical Usage in Millions of Units, Data taken from the annual returns of Engineering and Financial Statistics relating to Authorised Undertakings in Great Britain between 1920 and 1948. See Appendices 1 for full Data Table.

Region	1940			1941		
	Available Plant. kW.	Maximum Demand. kW.	Margin kW.	Available Plant. Kw.	Maximum Demand. kW.	Margin kW.
Central & South Scotland	757,200	622,200	135,000	754,100	658,200	95,900
North-East England	372,100	355,300	16,800	393,700	381,700	12,000
North-West England	1,202,000	1,260,300	-58,300	1,338,300	1,403,900	-65,600
Mid-East England	860,800	738,800	122,000	942,200	757,400	184,800
Central England	1,190,200	1,172,700	17,500	1,335,300	1,247,400	87,900
South-East England	2,273,900	1,926,800	347,100	2,644,700	1,830,900	813,800
South-West England	657,100	789,800	-132,700	751,100	883,400	-132,300
Totals	7,313,300	6,865,900	447,400	8,159,400	7,162,900	996,500

Table 6.2 Available Margin by Region 1940/41This table shows the gap between the generating capacity of each region and the demand in Kilowatts. Both North West and South West England show a significant and increasing shortfall between generating capacity and demand. [15]

[15] CAB 21/1541, 'Electricity Commission National Electricity Requirements. Additional Grid Connections. 19 June 1940.' (London, 1940), The National Archives, Cabinet Documents, p.7.

> Nearly 300,000 kilowatts of old plant which would normally be discarded, but which is being retained for use in an emergency. […]. No allowance, however, has been made for the late delivery of new plant which has been scheduled for completion in the early autumn of each year. Under peacetime conditions it has been found difficult to keep programmes in this respect, and under present conditions, the difficulty is accentuated. No allowance has been made for possible war damage.[16]

The Electricity Commissioners also noted that the planned building program for 1940/41 was already in arrears and that, even if plant was available, it could not be erected and connected to the Grid in time to make a difference for the coming winter. Furthermore, they suggested that the siting of additional war factories in the west of the country should be reconsidered until the power requirements could be met. As such the commissioners requested that the priority being given to the construction of the new war factories should be extended to the construction and extension of generating plant to provide the power needed for these new factories. The commissioners also recommended that some form of voluntary rationing of domestic and commercial supplies should be introduced, as they did not believe that compulsory rationing along the lines of the Fuel Rationing Order (1940) would have any appreciable effect. They pointed out that it would not be practical to simply shut off the supplies to domestic and commercial customers as this would have an adverse effect on supplies to services such as hospitals, telephone exchanges and police stations, which used the same lines.[17]

6.3.1. Interconnection.

The Electricity Commissioners also recommended the construction of additional high voltage lines interconnecting the east and west of the Country to enable the transfer of power from stations in the east, which had a surplus of capacity, to western areas where most of the new factories were being constructed. To achieve this within a useful time scale, the commissioners

[16] CAB 21/1541, 'Electricity Commission National Electricity Requirements. Additional Grid Connections. 19 June 1940.' (London, 1940), The National Archives, Cabinet Documents, pp.1-2.
[17] CAB 21/1541, 'Electricity Commission National Electricity Requirements. Additional Grid Connections. 19 June 1940.' (London, 1940), The National Archives, Cabinet Documents, pp.3-4.

argued that priority for steel supplies should be given to the construction of the required power lines. The construction of these new Grid lines was problematic, not only in terms of the cost and availability of the materials, but also due to opposition from the Air Ministry, relating to their plans to open approximately fifty aerodromes in that part of the country.[18] These concerns mirrored those which had first been expressed by the Air Ministry in the 1920s over the siting of pylons interfering with flying operations. Ultimately the Electricity Commissioners were able to proceed with a limited version of their plans for enhanced system of interconnections, although it is unclear as to whether the limitation was brought about by material shortages or due to restrictions imposed by military requirements. However, it does appear that, during the early years of the war, the construction of new generating plant and Grid interconnections were granted a high level of priority, at least on par with that given to war factories.

6.3.2. A High Priority.

As has been mentioned, when making predictions on future usage, the Electricity Commissioners did not consider any potential damage to generating plant by enemy action. In early September 1940, Fulham power plant was severely damaged in an air raid, which placed 10,000 kw of plant out of service. Subsequently, on 28 September, R.T.G. French, the secretary of the Electricity Commission, wrote a memorandum for the Treasury, requesting that the repairs to Fulham should be given special priority. He argued that if Fulham was the only station at risk or likely to be at risk, then there would be no need to expedite the repairs, but that:

[18] CAB 21/1541, ‘Extract From Production Council Minutes,’ 26 June 1940’ (London, 1940), The National Archives, Cabinet Documents.

> During the intensive air attacks on London, other important generating stations connected with the Grid System … have all been out of use for some period due either to damage to the stations themselves or their connection with the Grid System […]. A certain amount of damaged generating plant is now out of commission whilst substantial blocks may be immobilised at any time although undamaged.[19]

In light of this and fearing for the situation in the winter if further plant was damaged or put out of use, the Electricity Commissioners urged for the repairs to Fulham to be given the highest degree of priority possible.[20] Arthur Greenwood, MP for Wakefield, and serving as a Minister without Portfolio under Churchill, supported the request.[21] The level of priority was questioned by a member of the War Cabinet Secretariat, G. Flemming; however, Colonel Webb of the 'Central Priority Department' of the Ministry of Supply disagreed pointing out that 'It is unnecessary to labour the point importance of maintaining and providing a reserve for our electricity supply.' Webb concluded his reply to Flemming by pointing out that

> We feel here very strongly that on general grounds 1(a) ought to be accorded to all C.E.B. work, and as I have endeavoured to explain, the interference with other priority a. work would be negligible, but the added security gained would be considerable if such priority was given.[22]

This letter clearly demonstrates that officials at the Ministry of Supply not only considered electricity to be a vital resource for the war effort, but also that there was little point in constructing new war factories if there was insufficient electricity to power them.

---

[19] CAB 21/1541, 'Memorandum From The Electricity Commissioners To The Treasury Department, 28 September 1940.' (London, 1940), The National Archives, Cabinet Documents.

[20] CAB 21/1541, 'Memorandum From The Electricity Commissioners To The Treasury Department, 28 September 1940.' (London, 1940), The National Archives, Cabinet Documents.

[21] Greenwood was a Labour MP, He had served as Minister of Health in 1929 and had a long-standing interest in conditions in industry. He became deputy leader of the Labour Party in 1935. In World War Two he served on the War Cabinet on the Production Council and economic policy committee he was then moved to the reconstruction committee in 1941 but was sacked in 1942.
R. C. Whiting, 'Greenwood, Arthur (1880–1954).', *Oxford Dictionary Of National Biography* (Oxford: Oxford University Press, 2019) <https://doi.org/10.1093/ref:odnb/33543> [Accessed 29 November 2019].

[22] CAB 21/1541, 'Letter From F.B. Webb To G.N. Flemming, 4 October 1940.' (London, 1940), The National Archives, Cabinet Documents.

While the exchange recounted above would appear to indicate that the dispute had already been settled, this was not the case. A further memorandum by the Electricity Commissioners again emphasised the importance of electricity to the war, arguing that

> Individual generating stations and generating plant and equipment on order or to be ordered therefore must be regarded as units in the national scheme of power production; and it is vital to the war effort that the Grid system as a whole, and the stations and lines associated with it, should be kept going and new plant provided where necessary to meet the new war demands.

They went on to claim that it was only the existence of the Grid system which had enabled the construction of the new war factories within such a short period of time. The memorandum concluded with the recommendation that the Production Council agree to all C.E.B. work being granted the highest priority without the need for in-depth discussion and debate on each individual case.[23] When the Production Council met on 9th October 1940, the proposal from the Electricity Commissioners was swiftly passed with a minimum of debate on the matter. In fact, the Minister of Supply, Sir Andrew Rae Duncan 'Supported the proposal as concerned with a service which was essential to the work of all departments' further suggesting that it should be 'Dealt with under the new priority procedure contemplated by the Council and not by reference to Categories 1(a) or 1(b) of the existing Direction.'[24] The delay of less than two months between the damage to Fulham power station and the Ministry of Munitions agreeing that electrical power was so vital to the country that it required a higher level of priority than had previously existed, clearly indicates that electric power was a high priority for the government. Although it should be noted that the Ministry of Supply had already been

---

[23] CAB 21/1541, 'Memorandum From The Electricity Commissioners To The Treasury Department, 28 September 1940.' (London, 1940), The National Archives, Cabinet Documents.

[24] CAB 21/1541, 'Meeting Of The Production Council, 9 October 1940.' (London, 1940), The National Archives, Cabinet Documents.

Sir Andrew Duncan had served as chairman of the Central Electricity Board between 1927 and 1935. In February 1940 he was appointed as President of the Board of Trade before being moved to the Ministry of Supply in October the same year. He was appointed to supervise the productive capacity of war industries and remained in this r ole until the end of the war. He was consistently outspoken against all proposals to nationalise industry.

Keith Grieves, 'Duncan, Sir Andrew Rae (1884–1952).', *Oxford Dictionary Of National Biography* (Oxford: Oxford University Press, 2004) <https://doi.org/10.1093/ref:odnb/32929> [Accessed 30 November 2019].

considering the creation of a new higher category priority. However, and perhaps more importantly, this also reveals that although electrical supply had been granted a high level of importance and priority, it had nonetheless been in competition for materials and manpower with other industries, particularly those which had a more obvious link to wartime production. The minutes of the Production Council executive meeting for 30 January 1941 show that the executive had, almost unanimously, agreed that the Grid system and generating plant should receive the highest level of priority for repair work, 'irrespective of the cause of damage.'[25] This clearly acknowledges the central importance of energy security to the British war effort and in particular of electricity. Without electrical power the manufacturing capacity of the state would be almost completely paralyzed.

A further indication of the importance attached to electrical supply at this time was the decision in July 1940 to alter the policy regarding the granting of wayleaves for Grid Line Connections. In June of the same year the Production Council had approved the construction of new additional Gridlines. In order to ensure that the construction could be completed on schedule, the Minister of Transport proposed an amendment, under regulation 56 of the Defence Regulations of 1939, that the normal procedures for obtaining consent should be amended to save time. Thus, the Electricity Commissioners proposed that the usual 21-day period required to allow objections should be reduced to 7 days. Further to this the Board of Commissioners would have the authority to place any new lines agreed as being vital to the war effort, without needing to gain the consent of either the Minister of Transport or the local authorities. While this would only last for the duration of the war, it is clear that the requirement for electrical infrastructure now trumped the rights of private landowners and it is unlikely that these lines would be removed once they were established.[26]

---

[25] CAB 21/1541, 'Extract From The Minutes Of A Meeting Of The Production Executive, 30 January 1941.' (London, 1941), The National Archives, Cabinet Documents.

[26] CAB 75/8/109, 'National Electricity Requirements: Grid Line Connections: Overhead Line And Wayleave Procedure, 18 July 1940.' (London, 1940), The National Archives, Cabinet Documents.

6.3.3. The Labour Issue.

The high level of priority granted for the construction of new generating plant and Grid connections in 1940 was not automatically applied to later construction. It did apply to all plant planned for 1941/42 and particularly to any plant or Grid extensions scheduled to be completed prior to August 1941. The principle issue with completing this work lay in the allocation of unskilled and semi-skilled labour necessary for the construction of foundations.[27] The Electricity Commissioners argued for the continuation of this high level of priority to maintain sufficient generating capacity to account for unexpected increases in load from cold weather or war-related damage. While much of the planned construction was to take place in the north and south-west of the Country, near to the new areas of demand, the Electricity Commissioners had also requested extensions to power stations in the more vulnerable south-east. The area contained a high percentage of the large generating stations and had suffered the most disruption due to enemy action and damage by drifting balloons.[28]

Somewhat prophetically, the Electricity Commissioners had expressed concerns as to the

> Difficulties which might arise in this area if the war ended and there was a rapid restoration both of domestic demand, as the evacuated population returned, and of the demand for transport, and for street and shop lighting.[29]

As we will see in the following chapter, this decision to focus primarily on short term war goals was to cause critical problems in the harsh winter of 1946/7, which may have been avoided had these concerns been heeded. This same report also supports David Edgerton's claim that the British expected the war to be over quickly and as such had not planned for a long war when forecasting future electrical requirements:

[27] CAB 21/1541, 'National Electricity Requirements, 13 March 1941,' (London, 1941), The National Archives, Cabinet Documents, p.13.
[28] CAB 21/1541, 'National Electricity Requirements, 13 March 1941,' (London, 1941), The National Archives, Cabinet Documents, p.9.
[29] CAB 21/1541, 'National Electricity Requirements, 13 March 1941,' (London, 1941), The National Archives, Cabinet Documents, 9.

> The Commissioners and the Central Electricity Board have hitherto been budgeting on the assumption of a three years' war, and in the absence of any Government direction to the contrary, they had felt it necessary to plan for the provision of sufficient plant in 1942 to ensure full supplies during the winter of 1942-3 under peace-time conditions.[30]

However, in the short term, the Electricity Board continued to explore options for increasing the amount of power that could be transferred from the south-east to other regions, including the addition of new interconnecting circuits which would potentially increase the transfer capacity by 50,000kw.

The shortage of labour continued to cause severe delays in the construction of foundations for Grid towers. Table 6.3 indicates the severity of this shortage, although the delays in construction were not due to shortages of skilled workers, but instead was due to a lack of unskilled labour required for the more basic work.[31] These figures, provided in a Memorandum from the Minister of War Transport to the Production Executive of the War Council, indicate the extent of this problem: on average only one third of the required manpower was available to carry out the required work.[32] The work was deemed of such importance that the Secretary of State for War authorised the use of the Pioneers, as well as recommending that men be made temporarily available from munitions factories in order to ensure the work could be completed.[33]

---

[30] CAB 21/1541, 'National Electricity Requirements, 13 March 1941,' (London, 1941), The National Archives, Cabinet Documents, p.9.

[31] CAB 21/1541, 'Memorandum By The Minister Of War Transport, 20 June 1941.' (London, 1941), The National Archives, Cabinet Documents.

[32] CAB 21/1541, 'War Cabinet Production Executive. National Electricity Requirements, 20 June 1941.' (London, 1941), The National Archives, Cabinet Documents.

[33] CAB 21/1541, 'Minutes Of The Production Committee, 26 June 1941.' (London, 1941), The National Archives, Cabinet Documents.
The Royal Pioneer Corps was formed in 1939 as the Auxiliary Military Pioneer Corps, it was a combatant corps used to carry out light engineering tasks.

Location of Line	Number of men employed				Additional Number Required.			
	Week ended				Week ended			
	10.5.41	17.5.41	25.5.41	31.5.41	10.5.41	17.5.41	24.5.41	31.5.41
Oxford – Watford	79	80	82	84	121	120	118	116
Andover – Melksham	38	40	59	59	162	160	141	141
Nursling – Andover	18	25	28	32	82	75	72	68
Oxford-Gloucester	70	67	67	65	90	93	93	135
TOTALS	**205**	**212**	**236**	**240**	**455**	**448**	**424**	**460**

Table 6.3. Discrepancy in numbers of men employed on Grid Line Extensions 1941.[34]

By August 1941, the Electricity Commissioners realised that the planned program of new generating plant construction and expansion was likely to be insufficient to meet the predicted demand, primarily as a result of new war factories either being planned or already under construction. This additional load totalled some 142,000 kilowatts over the earlier forecasts. In order to meet this demand, and in light of the expectation that war requirements were likely to continue increasing, the Electricity Board proposed a new plan for construction and expansion that would bring an additional 315,000 kW of additional generating plant into operation during 1943.[35] As had been the case with previous programs of construction, there was a degree of resistance to granting the level of priority desired by the Electricity Commissioners. This was particularly the case in regard to any construction work requiring the use of unskilled labour. As such the Production Executive requested that all planned works be reviewed to determine whether it was really essential. However, the Production Executive also concluded that insofar as the requested work was shown to be essential, it should continue to be granted the necessary priority for manufacturing.[36] One of the primary difficulties experienced in assessing the relative importance of new power station construction and the

[34] CAB 21/1541, 'War Cabinet Production Executive, Memorandum By The President Of The Board Of Trade, 28 August 1941.' (London, 1941), The National Archives, Cabinet Documents.
[35] CAB 21/1541, 'War Cabinet Production Executive, Memorandum By The President Of The Board Of Trade, 28 August 1941.' (London, 1941), The National Archives, Cabinet Documents.
[36] CAB 21/1541, 'Minutes Of The Production Committee, 2 September 1941.' (London, 1941), The National Archives, Cabinet Documents.

allocation of labour and resources was the fact that the construction or expansion of generating plant took a long time to complete.

6.3.4. Colonial Competition.

A further complication was the need to provide generating plant and equipment to the colonies. In December 1941, the Production Council Executive had received a request for the provision of electrical plant for Imperial and Allied Countries, in particular India.

> The Government of India's proposals affected three major projects involving an expenditure of about £5,500,000 […]. They said that the delivery of this plant to India by the end of 1943 at latest, […], was essential if the projects were to come to fruition to meet anticipated demands for power for war industry. [37]

This letter also reveals the existence of a production policy restricting any projects which were unlikely to produce results beneficial to the war effort within two years. This was a potential problem for India. While this time limit could be extended to allow time for shipment of the required items, it could not account for the time taken to manufacture the required parts, which was estimated as 'not less than two years.'[38] However, the writer then argued that this rule should not be applicable to India, at least in part because India did not have recourse to a system like the National Grid, nor to a pool of spare parts, such as had been established in Britain prior to the war.

The amount of new construction required, combined with the time taken for the construction of a completely new power station, led Sir Andrew Rae Duncan, the President of the Board of Trade, to write a memorandum requesting a decision on whether the two-year period should be extended to three years. It is interesting that it was only the need for power extensions in India, a country which did not have access to a power network like the National Grid, which led to this realisation. The existence of the National Grid in Britain had enabled the transfer of

[37] CAB 21/1541, 'Letter From L.S.A To Colonel Llewellin, 16 February 1942.' (London, 1941), The National Archives, Cabinet Documents, p.1.
[38] CAB 21/1541, 'Letter From L.S.A To Colonel Llewellin, 16 February 1942.' (London, 1941), The National Archives, Cabinet Documents, p.2.

power from power stations in underutilised regions to the regions where power was required. By comparison, industry in India was often solely reliant on a single power station, with little to no backup in the event of a disruption to the power supply. As had occurred during the First World War, the immediate needs of the country took priority over long term planning, an issue for the power supply industry, due to the lengthy construction times. However, as the government realised that there was little point in building new munitions factories if there was no means of providing them with power to operate.

6.3.5. No Publicity.

In March 1942 the select committee on National Expenditure submitted a memorandum to the Prime Minister for the attention of the War Cabinet. This memorandum highlighted the precarious state of the national supply of electricity and pointed out that

> For reasons of national security, it is essential that no publicity should be given to the present position, or encouragement might be given to the enemy to make concentrated air attacks on power stations.[39]

The committee pointed out that the margin of available power was now so low that if a single large power station were to be damaged by enemy action, it would have grave consequences for the war effort and the national economy. Table 6.4 shows that the overall operating margin for the entire country was under now 100MW, with some areas of the country, particularly central and south-west England, experiencing severe shortfall in power generation.

Area	Scotland	N.E.E.	N.W.E.	M.E.E.	C.E.	S.E.E.	S.W.E.	Total Country
	MW.s.o.	MW.s.o.	MW.s.o.	MW.s.o.	MW.s.o.	MW.s.o.	MW.s.o.	MW.s.o.
Output capacity actually available	795	393	1,226	900	1,209	2,494	594	7,611
Peak Load	627	403	1,277	866	1,320	2,163	857	7,513
Operating Margin	+168	-10	-51	+34	-111	+331	-363	+98

Table 6.4. Operating Conditions Thursday, January 22nd, 1942, showing relation between output actually available and actual peak loads.[40]

[39] CAB 21/1541, 'Memorandum From The Select Committee On National Expenditure To The Prime Minister, March 1942,' (London, 1941), The National Archives, Cabinet Documents, p.1.
[40] CAB 21/1541, 'Memorandum From The Select Committee On National Expenditure To The Prime Minister, March 1942,' (London, 1941), The National Archives, Cabinet Documents, p.4.

This situation was attributed to both the slow rate of completion of new plant, and the amount of older plant temporarily out of order due to wear and tear on equipment. This was in part caused by the use of lower quality coal and partly due to the requirement to run older or obsolete plant at full capacity without the usual down time for repair and maintenance. As such the Committee recommended that:

> No further employees should be taken away from the power stations for any purpose whatsoever. [As] it is vital that the overhauls and repairs to existing plant should be proceeded with, and the ordinary maintenance kept up so far as the present strenuous load conditions permit.[41]

By the 9th of April 1942 the Minister of Labour & National Service, Ernest Bevin, had directed that

> In general, men, except clerical workers, in the electricity supply industry who are not deferred in their present employment shall be made available for re-allocation in the industry instead of being called up for the forces.[42]

As such, with the exception of clerical workers, all men employed within the electrical supply industry who not already restricted from active service, could now be reallocated to work in other areas of electrical supply as required by the demands of war and could not be called to serve in the armed forces.

Bevin had also arranged for the Electricity Commissioners to work closely with the Ministry of Works to examine the building and civil engineering programme and set the allocations and priorities which guided the work of the Ministry of Production. This resulted in a number of new power stations being given 'super preference for the supply of constructional labour.'[43] Electricity supply was now established as a priority by all the Ministries responsible for the allocation of manpower and materials for wartime production. While this did not eliminate

---

[41] CAB 21/1541, 'Memorandum From The Select Committee On National Expenditure To The Prime Minister, March 1942,' (London, 1941), The National Archives, Cabinet Documents, p.2.
[42] CAB 21/1541, 'Letter For Oliver Lyttelton From Ernest Bevin, 9 April 1942.' (London, 1942), The National Archives, Cabinet documents.
[43] CAB 21/1541, 'Letter For Oliver Lyttelton From Ernest Bevin, 9 April 1942.' (London, 1942), The National Archives, Cabinet documents.

the problems caused by conflicting demands for resources, it did clearly establish the generation and transmission of electricity as a high priority overriding almost all other concerns.

However, despite the increase in priority of generating plant and transmission systems for labour and materials, an increasing percentage of the installed generating capacity was unavailable to cope with the annual peak load. (See table 6.5)

Year	Plant not available %
1938-39	5.6
1939-40	11.1
1940-41	18
1941-42	15
1942-43	15.7
1943-44	19.6
1944-45	16.5

Table 6.5. Installed Generating Capacity Not Available at time of annual peak load.[44]

Peattie and Hacking argued that this increase was a direct result of the problems described above in obtaining priority for materials and labour, combined with changes in the nature of the annual load. These combined to minimise the time available for maintenance and repair. These problems were further exacerbated by damage caused by enemy action and stray barrage balloons as well as due to the use of low-quality coal.[45]

Table 6.6 shows the discrepancy between the maximum rated capacity of installed plant, the actual output at the point of maximum demand and the margin of spare capacity available. Despite the increased priority of power plant construction, as well as the continued use of older and obsolete plant, the Central Electricity Board was unable to meet their own requirement of a minimum of 350 MW of running spare plant. In the winter of 1944-45, the CEB actually had a negative margin, indicating that some plant was forced to run above its rated capacity in order to meet demand. As such the CEB and Electricity Commissioners were

[44] Hacking and Peattie, *The British Grid System in War Time,* p.470.
[45] Hacking and Peattie, *The British Grid System in War Time*, p.470.

forced to consider alternative measures to ensure the continued supply of electricity to vital services and the munitions industry. It should also be remembered that the existence of the domestic demand was considered to be a vital reserve from which power could be diverted in an emergency, although it is unclear whether this approach was actually utilised by the electrical authorities.

In order to attempt to meet the demands for electricity for industry, the Electricity Commissioners and the Central Electricity Board were forced to appeal to domestic users to reduce further their electrical usage. However, as was discussed earlier, any such appeals had to be carefully phrased so as not to alert the enemy as to the viability of deliberately targeting power stations. As the body responsible for electrical advertising, and by now, with an established network of showrooms and other outlets, the Electrical Development Association was the obvious choice to take the lead in attempting to reduce domestic electrical usage.

Item	1938-39	1942-43	1943-44	1944-45	1945-46
	MW	MW	MW	MW	MW
Maximum output capacity of plant installed	7,209	9,438	9,990	10,300	10,527
Capacity of plant over 20 years old		0,695	0,690	01,365	01,702
Output capacity not available owing to					
War damage	-	39	0,023	0,003	-
Breakdown	271	413	0,742	0,713	0,652
Overhaul	137	348	0,643	0,423	0,439
Unsuitable Fuel	-	146	0,166	0,209	0,237
Other Causes	-	266	0,261	0,294	0,532
Circuit Restrictions	-	266	0,122	0,055	0,016
Total	408	1,478	1,957	1,697	1,696
Output capacity available	**6,801**	**7,960**	**8,033**	**8,603**	**8,831**
Maximum Load Supplied					
Scotland	0,570	0,642	0,680	0,784	0,755
N.E. England	0,317	0,421	0,436	0,479	0,452
N.W. England	1,092	1,227	1,423	1,592	1,571
M.E. England	0,741	0,868	0,888	1,017	1,015
Central England	1,050	1,227	1,445	1,526	1,524
S.E. England	2,326	2,121	1,997	2,250	2,579
S.W. England	0,604	0,612	0,998	0,989	1,010
Total (country simultaneous demand)	**6,700**	**7,118**	**7,867**	**8,637**	**8,906**
Margin of Spare Capacity	+101	+842	+166	-34	-75
Margin as percentage of s.m.d[46]	+1.5	+11.7	+2.1	-0.4	-0.8
Additional margin of spare capacity obtained by overload	287	29	79	147	177
Frequency at time of s.m.d.	Normal	Normal	Normal	49.15 c/s	38.35 c/s

Table 6.6. Plant and Load Conditions at Time of Country Simultaneous Maximum Demand.

[46] S.m.d = Simultaneous Maximum Demand

6.4. Reducing Domestic Usage: The Role of the Electrical Development Association.

Rationing is a major feature in histories of civilian life in wartime Britain. While the focus of this scholarship, such as Angus Calder's *The People's War: Britain 1949-1945* has been food supplies, the rationing of energy was vital in enabling British industry to produce the munitions and other supplies necessary to fight. [47] However, while the need to divert energy from domestic use to munitions production was real, civilian access to electricity was also recognised as being vital to morale. The EDA recommended that households ensure that a single room was able to be fully lit, to maintain a sense of wellbeing, which would otherwise be endangered if the entire house was cloaked in darkness. Indeed, one EDA publication argued that using dimmer bulbs was not only a false economy, but also argued that

> Apart altogether from the depressing effect of spending long winter evenings in a house with dim, dismal and un-necessarily bad lighting, the harm that can be done to vision is in itself quite a serious thing.[48]

The need to restrict lighting, to save electricity and to maintain the blackout, needed to be balanced with the morale and health requirements of the British public. Reductions in domestic lighting would not in themselves significantly reduce electrical usage. Instead, to reduce domestic consumption of electricity, the EDA focused on the more energy intensive appliances, such as electric cookers, heaters and water heaters.

6.4.1. A Canadian Comparison.

Britain was not the only country to impose strict restrictions on electrical usage During the Second World War. In *Lights Out: Conserving Electricity for War in the Canadian City, 1939-1945,* Matthew Evenden assesses the effectiveness of the steps taken by the Canadian Government to respond to the electrical demands of the war, 'prioritising some uses and cities

[47] Angus Calder, *The People's War: Britain 1939-1945.* (London: Penguin, 1992).
[48] 'EDA 1385' (Manchester, 2019), Science and Industry Museum, Electrical Development Association.

over others' as well as the conservation measures adopted in urban centres and the discussions and debates that surrounded these measures.[49] Evendon argues that

> Whereas early twentieth-century conservation doctrines advocated resource management by experts for the greatest social utility and for the long term, wartime conservation operated with a strategic and military logic and assumed short term horizons. […]. It was not about reducing society's take of resources, but of diverting uses. It was not about future generations, but of meeting immediate needs.[50]

In discussing the strategies utilized by the Canadian Government, Evendon argues that one of the key factors in reducing demand lay in developing policies which would affect the behaviour, demands and expectations of consumers, particularly addressing the issue that

> Most end users did not think so much about consuming electricity as they did about the uses of electricity delivered by lights, appliances and machinery.[51]

This would appear to suggest that prior to the war, Canadian users had not been encouraged to think about the amount of electricity they used or how it was generated. This stands in contrast to inter-war advertising in Britain, which had focussed on the use of electricity as a means of reducing and controlling the consumption of coal. This of course may reflect the fact that the majority of electricity in Canada was generated using hydro sources, therefore it was likely that British consumers were more aware of the connection between electricity and fuel usage than their Canadian counterparts.

In Britain, the EDA continued to promote the use of electricity throughout the Second World War. The primary focus was to ensure that power was available for munitions production and to explain the rationing system that was being imposed by the Mines Department. They also offered suggestions as to the best ways for households to reduce their overall electrical consumption. In 1940, the Mines Department issued a fuel and lighting order intended to

---

[49] Matthew Evenden, 'Lights Out: Conserving Electricity For War In The Canadian City, 1939-1945', *Articles*, 34.1 (2013), 88-99 https://doi.org/10.7202/1016049ar, p.88.
[50] Evenden, Lights Out, p.88.
[51] Evenden, Lights Out, p.89.

control the consumption of coal, gas and electricity by all domestic and some small industrial consumers in Britain. An EDA leaflet pointed out:

> Munitions factories and industrial plants necessary for the conduct of the war naturally have first claim on fuel supplies. Consequently, the consumption by domestic and other small users will be rationed in order to conserve stocks and to guard against possible breakdown of communications.[52]

The Secretary for Mines had set the allocation for domestic users at 75 percent of the previous year's consumption, meaning everyone had to use 25 percent less coal, gas and electricity than in 1939:

> Every householder is entitled to at least 200 units of electricity, 2 tons of coal, and 100 therms of gas. These amounts are generally sufficient for the small house in which electricity is used for lighting, radio, electric iron and vacuum cleaner, where coal is used for a living room or kitchen fire, and where gas is used for cooking. If electricity is used for cooking, however, the minimum allowance of 200 units is increased to a minimum allowance of 1,000 units upon application to the Local Fuel Overseer.[53]

Having introduced the rationing scheme for coal, gas and electricity, the EDA went on to deal with potential fears regarding the security of the electricity supply, pointing out that customers needn't fear any failure of supply as

> The generating stations throughout the country are now linked together by means of the Grid Scheme, and should the supply be interrupted at any one station the Grid will ensure that supplies are continued from another source by means of carefully planned emergency schemes. Adequate arrangements have also been made for the immediate repair to any mains which might be damaged by enemy action.[54]

The same measures, put into place to safeguard supplies for industry, also ensured that domestic customers could be confident that they would continue to receive a supply of electricity in any and all circumstances. The EDA also focused on the safety of electricity,

---

[52] EDA 1547, 'What The Rationing Of Electricity Means: Advice For Domestic Consumers.' (Manchester, 1940), Science and Industry Museum, Electrical Development Association, p.2.
[53] EDA 1547, (Manchester, 1940), Science and Industry Museum, Electrical Development Association, p.2.
[54] EDA 1547, (Manchester, 1940), Science and Industry Museum, Electrical Development Association, p.3.

pointing out that there was no risk of fire or explosion and that even if wires were severed or short circuited, the current would be automatically cut off at the fuse box.[55]

In order to encourage the continued use of electrical appliances, within the limits imposed by rationing, the leaflet then provided a breakdown of the average electrical usage (in units) of different kinds of electrical appliances. This breakdown showed the average consumption of those devices per year and where applicable suggested ways in which the reader could economise on usage. Based on typical values they estimated that household lighting would consume between 100 -150 units per annum, while a radio set would, depending on the number of valves, would consume between 58 - 88 units.[56]

The three most power intensive appliances available for households, were electric cookers, heaters and water heaters. The EDA noted that

> The safety and convenience of an electric cooker makes it one of the greatest boons that electricity provides in the war-time household. The average consumption is only about 1 unit per person per day.[57]

The leaflet then went on to suggest a variety of ways in which the benefits of an electric oven could be maximised without increasing electrical usage. Indeed, an earlier leaflet for electrical demonstrator's notes that, since the outbreak of the war, demand for electric cookers had increased, possibly as a result of the increasing difficulty in finding and engaging domestic help.[58] However, it would appear that the increased safety of electric ovens over gas ovens was also a factor. If an electric oven was damaged the fuse would trip cutting off power to the appliance. In contrast to which a gas cooker would continue to leak gas, wasting fuel resources and creating the risk of an explosion. The same was true of gas and electric heating, the

---

[55] EDA 1547, (Manchester, 1940), Science and Industry Museum, Electrical Development Association, p.3.
[56] EDA 1547, (Manchester, 1940), Science and Industry Museum, Electrical Development Association, p.4.
[57] EDA 1547, (Manchester, 1940), Science and Industry Museum, Electrical Development Association, p.5.
[58] EDA 1553, 'Electric Cookery Demonstrations In War-Time.' (Manchester, 1940), Science and Industry Museum, Electrical Development Association, p.3.

explosion risk posed by gas fires meant that they were not considered safe to use in public or private air raid shelters.

6.4.2. The Heating Dilemma.

Electric fires were the only form of heating allowed in air-raid shelters, yet EDA leaflets pointed out that electric heaters were the single largest source of electrical consumption in British houses. As such the EDA suggested that economy should be observed in the use of electric fires, simply by switching heaters off in unoccupied rooms and using lower power settings to maintain heat once a room had reached the desired temperature.[59] Finally, the leaflet noted that water heaters consumed electricity in direct proportion to the quantity of water being heated. It was estimated that a 1 ½ gallon water heater used for domestic purposes would require 2 to 3 units of electricity per day, approximately 700-1,000 units per year, while filling a hot bath would use an additional 2 to 4 units per bath.[60] The EDA did not discourage people from purchasing electrical appliances or from using electricity, but rather suggested a more thoughtful, responsible approach to using electric current, only heating the minimum amount of water required, and switching off lights and electric heaters when rooms were unoccupied. Further EDA leaflets published in 1942 (Figure 6.2) continued to promote economic use of electricity and recommended that owners of electrical appliances should seek further advice from the nearest electrical showroom.[61]

[59] EDA 1547, (Manchester, 1940), Science and Industry Museum, Electrical Development Association, p.6.
[60] EDA 1547, (Manchester, 1940), Science and Industry Museum, Electrical Development Association, p.6.
[61] EDA 1593, 'Save Electricity and all Other Fuels.' (Manchester, 1942), Science and Industry Museum, Electrical Development Association.

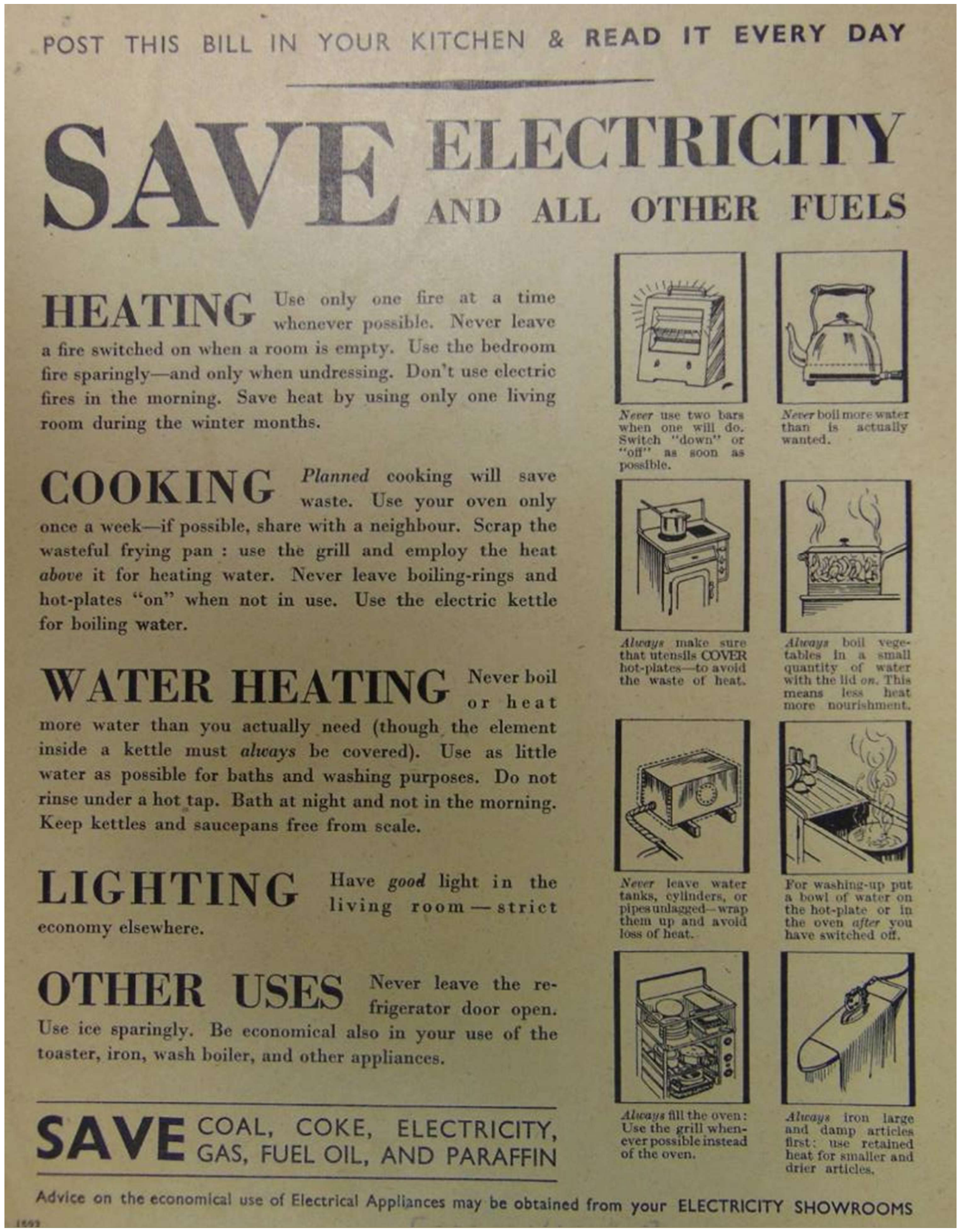


Figure 6.2: 'Save Electricity and all over fuels', EDA 1593, SIM Archives

6.4.3. Electricity and Air Raid Precautions.

To further promote the benefits of electrical lighting and appliances, the EDA released a booklet on the use of electricity in Air Raid Precaution facilities. They claimed that:

> The demands of Civil Defence on public electricity supply include practically every use to which electricity is applied for normal peacetime requirements - lighting, heating, motive power and communications. Electricity is therefore to be found in every unit of the A.R.P. organisation, from the small requirements of the trench shelters to the more complex organisation of headquarters.[62]

The EDA highlighted the use of electric lighting in air raid shelters, pointing out that the provision of adequate emergency lighting in air raid shelters was deemed to be vital in avoiding panic. Furthermore, electric lighting was considered to be more desirable than all other forms of lighting as 'Hurricane lamps or other flame type illuminants are to be deprecated except in dire emergency as they consume oxygen and so vitiate the atmosphere.'[63] This line of argument was almost identical to that used to promote electric lighting on health grounds in the 1920s and 1930s and, as we have already established, good lighting was believed to be vital for morale purposes.

Other uses for electricity in A.R.P. facilities included cooking, heating, ventilation, water heating and refrigeration, particularly in the case of storage of blood for transfusion purposes, which required specially designed combined refrigerator and heater cabinets. Almost all the devices used in A.R.P. centres were designed to run off mains power, with either a battery of manual backup system. However, some such as the blood storage units and heaters were completely reliant on mains electricity for power.[64] This EDA booklet demonstrated the utility of electricity in the defence of the country particularly in the provision of emergency shelters but did little or nothing to encourage any reduction in electrical usage. It is likely that these leaflets were primarily intended as a form of electrical propaganda intended to further

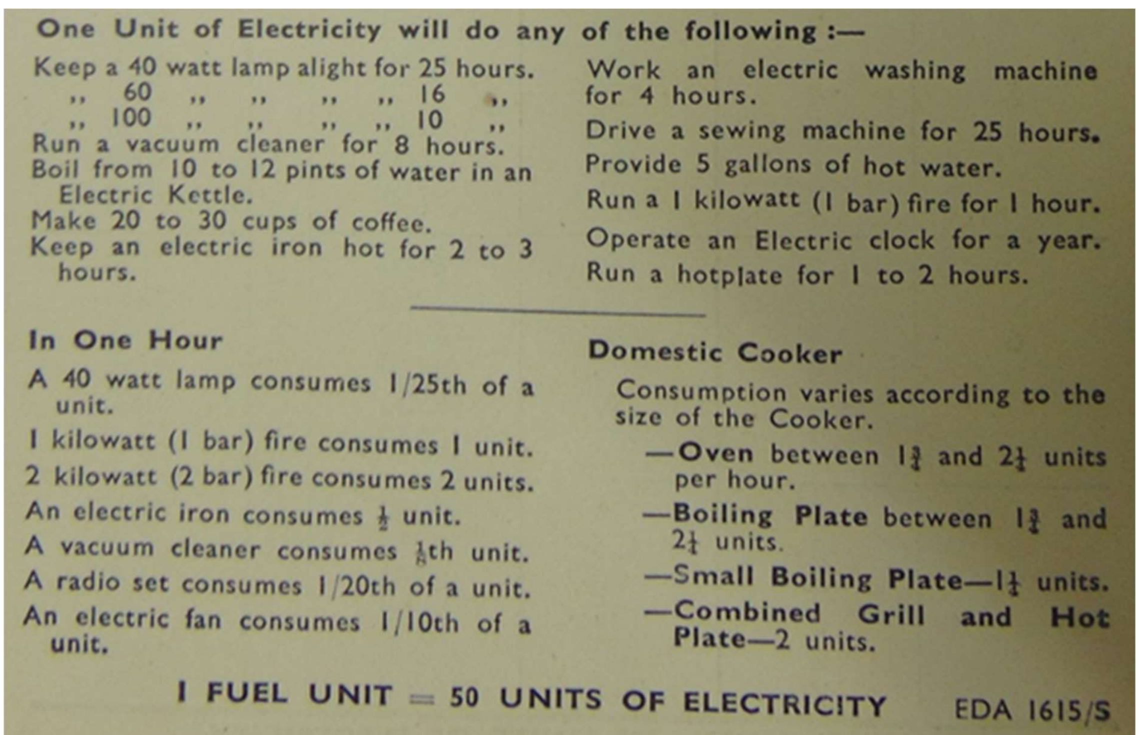
---

[62] EDA 1555, 'A.R.P Electricity' (Manchester, 1942), Science and Industry Museum, Electrical Development Association, p.1.
[63] EDA 1555, (Manchester, 1942), Science and Industry Museum, Electrical Development Association.
[64] EDA 1555, (Manchester, 1942), Science and Industry Museum, Electrical Development Association, pp.4-8.

familiarise potential customers with the utility and safety of electricity and to drive post-war sales.

6.4.4. 'The Battle for Fuel'.

The EDA described efforts to reduce electrical usage in militaristic terms as being 'The Battle for Fuel'. An EDA leaflet released in 1943 gave advice on the best way to spread electrical usage throughout the year, with tables showing electrical use for cooking, water heating, lighting, heating and other miscellaneous uses in each quarter of the year. The leaflet (Figure 6.3.) also featured a breakdown of the number of hours different devices could operate using a single unit of power, as well as how many units of electricity would be consumed by different appliances in an hour's use. While offering little advice beyond exhorting homeowners to



One Unit of Electricity will do any of the following :—

Keep a 40 watt lamp alight for 25 hours.
,, 60 ,, ,, ,, ,, 16 ,,
,, 100 ,, ,, ,, ,, 10 ,,
Run a vacuum cleaner for 8 hours.
Boil from 10 to 12 pints of water in an Electric Kettle.
Make 20 to 30 cups of coffee.
Keep an electric iron hot for 2 to 3 hours.
Work an electric washing machine for 4 hours.
Drive a sewing machine for 25 hours.
Provide 5 gallons of hot water.
Run a 1 kilowatt (1 bar) fire for 1 hour.
Operate an Electric clock for a year.
Run a hotplate for 1 to 2 hours.

In One Hour

A 40 watt lamp consumes 1/25th of a unit.
1 kilowatt (1 bar) fire consumes 1 unit.
2 kilowatt (2 bar) fire consumes 2 units.
An electric iron consumes ½ unit.
A vacuum cleaner consumes ⅛th unit.
A radio set consumes 1/20th of a unit.
An electric fan consumes 1/10th of a unit.

Domestic Cooker

Consumption varies according to the size of the Cooker.
—**Oven** between 1¾ and 2¼ units per hour.
—**Boiling Plate** between 1¾ and 2¼ units.
—**Small Boiling Plate**—1¼ units.
—**Combined Grill and Hot Plate**—2 units.

1 FUEL UNIT = 50 UNITS OF ELECTRICITY EDA 1615/S

Figure 6.3. EDA 1615, MSI Archives.

'Switch off electricity and gas when not in use', the breakdown of consumption by different appliances was clearly intended to encourage users to economise on the use of the more energy intensive devices.

Other adverts, such as those on the following page (Figure 6.4), made direct connections between the use of electricity in the home and the production of munitions and other war supplies. The adverts advised women that, by wasting electricity, they were depriving the workshops and factories of electric power. One poster offered the suggestion that neighbours should share the cooking: rather than using two ovens, they would only need one, saving half the power. These adverts are similar in format to a set produced in Canada and published in Hydro News. Eveden argues that these posters were intended to provoke a sense of anxiety in their female target audience, at the same time as affirming the importance of women as political actors through their management of household consumption.[65] This constrasts with pre-war advertising which, while recognising women as the primary user of electrical appliances, was equally targeted at men as the descion makers in charge of the family finances. Lizabeth Cohen argues that

> The moral judgment of 'good citizen' took on new gender specific meaning in wartime […]. Loyal female citizens were defined in consumerist ways, as keepers of homefront fires through their own disciplined patriotic market behaviour as well as through the enforcement of high moral standards in others.[66]

While this claim was made about the North American context, it is equally applicable to the situation in war-time Britain. Advertisments such as these placed the burden of responsibility on women and higlighted the importance of their actions not only in the home, but also by extension through the Grid network to the country as a whole.

---

[65] Evenden, Lights Out, pp.88-99.

[66] Lizabeth Cohen, *A Consumers Republic: The Politics Of Mass Consumption In Post-war America.* (New York: Random House US, 2008), p.75.

Figure 6.4. Fuel for Factories, EDA 1610, MSI Archives.

The EDA also relased a series of cookery books as well as providing 'electric cooking' demonstrations in towns and cities across Britain. The war-time demonstrations were intended to highlight the 'economical use of both foodstuffs and the electric cooker' and as such contained a great deal of information on nutrition and, rather than highlighting the cooker, demonstrated the entire cookery process from preperation to serving up. EDA leaflet 1553, which was written as a guide for cookery demonstrators, argued that:

> In war time there is a great deal to be said for the more practical type of demonstration … . Such deomnstrations are certainly good propoganda for the future so that when peace arrives consumers will have become so familiar with the wonders of electricity in the home that they will be ready to install appliances … [67]

As such we can see that EDA war time demonstrations served two purposes: Firstly, in conjunction with the Ministry of Food, they sought to teach and encourage people to make

[67] EDA 1553, 'Electric Cookery Demonstrations In War-Time.' (Manchester, 1940), Science and Industry Museum, Electrical Development Association.

more ecomical use of their food and fuel rations. Secondly, they were intended to encourage uptake of electric appliances on the resumption of peacetime trading conditions.

6.4.5. A Domestic Reserve.

However, it is equally important to note that as early as March 1941, the Central Electricirty Board and the Electricity Commissioners had recommended limits in the rationing of electricity. They argued that it was not possible to secure the necessary reductions by rationing alone, as the most intensive usage did not tend to occur at a time of day when it conflicted with industrial demands. Furthermore, they suggested that it made sense to maintain a certain level of 'relatively inessential consumption' arguing that:

> If a sudden breakdown occurs either to a generating station or a Grid line, it is necessary, if the system is already running near to its full capacity, to restore equilibrium between supply and load by rapidly cuting out areas of relatively inessential demand. A certain amount of relatively inessential consumption forms in effect an important second reserve in the system and experience has show the very great importance of such a reserve.[68]

The Electricity Board and Commisioners feared that if this reserve were to be eliminted it would increase the risk of a breakdown of supplies to vital factories and therefore cause delays in the output of munitions.

The Board also reccomended that in order to achieve the required economies, it would be better to broadcast an appeal to domestic users to restrict usage, but only to do so in emergency situations when requirements could not be met by other means. Among many considerations was the fear that if this was done too soon, it would be less effective if repeated and, more importantly, such a broadcast would potenitally serve to 'Invite special

[68] CAB 21/1541, 'National Electricity Requirements, 13 March 1941,' (London, 1941), The National Archives, Cabinet Documents, p.12.

attacks on the very conspicious targets offered by the generating stations.'[69] However, it is unclear whether such an annoucmemt was made during the war.

Figures provided by the Central Electricity Board show a significant reduction in the quantity of electricity used for domestic purposes during the war, demonstrating that, inconjeunction with the blackup households took the requirement to ration energy seriously, unlike coal, gas and electricity could not be sold on the black market. Throughout the war the EDA continued to promote responsible use of electricity in the home as a means of increasing the amount of energy availible for war work, pointing out the safety and economy of electricity in comparison to other sources of household energy, such as coal or gas. By emphasising the importance of electricity to the production of munitions as well as its utility to ARP Wardens, the EDA directly and indirectly encouraged more responsible and economic use of energy resources. However, no matter how much electricity was saved by reducing domestic usage, this would not be sufficient to keep pace with the expansion of industrial demand, although as Evendon points out:

> Power conservation in wartime may not have reduced demand as significantly as some had hoped, but it did have a strong effect on public discourses of electricity use and expectations of new opportunities in peacetime.[70]

This was certainly true of the advertising campaigns carried out by the Electrical Development Association over the course of the war. However for both Britain and Canada, these conservation tactics were only brought in once it was realised that there would be a probable shortfall between demand and generatig capacity due to cutbacks in pre-war expansion programs and the length of time it took to build or expand a power station, which was in part determined by the priority given to power station construction and repair by war-time governments.

[69] CAB 21/1541, 'National Electricity Requirements, 13 March 1941,' (London, 1941), The National Archives, Cabinet Documents, p.12.
[70] Evenden, Lights Out, p.97.

6.5. The Grid at War.

While the National Grid may not have been specifically designed for war, the flexibility offered by the interconnected system enabled the supply of electrical power to industry, military bases and domestic users to continue throughout the war with only minimal disruptions due to war-time activities. This was partly facilitated by the establishment of a National Reserve of spare transformers, switchgear and cabling, along with easily erectable wooden pylons. This reserve was distributed through 13 sites established around the country, in areas where it was considered unlikely to come under attack by German forces (Figure 6.5). The stores followed a basic design and contained an office, a workshop and an oil drainage system (so that in an emergency, oil could be drained from the stored transformers and switchgear). Altogether the cost of the spare equipment and the stores came to approximately £2,000,000 with more than 90% of the equipment and stores established prior to the outbreak of war.

6.5.1. The National Reserve.

The National Reserve was funded from the Electricity (Civil Defence) Fund, established in 1939. The fund was administered by the Central Electricity Board which provided half the money through a levy on the supply industry, and the remaining half was provided by the Treasury. The remainder of this fund was intended to be used by the Electricity Commissioners to meet any capital costs that were considered necessary to ensure the continued functioning of electricity undertakings. The reserve did not include any spare or replacement generating gear as it was felt that this could be provided by utilising the reserve generating capacity from connected stations. To ensure the ability to meet any demand, the CEB directed that all undertakers should avoid the decommissioning and removal of obsolete plant, unless it was being replaced with larger capacity equipment. They also requested any firms or undertakers still in possession of unused Direct Current based equipment to provide a listing of available machinery to help provide a backup system for those areas not yet connected to the National Grid.

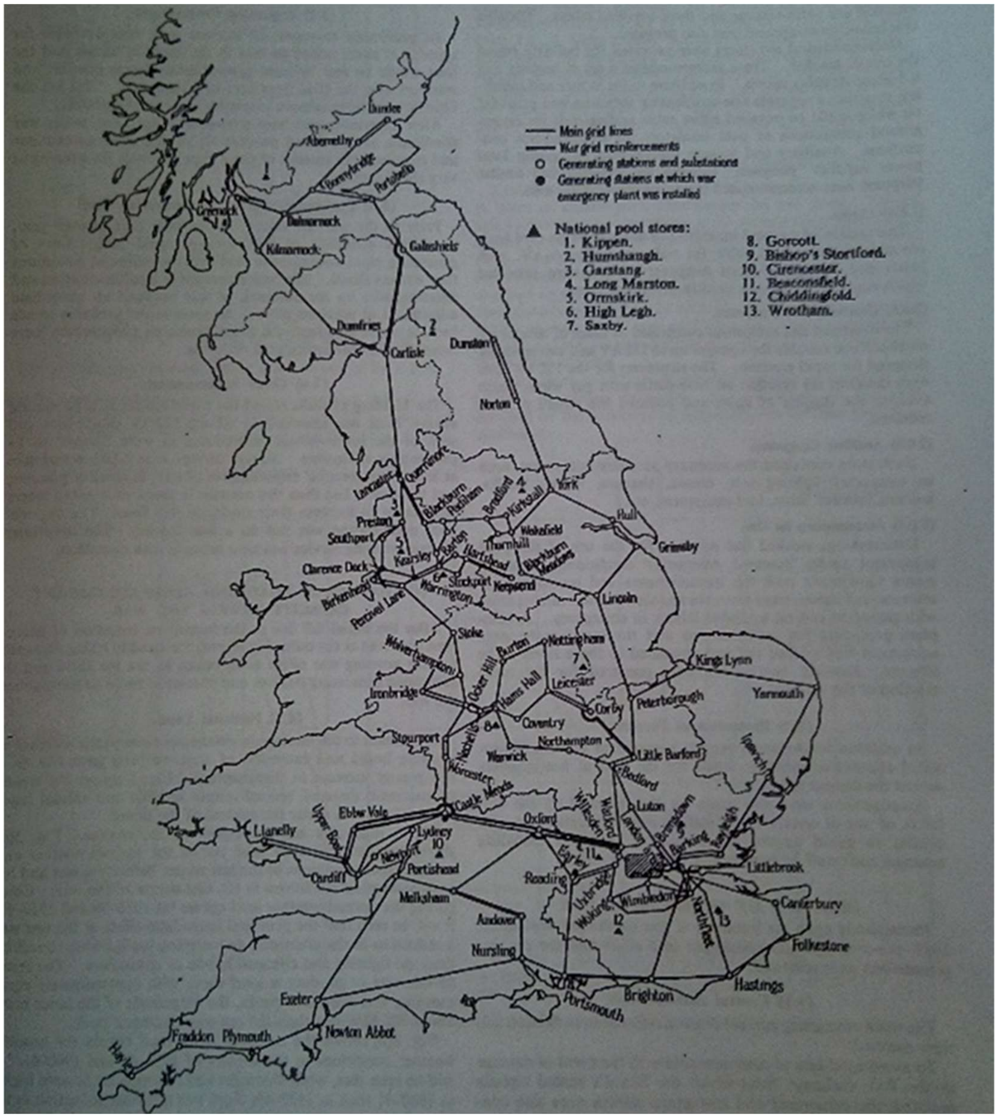


Figure 6.5. Principal Grid Connections, War Grid reinforcements, generating stations with war emergency plant, and national pool stores. Taken from: J. Hacking and J.D. Peattie, 'The British Grid System in War Time', Journal of The Institution of Electrical Engineers - Part II: Power Engineering*, 94.41 (1947), 463-476* [*https://doi.org/10.1049/ji-2.1947.0127*](https://doi.org/10.1049/ji-2.1947.0127)*, (p.465).*

The Electricity Commissioners also had plans to extend a number of existing power stations as well as for the construction of a number of entirely new power stations. However, in response to concerns voiced by the Air Ministry, they decided to limit all new construction to an absolute maximum of 200,000 MW. This would reduce the potential loss of generation from a single large power station such Battersea or Fulham being put out of action. Ultimately, the amount of damage sustained to either the Grid system or to power stations in Britain during the war was less than had been anticipated. The National Reserve was only called on 22 times over the duration of the war, only 16 of which were due to enemy action.[71]

6.5.2. Damage to Power Stations.

Power Stations made an obvious target for enemy bombers and, as the Air Ministry noted, they were often easy to locate, due to their emissions as well as frequently being located next to major rivers and railways.[72] While there is evidence that power stations were included on lists of approved targets for German bomber crews, there is little suggest that there was any form of concerted attack on British power infrastructure. An Air Ministry report on the 'Comparative Vulnerability of Power Plants to Air Attack', written in December 1940, indicated the extreme difficulty of causing serious long-term damage to a power plant. The author of the report pointed out that '[…] the nature of air attack is such that the point of impact of a bomb cannot be predicted within a few feet.'[73] In an attempt to ascertain the best means of putting a power station out of commission for an extended period of time the report examined the layout of power stations in Britain and Germany, comparing them to examples of damage sustained by British power stations in London during 1940. Based on this experience, the authors of the report suggested that steam generating plant should be considered a priority target. They argued that these tended to have a higher generating capacity than other types of power station, particularly hydroelectric; suggesting that if they were subjected to a deliberate and concentrated attack, it was likely that they would take a considerable length of time to repair.

The second area of electrical infrastructure mentioned on this list were the large switching stations which had the potential to 'Seriously interfere with the supplies to industrial areas, particularly where the incoming supplies are brought from distant points such as hydroelectric

---

[71] J. Hacking and J.D. Peattie, 'The British Grid System In War Time', *Journal Of The Institution Of Electrical Engineers - Part II: Power Engineering*, 94.41 (1947), 463-476 <https://doi.org/10.1049/ji-2.1947.0127>, (pp.475-476).
[72] Air 20/4830, 'Power, Unspecified Countries And Policy.' (London, 1940 - 1945), The National Archives, Air Ministry.
[73] Air 20/5823, 'Comparative Vulnerability Of Power Plants To Air Attacks,' December 1940.' (London, 1940), The National Archives, Air Ministry, p.1.

plants.'[74] While switching stations would have been a viable target in Germany, this was not the case for Britain. As was discussed in chapter five, the bulk of electrical generation in German was conducted at a remove from the industrial centres and was then transmitted to them via high tension cables. In contrast to this, switching stations in Britain served to connect to the National Grid and any damage would merely limit their ability to supply or draw power to and from the Grid. As we saw in chapter five, power stations such as Battersea were constructed so as to be in close proximity to their intended load. As such they would still be able to supply power to local industry in the event of damage to switching stations. In an attempt to further mitigate the risk, the Air Ministry suggested completely separating the switching stations from generating plant. However, this was rejected by the CEB as being impractical.

Hydroelectric plants were also included on the list of potential targets, although the lack of large-scale hydroelectric plant in Britain made it difficult to forecast the level of damage or disruption of a successful attack:

> These targets [called] for greater accuracy of bombing and [were] also more resistant to damage with a given calibre of bomb, both due to their heavier construction and the less effect of blast and splinters in the open.[75]

However, evidence from Operation Chastise, more popularly known as the Dam Busters raid, carried out on 16-17th May 1943, would appear to indicate that such targets were not worth the time and expense of carrying out the attack. Evidence show that the dams were repaired within a matter of weeks. Despite the destruction of the hydroelectric plants associated with the dams, and damage to seven other power stations, the supply of electricity was restored to the area by the 27th June. However, it is unclear whether this recovery was enabled by repairs to the local generating plant, or through transfers from another part of the country. Of greater

---

[74] Air 20/5823, 'Comparative Vulnerability Of Power Plants To Air Attacks,' December 1940.' (London, 1940), The National Archives, Air Ministry, p.25.
[75] Air 20/5823, (London, 1940), The National Archives, Air Ministry, p.25.

significance than the damage to power stations was the loss in coal production, which fell by 400,000 tons in May. In Britain, this loss of production would have had a severe impact on electrical production due to the reliance on coal burning generating plant.

Furthermore, the failure of the RAF to carry out follow up attacks on the dams enabled the rapid repairs to take place. This was noted by the both Albert Speer and Barnes Wallis. Speer commented that

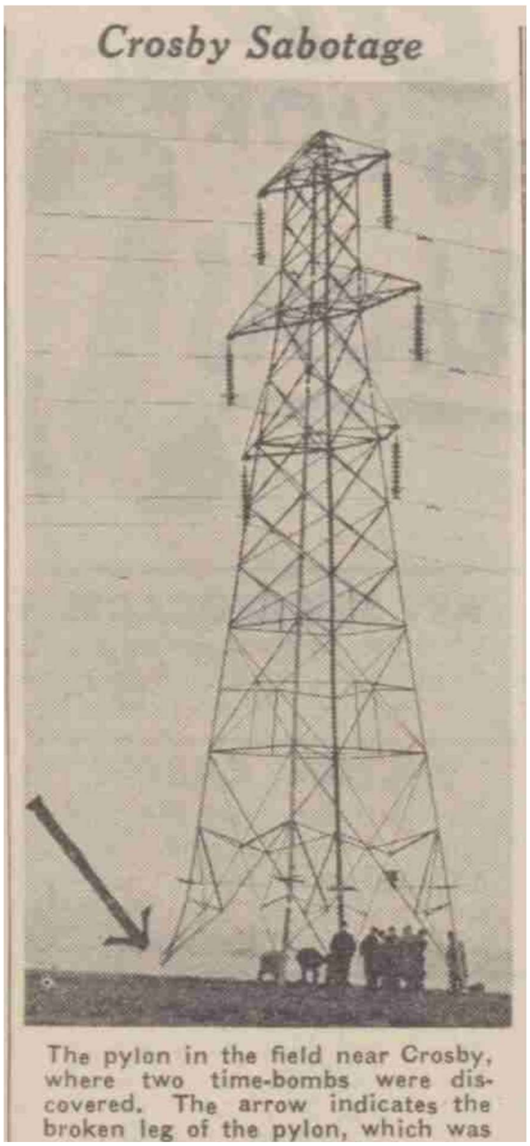
> The disruption of temporarily having to shift 7,000 construction workers to the Möhne and Eder to conduct repairs was offset by the failure of the Allies to follow up with additional (conventional) raids during the dams' reconstruction, and that represented a major lost opportunity.[76]

Wallis expressed his dissatisfaction with Bomber Command's failure to carry out conventional high level attacks on the repair work, which he argued would have severely delayed the recovery.[77] The same is undoubtedly true of the German attacks on British power stations and is an indication that while included on lists of desirable targets, any actual damage to power stations was purely the result of chance and the location of generating plant in a target rich environment such as central London.

[76] Albert Speer, *Inside The Third Reich: Memoirs.* (London: Cassell, 1999), p.385.
[77] Max Hastings, *Bomber Command, The Strategic Bombing Offensive: 1939-45.* (Pan MacMillan: London, 2012), p.262.

6.5.3. Attacking the Pylons.

The final target on the list were transmission lines and river crossings, which the Air Ministry believed would be more difficult to hit due to their small size. In the case of Britain, thanks to the existence of the National Reserve, they would also be easier to repair or replace. Indeed, British electrical authorities often made use of easily erectable wooden pylons to replace any which had been damaged by enemy action.


Crosby Sabotage

The pylon in the field near Crosby, where two time-bombs were discovered. The arrow indicates the broken leg of the pylon, which was

Figure 6.6. Liverpool Echo*, Tuesday January 17, 1939, p.12. Showing the damage caused by IRA bombs to the leg of a pylon.*

The resilience of pylons to bomb damage was first demonstrated in 1939 when the Irish Republican Army targeted Britain's electrical infrastructure. On 16th of January 1939, a bomb attached to a pylon carrying the main transmission lines between Liverpool and Manchester was detonated. While this caused damage to one of the legs, it failed to bring the pylon down which remained standing and was still carrying power.[78] This demonstrated the resilience of the pylon design and may have been taken as evidence that pylons would be largely immune to aerial attack. This idea can be further supported by the experience of aerial attacks on the transmission and receiving towers of the Chain Home stations during 1940, when despite precision attacks by Stuka dive bombers, the towers only sustained minimal

[78] 'Crosby Explosion Mystery Solved: Pylon Damaged By Bomb.', *Liverpool Echo,* 17th January 1939, p.12.
The first Edition of the Liverpool Echo was published in 1879 as a cheaper alternative to the Liverpool Daily Post.

damage as the lattice construction was not vulnerable to the pressure waves from High Explosive Bombs or to shrapnel damage.[79]

6.5.4. A Resilient System.

Based on the experience of damage to British generating plant by German bombs in 1940, the Air Ministry stated that the damage sustained had been less severe than had been anticipated prior to the war. furthermore,

> The damage that ha[d] occurred, and the means taken to rectify it, [were] so varied and unusual that it ha[d] been difficult to prepare a statement such as this report, or to attempt to give precise answers to general questions.[80]

Thus, it appeared that the only way to successfully disrupt a nation's electrical power supply was by consistent and coordinated attacks on the different components of the network. Steam-based generating systems would be the key targets due to the potential length of time for any damage to be fully repaired. Post war analysis of war-time faults showed that the Grid itself had proven to be highly resistant to enemy attack. While a total of 51.7% of all reported faults on the transmission system could be directly attributed to the war, only 8% could be attributed to enemy action, while 43.7% were as a result of the defensive measures taken against aerial attack. The largest single culprit was stray barrage balloons, which accounted for 35% of all faults between September 1939 and May 1945 (Table 6.7).

Due to the availability of the National Reserve and the lack of a concentrated attack on British Power Stations, the damage caused to Britain's electrical infrastructure during the war was minimal, with most damage being repaired in a matter of weeks. As was noted in the report on the '*Comparative Vulnerability of Power Plants to Air Attack'*, damage to the turbines and boilers of steam power plants could take up to 18 months to be installed, especially if completely new machinery was required. However, the existence of the National Grid meant

---

[79] Air 20/5823, 'Comparative Vulnerability Of Power Plants To Air Attacks,' December 1940.' (London, 1940), The National Archives, Air Ministry.
[80] Air 20/5823, (London, 1940), The National Archives, Air Ministry.

that in the event of damage to a local station, power could quickly be drawn from other parts of the country. Equally any damage to the long-distance transmission system was largely mitigated by the way in which power stations were constructed within the area they were intended to serve.

As we see in the following section, the damage caused to British power systems by stray barrage balloons provided a great deal of inspiration for what was to be one of the most cost-effective forms of attack of the Second World War, and is the only example of a successful, prolonged operation against a power supply network carried out during the Second World War.

Cause	*Total Number of Faults*	Percentage of Total Number of Faults
Faults directly attributable to the war		
Hostile Action		
Normal Bombs	303	6.6
Flying Bombs	40	0.9
Rocket Bombs	13	0.3
Enemy Aircraft	6	0.1
Enemy Shellfire	4	01.
Total due to Hostile Action	366	8.0
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	43.7
Total of War Faults	2,382	51.7
Faults not directly attributable to the war	2,225	48.3
Total of all faults	4,607	100%

Table 6.7. Faults on the Board's Transmission System during the Second World War. 3 September 1939 - 8th May 1945.[81]

[81] Hacking and Peattie, The British Grid System in War Time, p.472.

6.6. Operation Outward.

The single largest cause of faults to the British Grid system during the war resulted from damage caused by stray barrage balloons (Table 6.7 above). Incidents in 1939/40 occasioned complaints from the electrical authorities to Air-Vice Marshall Owen Tudor Boyd, in charge of the RAF's Balloon Command, who wrote that:

> Since the outbreak of war, I have had constant complaints from the electricity distributors regarding the damage done in this country by balloons which have broken away from their moorings. […] advantage might be taken of this to impede and inconvenience the enemy.[82]

The idea was picked up by a Royal Naval officer, Captain C.G. Banister, in command of the Royal Navy's boom defence. He suggested holding a series of trials to determine the best size and type of balloon and type of wire to use to disrupt German electrical supplies. He also contacted the CEB requesting information on whether the circuit breakers known to be used on German High Voltage cables would be capable of preventing excessive damage to switching stations or generating plant. British experts believed that the German system would be more vulnerable to such an attack than the National Grid, due to the use of Peterson coils[83] which were unable to cope with the phase to phase shorts likely to be caused by the trailing wires. This was exacerbated by the use of circuit breakers which had a slower response time than those in use on the National Grid. The engineers concluded that these design elements would likely lead to the destruction of the circuit breakers and transformers, which in turn would potentially lead to further, more catastrophic, faults.[84]

---

[82] ADM 199/848, 'Operation Outward - Offensive Use Of Free Balloons.' (London), The National Archives, Admiralty Papers.

[83] Petersen coils are used in ungrounded 3-phase systems to limit arcing currents during earth faults. The coil was first developed by W. Petersen in 1916.

[84] Raoul Drapeau, 'Operation Outward: Britain's World War II Offensive Balloons.', *IEEE Power And Energy Magazine*, 2011, pp. 94-105 <https://site.ieee.org/ny-monitor/files/2011/09/OPERATION-OUTWARD.pdf> [Accessed 31 October 2017]., (p.97).

Despite strong opposition from the Royal Air Force, who argued that the release of balloons would disrupt normal flying operations, the project went ahead with the support of Winston Churchill. Operation Outward was one of the most cost-effective operations of the entire war, with the cost estimated at roughly £2 per balloon released and caused approximately £1,500,000 worth of damage to the German electrical infrastructure. It was also the only offensive operation carried out by the Wrens.[85] Between 20th March 1942 and 4th September 1944, a total 99,142 balloons were released, over half of which carried the trailing wires intended to disrupt power cables.[86] Post-war analysis of the attacks indicated that the trailing wire balloons had caused significant damage to the German network, severely disrupting supplies. However, it is probable that the actual damage caused was higher than this due to the incomplete nature of the German records. In addition, the records only show the damage and disruption to the high-tension lines as the faults on low tension lines were too numerous and frequent for any accurate record to be maintained. Possibly the single greatest achievement of the operation was the destruction of Böhlen power station by fire, caused when a balloon struck a 110-kV line near Leipzig leading to the failure of a circuit breaker at the power station. Post-war analysis estimated that this single event had put 250 MW of generating capacity out of action and caused damage estimated at approximately £1,000,000.[87]

Overall, the operation was considered to have been a great success. The Admiralty were keen to publicise the results of the operation and to officially recognise the efforts of the personnel involved. However, this was not to be, the War Cabinet instead decided to suppress all records of the operation, believing that it was unwise to release details of a form of attack which had the potential to be successfully employed against Britain.[88] However, as has already been

[85] Women's Royal Naval Service.
[86] 'Air 20/2449, Operation Outward.' (London, 1944), The National Archives, Air Ministry.
[87] ADM 199/848, 'Operation Outward - Offensive Use Of Free Balloons.' (London), The National Archives, Admiralty Papers.
[88] ADM 199/848, (London), The National Archives, Admiralty Papers.

noted, the design of the British circuit breakers meant that the National Grid was, in theory, better able to withstand this kind of attack. In any event, the men and women involved received citations for having caused '[…] damage equivalent in naval parlance to the loss of a capital ship.' To put this into context, the capital ships of the Second World War consisted of Fleet Carriers, Battle-Cruisers and Battleships. The five King George V class battleships of the Royal Navy ordered in the mid-1930s each cost approximately £7,393,134. [89] The government decision also prevented the Central Electricity Board from publishing any reports or papers on the operation, or their post-war investigation into the state of the German electrical network.

6.7. Conclusion: Pushed to the Limit.

This chapter clearly demonstrates the central importance of energy security to the British War effort and to Britain's National Security. Without a secure supply of power British Industry would have been unable to function. By the outbreak of the Second World War the two main sources of fuel in Britain were coal and oil. Oil was primarily used by the military, unlike the United States, Britain did not have access to indigenous sources of oil, but instead relied on imports, which were vulnerable to interception.

British industry was largely reliant on electrical power. For Britain, lacking the hydro-resources of continental Europe or the United States, this meant coal. Electrical power and the National Grid helped to ensure the most efficient use of the countries coal resources. The Grid also enabled the transmission of power throughout the country, providing a back-up to local generation and ensuring secure supplies of electricity to industry as well as for Radar and transportation.

While the supply of electricity was rationed, we have seen that access to electricity was considered to be important to maintaining civilian morale during the blackouts. Furthermore,

[89] Drapeau, Operation Outward, p.102.
R. A Burt, *British Battleships 1919-1945*, 2nd edn (Annapolis: Naval Institute Press, 2012), p.389.

electric heaters were considered to be the only safe means of providing heating in air raid shelters. However, the authorities were careful not to take rationing too far as civilian use of the electric power provided a 'non-essential' load which could form a reserve for industrial users in the event of a shortfall in generating capacity.

The Grid system itself proved to be highly resistant to damage, with more disruption caused by defensive measures than by enemy action. During the war, the Grid enabled the transfer of power from underutilised regions to areas with high demand, and it also enabled supplies to be maintained in the event of damage to local power stations. However, the demand for electricity was higher than expected. In order to meet the demand for power it was necessary to run older and less economical plant, as well as to cut the time for maintenance. Furthermore, permission for new plant or extensions to existing plant was only granted where upgrades were likely to be completed in time to assist in the war effort. This was to have severe repercussions in the post war period. The Second World War also highlighted the problems caused by the over-reliance on coal for all forms of power, and Ministers began looking at means of reducing the country's dependence on coal, a dependence which was further highlighted during the winter of 1946/7, which is discussed in the following chapter.

The Second World War demonstrated the potential vulnerability of electrical infrastructure to attack. While wartime damage to the Grid and to British power stations was light, this was mainly due to the lack of any systematic and sustained attack on British electrical infrastructure. British operations against German electrical infrastructure were more successful. While Operation Chastise achieved its target of breaching the Möhne and Edersee Dams as well as damaging the Sorpe dam, the lack of any follow up attack largely negated the effectiveness of the campaign. By contrast, Operation Outward succeeded in causing massive disruptions to the German power supply network and was so effective that the entire operation was classified at the end of the war. However, confidential reports suggested that the National Grid would not be as vulnerable to this kind of attack as contemporary continental systems. This was particularly important due to the reliance on modern aerial defences, such as radar, on access to electricity.

The importance of the National Grid to the operation of the Chain Home Network cannot be overstated, in part due to the savings in aviation fuel enabled by the use of radar. While it would have been possible to operate the Chain Home Network using diesel or petrol generators, this would have been prohibitive in terms of fuel use. However, the importance of ensuring a continuous supply of electricity meant that all radar sites maintained a backup generator system which was tested on a daily basis.

Throughout this chapter, I have shown that electrical infrastructure was given the highest level of priority for construction, but this had only extended to plant which would be of material use to the war effort. Instead, ensuring security of supply was the overriding policy concern, more so than planning for future energy needs, a focus which was to have severe implications for post war Britain.

7. The Perfect Storm, 1946-1956.

7.1. Introduction.

By the end of the Second World War, the electricity supply system in Britain was on the brink of collapse. The Grid itself had come through the war essentially intact and the emergency stores which had been set up to repair damaged lines and substations remained largely untouched. The same could not be said of the generating stations themselves. While bomb damage had been relatively light, especially outside of London, repairing damaged stations interfered with the procurement of generating plant for new stations. In order to keep up with wartime demand, it had been necessary to make use of old and obsolete equipment, and to run plant with insufficient downtime for maintenance. The need to repair or replace worn out plant at the end of the war led to a significant drop in generating capacity, which was not matched by a corresponding drop in consumption. Due to the need to resume high levels of production for export, industrial consumption did not fall as far as predicted. At the same time, domestic use of electricity also increased rapidly with the end of the blackout, as well as the increasing availability of new domestic electrical products such as electrical heaters and ovens.

Dependence on coal for the generation of electricity was simultaneously one of the greatest strengths and one of the greatest weaknesses of British industry. Coal was a key strategic resource for Britain and one that needed to be carefully managed. Furthermore, the ongoing strife in the mining industry over pay and conditions was a significant threat to national security and one which had only intensified as the country became more dependent on electricity. However, the amount of coal excavated had fallen throughout the Second World War, as a large number of miners had left the pits to join the armed forces, many of whom did not return to the mines following demobilisation.

Throughout 1946, Emanuel Shinwell, the Minister of Fuel and Power, was engaged in negotiations with the miners over the planned nationalisation of the coal industry.[1] In order to avoid conflict with the miner's unions, he refrained from taking actions, such as the recruitment of Polish miners, in the hope that any goodwill would result in higher production rates. Finally, the severe winter of 1946/7 meant that the demand for coal, gas and electricity soared; due to the coal shortage most electrical and gas undertakings had insufficient stockpiles to deal with a prolonged period of high demand. This was exacerbated by the heavy snow falls throughout January and March 1947 which blocked the railway lines and froze rivers and canals, preventing the movement of coal from the pithead. The disruption to domestic coal supplies also caused many households to make greater use of electric fires, increasing the demand placed on generating stations. These elements snowballed to form a perfect storm. The urgent requirement for electrical power was such that work on city centre power stations such as Bankside continued even in the aftermath of the 1952 Great Smog of London. This highlights the degree to which the need for energy security was considered more important than environmental concerns, even when those concerns threatened the health of the population. However, the concerns over air pollution did contribute to the decision to complete Bankside Power Station to burn oil rather than coal as well as to the arguments for the civilian development of nuclear power stations.

While not explicitly linked to national security, establishing a diverse range of fuel sources for electrical generation was key to ensuring the continued supply of electrical power to British industrial and domestic users; providing employment and enabling the redevelopment of the country. The same is true for the measures to limit air pollution following the 1952 smog. A

[1] Emanuel Shinwell was a Labour politician and a strong supporter of the Unions. He was prominent in discussions on Labour's policies, particularly those relating to coal and energy. He was made Minister of Fuel and Power in Attlee's post war Government but was demoted in 1947 over his handling of the fuel crisis.
Kenneth O. Morgan, 'Addison, Christopher, First Viscount Addison (1869–1951).', *Oxford Dictionary Of National Biography* (Oxford: Oxford University Press, 2004) <https://doi.org/10.1093/ref:odnb/30342> [Accessed 28 October 2019].

population that is ill or experiencing deaths due to pollution is not able to maintain high levels of productivity and would likely be considered unfit for military service in time of war.

This chapter begins by examining the causes and consequences of the disruptions to electrical supply during the winter of 1946/7. This followed by an examination of the debates relating to the Nationalisation of the Electrical Supply Industry and the development of a National policy relating to the utilisation of energy resources, particularly considering the diversification of fuels and the development of oil and nuclear power.

7.2. The Aftermath of War and the Beginning of Reconstruction.

The surprise victory of the Labour Party under Clement Attlee in the General Election of 1945 gave Labour its first ever majority government, as well as a strong mandate to pursue their program of nationalisation and reform. Key industries such as the railways, coal mining, gas production, and the generation and distribution of electricity, were to be brought fully under national control and ownership.[2] This situation made it more difficult for the new Minister of Fuel and Power, Emmanuel Shinwell, to deal with the ongoing coal shortage. Moreover, the exhausted and poorly maintained plant in use was no longer able to make as efficient use of the available coal supplies. However, the uncertainty over the compensation to be paid to the owners of mines and power stations may have served to dissuade owners from engaging in any expensive upgrades or extensions to the sites as they could not be sure of a return on their investment. However, this would not have been a significant problem; as has previously been acknowledged, the construction or extension of a power station was a long-term process, often taking up to five years to complete. As such, it was extremely unlikely that any

[2] Clement Attlee (1883-1967) Labour politician and Prime Minister (1945-1951). He was first elected to Parliament in 1922 and retained the same seat until 1950. During the late 1920s he regularly addressed parliament on matters relating to electricity and local government. During the Second World War Atlee chaired the food and home policy committees.
R. C. Whiting, ‘Attlee, Clement Richard, First Earl Attlee (1883–1967).’, *Oxford Dictionary Of National Biography* (Oxford: Oxford University Press, 2004) <https://doi.org/10.1093/ref:odnb/30498> [Accessed 1 November 2019].

construction authorised after 1943 would have been completed in time to materially affect the supply of electricity in 1946/7.

7.2.1. State of the Grid.

At the end of the Second World War, the National Grid was in surprisingly good shape, especially when compared to the fears of the Central Electricity Board prior to the war. The 13 depots which had been established containing spare parts for the transmission and distribution system remained largely untouched and indeed were quickly sold off. The CEB annual report for 1944, showed that the precautions taken prior to the war had largely mitigated against any serious damage to the Grid infrastructure, noting that:

> Damage to the Board's substations was less than had been anticipated and in only a few cases involved any prolonged interruption of supplies. Frequently when bombs fell in the vicinity, their effect was neutralised by the blast walls, which proved very effective. […]. As the damage was comparatively light, the Board's calls on the National Pool of Spares were infrequent.[3]

The CEB report noted that by the end of 1943, there were only 19 occasions on which equipment was issued from the National Pool and of these on 12 were related to enemy action.[4] The report also pointed out the lack of any significant long-term damage to generating plant, claiming that:

> The most serious incident was the damage to Fulham Generating Station on the 9th September 1940, when bombs fell on the engine room and put 190,000 kilowatts of plant out of service. Fortunately, the Board's substation and the interconnecting transformers and cables were undamaged, and it was therefore possible to resume within a few hours and thereafter to maintain local supplies from the Grid system. The loss of output capacity due to enemy action has naturally varied but has never exceeded 400,000 kilowatts at any one time.[5]

---

[3] 'Annual Report Of The Central Electricity Board, 1944.' (Manchester, 1944), Science and Industry Museum, Electricity Council, p.33.
[4] 'Annual Report Of The Central Electricity Board, 1944.' (Manchester, 1944), Science and Industry Museum, Electricity Council, p.33.
[5] 'Annual Report Of The Central Electricity Board, 1944.' (Manchester, 1944), Science and Industry Museum, Electricity Council, p.34.

From this, it would appear that, despite the damage to individual power stations, the damage to the generating capacity of the Grid as a whole was minimal. It also demonstrates that the Grid system had worked in precisely the manner alluded to in the first annual report of the CEB from 1928, mentioned in chapter five.[6] The main difficulty experienced appears to have been keeping up with the rapid increases in demand from industry. One means of doing this had been to continue to run older, less efficient generating plant, particularly at times of peak demand. Another strategy, which is alluded to in the report, was the reduction the normal maintenance to a bare minimum. The report noted that:

> Repair work during and after air raids [wa]s urgent and difficult. It must take precedence over normal maintenance, and consequently, the peace-time routine maintenance was abandoned for a restricted programme covering only work immediately necessary to ensure continuity of supply.[7]

It was this lack of routine maintenance during the war, which was to have the most severe impact on power generation in the immediate post-war period. While the total potential generating capacity of the network increased, this was offset by the amount of plant taken out of commission for maintenance and repair. However, the poor state of repair of generating plant was not the only problem. In 1946/7 the long-standing issue of fuel supply in the form of coal shortages returned with dire consequences.

7.2.2. The Coal Crisis.

Barry Supple has described coal mining during the 1940s and 1950s as being 'perhaps the most important industry in Britain. [Noting that] it was also the industry which was most persistently in the forefront of public and political consciousness.[8] Supple argued that the coal mining industry was one of the best represented industries in Parliament, with a large number of Labour MPs having some form of affiliation with the National Union of Mineworkers. This

---

[6] See discussion in Ch.5 on pages 140-141.
[7] 'Annual Report Of The Central Electricity Board, 1944.' (Manchester, 1944), Science and Industry Museum, Electricity Council, p.35.
[8] Supple, *The History of the British Coal Industry, 1913-1946, p.*592.

Figure 7.1. Emanuel (Manny) Shinwell, 1940s.

influence remained strong throughout much of the period covered in this thesis and was a significant factor in the years immediately following the Second World War.[9] This was certainly the case with the new Minister of Fuel and Power, Emanuel Shinwell (Figure 7.1), who was MP for Seaham.[10] Robertson argued that this limited his ability to negotiate with the miners during 1946, and almost certainly mitigated against the employment of Polish personnel in the mines during mid to late 1946.[11] Resorting to overseas workers was a measure which, as we will see, was finally implemented in early 1947, following the nationalisation of the industry and in response to the unusually severe weather conditions.

According to Supple, the nationalisation of the coal mining industry became almost inevitable because of the Second World War. He claimed that the war had highlighted problems in the organisation of the industry, which could not be tackled without bringing the mines under national control.[12] He also noted reform of the coal mining industry was a central factor in the long-term recovery of the British economy.[13]

The Coal Industry Nationalisation Bill was introduced to Parliament on 19th December 1945 and rapidly passed through Parliament with some amendments, before receiving Royal Assent on 12th July 1946.[14] Perhaps the most surprising factor in the nationalisation of the coal mines is the lack of resistance from the mine owners themselves. This may in part have been due to

[9] Supple, *The History of the British Coal Industry, 1913-1946, p.*593.
[10] Seaham was a strong Labour seat with a significant mining community.
[11] Alex J Robertson, *The Bleak Midwinter, 1947* (Manchester: Manchester University Press, 1987).
[12] Supple, *The History of the British Coal Industry, p.*611.
[13] Supple, *The History of the British Coal Industry, p.*624.
[14] Supple, *The History of the British Coal Industry, p.*628.

Shinwell's own attitude towards the mine owners and his promises that any legitimate capital expenditure undertaken after the 1st August 1946 would be reimbursed.[15]

Government hopes that the end of the war would bring an end to the shortage of trained labour in the mines were not realised. One of the key problems experienced during both the First and the Second World War had been the number of skilled and experienced miners who had signed up for the armed forces and for whatever reason did not return to the mines once demobilized. During the Second World War, these experienced miners had been replaced with older men, not eligible for military service, as well as by a group known as Bevin's Boys. In an effort to replace the miners who had joined the forces earlier in the war, one in ten of the of the men called up to service, between 1943 and 1945, were instead conscripted to the mines. However, these men, often with no relevant experience, could not hope to replace the experienced miners in terms of productivity. Bevin's Boys were amongst the last group of servicemen to be demobilized and remained working in the mines up until 1948. These measures indicate the importance being placed on maintaining the supply of coal. However, simply increasing the quantity of coal extracted was insufficient; another key problem was the ability of the transportation system to move the coal from the pitheads to the power stations.

7.2.3. Transporting Coal.

During the Second World War the rail networks had been forced to operate with a minimum of downtime for maintenance to locomotives and other rolling stock. According to Alex Robertson, Shinwell had largely attributed the breakdown of January 1947 to deficiencies in the transportation system, in effect shifting the blame to the Minister of Transport.[16] Indeed the shortage of rolling stock, and of heavy freight locomotives did cause some problems, resulting in a temporary build-up of stockpiles at the pit heads in October 1946. However, this stockpile was steadily reduced throughout November and December and had been largely

[15] Supple, *The History of the British Coal Industry, p.*633.

[16] Robertson, *The Bleak Midwinter, p.*85.

distributed by the end of the year.[17] This is supported in Barry Supple's account in which he claimed that the 'Origin [of the crisis] lay less on the side of production (except in so far as earlier restrictions on output had prevented the accumulation of abundant local stocks) than in the field of distribution.[18] Supple pointed out that by December 1946 the level of employment in the industry had increased and that part of the reason for the slow increase in local stocks was the higher than expected demand from industry. In December 1946 the *New Statesman and Nation*, warned that, 'Despite everything which has been achieved in the past twelve months, an extended period of snow or fog could still cause something like a national close-down of industry.'[19]

However, it is far from clear if anything could have been done to prevent the problems with transporting coal which came about because of the severe weather of early 1947. Full stockyards of coal would not have enabled trains to move on the blocked railway lines, although they would have helped tide power stations and industry over until deliveries could be resumed.

In line with many other industries the railway companies were in the process of converting some of their locomotives from coal burning to oil burning. This would have helped to reduce the demand for coal from the railways and would have potentially enabled the network to remain at least partially operational in the event of a serious coal shortage. Although, it would not be able to overcome the issue of blocked lines. In August 1946, the railway companies had entered into an agreement with the Ministry of Fuel and Power to convert a total of 1,279 locomotives to burn oil rather than coal by the end of December 1946. However, as with other

---

[17] Central Statistics Office, Monthly Digest, No24, December 1947, table 25.
[18] Supple, *The History of the British Coal Industry, p.*669.
[19] *New Statesman & Nation,* 28th December 1946. In Supple, *The History of the British Coal Industry,* p.669. This paper was created out of a merger of the New Statesman, a Labour affiliated publication, and the Nation, which was a liberal leaning publication.

oil conversion projects, it was held up by difficulties in obtaining the conversion kits, and only twenty conversions had been completed by the end of February 1947.[20]

7.2.4. Supply and Demand.

According to both Leslie Hannah and Alex Robertson, one of the most significant factors in the failure of the electrical authorities to maintain adequate supplies of power was the rapid and unpredicted increase in electrical demand following the end of the war. This was at least in part due to homeowners turning to electricity for heating and cooking, as further restrictions on coal use were authorised by the government. By October 1946, one of the biggest fears of Emmanuel Shinwell and the officials of the Ministry of Fuel and Power was not that there would be insufficient coal, but rather that the electricity supply industry would not be able to take advantage of the available supplies. In October 1946 Shinwell pointed out that:

> These interruptions of electricity supply are due to a shortage of generating plant, which is insufficient to meet peak loads. The shortage arises from the fact that only a few power stations could be built during the war, while consumption has increased to 55 percent above 1938.[21]

This problem had been picked up as early as January 1946, when the *Financial Times* published an article in which they emphasized that, while demand had continued to rise, the amount of electricity generated had fallen. The paper attributed the fall in electrical production to shortages in manpower and materials common to industry at the time.[22] Figures in *The Times* for 16 January 1946 showed that electrical output for 1945 had decreased by 1,080 million units or 2.8 percent, over the previous year.[23] Again it should be emphasized that this was a decrease in generation rather than a decrease in consumption which, as can be seen below, was actually increasing.

---

[20] PREM 8/443/II, 'A. Barnes To Fuel Committee' (London, 2019), The National Archives.
[21] 'ELECTRICITY SUPPLY (INTERRUPTIONS)' *HC Deb 31 October 1946 vol 428 cc787-90.*
[22] 'Electricity Output Declines', *The Financial Times,* 16th January 1946, p.3.
The Financial Times was first published in 1888 as the London Financial guide and we renamed later that year. Until the late 1950s the paper was primarily focused on investment in Britain and was largely disinterested in foreign investment.
[23] 'Electricity Output', *The Times,* 16th January 1946, p.7.

While the use of electricity in industry had fallen from a peak of 20941 million units in 1943, to 17941 million units in 1946, this was still considerably higher than the level of 10756 million units of electricity used by industry in 1938. In addition to this, domestic usage of electricity had continued to increase throughout the war from 8438 million units in 1938 to 9804 million units by the end of 1943. From this point the increase had become more dramatic, increasing to 12337 million units by the end of 1945 with a further increase to 15517 million units by the end of 1946. Total electrical usage increased from 20828 million units in 1938 to 35059 million units by the end of 1946.[24] (see Figure 7.2)

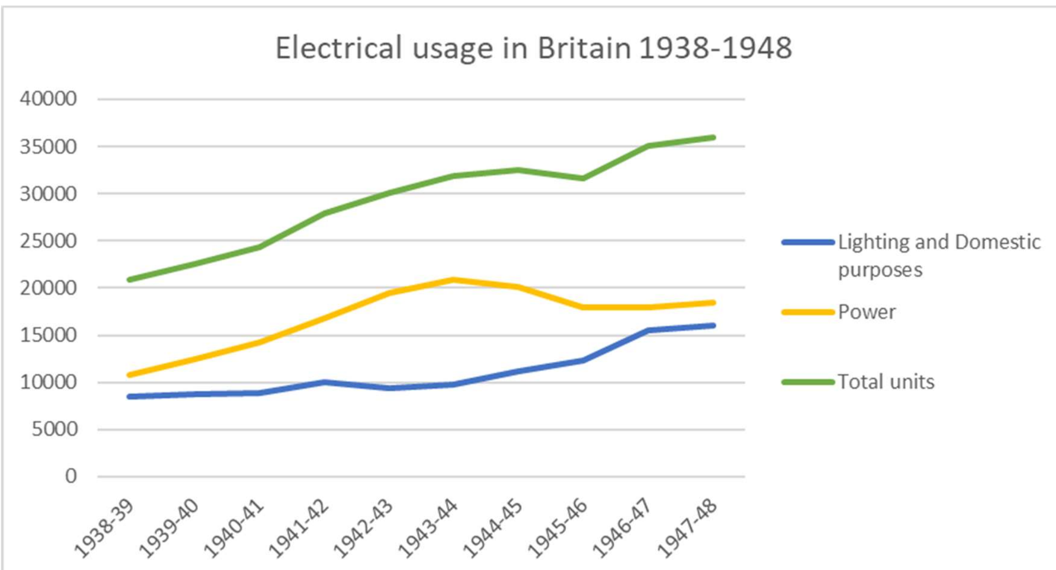


Figure 7.2. Electrical Usage 1938-1948, Data taken from the annual returns of Engineering and Financial Statistics relating to Authorised Undertakings in Great Britain between 1920 and 1948. These were compiled on behalf of the Electricity Commissioners in order to provide comparative statistics in a readily accessible form to assist in carrying out their duties. The full breakdown of these figures is available in Appendices 1.

Leslie Hannah has attributed many of the problems experienced by the electricity supply industry in the immediate post war period to what he argued was the low priority given to the construction of generating stations, as well as severe shortages of both manpower and materials. However, as we have seen in the previous chapter, the construction or extension of generating stations had been given a high priority throughout the war, to the point of the

[24] Data taken from the annual returns of Engineering and Financial Statistics relating to Authorised Undertakings in Great Britain between 1920 and 1948.

ministry of labour providing men from the pioneer corps to help ensure the completion of Grid connections. Rather then, it appears that one of the key problems was the difficulty experienced by the Central Electricity Board in accurately forecasting the electrical requirements of the country. One element which had served to complicate this issue was the general increase in electrical usage for domestic purposes throughout the war. A further factor was the increased electrification of industry. On 18 January 1946, *The Economist* had reported on changes in the consumption of electricity during the war, pointing out that the use of electricity for industry had almost doubled during the war, and suggested that this was, 'not merely a reflection of the intensity of industrial operations, but [suggested] the introduction of a large volume of new equipment much of which [could] be utilised in peace.'[25] When considering the sales figures, the paper pointed out that, during the last quarter of 1945, despite a reduction in industrial demand, sales were almost as high as they had been for the corresponding quarter of 1944. A proportion of this could be accounted for by the end of the blackout and an increase in the usage of electricity for domestic purposes. However, it also indicated that the use of electricity in industry had been largely maintained.[26] It would appear that the primary issue facing the electrical supply industry was not meeting the industrial load, a task which had been successfully accomplished during the war, but rather coping with the high levels of peak time demand, resulting from increased domestic use.

7.2.5. Domestic Demand.

A 1946 report by the Fuel and Power Advisory Council on Domestic Fuel Policy argued that the majority of solid fuel burning fireplaces and stoves in British houses were inefficient and polluting and that the use of coal in this manner was a 'waste of national resources.'[27] They claimed that coal was used with a degree of inefficiency not approached by any other

---

[25] 'Consumption Of Electricity', *The Economist,* 19th January 1946, p,108.
The Economist was founded in 1843 primarily supporting free trade and the repeal of the Corn Laws and has maintained this stance to the present day.
[26] 'Consumption Of Electricity', *The Economist,* 19th January 1946, p,108.
[27] Cmd. 6762, 'Domestic Fuel Policy Report By The Fuel And Power Advisory Committee, March 1946.' (London, 1496), The National Archives, p.2.

(western) nation, resulting in the waste of millions of tons of coal each year. They summarised by claiming that:

> We are using excessive quantities of coal; we are providing inadequate heating in the houses; we are pouring out masses of soot and tar into the atmosphere. In our view we cannot afford to maintain our low standards of heating; we cannot afford to depress and destroy the life of our cities by smoke pollution; we cannot afford to waste our limited national coal reserves.[28]

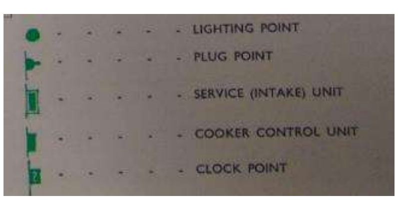
The advisory council listed four key objectives. First, to ensure 'good standards of heating' in British houses. 'Good' was defined as the ability to maintain a minimum background temperature of between 45-50 F, as well as providing piped hot water to the kitchen and bathroom. Second, that any system employed should be cost efficient to the householder. Third, to ensure that fuel was used in the most 'efficient and economic manner' and with regard to the need to conserve national reserves of coal. The final objective was to abolish atmospheric pollution from domestic sources. The report identified the traditional open fireplace as being the most wasteful means of heating a home, as well as being the 'chief sinner in rendering our cities unfit for human habitation by its smoke.'[29]

When considering new designs of stoves, either solid fuel or gas/electric, fuel efficiency was viewed as being a primary consideration, particularly with regards to the establishment of National Minimum Standards, which the committee also recommended should be regularly updated to take account of any improvements in technology. The committee also recommended that the government should ensure the all appliances installed in new houses should be required to meet these standards. furthermore, the committee recommended the creation of a subsidy to replace all the old-style coal fires and grates in use in older housing stock. The two primary reasons given for these recommendations were, firstly, the substantial savings in fuel to both the householder and the nation as a whole, and secondly, the reduction of atmospheric

---

[28] Cmd. 6762, (London, 1496), The National Archives, p.3.
[29] Cmd. 6762, (London, 1496), The National Archives, p.6.

pollution. The findings of this report played a major role in the design of the core living spaces in post war housing, particularly in the case of the temporary prefabricated housing, constructed between 1945 and 1950. One consequence of this report was that much of the housing stock built during 1945/46 was reliant on electricity for heating and cooking. This is supported by a 1945 EDA pamphlet on the use of electricity in the Ministry of Works experimental houses at Northolt. In the M.O.W. houses the lighting and heating services were subject to a standard arrangement so as to avoid influencing the total cost of houses built by different methods of construction. This arrangement broadly consisted of the use of electricity for lighting, solid fuel for the main space and water heating, electric and gas cookers in alternate houses, electric plug points for a refrigerator and electric fires for bedroom and other intermittent heating.[30] Each house came equipped with two electric fires, one fixed on the wall in the bathroom, along with a further portable fire in the living room which could be used at any point throughout the house with a wall socket. These new houses retained a fireplace in the living room for heating, with a back boiler for heating water. However, they were designed in such a way as to make it impossible to cook on, forcing the homeowner to use more electricity. This also meant that when supplies of domestic coal were restricted, homeowners were unable to heat water without utilising the electrical immersion heaters, thus increasing the demand on the power stations. (figure 7.3).



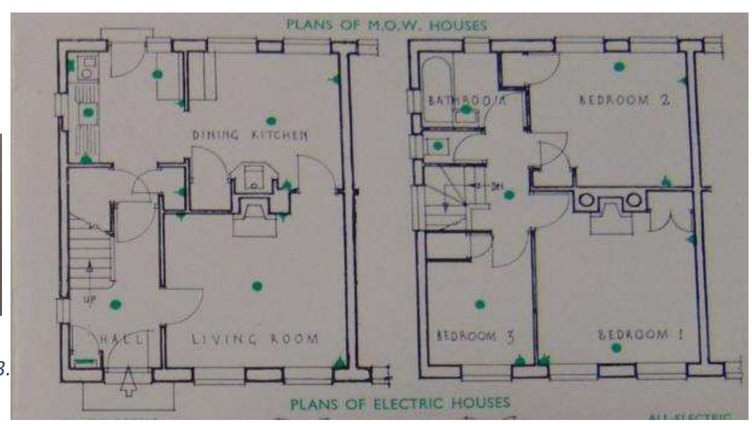


Figure 7.3. EDA 1623, MSI Archives, 1945, p.3.

[30] EDA 1623, 'Electricity At Northolt.' (Manchester, 1945), Science and Industry Museum, p.2.

Leslie Hannah argues that one of the key reasons for the post war increase in electrical usage was increased use of electric heaters in place of solid fuel fires. In and of itself this should not have been problematic; after all the electricity industry still maintained that using electricity for heating and cooking was more efficient than burning coal in the home. However, the EDA soon became involved in attempts to reduce the domestic consumption of electricity, particularly at times of peak demand, and especially when the peak domestic demand clashed with the requirements of industry.

7.2.6. Managing Domestic Demand: The Electrical Development Association.

Carlton-Hyslop and Pearson examine the attempt by the Electrical Development Association to control the demand for electricity.[31] They show that, throughout this period, the EDA worked to shape the way in which the British public used electricity, shifting demand from peak periods in order to create a more even load on the system. Initially this meant discouraging the use of electric heaters at peak times, while later it meant encouraging consumers to switch to using night storage heaters. Both of these approaches attempted to increase the use of electricity in periods which had traditionally experienced lower levels of demand, thereby leading to a more balanced load. While intended to promote greater use of electricity, the EDA was also involved in efforts to reduce the demand for electricity from domestic customers. As has already been noted, the greater part of this enhanced demand was due to the widespread use of electric fires. During the Second World War, the use of gas fires had increased by 21% while the use of electric fires increased by 41%. One of the main reasons for this shift was the restrictions imposed by coal rationing. Pearson's. account for the sharp increase in the demand for electricity following the end of the war by pointing out that electricity was being sold at less than the cost of generation. At peak times some customers only paid one third of the cost of supply. The accessibility of electricity and of electric heaters, combined with the ongoing coal shortage, meant that many households, often on the advice

[31] Anna Carlsson-Hyslop and Peter J.G. Pearson, *How Did The Electrical Development Association Attempt To Mould Domestic Electricity Demand In Britain, 1945-1964?* (Cardiff: Realising Transition Pathways Project, 2013)

of the Local Authority Fuel Officer, increased their electrical usage. Unfortunately, much of this increased usage came at times of peak load. Further to this, during the second quarter of 1946, approximately 200,000 electric fires were produced for domestic markets. The relatively high levels of wages and lack of other types of domestic goods may have helped encourage consumers to purchase more electrical appliances, particularly electric fires, which were not rationed.[32]

Until the autumn of 1946, the EDA had been primarily focused on encouraging the 'unrestricted use of electricity' the first sign of a change in this attitude was the cancellation of a planned promotional campaign.[33] In place of their planned campaign, they ran a new one under the slogan 'Four million electric fires can be wrong!', the advertisement, which ran in newspapers and magazines across the country, was primarily aimed at educating the public about the need for reductions in electrical usage, particularly of electric fires, and pointing out the strain which had been placed on power stations by the demands of the war. It ended with an appeal to self-interest:

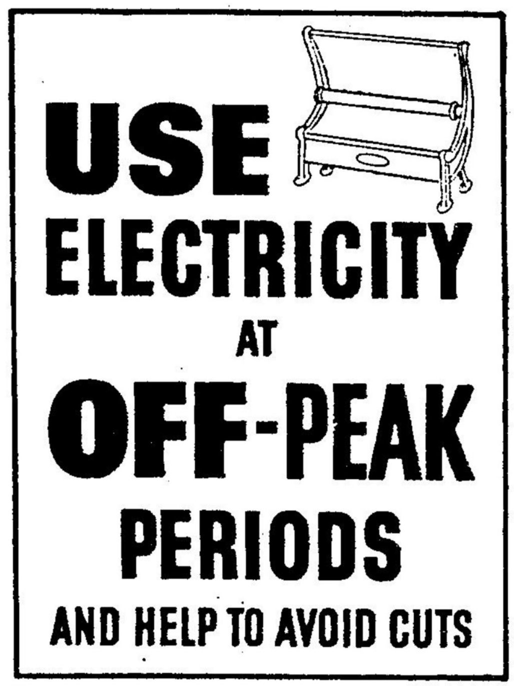


Figure 7.4. The Times, Wednesday, Nov 20, 1946; p.3.

> to save yourself inconvenience – even hardship – please do not use Electricity during a Peak Period, unless you really must. Use it instead, at OFF-peak periods; there is no danger then. If everyone will honestly try to help, cuts will be fewer, and shorter in duration.[34]

---

[32] Pearson and Hyslop, *How did the Electrical Development Association attempt to mould domestic electricity demand in Britain*, 8.
[33] 'EDA General Meeting, EDA Bulletin Number 135, April 1947.' (Manchester, 1947), Science and Industry Museum, Electrical Development Association.
[34] 'British Electrical Development Association.', *The Times,* 20th November 1946, p.3.

Carlsson-Hyslop and Pearson note that, while the Electrical Development Association believed in the power of advertising, it is difficult to assess the impact of these materials and there is no evidence showing how the organisation measured the impact of the advertising campaigns during this period.[35] As we see in the following section, voluntary reductions in electrical use were likely to be short lived in the face of the severe winter of 1946/47.

7.3. Winter 1946/47: Weathering the Storm.

The first tangible hints that the measures taken by the Ministry of Fuel and Power would be inadequate to ensure the supply of electricity for winter, were felt in October 1946. When electricity undertakings across the country announced cuts to industrial consumers. The primary reason for these cuts was the shortage of generating plant in operation to meet the higher than predicted levels of demand. On paper, the Central Electricity Board had a total of 11,300 megawatts of generating capacity, however in January 1946 they had only been able to supply a total of 8,906 megawatts against a peak demand of 9,210 Mw.[36] Many power stations were also suffering from shortages of coal and stockpiles were insufficient to cope with a major increase in demand or a reduction in deliveries from the collieries. Leslie Hannah has argued that despite the shortage of generating plant, the key problem was the reduction of coal stocks to less than four weeks supply, a level which the Central Electricity Board considered to be dangerously low.[37]

The first major snows of the winter occurred on Thursday 23rd January, marking the beginning of a period of 55 days in which snow was reported to have fallen somewhere in the UK. Metrological office records show that the mean temperature for February was below freezing

---

[35] Pearson and Hyslop, *How did the Electrical Development Association attempt to mould domestic electricity demand in Britain*, p.11.
[36] 'Survey Of Export Industries.', *The Times,* 1st January 1947, p.14.
[37] During the War the CEB had established a minimum of six weeks supply as a basic requirement. Hannah, *Electricity Before Nationalisation*, p.315.

with temperatures rarely rising above freezing point.[38]On Friday 24th January 1947, the front page of the *Hull Daily Mail* reported that 'Russian winds bring cold spell' and warned of 'more snow and frost to come'. The paper also reported that despite the freezing temperatures electrical supplies had been cut in the city, although the outage had not affected domestic customers.[39] Electrical users had become accustomed to intermittent power cuts and reductions in voltage towards the end of the Second World War, and these occurrences had become more common as demand had increased faster than new plant could be brought online. By 27th January, less than a week after the first major snow falls, newspapers across the country reported on increased cuts to electricity supplies. *The Derby Telegraph* reported that:

> The biggest-ever electricity cut – 20 percent. – was imposed to-day in South-East England and the Midlands. In Derby and district hundreds of homes were without heat or light, but more would have been affected but for the fact that the testing plant of Rolls-Royce Ltd., closed down voluntarily. […] .[40]

Domestic supplies were only able to be maintained by shutting down or limiting supplies to industry, reversing the wartime trend of limiting domestic consumption in favour of industrial use. It is also important to note that one of the reasons behind the higher than predicted growth in electrical demand was the rapid recovery of industry following the end of the war. Had this recovery occurred as had been predicted by the Central Electricity Board, it is likely that the supply of electricity would have been sufficient to meet the demands of the winter, without reducing supplies to industry.

The position of the electrical supply industry was made worse as the extreme cold caused many domestic users to increase their use of electric heaters and immersion heaters. This led to even greater demands on the network, particularly during the daytime when the demand

---

[38] Met Office, 'Winter 1947 Brought A Freeze To Post-War Britain', *Official Blog Of The Met Office News Team*, 2019 <https://blog.metoffice.gov.uk/2017/01/26/winter-1947-brought-a-freeze-to-post-war-britain/> [Accessed 1 November 2019].
[39] 'More Snow And Frost To Come', *Hull Daily Mail,* 24th January 1947, p.1.
[40] 'Biggest-Ever Power Cut', *Derby Daily Telegraph,* 27th January 1947, p.1.
Derby Telegraph was a local paper established in 1879, the paper had conservative leanings and appears to have been part of the Northcliffe group of papers.

from industry was at its highest. Daily newspapers carried regular warnings of reductions in voltage, as well as localised power cuts at peak times of day. In addition to the increased demand from domestic users switching on heaters, the power stations also had to cope with problems such as coal freezing in the stockpiles, and disruptions to coal deliveries as the heavy snow blocked railway lines and froze the canal network. According to the annual report of the Central Electricity Board for 1946, by early February coal stocks had been reduced to an average of one and a half weeks across the entire country, with some power stations reduced to even lower levels of supply.[41] On 5 February the Gloucester Echo reported that:

> The Ministry of Fuel and Power issued a statement to-day that a most serious situation has arisen in regard to the supply of coal throughout the country through far-reaching interruptions on the railways and coastline shipping caused by the cold weather inland and heavy gales at sea. […] Railway workings have been very seriously interfered with by the snow both in the Midlands and in Durham and Northumberland. Colliery sidings have been blocked by snow and a number have been unable to work.[42]

Power stations in the south of Britain were the most seriously affected by the interruptions to the coal supply; these were also the areas which had the highest overall demand for electricity. Leslie Hannah argued that:

> With rising domestic consumption, the regional pattern of demand was almost the reverse of that experienced in wartime, but fortunately the Grid Control Centres were able to use the strengthened inter-area tie-lines built in wartime to transmit the reverse flows of power now required. In the crisis conditions of 29 January 1947, for example, the South-East England area imported 168 MW at peak load time from neighbouring Grid areas.[43]

---

[41] 'Central Electricity Board Annual Report 1936.' (Manchester, 1946), Science and Industry Museum, Electricity Council, p.11.
[42] 'Coal Situation Most Serious', *Gloucestershire Echo,* 5th February 1947, p.1.
The Gloucestershire Echo was established in Cheltenham in 1884. There is no information about its political leanings.
[43] Hannah, *Electricity Before Nationalisation*, p.314.

However, as Hannah pointed out, this was still insufficient to meet the enhanced demand, requiring undertakers to shed load and impose prolonged power cuts across the country.[44]

One of the key difficulties for the electrical authorities was their inability to control the way in which consumers used electricity. By mid-February 1947, the Ministry of Fuel and Power had been forced to introduce restrictions on the use of fuel and especially on electrical usage. 'Non-essential' industries were subjected to severe cuts in working hours, street lighting and lighting for weekday sports fixtures were also cut, as were supplies to commercial businesses. Finally, domestic customers were ordered not to use electricity during the peak hours of 9 am to 12 noon and 2pm to 4pm.[45] While there was some initial compliance with these restrictions, the prolonged cold weather and lack of coal for domestic use meant that households turned to electric heaters for warmth. However, short of completely cutting off the supply of electricity, it was impossible for either the government or the electrical authorities to effectively control the ways in which people used electricity within the home. With the war over, authorities were unable to appeal to patriotism to encourage households to use less electricity. Instead, to save coal supplies and maintain the flow of power, it was necessary to find other means to supplement the supply of electricity.

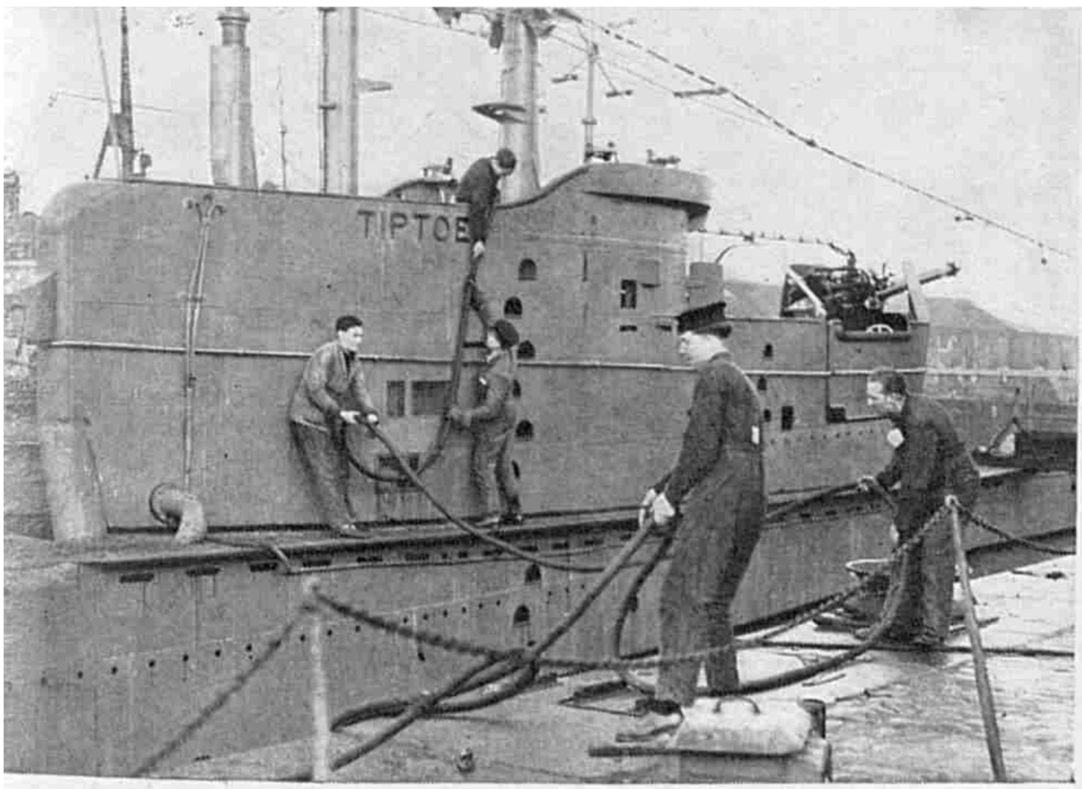
7.3.1. Operation Blackcurrant.

In what was to be the first full scale mobilisation of the submarine fleet since the end of the war, on 8th January 1947 the Flag Officer Submarines (FOSM) received orders to deploy a total of 26 submarines to provide power for the Naval dockyards. Three dockyards which received power in this way were Portsmouth, Devonport and Sheerness. The move, which was widely reported in the press, was expected to save approximately 2,000 tons of coal per week. Each submarine was expected to supply 1,000 kilowatts per day to the dockyards; the *Daily Herald* claimed that this supply would enable the use of 1,000 electric bar fires or 10,000 100 watt

[44] 'Peak Conditions 1946/7, Electricity Commissioners, Twenty Second Report, 1947.' (Manchester, 1947), Science and Industry Museum, Electricity Council, pp.7-8.
[45] Robertson, *The Bleak Midwinter, 1947*, pp.17-18.

light bulbs.[46] Another paper, *The Hampshire Telegraph,* pointed out that this was not the first occasion on which submarines had been called on to provide electricity supplies: the Royal Navy had done so for London during the 1926 strike, as well as for the Italian city of Naples after the retreating German forces had destroyed all the local generating equipment.[47]

The use of submarines in this role was to have long term consequences for the British Submarine fleet. The submarines involved were rotated out of operation for maintenance and to discharge their batteries, although Hennessey and Jinks note that at least one submarine provided continuous power for almost a month. The operation, which continued until 31st



TIPTOE'S " LINK WITH THE SHORE : Fixing one of the four main cables before the submarine's generating plant began to supply power to Sheerness Dockyard

Figure 7.5: The Sphere 18 Jan 1947.

[46] 'Submarines As Power Houses For Dockyards', *Daily Herald,* 9th January 1947, p.1.
The Daily Herald was a Socialist funded daily paper published in London from 1912. Following financial problems during the First World War the paper was given to the Labour Party and became the official paper of the Trades Union congress.
[47] 'Submarines In Peacetime Role', *Hampshire Telegraph,* 10th January 1947, p.1.
The Hampshire Telegraph was established in 1799 as Mottley's Naval and Military Journal. It served Portsmouth and the surrounding region.

March 1947, saved a total of approximately 7890 tons of coal, this amounted to about 10 minutes' worth of output from the coal mines. In order to deliver this service, the submarines were required to run their diesel engines for extended periods of time, the equivalent of 29,000 hours of normal operations, requiring seven complete engine refits costing a total of £161,000.[48] Insofar as it saved coal stocks and potentially allowed more electricity to be diverted to industrial or domestic users, Operation Blackcurrant was a success. However, it was neither an economical nor a practical solution. While there are no figures available for the amount of diesel required, as we have seen when looking at the potential cost of powering the Chain Home Network with diesel generators, this would have required a substantial amount of fuel, which certainly cost significantly more than the equivalent quantity of coal. However, even at the time it was clear that measures such as this would not significantly affect the electrical supply for the entire country. In early February, responding to the fuel crisis, the government established a new Fuel Committee, chaired by the Prime Minister, taking direct control of fuel allocation and distribution in addition to energy production at power stations and gas plants.[49]

7.3.2. Fuel Committee.

In order to help deal with the crisis, the Fuel Committee received daily reports on all aspects of energy production, demand, and distribution. A special executive committee met every-day to deal with situations as they arose, while the main committee met every three days.[50] Robertson argued that one of the primary reasons behind Attlee's decision to establish the Fuel Committee was that it effectively side-lined Shinwell without having to dismiss him - a move which would have upset the mining community (a significant proportion of Labour's powerbase) and so could have led to further industrial unrest and increased coal shortages.

---

[48] Peter Hennessy and James Jinks, *The Silent Deep: The Royal Navy Submarine Service Since 1945.* (London: Allen Lane, 2015), pp.70-71.
[49] Robertson, *The Bleak Midwinter, 1947*, p.90.
[50] PREM 8/426, 'Cabinet Fuel Committee, Note By Cabinet Secretary, 12th February 1947.' (London, 1947), The National Archives.

One of the first actions taken by the new committee was to extend the restrictions on electrical use already in place. They also considered implementing restrictions on the use of gas, but decided that this could not be justified.[51] While restricting the consumption of gas would have helped to maintain coal stocks, this would have had little effect on industry.[52] Moreover, because the town gas networks were unable to be interconnected, the failure of the gas supply in one location could not impact on the supply in other towns, cities and villages in the same way as the interconnected systems of the National Grid. Conversely, this also meant that the failure of a gas plant in one region could not be compensated for by transferring gas from another. In addition to this, the moral benefits of maintaining the supply of gas to domestic dwellings far outweighed any potential savings of fuel. By the end of February, over 350,000 tons of coal had been added to power station stockyards, on average raising the level of coal in store to two weeks' worth of stocks. However, it should be pointed out that many power stations, particularly major London power stations such as Fulham, found it difficult to reach or maintain this level.[53]

Robertson noted that while the Fuel Committee was able to 'promulgate' regulations prohibiting domestic electrical use during 'restricted hours' the main functions of the committee were 'not coercive but rather supervisory, exhortatory and analytical […].'[54] When it came to the implementation of the regulations, the Fuel Committee found itself to be severely limited by the nature of the electrical supply networks. They found it impossible to effectively enforce the peak time restrictions. Unregulated consumers, such as hospitals and public utility providers, who were allowed to utilise electricity at peak times, were supplied on the same network as consumers who were subject to the restrictions. As such, it proved practically impossible to restrict supplies to one group while allowing the other full access.[55] As

---

[51] PREM 8/426, '2nd Meeting of the Fuel Committee, 14th February 1947.' (London, 1947), The National Archives.
[52] Few industries relied on supplies of town gas for power and the town gas networks did not experience the peak load issues of the electrical networks.
[53] 'Details of coal stocks in power stations and gas works from Daily Situation Reports for the Fuel Committee.' PREM 8/443/I, TNA.
[54] Robertson, *The Bleak Midwinter, 1947.* Manchester: Manchester University Press, p.101.
[55] PREM 8/426, '1st Meeting of the Fuel Committee., 12th February 1947'. (London, 1947), The National Archives.

such the committee tended to favour encouraging voluntary compliance with the regulations. While Robertson argued that the government was able to do this thanks to its strong links with the unions, I argue that the government chose not to attempt to enforce these regulations as had they tried and failed, they would have lost credibility.

As suggested earlier in the chapter, the increased reliance on electricity for heating and cooking caused severe problems for some families, particularly those 'lucky enough' to have one of the 'all electric homes'. While some of these had been given away as prizes by electricity corporations throughout the inter-war period, many of the prefabricated houses built since the end of the Second World War relied primarily on electricity for heating and cooking and many such households struggled to boil water for the morning cup of tea.[56]

Robertson pointed out that the power restrictions introduced in October 1946, and then strengthened by the Fuel Committee in February 1947, were intended for the benefit of industry rather than for domestic users. The restricted hours between 9am and 12 noon in the morning and 2pm and 4pm in the afternoon reflected the periods of heaviest power consumption from industry. One typical example from the Mass Observation surveys complained about living in an all-electric house which only contained

> [..] one decorative but extremely inefficient coal fire. I have found it extremely difficult to deal with the baby's daily washing. Everything else, cooking, ironing, washing, cleaning, bathing, has either to be arranged for other times or improvised – hay box for cooking, tin kettle in the fire for small quantities of hot water, flask kept for hot drinks, […].[57]

It is perhaps small wonder that after six years of wartime restrictions people found it difficult to accept the need for continued cuts to electrical use, particularly in the face of such extreme weather. It is likely that calls for voluntary economy in the use of electric heaters would be

[56] 'Britain Improvises As Power Gas And Water Fail', *Derby Daily Telegraph,* 30th January 1947, p.1.
[57] MO 2483, 'Fuel Crisis, May 1947' (Brighton, 1947), University of Sussex, Mass Observation Archive, p.15.

taken somewhat less seriously by people who had been used to compulsory orders during the war.

7.3.3. After the Storm.

In any case, while restrictions on the use of electricity in home remained in effect into April 1947, the worst of the snows had passed with a final blizzard on the 12 - 13 of March. However, the warmer weather was also accompanied by heavy rain across the country. When combined with the melting snow this resulted in extreme flooding across Britain. This not only caused further disruption to the extraction and distribution of coal, but also caused some gave rise to further disruptions to the generation and distribution of electricity, particularly in low-lying regions. On 22nd March, the *Birmingham Daily Gazette* reported that, 'The huge power plant at Stourport supplying the electricity to many parts of the Midlands [was] closed down after a week's fight against the rising waters.[58] Similar stories took place in towns, cities and villages throughout Britain as infrastructure in low lying areas fell victim to the rising flood waters. Banbury in Oxfordshire lost power as the local substation was flooded under a foot of water. The district manager for the Shropshire, Worcestershire and Staffordshire Electric Power Company reported that despite the precautions taken to guard against this type of incident, 'The speed with which the water rose made it impossible to prevent the flood level reaching the 11,000-volt cable terminals.' While power was fully restored by 4pm, the chief engineer reported that a great deal more work, including the replacement of high voltage apparatus, needed to be carried out in order to restore the plant to full operation.[59] The continued disruption to power supplies not only added to the delays in restoring industry to normal working conditions, but also created new orders for replacement equipment to add to the already extensive backlog of orders being experienced by manufacturing firms.

---

[58] 'Floods Close Down Big Midland Power Station', *Birmingham Daily Gazette,* 22nd March 1947, p.1.
Birmingham Daily Gazette was originally published as a weekly paper in 1741 before adopting a daily publication routine in 1862 after the abolition of paper duty. It was originally criticised due to the large number of advertisements carried. There is no information about the politics of the paper or its owners.

[59] 'Banbury Without Light And Power', *Banbury Guardian,* 20th March 1947, p.5.
The Banbury Guardian has been published in Banbury, Oxfordshire since 1843, there is no information on the politics of the paper or its owners in the period covered by this thesis.

The extreme weather of early 1947 enhanced the problems experienced by the Central Electricity Board in the construction of new power stations and ancillary equipment. Thanks to the restrictions on industrial working over the wintery conditions, supplies of steel had fallen behind schedule and could not keep up with the demand from all areas of industry. The lack of steel also seriously disrupted the conversion of select industries from coal to oil, a program which had promised to reduce the demand for coal by almost five million tons. By the end of 1947, the conversion programme had ground to a halt, primarily due to the shortage of steel. Many planned conversions were cancelled, and other firms were pressured to reconvert from oil to coal. The primary reason for this appears to be down to difficulties in transporting oil, both on land and at sea. In order to meet the need for rail-based oil transport the Ministry of Fuel and Power planned for the construction of 1,750 tank wagons to be completed by April 1948. However, the steel shortage combined with a lack of suitable workshop capacity on the part of railway wagon manufactures who in any case were tied up with the production and repair of coal wagons. The other crucial resource lacked by Britain at this time was access to a tanker fleet with the capacity for transporting large volumes of oil. Much of the British tanker fleet was comprised of smaller vessels of less than 10,000 GRT.[60] These problems were further compounded by an increase in the price of oil increasing the cost to the point that its value as a low-cost alternative to coal was now uncertain.

By the end of December 1948, the government had largely curtailed the ongoing conversion programmes.[61] However, this seems to have primarily impacted the plans for railway conversions and heavy industry. Plans for oil fired power stations, such as Bankside, remained in place, in part because the use of oil in place of coal promised to reduce the emissions problem, but also because it meant that restrictions in the supply of coal would not completely endanger the power supply of the capital. In addition to Bankside, a number of other oil-burning power stations were constructed during the 1950s and 60s, primarily situated in the

[60] Gross Register Tonnage.
[61] Robertson, *The Bleak Midwinter,* p.169.

south-eastern area of England. Robertson points out it is possible that the stations constructed in the mid-1950s and onwards were a response to the continuing problems with coal production in 1949/50 when the demand for coal exceeded supply by almost 2.5 million tons.[62]

In the meantime, the Labour Party's program of nationalisation was continuing. The coal mines had come under national control in January 1947, and the electrical and railway industries were next on the menu. Robertson claims that the fuel crisis had a negative impact on the public perception of nationalisation. However, this appears to have had little impact on the nationalisation of the electrical network, if anything it appears that the fuel crisis may have reduced opposition to the Bill.

7.4. Nationalisation.

The nationalisation of the electricity supply in Britain fulfilled a long-standing promise of the Labour Party. It has been described as the logical culmination of all of the prior electrical legislation, which had specifically provided for eventual transfer of private supply companies to public (municipal) ownership. This viewpoint is backed up by Hannah who has highlighted the belief of senior labour members that the 1926 Electricity (Supply) Act and the creation of the Central Electricity Board was a 'step in the right direction of full public ownership.'[63] Hannah had also identified the split within the Conservative Party over the issue of national control. He pointed out that while the Conservative Party election Manifesto warned of the dangers of nationalisation in general terms, when it came to discussing gas and electricity it merely stated the need for the stimulation of increased efficiency, without giving any indication as to how this should be achieved.[64]

Indeed, an examination of Hansard records shows a surprising lack of serious opposition to the passage of the Bill, especially when compared to the passage of earlier legislation related to

[62] Robertson, *The Bleak Midwinter*, pp.174-177.
[63] Hannah, *Electricity Before Nationalisation*, p.330.
[64] Hannah, *Electricity Before Nationalisation*, p.347.

the organisation of electricity supply. Furthermore, it quickly becomes apparent that for both sides of the House of Commons, the reorganisation of the electricity supply was seen as being vital to the future of the country. For the predominantly Conservative opposition, the main difficulties arose over the terms of compensation to be offered to both private and municipal companies, and the degree of powers to be given to the Minister of Fuel and Power. These themes are highlighted in a more detailed examination of the second reading of the Bill on 3rd /4th February 1947.

In introducing the second reading of the Bill, Emanuel Shinwell, the Minister for Fuel and Power, argued that no matter which of the parties had won the 1945 General Election, they would have been

> compelled to introduce long-overdue legislation to reorganise the distribution side of the electricity supply industry. That is expected by everyone in the industry. Even private companies are well aware that the present state of affairs cannot be left unchanged, […].[65]

Shinwell was essentially claiming that everyone recognised the need for changes to the organisation of electrical supply although, as had been the case since the First World War, there was little agreement as to what form these changes should take. One of the key problems highlighted by Shinwell was that there was no obvious means by which undertakings could be induced to modernise and standardise their systems of generation and supply. He went on to argue that

[65] Commons Sitting, Monday 3rd February 1947, fifth series, volume 432, cc1367-1542.

> I am satisfied that the national interest makes it imperative that the work started in the 1926 Act should be carried to its obvious conclusion and that the responsibility for generating electricity should be placed firmly and squarely on one national body [..]. These power stations are very expensive to construct and will for many years to come require a substantial proportion of the national industrial resources. If only for that reason I am convinced that there must be one body responsible for the construction and operation of all power stations.[66]

Interestingly, Shinwell does not make it clear what is meant by the term 'national interest', although it is clear that he believed the development and expansion of the supply of electricity was vital to the future economic development of the country. Later in the address he also noted the importance of increasing the domestic use of electricity in order to expand the electricity supply.

The main opposition to the Bill at this point came from Conservative MP and former Agriculture Secretary R.S. Hudson, who argued that none of the reasons given for the nationalisation of the mining industry applied to the electricity supply industry.[67] Apart from this example, it would seem that the main opposition to the Bill was that the nationalisation of the industry was not in the interests of business owners or shareholders.

Further issues, relating to costs, included the accusation that the Bill would not have any immediate impact on prices and that, in some cases, connecting to the Grid may initially be more expensive than a connection to a local power station. Commander Galbraith, the Conservative MP for Glasgow, cited a Second World War factory which had been

[66] Commons Sitting, Monday 3rd February 1947, fifth series, volume 432, cc1367-1542.

[67] Robert Spear Hudson (1886-1957) Was a Conservative politician first elected to parliament in 1924. During the Second World War he served as Minister of Agriculture and Fisheries where he proved effective in maximising land use for the growth of crops. In addition to guaranteeing prices and markets for goods he also encouraged the development of district committees to manage land use.
William Gavin and Marc Brodie, 'Hudson, Robert Spear, First Viscount Hudson (1886–1957).', *Oxford Dictionary Of National Biography* (Oxford: Oxford University Press, 2004) <https://doi.org/10.1093/ref:odnb/34037> [Accessed 4 November 2019].

> erected during the war in the vicinity of a great industrial area. With the Grid actually passing over its premises, the estimated cost of connecting that factory to the Grid was £131,500 and connecting it to the nearest powerhouse direct by cable, £89,000.[68]

However, this disregards the point that while simply connecting to the local power house may have been cheaper, it did not provide any security of supply: If the power house was damaged, or for any other reason unable to supply power, then the factory would have been unable to operate.

The closing statement for the first day of debate on the Bill was made by Viscount Hitchingbrooke, who highlighted the two key reasons for the opposition from Conservative members.[69] The first reason was compensation to private and municipal companies, although he denied the importance of this, instead claiming that the electrical supply industry was simply not suitable for nationalisation. The second key reason was ideological. He descried the Bill as 'pure socialism and a 'threat to democracy'.[70] The debate on the Bill continued the following afternoon, with the opening statement on behalf of the Conservative benches this time describing the measure as a form of Nazism or totalitarianism.[71]

One of the most powerful speeches relating to the Bill on 4th February was that of the MP for Blackburn Mrs. Castle, who presented herself as an ordinary housewife and as a representative of the 'ordinary domestic consumer'.[72] She compared the five-year plans of private enterprise in Britain with those of the Soviet Union, claiming it made the 'State Planning Commission in

---

[68] Commons Sitting, Monday 3rd February 1947, fifth series, volume 432, cc1466-1467.
Thomas Dunlop Galbraith (1891-195) was a Conservative politician with the Scottish Unionist Party. During the First World War he served in the Royal Navy before retiring from the Navy to enter politics. He served as MP for Glasgow between 1940 and 1985.
Charles Mosley, *Burke's Peerage, Baronetage And Knightage* (Stokesley: Burke's Peerage & Gentry, 2003), pp.*3774–3776.*

[69] (1906-1995) Known as Viscount Hinchinbrook between 1916 and 1962. Was a Conservative politician. In 1941 he was elected as MP for South Dorset holding the seat until 1962.Andrew Roth, 'Montagu, (Alexander) Victor Edward Paulet, Tenth Earl Of Sandwich (1906–1995).', *Oxford Dictionary Of National Biography* (Oxford: Oxford University Press, 2004) <https://doi.org/10.1093/ref:odnb/58043> [Accessed 4 November 2019].

[70] Commons Sitting, Monday 3rd February 1947, fifth series, volume 432, cc1523-1531.

[71] Commons Sitting, Tuesday 4th February 1947, fifth series, volume 432, cc1585-1587.

[72] Barbara Anne Castle (1910-2002) Labour MP for Blackburn between 1945 and 1979. She identified strongly with her constituents going out of her way to learn about local trades and family life.
Anthony Howard, 'Castle [Née Betts], Barbara Anne, Baroness Castle Of Blackburn (1910–2002).', *Oxford Dictionary Of National Biography* (Oxford: Oxford University Press, 2012) <https://doi.org/10.1093/ref:odnb/76877> [Accessed 4 November 2019].

Moscow look like a local branch of the Conservative Party,' and further likening these plans to the 'deathbed repentance of a condemned man' which offered no assurance that if industry was left to its own devices that it would deliver on these promises. She then proceeded to cite Conservative Party documents which showed that, not only had the Conservatives been in support of further rationalisation and reorganisation of the electrical supply industry, but also that they believed this reorganisation needed to be compulsory in order to be effective. She concluded by pointing to the ways in which standardisation and the further availability of electricity in the home would be beneficial to the nation, stating that:

> In my opinion this Bill, with the possibilities it presents of a sound basis for going forward with the electrification of the home, the setting free of vast resources of women power in this country, and the saving of human energy and prevention of ill health, can be a most important factor in winning the peace.[73]

By framing electrical development and the rebuilding of the country in the same light as fighting the war, Mrs. Castle further demonstrated that the reorganisation of the electricity supply was firmly in the national interest.

Throughout the debate both Labour and Liberal MPs frequently argued that the Bill was to a certain extent simply the logical endpoint of all earlier legislation under which, after a period of 42 years, the public sector would have had the option of taking over private undertakings, bringing them under public control. Many members on both sides of the House pointed to the consistent improvements to electrical services, which had been disrupted by the Second World War. On the second day of the debate, Colonel Hutchinson MP for Glasgow Central argued that:

> Here we have a record of growing consumption of electricity, of constantly reducing prices, of constantly improving fuel efficiency. Is that progress to be continued under this Measure? Is it not a natural assumption that if the war had not intervened that progress would have been continued?

[73] Commons Sitting, Tuesday 4th February 1947, fifth series, volume 432, cc1621-1631.

Further claiming that this improvement would, without interference from the state, continue into the future.[74] This viewpoint, while factually correct, ignores one of the key purposes of the Bill: by bringing the entire industry under state control it would be possible to mitigate against that sort of disruption in any future conflict. Overall, the main problem with the arguments against the Bill was the lack of any viable alternative, beyond letting the industry continue as it currently existed (and a move which the majority of opposition members did not believe was correct). This is broadly supported by the vote on the second reading - 340 votes in favour and only 160 against - following which the Bill was committed to a Standing Committee. [75]

The final reading of the nationalisation Bill was passed with a margin of 321 votes in favour to 173 against, a similar margin to the previous votes on the matter, and indicative of the broad level of support for the nationalisation of the electrical supply industry. In the final reading of the Bill on 30th June 1947, Hugh Gaitskell, the Parliamentary Secretary to the Ministry of Fuel and Power, pointed out that, while there had been areas of contention, dealings had in general been 'reasonably business-like and harmonious,' and that as a result of the debates some important changes, particularly in terms of compensation had been made.[76] When it came to the establishment of the British Electrical Authority, he claimed that:

[74] Commons Sitting, Tuesday 4th February 1947, fifth series, volume 432, cc1654-1655.
James Riley Holt Hutchison (1893-1979) Was the Conservative MP for Glasgow Central, elected in the 1945 General Election. He was a firm opponent of nationalisation.
'Sir James Hutchison', *The Times,* 19th November 1979, p.26.
[75] Commons Sitting, Tuesday 4th February 1947, fifth series, volume 432, cc1694-1696.
[76] 'ELECTRICITY BILL', *HC Deb 30 June 1947 vol 439 cc968-970.*
Hugh Gaitskell (1906-1963) Labour politician elected to Parliament for South Leeds in 1937. He was a strong believer in the nationalisation of industry on the basis of efficiency and economy of scale but did accept that there were shortcomings to national ownership and control. In October 1947 Gaitskell took over from Shinwell as Minister for Fuel and Power where he encouraged the construction of oil refineries and the development of the British petrochemical industry.
Brian Brivati, 'Gaitskell, Hugh Todd Naylor (1906–1963).', *Oxford Dictionary Of National Biography* (Oxford: Oxford University Press, 2004) <https://doi.org/10.1093/ref:odnb/33309> [Accessed 5 November 2019].

> Few would deny that the system of selected stations and dual control which has existed for the past 21 years is now out of date, […], that it does not involve the use of labour and technicians to the best advantage for the country as a whole, and that it does not give rise to the best planning and construction of power stations. […]. I can confidently say that it has hardly been challenged by anyone in the course of all our rather long discussions of the Bill.[77]

Again, emphasising that while opponents had disagreed on the levels of compensation to be paid, they had largely agreed on the need for reorganisation, to make the best use of electricity for the advantage of the nation as a whole.

It is clear that the reorganisation of the electricity supply industry was widely regarded as being in the national interest. However, members on both sides of the House were quick to point out that there were no guarantees of the legislation having any immediate impact on the generating capacity of the industry. Indeed, on the vesting date of Wednesday 1st April 1948, when the companies, both municipal and private, officially came under the control of the state, the situation was largely unchanged. Demand was continuing to rise and generating capacity was still insufficient to meet the peak-time demands for the winter months. However, the extensions to generating plant begun towards the end of the war continued, as did plans for the utilisation of alternative fuel sources, particularly oil and nuclear, which at the very least would alleviate the dependence on coal. A dependence which would be further reduced through the introduction of natural gas in 1959.

7.4.1. Exploring the Alternatives: A National Fuel Policy.

Even with the end of the Second World War, the supply of electricity was still inextricably linked to weapons manufacture. In July 1951, the Minister of Fuel and Power appointed a Committee on National Fuel Policy. 'In view of the growing demands on all forms of fuel and power arising from full employment and the rearmament program', the Committee aimed 'to

---

[77] 'ELECTRICITY BILL', *HC Deb 30 June 1947 vol 439 cc969-971.*

consider whether any further steps can be taken to promote the best use of our fuel and power resources.'[78]

This committee initially sought to establish precisely what was meant by the term 'best use' and established four criteria for this:

(1) To meet in full the demands of the community for the different fuel and power services, when those services are sold at prices which closely correspond to the relevant costs of production and distribution
(2) To provide for export fuels on such a scale and of such types as can be sold abroad with most gain for the country.
(3) To promote the maximum economic efficiency in each use of each fuel.
(4) To encourage the use for particular services of the fuel which gives the best returns for the resources consumed.[79]

It was readily accepted that coal was the primary fuel type available in Britain, and as such a large proportion of the report was focussed on ensuring the most economical use of coal. This committee was separate from the newly established British Electrical Authority, and gathered information from a wide variety of sources, including the coal board and gas authorities. In examining the use of fuel within the home, the committee noted that using a combination of solid fuel, gas and electrical devices was often more fuel efficient than just using solid fuel, gas or electricity in isolation. In particular, it noted that:

> The use of gas instead of electricity for heating services during electricity peak hours might not only result in better use of coal and other scarce resources but would also result in increased supplies of coke […].[80]

The committee recommended that changes should not be imposed on consumers by means of legislation but should instead be encouraged by the introduction of a new tariff system, encouraging reduced electrical usage at peak times by increasing the cost during these periods. However, they also advocated for greater use of electricity for all purposes other than space heating, on the basis that it was more versatile and, providing the less efficient older

[78] Cmd, 8647, 'Report Of The Committee On National Fuel Policy For The Use Of Fuel And Power Resources, July 1952.' (London, 1952), The National Archives, p.iii.
[79] Cmd, 8647, (London, 1952), The National Archives, p.1.
[80] Cmd, 8647, (London, 1952), The National Archives, p.34.

plant was replaced, more economical than using either coal or gas. furthermore, electricity could also be generated by burning the lower grade coals, which would otherwise have no economic use. Overall, the approach advocated by the committee was for a greater degree of cooperation and coordination between the fuel and power companies, particularly focusing on ensuring the gas and electricity industries worked with the coal board to make the best use of available fuel resources.[81]

A key fuel recognised by the committee was oil. However, while oil was acknowledged to be a useful resource, the committee noted that:

> Apart from the commercial factors in greatly increasing oil supplies there are also issues of national policy: the strategic risk of increasing the country's reliance on an imported material for basic fuel requirements, and the foreign exchange problem of paying for the imports.[82]

These issues did provide some cause for concern but while it was risky to become too reliant on oil, remaining entirely dependent on coal was equally risky. As was mentioned earlier in the chapter, the government had already instituted a programme to increase the use of oil by selected industries, particularly on the railways, although the committee did note that

> If diesel engines were used it might be said that to rely on diesel oil fuel would be dangerous for strategic reasons, […] it is clear that we are already entirely dependent on oil in time of war for the fighting services and the rest of our transport.[83]

Reliance on oil for all forms of transportation was therefore perceived as being as risky as continuing to be completely reliant on coal for electrical generation. However, oil could also be used as the primary fuel for electric power stations or mixed with lower quality coal. At any rate oil offered more immediate prospects than nuclear power in dealing with the ongoing fuel shortages affecting the country. However, it is also clear that oil was regarded as

---

[81] Cmd, 8647, (London, 1952), The National Archives, pp.33-35.
[82] Cmd, 8647, (London, 1952), The National Archives, p.10.
[83] Cmd, 8647, (London, 1952), The National Archives, p.50.

supplementing rather than replacing coal as the primary source of fuel. A memorandum by the Petroleum Industry Advisory Committee noted that:

> In considering the part to be played by oil in meeting the future requirements of fuel and power in the United Kingdom it is accepted that the U.K. is primarily a coal producing country, and, therefore, the country's needs for fuel and power must mainly be based on coal, leaving oil to provide for those specialist uses where it has both technical and economic advantages.[84]

Power generation was potentially one of these areas, in part due to the higher energy potential of oil compared to coal. It also had the added benefit of producing lower levels of emissions than traditional coal power stations, making it particularly suitable for use in city centre power stations such as Bankside in London.

7.4.2. Alternative Fuels: Oil.

In a bid to alleviate some of the problems caused by the shortage of coal, the Ministry of Fuel and Power explored the possibility of converting boilers and furnaces to burn oil rather than coal. This program had its origins in the Second World War at a time when reserves of fuel oil remained largely unused throughout the country. The Ministry of Power had begun investigating which industries could most economically and profitably be converted to using oil or a combination of oil and coal. However, it is unclear as to whether any of these proposed conversions were actually carried out. By 1945 the situation had again changed, thanks to increased naval operations in the Pacific, fuel oil reserves were no longer as abundant as had been the case just two years previously. As a result, plans for further conversions were shelved. However, once the war had ended, these plans were re-examined in light of the continuing coal shortage. As had been the case during the war, the conversion effort primarily focussed on those industries with the greatest potential for saving coal supplies. Although, the end of lend lease agreement with the United States of America meant that oil supplies were no longer as secure and, as had been pointed out by Robertson, would now need to be paid for out of Britain's

[84] Cmd, 8647, (London, 1952), The National Archives, p.112

rapidly dwindling supply of US Currency.[85] This changed in the Spring of 1946 when oil became available from Iran and Curacao. This new oil source, which could be paid for in sterling rather than dollars, offered the prospect of effecting considerable savings in coal usage. On 8th April 1946, Shinwell announced that the Ministry of Fuel and Power was anxious to make 'greater use of fuel oil for industrial purposes [and hoped].' Shinwell also expressed hope that there would be a greater expansion in oil use towards the end 1946 and reassured manufacturers that the Ministry of Fuel and Power would 'render every possible assistance to them' if they decided to convert to oil.'[86]

The response from industrial users of coal was enthusiastic. By July 1946, the Ministry was involved in approximately 600 conversion projects; indeed, the greatest threat was that the demand for fuel oil would outpace supply.[87] As was discussed earlier in this chapter, the shortage of steel had led to the cancellation of many of the oil conversion projects. However, one project which was not cancelled was the construction of Bankside Power Station in London.

7.4.3. The Bankside Story.

Bankside (A) power station, located on the south bank of the Thames, first began generating electricity in 1893, and was extended multiple times. While designed as a coal fired station, boilers were reconstructed to burn oil during the early 1920s, in response to the ongoing issues with coal mining throughout this period. At its peak in the mid-1930s, Bankside was able to generate a total of 89 MW. By 1939, the plant was outdated with poor efficiency ratings. The Central Electricity Board had drawn up plana for a new power station on the site, however, the outbreak of the Second World War delayed its implementation.

Towards the end of the war, the City of London Electric Lighting Company revived its plans for Bankside, planning to build a new 300 MW station. These plans were approved by the British

---

[85] Robertson, *The Bleak Midwinter, p.*70.
[86] FUEL OIL (INDUSTRIAL USE), HC Deb 08 April 1946 vol 421 cc1763-8.
[87] POWE 33/1623, 'Ministry Of Fuel And Power, Internal Memo, 27 September 1946.' (London, 1946), The National Archives, Ministry of Fuel and Power.

Cabinet in April 1947. While the station had originally been designed to be coal fired, concerns over emissions as well as the fuel crisis of 1946/7 led to the station being redesigned to make use of heavy fuel oil. Stephen Murray's unpublished 2014 thesis on *'Bankside Power Station: Planning, Politics and Pollution',* highlights the difficult process the planning committee had to undergo in gaining permission for the construction of the new station, and particularly emphasises the importance of the winter of 1946/47 in gaining final approval for the construction.[88] Murray noted that Bankside (B) was the 'last power station to be built in central London', and identifies two reasons for this shift away from inner city sites. Firstly, the development of ever larger generating sets, which could not be supported on inner-city sites. Secondly, the development of the 'super-Grid' in the early 1960s which enabled new stations to be built in more remote areas and in closer proximity to the coal fields.[89] Murray noted that Bankside (B)'s use of oil rather than coal had enabled the power station to remain in operation during the coal strikes of the 1970s, although after this point increases in oil prices led to the general decline of Bankside as operating costs increased. This is very much in line with the concerns voiced by the 1951 Committee on National Fuel Policy, which, as we saw earlier, had warned of the dangers of reliance on an imported fuel source.

Planning for a new station on the Bankside site recommenced immediately following the war, as the Central Electricity Board came to the realisation that a large proportion of the existing plant would need to be decommissioned by 1950. In order to replace this plant and meet the growing demand for electricity they would need to construct a further 1220 MW, or the equivalent of six new 200 MW power stations.[90] Bankside was to be one of these new stations and was included in the CEB's construction programme for 1948/9. However, the project quickly ran into difficulties, due to the planned redevelopment of the area by the London City

---

[88] Stephen Murray, 'Bankside Power Station: Planning, Politics And Pollution' (unpublished PhD, University of Leicester, 2014), p.35.
[89] Stephen Murray, 'Bankside Power Station', p.16.
[90] Stephen Murray, 'Bankside Power Station', p.95.

Council. The Council planned to redevelop the south bank of the Thames from what was described as a 'dreary industrial scene' , to a cultural centre of theatres and concert halls with a riverside embankment backed by modern office spaces and flats.[91] While Murray concludes that Bankside was an example of a case that could not be resolved by local authorities, he does not appear to connect this to the importance of electrical development for national security. He did, however, highlight the level of ministerial involvement in the negotiations, demonstrating that while all the ministries were part of the same government, they did not necessarily have the same agenda. Electricity was important to the LCC and the Ministry of Town and Country Planning, but it did not take precedence over the architectural and aesthetic concerns.[92] Due to the disagreement between the Ministry of Fuel and Power and the Ministry of Town and Country Planning, Lord Dalton suggested that the matter be referred to the cabinet for a decision to be made.[93]

At the Cabinet discussion on 1st April 1947, the Air Ministry objected to locating a new power station at either Bankside or the alternative London site at Rotherhithe, arguing that in a future war the power station would be considered a potential target and would be vulnerable to attack.[94] Attlee dismissed these concerns, arguing that with the development of nuclear weapons the loss of a few power stations would be irrelevant in the grander scheme.[95] However, it is also possible that the ongoing fuel crisis was a more immediate threat than any hypothetical nuclear attack on the country. Murray then notes that the cabinet approved the construction of Bankside on the basis that it would be fuelled by oil rather than coal, ostensibly for reasons of amenity, to make the area more attractive to businesses.[96] However, while Murray claims that the intent of this decision was to improve amenities, I contend that the

---

[91] Patrick Abercrombie and J. H. Forshaw, *County Of London Plan*, 1st edn (London: H.M. Stationery Off., 1943), pp. 126-132.
[92] Stephen Murray, 'Bankside Power Station', p.109
[93] CAB 129/18, 'Memorandum By The Chancellor Of The Exchequer, C.P. (47)110, Dated 26 March 1947' (London, 1947), The National Archives, Cabinet Papers.
[94] CAB 129/18, (London, 1947), The National Archives, Cabinet Papers.
[95] CAB 195/5, 'Cabinet Secretary's Minutes C.M.34(47) F.189 On 1 April 1947.' (London, 1947), The National Archives, Cabinet Papers.
[96] Stephen Murray, 'Bankside Power Station', p.126.

intent was instead more closely related to the impact of the fuel crisis and the need to diversify away from reliance on coal. The decision to utilise oil rather than coal was a political decision, made without consultation or discussion. Even when later cabinet discussions highlighted the higher costs of oil over coal, the decision to go ahead with oil remained. The Cabinet concluded that having an oil-fired station on the Thames would be advantageous to increase the diversity of supply in the region.[97]

Bankside was the last power station constructed in Britain to go through such a lengthy planning consultation process. The Town and Country Planning Act of 1947 enabled buildings such as power stations to be given consent by the Ministry of Fuel and Power, without needing to involve the Ministry of Town and Country Planning. Furthermore, a public enquiry would only be held if a local authority raised any objections to the construction.[98] Murray notes that the debate surrounding Bankside provides insight into the tensions between government departments. However, he does not consider the implications of power stations being granted exemptions from the usual planning procedures, or that the provision of electricity was deemed more important than environmental or aesthetic considerations.

One key aspect which was to govern the future utilisation of Bankside was the cost of oil, particularly in relation to coal. Because of this the degree to which Bankside was operated fluctuated depending on the economic cost. Due to high oil prices in the early years of operation, Bankside was operated to meet the peak daytime load and was shut down at night, allowing coal-fired power stations to maintain the base load. Coal and oil, however, were not the only fuels available. The potential of nuclear power was also under consideration during this period.

---

[97] CAB 128/9, 'Cabinet Minutes 22 May 1947, C.M. (47)49, F.49.' (London, 1947), The National Archives, Cabinet Papers.
[98] Stephen Murray, 'Bankside Power Station', pp.135-136.

7.4.4. Alternative Fuels: Entering the Nuclear Age.

In March 1947, J.B. Priestley wrote that:

> It does not matter a rap what your work or your interest or your hobbies or your outlook may be, whether you are looking for sheep in the Grampians, rehearsing Dvorak's 'cello concerto in Kensington, getting your trousseau together in Truro, making notes for a sermon in East Anglia, running a golf club in West Kent or a reparatory theatre in East Lancashire, you cannot by any amount of wriggling, squirming or running put yourself outside the sphere of these talks. It simply cannot be done. We are now living in the atomic age.[99]

This new nuclear reality for Britain, and indeed for the whole world, was to have an immediate impact on post war planning, particularly for large urban areas such as London. Jonathan Hogg has argued that the initial wave of concern over the existence of nuclear weapons was gradually eroded as these weapons formed part of the background to everyday life. Living with the threat of nuclear annihilation came to be considered normal.[100] This, however, could not be the case for either the military or the Central Electricity Board. In 1946, the Air Ministry had expressed concerns over the decision to construct a major new power station in the Poplar area of London. They argued that the addition of another major power station in the region, regardless of the energy demands of the metropolis, would risk concentrating too much generating capacity within a small area. This was an area already crowded with industry as well as being the seat of the British Government. The experience of the Blitz had demonstrated the vulnerability of London to a conventional bombing attack. During the war all the major London based power stations had suffered some form of damage, although the National Grid had enabled power to be transferred from other parts of the country, minimising the disruption.

---

[99] John Boynton Priestly, 'On The Stairway Of The Stars', *The Listener*, 13th March 1947, p.355.
John Boynton Priestley (1894-1984) was a British writer born in Bradford. While working as a clerk for a local firm he began writing for the Bradford Pioneer, a Labour Partly weekly. He served on the Western Front during the First World War and was commissioned as on Officer. On his return from the War he attended University at Cambridge studying history and political science. During the Second World War he briefly hosted a popular radio broadcast in which he regularly cautioned against the unemployment and poverty of servicemen following World War One. As such his show was stopped in October 1940.
Judith Cook, 'Priestley, John Boynton (1894–1984).', *Oxford Dictionary Of National Biography* (Oxford: Oxford University Press, 2016) <https://doi.org/10.1093/ref:odnb/31565> [Accessed 5 November 2019].
[100] Jonathan Hogg, *British Nuclear Culture: Official And Unofficial Narratives In The Long 20Th Century.* (London: Bloomsbury, 2016), p.2.

They feared that a nuclear strike on London would not only risk the loss of the Government, but the loss of industrial capacity and above all generating capacity would cripple the country.

However, Nuclear power was not merely considered as threat. The potential of nuclear technologies to benefit medical treatment, agriculture and industry development was well recognised. However, at least for Britain, the potential of nuclear power for electrical generation offered the most immediate benefits.

The first nuclear reactor constructed in Britain was the 3 kW Graphite Low Energy Experimental Pile (GLEEP) at Harwell in Oxfordshire. This experimental reactor was commissioned in 1946. Harwell was chosen due to its proximity to London, access to universities, relative isolation and the existence of pre-existing infrastructure in the form of roads and buildings.[101] The siting of Britain's early nuclear reactors was dictated by the need to quickly establish the facilities, balanced with safety concerns for the local inhabitants. This led to Britain abandoning the guidelines established for the American nuclear program, mainly due to a lack of viable sites. This in turn led to a decision by the British Nuclear authorities to use gas cooling rather than water cooling for reactor designs, opening up a wider variety of sites, including the Sellafield site, for future development. Christopher Hinton, the supervising engineer during the construction of Calder Hall, later commented that, 'from 1946 to 1954 atomic energy was a defence industry, hence speed was vitally necessary and great risk of failure had to be accepted.'[102] Although Britain now had an active experimental program, the primary focus of this research was the eventual development of weapons grade plutonium.

7.4.5. Calder Hall.

While the development of an independent nuclear deterrent was the main focus of British Nuclear research, this was largely carried out in secret. In contrast, the idea of using atomic energy for the peaceful generation of electricity was more widely publicised. The use of

---

[101] Cockcroft J, 1948. The Genesis of AERE. Reproduced in: John Sandalls, *Thirty-Six Years At The Atomic - My Time At AERE Harwell, 1958-1994.* (London: Wantage, 2004).
[102] Tony Hall, *Nuclear Politics: The History Of Nuclear Power In Britain.* (London: Penguin Books, 1986).

nuclear power for electrical generation was just as vital to national security as the development of nuclear weapons. The majority of histories of nuclear power in Britain such as Fred Roberts *60 Years of Nuclear History: Britain's Hidden Agenda* and Tony Hall's *Nuclear Politics, The History of Nuclear Power in Britain*, focus almost exclusively on the development of nuclear weapons.[103] Where they do talk about the power generation side of the industry, they point out that most of the civilian reactors were also designed to produce plutonium for use in nuclear weapons production. The value of the plutonium produced was intended to be offset against the cost of the power plant, reducing the overall operating costs of the plant and bringing down the cost of the electricity produced. However, this is not the entire story. Tony Hall's 1986 account *Nuclear Politics* highlights the importance of electrical production in the development of nuclear power in Britain. Hall notes that the military origins of nuclear power were key to shaping the relations between the nuclear establishment and the government. He argues that in deciding to build a series of nuclear power stations, Britain

> Was showing that it had a world lead in the development of nuclear power. The power stations would bring cheap power to millions. They would end once and for all the threat to power supplies from the shortage of coal that had so dogged the post war economy.[104]

The development of civilian nuclear reactors was a vital propaganda tool, showing that Britain was not dependent on the United States for the future development of nuclear technology. When combined with the promise of nuclear energy to bring a permanent end to the fuel crisis, it clearly provided a strong incentive to quickly develop civilian reactors.

Hall notes the somewhat surprising lack of discussion, even at cabinet level, on the development of nuclear power, noting that most key decisions during this period were taken directly by the Prime Minister and pointing out that:

---

[103] Fred Roberts, *Sixty Years Of Nuclear History* (Oxford: Jon Carpenter, 1999).
Tony Hall, *Nuclear Politics: The History Of Nuclear Power In Britain.* (London: Penguin Books, 1986).
[104] Tony Hall, *Nuclear Politics*, p.10.

> The atomic bomb for any government, l*et al.*one a Labour one, posed a multitude of moral as well as economic problems. And the peaceful use of atomic power promised to ameliorate one of the great problems of the post-war government, which was the shortage of coal preoccupying ministers and crippling the British economy.[105]

Hall makes the point that, during this period, decisions on nuclear policy and spending, whether on defence or on power generation, were taken in secret; neither the deliberations or the decisions made were reported to the cabinet or any other branch of government. It would also appear that for the most part Members of Parliament, the press and even the scientists involved were content to allow this situation to remain unchallenged.[106] In this respect the development of nuclear power can be seen as the ultimate combination of electrical development with national security. Thanks to its origins in weapons research, the British nuclear weapons program had essentially unlimited resources and little in the way of restrictions. This carried over to the development of nuclear power for electrical generation, at least during the years covered in this thesis. In practical terms, there was little to no distinction between nuclear weapons research and the development of nuclear power stations, and indeed both areas of work were closely related.

In contrast to Hall's argument R.F. Pocock shows that from the early 1950s the British Government had viewed the development of Nuclear Power as being vital to supplement Britain's coal supplies. Pocock shows that by 1948 the demand for coal exceed the productive capacity of the industry and by 1951 Britain had been forced to begin limited imports of foreign coal.[107] Pocock shows that unlike the United States, Britain suffered from high coal prices, had few suitable sites for large scale hydro-power developments and lacked any indigenous oil. As such the development of nuclear power was the 'sole existing answer' to the immediate energy needs of the country.[108] He claims that the aim of Britain's nuclear power

---

105 Hall, *Nuclear Politics*, p.26.
106 Hall, *Nuclear Politics,* pp.27-31.
107 Pocock, *Nuclear Power*, pp.45-46.
108 Pocock, *Nuclear Power*, p.47.

programme was to ‘provide for the expansion of electricity supplies to meet anticipated increases in demand without a corresponding increase in coal consumption.’ Furthermore, he claims that the ‘economic cost of providing this nuclear capacity was not really a factor in the Ministry’s decision to initiate the programme.’[109]

On the 18th October 1956 the Daily Herald published a two-page spread under the title ‘The start of a new era’, which extoled the virtues of nuclear energy. It included a picturesque description of the newly opened Calder Hall power station.

> No smoke pall hangs over it. No great coal and ash tips surround it. On one side, there are the clear waters of the Irish Sea; on the other side, farmers till the rich Cumberland soil. But through the great overhead cables today is passing enough electricity to keep 65 million small electric fires burning.[110]

Following on the heels of years of coal shortages which had resulted in during the cold winters, this was a powerful image of a modern Britain, but one which was in touch with its traditional roots. These descriptions of clean, smoke free air and the lack of piles of coal and ash were even more powerful in the wake of the severe smogs of the early 1950s.

7.5. London Smog and the Clean Air Act.

On 5th December 1952 London ground to a halt as a thick heavy fog settled over the city. For four days the city was at a standstill as all transport, with the exception of the tube system, was cancelled. The fog was so dense that it was able to penetrate buildings leading to the cancellation of concerts and films as it became hard to see the stage or screen through the haze.[111] By the time the fog cleared on the 9th December at least 4,000 had people had died and recent research suggests that as many as 12,000 people may have died as a direct result of

---

[109] Pocock, *Nuclear Power*, p.48.
[110] ‘The Start Of A New Era.’, *Daily Herald,* 18th October 1956, pp.8-9.
[111] ‘BBC ON THIS DAY | 9 | 1952: London Fog Clears After Days Of Chaos’, *News.bbc.co.uk*, 2019 <http://news.bbc.co.uk/onthisday/hi/dates/stories/december/9/newsid_4506000/4506390.stm> [Accessed 5 November 2019].

the smog.[112] The 1952 Smog had been formed by the combination of cold weather causing many people to light fires, with anticyclonic conditions, pushing air downwards and creating an inversion layer which trapped the chimney gasses close to the ground. David Bates has recently claimed that the post war economic situation may also have contributed to the problem as many houses and power stations were burning low-quality, high-sulphur coals as the more expensive low-residue and low-sulphur coal was required for export.[113]

Thick fogs were not a new occurrence in London, as was suggested in the earlier discussion on Bankside Power Station as well as the discussion on Battersea Power Station in chapter five, the cleanliness of the air in British cities was an important consideration. The idea that switching to electricity for lighting, heating and cooking would help to reduce the emissions from domestic dwellings had been key to much of the inter-war electrical advertising by the Electrical Development Association. However, as was demonstrated by the concerns over Battersea Power Station, some people argued that there was little point in replacing lots of small chimneys with a single large chimney, which would still put significant quantities of soot and sulphur into the local atmosphere.

One of the most direct impacts of the 1952 Smog was the passage of the 1956 Clean Air Act. Almost immediately after the fog had cleared the Government had appointed a committee under the chairmanship of Sir Hugh Beaver, a noted civil engineer. In November 1954 the Committee issued its final report, recommending that the use of domestic coal should be replaced with coke and that where possible homes should switch to using gas and electricity for light heat and power.[114] The Government initially resisted implementing new legislation, however, the introduction of a Private Members Bill by Conservative MP Gerald Nabarro spurred the Government to action. Nabarro withdrew his Bill in favour of a Government Bill

---

[112] E Dooley, 'Fifty Years Later: Clearing The Air Over The London Smog.', *Environmental Health Perspectives*, 110.12 (2002) <https://doi.org/10.1289/ehp.110-a748>.
[113] DV Bates, 'A Half Century Later: Recollections Of The London Fog', *Environmental Health Perspectives*, 110.12 (2002) <https://doi.org/10.1289/ehp.110-a735>.
[114] Sheail, *An Environmental History of Twentieth Century Britain*, pp.247-249.

which was introduced in June 1955 and enacted in July 1956.[115] The Act banned emission of black smoke and stipulated that residents and businesses in urban areas should convert to burn smokeless fuels. While power stations such as Battersea and Bankside employed sulphur scrubbing techniques to reduce emissions, these were not entirely effective. It is probable that the 1956 Clean Air Act was at least in part responsible for the fact that after Bankside power station was completed, no new power stations were constructed in urban areas in Britain.

At the same time the British Electrical Authority (BEA) had begun work on the 'super Grid' to consist of 275 Kilo-volt power lines carried on 156-foot-tall pylons. According to Katrina Navickas, this new grid system was intended to strengthen inter-regional connections and to enable to the BEA to shift London's power generation from inner city power stations such as Battersea and Bankside, to new superstations constructed near to the cheaper coal fields in Northern and Central England.[116]

7.6. Conclusion: Security in Diversity.

Chapter Seven revealed the damage caused to British power infrastructure by the short-term focus on security of supply and meeting the immediate needs of the war effort. By the end of the war, generating plants across the country were on the verge of breakdown. The lack of maintenance during the war, as well as the shortage of new plant being completed, meant that generating capacity fell for the first time since the Grid had been completed. This was further complicated by the fact that rather than falling, as it had done at the end of the First World War, demand for electricity actually rose in 1946. Much of this new demand was accounted for by increases in domestic use of electricity, primarily for devices such as electric heaters. This situation was again complicated by the ongoing problems in the coal mining industry, partially related to government plans for the nationalisation of the industry. Finally,

---

[115] Sheail, *An Environmental History of Twentieth Century Britain*, p.249.
[116] Katrina Navickas, 'Conflicts Of Power, Landscape And Amenity In Debates Over The British Super Grid In The 1950S', *Rural History*, 30.1 (2019), 87-103 https://doi.org/10.1017/s0956793319000013, (p.97).

this culminated in what I have described as a 'perfect storm' when the severe winter of 1946/47 prevented the movement of coal supplies around the country. Coal stocks, which were already low, quickly ran down and many industries were forced to halt or reduce production. In order to help prevent shutdowns due to lack of coal, the Ministry of Fuel and Power had encouraged the partial conversion of key industries from coal burning to oil burning furnaces. While many of these schemes were later abandoned, the construction of Bankside power station as an oil burning station went ahead.

The nationalisation of the electrical supply industry, in January 1948, brought the industry fully under national control and ownership. While the Nationalisation Bill was broadly supported in Parliament, there was significant opposition from members of the Conservative Party, particularly those with financial interest in the electrical supply industry. Consequently, the eventual cost of the Bill was higher than anticipated as Ministers agreed to pay higher levels of compensation to owners and shareholders than had been included in earlier drafts of the Bill.

By the end of 1956, electrical generation and military interests were inextricably linked by the development of the nuclear industry in Britain. However, the links between electrical development and national security ran deeper than mere weapons development. The security of the electrical supply system in Britain was vital to the redevelopment of British industry and for the political security of the state; particularly in the face of the growing threat from the Soviet Union. Ensuring the supply of electricity to industry helped to safeguard manufacturing jobs, keeping people in employment and therefore less likely to become involved in any action against the state. While British industry, and electrical generation in particular, was still highly dependent on coal, the introduction of both oil and nuclear power stations went some way towards attenuating the power of the miners' unions, although as was seen in the 1970s, neither oil or nuclear power succeeded in removing King Coal from its throne.

8. Reassessing the Role of the State in Britain's Emerging National Electricity Network, 1914-1956.

8.1. Conclusion.

The period between 1914 and 1956 saw dramatic developments in the supply of electricity in Britain, culminating in January 1948 with the nationalisation of the electrical supply industry. Whereas prior accounts, such as those by Thomas Hughes and Leslie Hannah, have explained these events purely in terms of the economics of technological efficiency, I have shown that national security has played a key role in the development of electrical supply in Britain. I have argued the development of a nationalised centrally co-ordinated electricity supply could not simply be explained as a result of either technological progress or economic superiority. Government concerns for National Security, primarily in the form of an imperative for energy security, served as a catalyst for reform of electricity supply in Britain. As was demonstrated in the introduction, national security is a multifaceted term that can mean subtly different things to different people at different times. Nevertheless, I have shown that no matter how national security is defined, ensuring the security of the national energy supply central to ensuring the political, economic and military security of the nation.

This thesis has focused on several interrelated research questions, relating to the comparative significance of economic and technological efficiency versus security of supply in the development of the British National Grid. Both security of supply and economic and technological efficiency form aspects of energy security. I have shown, however, that the degree to which either of these aspects is dominant at any given time is largely dependent on economic and political circumstances. Furthermore, issues relating to economic efficiency and security of supply are important to both the State and to the individual companies involved in the supply of electricity. However, for the State, ensuring security of supply is the most important factor, whereas for the industry itself economic considerations took priority. I have shown that the National Grid was key to dealing with both of these aspects of energy security. The Grid provided for security of supply through the interconnection of power stations; ensuring that in the event of the loss of generation at a local power station due to enemy attack, industrial action or accidental damage, power could be quickly supplied from a neighbouring region. The Grid also provided for enhanced economic efficiency by enabling generation to be concentrated in the most efficient generating plants, as well as reducing the amount of standby plant required.

This approach builds on Edgerton's Warfare State thesis and shows how events during both the First and Second World Wars served to influence peacetime decisions relating to the supply of electric power. From this viewpoint, there is little distinction between peace and war. Indeed, I have shown that the provision of a secure supply of electricity was vital to the development of that Warfare State. I have shown that one of the key purposes behind the national grid was to ensure the most economical use of Britain's coal reserves. Unlike continental powers such Germany or the USA, Britain was almost entirely reliant on coal for the generation of electricity. The development of the National Grid enabled more economical use to be made of coal supplies and in theory gave the authorities greater control over the way in which that energy was distributed. However, as was demonstrated during the winter of 1946/7 this control was restricted by the nature of the grid often making it impossible to restrict power to domestic users without cutting of supplies to essential services. A further topic explored has been the importance of diversification of fuel supplies. While the grid enabled more economical use of coal, the increased reliance on electricity by industrial users combined with the lack of other fuels made the system vulnerable to disruption to the supply of coal. This was a key factor in the development of nuclear energy and oil-fired power stations. However, as was demonstrated in chapter seven this was complemented by both the military interest in nuclear energy and oil as well as the increasing awareness of the dangers of air pollution highlighted by the severe smogs of 1952. Finally, I have shown how the previously undocumented interest of the British armed forces, particularly the Royal Air Force and Army, in the development of electrical supply influenced the design and operation of the National Grid. However, due to the interconnected nature of these aspects of security, it has been impossible to deal with each of these separately; factors relating to security of supply are inextricably linked with those relating to economic efficiency. The singular exception to this was the military interest, which was almost entirely based on ensuring security of supply. The next section will trace these themes through each of the chapters, highlighting the conflict between these two main aspects of energy security.

8.2. Chapter Analysis.

In Chapter three, I showed that the use of electricity and the interconnection of generating stations during the First World War improved security by enabling the more efficient use of coal supplies. The use of electricity for munitions production also enabled the rapid expansion of industry needed to meet the high demand for munitions brought on by the war. As a result of the economies in coal use demonstrated by the state management of electricity, the Coalition Government came to recognise the importance of electricity to industrial development and as a means of securing Britain's economic security in the coming peace. Two committees were established to investigate the future of the electrical supply industry, both of which reported that the creation of a central authority to regulate the supply of electricity was in the 'national interest'. However, neither could agree on precisely how this authority should be organised or how it would impact on the ownership of power stations. This period also demonstrates the similarities between military and civilian uses of electricity and highlights the close parallels between civilian and military development, particularly in terms of the lack of standardisation.

In Chapter four, I showed how, with the end of the First World War, the splits between Parliamentary groups over the organisation and ownership of energy and transport infrastructure became more apparent. As a result, the 1919 Electricity (Supply) Act, while establishing the Electricity Commissioners to oversee the establishment of regional networks, did not give them the powers needed to coerce companies to cooperate, instead relying on voluntary cooperation. The chapter also highlighted the growing importance of electricity to military operations, with both the Army and Air Force demonstrating a strong interest in the operation of civilian power stations and the layout of pylon networks. In contrast to the degree of interest exhibited by the Army and Air Force, the Royal Navy appears to have been largely uninterested in the development of civilian power supply networks, although some facilities did require connection to local civilian power supplies. In society more widely, the use of electricity continued to be explicitly linked to savings in coal, advertisements by the Electrical Development Association claimed that the use of electricity was in the 'national interest' as this would enable greater savings in coal. This was particularly important due to the ongoing disruption within the coal mining industry.

Chapter five focused on the passage of the 1926 Electricity (supply) Act and the subsequent construction of the National Grid, demonstrating how industrial unrest as well as military concern had served to shape the development of the National Grid. The 1926 General Strike revealed the danger of purely localised generation, as well as of the reliance on a single fuel for the generation of electricity. While disruption to electrical supplies due to the strike was minimal, it was certainly alarming to the government and likely hastened the passage of the Act. For the state, interconnection by means of a national network offered a means of preventing the loss of a single generating station causing power cuts to centres of government or to key industries and facilities. In 1925, Sir John Snell had talked of the development of larger power stations in 'strategic positions' to help ensure security of supply as well as preventing unneeded investment in spare plant. Battersea power station was one such station and was constructed despite strenuous local opposition. As was mentioned in Chapter 4, the first annual report of the Central Electricity Board had described the National Grid as 'an elongated busbar' which would enable the transmission of power from any connected station to wherever it was needed, even, as occurred during the Second World War, in the event of damage to local generating stations. The Grid enabled both security of supply as well as the realisation of greater economic efficiency in the generation and use of electricity. For the Government, the construction of the National Grid was primarily about ensuring security of supply. The case of Battersea power station also highlights the growing importance of atmospheric pollution in the development of power infrastructure, although it is important to note that the environmental concerns raised were primarily related to the amenity of the site and had little to do with the effects of air pollution on national health.

The military, in particular the RAF, was also interested in the development of the Grid during this period. The RAF was heavily reliant on the rail network for transport of men and materials around the country and were concerned that the proposed electrification of the rail network would have an adverse effect on operation in the event of damage to power supplies. The RAF therefore attempted to influence the internal layout of power stations to minimise bomb damage, although these proposals were discarded as being uneconomical. The RAF also had considerable influence on the layout of the pylon network to minimise the risk to British pilots making emergency landings, although it should be noted that this also helped to minimise the potential damage to power cables by aircraft. While issues of economic efficiency clearly had some importance, and in the case of power station design took priority, in general the emphasis during this period was on enhancing security of supply.

Chapter six clearly demonstrates the importance of the Grid to Britain's war effort and, throughout this period, security of supply was clearly the overriding factor. As had been the case in the First World War, the development of electrical networks was vital in enabling the rapid growth in munitions production needed to supply the armed forces. The Grid was also essential to the existence of the Chain Home Early Warning System, which would have been unable to operate without access to a secure supply of electrical power. As had been the case in the First World War, the demand for electricity rapidly outstripped the economic production capacity of the Grid. In order to meet demand, power stations were forced to run older and less economical plant, as well as reducing the amount of downtime for maintenance, with severe consequences for post-war electrical generation. During the war electrical plant routinely received the highest level of priority for construction and repair, disrupted only by shortages of manpower and materials. In an effort to fill the gap in demand, housewives were encouraged to further economise on their use of electricity and domestic electrical use was directly linked to munitions production. Both Hannah and Hughes have focused on the development of the domestic load as a means of achieving greater economy in electrical generation. Increased domestic usage provided a more even base load on generating stations as different industries and domestic users required power at different times throughout the day. The Grid enabled supply over a wider area, leading to a more even overall demand. However, both Hannah and Hughes have ignored the potential of domestic users to serve as a reserve of power for industry. As was shown in Chapter six, the CEB viewed electricity used by domestic users as a reserve, which could be diverted to industrial users in the event of a serious shortfall in generating capacity. The Grid itself proved to be highly resilient to damage, possibly due to the lack of any systematic attack on British power infrastructure. The Royal Navy had carried out a highly successful attack on German electrical infrastructure, which remained classified at the end of the war, in part out of fears that it could be adapted to attack the National Grid.

In Chapter seven, the ‘perfect storm’ of 1946/7 revealed the vulnerability of inefficient plant and systems to external pressures and the need for a balance between economic efficiency and security of supply. The full nationalisation of coal mining, electrical generation and distribution, and gas infrastructure from 1946 shows the development of a more integrated approach to energy security, one which was only possible with state control of both the primary source of fuel and the systems of distribution. In 1947 Emmanuel Shinwell, Minister of Fuel and Power, described the 1947 Electricity Act as being the ‘obvious conclusion’ to ‘the work started in the 1926 Act’. However, I have shown that it is instead the obvious conclusion to the work started during the First World War by the Ministry of Munitions. The establishment in July 1951 of the Committee on National Fuel Policy further highlights the development of this more integrated approach to energy security. Much of the work of this committee was focused on ensuring the most efficient use of coal; other fuels such as oil were considered to be important in supplementing coal but could not be relied upon as the fuel sources were outside of British control.

The Great London Smog of December 1952 was a consequence of the large amounts of coal burnt in the capital for heating and power generation, which, when combined with windless anticyclonic conditions had enabled the formation of a thick layer of smog lasting for four days, causing approximately 4,000 fatalities. The 1952 smog caused the government to launch a series of investigations leading to the 1956 Clean Air Act. The 1952 smog certainly contributed to the decision made not to build any new city centre power stations and was used as an argument in favour of developing nuclear power stations in Britain. Although it should be noted that most of the efforts to reduce coal emissions were targeted at domestic users rather than industry or power stations.

Finally, there are the implications of nuclear weapons on the layout of the Grid and location of new power stations. In 1946 the Royal Air Force recommended that new power stations should be constructed away from built-up urban areas, fearing that power stations would make major cities such as London even more attractive targets for nuclear attacks. However, these concerns were dismissed in 1948 by the Prime Minister. Bankside was the last major city centre power station to be constructed in Britain. While this may be in part due to the large amount of space needed for new plants, the importance of location in terms of aerial defence should not be discounted. Furthermore, Attlee's decision to dismiss the concerns of the Air Force and grant permission for the construction of Bankside power station may simply indicate that, in the immediate post-war period, the shortage of electricity was a more significant threat to national security, than any hypothetical nuclear conflict.

Overall, this thesis has shown that energy security is about more than economic or technological efficiency. Security of supply has been a significant factor in the design, development and operation of the British National Grid. However, as I have shown, it is almost impossible to disentangle security of supply from issues of economic and technological efficiency. Throughout each chapter I have shown that security of supply and economic and technological efficiency have been held in tension with each other; however, overall, ensuring security of energy supply was an overriding concern for the multiple governments in office between 1914 and 1956.

8.3. Rethinking Relations Between Energy, Industry, Security and the State.

This thesis offers historians of technology and policymakers concerned with contemporary energy security two new insights. The first is to demonstrates the value of applying Edgerton's Warfare State approach to a civilian technology and the development of national energy infrastructure. In doing so, it offers a revised structure to the standard economic and technological focus of mainstream histories of electrification. The second insight is that this thesis has presented an historical argument demonstrating that energy security requires a balance between security of supply and economic efficiency. As we have seen in the Introduction to this thesis, contemporary political economists tend to either disregard, or subsume, national security within a broadly defined and economically based concept of energy security. That approach obscures the complex interaction between efficiency and state security revealed by the history considered in this thesis.

As Edgerton stresses, historians have been reluctant to consider the role of the military in science and technology, or where they do so, to attribute to military personnel or strategic decision-making a positive and decisive influence over industrial development during peacetime periods. The general role of the military, Edgerton notes, especially in civil technologies of production, communication and control, has been neglected. The National Grid fits within this framework as a technology of control, facilitating state management of national energy resources. The thesis has sought, to use Edgerton's phrase, 'put the military into' the history of British early-twentieth-century technology and industry as exemplified by the story of the National Grid.[1] In doing so, it supports Edgerton's view of how the interaction of militarism and technocracy was a complex process: the military did not simply adopt electrical supply provided by the state; indeed the Royal Navy developed its own systems. Yet conversely, without the Grid, for example, it is difficult to see how the development of the Chain Home Network would have been viable. The development of the National Grid was a product of the experience of the First World War and military needs and concerns, and therefore militarism was a vital factor in enabling the rapid expansion of industry that took place in the mid to late 1930s and into the Second World War.

Throughout the period covered in this thesis, most power companies remained privately owned, whereas the Grid itself was owned and run by the state. The hybrid functioning of the state-run Grid network with private industry operating generation facilities ensured that security of supply remained a high priority. The thesis also demonstrates how domestic users were co-opted by the electrical authorities as agents in the industrial development of the Grid - rather than the more usual connection of these groups as consumers motivated by price and therefore part of the efficiency of supply equation. Furthermore, during this period, the Central Electricity Board controlled the price at which power companies could sell or purchase electricity. A company could only make a profit if they were able to produce electricity in line

[1] Edgerton, *Warfare State*, p.327.

with these set costs. As such, companies then, as now, were only willing and able to risk the construction of new generating plant if they could reasonably forecast to turn a profit. This unwillingness, on the part of private companies, to invest, was part of the reason for the nationalisation of the industry in 1948. This history demonstrates how security of supply and economic efficiency were in tension with each other in managing electrical supply: greater security of supply tended to come at the cost of efficiency; however, security of supply also required a certain degree of economic efficiency, which in turn was not possible without a certain degree of security.

This historical position contrasts with that of today. The re-privatisation of electrical supply, including the privatisation of the National Grid in the 1990s, has resulted in economic efficiency becoming the dominant factor in the management of electrical supply, as private companies accountable to shareholders generally put profit ahead of the national interest. In February 2018, Jeremy Hodges argued that:

> U.K. utilities may have to delay or give up on building power stations as new generators won only a fraction of the capacity offered in a tender to provide backup electricity. […] Britain has pledged to phase out coal generation by the middle of the next decade, but some plants could shut down sooner. Without additional income from capacity contracts from 2021, it will be difficult for operators to run stations profitably'.[2]

Just as the intensive focus on security of supply during both the First and Second World Wars was detrimental to the long-term provision of electricity, so too is the short-term focus on economic efficiency and profits detrimental to the long-term provision of electrical supply in Britain. However, the predominance of private industry in the management of electrical supply is detrimental to security of supply as it is rarely cost effective. Attention to the history of the National Grid shows that instead it is better to think in terms of degrees of security, with different factors taking priority, depending on the economic and political circumstances.

---

[2] Jeremy Hodges, 'U.K.'S Planned Power Plants Face Uncertainty In Auction Low', *Bloomberg.Com*, 2018 <https://www.bloomberg.com/news/articles/2018-02-09/britain-s-planned-power-plants-face-uncertainty-in-auction-low> [Accessed 10 June 2018].

8.4. Further Research.

This thesis has brought to light three topics which are highlighted as fertile ground for further research. The first of these would be to extend this current thesis to examine the continued development and operation of the National Grid and electrical supply throughout the Cold War. Of most value would be a particular focus on the development of the 200 kV Super Grid in the mid-1960s, as well as on the continued diversification of generating plant and the oil crisis and miners' strike in the 1970s. The source material for this study is available in the National Archives, the Electricity Council Archives at the Science and Industry Museum and in the Oral histories available through the National Life Stories Project with the British Library.

Secondly, the development of backup electrical power infrastructure merits further investigation. During the 1926 General Strike and again during the winter of 1946/47, the Royal Navy employed submarine diesels as a means of supplying power to port facilities, including warehouses. However, permanent backup electrical facilities at hospitals, telephone exchanges and other key locations apparently did not become standard until more recently. The development of backup power supplies, such as batteries and generators, for defence as well as civilian use, would be one fruitful area for further research: the RAF Radar Museum in Neatishead, Norfolk has an extensive and largely unresearched archive, including significant sections on portable field generators which could prove to be useful in this respect.

Finally, additional research could examine the introduction of natural gas to replace town gas from the 1960s, and the development of the National Grid for Gas. The introduction of natural gas had significant implications for energy security as it further reduced British reliance on coal. The National Grid for Gas was closely modelled on the National Grid, in terms of management, and in terms of the physical infrastructure, which was intended to ensure security of supply to all connected areas. Potential sources for this study would be papers from the Ministry of Fuel and Power at the National Archives and the National Gas Archive in

Warrington. In addition, the transitional issues involved in the shift from town gas to natural gas would merit historical examination to assess the role of arguments regarding efficiency versus national security within wider debates over energy security.

Bibliography

Archival Sources.

All Archival Documents are referenced in full on their first usage and so are not repeated here.

Museum of Science and Industry Archival Centre

The SIM document archives contain records of many Manchester based electrical manufacturers, particularly the Ferranti Company archives. The archive also contains the minutes and papers of the Electricity Council and elements of the Warrington Collection relating to power stations. This collection also contains the records of the Electrical Development Association, including copies of all published and unpublished advertisements as well as the records of all the meetings of the marketing division.

National Archives

Discovery online lists over 260 entries in the Cabinet papers (CAB) relating to electricity between 1900 and 1949, with a further 1,894 for the Ministry of Power (POWE), 4,750 for the War Office (WO), 4,012 for the Board of Trade and its successors (BT) and 568 for the Department of Scientific and Industrial Research (DSIR) as well as a total of 6,961 split between other ministries such as the Admiralty (ADM), the Ministry of Aviation (AVIA) the Ministry of Transport (MT) and others.

Hansard Online

Searching Hansard for debates relating to Electricity during the 20th Century lists a total of 3,794 entries between 1900 and 1910, 3,327 between 1909 and 1919, 6,493 between 1920 and 1929, 6,126 between 1930 and 1939, with a further 7,825 entries between 1940 and 1949.

Gale Newsvault

This online archive contains the full run of *The Times, The Independent, The Economist* and the *Daily Mail*, which are key national newspapers for this period. *The Times* and the *Daily Mail* particularly so a both regularly carried stories and editorials on issues related to technology.

British Newspaper Archive

Searchable digitised online collection of local and national newspapers covering all areas of Britain. The Archive holds copies of papers from across the political and economic spectrum.

Grace's Guide

This online archive is a leading source of historical information on industry and manufacturing in the UK.

Mass Observation Archive

The Mass Observation Archive housed at the University of Sussex, preserves the papers of the original Mass Observation Movement documenting everyday life in Britain from 1937 into the 1950s.

The Lloyd George Papers

Collection of letters and diaries held by the National Library of Wales pertaining to the life and career of David Lloyd George.

RAF Air Defence Museum Archives

Collection of papers, manuals and documents relating to the development of Radar. This includes original manuals and specifications for backup generators.

Journals.

The Electrician:

Volumes between 1912 and 1960, held in the University of Leeds Library. The Electrician was published on a weekly basis and contained contributions from across the industry, including generation, distribution and manufacturing. It was a key forum for engineers to discuss key theoretical and practical problems relating to the supply of electricity and its associated legislation.

The Electrical Times:

Volumes between 1912 and 1960. – Held in the Science and Industry Museum Archives. These contain detailed breakdowns of new electrical equipment and descriptions of power station designs and innovations. This was the home of significant debate over national standards for the generation and transmission of electricity.

The Journal of the Institution of Electrical Engineers

Volumes between 1912 and 1960, Held in the University of Leeds Library and the IET Archives.

The Electrical Review

Volumes Between 1912 and 1960, Held in the University of Leeds Library and the Science and Industry Museum Archives.

Garcke Manuals

Volumes between 1912 and 1960, Held in the IET Archives and the Science and Industry Museum Archive Centre. These annual journals contain listings of all electrical manufacturers and undertakers in Britain as well as detailed information on the amount of electricity generated and new plant installed. They also contain a summary of all legislation passed that year.

The Electrician and Electrical Times.

‘Amendment of Munitions Act’, *The Electrician*, LXXVI (1915), p.293

Beale, A. M., ‘Power-Canada's Opportunity’, *The Electrician*, LXXXII (1919), p.12

‘Birmingham’, *The Electrician*, LXXVI (1915), p.68

‘Bootle’, *The Electrician*, LXXV (1915), p.971

‘Business as Usual’, *The Electrician*, LXXII (1914), p.779

‘Coal Supplies’, *The Electrician*, LXXV (1915), p.403

‘Coal Supplies for Electricity Works’, *The Electrician*, LXXVI (1915), p.369

‘Coal Supply for Electricity Works’, *The Electrician*, LXXIV (1915), pp.542-543

‘Conference on Coal Supplies’, *The Electrician*, LXXV (1915), pp.195-198

‘Effect of The Power Load’, *The Electrician*, LXXVII (1916), p.342

‘Electrical Legislation In 1914’, *The Electrician*, LXXIV (1914), pp.396-398

‘Electricity in Explosive Works’, *The Electrician*, LXXI (1913), p.153

‘Electricity Supply and The War’, *The Electrician*, LXXIV (1915), p.802

‘Electricity Supply at Birmingham’, *The Electrician*, LXXIV (1915), p.479

‘Extensions’, *The Electrician*, LXXII (1914), p.151

‘Extensions’, *The Electrician*, LXXIV (1914), p.60

‘Extensions’, *The Electrician*, LXXIV (1914), p.194

‘Extensions’, *The Electrician*, LXXIV (1914), p.301

‘Extensions’, *The Electrician*, LXXIV (1914), p.126

‘Extensions’, *The Electrician*, LXXIV (1914), p.335

‘General’, *The Electrician*, LXXIV (1914), p.60

‘General’, *The Electrician*, LXXIV (1914), p.160

‘Interesting Features at Bradford’, *The Electrician*, LXX (1912), p.20

‘Linking-Up’, *The Electrician*, LXXVII (1916), p.239

‘London Electrical Engineers Recruiting’, *The Electrician*, LXXIV (1914)

‘Manchester’, *The Electrical Times*, XLVII (1915), p.461

‘Manchester’, *The Electrician*, LXXIV (1914), p.829

‘Manchester’, *The Electrician*, LXXVI (1915), pp.294-295

‘Manchester’, *The Electrician*, LXXVI (1916), p.651

'Municipal Employees and The War', *The Electrician*, LXXV (1915), p.42

'Municipalities and Electricity Supply', *The Electrician*, LXXXII (1919), p.159

'National Electric Power Supply Joint Committee', *The Electrician*, LXVIII (1916), pp.56-57

'National Electricity Supply', *The Electrician*, LXXXII (1919), pp.170-071

'Provisional Lighting Order', *The Electrician*, LXXVI (1915), p.460

'Recruiting and Common Sense', *The Electrician*, LXXVI (1915), p.185

'Sheffield', *The Electrician*, LXXV (1915), p.30

'Sheffield', *The Electrician*, LXXVI (1915), p.255

'Sheffield', *The Electrician*, LXXVII (1916), p.366

'Some Electrical Events Of 1915', *The Electrician*, LXXVI (1915), pp.462-464

'The Central Station as A Controlled Works', *The Electrician*, LXXVI (1916), p.657

'The Coal Position', *The Electrician*, LXXVI (1915), p.75

'The Interconnection of Lancashire And Cheshire Electricity Supply Systems', *The Electrician*, LXVIII (1916), pp.53-56

Williams, Ernest T., 'Electricity Supply', *The Electrician*, LXXVIII (1916), p.25

'Women Electricians', *The Electrician*, LXXVI (1915), p.327

Newspaper Sources.

Historic Newspapers Accessed from the Gale News Vault and the British Newspaper Archive.

'Britain Improvises As Power Gas And Water Fail', *Derby Daily Telegraph,* 30th January 1947, p.1

'British Electrical Development Association.', *The Times,* 20th November 1946, p.3
'Development Of Electricity', *The Times*, 21st November 1925, p. 14

'Coal Situation Most Serious', *Gloucestershire Echo,* 5th February 1947, p.1

'Crosby Explosion Mystery Solved: Pylon Damaged By Bomb.', *Liverpool Echo,* 17th January 1939, p.12

'Electricity Output Declines', *The Financial Times,* 16th January 1946, p.3

'Emergency Powers Home Secretary's Statement.', *The Scotsman,* 6th May 1926, p.5

'Ferranti, Electrical Engineers To The 20th Century.', *Portsmouth Evening News,* 23rd September 1933, p.5

'Ferranti, Ltd. Turnover Well Maintained: Stronger Position.', *The Yorkshire Post and Leeds Intelligencer,* 6th October 1928, p.14

'Floods Close Down Big Midland Power Station', *Birmingham Daily Gazette,* 22nd March 1947, p.1

'HMS M3 Supplying Power to The London Docks', Illustrated London News, 15th May 1926, p.5

'Power Plants, New Size Records Being Established.', *Yorkshire Post and Leeds Intelligencer*, 13th December 1928, p.4

'Stoppage Of The Birmingham Tram Service', *Birmingham Mail*, 12th October 1915, p.3

'Submarines As Power Houses For Dockyards', *Daily Herald,* 9th January 1947, p.1

'Submarines In Peacetime Role', *Hampshire Telegraph,* 10th January 1947, p.1

'The Electricity Bill, A Growing Revolt.', Dundee Courier, 5th November 1926, p.6

'The Future of Nuclear Power', *Portsmouth Evening News,* 29th September1954, p.2

'The Revival Of Trade', *Yorkshire Post and Leeds Intelligencer*, 29th October 1914, p.7

C. B. Clapcott, C. B., E. Guy Dawber, Dawson, Des Voeux, Meath, and J. S. Owens, 'Power 'Stations In Cities', *The Times*, 9th April 1929, p.17

Charles à Court Repington, 'Need For Shells', *The Times*, 14th May 1915, p.8

'Ferranti Ltd', *The Yorkshire Post and Leeds Intelligencer*, '19th October 1928, p.18

Harvey, Fiona, 'Engineers Warn of Looming UK Energy Gap', *The Guardian*, 2016 <https://www.theguardian.com/environment/2016/jan/26/engineers-warn-of-looming-uk-energy-gap> [Accessed 8 August 2017]

John Boynton Priestly, 'On The Stairway Of The Stars', *The Listener*, 13th March 1947, p.355

'Biggest-Ever Power Cut', *Derby Daily Telegraph,* 27th January 1947, p.1

'Electricity Committee', *Dover Express*, 6th November 1914, p.4

'Changing London', *Daily Record,* 16th December 1914, p. 4

'Length of the War', The Times, 27th March 1915, p.8

'Labour At Power And Light Works', *The Times,* 10th November 1915, p.5

'Our Waning Air Power', *The Times*, 22nd April 1922, p.13

'Armaments And World Peace', *Courier and Argus*, 24th July 1923, p.5

'Hospitals Hampered.', *The Northern Whig*, 8th May 1926, p. 7

'The Electricity Bill', Dundee Courier, 5 November 1926, p.6

'Dawn Of The Electricity Age', Hull Daily Mail, 26 November 1926, p.11

'News In Advertisements', *The Times*, '16th March1927, p.13

'Big Electricity Scheme.', *Leeds Mercury*, 1st March 1928, p. 2

'Last Of 26,265 Pylons.', *Western Daily News,* 5th September 1933, p.7

'Consumption Of Electricity', *The Economist,* 19th January 1946, p,108

'Electricity Output', *The Times,* 16th January 1946, p.7

'More Snow And Frost To Come', *Hull Daily Mail,* 24th January 1947, p.1

'Survey Of Export Industries.', *The Times,* 1st January 1947, p.14

'The Start Of A New Era.', *Daily Herald,* 18th October 1956, pp.8-9

'Sir James Hutchison', *The Times,* 19th November 1979, p.26

'Banbury Without Light And Power', *Banbury Guardian,* 20th March 1947, p.5

'Demands For Electrical Power', *Birmingham Mail*, 31st December 1914, p.4

Primary Literature

Abercrombie, Patrick, and J. H. Forshaw, *County of London Plan*, 1st edn (London: H.M. Stationery Off., 1943)

Authority, 'Second Supplement to The London Gazette', *London Gazette*, 1914, pp. 6379-6383 <http://www.thegazette.co.uk/London/issue/28869/supplement/6379/data.htm> [Accessed 1 October 2016]

Central Statistics Office, *Monthly Digest, No24,* December 1947, table 25.

Ferranti, *The True Way to Radio*, 6th edn (Manchester: Ferranti, 1935)

Hacking, J., and J.D. Peattie, 'The British Grid System in War Time', *Journal of The Institution of Electrical Engineers - Part II: Power Engineering*, 94 (1947), 463-476 <https://doi.org/10.1049/ji-2.1947.0127>

Houses of Parliament, *Official Secrets Act, 1911* (London: His Majesty's Stationary Office, 1911), pp. 1-8

Mayber, John M., *Electrical Supply in Warships: A Brief History.* (London: Ministry of Defense)

MO 2483, 'Fuel Crisis, May 1947' (Brighton, 1947), University of Sussex, Mass Observation Archive

RIMMER, Edward Johnson, and George Read ALLEN, *The Electricity-Supply-Act, 1926, Explained and Annotated, With the Text of The Electricity Supply Acts, 1919 & 1922, As Amended* (London: Solicitors' Law Stationery Society, 1927)

Speer, Albert, *Inside the Third Reich: Memoirs.* (London: Cassell, 1999)

Stirling, Yates, *Fundamentals of Naval Service* (Philadelphia: J.B. Lippincott Co, 1917)

Studholme, Richard Home, *Electricity Law and Practice. A Handbook on The Application and Effect of The Electricity Supply Acts. 1882 To 1935.* (London: Sir I. Pitman & Sons, 1935)

The True Road to Radio., 6th edn (Manchester: Ferranti, 1935)

Wolfers, Arnold, ''National Security' As an Ambiguous Symbol', *Political Science Quarterly*, 67 (1952), 481-502 <https://doi.org/10.2307/2145138>

Unpublished Thesis.

Baker, John Leon, "Planning The Future Of The Electricity Supply Industry 1935-48" (unpublished Doctoral Thesis, University of Birmingham, 1991)

Berry, Dominic, ‘Genetics, Statistics, And Regulation at The National Institute of Agricultural Botany, 1919-1969.’ (unpublished Doctoral Thesis, University of Leeds, 2014)

Brown, Warwick Michael, ‘The Royal Navy's Fuel Supplies 1989-1939: The Transition from Coal to Oil.’ (unpublished Doctoral Thesis, King's College London, 2003)

Hankin, Emily, ‘Buying Modernity? The Consumer Experience of Domestic Electricity in The Era of The Grid.’ (unpublished Doctoral Thesis, University of Manchester, 2012)

Murray, Stephen, ‘Bankside Power Station: Planning, Politics and Pollution’ (unpublished Doctoral Thesis, University of Leicester, 2014)

Newman, Leslie T., "The Electrification Of Rural England And Wales" (unpublished Masters Thesis, University of Reading, 1991)

Theaker, Martin, ‘Power Politics: Britain And Atomic Energy, 1945-62.’ (unpublished Masters Thesis, University of Birmingham, 2011)

Walker, Graham, ‘UK Power Networks: The Political Discourse of British Nuclear Energy.’ (unpublished Doctoral Thesis, University of ESSEX, 2019)

Woodward, Gordon, ‘Electric Power System Evolution in Merseyside And North Wales: The Technical History of a Region’s Electrification, 1879-1948.’ (unpublished Doctoral Thesis, University of Manchester, 1996)

Secondary Literature.

Aldcroft, Derek Howard, *The British Economy Between the Wars.* (Oxford: Philip Allan, 1983)

Aldcroft, Derek Howard, *The Inter-War Economy: Britain, 1919-1939.* (London: The Bodley Head, 1965)

'Amenity', *Oxford English Dictionary Online* (Oxford: Oxford University Press, 2019) <https://www.oed.com/view/Entry/6315?redirectedFrom=amenity#eid> [Accessed 25 August 2019]

Azzuni, Abdelrahman, and Christian Breyer, 'Definitions and Dimensions of Energy Security: A Literature Review', *Wiley Interdisciplinary Reviews: Energy and Environment*, 7 (2017), 1-34 <https://doi.org/10.1002/wene.268>

BALDWIN, DAVID A., 'The Concept of Security', *Review of International Studies*, 23 (1997), 5-26 <https://doi.org/10.1017/s0260210597000053>

Bates, DV, 'A Half Century Later: Recollections of The London Fog', *Environmental Health Perspectives*, 110 (2002) <https://doi.org/10.1289/ehp.110-a735>

'BBC NEWS | Wales | North West Wales | Electricity Switch-On for Village', *News.bbc.co.uk*, 2008 <http://news.bbc.co.uk/1/hi/wales/north_west/7790280.stm> [Accessed 24 July 2018]

'BBC ON THIS DAY | 9 | 1952: London Fog Clears After Days of Chaos', *News.bbc.co.uk*, 2019 <http://news.bbc.co.uk/onthisday/hi/dates/stories/december/9/newsid_4506000/4506390.stm> [Accessed 5 November 2019]

Bijker, Wiebe E, Thomas Parke Hughes, T. J Pinch, and Deborah G Douglas, *The Social Construction of Technological Systems* (Cambridge, Mass.: MIT Press, 2012)

Bolton, Paul, *Energy Imports and Exports* (London: House of Commons Library, 2018), pp. 1-11 <http://www.parliament.uk/commons-library | intranet.parliament.uk/commons-library> [Accessed 20 October 2018]

Bowler, Catherine, and Peter Brimblecombe, 'Battersea Power Station and Environmental Issues 1929–1989', *Atmospheric Environment. Part B. Urban Atmosphere*, 25 (1991), 143-151 <https://doi.org/10.1016/0957-1272(91)90048-j>

Brassley, Paul William, Jeremy Burchardt, and Karen Sayer, *Transforming the Countryside: The Electrification of Rural Britain.* (Oxon: Routledge, 2017)

Brivati, Brian, 'Gaitskell, Hugh Todd Naylor (1906–1963).', *Oxford Dictionary of National Biography* (Oxford: Oxford University Press, 2004) <https://doi.org/10.1093/ref:odnb/33309> [Accessed 5 November 2019]

Bruton, Elizabeth, 'The Cable Wars: Military and State Surveillance of The British Telegraph Cable Network During World War One.', in *Historicizing Infrastructure.* (Aalborg: Aalborg University Press, 2017), pp. 159-182

Bureau of the Census, *Historical Statistics of The United States, Colonial Times To 1957.* (Washington D.C.: U.S. Department of Commerce, 1960), p. 355

'Burntisland Shipbuilding Co - Graces Guide', *Gracesguide.co.uk*, 2019 <https://www.gracesguide.co.uk/Burntisland_Shipbuilding_Co> [Accessed 29 October 2019]

Burt, R. A, *British Battleships 1919-1945*, 2nd edn (Annapolis: Naval Institute Press, 2012)

Buzan, Barry, *People, States, And Fear: The National Security Problem in International Relations.* (Chapel Hill: University of North Carolina Press, 1983)

Calder, Angus, *The People's War: Britain 1939-1945.* (London: Penguin, 1992)

Carlsson-Hyslop, Anna, and Peter J.G. Pearson, *How Did the Electrical Development Association Attempt to Mould Domestic Electricity Demand in Britain, 1945-1964?* (Cardiff: Realising Transition Pathways Project, 2013) <https://www.escholar.manchester.ac.uk/api/datastream?publicationPid=uk-ac-man-scw:246890&datastreamId=FULL-TEXT.PDF> [Accessed 1 November 2019]

Cherp, Aleh, and Jessica Jewell, 'The Three Perspectives on Energy Security: Intellectual History, Disciplinary Roots and The Potential for Integration.', *Current Opinion in Environmental Sustainability*, 3 (2011), 202-212 <https://doi.org/10.1016/j.cosust.2011.07.001>

Cohen, Lizabeth, *A Consumers Republic: The Politics of Mass Consumption in Postwar America.* (New York: Random House US, 2008)

Cohn, Julie A, *The Grid: Biography of An American Technology.* (Cambridge MA: MIT Press, 2017)

Cook, Judith, 'Priestley, John Boynton (1894–1984).', *Oxford Dictionary of National Biography* (Oxford: Oxford University Press, 2016) <https://doi.org/10.1093/ref:odnb/31565> [Accessed 5 November 2019]

Corley, Thomas Anthony Buchanan, *Domestic Electrical Appliances* (London: Cox & Wyman Ltd, 1966)

Cowan, Ruth Schwartz, *A Social History of American Technology* (New York: Oxford Univ. Press, 1997)

Cowan, Ruth Schwartz, *More Work for Mother* ([New York, NY]: Basic Books, 1983)

Cox, Sebastian, 'The RAF's Response.', in *The Burning Blue: A New History of The Battle of Britain.* (London: Plimco, 2000), pp. 55-68

Cozzens, Susan E., Wiebe E. Bijker, Thomas P. Hughes, and Trevor Pinch, 'The Social Construction of Technological Systems: New Directions in The Sociology and History of Technology', *Technology and Culture*, 30 (1989), 705 <https://doi.org/10.2307/3105993>

Craig, Fred W. S, *British General Election Manifestos, 1900-1974.* (London: Macmillan, 1975)

Dahl, Erik J., 'Naval Innovation, From Coal to Oil.', *Joint Force Quarterly*, 27 (2001), 5-56

Denman, James, and Paul McDonald, 'Unemployment Statistics From 1881 To the Present Day.', *Labour Market Trends*, 104 (1996), 5-18

Dobinson, Colin, *Building Radar: Forging Britain's Early-Warning Chain, 1935-1945.* (London: Methuen, 2010)

Dolata, Petra, 'The End of The Security Paradigm Under Obama - Trump and Energy Security: Revival of An Old Concept?', *Journal of Military and Strategic Studies*, 17 (2017), 92-106

Dolden, A. Stuart, *Cannon Fodder* (London: Blandford, 1988)

Dooley, E, ‘Fifty Years Later: Clearing the Air Over the London Smog.’, *Environmental Health Perspectives*, 110 (2002) <https://doi.org/10.1289/ehp.110-a748>

Drapeau, Raoul, ‘Operation Outward: Britain's World War II Offensive Balloons.’, *IEEE Power and Energy Magazine*, 2011, pp. 94-105 <https://site.ieee.org/ny-monitor/files/2011/09/OPERATION-OUTWARD.pdf> [Accessed 31 October 2017]

Edgerton, David, *Britain's War Machine: Weapons, Resources and Experts in The Second World War.* (London: Allen Lane, 2011)

Edgerton, David, *England And the Aeroplane: Militarism, Modernity and Machines.*, 2nd edn (London: Penguin, 2013)

Edgerton, David, *The Rise and Fall of The British Nation.* ([London]: Allen Lane, 2018)

Edgerton, David, *Warfare State* (Cambridge: Cambridge University Press, 2006)

Edwards, John Richard, ‘Touche [Formerly Touch], Sir George Alexander, First Baronet1861–1935).’, *Oxford Dictionary of National Biography.* (Oxford: Oxford University Press, 2004) <https://doi.org/10.1093/ref:odnb/47822> [Accessed 1 October 2019]

Electricity Supply in Great Britain (London: Electricity Council, 1973)

Evenden, Mathew, and Jonathan Payton, ‘Hydroelectricity’, in *Powering Up Canada: A History of Power, Fuel and Energy From 1600.* (Montreal: McGill-Queen’s University Press, 2016), pp. 251-273

Evenden, Matthew, ‘Lights Out: Conserving Electricity for War in The Canadian City, 1939-1945’, *Articles*, 34 (2013), 88-99 <https://doi.org/10.7202/1016049ar>

Gavin, William, and Marc Brodie, ‘Hudson, Robert Spear, First Viscount Hudson (1886–1957).’, *Oxford Dictionary of National Biography* (Oxford: Oxford University Press, 2004) <https://doi.org/10.1093/ref:odnb/34037> [Accessed 4 November 2019]

Gooday, Graeme, *Domesticating Electricity: Technology, Uncertainty and Gender, 1880–1914.* (London: Routledge, 2008)

Greenhill, Robert G., ‘Williamson, Archibald, First Baron Forres (1860–1931).’, *Oxford Dictionary of National Biography.* (Oxford: Oxford University Press, 2004) <https://doi.org/10.1093/ref:odnb/48399> [Accessed 28 October 2019]

Grieves, Keith, ‘Duncan, Sir Andrew Rae (1884–1952).’, *Oxford Dictionary of National Biography* (Oxford: Oxford University Press, 2004) <https://doi.org/10.1093/ref:odnb/32929> [Accessed 30 November 2019]

Grieves, Keith, ‘Geddes, Sir Eric Campbell (1875–1937), Politician and Businessman.’, *Oxford Dictionary of National Biography* (Oxford: Oxford University Press, 2015) <https://doi.org/10.1093/ref:odnb/33360> [Accessed 28 October 2019]

Grieves, Keith, *Sir Eric Geddes, Business and Government in War and Peace.* (Manchester: Manchester University Press, 1989)

Hall, Tony, *Nuclear Politics: The History of Nuclear Power in Britain.* (London: Penguin Books, 1986)

Hannah, Leslie, *Electricity Before Nationalisation: A Study of The Development of The Electricity Supply Industry in Britain to 1948.* (London: Macmillan, 1979)

Harvey, Fiona, ‘Engineers Warn of Looming UK Energy Gap’, *The Guardian*, 2019 <https://www.theguardian.com/environment/2016/jan/26/engineers-warn-of-looming-uk-energy-gap> [Accessed 8 August 2017]

Hasenöhrl, Ute, ‘Rural Electrification in The British Empire’, *History of Retailing and Consumption*, 4 (2018), 10-27 <https://doi.org/10.1080/2373518x.2018.1436220>

Hastings, Max, *Bomber Command, The Strategic Bombing Offensive: 1939-45.* (Pan MacMillan: London, 2012)

Hausman, William., Peter Hertner, and Mira Wilkins, *Global Electrification: Multinational Enterprise and International Finance in The History of Light and Power, 1878-2007.* (New York: Cambridge University Press, 2008)

Hennessy, Peter, and James Jinks, *The Silent Deep: The Royal Navy Submarine Service Since 1945.* (London: Allen Lane, 2015)

Hinchliffe, Steve, ‘Technology, Power, And Space—The Means and Ends of Geographies of Technology’, *Environment and Planning D: Society and Space*, 14 (1996), 659-682 <https://doi.org/10.1068/d140659>

Hodges, Jeremy, ‘U.K.'S Planned Power Plants Face Uncertainty in Auction Low’, *Bloomberg.Com*, 2018 <https://www.bloomberg.com/news/articles/2018-02-09/britain-s-planned-power-plants-face-uncertainty-in-auction-low> [Accessed 10 June 2018]

Hogg, Jonathan, *British Nuclear Culture: Official and Unofficial Narratives in The Long 20Th Century.* (London: Bloomsbury, 2016)

Howard, Anthony, ‘Castle [Née Betts], Barbara Anne, Baroness Castle of Blackburn (1910–2002).’, *Oxford Dictionary of National Biography* (Oxford: Oxford University Press, 2012) <https://doi.org/10.1093/ref:odnb/76877> [Accessed 4 November 2019]

Howarth, Richard W, *Farming for Farmers? A Critique of Agricultural Support Policy,* (London: Institute of Economic Affairs, 1985)

Hughes, Thomas P, *Networks of Power: Electrification in Western Society, 1880-1930.* (Baltimore: The Johns Hopkins University Press, 1983)

Hughes, Thomas, ‘The Evolution of Technological Systems’, in *The Social Construction of Technological Systems* (Cambridge, Mass.: MIT Press, 2012), pp. 45-76

Jeffery, Keith, ‘Wilson, Sir Henry Hughes, Baronet (1864–1922).’, *Oxford Dictionary of National Biography* (Oxford: Oxford University Press, 2004) <https://doi.org/10.1093/ref:odnb/36955> [Accessed 28 October 2019]

Jones, Robert, and Oliver Marriott, *Anatomy of A Merger: A History of G.E.C., A.E.I., And English Electric.* (London: Jonathan Cape, 1970)

Laybourn, Keith, *The General Strike Of 1926* (Manchester: Manchester University Press, 1993)

Lenin, Vladimir, *Lenin's Collected Works,* 4th edn (Moscow: Progress Publishers, 1965), pp. 408-426

Lodge, Tony, and Daniel Mahoney, *The Hidden Wiring: How Electricity Imports Threaten Britain's Energy Security/* (London: Centre for Policy Studies, 2017), pp. 1-16

<https://www.cps.org.uk/files/reports/original/171024092454-TheHiddenWiring.pdf> [Accessed 10 August 2018]

Lovell, Bernard, ‘Rowe, Albert Percival (1898–1976).’, *Oxford Dictionary of National Biography* (Oxford: Oxford University Press, 2004) <https://doi.org/10.1093/ref:odnb/51630> [Accessed 29 November 2019]

LOWE, Rodney, ‘Plumbing New Depths: Contemporary Historians and The Public Record Office’, *Twentieth Century British History*, 8 (1997), 239-265 <https://doi.org/10.1093/tcbh/8.2.239>

Luckin, Bill, *Questions of Power: Electricity and Environment in Inter-War Britain.* (Manchester: Manchester University Press, 1990)

Lukasik, Stephen, "Why The Arpanet Was Built", *IEEE Annals Of The History Of Computing*, 33 (2011), 4-21 <https://doi.org/10.1109/mahc.2010.11>

Mahoney, Ross, ‘Trenchard’ s Doctrine: Organisational Culture, The ‘Air Force Spirit’ And the Foundation of The Royal Air Force in The Interwar Years.’, *British Journal for Military History*, 4 (2018), 143-177

Marklund, Andreas, and Mogens Rüdiger, *Historicizing Infrastructure* (Aalborg: Aalborg University Press, 2017)

Marquand, David, ‘Macdonald, (James) Ramsay (1866–1937), Prime Minister.’, *Oxford Dictionary of National Biography* (Oxford: Oxford University Press, 2015) <https://doi.org/10.1093/ref:odnb/34704> [Accessed 28 October 2019]

Matthew, H. C. G., ‘Haldane, Richard Burdon, Viscount Haldane (1856–1928).’, *Oxford Dictionary of National Biography* (Oxford: Oxford University Press, 2011) <https://doi.org/10.1093/ref:odnb/33643> [Accessed 28 October 2019]

Met Office, ‘Winter 1947 Brought A Freeze to Post-War Britain’, *Official Blog of The Met Office News Team*, 2019 <https://blog.metoffice.gov.uk/2017/01/26/winter-1947-brought-a-freeze-to-post-war-britain/> [Accessed 1 November 2019]

Mitchell, B. R, *British Historical Statistics* (Cambridge: Cambridge University Press, 1988)

Morgan, Kenneth O., ‘Addison, Christopher, First Viscount Addison (1869–1951).’, *Oxford Dictionary of National Biography* (Oxford: Oxford University Press, 2004) <https://doi.org/10.1093/ref:odnb/30342> [Accessed 28 October 2019]

Morgan, Kenneth O., ‘'George, David Lloyd, First Earl Lloyd-George Of Dwyfor (1863–1945), Prime Minister'.’, *Oxford Dictionary of National Biography* (Oxford: Oxford University Press, 2018) <https://doi.org/10.1093/ref:odnb/34570> [Accessed 6 October 2019]

Morgan, Kenneth O., ‘Shinwell, Emanuel, Baron Shinwell (1884–1986).’, *Oxford Dictionary of National Biography* (Oxford: Oxford University Press, 2004) <https://doi.org/10.1093/ref:odnb/39859> [Accessed 1 November 2019]

Morris, Joseph, *The German Air Raids on Great Britain, 1914-1918* (Darlington, East Sussex: Naval and Military Press, 1993)

Mosley, Charles, *Burke's Peerage, Baronetage And Knightage* (Stokesley: Burke's Peerage & Gentry, 2003)

Mussell, James, *The Nineteenth-Century Press in The Digital Age* (London: Palgrave Macmillan, 2014)

Navickas, Katrina, ‘Conflicts of Power, Landscape and Amenity in Debates Over the British Super Grid in the 1950s’, *Rural History*, 30 (2019), 87-103 <https://doi.org/10.1017/s0956793319000013>

Nead, Lynda, ‘'As Snug as A Bug in A Rug': Post-War Housing, Homes and Coal Fires.’, *Science Museum Group Journal*, 9 (2018) <https://doi.org/10.15180/180902>

Nye, David E, *Electrifying America: Social Meanings of a New Technology, 1880-1940.* (Cambridge, Mass.: MIT Press, 1992)

O'Brien, Sorcha, *Powering the Nation: Images of The Shannon Scheme and Electricity in Ireland* (Newbridge: Irish Academic Press, 2017)

Pattinson, Juliette, ‘‘Shirkers’, ‘Scrimjacks’ And ‘Scrimshanks’?: British Civilian Masculinity and Reserved Occupations, 1914-45’, *Gender & History*, 28 (2016), 709-727 <https://doi.org/10.1111/1468-0424.12246>

Pocock, Rowland F, *Nuclear Power: Its Development in The United Kingdom.* (Old Woking: Unwin Brothers, 1977)

Post, Robert, ‘National Security and The Amended Freedom of Information Act’, *The Yale Law Journal*, 85 (1976) <https://doi.org/10.2307/795448>

Pugh, Martin, *We Danced All Night: A Social History of Britain Between the Wars.* (London: Vintage, 2009)

Radetzki, Marian, *Uranium: A Strategic Source of Energy* (London: Routledge, 1980)

Roberts, Fred, *Sixty Years of Nuclear History* (Oxford: Jon Carpenter, 1999)

Robertson, Alex J, *The Bleak Midwinter, 1947* (Manchester: Manchester University Press, 1987)

Rodgers, Terence, ‘Smith, Sir Allan Macgregor (1871–1941).’, *Oxford Dictionary of National Biography* (Oxford: Oxford University Press, 2004) <https://doi.org/10.1093/ref:odnb/48196> [Accessed 28 October 2019]

Romm, Joseph J, *Defining National Security* (New York: Council on Foreign Relations Press, 1993)

Roth, Andrew, ‘Montagu, (Alexander) Victor Edward Paulet, Tenth Earl of Sandwich (1906–1995).’, *Oxford Dictionary of National Biography* (Oxford: Oxford University Press, 2004) <https://doi.org/10.1093/ref:odnb/58043> [Accessed 4 November 2019]

Rutherford, J.P., E.W. Scharpf, and C.G. Carrington, ‘Linking Consumer Energy Efficiency with Security of Supply’, *Energy Policy*, 35 (2007), 3025-3035 <https://doi.org/10.1016/j.enpol.2006.10.031>

‘S. P. Austin And Son - Graces Guide’, *Gracesguide.co.uk*, 2019 <https://www.gracesguide.co.uk/S._P._Austin_and_Son> [Accessed 29 October 2017]

Sandalls, John, *Thirty-Six Years at The Atomic - My Time at AERE Harwell, 1958-1994.* (London: Wantage, 2004)

Sandwell, R. W., *Powering Up Canada: A History of Power, Fuel and Energy From 1600.* (Montreal: McGill-Queen's University Press, 2016)

Sheail, John, *An Environmental History of Twentieth-Century Britain* (Houndmills, Basingstoke, Hampshire: Palgrave, 2002)

Sheail, John, 'Power to The People: Power Stations and The National Grid.', in *Transforming the Countryside: The Electrification of Rural Britain.* (Oxford: Routledge, 2017), pp. 38-50

Sheail, John, *Rural Conservation in Inter-War Britain* (Oxford: Clarendon Press, 1981)

Shulman, Peter A, *Coal & Empire: The Birth of Energy Security in Industrial America* (Baltimore, Maryland: Johns Hopkins University Press, 2015)

Sommerville, Iain, and James Anderson, 'Ships Built by The Burntisland Shipbuilding Company Ltd: Arranged by Date of Launch', *Burntisland.Net*, 2008 <https://www.burntisland.net/ships-list-anderson.htm> [Accessed 29 October 2017]

Sprenger, Elizabeth, and Pauline Webb, 'Persuading the Housewife to Use Electricity? An Interpretation of Material in The Electricity Council Archives', *The British Journal for The History of Science*, 26 (1993), 55-65 <https://doi.org/10.1017/s0007087400030132>

Supple, Barry, *The History of The British Coal Industry, 1914-1946: The Political Economy of Decline.* (Oxford: Clarendon, 1987)

Suttie, Andrew, *Rewriting the First World War: Lloyd George, Politics and Strategy 1914-1918.* (London: Palgrave Macmillan, 2005)

Swale, William Eric, *Forerunners of The North Western Electricity Board* (Manchester: North Western Electricity Board, 1963)

Swords, Séan S, *Technical History of The Beginnings of Radar.* (London, U.K.: P. Peregrinus on behalf of the Institution of Electrical Engineers, 1986)

Symons, Julian, *The General Strike* (London: The Cresset Press, 1957)

Taylor, Alan J. P, *English History: 1914-1945.* (Oxford: Clarendon Pr., 1988)

Tosh, John, and Sean Lang, *The Pursuit of History: J. Tosh and S. Lang, The Pursuit of History: Aims, Methods and New Directions in The Study of Modern History.*, 4th edn (Harlow: Pearson Longman, 2008)

Watson, Andrew, 'Coal in Canada', in *Powering Up Canada: A History of Power, Fuel and Energy From 1600.* (Montreal: McGill-Queen's University Press, 2016), pp. 213-250

Watson, Raymond C, *Radar Origins: Worldwide: History of Its Evolution In 13 Nations Through World War II.* (Bloomington: Trafford Publishing, 2009)

Whiting, R. C., 'Attlee, Clement Richard, First Earl Attlee (1883–1967).', *Oxford Dictionary of National Biography* (Oxford: Oxford University Press, 2004) <https://doi.org/10.1093/ref:odnb/30498> [Accessed 1 November 2019]

Whiting, R. C., 'Greenwood, Arthur (1880–1954).', *Oxford Dictionary of National Biography* (Oxford: Oxford University Press, 2019) <https://doi.org/10.1093/ref:odnb/33543> [Accessed 29 November 2019]

‘William Mclellan - Graces Guide’, *Gracesguide.co.uk*, 2019 <https://www.gracesguide.co.uk/William_McLellan> [Accessed 8 August 2019]

Wilson, John F, *Ferranti A History: Building A Family Business, 1882-1975.* (Lancaster: Carnegie Pub, 2003)

Winzer, Christian, *Conceptualizing Energy Security*, Cambridge Working Paper in Economics (Cambridge: Electric Policy Research Group, 2011)

Wrigley, Chris, ‘Trade Unionists, Employers and The Cause of Industrial Unity and Peace, 1916-21.’, in *On the Move: Essays in Labour And Transport History Presented to Philip Bagwell.* (London: Hambledon, 1991), pp. 155-180

Yergin, Daniel, *The Prize: The Epic Quest for Oil, Money and Power* (New York: Simon & Schuster, 1991)

Zimmerman, David, *Britain's Shield: Radar and The Defeat of The Luftwaffe.* (Stroud: Amberley, 2010)

Zohar, Bahman, *Application of Compact Heat Exchangers for Combined Cycle Driven Efficiency in Next Generation Nuclear Power Plants* (Cham: Springer International Publishing, 2016)

Appendices 1

All Data has been taken from the annual returns of Engineering and Financial Statistics relating to Authorised Undertakings in Great Britain between 1920 and 1948. These were compiled on behalf of the Electricity Commissioners in order to provide comparative statistics in a readily accessible form to assist in carrying out their duties

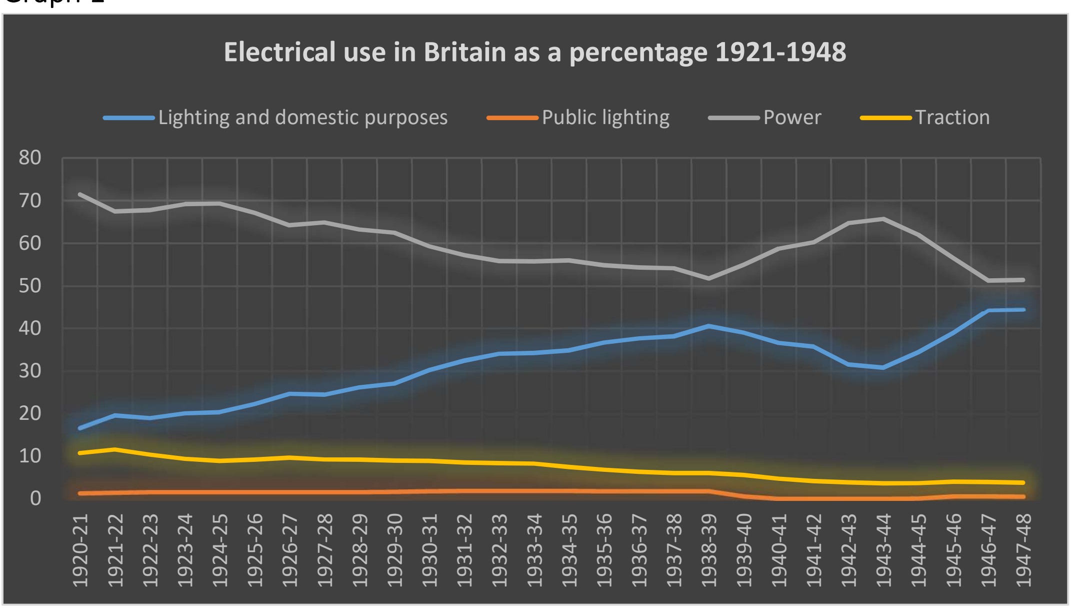
Graph 1 shows the percentage of electrical power in Britain used for domestic purposes, street lighting, Industry and Transportation between 1920 and 1948. While as a percentage industrial use of electricity fall during the inter-war period the second graph indicates that the total amount of electricity used by industry continues to rise throughout the period. The same is true of domestic use which as a percentage rises until the Second World War and then drops.

Graph 2 indicates that the number of units of electricity used for domestic purposes did fall during war as did the amount of electricity used for street lighting and transportation. This fall along with the increase in units being generated enabled a rapid increase in industrial capacity.

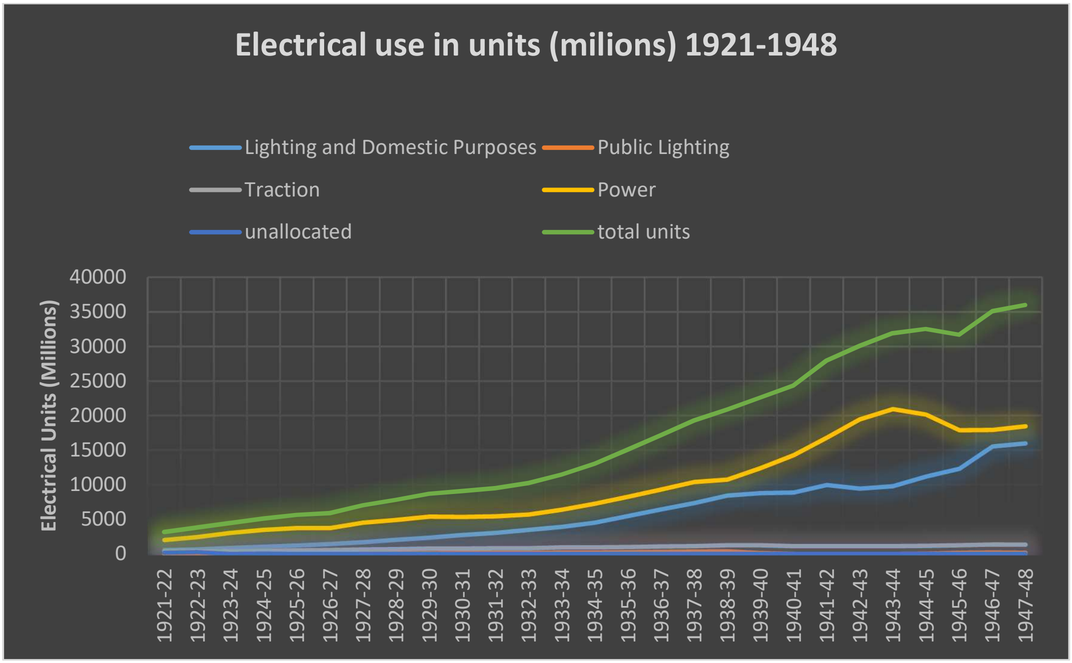
Graph 3 shows the changes in the source of energy used by authorised undertakers in Britain between 1922 and 1948 in relation to the total number of electrical undertakings in the country at that time. The Graph shows that the total number of undertakings increased between 1923 and 1931 before falling as the first stage of the National Gridiron was completed in 1933. The number of undertakings fell steadily from this point as smaller companies and municipal undertakings amalgamated. More significantly in terms of this thesis is the switch from undertakers generating their own electrical supply to taking a bulk supply from an external source. From 1929-30 onwards most undertakings in Britain were now receiving their electricity in bulk from the National Gridiron while a rapidly decreasing number continued to rely solely on their own generating equipment. It is likely that these undertakings were in more remote regions which had not yet been connected to the grid system. It is also possible than some of the undertakings which continued to generate their own electricity were still supplying Direct Current rather than Alternating Current and as such were not compatible with the rest of the Grid system.

Graph 4 shows the total amount of electricity generated in Britain between 1923 and 1948 in comparison to the number of generating stations in operation. It indicates that as older stations closed, they were replaced by a smaller number of larger power stations supplying the National Gridiron rather than just catering for local demand. Following the completion of the first stage of the grid network in 1933 the overall number of generating stations continues to decline at a steady rate, it would be interesting to add a further comparison showing the number and capacity of new generating stations added throughout this period alongside the number and generating capacity of older stations which ceased generation.

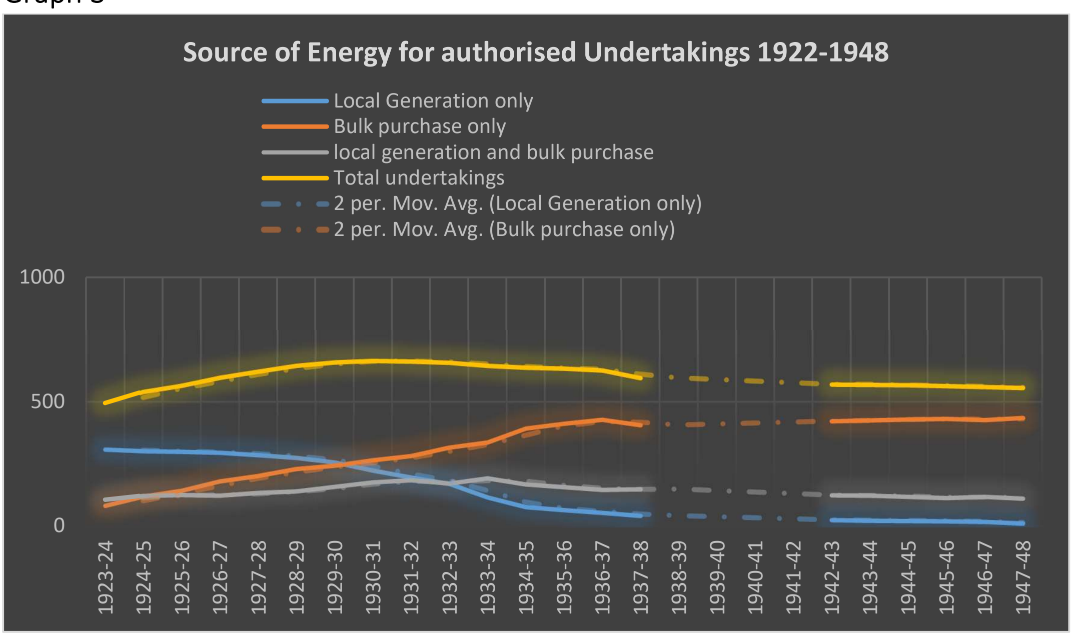
Graph 1



Graph 2

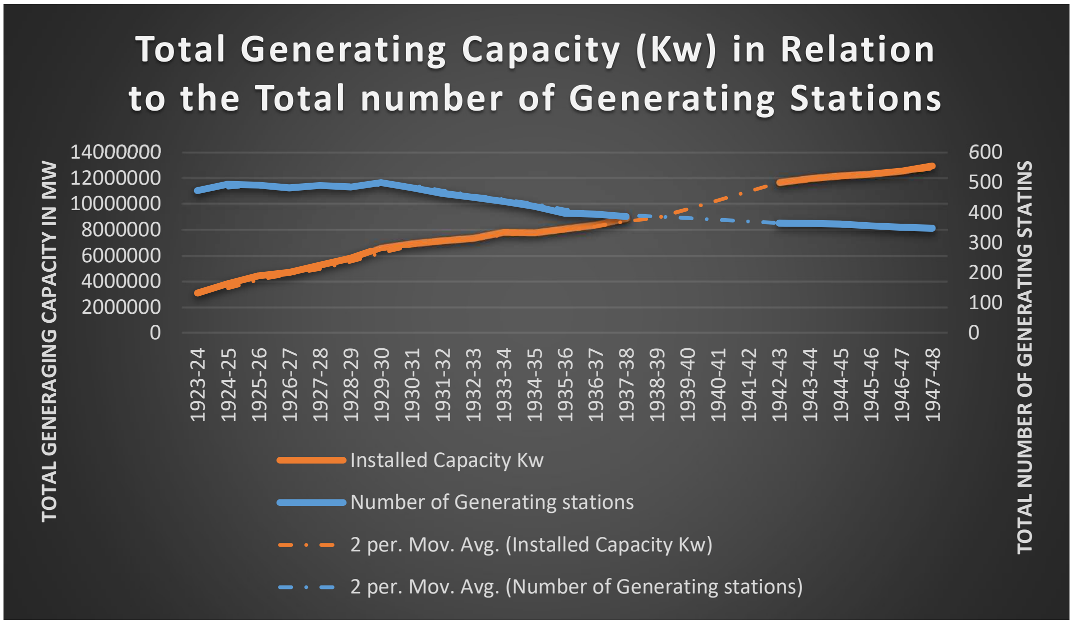


Graph 3



d

Graph 4



Total Generating Capacity (Kw) in Relation to the Total number of Generating Stations
TOTAL GENERAGING CAPACITY IN MW
TOTAL NUMBER OF GENERATING STATINS
14000000
12000000
10000000
8000000
6000000
4000000
2000000
0
600
500
400
300
200
100
0
1923-24
1924-25
1925-26
1926-27
1927-28
1928-29
1929-30
1930-31
1931-32
1932-33
1933-34
1934-35
1935-36
1936-37
1937-38
1938-39
1939-40
1940-41
1941-42
1942-43
1943-44
1944-45
1945-46
1946-47
1947-48
Installed Capacity Kw
Number of Generating stations
2 per. Mov. Avg. (Installed Capacity Kw)
2 per. Mov. Avg. (Number of Generating stations)

Electrical Use in Millions of Units 1921-1948 - Data for Graphs 1 & 2.

	1921-22	1922-23	1923-24	1924-25	1925-26	1926-27	1927-28	1928-29	1929-30	1930-31	1931-32	1932-33	1933-34	1934-35	1935-36	1936-37	1937-38	1938-39	1939-40	1940-41	1941-42	1942-43	1943-44	1944-45	1945-46	1946-47	1947-48
Lighting and Domestic Purposes	563.6	657.7	890.8	1037.6	1244.5	1443.4	1707.9	2035.7	2344	2744.3	3071.6	3468.6	3916.1	4534.7	5504.7	6453.7	7348.5	8438.4	8803.3	8886.2	9976.9	9446.8	9805.1	11180.9	12337.3	15517.9	15981.7
Public Lighting	49.5	58.6	67.6	78.3	89.7	96.4	114.3	127.8	144.1	164.1	182.8	198.4	218.6	243.4	270.8	302.3	341.1	379.2	142	16.3	20.2	20.7	20.3	35.3	200.1	230	189
Traction	333.2	366.1	415.5	445.3	511.8	561.2	643.6	710	769.9	794.3	811.3	849.8	941	966.8	1023.9	1078.6	1151	1253.6	1246.3	1137.3	1145.9	1147.7	1137.3	1169.7	1247	1370.4	1347.9
Power	2014	2444.8	3067.5	3503.7	3760.1	3767.1	4537.6	4926.6	5408	5371	5435.5	5693.2	6391.6	7284.9	8250	9312.6	10422.2	10756.8	12409.8	14272.2	16801.4	19434	20941	20135.1	17899.4	17941.1	18464.5
unallocated	185.5	262.1	21.3	27.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
total units	3145.8	3789.3	4452.7	5092.1	5606.1	5868.1	7003.4	7800.1	8666	9073.7	9501.2	10210	11467.3	13029.8	15049.4	17147.2	19262.8	20828	22601.4	24312	27944.4	30049.2	31903.7	32520.9	31683.8	35059.4	35983.1

Sources of energy for Authorised Undertakers – Data for Graph 3.

	1923-24	1924-25	1925-26	1926-27	1927-28	1928-29	1929-30	1930-31	1931-32	1932-33	1933-34	1934-35	1935-36	1936-37	1937-38	1938-39	1939-40	1940-41	1941-42	1942-43	1943-44	1944-45	1945-46	1946-47	1947-48
Local Generation only	307	301	298	294	285	274	256	223	195	170	115	77	64	53	42					25	22	21	20	17	11
Bulk purchase only	82	119	142	179	201	229	243	264	281	315	336	391	411	426	405					421	424	428	430	425	434
local generation and bulk purchas	105	121	125	123	134	140	158	176	184	171	192	168	157	146	148					124	122	118	113	118	111
Total undertakings	494	541	565	596	620	643	657	663	660	656	643	636	632	625	595					570	568	567	563	560	556

Total Generating Compacity Compared to the Number of the Generating Stations – Data for Graph 4.

	1923-24	1924-25	1925-26	1926-27	1927-28	1928-29	1929-30	1930-31	1931-32	1932-33	1933-34	1934-35	1935-36	1936-37	1937-38	1938-39	1939-40	1940-41	1941-42	1942-43	1943-44	1944-45	1945-46	1946-47	1947-48
Number of Generating statio	473	494	491	482	490	485	500	483	464	451	437	421	398	395	387					365	364	362	356	351	348
Installed Capacity Kw	3093679	3823513	4421602	4682609	5258257	5801770	6600225	6945805	7194571	7365869	7837154	7785206	8099870	8398241	8913478					11679042	11972391	12177318	12320198	12546182	12951120

Fuel Consumption and costs 1942 – 1948.

Data taken from the Ministry of Power Statistical Digest.

Fuel consumed in electrical generation in Tons.

Fuel	1942-43	1943-44	1944-45	1945-46	1946-47	1947-48
Coal and coke	20,866,003	22,696,489	23,399,270	23,030,941	25,963,222	26,147,636
Total oil fuel	18,204	14,592	18,658	19,992	38,613	44,238
Gas	1,825.8	1,421.7	1,293.7	4,323.396*	1,352.7	1,423.5

** This outlier is not explained in any of the records and may indicate a printing error.*

This table shows the increase in the amount fuel used for electrical generation. Between 1942 and 1948 the amount of coal used increased by over 6 million tons. The use of oil in electrical generation remained relatively stable throughout the war but increases dramatically in 1945-46 and had more than doubled by the end of 1948. In general, the use of gas for electrical production declines throughout this period, with the apparent exception of 1945-46.

Average costs of fuels per ton

Fuel	1942-43	1943-44	1944-45	1945-46	1946-47	1947-48
Coal and Coke	33s 6d	34s 9d	39s 5d	44s 3d	45s 9d	49s 4d
Oil Fuel	199s 2d	226s 7d	223s 6d	200s 8d	142 1d	160s 8d

This data indicates that as the demand for coal increased so too did the price. This can be measured against the cost of oil which increased throughout the Second World War, presumably due to the demand from the military. The cost of oil drops in 1946-47 before substantially increasing in 1947-48, presumably in response to the coal shortage. However, it should be noted that even with coal at its highest price in 1947, it is still over three times cheaper than oil. This is indicative of the high importance placed on maintaining the supply of electricity despite the economic cost.