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ARTICLE

Britain's First Net Zero: Turning the Lights On and the Railways Off 1953–73

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This paper assesses a major transition in energy usage and distribution in the United Kingdom (UK) between 1953–73 as domestic coal gave way to electricity, and a centralized electricity generation and distribution system reached every home in the country. Our analysis significantly extends and reinterprets the business history of the National Grid by exploring the consequences of its completion. We argue that the National Grid facilitated the removal of the railways as an energy distribution network and enabled prototype "Net Zero" policies in the context of atmospheric pollution. We tie these themes together to conclude that the construction of the national grid was a major environmental success but removed an essential rationale for much of the rail network.

Keywords: Energy; Networks; Net Zero

Introduction

Between 1953 and 1973, a rapid expansion of the British electricity grid allowed a revolution in domestic fuel use, positively impacting the environment and displacing other energy infrastructures. Nationalization facilitated the interdependent transformation of electricity, coal, and rail, allowing a new political economy in which the British Energy Authority, the British Railways Board, and the National Coal Board were able to operate as national entities with governmental-scale resources and a mandate to build a new national future.[1] We do not argue that their actions were perfectly synchronized and deliberate, but instead argue that the events we describe here were certainly contingent upon each other and frequently clustered together around coincident deadlines. Our arguments are a novel approach to these topics in

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1. Edgerton, *The Rise and Fall of the British Nation*, 281–282.

historical terms and one that explains the remarkable level of national resources devoted to the national grid.[2] In our times, it resonates with the current dilemma over infrastructure to support either hydrogen or battery vehicles and the controversies over Net Zero and Ultra Low Emission Zones.

Despite the pivotal and positive role played by the national grid in practically every aspect of British business and domestic life, there are surprisingly few recent systematic business histories of its development, and even fewer that look at the impacts and consequences. The creation and management of the national grid as a system and an organization is handled principally in two books by Leslie Hannah published in 1979 and 1982. Elsewhere, Martin Chick's more recent works on industrial policy examine the grid as part of a wider review of interwar corporations.[3] Moreover, he considers it as part of how policy affected resource allocation in the United Kingdom (UK) after 1951.[4] Like Hannah, Chick's perspective concerns the "commanding heights" of political economy, the ideas that influenced governments in making investment decisions over many decades, and how top civil servants and government ministers subsequently evaluated those decisions.[5] There are also half a dozen articles in engineering journals that briefly cover the development of the system holistically but whose focus is primarily on the technical solutions to specific engineering problems encountered in the construction and operation of the national grid.

In addition to their vintage and varying specificity, the literature merits a revisit because it does not address the consequences or the process of electrification. This situation contrasts with the profusion of literature about railways, coal, and, to some extent, motorways, especially in terms of their wider significance to British society.[6] We want to bring our understanding of the grid into line with other infrastructures and explore a fuller import of the national grid as a project that changed society, mostly for the better, but sometimes in unanticipated or unpopular ways. In this paper, we especially concentrate on the reduction of the railway network and the highly visible lessening of atmospheric pollution.

As evidence, we use a variety of records from the central government and nationalized industries associated with the transformation of the energy supply industry and pollution. These records are held in the National Archives at Kew in London and are organized on departmental lines. The papers of the nationalized coal industry are held under the reference COAL 31, and we have used the papers of the Chairman and Vice Chairman alongside the British Rail files involving the General Manager of the London Midland Region and the British Railways Board papers of Dr. Richard Beeching (AN 172 and AN18 series respectively) as well as the Director of Operations for British Railways (AN 183 series). The Ministry of Fuel and

2. Hannah, *Engineers, Managers and Politicians*, 139. The 1965 Interdepartmental Review of Fuel Policy, chapter seven, paragraph 21. POWE 58/38.

3. Chick, *Industrial Policy*, Chapter Six, 137–165.

4. Chick, *Changing Times*, 214–215.

5. Chick, *Electricity and Energy Policy*, 133–136.

6. The number of books and articles on coal and railways in Britain is too prolific to list here, but Terry Gourvish's series (1986, 2002, and 2008) is emblematic of the depth of study into railways while Barry Supple's work (1988), and William Ashworth and Mark Pegg (1986) and Henry Townsend-Rose (2017) do similar jobs among many others for the coal industry. Roads have attracted slightly less scholarship, but the three volumes on Britain's motorway achievement (2004, 2002, and 2008) offer both a detailed and panoramic view.

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Power papers cover energy policy development, especially concerning retail distribution (POWE 26 series) and electricity generation and distribution (POWE14 and POWE 58 series). Finally, we have also consulted the records of the Ministry of Local Government and Planning (HLG 51 Series) on the response to the poor air quality. For the administration of air pollution and smoke abatement, HLG 55 has proved useful.

We frame the railways in the mid-twentieth century as a socialized, universal energy distribution network for coal. The delivery of coal by rail ceased to be a primarily free market activity during the First World War.[7] Socialization arose via the nineteenth-century universal carrier obligations, the Railway Rates Tribunal, and then full nationalization in 1947. The movement of coal by rail was a highly complex and differentiated activity where 600,000 coal wagons and tens of thousands of small coal merchants operated out of station coal yards ranging from the colossal facilities at London termini to minor rural halts. Taken together, these elements formed a railway-based conduit through which energy was distributed across the UK from mines to domestic backyards, cellars, gas works, local power stations, and minor and major industries. We see the ubiquity and density of dispersal points and government control of pricing as an acknowledgment that the railways were, amongst many other things, an essential energy network that could not be shut off even if the activity was highly inefficient and unprofitable.

Therefore, one consequence of connecting all homes, including those in remote rural areas, to the national electricity grid during the 1950s and 60s would be that much of the national railway system became redundant. In early summer 1963, 18 months ahead of schedule, the Central Electricity Generating Board (CEGB) announced proudly that 85% of British farms in rural areas were now linked to electricity supply, an event symbolizing the more or less complete connection of all households across the British Isles.[8] In March 1963, the chairman of the British Railways Board, Dr. Richard Beeching, published his report "The Re-Shaping of British Railways" advocating the closure of roughly 2,400 stations and 8,000 kilometers of track. The report clarified that British Rail no longer intended to distribute individual wagon loads to a constellation of small coal yards.

This did not mean that railways stopped moving coal entirely. However, coal would now be distributed by "single consist" trains delivering entire loads to major concentration points or power stations.[9] The logical endpoint of this rationalization was the Merry-Go-Round trains that moved short distances between mines and power stations in the north of Britain. There, it would be converted into electricity that would then mostly flow south, a continuity in the pattern of national energy production and distribution, albeit via different systems.

The simultaneity of these announcements in 1963 by BRB and CEGB senior management was genuinely coincidental, but they were nevertheless closely contingent upon one another. The ability to switch lights, cookers, and electric heaters on meant domestic coal fires became discretionary rather than essential to daily life. Therefore, the uneconomic and inefficient delivery of domestic coal via thousands of small station yards lost its fundamental justification, as did much of the rail network.

7. See Standing Committee on Mineral Transport, HMSO.
8. Hannah, 210.
9. *The Re-shaping of British Railways*, 60.

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Yet there was another sphere beyond changing patterns of domestic energy consumption and transport in which the arrival of the grid also affected the daily lives of British people palpably. In the winter of 1952–53, London experienced a public health disaster caused by a dense fog of coal smoke known as "smog." The smog experienced by British cities was frequently so intense that visibility was reduced to a few meters and all traffic halted. As well as the severe inconvenience to movement, these sulfurous clouds of pollution were corrosive to human health and physical infrastructure alike. Arising primarily as the product of hundreds of thousands of domestic fires burning constantly through the winter months, they produced fumes and soot so acid and conductive that their accumulation on the national grid's urban electricity wires rapidly corroded the metal and caused flashovers after just a few hours.[10] We think that the move to electricity for cooking and domestic space heating in millions of homes[11] is an essential precondition to meeting the requirements of the Clean Air Act of 1956. This Act gave homeowners and industry in the newly created smoke-free zones seven years to cease emitting smoke, meaning that the deadline for compliance would fall in 1963. Again, the precise concurrence of the date with the CEGB announcement of full connectivity is a coincidence, but nevertheless indicative.

Before we close this introductory section, we should acknowledge that in national transformations as significant as the switch to electricity for domestic energy, the reduction of atmospheric pollution, and the removal of one-third of the national rail network, there are other factors and effects besides those mentioned above. Two of the most prominent are domestic gas and the growth of motorways and road vehicles. The development of gas supply is a complex and interesting topic that deserves its own study. For our current purposes, it played a relatively minor part in the 1953–73 energy transition for several specific reasons. The first was that between 1953–73 gas supply was principally via town gas.[12] The production of town gas depended on the hyperlocalized system of coal supply that the railways were keen to eliminate. They operated many different local systems at too low pressures to be suitable for nationwide distribution.[13] There was nothing comparable in the gas industry to the preexisting national electricity grid in 1949, and while much progress had been made by 1957, gas transmission remained in no way equivalent to the breadth of coverage and consequent capability to meet spikes in demand that the electricity system had already long achieved.[14] Town gas also relied on a quality of coal to generate gas that was significantly more expensive than the coal used to generate electricity.[15] It would have been technically very difficult for town gas to become a truly integrated national system, even if the costs had not been prohibitive.

By contrast, natural gas was a plausible nationwide alternative to electricity for domestic space heating, but it only became available in sufficient quantities with the discovery of the North Sea reserves in the mid-1960s, and the subsequent development of its potential lies mostly outside the timeframe of this paper. Finally, we note that there were major concerns

10. Forrest, "Early Days of the Grid," 687.

11. In 1953, 4,955 gigawatt hours of electricity were sold to domestic consumers for heating. By 1970, this had increased to 25,276 gigawatt hours (Hannah, 292).

12. POWE 58/38. Interdepartmental Review of Energy Policy 1964-65.

13. Wilson, 148; Hatheway, "Technical History of the Town Gas Plants of the British Isles," 3–4.

14. Manners, "Recent Changes in the British Gas Industry," 154–155.

15. Ibid, 161.

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over gas safety which made electricity preferable,[16] and the majority of consumer goods require electricity. All these factors made electricity overwhelmingly the dominant replacement for domestic energy 1953–73.

The rise in the number of registered vehicles, and the construction of motorways is another influence that we acknowledge. Though these developments had little impact on energy usage in the home, their impact on rail passenger traffic and light/medium, perishable, and manufactured goods delivery was significant. However, we argue that while lorries grew in number and weight, they were never considered a plausible means to move tens of millions of tonnes of domestic coal from mines to minor coal yards across the nation in the way that railways did. Furthermore, we observe that the motorway network arrived quite late compared to the National Grid. Earlier, we pointed out that the National Grid was declared essentially complete in mid-1963. We contrast that with the fact that the very first motorway in the UK had only opened in 1958. By the summer of 1963, there were just 373 km of motorway in the UK[17] Furthermore, we suggest that the system did not amount to a truly national network until the mid-1970s.[18] In summary, we recognize that many factors lie behind a national transformation in energy usage and distribution on the scale we are discussing here. Nevertheless, the factor we identify in this paper, the development and completion of the National Grid, has a good claim to be the most significant and relevant national phenomenon in the period we examine.

Therefore, focusing on 1953–73 as our period for analysis; and with nationalization as the catalyst for developments, we bring together three significant themes in our narrative. Firstly, the successful expansion of the national grid and transformation of domestic energy usage.[19] Secondly, the reduction and repurposing of the railway network, and thirdly the drop in visible atmospheric pollution following a public health disaster in London in early 1953. This new metanarrative concerning the wider significance of the national grid for British society offers a novel and relevant discussion for us today, as well as a considerably enhanced explanation of the exceptional level of national investment directed at the grid.[20]

Interwar Background

The rapid growth of the National Grid 1953–73 was possible because of extensive previous work in the interwar years which provided a skeleton national infrastructure and made the grid a proven technical and administrative concept. Electricity generation and distribution in the UK began late in the nineteenth century, following a similar pattern to earlier industries

16. Pearson, "Ronan Point Apartment Tower Collapse and Its Effect on Building Codes," 176.

17. The UK Motorway Archive, "Openings," accessed 18 September 2024, https://ukmotorwayarchive.ciht.org.uk/openings/.

18. Roads.org.uk, "Motorway Database, Chronology Maps," accessed 18 September 2024, https://www.roads.org.uk/motorway/chronology.

19. Between 1953 and 1973, the British daily generating capacity grew from 66 to 263k MW. Domestic daily consumption grew from 18 to 91k MW, overtaking industrial consumption. This rate of growth has not been equaled before or since. Department for Business, Energy and Industrial Strategy: Historical Electricity Data 1920-2021.

20. Hannah, 3.

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such as coal and railways which were disaggregated, localized, and technologically divergent.[21] The demands of the First World War revealed systemic weaknesses rooted in the industry's fragmented structures. In 1919, Parliament passed the Electricity (Supply) Act, which appointed a Commission to encourage local suppliers to form Joint Electricity Authorities.[22] However, mere encouragement proved ineffective. In 1924, there were 494 power stations in Britain, 207 of which produced less than 1 Mega Watt (MW), and only 13 could produce more than 50MW.[23] This miscellaneous collection of generating plants, in turn, powered a network of 386 alternating current (AC) systems, of which 288 operated 50 cycles per second and the remainder at a variety of other frequencies between 25 and 100 cycles per second. In addition, 191 networks used direct current (DC) systems. Some 563 different organizations managed this tangled web.[24]

In 1926, Parliament passed another Electricity Supply Act that created the Central Electricity Generating Board (CEB) and gave it powers to construct and operate a national transmission system.[25] By 1938, overall electricity production had quadrupled from 6.5 to 24 Terawatt hours (TWh), but the sources of generation remained fragmented. In 1948, there were still 200 private companies, 369 local authority undertakings, and nearly 300 power stations scattered around Britain.[26]

However, much had been achieved in the realm of distribution. Starting in 1927, the CEB began constructing a truly national grid capable of transmitting 132 Kilovolts (kV), which could then be transformed down to the 11, 22, and 66 kV local systems suitable for domestic and most industrial requirements. By 1933, there were 4,800 kilometers of 132 kV power line, supported by 26,000 pylons, 273 transforming stations, and 122 of the 300 power stations that the Board had selected as suitable for inclusion in the grid.[27] A basic national power system was now complete. The system continued to operate regionally until 1938, when unofficial experimentation revealed that it was, in fact, capable of operating as a national unit—the largest in the world at that time.[28] Between 1926 and 1939 domestic electricity usage grew eightfold from 0.75 to 6TWh.[29]

Despite World War II, domestic consumption continued to increase rapidly, reaching 9 TWh by 1945. It also sped up the Government's mind on the necessity of unification. In 1942, the Jowitt report into the electricity industry rejected voluntarism as the basis for making any progress with coordination and proposed nationalization.[30] Its justifications covered economies of scale, load factors, and other technical efficiencies. It also noted that the variation in pricing levels and distribution voltages across the multiplicity of different

21. For electricity, see Millward, *Diffusion of Electrical Power Technology*, 113. See also the coal and railway industry in Millward and Singleton, *The Political Economy of Nationalisation*, 45 and 117.

22. Snow, "The First National Grid," 215.

23. By comparison, the current generating capacity of the Sizewell B power station is 1200 MW.

24. GBR/0014/HINT/3/5. Speech to the British Electrical Power Convention, 1961.

25. Forrest, "Early Days of the Grid," 686.

26. Hannah, 7.

27. Snow, 219.

28. GBR/0014/HINT/3/5. Speech to the British Electrical Power Convention, 1961.

29. Department for Business, Energy and Industrial Strategy: Historical Electricity Data 1920-2021, https://www.gov.uk/government/statistical-data-sets/historical-electricity-data accessed 21 July 2023.

30. Chick, *The Political Economy of Nationalisation*, 269.

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electricity suppliers had irritated large numbers of domestic and industrial consumers, as pricing was opaque, and movement into different areas of AC- or DC-current-rendered equipment and domestic appliances useless.[31] This indicated that electricity was gradually assuming the position, like water, gas, and coal, of being regarded as a necessity of normal life and, therefore, nationalization would be "unlikely to excite any controversy."[32] The industry was nationalized in 1947, and by 1953 domestic demand for electricity had risen by almost 100% in eight years to reach 17.7TWh, compared with domestic coal use of 73TWh (Table 1).[33] The vertiginous rise of electricity was poised to overturn coal's long supremacy.

National Energy Strategy and the Postwar Expansion of the Grid

National energy strategy until the early 1950s was a frantic race to expand coal production, electricity generation, and distribution.[34] Within the electricity industry, there was an additional task of standardizing pricing and voltages.[35] In terms of other options, gas had neither the generating capacity nor the distribution network at this stage,[36] while oil was an import that Britain could either hardly afford or it was from regions slipping out of British control. Significant state investments in nuclear capacity had been focused on producing a British atomic bomb, though there were high hopes for domestic energy in due course.[37]

On nationalization, the Electricity Act stated that: "The main function [of the BEA] is to develop and maintain an efficient, coordinated and economical system of electricity supply… [the BEA] must promote the use of all economical methods of generating, transmitting and distributing electricity; secure, so far as practicable, the development and cheapening of supplies, and the extension of supplies to rural areas…Finally, it is the duty of the Authority to see that the combined revenues… are not less than sufficient to meet combined outgoings charged to revenue account taking one year with another. In other words, the national industry as a whole has to pay its way."[38] This allowed the industry to view its capital investments ex post, provided that its annual revenues met its annual operational expenditures, permitting a breakneck growth in physical infrastructure with little regard for opportunity costs.[39]

The determination to achieve growth can also be seen in how the industry's governance evolved over the 1950s. After nationalization, subsequent governments became concerned that the centralization of powers and responsibilities at the BEA was too great and that it was

31. Ibid, 268.
32. Ibid, 272.
33. Department for Business, Energy and Industrial Strategy: Historical Electricity Data 1920-2021 and Department for Business, Energy and Industrial Strategy: Historical Coal Data 1853-2021 https://www.gov.uk/government/statistical-data-sets/historical-coal-data-coal-production-availability-and-consumption accessed 21 July 2023.
34. Barnett, *Lost Victory*, 273–275, 279 and 282–285.
35. Ibid, 76–77.
36. Wilson, 148.
37. Hannah, 230–231.
38. British Electricity Authority, 11–13.
39. Chick, *Changing Times*, 20.

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Table 1. British energy production and domestic consumption 1953-73

Date	National coal production Annual millions of tonnes	Domestic coal consumption Annual millions of tonnes	Domestic coal consumption Equivalent annual TwH	National electricity production Annual TwH	Domestic electricity consumption Annual TwH
1953	227	38	73.2	61.6	17.7
1954	227	39	75.1	68.6	19.0
1955	226	38	73.2	75.3	21.1
1956	226	38	73.2	81.9	23.8
1957	228	36	69.3	85.5	24.9
1958	220	37	71.2	92.7	28.0
1959	210	34	65.5	98.9	30.5
1960	198	36	69.3	116.9	35.3
1961	195	34	65.5	120	39.0
1962	203	34	65.5	132.8	47.6
1963	200	34	65.5	162.7	54.5
1964	198	29	55.8	170.9	54.4
1965	192	29	55.8	169.6	57.2
1966	180	27	52	175.4	59.8
1967	178	24	46.2	181.1	62.4
1968	170	24	46.2	193.5	66.7
1969	156	22	42.4	206.4	72.2
1970	147	20	38.5	215.7	77.0
1971	154	17	32.7	222.9	80.7
1972	127	15	28.9	229.5	86.9
1973	132	15	28.9	245.4	91.3

Sources: Department for Business, Energy and Industrial Strategy: Historical Electricity Data 1920–2021, Coal Production 1853–2021, and authors' own calculations.

hindering the speed of the construction of new power stations.[40] In 1954 the Government commissioned a committee of inquiry into the Electricity Supply Industry (The Herbert Report). However, the Government did not wait for the committee to reach its conclusions, and in 1955, while the inquiry was still deliberating, it deprived BEA of its Scottish power generation and distribution facilities, devolving them to the Scottish Office. Holding on to residual English and Welsh responsibilities, the BEA was briefly reconfigured as the Central Electricity Authority (CEA), which lasted for just two more years. In 1956, the Herbert Report agreed that the Authority should be further broken up with a view to speeding the process of expanding generation capacity.[41] On 1 January 1958, the CEA became the Central Electricity Generating Board (CEGB), with responsibilities for generation and distribution, and the Electricity Council assumed oversight of the entire industry. Hannah comments that the reorganization allowed more autonomy for regional boards and new men like Sir Christopher Hinton to bring fresh ideas and dynamism to an industry that had become rather ossified under Lord Citrine.[42]

40. Hannah, 161–162.
41. POWE 24/16, The Report of the Committee of Inquiry into the Electricity Supply Industry, 1956.
42. Hannah, 186–187.

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Table 2. British energy distribution networks 1953–73

Date	The total railway network ('000 km)	The total national grid network including the 132kV network ('000 km)	The "super grid" 275kV network ('000 km)	The "super grid" 400kV network ('000 km)
1953	30.9	7.4	0.1	-
1954	30.8	8.0	0.1	-
1955	30.7	8.5	0.4	-
1956	30.6	8.9	0.8	-
1957	30.5	9.5	1.2	-
1958	30.3	10.1	1.5	-
1959	29.9	11.2	2.1	-
1960	29.6	12.1	2.4	-
1961	29.3	12.6	2.7	-
1962	28.1	13.1	2.9	-
1963	27.3	13.4	3.1	-
1964	25.7	14.1	3.2	-
1965	24	14.9	3.2	0.3
1966	22.1	15.8	3.1	1.3
1967	21.2	15.9	2.6	2.1
1968	20.1	16.5	2.5	2.8
1969	19.4	17.1	2.4	3.6
1970	18.9	17.7	2.5	3.8
1971	18.7	17.8	2.3	4.2
1972	18.4	17.8	2.3	4.3
1973	18.2	17.9	2.2	4.4

Sources: Department for Transport Rail Statistics, Table TSGB0601 (RAI0101); National Archives, POWE 15/26-30; The Institute of Engineering and Technology Library, BASE 621.311 CEN CEGB Annual Reports and Accounts 1958–73; The British Library, BEA Annual Reports and Accounts 1953–54.

The grid expanded by an average of just under a thousand kilometers a year in the decades 1953–73.[43] Moreover, the grid grew not only in scale but also in capacity as the 275kV and 400kV "supergrid" grew from nothing to 25% of the network over the same period (Table 2). Generating capacity also rose by an average of 7 percent annually, producing roughly 60TwH in 1953 to just over 245TwH in 1973 (Table 1). After 1953, except for the unusually harsh winter of 1962–63, at no point did generating output fall beneath the maximum load.[44] Given that domestic electricity consumption expanded five-fold in the period (Table 1) we consider meeting this demand to be no mean achievement. The rate of investment into electricity generation and distribution remained at a remarkable average of between 8 percent and 11 percent of the UK's entire fixed capital investment over two decades,[45] averaging £8 billion of investment expenditure in current terms annually (Table 3). This resulted in a 40 percent rise in the thermal efficiency of power stations and the construction of 30 brand new plants of over 300MW[46] 1953–63 is also evidence of the successful application of technological innovation (Table 4)

43. British Electricity Authority, 8–9. There are interesting parallels to the railways, where 50 percent of stations generated just 2 percent of revenues. Beeching, *The Re-shaping of British Railways*, 66.

44. Ibid, 291.

45. In 1953 there was just one power station capable of generating more than 320MW.

46. Hannah's figures on p. 139 suggest an average of 8 percent. The 1965 Interdepartmental Review of Fuel Policy estimates 10–11 percent. Chapter seven, paragraph 21. POWE 58/38.

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Table 3. Investment by the British Electricity Authority, the Central Electricity Authority, and the Central Electricity Generating Board 1953–73

Date	2021 Real project cost[a] (annual £ billions)
1953	5.5
1954	6.5
1955	7.1
1956	6.6
1957	6.8
1958	7.4
1959	8.4
1960	8.3
1961	8.6
1962	9.4
1963	11.3
1964	11.8
1965	12.3
1966	12.9
1967	11.3
1968	8.7
1969	6.9
1970	7.5
1971	3.5
1972	3.4
1973	3.2

Source: National Archives POWE14/2308 Capital Investment Review in the Electricity Industry 1970.
[a] The real project cost comparator compares cost to an index of all output in the economy using a GDP deflator.

However, while the underlying commitment to electricity remained constant, there were some strategic debates. The Government's 1965 fuel review examined gas, nuclear, and oil as alternative fuels, coal to generate electrical energy centrally at power stations, and domestic coke and gas as potential direct domestic supplements. The discussion in the government papers and annual reports reveals why coal-fired power stations and domestic electricity became and remained supreme in our period.[47] Simply, the costs of atomic energy escalated immensely, dependence on the Middle East meant that the security and continuity of oil supply could not be guaranteed, and coke could not be produced at sufficient volume or an acceptable price. This left gas. As we have noted, the Government was prepared to make limited investments in expanding an expensive network, but it was only the discovery of natural gas in the North Sea in 1965 that made this a fuel for a plausible universal and integrated system at a future point.[48] Therefore, electrical generation and distribution remained paramount, and investment flowed accordingly. Such a phenomenal expansion in a national infrastructure necessarily had consequences that went beyond the obvious and the immediate. We now examine two of them: the reconfiguration of the railways and the disappearance of visible atmospheric pollution.

47. Edgerton, 294.

48. POWE58/38, Interdepartmental Review of Energy Policy 1964-65; POWE14/822, Capital Investment Programmes in the Electricity Supply Industry 1955-60; POWE14/2308 Capital Investment Programmes in the Electricity Supply Industry 1970; POWE 28/275, The next seven years in the field of UK energy supply (1957); BASE621.311CEN series, CEGB Annual Reports and Accounts 1958-73.

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Table 4. The generating power and thermal efficiency of British power stations 1953–73

Date	Total power stations	<10 MW	Between 10–80 MW	Between 80–320MW	>320MW	Average thermal efficiency (%)
1953	287	111	98	76	2	23.4
1954	291	107	101	80	3	23.8
1955	276	88	97	88	3	24.3
1956	274	78	97	94	5	24.9
1957	262	63	90	100	9	25.5
1958	253	55	82	106	10	26.1
1959	234	40	71	104	19	26.5
1960	230	36	67	104	23	26.8
1961	233	36	68	103	26	27.3
1962	236	33	68	103	32	27.4
1963	233	-	-	-	-	27.7
1964	233	-	-	-	-	27.5
1965	230	-	-	-	-	27.3
1966	226	-	-	-	-	27.5
1967	201	-	-	-	-	28.0
1968	216	-	-	-	-	28.3
1969	193	-	-	-	-	28.3
1970	187	-	-	-	-	28.4
1971	183	-	-	-	-	28.9
1972	174	-	-	-	-	29.8
1973	169	-	-	-	-	30.6

Sources: The Institution of Engineering and Technology Library, BASE 621.311 CEN CEGB Annual Reports and Accounts 1958–73; The British Library, BEA Annual Reports and Accounts 1953–54.

Railways Change from a Universal to a Concentrated Energy Distribution Network

It is easy to visualize electrical energy transmission as seamlessly, directly, and constantly flowing along wires from power stations to the consumer. By contrast, a supply of solid fuel to consumers is necessarily via more iterative, individual, and distinct loads. Nevertheless, it can be helpful to view Britain's former railway network similarly as another dense system of lines along which energy was constantly running to even the most minor destinations in the country: an endless, flowing transmission belt for coal.[49] Railways are now understood and debated in policy terms fundamentally as passenger carriers, either via high-speed, long-distance routes or as short-distance but intensive urban commuter networks. Freight is only a niche capacity.[50] This is far removed from railways' early nineteenth-century origins, which were symbiotic with coal and whose traffic largely determined the shape, pattern, and operation of the British network.[51]

49. Edgerton, *The Rise and Fall of the British Nation*, 81.

50. Great British Railways: The Williams-Shapps Plan for Rail. "Our Promise to Passengers and Freight Customers," 10–11, HMSO, 2021. The last coal train load to a power station was delivered to Ratcliffe on Soar on 28 June 2024. The UK's last coal-fired power station set to close http://www.bbc.co.uk/news/articles/ckgn4gg5y2yo accessed 3 October 2024.

51. Kitsikpoulos, *An Economic History of British Steam Engines, 1774-1870*, 250-53; AN18/9. Speech by Dr Beeching to the Coal Industry Society, March 1962, 1.

Along with railways linking mines to thousands of small towns and villages, this energy network also depended on a very numerous, fragmented, and variegated community of approximately 27,000 retail coal merchants. They were attached to the roughly 6,000 railway coal depots distributed across virtually every part of Britain, and in 1953, merchants still sold 38 million tonnes of domestic coal annually, a total similar to previous decades.[52] British Railways calculated that each coal depot was, on average, 5km away from the next depot on the same line and 8km away from another depot on a separate line, thus serving an average area of just 20 square kilometers.[53] Of those 6,000 depots, 4,000 handled less than 100 tonnes of coal per week, and another 1,000 locations handled 100–250 tonnes per week. Amongst the merchants, half of the 27,000 in Britain sold less than 20 tonnes of domestic coal weekly, at rates that varied widely across the country and in bespoke quantities and qualities that defied attempts at mechanization and rationalization.[54]

By 1959, the British Railways Board was well aware that supporting this hyperlocalized retail system was very inefficient and inhibited what it termed the "pruning of unremunerative services" and "drastic rationalisation."[55] An area study on domestic coal traffic begun in the late 1950s by the London Midland Region of British Railways was reported in detail in 1961.[56] Its findings were simple: (1) The true cost of lost "demurrage"[57] in coal transit to the railways was severe (2) The conditions in the coal trade did not encourage investment. (3) The impact of the Clean Air Act and the incursion of alternatives [electricity] in domestic space heating were being felt, and merchants believed it would cause considerable shrinkage of tonnages handled. (4) Large mechanization schemes were not practical, especially in handling domestic coal.

The merchants handled no less than 36 different types and grades of domestic coal, making standardization and bulk loads impossible.[58] The report concluded, confidentially, that the trade would need to be concentrated on a very few large depots, and small stations and branch lines should be shut. It noted: "To achieve savings in full, it is necessary that the whole of the stations on the line of route cease to deal with freight… [and] where the abandonment of the stations and railway works associated with it… [are] a branch line which could be closed, further savings are possible."[59] We see this investigation into the problems of domestic coal as an embryonic Beeching report. It even contained a series of maps highlighting which stations and coal depots should become concentration points and, by implication, which stations, depots, and lines could, therefore, be shut.[60]

52. AUJO 5/5 Minister's Speech to Coal Merchants, May 1956.

53. Ibid, 4.

54. POWE 28/107. Report on the Future Organisation of Solid Fuel Distribution: The Retail Trade in Coal, July 1945, 3 and 25.

55. MT115/280. Reappraisal of Railway Modernisation Plan and Progress Towards Financial Break Even. British Transport Commission Report, July 1959, 7.

56. AN172/9. British Transport Commission. Future Policy for Handling Domestic Coal Traffic. Joint Investigation into the Concentration of Coal Traffic 1961.

57. The National Coal Board used the railways' huge fleet of roughly 500,000 16-tonne coal trucks as a free storage facility.

58. Ibid, Meeting Minutes from 3 July 1961.

59. Ibid. Joint Investigation into the Concentration of Coal Traffic 1961, 2.

60. AN172/11. The Martech Inquiry. Coal Concentration on the Midland Region 1960, maps one and two.

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Eighteen months later, the new chairman of BRB addressed the Coal Merchant's Federation of Great Britain: "The important question is how long will we have to wait while alternative means of handling [coal] traffic are found? Here, the best service I can do for you is to impress on you the answer: not very long. Selective closure of stations handling coal must proceed at an accelerating rate from now on. Several thousand ought to be closed in the next five years, and ten years' time there should only be a few hundred."[61]

While the highly profitable coal traffic had been the main raison d'etre for much of the development of the railway network during the nineteenth century, its contribution to revenues became more ambiguous in the twentieth century. As profitability declined, long-term concerns about the value of the assets tied up in the universal provision of coal transport by rail and its operational effects on the whole network grew. The private owner wagon became disliked by railway traffic managers, as they were used for coal storage, not just in colliery sidings but across the entire network at local goods yards everywhere. The wagons blocked sidings and slowed and complicated all other railway operations. They also had to be taken back empty to their source colliery or trader who owned them. The railways made much of this, claiming that such wagons should be pooled, although there was little in the way of traffic that could be used as a return load. These wagons were also subjected to demurrage, and rental for the wagon standing in the siding under load, and this was continued into the period of public ownership. In 1958, this detained wagon charge was nine shillings per day for two days, then rose to ten shillings per day thereafter.[62] British Railways did not believe this covered the true cost of their operations and claimed that they were underwriting the National Coal Board (NCB) by providing cheap storage facilities.

Getting the correct coal into a grate or under a boiler required both complex material handling and transportation. Coal was extracted and graded at the pithead for sorting into wagons. The summer period saw coal stored for the winter period in wagons at sidings, to be transported when demand arose during the winter months. When the wagon was called for delivery, it was rare that the train would run directly to the customer; it usually had to be marshaled in yards and taken into other trains for delivery. Therefore, part of the energy transition story is associated with investment in new railway technology, especially wagons, within the context of a declining market and how they were employed. The many critics of railway operations – including those who investigated these issues for the Duckham Committee in the late 1920s – believed that nationalization of the railways would be the solution.[63]

Duckham was established out of the Sankey Commission on the coal industry and was charged with investigating the underlying economics and operations of coal haulage. There were three rail recommendations: Firstly, a 20-ton wagon, as opposed to 10 or 12-ton ones, should be standardized. Secondly, pooling all privately owned wagons should be the norm, and there should be higher demurrage charges to encourage a quicker turn round of wagons. The gist of the report was that getting rid of private owner wagons

61. AN 18/12. Address by Dr. Beeching to The Coal Merchants Federation of Great Britain, January 1963, 2.
62. Monk-Steel, *Merry-Go-Round*, 17.
63. Duckham Committee Standing Committee on Mineral Transport, Cmd. 3420.

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and increasing their size would enable the railway to regain efficiency. The committee skated over the expense of storing coal on the ground as a factor driving its storage in wagons.[64]

Although these ambitions were partially realized through nationalization and reequipping new rolling stock, by the 1950s railway managers had realized that a system based on the distributions of hundreds of thousands of small loads could never realize the required efficiencies.

Nevertheless, the report began a chain of innovations in rolling stock, eventually leading to the MGR system. In the interwar period, the haulage of coal was in wagons standardized by the Railway Clearing House and, for the most part, privately owned by collieries, coal factories, and, in some cases, customers. Both the Great Western Railway and London North-Eastern Railway attempted to build wagons of larger capacity of 20 tons and over, but these fell foul—literally—of inadequate colliery sidings and were unable to be used with existing port loading facilities for the still considerable export trade. Progress of sorts was made when, in 1938, a new all-steel wagon rated at 16 tons was built for the London Midland and Scottish Railway. The new British Railways adopted this as a standard, and between 1945 and 1949, 70,000 of these were built. This was supplemented by the construction of 25,000 21-ton coal hoppers, based on an LNER design, with automatic vacuum brakes. These were used to replace the aged coal wagons built for private customers.

While the ubiquitous distribution of small-scale loads of coal and its attendant inefficiencies was out of favor with railway management, this did not mean that all coal transportation was loss-making. The General Classification of Goods developed as a framework for regulated pricing included an explicit cross-subsidy between high-value and low-value products, and this carried on until nationalization and into the 1960s. This was redesigned due to the 1921 Railway Act, with the railway companies meeting through the Railway Clearing House and implemented via a Railway Rates Tribunal. Coal traffic was placed in a low classification in 1928, benefitting colliery owners but harming railway balance sheets. But by the 1950s, high-value merchandise diminished significantly because of road competition "skimming the cream" of general merchandise traffic. Indeed, it may well be the case that by the 1950s coal was relatively more important to the railway than had been the case in the interwar period.

This view was articulated by Gilbert Walker, a professor of economics at the University of Birmingham who authored a 1937 book, *Road and Rail*, which examined the economics of these two modes of transport and, in particular, how the mechanism of price setting led to different outcomes. The classification-based railway schedules of freight charges were based on cost proxies and a notion of product value – the so-called "what the traffic will bear." Road haulage was unregulated and based on cost plus price setting and a free permanent way, although road tax was a general tax supposed to cover road use. The 1921 Railway Act provided for a Rates Tribunal and devised a new classification. The former was continued postnationalization, and the latter was redesigned, but the foundational principles remained the same. The classification puts high-value products further up the classification than low-

64. Duckham Committee Report, 42.

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value products. Coal and mineral traffic were thus placed in Classes 1 to 4. As Walker noted: "High-classed high-rated merchandise was traditionally supposed to provide the higher margins over direct costs out of which were found the contribution to overheads and net revenue."[65] Walker went on to state that he did not understand "how the relationship of costs to rate stands as between high- and low-classed goods." Furthermore: "The railways had always considered that high profit went with high rates. But low-classed merchandise is also cheap to carry. Coal, minerals, and heavy merchandise move, it is true, at rates less than the average of all receipts per ton-mile and at rates which are less than road hauliers could afford. But these traffics move in full truck and often in train loads and require no handling. Traffic in these classes constitutes over two-thirds of the total ton-mileage hauled by rail and contributes one-half of the gross revenue from freight. I should not be at all surprised to find, contrary to received opinion among railwaymen and many others, that the cream lies at the bottom of the railways' bottle and not on the top".[66]

This was supported by Gourvish, whose cost analysis associated with the preparation of the Modernisation Plan for British Rail in 1955 revealed that surpluses on coal and mineral traffic were covering losses[67]. He further notes that by 1959, coal and coke revenue was £111.5m with direct costs of £68.9m, giving a surplus of £42.6m. Even after a deduction of £18.9m in joint costs, there was still a surplus of £23.7m. This compares with general merchandise revenue of £101m and direct costs of £126.6m, giving a loss of £23.6m even before the allocation of £25.5m of joint costs[68].

These calculations showed that localized coal and general merchandise distribution could now be axed, but high-volume, standard-quality coal could be hauled in endlessly circulating train loads from specialized yards to the large, new coal-fired power stations in a profitable way. The Chief Operating Officer at BR, Gerald Fiennes, pushed this idea to maximize the efficiencies of large volume, single-consist, freight distribution. The introduction of this technology required coordination across the supply chain from NCB at the collieries BR transportation and the CEGB at the destination. As an example, a major investment of 550 24.5-ton hopper wagons was pending to operate between Monktonhall Colliery in Scotland and a new power station at nearby Cockenzie. Fiennes redid the calculation based on MGR principles and determined that a mere 44 wagons of 32.5 tons would suffice, representing a colossal efficiency saving. His approach to the CEGB was successful in that they agreed to proceed with the required infrastructure on all of the new coal-fired power stations, together with a redesign of some existing facilities. According to Fiennes, BR's approach to the NCB was "less clever" and it seems to have been Beeching's attempts to obtain payment for the new assets that was to blame. Fiennes noted, "we ran foul of a cross current" that delayed progress for 5 years.[69] This was exacerbated by what Stewart Joy called the "tri-lateral monopoly" of BR, the NCB, and CEGB, who had to negotiate a settlement where only two, BR and CEGB, would benefit.[70]

65. Walker (1953) Transport Policy Before and After 1953, *Oxford Review of Economic Papers*, Vol. 5, no 1.
66. Walker, *Transport Policy*, 98.
67. Gourvish, *British Railways*, 194–195
68. Gourvish, *British Railways*,195.
69. Fiennes, *I tried to Run a Railway*, 81.
70. Joy, *The Train That Ran Away*, 71.

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This can be seen in files that trace the relationship between the NCB and BR. Beeching attempted to obtain a £40 million pa payment from the NCB, which would allow the latter to recover from a four-shilling increase in coal prices and for BR to benefit from the return of road deliveries to rail. The NCB was not impressed, and an analysis by Sir Derek Ezra noted that Beeching was only interested in making BR pay “without regard to the economies of other industries or to the general public interest.”[71] In a later note, Ezra observes that Beeching’s own senior traffic officers seemed to understand the NCB’s position.[72] Eventually, the introduction of MGR was achieved by giving rebates on coal hauled to both the NCB and CEGB, depending on how much capital investment was forthcoming to develop terminal facilities. For example, in July 1963, the CEGB was offered a rebate of 4d per ton for the use of MGR and an additional 4d per ton for using 32-ton wagons.[73]

The infrastructure base that had sustained a model of universal distribution was redundant, and remodeling it was essential. Table 5 shows the steady decline in all traffic, especially the high-value general merchandise. Nationalization facilitated a confluence of policies and technologies that led to a shift in how coal was to be transported. The centralization of power generation and distribution from a grid was an opportunity for the railways to rationalize, the need for which had predated Beeching.[74] However, taken in conjunction with the completion of the nationwide electrification scheme, these factors significantly facilitated Beeching’s confidence in suddenly accelerating the rundown of the rail network.

Beeching could be confident because universal domestic electrification meant that objections to rail closure through Transport User’s Consultative Committees were unlikely to raise the loss or cost of domestic fuel as an unbearable social hardship argument to prevent closures. This confidence was vindicated, as when the “Re-shaping of British Railways” report and the TUCCs discussed hardship, it was considered overwhelmingly from the perspective of passenger amenity rather than energy supply. Substituting buses for trains was generally deemed a sufficient solution.[75]

In summary, nationalization allowed three major industries, electricity, coal, and the railways, to transform the scope of their activities in relation to one another. The construction of the national grid was the essential enabler of the closure of much of the national

Table 5. Gross freight receipts (excluding interest)

Date	General merchandise (£ millions)	Minerals	Coal and coke	Total
1953	108.8	45.2	109	253
1960	89.8	48.9	108.6	247.5
1961	88.9	43.1	104.8	236.8

Sources: COAL 31/61 Memo 5 April 1952 and BTC Reports and Accounts 1961.

71. COAL 31/61 Record of Meeting with Beeching 5 April 1962.
72. COAL 31 61 Memo British Railways Rationalisation of traffic 6 July 1962.
73. AN 183/93 br Boars Memo Williams to Margett 9 July 1963.
74. COAL 31/61 Note to Chairman 14 February 1961.
75. See Loft, 214–215 and Faulkner, 55–57.

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railway system. We portray this major socioeconomic event as the substitution of one energy distribution network for another. Coal henceforth moved in mass over relatively short distances by rail within the north of Britain, while domestic energy continued to mostly flow south as it had before, but via pylons rather than rails. We think that the historiography of these events has understandably but mistakenly focused exclusively on passengers and stations. An improved understanding lies in recognizing the significance of changing networks of pylons and coal yards.

The Grid Enables the Clean Air Acts and the First "Net Zero"

Atmospheric pollution from industry and domestic fires only began to be systematically measured in Britain after 1912.[76] In 1921, the Newton Committee reported that 2 ½ million tonnes of soot from domestic fires and 500,000 tonnes of soot from industrial processes were emitted annually in Britain. Power stations were particular targets of public irritation because of the high volume of grit that their chimneys emitted, but as a 1932 report by the Electricity Commission pointed out, 60 percent of atmospheric pollution in Britain was caused by domestic fires and only 40 percent by industry. Of that 40 percent, electricity generation was only a fraction of overall industrial activity.[77] Due to their relatively low burning temperature, domestic fires were a particularly inefficient combustion method and often burned low-quality coal continuously from October until around April every year. The result was that tar, sulfur, sulfur dioxide, ash, and grit combined in periods of anticyclonic weather to form a very dense, yellowish-gray, and slightly acidic smog in major cities, rendering travel almost impossible and causing cumulative damage to buildings as well as severe ill health.[78]

Atmospheric pollution gained decisive traction in the political agenda during 1953. Between 5–9 December 1952 an exceptionally thick smog settled over London, with concentrations of particulates in the air rising from 0.49mg to 4.46mg per square meter.[79] At the time, the Government attributed excess deaths from December 1952 to March 1953 to influenza, but subsequent research suggests that some 12,000 additional deaths in that period were attributable to air pollution.[80] MPs raised Parliamentary questions about atmospheric pollution on 22 and 27 January, 24 February, and 18 and 31 March 1953. They disbelieved the Government's mortality figures and contemptuously criticized the sum spent on research into the phenomenon.[81] In April 1953, the Times newspaper published a series of articles demanding action. It called for a 10 percent reduction in coal consumption generally, coal washing, improvements in grit filtering at large industrial enterprises, and replacing low-grade domestic coal with smokeless coal.[82] In response, the Government set up the Beaver Committee in

76. Mosley, *Measuring and Monitoring Air Pollution in British Cities, 1912-1960*, 274.
77. POWE 14/123. Electricity Commission Report on the Measures Taken in This Country and Others to Obviate the Emission of Soot, Ash, Grit and Gritty Particles from the Chimneys of Electric Power Stations, 1932.
78. Luckin, *The Heart and the Home of Horror: The Great London Smogs of the Late 19th Century*, 34.
79. Laskin, *The Great London Smog*, 43.
80. Bell et al., *A Retrospective Assessment of Mortality from the London Smog Episode of 1952*, 8.
81. Hansard. Atmospheric Pollution (Research) Debate, Volume 511, Column 1913.
82. The Times, Polluted Air Over the Towns, 21 April 1953.

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the summer of 1953, which produced an interim report at the end of that year. The committee's full report arrived a year later, in November 1954. It called for a new and more powerful Clean Air Act to supersede the insufficiently stringent powers of the existing Public Health (Smoke Abatement) Act 1936 and envisaged an 80 percent reduction in smoke emissions in the UK by 1970.[83]

The Government soft-pedaled the Beaver Committee's recommendations until backbench MPs proved determined to introduce a private members' bill of their own,[84] forcing the Government into action. The new Clean Air Act became law on 5 July 1956. The Act's opening provision was simple: "dark smoke shall not be emitted from a chimney of any building, and if, on any day, dark smoke is so emitted, the occupier of the building shall be guilty of an offence."[85] In addition, Section Eleven allowed local authorities to declare their districts to be a "smoke control area" in which any type of smoke, dark or otherwise, was prohibited. Nevertheless, the Act also contained a long list of exemptions. It allowed the owners of coal fires up to seven years—until 1963—to have time to take action and gave them the right to claim various forms of necessity in defense of continuing to produce smoke.[86] Importantly, homeowners could also claim at least 70 percent of the cost of any necessary adaptations to dwellings from a combination of the local Authority and central government.[87]

The Act was not so generous to industry. The majority of its clauses related to restrictions governing the height of chimneys, fuel types, and the design and control of furnace emissions. This did not make much sense, as research had shown that the majority of smoke pollution was caused by domestic coal fires burning inferior fuel at comparatively low temperatures.[88]

However, placing the burden of alleviating smoke pollution on industry did help manage public opinion. We argue that public opinion strongly favored cleaner air as a general concept but that the public's consent to legally enforced smoke-free zones hinged on specifics, namely the price and availability of alternatives to the cheap, poor-quality fuel they were accustomed to burning. The conditional nature of this consent can be seen in the long series of derogations granted in the first Clean Air Act, a succession of scare stories run in the national media in the early 1960s,[89] and the relatively slow progress of smoke-free areas apart from those in London 1956–63.[90]

Smoke-free coke and town gas were the Government's preferred substitutes for consumers' poor-quality cheap coal, but industry insiders were skeptical from the outset. In 1955, the Coal Merchants Federation of Great Britain questioned the capacity of the coke-producing industry to meet demand and the Government's ability to pay for infrastructural improvements that would support a transition to gas. It doubted there would be sufficient supplies of either form

83. Brimblecombe, *The Clean Air Act after 50 years*, 311.
84. Sanderson, *The National Smoke Abatement Society*, 205–251 and Mister, *Britain's Clean Air Acts*, 270.
85. The Clean Air Act 1956, Section 1(1).
86. Ibid, Sections 1(2) – 1(5) and 2.
87. Ibid, Section 12(1)
88. POWE 14/123. Response of the Electricity Division to the Times' article of 21 April 1953.
89. POWE 58/33. White Paper on Domestic Fuel Supplies and the Clean Air Policy, Part One. Press Reactions, January 1964.
90. Mister, 272. Chick, *Changing Times*, 259.

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of energy to be a realistic alternative.[91] We argue that universal access to cheap, reliable electricity was the key factor in making a clean air policy not just desirable, but credible and viable.

By 1963, smoke particulate emissions in the London area had dropped by about 50 percent after the 1956 Act (Table 6). However, London was prosperous and had been unusually well connected to the national grid since the 1930s.[92] Across the entire UK, the picture was very different. Nationally, demand for domestic coal fell 11 percent between 1958 and 1963. However, this disguised a significant difference, where demand fell by only 1.5 percent in "northern" Britain and 31 percent in "southern" Britain.[93] Smokeless zones were particularly difficult to establish in areas where miners were entitled to so-called "concessionary coal." Often of poor quality, it was coal that miners received as payment in kind from their employers to heat their homes.[94] In 1963, around 1.5 million of the 6.7 million targeted households were in smoke-free districts. These 1.5 million households were overwhelmingly in the south (London), and the Government judged progress at this point to be far too slow to reach 80 percent emissions reduction by 1970.[95] To make matters worse, figures from the time show that the production of smokeless coke substitutes for coal had stalled[96] Moreover, even if they had been available, a government report conceded that: "It is inconceivable that open fire fuel at this cost would be an acceptable compulsory replacement in wage earners homes in the [northern] areas which have been accustomed to cheap house coal."[97]

We think that no further significant progress towards smoke reduction could be achieved in the face of public and media disquiet about both the price and future shortages of coke substitutes for coal.[98] While the coke industry was confident about maintaining existing supply, it could not guarantee that future increased demand could be met.[99]

At the time of the 1963 deadline, the Government was aware that progress had been made in reducing coal fires, above all due to a huge increase in electricity usage for domestic purposes (Table 7).[100] It helped that between 1953 and 1963, the price of electricity remained stable,

91. HLG 55/76. The Coal Merchant's Federation of Great Britain Views on the Report of the Beaver Committee, paragraphs 9 and 13, 1955.

92. HLG 51/587. Electric Power Stations and Proposed New Stations for England. Central Electricity Board Map of the Complete Scheme of Transmission Lines, 1948.

93. POWE 58/34 White Paper on Domestic Fuel Supplies and the Clean Air Policy, Part Two. Coal Utilisation: The Domestic Market, paragraph 7. "Northern" and "Southern" Britain were divided by a line running from the Bristol Channel to the Wash.

94. Moseley, *Cleaning the Air*, Policy Paper, https://www.historyandpolicy.org/policy-papers/papers/clearing-the-air-can-the-1956-clean-air-act-inform-new-legislation accessed 11 April 2024.

95. Ibid, paragraphs 8 and 9.

96. COAL 31/34. The 1963 Coal Board report on domestic fuel supplies and clean air attributes this to reductions in town gas production and states that there will be a shortage of smokeless fuels after 1965, rising to 2 million tonnes a year by 1970, 1–2.

97. Ibid, Minutes of the Conference on Coal Distribution, 2.

98. The Daily Mail, Smokeless Fuel Shortage, 18 December 1963; The Telegraph, Clean Zones Short of Fuel, 13 August 1963 and The Times, Coke Scarcity Impedes Smoke Control, 17 December 1963.

99. POWE 58/33. White Paper on Domestic Fuel Supplies and the Clean Air Policy, Part One. Coal Merchants Federation of Great Britain Report, Change in Clean Air Policy, 1964.

100. Consumption doubled between 1956 and 1963, changing from representing a third of its coal energy equivalent to almost matching it.

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Table 6. Average atmospheric pollution in the inner London area 1956–73

Date	Soot particles (micrograms per cubic meter)	Sulfur dioxide (micrograms per cubic meter)
1956	310	340
1957	280	310
1958	250	280
1959	220	280
1960	200	300
1961	180	325
1962	160	350
1963	140	370
1964	120	330
1965	100	300
1966	90	250
1967	80	210
1968	70	220
1969	65	190
1970	60	185
1971	60	190
1972	50	150
1973	40	140

Sources: Brimblecombe, Peter. "The clean air act after 50 years." *Weather* 61, no. 11 (2006): 313 and authors' own calculations.

while the price of gas rose by 10 percent and coal rose by 30 percent.[101] Nevertheless, the doubling of the number of electrical storage heaters in the UK in 1956–63 still seems puzzlingly excessive if this was done on cost-benefit grounds alone. A government review explains this mystery: "Although calculations show electric space heating to be expensive, they cannot allow fully for the attractions of flexibility, cleanliness, convenience and safety of the direct electric appliance."[102] Electricity had a social status that went beyond a rational assessment of its benefits. A combination of pricing, available infrastructures, safety, and the ubiquity of appliances allowed electricity to win the competition with gas for consumers in the period 1953–73. In later decades, gas would become the obvious choice for domestic space heating, but in 1965, only 2.5 million British homes had central heating of any type.[103]

We surmise that when homeowners or landlords found themselves in a newly created "smoke-free zone" they were reasonably willing to convert to electricity, reasoning firstly that much of the capital cost would be recoverable via the Local Authority and secondly that improvements to their home's mains capacity dovetailed with the general growth in desirable white goods such as refrigerators, cookers, and televisions. However, the majority of British people were social housing tenants. Here, the change was involuntary. Councils cleared old slums and built new homes and flats with mains electricity, but fewer fireplaces or none at all.

101. POWE 58/38 Interdepartmental Review of Fuel Policy 1964-65. Trends in fuel prices 1930-1965.

102. Ibid, section seven, paragraph 31.

103. Hanmer and Abram, *Actors, Networks, and Translation Hubs: Gas Central Heating as a Rapid Socio-Technical Transition in the United Kingdom*, 178–180.

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Table 7. Domestic fuel consumption in Britain 1956–63

	Solid fuel (million tonnes of coal equivalent)		Nonsolid fuel (million tonnes of coal equivalent)		
Date	Coal	Smokeless Coke	Oil	Gas	Electricity
1956	38	5	1	9	15
1958	37	5	2	9	17
1960	36	5	3	8	21
1962	34	6	3	9	28
1963	33	6	4	9	31

Sources: POWE 58/34 White Paper on Domestic Fuel Supplies and the Clean Air Policy. Actions Arising Following Publication Part Two, and authors' own calculations.

But this compulsory loss of fireplaces did not appear to cause much resentment per se. When asked, what tenants wanted was more sockets for their consumer durables.[104]

We recognize that consumers' ability to purchase or hire white goods depended on a rollercoaster of hire-purchase controls, income tax and interest rate fluctuations, and periodic wage freezes that characterized the period's "stop-go" economic climate.[105] Nevertheless, we think there can be no doubt of three things: Firstly, irrespective of changing controls, ownership of white goods rose spectacularly.[106] Secondly, electricity was essential to use the vast majority of new consumer goods.[107] Thirdly, possession of such goods was synonymous with modernity, prosperity, cleanliness, changing work patterns, and social prestige.[108] Chick suggests that these social influences were so pervasive that many conversions to electricity were voluntary.[109] Furthermore, as we saw earlier, the immense investment and growth in new local authority housing during the same period firmly pushed occupiers towards electricity as flats and houses were all fitted with plug sockets as standard.[110] Over and above providing these facilities, local authorities allowed their tenants' handbooks to include advertisements for radios, refrigerators, televisions, vacuum cleaners, and cookers.[111]

The results of all these multiple influences can be seen in Table 7 where domestic electrical consumption grew to almost equal coal by 1963, whereas consumption of all other fuels remained stable or negligible. Looking to the future, the 1964 government review noted that the electricity industry, encouraged by the Ministry of Power, was stimulating the development of cheaper and more flexible storage heaters and that further growth in electricity demand was to be expected, and, by implication, even encouraged.[112] By 1973, domestic energy consumption of electricity was three times that of coal (Table 1).

104. Hollow, *The Age of Affluence Revisited*, 283.
105. Dell, *The Chancellors*, see Part Two: Downhill All the Way, 207–370.
106. Hollow, 283.
107. Offer, *The Challenge of Affluence*, 176.
108. Mosely, *Selling the Smokeless City*, 207.
109. Chick, *Changing Times*, 261.
110. Hollow, 282.
111. Ibid, 284.
112. POWE 58/38 Interdepartmental Review of Fuel Policy 1964-65, paragraphs 26 and 34.

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The fact that electricity increased its share of the energy market reflects both price and nonprice competitive advantages vis-à-vis both gas and coal.[113] Despite a quasi-romantic perspective vis-à-vis open fires, we argue that solid fuel was an inferior good compared with both gas and electrical energy: its monetary price understated its true cost to the consumers since it entailed significant transaction and operating costs these other energy sources avoided.[114] Solid fuel required episodic physical deliveries with ordering and handling costs and demands on the consumer's time. Solid fuel also required secure and dry storage, and then physical movement to the points where it was burned. Once burned, the ashes and waste needed to be removed, stored, and then disposed of safely.[115] Using solid fuel was less convenient in "setting fires": arranging the fuel and its kindling in its combustion chambers, setting the fire to burn efficiently, and then physically managing its combustion for the greatest effectiveness—regularly stoking the fire to maximize the heat, or "banking" fires to minimize fuel consumption while maintaining the fire during less active periods, such as overnight. Using solid fuel was a labor-intensive process: both gas and electricity were available with no transactions, delivery costs, or effort needed, rather than discrete deliveries of solid fuel that imposed physical workloads and storage requirements of both gas and electricity were continuously available with their usage constantly metered. Their use required nothing more than the flip of a switch or turn of a dial; or, in the case of gas sometimes, the simple lighting of a readily lit flame.[116] There are commentaries in which consumers complain about the difficulties of using coal fires in their households. Safety was an additional nonpecuniary benefit over energy sources dependent on open-flame combustion. With roughly two-thirds of energy consumption devoted to heating the benefits arising from shifting to more convenient modes were significant.[117] The substitution of electrical and gas energy for coal required investments in new heating systems and technologies. Fouquet and Pearson observe that "tangible service benefits…especially at the early phases of transitions…."[118] were significant nonprice considerations driving energy demands. The consumer transition away from coal was facilitated by the earlier installation of electrical systems for lighting and powering domestic appliances.

A multilevel perspective[119] recognizes the effects of electricity's competitive advantage in its flexibility. As noted above, consumers wanted more outlets within their homes—the benefits of an extensive distribution network applied not only at the macrolevel National Grid but even more powerfully within the microlevel home distribution "network" where every room could have multiple connection points for a wide variety of uses. Electric space heaters allowed much greater flexibility in providing heating dispersed throughout a household—Standards of comfort meant not just more heat but also more heated spaces and rooms.[120] Small domestic appliances were exclusively powered by electricity and provided households

113. Fouquet and Pearson, 2.
114. Rudge, 6–9.
115. Beaton, 80.
116. Kuijer and Watson, 82.
117. Ibid, 77.
118. Fouquet and Pearson, 4.
119. Bolton and Foxon, 540.
120. Kuijer and Watson, 78; Shove, 276; Rudge, 9.

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with more convenient and effective cooking (toasters and electric kettles), cleaning (vacuums, washing machines), leisure (radio and television, lighting for reading), and other activities impossible using solid fuel and gas (such as the refrigeration or freezing of perishable foodstuffs.) The increasing consumption of electrical energy was contingent on the manufacture of domestic appliances, and that industry grew in parallel with and complemented the supply system as Mayers[121] describes the significant growth and differentiation within the British domestic appliance industry.

Electrical energy enjoyed a symbiotic relationship with societal developments: it enabled social change, and those changes increased its demand.[122] These developments were driven not only by individuals within their own, private households but were also very significantly implemented by local governments with their programs building social housing. In the period, 1953–73, literally millions of homes were built by local authorities throughout the UK; often replacing older homes being demolished.[123] These developments were guided by design principles that specified energy provision recognizing its existing, likely, and desired uses. The point is that these houses were designed and constructed to improve the lives of their residents with lifestyle changes reflected in the provision and use of energy. Kuijer and Watson trace the effects of local authorities acting as social reformers within their housing plans and designs.[124] They emphasize the impact of local and national housing associations "…progressive pursuit for *a spatial separation of domestic functions….*"[125] Notably, where prewar houses typically concentrated many domestic activities in one room later technical developments facilitated the movement of heating-dependent activities throughout the house with dedicated kitchens, bathrooms, living rooms, and bedrooms. These rooms could be quickly and easily heated using gas or electricity when needed when earlier coal-fired heating was impractical.[126]

To conclude, the problem of atmospheric pollution had a long antecedence as a political issue, and the public favored cleaner air as a general concept. However, persuading the public to bear the cost of specific actions to do something about it required both the 1953 public health disaster and a truly ubiquitous, cheap alternative energy source appearing across the UK via the national grid. It was true that smokeless coke was also proffered as an alternative, but while it was congruent with existing energy infrastructures, it was also expensive, and there were public anxieties about supply which the industry could not fully allay. These concerns, combined with a rapid rise in consumer prosperity that culturally equated electricity with status and modernity, meant that conversion to electricity proved much more popular from the outset than had been expected.[127]

When the Government paused to review progress towards its 80 percent smoke reduction target in 1963–64, it realized that electricity had become twice as large a source of domestic energy as all other nonsolid fuel types put together and that it was the only alternative to coal

121. Mayers, 23.
122. Bolton and Foxon, 539.
123. Fouquet, 145.
124. Kuijer and Watson,79.
125. Ibid, 80; Carlson-Hyslop, 99.
126. Ibid, 81.
127. COAL 31/34. The 1963 Coal Board Report on Domestic Fuels Supplies and Clean Air, 8.

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with a truly nationwide distribution network. Electricity had picked up the majority of the domestic demand arising from reducing coal and meeting the demands of the new patterns of consumption.[128] This would be the shape of developments going forward as well. We argue that without the national grid, a smoke-free Britain would have remained a perpetual "good idea" that the public liked in principle but was either resigned to it not being practically obtainable or took fright when the specifics of the costs to them as individuals were made clear to them.

Conclusions

On 28 June 2024, GB Railfreight delivered the final coal train to a British power station from the port of Immingham to the Ratcliffe-on-Soar power station in Nottinghamshire. Immingham itself was opened in 1912 in association with the Great Central Railway and was built expressly for the export of coal. The power station began generation in 1968 as part of the expansion of centralized generating capacity. This event marked the end of coal as a means of energy production on a nationwide scale in the United Kingdom.

The symbolism of this event was mostly unnoticed, but in this paper, we have brought together three complex narratives arising from the construction of the national grid into a single story to explain a major historical transition in British energy use and distribution. This major transition is oddly unacknowledged and undiscussed in current debate both in social terms regarding "Net Zero" and its impacts on how we live, as well as in general historical terms where we think that energy distribution networks' impact on events is underdiscussed. Therefore, we would hope this paper stimulates future work, in the UK and abroad, on the relationship between railways, electrification, and freight, as well as the direct consequences for consumers and society at large in Britain. There is much potential to learn from the interaction of energy generation, transport, and consumption. From a policy perspective, the period of the 1960s is critical as coal, oil, nuclear, town, and North Sea gas were all in transition, and the decisions made during this period shaped the sector for decades afterward. Furthermore, our analysis underlines the importance of understanding the relationship between transport and energy especially the constraints and complementarities that exist in the investments that shape the underlying infrastructure. For example, the role of coal distribution by rail and then road prior to 1939 would help us understand the relationship between the domestic and business markets and how these were managed. The emergence of petroleum in the first half of the twentieth century, both for vehicles as well as power generation, also relied initially on rail distribution and a new set of operational, distribution, and storage assets. A comparative approach here would facilitate an analysis of the emergence of global as well as national supply chains.

In national terms, we have assessed the generally unpopular implications of this energy changeover for the railways and the more desirable significant reduction in atmospheric pollution. The result is a wide-ranging analysis of the National Grid as a countrywide

128. Ibid, 9.

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development that changed the way everybody lived from new and radical perspectives that, with hindsight, we judge to be clear but do not appear to have transitioned into business history or, indeed, wider social, political or economic history to any great extent. We believe that nationalization enabled the visible, though not direct, synchronicity between the progress of the Electricity industry, the plans of the National Coal Board, and the strategy of the British Railways Board which transformed the nature of their interdependence on one another. In particular, the NCB and BRB have converted into capital-intensive industries. In the background, Government legislation via the Clean Air Act lent encouragement and a certain amount of coercion to the process.

This brought about some of the most profound changes to how people lived in Britain in the twentieth century over a relatively short period, the 20 years between 1953 and 1973. Moreover, those changes altered not just daily life but the physical landscape of the whole country. Physically imposing lines pylons appeared across the countryside, and thousands of railway stations lapsed from busy and sometimes grand centers of communities into dereliction. Smog vanished from the cities, and handsome buildings eventually emerged from under their coat of physical grime. These changes have been variously lauded and resented as the results of technological progress, scheming or inept politicians, and growing consumer affluence. Few people, then or now, seem to have connected all these events and realized that they were experiencing the transition from one national energy infrastructure to another.

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