

# **The genesis of the electricity supply industry in Britain: A case study of the NESCo from 1889-1914**

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## **Abstract**

A study of the NESCo provides a micro-history of the emergence of the electricity supply industry in Britain up to the First World War. This research examines the role of social capital in the establishment and growth of the NESCo, the only financially successful British electric power company. Temporal bracketing was adopted to evaluate two distinct time periods: emergence from 1889-1899; and growth from 1900-1914. Family, business and social networks together with geographical and political factors secured the company's dominant position. The structural relationship with Merz & McLellan contributed to growth through acquisitions, joint ventures, and access to new markets.

Keywords: NESCo, industry emergence, electricity supply industry, social capital

## **1. Introduction**

The study of the emergence of new industries has been 'relatively neglected' by researchers.<sup>1</sup> The emergence stage in the life cycle model is the time period following the commercialisation of the product and immediately before the growth stage.<sup>2</sup> One reason for the dearth of research is a lack of cogent theories of entrepreneurship at the micro-level.<sup>3</sup> This means that emerging industries are not easy to study and are often not identified until after they have matured.<sup>4</sup> Forbes and Kirsch argued that economic and sociological theories have focused on explaining industry evolution over their lifespans.<sup>5</sup> However, this research has not been set within a historical context and has generally excluded the period prior to industry emergence where important decisions are made about technologies and business models that impact on the evolution of the industry.<sup>6</sup>

Kirsch et al. suggested that a historicist perspective (which recognises that industry knowledge is contextually embedded) could be helpful to researchers for understanding decisions, choices and agency in the development of industries.<sup>7</sup> Many firms and industries have extensive historical archives which could be used for testing theoretical propositions across various stages of an industry lifecycle.<sup>8</sup> These historical sources and methods could provide insights into issues not addressed by extant theory.<sup>9</sup>

This research has drawn upon an extensive and well-preserved archive to investigate the emergence and growth of the electricity supply industry in Britain by examining the establishment and

expansion of the Newcastle upon Tyne Electric Supply Company (NESCo). The NESCo was selected as a case study because it was a pioneer in a new industry and before the First World War had established the largest integrated power system in Europe.<sup>10</sup> Further, it was the only financially successful British power company during this period.<sup>11</sup> Previous research has examined the development of the electricity supply industry in Britain which has included a description of the growth of the NESCo.<sup>12</sup> However, this earlier research was based on limited company documents because according to Hannah: 'The archives of NESCo do not appear to have survived'.<sup>13</sup> The researchers in this case have had access to company documents which has enabled them to document and examine the strategy pursued by the NESCo from its establishment in 1889 to 1914.

In this paper, we draw upon the role of social capital in personal and business networks to examine their impact on the emergence and growth of the NESCo.<sup>14</sup> A network is a potent asset that provides a firm with access to information, knowledge, capital, power and other networks.<sup>15</sup> There is, however, less agreement on how networks impact on the development and growth of an enterprise.<sup>16</sup> Some researchers have argued that strong ties contribute to firm growth during the emergence stage.<sup>17</sup> Elfring and Hulsink qualified this assertion by arguing that new companies pursuing radical innovations benefit from strong ties during the opportunities discovery process, whilst weak ties are important for acquiring legitimacy.<sup>18</sup> Social capital performs an important role in small firm networks, but little is known on how it contributes to company growth.<sup>19</sup> Our aim is to address this research gap by examining the role of social capital in the emergence and growth of the NESCo. In particular, the research assesses the influence of social capital and its dimensions<sup>20</sup> on two phases in the NESCo's development: (i) the emergence period from 1889 to 1899 and (ii) the major investment boom in the electricity supply industry from 1900 up to the outbreak of war in 1914.

This study is organised into six sections. After the introduction the concepts of networks and social capital are discussed. In the third section, we outline how the case analysis was conducted. The fourth section briefly outlines the birth of Britain's electrical supply industry. Two distinct phases in the development of the NESCo are examined: the emergence period from 1889-1899 and the growth period from 1900-1914. The latter section discusses how the company expanded through traction, economies of scale and acquisitions. The final section summarises the contribution of the research to advancing our understanding of emerging industries.

## **2. Networks and Social Capital**

An entrepreneur's personal and social networks are the most important resource at the start-up phase of a firm.<sup>21</sup> Social capital comprises both the network and the assets accessed through the network.<sup>22</sup> The social capital that an entrepreneur gains access to through his/her personal network builds legitimacy for the firm, provides access to other actors' resources, information and knowledge, and the opportunity to identify and exploit opportunities.<sup>23</sup> To Bourdieu, 'social capital is the sum of the resources, actual or virtual, that accrue to an individual by virtue of possessing a durable network of more or less institutionalized relationships of mutual acquaintance and recognition'.<sup>24</sup> The three main, albeit interrelated, dimensions of social capital are structural, relational and cognitive.<sup>25</sup> The structural dimension of social capital comprises an individual's network of ties which includes the density, connectivity, centrality and hierarchical nature of the

relationships. Individuals accumulate and acquire access to resources through their networks.<sup>26</sup> The relational dimension includes respect, friendship, trust, obligations and expectations. The potential benefits for an actor stems from the nature of the relationships that they have with others in the network.<sup>27</sup> Finally, the cognitive dimension of social capital refers to shared interpretations/language and systems of meaning among the various parties.<sup>28</sup>

Hite and Hesterly argued that to attract resources and mitigate environmental uncertainty firm networks evolve from mainly identity-based links during emergence to calculative based connections during early growth.<sup>29</sup> They defined identity based networks 'as egocentric networks that have a high proportion of ties where some type of personal or social identification with the other actor motivates or influences economic action'.<sup>30</sup> Strong, embedded ties are associated with trust and the exchange of fine-grained information between partners.<sup>31</sup> Calculative networks are characterised by "a greater majority of weak ties that are more market-like than socially embedded...."<sup>32</sup> Research findings are ambiguous on whether strong or weak ties are more beneficial to entrepreneurs.<sup>33</sup>

Granovetter argued that novel information is more likely to flow through networks where actors are connected through weak ties as opposed to those where there are strong personal ties.<sup>34</sup> Burt contended that bridging the structural holes in sparsely connected networks provided the entrepreneur with access to new ideas and opportunities.<sup>35</sup> Social capital emanating from strong ties was deemed less valuable because the information provided was homogeneous and redundant. Granovetter subsequently reviewed his position and reasoned that in uncertain environments entrepreneurs were more likely to rely on strong as opposed to weak ties.<sup>36</sup> Uncertainty impacts on how firms select network partners. Alvarez and Barney distinguished between entrepreneurs' decision-making in a discovery context (characterized by risk) with that made in a creation context (characterized by uncertainty). In the former case, information is available to assess the risks of exploiting a business opportunity, whilst in the latter case information is sparse and decisions are likely to be based on heuristics, biases, or inductive, iterative, and incremental processes such as effectuation or bricolage.<sup>37</sup> An entrepreneur is likely to use the yardstick of 'acceptable losses' as part of their judgement criteria in a creation context.<sup>38</sup> Hmieleski et al. found that weak ties were more valuable in discovery (stable) as opposed to creation (dynamic) contexts.<sup>39</sup> Companies may seek network benefits by developing an optimal mix of strong and weak ties.<sup>40</sup>

### **3. Research Method**

Kirsch et al. argued that particular aspects of industry emergence and development are omitted from social science models of industry evolution.<sup>41</sup> For example, the pre-history stage before product commercialization including decisions about technologies, applications and business models which could impact on industry evolution. How is industry knowledge ordered and re-ordered? The recording of firm behaviour is based on retrospective sensemaking as opposed to real-time observations. Theoretical myopia excludes alternative interpretations by shaping and re-ordering data to satisfy extant social scientific theory. Kirsch et al. stated that there is 'real value to using historical evidence to test and elaborate existing theory'.<sup>42</sup> The NESCo case provides an opportunity to examine the choices made by organisational actors and the factors that impacted on inception and growth.

The researchers drew upon data from a wide range of sources including books on the electricity supply industry.<sup>43</sup> Forbes and Kirsch argued that 'historical archives represent a critical and under-

exploited resource for the study of emerging industries'.<sup>44</sup> The NESCo archive contained board minutes, ledgers, company reports and accounts, and various company documents which enabled the researchers to document the development of the company. A privately published history of the Merz & McLellan Company included information on the family background and career of Charles Merz. The authors had access to Charles Merz's notes written for his family which contained his personal perspective on his training, work experiences, the people he met, and the development of the electrical supply industry in the North-East of England. Charles Merz produced technical papers and articles on power generation which outlined his vision for the industry. The researchers used these various sources to triangulate and validate the data.

The researchers followed the approach advocated by Langley for analysing process data.<sup>45</sup> First, we constructed a narrative on the establishment and growth of the NESCo from 1889 to 1914. Second, a temporal bracketing strategy was adopted to separate the data into two distinct time periods: (i) company emergence from 1889-1899; and (ii) the growth strategy from 1900-1914. According to Langley, temporal decomposition permits 'the constitution of comparative units of analysis for the exploration and replication of theoretical ideas'.<sup>46</sup> The first period focuses on the NESCo as a lighting company, whilst the second period examines its new strategy as a power company. These strategies were analysed in sequence in order to investigate the role of social capital in the company's emergence and growth.

#### **4. The British electrical supply industry**

The birth of the electricity supply industry stemmed from Faraday's discovery in 1831 of electromagnetic induction whereby electricity could be generated from mechanical power. During the following decades the dynamo or early forms of electric generators were developed. Arc lighting was installed in the Blackwall Lighthouse in 1857.<sup>47</sup> The intensity of arc lighting made it suitable for this type of application, although an experiment at the South Foreland Lighthouse in 1858 found that it was three times more expensive than oil.<sup>48</sup> The concept of carbon arc lighting was demonstrated by Sir Humphry Davy in 1808, but it was not commercially applied until the late-1870s when companies such as Brush, Cromptons and Siemens produced economical dynamo and arc-lighting sets.

Lighting in homes during this period came from candles, paraffin lamps, and in urban areas, gas light. Electric arc light beams were too intense for domestic use whilst gas provided poor quality illumination.<sup>49</sup> This problem was resolved when Joseph Swan demonstrated his incandescent light bulb in Newcastle upon Tyne in 1878 and obtained a patent for his invention in 1880.<sup>50</sup> Edison had also produced an incandescent lamp using similar scientific principles. Swan initially produced 25 candle power (c.p.) lamps but he reduced them to a luminous intensity of 16 c.p. to match the incumbent and deeply embedded gas lighting. Incandescent lighting offered significant advantages over gas lighting because it was 'cleaner, did not vitiate the atmosphere or blacken decorations'.<sup>51</sup> By the early 1880s many companies were established to exploit arc and incandescent lighting systems.

The passage of the Electric Lighting Act of 1888 amended the 1882 Act by extending private enterprises' tenure of central power stations from 21 to 42 years. This was expected to lead to a

large increase in demand for power generation equipment.<sup>52</sup> However, the two Acts still left the municipalities in a strong position, and some hindered applications from companies for local franchises in order to protect their municipal gas businesses.<sup>53</sup> There was therefore limited electrical street lighting in Britain because of the strong competition from gas, and the electrical industry consequently operated on a small-scale in a small market.<sup>54</sup> Technically, it was 'little more than a collection of huts and basements with clanking reciprocating steam engines supplying lamps within a relatively small radius, providing challenges to the intellect of the engineer and an expensive, luxury illuminant for consumers, but with few spin-offs affecting the life and work of the nation in any significant way'.<sup>55</sup>

## **5. The growth of the NESCo**

During the emergence phase electricity was produced in company installations or in small inefficient generating stations. Steam engines were widely used for producing power. In 1889 the NESCo was a local lighting company supplying an area of 10 square miles which, by 1900, had increased to just 16 square miles.<sup>56</sup> Thereafter, with its re-emergence as a power company, the NESCO expanded rapidly aided by Parliamentary legislation which granted power companies the right to supply electricity over larger areas. This enabled the NESCo and its associates to establish by 1911 a network of interconnected transmission lines to supply three-phase alternating current at 40 cycles to 1,400 square miles in the North East of England.<sup>57</sup> The difference between the northern and southern extremities of the transmission system was 70 miles.<sup>58</sup>

### ***5.1 Period 1: The emergence of the NESCo from 1889-1899***

Two rival companies were established in Newcastle in January 1889 to supply electricity for lighting: the Newcastle upon Tyne Electric Supply Company (NESCo) and the Newcastle and District Electric Light Company (DisCo). Parliament allocated to both companies the same areas of supply in Newcastle. Representatives from the two companies met to discuss possible arrangements. The NESCo had ruled out an amalgamation because of the presence of London directors on the DisCo board and of being bound to any particular system (alternating current versus direct current).<sup>59</sup> An agreement was concluded whereby the NESCo would supply the eastern part of the city and the DisCo, one of whose directors was Charles Parsons,<sup>60</sup> would concentrate on the western part. The benefit of this arrangement was that it 'saves useless expenditure of capital which would be involved in the laying of two sets of mains in the same streets and the consequent additional interference with the public thoroughfares'.<sup>61</sup>

Dr Theodore Merz and Dr Robert Spence Watson formed the NESCo as a lighting company following the passage of more favourable legislation in 1888.<sup>62</sup> The social and cultural capital of the two men played an important role in the company's formation. They were brother-in-laws and both were Quakers. Theodore Merz was an intellectual of German origins who wrote a four-volume History of European Thought in the Nineteenth Century. He was also a chemist and industrialist who had invested in Joseph Swan's incandescent light company.<sup>63</sup> Merz was married to the sister of John Wigham Richardson who was a leading shipbuilder on the River Tyne.<sup>64</sup> Robert Spence Watson was a solicitor and an important public figure in the North of England. He was the Chairman of the National Liberal Federation and became a Privy Councillor in 1907.

The NESCo was incorporated on 8 January 1889 with a small paid up capital. On 29 March 1,889 shares were allotted to the amount of £8,850. To obtain a license from the Board of Trade to maintain electricity works in Newcastle required the support of the Corporation. It could be argued that the NESCo's formation was very opportune as local authorities were not actively engaged in electricity supply because its success had not been demonstrated.<sup>65</sup> The NESCo operated under a license for three years until it obtained Provisional Orders through an Act of Parliament. In return for the Corporation withdrawing its opposition to the granting of Provisional Orders, the NESCo agreed to supply and distribute electricity in Newcastle for thirty-one years as opposed to the forty-two years fixed by the Act of 1888.<sup>66</sup> As the production of electricity became successfully established, the local authorities entered the industry in the 1890s. In some cases buying out on favourable terms the operations of the private companies. The Newcastle Corporation considered purchasing the NESCo in 1895 but was dissuaded from doing so because the company charges were low, there was a competing company that would also have to be purchased, and the savings would not be large.<sup>67</sup>

The board of directors comprised men from some of the most important industrial concerns in the North East of England who provided the critical mass of structural and financial capital to establish the company. These directors included: the chairman Alderman Thomas Gibson (Mayor of Newcastle in 1882); Dr John Theodore Merz; Dr Robert Spence Watson; Sir Lindsay Wood (Managing Director of Hetton Collieries and Chairman of the Durham Coalowners' Association); John H Armstrong (Armstrong family and later Chairman of the NESCo); and Sir James Knott (shipping magnate who established the Prince Line Company in 1895, and a coal owner). These directors' social and cultural capital provided the legitimacy to establish the NESCo in the market. Additionally, the directors provided cognitive capital in the form of managerial expertise and knowledge of their industry domain, and structural capital by affording access for the provision of electricity.

A power station containing two 100-cycle 75 kilowatt Mordey alternators, each driven by a Robey slow-speed steam engine was built at Pandon Dene close to the Blythe and Tyne branch of the North Eastern Railway. Additional alternators were later installed of which the largest was 500 kilowatts. The directors were convinced that there was a large demand for electricity for lighting. However, with little pre-existing information available and operating in a creation context with uncertain market conditions, the directors adopted a flexible strategy. A capital outlay of £8,000 was invested to supply electricity for lighting for 4,800 ten (reduced to eight) candle power lamps of which 3,000 could be alight at any one time. Electricity was supplied to consumers at a price range from 3.6d (pence) to 4.5d per kWh which with discounts averaged out at 4d per kWh.<sup>68</sup>

The NESCo was able to grow through the financial support provided by the Chairman, Thomas Gibson, and the legal advice of Robert Spence Watson.<sup>69</sup> Table 1 shows that from 1891 to 1899, sales grew from £4,000 to £17,000 whilst net profits increased from £1,000 to £6,000. Finance was provided from local sources in the North East of England. Equity grew from £20,000 in 1891 to £64,000 in 1898 and then £115,000 in 1899 whilst debentures of circa £15,000 to £25,000 were held until their repayment in 1899. The NESCo profited from the Newcastle Corporation's lack of interest in becoming a supplier of electricity, and the north bank of the Tyne comprised small municipal districts.<sup>70</sup> There was available locally an abundance of cheap bituminous coal. Further, Tyneside had a dense industrial base and many regional companies had been progressive in adopting electricity. The shipbuilding industry was booming.<sup>71</sup> Shipbuilders were early adopters of electricity and many Tyneside shipyards had installed electric power by the 1890s.

### **Insert Table 1** The NESCO extracts from Financial Statements, 1891-1914 (£000)

In 1898 the Newcastle Corporation filed a Bill in Parliament to erect a generating station to supply electricity to the tramways. The NESCo and the DisCo opposed the Corporation's Bill on the grounds that their Provisional Orders gave them the sole right to supply electricity within the Parliamentary boundary.<sup>72</sup> However, their case was rejected and the opportunity to expand into traction was lost.

The development of the electric motor now enabled electricity previously restricted to providing lighting to be used for power.<sup>73</sup> Unfortunately, the lighting companies' ability to supply this market was constrained by the small-size of the generating stations, the smallness of the area that they supplied under the Provisional Orders, and the liability to be purchased by the municipality. These constraints were removed following the recommendations of the Cross Committee (1898) and the Kitson Committee (1900). The companies, nevertheless, complained that these disabilities were removed only to be replaced by new constraints. Power companies received authorisation to provide a bulk supply in areas where there were no authorised distributors, but they were excluded from supplying in areas where there was an authorised distributor unless they received the latter's consent. This consent could not be unreasonably withheld if the company could supply at a cheaper rate to consumers. Large towns were excluded from the power companies' areas because of the opposition of the municipalities.<sup>74</sup> This policy change shaped the strategic thinking of the NESCo directors.

At the end of 1899, the NESCo had 'an antiquated system of supply, difficult to extend and one from which it was impossible to supply motive power'.<sup>75</sup> Its system was out-of-date and the Pandon Dene station was too small and supplied lighting to a small area of Newcastle.<sup>76</sup> Between 1889 and 1900 the NESCo had increased the area that it supplied with electricity from 10 to 16 square miles.<sup>77</sup> A sum of £130,000 had been invested in the old system but it was plagued by constant faults and interruptions to supply.<sup>78</sup> In response, the management invested £100,000 in laying a new direct current system and extending the Pandon Dene Power Station.<sup>79</sup> There was a growing demand for electricity for lighting especially in the metropolitan areas and electricity was replacing steam power in some large factories. The application of electricity for traction was similarly increasing. Electrical generating plant had improved considerably as well as the methods for transmission of current. Competition from the DisCo was more intense. The NESCo's strategic choice to meet the potential increase in demand was to develop a larger scheme, or to 'merge our small undertaking into the larger organisation which was being planned to embrace the whole district'.<sup>80</sup> In the winter of 1899, the directors made the strategic decision to transform the NESCo into a power company.<sup>81</sup> The problem was that none of the directors had the knowledge of how to develop a district wide scheme.<sup>82</sup>

### **5.2 Period 2: The Growth of NESCo 1900-1914**

In response to the Corporation's Bill, and the more favourable environment for power companies, the NESCo and the DisCo strategies focused on developing schemes to supply electricity for general power purposes. Charles Parsons and Alan Campbell Swinton<sup>83</sup> filed a Bill to Parliament under the name of the Tyneside Electric Power Company to supply the whole of Tyneside. If the Parsons' Bill was successful, the NESCo would in the interests of its shareholders have had to consider merging into the larger organisation.<sup>84</sup> This is where the family and Quaker connections were to play a crucial role.

John Wigham Richardson was a shipbuilder who had established the Neptune Works on the River Tyne. He was also a director of the Walker and Wallsend Gas Company which had pioneered the use of gas for industrial purposes along the north bank of the River Tyne. Wigham Richardson had experience of the application of electrical power in shipbuilding and in 1898 he encouraged the Gas Company to enter into the electricity supply business. This would provide the company with insurance to focus on whichever energy source became predominant.

Charles Merz, Theodore's son, was engaged in a consultancy capacity to present the technical evidence to the Parliamentary Committee. He was 24 years old. Charles Merz read engineering at Armstrong College but never graduated. Instead he took an apprenticeship with the NESCo and in 1892 began work at the Pandon Dene generating station where he gained experience of electrical generation, installation, and repairing boilers and faults in generators and cables.<sup>85</sup> He spent part of his apprenticeship at Robey's to increase his mechanical knowledge of boilers. Merz then joined Thomson-Houston (BTH), an American subsidiary where his father was a director, to supervise the installation of steam engines and alternators at the Bankside Power Station on the Thames in London. From 1896 to 1898 he worked on the construction of a new power station at Croydon where he was responsible for the installation of generating equipment and the workings of substations and street-lighting systems. On its completion, Merz was appointed manager and engineer and was accountable for operating the plant and electricity sales. After a brief period at BTH headquarters arranging subcontracts for equipment, he was sent to Cork in 1898 to install a tramway system. Charles Merz had accumulated considerable human capital through experience and practical learning from his various work placements. He had developed a keen interest in the application of electricity for power purposes.<sup>86</sup>

Family connections provided Charles Merz with his first major break as John Wigham Richardson was his maternal uncle. Parliament passed the Bill in 1899 on condition that the Neptune Bank site which had been purchased for the provision of gas was used. Charles Merz turned down the position of chief electrical engineer to the Gas Company, but agreed to supervise the construction and development of the Neptune Bank Power Station as an independent consulting engineer. He recruited William McLellan as his assistant. They had worked together on developing a tramways and lighting system in Ireland for the Cork Electric Tramways and Lighting Company.<sup>87</sup> McLellan was an engineering graduate from Liverpool University. He had previously worked at Cochran, the boiler manufacturer, and Siemens. The two men formed a formidable team: 'Merz was a man of imagination and drive and financial acumen.... Whilst McLellan.....was the severely practical man, with a wide knowledge of all the electrical apparatus, from dynamos and motors to switchgear and cables'.<sup>88</sup>

The Gas Company had similar ambitions to the NESCo to supply electricity to Tyneside. Theodore Merz, John Wigham Richardson together with Charles Merz and William McLellan devised a rival scheme to that being proposed by Charles Parsons and Alan Campbell Swinton. This involved connecting the NESCo system to the Gas Company's Neptune Bank Power Station to supply the north bank of the Tyne.<sup>89</sup> The close family ties helped to cement the agreement between the two companies. Robert Spence Watson's law firm took on the legal work associated with promoting the Private Bill.

In 1900 a Parliamentary Committee chaired by Sir James Kitson considered the two rival Bills. The NESCo case relied on the legal advice of Robert Spence Watson, the expert witness of Charles Merz, and the legal counsel who had previously defended the Newcastle Corporation's position. Sir James Kitson was both a Liberal Member of Parliament and a Unitarian. He was also a member of the Institution of Civil Engineers and the Institution of Mechanical Engineers and had a very good understanding of industrial supply issues compared to the average politician.<sup>90</sup> Kitson was also a director of the North-Eastern Railway Company.<sup>91</sup> Charles Merz believed that the case put forward in support of the Tyneside Bill was ill-prepared which led to it being rejected.<sup>92</sup> The NESCo-Walker scheme received Royal Assent paving the way for the NESCo to supply electricity to districts on the north and south banks of the River Tyne.

The Pandon Dene Power Station was too small to meet the increasing demand for electricity for lighting and the new growing demand for power purposes. Additional generating plant was required which led to the NESCo purchasing from the Gas Company the incomplete Neptune Bank Power Station. Under the agreement the NESCo agreed to sell bulk electricity to the Gas Company for supply to its customers. The acquisition of the Gas Company's electrical undertaking was more for strategic than revenue purposes '.....it is no doubt been the correct policy for the Company to obtain entire control of it and thus avoid any risk of the progress of electricity being prejudiced due to the Gas Company having both a Gas and Electricity Department'.<sup>93</sup>

Charles Merz was appointed the Consulting Engineer to the NESCo.<sup>94</sup> In 1901 McLellan's name was incorporated into the name of the new firm now known as Merz & McLellan. That year Merz & McLellan was tasked with linking the NESCo transmission system with those already connected to the Neptune Bank Power Station.<sup>95</sup> It was the first power station to be designed by the two men and incorporated their views on the 'primacy of industrial load, economy of scale, and turbine efficiency'.<sup>96</sup> The station had the lowest generating costs in Britain.<sup>97</sup> It was the world's first power station to provide electricity for power as opposed to lighting and the first in Britain to use a three-phase system.<sup>98</sup> Charles Merz used his network to seek advice on three-phase electric power from engineers at the General Electric Company in the US and Swiss engineers working for Brown Boveri.<sup>99</sup> The advantage of three-phase supply was that higher voltages could be used by industrial motors and lower voltages could be supplied to domestic users.<sup>100</sup> A periodicity of forty cycles per second (40Hz) became the standard frequency for the North East Coast area as it was suitable for lighting as well as rotary converters used in traction.<sup>101</sup>

By the beginning of 1901 Neptune Bank was supplying three-phase alternating current to several shipyards and engineering companies including Armstrong Whitworth and Swan Hunter.<sup>102</sup> Sir George Burton Hunter, the Chairman of Swan Hunter, had joined the NESCo board in 1900 along with Sir John Henry Brunel Noble whose directorships included the London and North Eastern Railway Company, the Easington Coal Company, and the North Eastern Board of Martins Bank. His father, Sir Andrew Noble, was the Chairman of Armstrong Whitworth. The power station was publicly opened in June 1901 by Lord Kelvin. Sir Andrew Noble presided at the opening.<sup>103</sup> The ceremonial opening of the power station by a renowned physicist and a prominent industrialist demonstrated the regional stature of the NESCo.

The boundaries of the electricity supply industry had been redefined to include power as well as lighting. The generating plant comprised four 700 kilowatt alternators driven by slow-speed marine

reciprocating engines supplied by the family connected firm of Wigham Richardson & Company and the Wallsend Slipway & Engineering Company.<sup>104</sup> Merz and McLellan adopted the marine engines, first, because of their reliability and, second, the chief consumers were expected to be marine engineers.<sup>105</sup> Further, the Merz & McLellan team possessed the relevant cognitive capital to persuade the engineers and Tyne shipbuilders of the cost advantages of replacing their small steam and gas engines by more adaptable electric power.<sup>106</sup> In 1902, two Parsons 1,500 kilowatt steam turbine driven turbo-alternators, then the largest in the world, were installed to increase power production.<sup>107</sup> Neptune Bank was the only British power station that had installed both reciprocating engines and turbines to generate electricity.<sup>108</sup>

The strong structural interrelationship between the NESCo and the firm of Merz & McLellan was demonstrated by the consulting engineers being listed on the former's organisational structure.<sup>109</sup> Merz and McLellan attended the NESCo 'meeting of officers' which discussed project planning and network operations.<sup>110</sup> Merz produced 'plant capacity reports' to assist the NESCo with its strategic planning.<sup>111</sup> He developed the technological and economic strategy that transformed the NESCo from an urban lighting utility into a regional power company.<sup>112</sup> The two companies had complementary capabilities: Merz & McLellan designed the power stations and possessed the cognitive capital to build trusting relationships with organisations located on the North East coast of England to persuade them to take power from the NESCo. Merz & McLellan would then provide the consultancy service to design and install the equipment required by these new customers. Other electrical utilities also used consulting engineers, but the closeness of the relationship between the NESCo and Merz & McLellan was unique amongst British electrical utilities which shaped the style of the regional system that developed.<sup>113</sup>

### **5.2.1 Traction**

In 1902 the NESCo sought Parliamentary approval to provide power on the north bank of the Tyne to the Tyneside Tramways and Tramroads Company. Family and cross-directorate connections played an important role in this expansion as John Wigham Richardson was an investor in the company. The NESCo expected to make 9.4% return on capital from this investment which was below the target return of 15%.<sup>114</sup> This investment was approved on the basis of attracting more customers as the mains were laid. A new agreement was signed in July 1904 which committed the Tramways Company to take energy from the NESCo for the next 15 years.<sup>115</sup> The NESCo took a £13,000 shareholding in the company and Theodore Merz (who later became Chairman) and Sir John Noble were appointed to the board.<sup>116</sup>

Merz and McLellan argued that electrification enabled tramways to compete with railways because the increase in new passengers was 'frequently ten times as great as formerly'.<sup>117</sup> There was opposition from the North-Eastern Railway (NER) which feared the impact on its business. During the Parliamentary inquiry, Charles Merz suggested to George Gibb, the NER's General Manager, that the company should consider electrifying the railway line.<sup>118</sup> Merz had the appropriate cognitive capital to understand the NER's strategic and operational requirements from observing inter-urban railway systems in the United States. He had also acquired, whilst planning the Neptune Bank Power Station, knowledge of the Swiss mountain railway system which operated with three-phase alternating current. Shortly afterwards, Merz & McLellan was commissioned by the NER to draw up a scheme to create the first electric suburban rail network in Britain operating some 82 miles of single

track.<sup>119</sup> Merz's ability to draw on this structural mix of strong social and weak technical ties enabled him to apply knowledge in a new context and provide a technical solution which turned an objector into a customer and supporter.<sup>120</sup> Gibbs and Merz became close friends which produced a trusting relationship between their companies resulting in the accumulation of relational capital.<sup>121</sup> From a structural capital perspective, Merz & McLellan provided the NESCo with access to a new market.

The few railways that had used electricity for traction had built their own power station to generate electricity. Merz viewed this as uneconomic and preferred to spread the load factor between industrial, domestic and traction in order to reduce prices.<sup>122</sup> He proposed to supply a portion of the electricity from the Neptune Bank Power Station which was nearly fully loaded with the bulk of the supply coming from the planned larger station at Carville.<sup>123</sup> The NER would pay the NESCo 1.0d for the first 3 million kilowatt hours (kWh) in any one year, 0.75d for the next 3 million kWh and 0.55d for all units over 6 million in any one year. A further guarantee was that the quantity of electrical energy taken or paid for would not be less than 5 million kWh in any year.<sup>124</sup> The contract allowed the NESCo to use the new mains and substations to supply electricity to other consumers, which would reduce unit costs.<sup>125</sup> The first part of the electrification scheme came into operation on 29 March 1904 and was the first example in Britain of a steam railway converting to electric traction.

### ***5.2.2 Economies of Scale***

Before 1914 typically 40% of electricity was produced in generating stations and 60% on premises by the users.<sup>126</sup> The average generating capacity of a power station was 5,000 horse power, 'or about one-fourth of the capacity of one single generating machine of economical size and about one-thirtieth of the size of what may be considered as an economical power station unit'.<sup>127</sup> Most of these power stations were 'principally enlarged versions of the lighting stations built at the turn of the century'.<sup>128</sup> In general, the industry with the exception of the NESCo found it difficult to achieve economies of scale.<sup>129</sup>

Table 2 shows that the NESCo's electricity output increased from under 1 million kWh in 1899 to just over 9 million kWh in 1903 which was 'a comparatively small output for a power scheme'.<sup>130</sup> The environment in which the NESCo was operating conformed to that of a creation context with considerable uncertainty about how to develop new business opportunities.<sup>131</sup> Large power stations had been created in other areas of Britain to deliver bulk supply whereas the NESCo had invested in 'detailed distribution'.<sup>132</sup> Merz contended that economic electricity production demanded large central power stations supplying large areas with lighting, traction and power.<sup>133</sup> A mass production strategy aimed at high load factor users such as traction, collieries and chemical works was implemented which was based on similar strategies adopted by American and German companies.<sup>134</sup> This was a way of spreading risk against fluctuations in demand in any one sector.<sup>135</sup> Merz and McLellan recognised that a power supply company's commercial success depended upon 'the cheapness and reliability of supply',<sup>136</sup> which took precedence over 'economy of production'. This principle was embodied in the ground-breaking Carville generating station which opened in 1904.<sup>137</sup>

**Insert Table 2** Electricity Sales of the NESCo from 1891-1913 (millions kWh)

Merz and McLellan focused on controlling capital costs rather than running costs by emphasising simplicity of design together with a provision for future extensions. Their unit system of construction comprised several independent units, each consisting of a boiler, generating set and switch-gear.<sup>138</sup> This made it easy to isolate and repair faulty units. The Carville Station was a clad steel frame building as opposed to brick and was 'the first large generating station of the modern type' in the world.<sup>139</sup> Carville was the lowest cost power station in Britain with a capital cost of £16 per kW compared to £20-£26 per kW for other contemporary stations.<sup>140</sup> The station running costs were as low as or lower than other power stations.<sup>141</sup> It was the largest public power station in Europe and was powered by Parsons' steam turbines – two 1,500 kilowatt units and two 3,500 kilowatts units; the latter were twice the size of any turbine that had been constructed.<sup>142</sup> Carville accounted for 64% of the system's capacity from 1906-10 and was the foundation of the NESCo's rapid growth during this period.<sup>143</sup> Carville was also the first British power station to have a Control Room to manage the entire system on the control diagram and to make decisions on the loads carried by the various stations.<sup>144</sup> Merz had taken this idea from practice in American power stations and it became a standard feature for all large electrical systems.<sup>145</sup> In 1910 the NESCo opened the Dunston Power Station which contained turbo-alternators produced by Brown Boveri of Switzerland and AEG of Germany providing a total generating capacity of 33,850 kilowatts. The capital cost was £11 per kW which was well below the national average.<sup>146</sup>

The growth in electricity demand produced an increase in generation factors from 8-12% in the 1890s (mainly lighting) to over 20% from 1908 to 1914.<sup>147</sup> As the NESCo used its capital equipment more intensely, its load factor after 1907 averaged 40-50%.<sup>148</sup> This allowed the NESCo to significantly reduce its production costs and electricity prices. The average price per unit was predicted to decrease because manufacturers expected 'an excessively low price for power, and.....they expect(ed) to get their lighting thrown in at the same price'.<sup>149</sup> It was difficult to charge separately for power and lighting as many manufacturers used the same circuits for both. In 1900 the NESCo's average price charged to manufacturers was 3d per kWh and for lighting 4.09d.<sup>150</sup> By 1905 the average price for electricity had fallen to 1.16d per kWh,<sup>151</sup> and by 1913 it was less than ½d per kWh.<sup>152</sup> Charles Merz was able to claim that there was not 'a single firm of shipbuilders or engineers on the north bank of the Tyne inside the power company's area of supply which does not take 95 per cent of its power from the company, the remaining 5 per cent being produced from small gas engines or from boilers fired with scrap wood'.<sup>153</sup>

The success of the mass production strategy is shown by the large expansion in sales after 1905 to the collieries, chemical and process industries, as well as the traditional manufacturing sectors (see Table 2). Bulk sales also grew as some local authorities such as Middlesbrough, Tynemouth and Stockton opted to buy electricity in bulk from the NESCo rather than extend their own generating capacity. This strategy produced an increase in net profit to £132,000 by 1914 and the growth in equity to over £1 million (see Table 1). Up to 1905, finance had been raised locally, but the growth strategy required raising finance nationally. Charles Merz had developed a relationship with the merchant bankers, Leonard and Walter Cunliffe. George Gibb had introduced Merz to Walter Cunliffe (later Lord) who had been appointed a director of the NER in 1905.<sup>154</sup> This led to an introduction to Sir Robert Kindersley who was a partner in the merchant bank Lazard Brothers. Debentures were issued through Lazard Brothers in 1906 followed by a large issue of 4½% debentures for £688,000 in 1909.<sup>155</sup> Leonard Cunliffe joined the NESCo board in 1908 followed by

Robert Henry Brand (later Lord Brand) of Lazard brothers in 1913.<sup>156</sup> The NESCo had the financial network to raise capital for further expansion.

### **5.2.3 Acquisitions**

In the neighbouring areas across the Tyne in Gateshead and Durham, electrification had been developed on a small-scale compared with the north side of the river.<sup>157</sup> Small power stations were established at Jarrow, Gateshead and Durham supplying direct current for lighting and traction. Electricity generation and supply resided with two companies controlled by the British Electric Traction Company (BET): the County of Durham Electric Power Distribution Company (CDEPDC); and the County of Durham Electric Supply Company (CDEPSC).

Charles Merz used his connection with William Madgen who was a director of the CDEPDC to persuade the Durham Company to take a bulk supply from the NESCo.<sup>158</sup> High tension cables were laid over the High Level Bridge to connect the Manors substation and the Gateshead Power Station which linked the two distribution systems.<sup>159</sup> Under the agreement, the Durham Company adopted the same 'voltage and periodicity' standards as the NESCo.<sup>160</sup> When the BET faced financial difficulties in 1904, the NESCo acquired the two Durham Power companies for £256,000 to control electricity supply on the north and south banks of the Tyne.<sup>161</sup> Although the CDEPDC and the NESCo operated as separate companies, the majority of the directors on the Durham Company board were from the NESCo.<sup>162</sup> The Gateshead and Jarrow power stations were connected to Carville and were in effect distribution centres to enable the NESCo to supply electricity to other large towns and collieries in County Durham. Overhead lines were not feasible so a 22,000 volts underground cable system, which was the highest voltage in Britain, was laid to minimise power losses over long distances.<sup>163</sup> As no British cable maker would take on this job, Merz and McLellan used their international links to contract it to Allgemeine Electricitat Gesellschaft of Berlin.<sup>164</sup>

The Cleveland and Durham County Electric Power Company was established in 1903 to supply electricity to the Durham coalfield, Darlington, Stockton, Middlesbrough and parts of Teesside, but faced financial difficulties from its inception. Merz and McLellan provided support to the Cleveland Company as the NESCo was fully occupied with its recent acquisition of the Durham companies to engage in another take-over.<sup>165</sup> In 1906 Merz and McLellan conceived the idea of floating a new company to acquire the Cleveland Company plus the failing Northern Counties Electric Supply Company which supplied electricity to some small towns in Northumberland, Durham and North Yorkshire.<sup>166</sup> The latter had produced a power scheme for Northumberland, but Parliamentary approval was given in 1902 to the rival scheme produced by the NESCo. Under the new proposal, the Cleveland and Durham County Electric Power Company retained its name and continued to operate as a separate entity, although the new board contained directors who were close associates of Charles Merz.<sup>167</sup> Merz arranged for the Cleveland Company to be physically connected to the NESCo by a 20,000 volt cable laid under the Tyne at Hebburn.<sup>168</sup> The Cleveland Company was not a financial success and its share capital was acquired by the NESCo in 1917.<sup>169</sup>

The NESCo, Durham and Cleveland companies were registered as separate entities, though all three companies were controlled by one staff based in Newcastle. It was an 'unwieldy arrangement', but amalgamating all three companies would have required Parliamentary approval which may have

'stir(red) up a lot of opposition'.<sup>170</sup> In 1907, the NESCo acquired the Durham Collieries Electric Power Company which was supplying power to the local collieries and the Sunderland District Electric Tramways. Many of these companies operated at different cycles and pursuing uniformity delayed the development of the system. However, the economies of integration and large-scale operation justified the conversion to a common system.<sup>171</sup> In 1909 the NESCo, Cleveland and Durham systems which were supplying areas in close proximity were connected together to create the first grid system in Britain running from north of the Tyne to south of the Tees.<sup>172</sup> It was the largest integrated network in Europe.<sup>173</sup> Charles Merz has been described as the 'British Edison'<sup>174</sup> for his work on developing an economic and integrated electricity supply system in North East England.

Charles Merz recognised that potentially useful energy was being wasted in factories, collieries and steel manufacturing. In 1902 the Owners of the Priestman Collieries (OPC) planned to establish a modern coke-making plant near Blaydon Burn with eighty ovens that produced coal gas as a by-product which could be used to generate electricity. This provided the NESCo with an opportunity to expand into the Blaydon district at the expense of its then competitor the CDEPDC. Merz & McLellan acted as a broker between the NESCo and the OPC and the commissioned report produced by the partners recommended constructing a power station at Blaydon to utilise the waste heat and gas. The NESCo and the OPC established the Priestman Power Company to administer the facility. Two Babcock and Wilcox boilers supplied steam to two 275 kilowatt Parsons three-phase alternators which began operating in 1904 supplying electricity to the Blaydon Burn Colliery. In early 1905 the Blaydon Power Station was connected by underground cable to the NESCo network enabling it to supply electricity to the CDEPDC network. The NESCo acquired the Priestman Power Company in 1914.

Additional companies were formed to utilise the waste heat and gases from industrial processes. The Durham Collieries Electric Power Company was formed in 1905 to supply electricity to collieries in north Durham. When the company faced financial difficulties in 1907 its debts were underwritten by the NESCo which took control of the power station, and from 1909 operated its distribution system.<sup>175</sup> In 1907 the Waste Heat and Electrical Generating Stations Company was formed to establish power stations in South Durham and Teesside to utilise the waste heat and gas from local blast furnaces, coke ovens and industrial sites to feed into the NESCo network. By the end of the First World War, the NESCo had 11 waste heat stations in operation.<sup>176</sup> The interconnecting of the generation stations allowed Carville which had a capacity of 25,000 kilowatts following its extension in 1907 to supply the base load, the smaller stations were used for peak use, and the waste heat stations provided electricity at a very low marginal cost.<sup>177</sup>

## **6. Discussion and Conclusions**

The main contribution of this research is to examine historically how social capital contributed to the emergence and growth of the NESCo. In particular, the research examined the role of the different dimensions of social capital in the emergence and growth stages. The data were separated into two distinct time periods to examine the transformation of the NESCo from a lighting company confined to the eastern part of Newcastle into a regional power company. Social capital had an important impact on operational performance as well as financial measures. This is indicated by the large growth in output from the mid-1900s and with it a large reduction in the costs of production.

The social and cultural capital of Theodore Merz and Robert Spence Watson were critical for establishing the company and for raising finance locally through personal and business networks. Their spur was the more favourable legislative changes introduced by the Electric Lighting Act of 1888. Merz and Spence Watson were able to use their respective social standing in the North East of England to attract to the NESCo board leading industrialists who provided the structural capital to establish the company and cognitive capital in the form of managerial expertise. Strong ties were important in both phases of the NESCo's development as the industry environment was characterised by uncertainty (creation) as opposed to risk (discovery). Of the fifteen power companies that were formed up to 1912 only the NESCo was financially successful.<sup>178</sup> The institutional arrangements that governed the area of supply and the regional nature of the NESCo were also factors in the importance of maintaining strong ties.

Among the major factors that assisted the transformation of the NESCo from a lighting company into a power company were the favourable economic and geographical features of the North of England. The NESCo supplied a region that had 5.1% of the population, mined 19.6% of the coal, made 36.5% of the coke, mined 37.5% of the iron ore, produced 37.7% of the pig iron, and built 51% of the merchant ships in Britain.<sup>179</sup> Charles and Theodore Merz were able to capitalise on these advantages to build a strong regional network comprising relatives, Quakers and professional associates.<sup>180</sup> Their close connections with the leading industrialists in the region from shipbuilding, engineering, mining and traction were a conduit for providing electricity to these industries. The power and influence of this industrial, financial, political and social network helped the NESCo to cross 'parochial political boundaries' to expand its operations.

Hughes argued that whilst geographical, economic and organizational factors were propitious, the principal reasons for the evolution of the NESCo into a regional power company were political and social.<sup>181</sup> Many local authorities in rapidly expanding industrial towns and cities in northern England (without ports, racecourses, or piers) viewed profits from municipal enterprises as a means of financing health programmes without putting all of the burden on the ratepayers.<sup>182</sup> From 1898 to 1902, some 62 municipal authorities began supplying electricity, and by the end of 1903, two-thirds of the connections to the public supply mains (measured in kW) were accounted for by the municipalities.<sup>183</sup> The NESCo, however, enjoyed a 'comparative freedom from municipal opposition'.<sup>184</sup> Further, the company was awarded powers to extend its area of supply by defeating its opponents before Parliamentary Committees.

There are several reasons for the unique position enjoyed by the NESCo. The Tyneside economy was dominated by heavy industry, but Newcastle was a service and commercial centre for the industrial region. Newcastle had by the early 1880s become the second most important British port in terms of export tonnage and the sixth most important in terms of export value.<sup>185</sup> The estate income from the port partly explains why the Newcastle Corporation did not establish municipal gas, water and electric enterprises. A further reason was that Newcastle had a highly dynamic economy that was dominated by an integrated entrepreneurial elite that not only 'exercised immense economic power, but also controlled many of the wider social and political institutions'.<sup>186</sup> They sat on the boards of each other's companies. They were also major investors in the utilities which provided services to their companies. Hughes concluded that '(t)he leaders of this industrial community used their political and financial power to support the privately owned NESCo while most other urban centers, excluding London, promoted government-owned electric supply'.<sup>187</sup> The Corporation therefore left the established

utilities in private control, but opted to launch a municipal tramway system that began operating at the end of 1901. A municipal power station was completed in 1904 to supply power to the tramway system.

Organisational growth after 1900 also stemmed from the close structural relationship that was established between the NESCo and the consulting engineering firm of Merz & McLellan. The two companies had complementary capabilities: the former supplied the electricity whilst the latter had the capability to design innovative power stations and to manage complex projects. The level of social capital is increased when the structural effects are enhanced by a strong relational element.<sup>188</sup> The relationship was underpinned by a shared cognitive capital based on family values, mutual respect and trust. Charles Merz and William McLellan possessed valuable cognitive capital and provided technical and business advice which contributed to the NESCo's expansion strategy and entry into new markets such as traction and the utilisation of waste heat. The relational social capital based on close family ties encouraged the two companies to work closely together on developing their mutual business interests. It reduced the likelihood of either party engaging in opportunistic behaviour to pursue their individual interests which strengthened their social capital.<sup>189</sup> The strong relational capital was reflected by the interchange of staff between the two companies.<sup>190</sup>

As the NESCo expanded it increased its network diversity and complexity through acquisitions and joint ventures with Merz & McLellan acting as an intermediary to both strong and weak network ties. This resulted in a differentiated as opposed to a homogenous composition of social capital which provided the NESCo with access to novel information, resources, and new market opportunities.<sup>191</sup> Charles Merz and the firm of Merz & McLellan provided the bridging<sup>192</sup> social capital to the weak network ties that furnished the NESCo with crucial knowledge on three-phase electricity, high voltage cable, and suburban railway electrification. Charles Merz's ability to develop his social networks and build strong relationships with actors from different industries and networks transformed his private social capital into a public good for the benefit of both the NESCo and Merz & McLellan.<sup>193</sup> The relationship with Merz & McLellan prevented any relational lock-in to existing network ties.<sup>194</sup>

Analysing the emergence and growth of the NESCo in a historical context has shown that industry emergence is a complex phenomenon that involves organisations, institutions, political factors, the economic and geographical context, as well as the role of individual actors. By drawing upon historical documents, this research has been able to explore the emergence of the company and, how under conditions of uncertainty, the NESCo was able to transform itself from a lighting company into a successful power company.

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## Notes

<sup>1</sup> Forbes and Kirsch, "Emerging industries," 590.

<sup>2</sup> Agarwal and Tripsas, "Technology." 4.

<sup>3</sup> MacMillan and Katz, "Idiosyncratic," 6.

<sup>4</sup> Forbes and Kirsch, "Emerging industries," 589.

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- <sup>5</sup> Ibid., 593.
- <sup>6</sup> Kirsch, Moeen, Wadhvani, "Historicism," 221.
- <sup>7</sup> Ibid., 220.
- <sup>8</sup> Forbes and Kirsch, "Emerging industries," 596.
- <sup>9</sup> Kirsch, Moeen, Wadhvani, "Historicism," 235.
- <sup>10</sup> Hannah, *Electricity*, 33.
- <sup>11</sup> Byatt, *British Electrical Industry*, 115.
- <sup>12</sup> Byatt, *British Electrical Industry*; Hannah, *Electricity*.
- <sup>13</sup> Hannah, *Electricity*, 365, note 64. This was also confirmed in a conversation with Professor Les Hannah in March 2016. The Tyne and Wear Archives and Museums has brought together this collection of company documents. Some documents were held by the North Eastern Electricity Board but may not have been catalogued or available. Private individuals and organisations held other documents.
- <sup>14</sup> Birley, "Networks"; Hansen, "Entrepreneurial networks."
- <sup>15</sup> Elfring and Hulsink, "Networks," 409.
- <sup>16</sup> Steier and Greenwood, "Entrepreneurship," 164.
- <sup>17</sup> Hite and Hesterly, "Firm networks," 278.
- <sup>18</sup> Elfring and Hulsink, "Networks," 420-421.
- <sup>19</sup> Maurer and Ebers, "Dynamics," 262.
- <sup>20</sup> Nahapiet and Ghoshal, "Social capital."
- <sup>21</sup> Ostgaard and Birley, "Personal networks," 282.
- <sup>22</sup> Westerlund and Svahn, "Relationship value," 493.
- <sup>23</sup> Elfring and Hulsink, "Networks", 410; Granovetter, "Embeddedness," 46; Maurer and Ebers, "Dynamics," 26. Granovetter, "Embeddedness," 46; Maurer and Ebers, "Dynamics," 26.
- <sup>24</sup> Bourdieu, "Capital," 248.
- <sup>25</sup> Naphiet and Ghoshal, "Social capital," 243
- <sup>26</sup> Burt, "Contingent Value," 343.
- <sup>27</sup> Kostova and Roth, "Social capital," 301.
- <sup>28</sup> Naphiet and Ghoshal, "Social capital," 244.
- <sup>29</sup> Hite and Hesterly, "Firm networks," 278.
- <sup>30</sup> Ibid.
- <sup>31</sup> Rowley, Behrens, Krackhardt. "Redundant," 369.
- <sup>32</sup> Hite and Hesterly, "Firm networks," 278.
- <sup>33</sup> Rowley, Behrens, Krackhardt. "Redundant," 369-370.
- <sup>34</sup> Granovetter, "Strength," 1376.
- <sup>35</sup> Burt, *Structural Holes*, 65.
- <sup>36</sup> Granoveter, "Network theory," 209.
- <sup>37</sup> Alvarez and Barney, "Discovery and creation," 18.
- <sup>38</sup> Ibid., 19.
- <sup>39</sup> Hmieleski, Carr, Baron, "Entrepreneurial action," 305.
- <sup>40</sup> Elfring and Hulsink, "Networks," 410.
- <sup>41</sup> Kirsch, Moeen, Wadhvani, "Historicism," 220-223.
- <sup>42</sup> Ibid., 229.
- <sup>43</sup> Byatt, *British Electrical Industry*; Hannah, *Electricity*; Hughes, *Networks of Power*.
- <sup>44</sup> Forbes and Kirsch, "Emerging industries," 590.
- <sup>45</sup> Langley, "Process data."
- <sup>46</sup> Ibid., 703.
- <sup>47</sup> Parsons, *Power Station*, 2.
- <sup>48</sup> Byatt, *British Electrical Industry*, 11.
- <sup>49</sup> Hannah, *Electricity*, 3.
- <sup>50</sup> Fleming, "Personal recollections," 293-295.
- <sup>51</sup> Byatt, *British Electrical Industry*, 15.
- <sup>52</sup> Hughes, "Industry lag," 37-38.
- <sup>53</sup> Hannah, *Electricity*, 8.
- <sup>54</sup> Shiman, "Collapse," 320-324; Wilson, *Ferranti*, 49.
- <sup>55</sup> Hannah, *Electricity*, 10.
- <sup>56</sup> DU/EB/60/4, *Electric Power on the North-East Coast*, 7.

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- <sup>57</sup> Ibid.
- <sup>58</sup> Ministry of Reconstruction, *Interim Report*, 26.
- <sup>59</sup> DU/EB/1/1, Directors' Meeting Minutes, 5 December 1888.
- <sup>60</sup> Sir Charles Parsons who developed the steam turbine in 1884.
- <sup>61</sup> Annual Report of the Directors, 17 March 1890.
- <sup>62</sup> DU/EB/60/1, Beard, "NESCo," 1.
- <sup>63</sup> Weightman, *Children of Light*, 121.
- <sup>64</sup> Rowland, *Progress in Power*, 12.
- <sup>65</sup> Garcke, *Electrical Enterprise*, 33.
- <sup>66</sup> National Civic Federation, *Municipal*, 268.
- <sup>67</sup> Ibid., 255.
- <sup>68</sup> DU/EB/34, Report of the Chairman and Directors, 6 May 1889. During the 1880s the capacity of a power station was rated by the number of lamps that it supported.
- <sup>69</sup> DU/EB/60/1, Beard, "NESCo," 1.
- <sup>70</sup> Byatt, *British Electrical Industry*, 116.
- <sup>71</sup> Ibid.
- <sup>72</sup> DU/EB/60/1, Beard, "NESCo," 4.
- <sup>73</sup> Ministry of Reconstruction, *Interim Report*, 28.
- <sup>74</sup> Ibid., 23-25; Hannah, *Electricity*, 25-27.
- <sup>75</sup> DU/EB/36/1, Report on the position of the company at the end of 1902, 13.
- <sup>76</sup> Hughes, *Networks of Power*, 455.
- <sup>77</sup> DU/EB/60/4, *Electric Power on the North-East Coast*, 7.
- <sup>78</sup> DU/EB/36/1, Report on the position of the company at the end of 1902, 13.
- <sup>79</sup> Ibid., 19.
- <sup>80</sup> DU/EB/60/1, Beard, "NESCo," 2.
- <sup>81</sup> DU/EB/36/1, *Report on the position of the company at the end of 1902*, 20.
- <sup>82</sup> DU/EB/60/1, Beard, "NESCo," 2.
- <sup>83</sup> Alan Campbell Swinton worked with Charles Parsons on the development of the steam turbine and the first turbine ship the Turbinia.
- <sup>84</sup> DU/EB/60/1, Beard, "NESCo," 2 and 4
- <sup>85</sup> Rowland, *Progress in Power*, 13.
- <sup>86</sup> Charles Merz, Unpublished Notes (June 1936), Apprenticeship and early training, 4.
- <sup>87</sup> Rowland, *Progress in Power*, 18-20.
- <sup>88</sup> Ibid., 20.
- <sup>89</sup> Charles Merz, Unpublished Notes (June 1936), Cork and the North-East coast, 11.
- <sup>90</sup> Rowland, *Progress in Power*, 28.
- <sup>91</sup> DU/EB/60/1, Beard, "NESCo," 7.
- <sup>92</sup> Charles Merz, Unpublished Notes (June 1936), Cork and the North-East coast, p.12.
- <sup>93</sup> DU/EB/36/1, NESCo, Report on the position of the company at the end of 1902, 10.
- <sup>94</sup> Charles Merz, Unpublished Notes (June 1936), Cork and the North-East coast, p.15.
- <sup>95</sup> Rowland, *Progress in Power*, 29.
- <sup>96</sup> Hughes, *Networks of Power*, 456.
- <sup>97</sup> Hannah, *Electricity*, 30.
- <sup>98</sup> Byatt, *British Electrical Industry*, 117.
- <sup>99</sup> Rowland, *Progress in Power*, 25. Bown Boveri was the first firm in Europe to install a three-phase system.
- <sup>100</sup> Hannah, *Electricity*, 29.
- <sup>101</sup> NESCo, *Electric Power*, 17 (5,500 volts transformed down at substations to 240 volts direct current for lighting and 480 volts for power).
- <sup>102</sup> Rowland, *Progress in Power*, 27.
- <sup>103</sup> Ibid.
- <sup>104</sup> The Engineer (13 September 1901): 278-279; The Engineer (20 September 1901): 293-295.
- <sup>105</sup> Rowland, *Progress in Power*, 25-26.
- <sup>106</sup> Ibid., 26-27.
- <sup>107</sup> Ibid., 29.
- <sup>108</sup> Ibid.
- <sup>109</sup> DU/EB/36/2, Report on the position of the company at the end of 1905, 30.

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- <sup>110</sup> DU/EB/5/1, Minute book, Officers' Meetings.
- <sup>111</sup> Charles Merz, Unpublished Notes (June 1936), Cork and the North-East coast, 17.
- <sup>112</sup> Hughes, *Networks of Power*, 451
- <sup>113</sup> *Ibid.*, 449.
- <sup>114</sup> DU/EB/36/2, Report on the position of the company at the end of 1905, 3.
- <sup>115</sup> DU/EB/36/3, NESCo and CDEPDC, Report on the position of the companies at the end of 1905, 6.
- <sup>116</sup> Benwell Community, *Ruling Class*, 34.
- <sup>117</sup> The Engineer (9 September 1904): 260.
- <sup>118</sup> Rowland, *Progress in Power*, 31.
- <sup>119</sup> Merz and McLellan, "North-Eastern Railway," 260; Charles Merz, Unpublished Notes (June 1936), Cork and the North-East coast, 19.
- <sup>120</sup> Powell, Koput, Smith-Doerr, "Interorganizational"; Uzzi, "Social structure."
- <sup>121</sup> Uzzi, "Social structure," 43-45.
- <sup>122</sup> Rowland, *Progress in Power*, 32.
- <sup>123</sup> Technical details available in The Engineer (24 July 1903): 88-89.
- <sup>124</sup> DU/EB/36/1, Report on the position of the company at the end of 1902, Schedule F, 26.
- <sup>125</sup> Byatt, *British Electrical Industry*, 118.
- <sup>126</sup> *Ibid.*, 95-96.
- <sup>127</sup> Ministry of Reconstruction, *Interim Report*, 11.
- <sup>128</sup> Byatt, *British Electrical Industry*, 96.
- <sup>129</sup> *Ibid.*, 98.
- <sup>130</sup> DU/EB/36/1, Report on the position of the company at the end of 1902, 16.
- <sup>131</sup> Alvarez and Barney, "Discovery and creation," 15-17.
- <sup>132</sup> DU/EB/36/1, Report on the position of the company at the end of 1902, 15.
- <sup>133</sup> Rowland, *Progress in Power*, 36.
- <sup>134</sup> Hughes, *Networks of Power*, 250.
- <sup>135</sup> NESCo, *Electric Power*, 9.
- <sup>136</sup> Merz and McLellan, "Power station," 697.
- <sup>137</sup> Merz and McLellan, "North-Eastern Railway," 283-284 for technical details.
- <sup>138</sup> Byatt, *British Electrical Industry*, 119.
- <sup>139</sup> The Electrician 47, 1901, 319-27.
- <sup>140</sup> Byatt, *British Electrical Industry*, 118 and 120; Merz and McLellan, "Power station," 697-704.
- <sup>141</sup> Byatt, *British Electrical Industry*, 120.
- <sup>142</sup> Hannah, *Electricity*, 30.
- <sup>143</sup> Byatt, *British Electrical Industry*, 122.
- <sup>144</sup> DU/EB/60/4, Electric Power on the North-East Coast, 19.
- <sup>145</sup> Rowland, *Progress in Power*, 35.
- <sup>146</sup> Byatt, *British Electrical Industry*, 122.
- <sup>147</sup> Hannah, *Electricity*, 432.
- <sup>148</sup> Byatt, *British Electrical Industry*, 122.
- <sup>149</sup> DU/EB/36/1, Report on the position of the company at the end of 1902, 17.
- <sup>150</sup> *Ibid.*, Schedule O, Table 4.
- <sup>151</sup> DU/EB/36/2, Report on the position of the company at the end of 1905, Schedule no.1, 26.
- <sup>152</sup> Ministry of Reconstruction, *Interim Report*, 13.
- <sup>153</sup> Merz, "Power," 629.
- <sup>154</sup> Charles Merz, Unpublished Notes (June 1936), London 7.
- <sup>155</sup> Charles Merz, Unpublished Notes (June 1936), Extension of area of supply on North East Coast, 3.
- <sup>156</sup> Robert Brand became Managing Director of Lazard Brothers in 1919. Walter Cunliffe was Governor of the Bank of England from 1913-1918.
- <sup>157</sup> DU/EB/34, Special report on the provisional agreement for the purchase of shares in the County of Durham Electrical power Distribution Company, Limited, 24 February 1905, 24 February 1905.
- <sup>158</sup> Charles Merz, Unpublished Notes (June 1936), Extension of area of supply on North East Coast, 1.
- <sup>159</sup> Beard, "NESCo," 8; Hannah, *Electricity*, 31.
- <sup>160</sup> DU/EB/36/1, Report on the position of the company at the end of 1902, 12.
- <sup>161</sup> DU/EB/34 Special report on the provisional agreement for the purchase of shares in the County of

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- Durham Electrical power Distribution Company, Limited, 24 February 1905, 24 February 1905.
- <sup>162</sup> Ibid.
- <sup>163</sup> Byatt, *British Electrical Industry*, 120.
- <sup>164</sup> Charles Merz, Unpublished Notes (June 1936), Extension of area of supply on North East Coast, 2.
- <sup>165</sup> Beard, "NESCo," 9.
- <sup>166</sup> Charles Merz, Unpublished Notes (June 1936), Extension of area of supply on North East Coast, 4.
- <sup>167</sup> Ibid.
- <sup>168</sup> Hannah, *Electricity*, 31; Rowland, *Progress in Power*, 37.
- <sup>169</sup> Charles Merz, Unpublished Notes (June 1936), Extension of area of supply on North East Coast, 6.
- <sup>170</sup> Ibid.
- <sup>171</sup> Hannah, *Electricity*, 32.
- <sup>172</sup> Byatt, *British Electrical Industry*, 122.
- <sup>173</sup> Hannah, *Electricity*, 33.
- <sup>174</sup> Ibid.
- <sup>175</sup> Byatt, *British Electrical Industry*, 120 and 122.
- <sup>176</sup> Ministry of Reconstruction, *Interim Report*, 28.
- <sup>177</sup> Byatt, *British Electrical Industry*, 122.
- <sup>178</sup> Ibid., 115.
- <sup>179</sup> Ministry of Reconstruction, *Interim Report*, 26.
- <sup>180</sup> Hughes, *Networks of Power*, 448.
- <sup>181</sup> Ibid., 459.
- <sup>182</sup> Millward, "Public sector," 392.
- <sup>183</sup> Ibid.
- <sup>184</sup> Garcke, *Electrical Enterprise*, 34.
- <sup>185</sup> Lendrum, "Integrated elite," 29.
- <sup>186</sup> Benwell Community, *Ruling Class*, 7.
- <sup>187</sup> Hughes, *Networks of Power*, 449.
- <sup>188</sup> Kostova and Roth, "Social capital," 303.
- <sup>189</sup> Adler and Kwon, "Social capital," 24.
- <sup>190</sup> James Beard joined the NESCo in 1905, transferred to M&M in 1907, later became a senior partner. R.P. Sloan joined M&M soon after it was set up. He transferred to the NESCo and in 1926 became chairman.
- <sup>191</sup> Maurer and Ebers, "Dynamics," 286.
- <sup>192</sup> Davidsson and Honig, "Human capital," 310.
- <sup>193</sup> Kostova and Roth, "Social capital," 304.
- <sup>194</sup> Maurer and Ebers, "Dynamics," 275.

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Table 1 The NESCO extracts from Financial Statements, 1891-1914 (£000)

Year	Total Revenue	Net Profit	Total Equity	Preference Shares	Debentures
1891	4	1	20	-	15
1892	6	2	27	-	15
1893	7	1	31	-	17
1894	8	2	35	-	20
1895	9	2	41	-	20
1896	10	3	48	-	20
1897	13	5	51	-	25
1898	15	5	64	-	25
1899	17	6	115	-	-
1900	20	9	140	52	-
1901	23	11	204	125	-
1902	45	18	241	170	140
1903	76	28	409	245	250
1904	109	41	550	357	250
1905	140	50	604	375	250
1906	177	52	517	400	381
1907	241	57	559	438	438
1908	N/A	44	808	688	439
1909	N/A	65	841	688	688
1910	N/A	64	845	688	688
1911	N/A	70	870	688	688
1912	N/A	76	861	688	688
1913	N/A	105	937	688	1,088
1914	N/A	132	1,022	912	1,088

Total Revenue = Sales of electricity + apparatus rental income; Net Profit is calculated after tax but before interest; Total Equity is ordinary share capital plus reserves

Table 2 Electricity Sales of the NESCo from 1891-1913 (millions kWh)

Year	Lighting & Heating	Traction	Manufacturers	Collieries	Chemical & Process	Bulk Supply	Total
1891	0.24						0.24
1892	0.34						0.34
1893	0.36						0.36
1894	0.40						0.40
1895	0.45						0.45
1896	0.54						0.54
1897	0.66						0.66
1898	0.80						0.80
1899	0.97						0.97
1900	1.01						1.01
1901	1.47		1.03				2.50
1902	1.88	0.19	2.96				5.54
1903	2.59	0.70	4.74			1.00	9.03
1904	2.90	6.00	6.29			2.00	17.19
1905	2.71	12.31	8.74	0.42		6.20	30.38
1907	4.90	13.30	38.30	7.80	30.60	4.80	99.70
1909	4.90	14.20	40.10	34.30	36.10	4.70	134.30
1911	5.90	15.50	49.90	44.90	42.00	7.60	165.80
1913	7.90	15.30	75.90	76.80	35.90	20.60	232.40

Sources: 1891-1900, NESCo, 1904, p.50; 1901-1905, NESCo, 1903 plus authors' estimates from company data.

Small motors have been classified under manufacturing. The total sales for 1902 is a revised figure and is greater than the sum of the individual categories. 1907-1913, Byatt, 1962, p.151

\*1905 The NESCo provided a bulk supply of nearly 6.2 million kWh to the CDEPDC and 14,170 kWh to the Tynemouth Corporation. The CDEPDC supplied the electricity to manufacturers, collieries, the tramways and to customers for Lighting & Heating. This needs to be taken into account when interpreting the data from 1909 to 1913.

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