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THE ROLE OF INDUSTRY IN THE ELECTRIFICATION OF FINLAND

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The paper deals with the relationships of electrification and industrialisation in Finland. It focuses on demand for electricity and examines the role of industry as a consumer of electric energy.

From the very beginning, manufacturing industry played an important role in the application of electrical technology in Finland. Early experiments on arc lighting equipment were carried out in an engineering workshop in Helsinki in 1877. The first permanent installation of electric lighting was erected in a cotton mill in Tampere in 1882. The earliest electric motor was commissioned in a printing shop in Viipuri in 1893. Several manufacturing industries in Finland introduced electric motors around the turn of the century. Half of the industrial motive power was electrified by the mid-1920s. The electrification of industrial motive power was completed by 1960, i.e. just within 70 years. That process might have been completed within a shorter period if electrification had not proceeded relatively slowly in the mechanical pulp industry, which consumed motive power more than any other sector of manufacturing.

The experience of Finland firstly shows that it was geographically fairly small local networks which dominated the production and consumption of electricity up to World War II. For half a century, most of the electricity was consumed within the same industrial company or within the same small local network where it was generated.

Another noteworthy point in the electrification of Finland is the dominant role of industry in both generation and use of electric energy. Manufacturing was the trail blazer which set the pace for the development.

The third point emphasised in the paper is the pivotal role of the electric motor as the promoter of electrification. Manufacturing in Finland required an exceptional amount of mechanical drive, and for several decades, electric motors of industry consumed over half of all electricity.

Electricity was the essence of the power revolution in modernising Finland, where industrialisation and the utilisation of electric energy mutually reinforced one another. The extensive electrification advanced Finland's endeavours utilising its main natural resource, timber, more efficiently and modernising its economy at a fairly brisk pace.

KEY WORDS: Electrical energy, motive power, manufacturing industry, industrialisation, history, Finland.

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ABBREVIATIONS

ABI	The Archives of the Board of Industry
ACSOF	The Archive of Central Statistical Office of Finland
GDP	gross domestic product
GWh	gigawatthour (1,000,000 kWh)
kW	kilowat (1,000 watts or 1.36 horsepower)
MW	megawatt (1,000 kW)
NAF	The National Archives of Finland
OSF	The Official Statistics of Finland
SOS	Sveriges officiella statistik
TWh	terawatthour (1,000,000 kWh)

THE ROLE OF INDUSTRY IN THE ELECTRIFICATION OF FINLAND*

Timo Myllyntaus

Introduction

The past twelve decades have seen the era of electricity. All over the world, electricity production soared and this new form of energy spread nearly everywhere throughout society. Historians have generally been apt to research these developments from a viewpoint of the electricity supply industry.[1] Power companies and electricity supply utilities were, of course, vital elements in the process. In this paper, I am applying

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a different approach. I am focusing on demand for electricity and examining the role of industry as a consumer of electric energy.

In its early years - in the 1870s and 1880s - electricity was, as a rule, an "exclusive" energy source used for lighting purposes in palaces, theatres, opera houses, luxurious shops and on some main streets of big cities. For a long time, lighting remained the most widespread use of electricity and it has greatly fascinated historians, too. During this century, the service sector and households, which used the new energy form primarily for lighting, have nevertheless seldom ranked first in the consumption of electricity. A great deal of electric energy has been consumed in places outside the public eye.

What gave the most dynamic impetus for the growth of electricity consumption? I argue that although the lighting of public places and private houses had a marked impact on public opinion about electricity, it did not set the pace for the rise of electricity consumption in Finland after the turn of the century. It was not the desire of the tidy middle-class to light their environs which primarily dictated the growth of electricity consumption and the pattern of electrification, but rather the power needs of the dirty electric motors in the dark bowels of industrial machinery.

The Power Revolution in the Industrialisation of Finland

Right from the outset, modern industry in the grand duchy of Finland (1809 - 1917) began to develop towards the high intensity of mechanical drive. From the mid-nineteenth century, the four major industries of the country, viz. sawmilling, ironworks, textile manufacturing and papermaking, introduced more and more working machines and prime movers. On the one hand, this was surprising because 19th-century Finland was short of capital, but it had a lot of underemployed labour free from feudal bondage. One might have expected that labour-intensive manufacturing and handicrafts would have suited such conditions better. On the other hand, the country had relatively abundant endowments of cheap waterpower, harnessable with rather simple technology due to numerous medium-sized rivers and the low heads of waterfalls. Hence, the Finnish industrial revolution was powered by hydraulic energy - not primarily by steam power. The capacity of industrial prime movers was 2,800 kW in 1850 and 182,800 kW in 1913, which meant that the average annual growth rate was 6.8 per cent. Although the capacity of reciprocating steam engines and steam turbines surpassed that of waterwheels and hydroturbines around 1910 for two decades, the latter on average had a longer annual operation time, and therefore, produced more energy.[2]

Considering the general level of the country's economic development, Finnish industry utilised an exceptionally large amount of motive power per worker, as Table 1 illustrates. In this respect, the grand duchy had overtaken the largest industrialised countries of Europe before World War I. The high power intensity of Finnish manufacturing can be attributed to the dominating role of the forest industries, the main sectors of which were sawmilling, pulping and papermaking. Evaluating on the basis of the ratio between the capacity of motive power and the number of workers, Finnish industry was noticeably more capital intensive than a late industrialising country would have expected to have been. The relative lack of capital in the country did not prevent sizeable investments in industrial machinery being made.

Table 1. Motive power in industry per 100 workers in Finland and some other countries, 1906 - 1910

Country		Year	kW	Country		Year	kW
Finland	a	1910	126	USA	b	1910	208
Sweden	a	1906	132	England	b	1907	112
Russia	a	1908	40	France	b	1907	63
- " -	b	1908	77	Germany	b	1907	54

a All industry
b Large-scale industry excluding mining

Sources: V. Källström, "Den svenska industriens mekanisering", *Kommersiella meddelanden* 17 (1930) no 8, p, 423; P. I. Lyashschenko, *History of the National Economy of Russia* (New York, 1970), p. 673; T. Myllyntaus, "Teollisuuden voimakoneet", *Suomen energiatekniikan historia* (Unpublished manuscript).

The four decades prior to World War I constituted a period of great changes in industrial power technology. In no other period in Finnish industrial history, have more new prime mover innovations been introduced than in the period 1875 - 1913. In these years steam turbines alongside with new boiler models, fast-revolving Francis hydroturbines, and

various kinds of internal combustion engines, such as gas motors, petrol and diesel engines, were put in operation. From the industrial point of view, the electric motor was, however, the most epoch-making innovation of the era.

From the very beginning, the manufacturing industry was a trail blazer in the application of electrical technology in Finland. Early experiments on arc lighting equipment were carried out in the engineering workshop of the State Railways in Helsinki in December 1877. The first permanent installation of electric lighting was erected in the weaving hall of the Finlayson cotton mill in Tampere in 1882. In Europe, this was the first electric lighting plant on industrial premises where the Edison system of incandescent lamps was applied. At the time, artificial lighting was sorely needed in Finnish industry, especially during the dim wintertime, and lighting devices with open fires were not very attractive alternatives due to their marked fire hazards in wooden buildings. Finnish industrialists were quick to consider incandescent lamps a technically competitive option with a good fire safety factor, and therefore most of the first electric lighting plants were installed in factories.

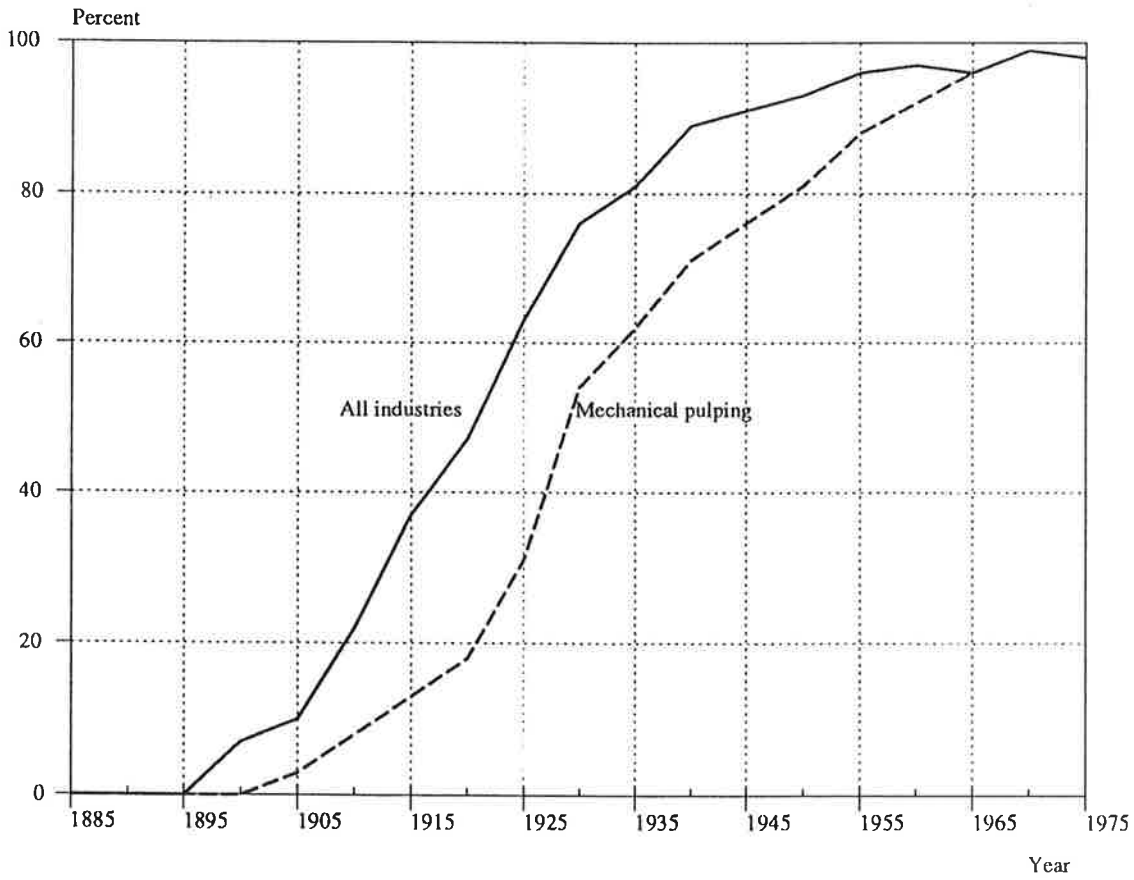
The first electric motor was commissioned in a printing shop in Viipuri in 1893. As in many other countries, the printing industry took the lead in the electrification of the motive power.[3] By 1904 that industry had electrified 40 per cent of its mechanical drive and by 1920 it became completely electrified.[4]

Several manufacturing industries in Finland introduced electric motors around the turn of the century. Half of the industrial motive power was electrified by the mid-1920s.[5] The diffusion of electric motors can be represented by quite a regular S curve, the steepest section of which is dated between 1905 and 1930. As shown in Figure 1, by 1960 diffusion reached its saturation point at the level of about 97 per cent; hence the electrification process of industrial motive power was carried out just within 70 years.

The process might have been completed within a shorter period if electrification had not proceeded substantially more slowly in the ground-wood pulp industry than in the rest of manufacturing on average.[6] From the early 1890s, mechanical pulping used motive power more than any other sector of production, and therefore, the electrification of this industry had a marked impact on the overall degree of electrification in manufacturing. In 1900 pulp grinding mills accounted for about 25% of the total capacity of motive power coupled with the working machines of industry. In 1913 the figure was 39%, in 1925 20%, in 1950 17% and in 1975 11%.[7] Grinding machines coupled directly with Francis hydroturbines fitted well into the technological requirements of the Finnish woodpulp mills in the early twentieth century. They were simpler and often cheaper than grinding machines with electrical drive. Later, directly coupled grinding machines were replaced by electrical drive, because the former strictly limited the location and rational layout of pulp mills. As time went by, the relative

price of electrical and non-electrical equipment changed in the favour of electric drive as well.

Figure 1. **The degree of electrification of mechanical drive in industry as a whole and in mechanical pulping in Finland, 1885 -1975.**



Sources: The Archives of the Board of Industry 1885 - 1930, *The National Archives of Finland and The Archive of Central Statistical Office of Finland; Official Statistics of Finland, 18. Industrial Statistics 1885 - 1975* (Helsinki, 1887 - 1977).

Because the other sectors of woodprocessing, e.g. chemical pulping, paper and cardboard making, were also fairly energy intensive, the demand for electric power from the forest industries as a whole rose to fairly high amounts in the course of time. For example in 1950, the pulp, paper and timber industries possessed 53 per cent of the total industrial installed power and 50 per cent of all electric motor capacity in manufacturing and mining.[8]

Although Finland was a late starter in industrialisation, it was not a latecomer in the electrification of mechanical drive in industry even if it did not participate in experimental and pioneering projects in this field in the 1880s and early 1890s. From the turn of the century, the proportion comprised by electric motors of the total installed power in the grand duchy was moderately high by international standards. In the USA, the capacity of electric motors accounted for 5 per cent of the total mechanical drive in manufacturing establishments in 1899; in Finland the corresponding figure was 7 per cent in 1900.[9]

According to Table 2, in 1913 Finland was in an intermediate position but between 1913 and 1925, it fell somewhat behind. By 1938, the industry of the country had, however, leaped close to the leading electrifiers abroad. During World War II and the time of reconstruction, it pre-

served - and even improved - its relative position. In the early 1950s, Finnish industry ranked fairly high in terms of the degree of electrification of mechanical drive in international comparisons.

Table 2. The capacity of electric motors as a percentage of total motive power installed in industry in various countries, 1909 - 1951

Country	Year 1913	DoE %	Year 1925	DoE %	Year 1938	DoE %	Year 1950	DoE %
Japan	1914	30	1926	88	1940	82		..
Sweden	1913	48	1925	77	1938	89	1950	97
USA	1913	36	1926	77	1937	85	1948	84
Italy	1911	48	1927	74	1938	88	1951	88
Canada		..	1925	67		..		..
Norway		..	1925	67	1938	82	1948	89
Germany		..	1925	66		..		..
Finland	**1913**	**32**	**1925**	**63**	**1938**	**87**	**1950**	**93**
Holland		..	1926	55		..		..
Britain	1912	23	1924	49		..		..
Estonia		..	1925	43*	1937	52		..
Poland		..	1925	27		..		..

DoE The degree of the electrification of mechanical drive
.. No data available
* The author's estimate

Source: T. Myllyntaus, *The Electrification of Finland 1877 - 1977, The Transfer of a New Technology into a Late Industrialising Economy,* (Unpublished Ph. D. thesis, London School of Economics 1988), p. 328

In the technologically leading countries of the late nineteenth century, electric energy was also applied to purposes other than mechanical drive. Before World War I, electricity was widely used in various chemical and metallurgical processes, electroplating and arc welding as well as for heating purposes in various industries.

Within a few decades from the 1880s, a great number of new electrochemical factories was founded primarily in industrialised countries. In this field, Finland did not manage to follow major Western countries and its Scandinavian neighbours, although from early on there were plans to set up electrochemical factories which would utilise Finnish hydropower resources. The first boom in the Finnish electrochemical industry began in the late 1890s but it soon faltered due to poor economic and technological performance.

The high profitability of electrochemical production requires well-chosen raw materials, profound technological expertise and cheap energy. Finland did not have ample raw material resources and there were no power plants which would have been able to supply electricity as cheaply as, for example, some Scandinavian countries. In Europe and America, there are many areas which have more favourable geographical and hydrological conditions than in low lying Finland. In those areas, abundant hydropower resources stimulated the building of power plants especially

for chemical processes. In mountainous Norway, the electrochemical industry consumed nearly half of the hydroelectricity produced, in Sweden about 30 per cent but only two per cent in Finland in the early 1920s.[10]

The Finnish chemical industry developed comparatively slowly, concentrating on the home market; its rapid expansion started only in the early 1960s. The most pivotal single reason for the accelerated growth was the commencement of oil refining by Neste Oy, a new state-owned company, in 1957.[11] By 1960, the chemical industry was, nevertheless, the second largest electricity user of the manufacturing sectors, coming after the pulp and paper industry and consuming 9 per cent of all electricity used in industry. By 1977 the chemical industry had increased its share to 13 per cent of the total industrial electricity consumption.[12]

In Finland, Elektrometallurgiska Aktiebolaget began to produce foundry pig iron at their Vuoksenniska and Nokia smelting plants in 1916 - 1917. The necessary technology was bought from Sweden, where the first *Elektrometall* furnaces had been built in 1910. In 1937 the Finnish electrometallurgical industry took a big step forward. One of the world's most modern electric furnaces was brought into operation at the Imatra Ironworks of Oy Vuoksenniska Ab, a domestic company. The capacity of this electric furnace was 100,000 tons of pig iron per annum.

In post-1945 Finland, the electrometallurgical industry did not sport high production. The metal industries' share of the total industrial elec-

tricity consumption increased from 6 per cent to 12 per cent between 1960 and 1977. The sector was thus catching up with the chemical industry.[13]

In the interwar electricity supply system, there were considerable daily, weekly and seasonal variations in load. In order to improve the load factor, off-peak surplus power was used for heating electric boilers which produced steam for various industrial processes. By replacing fuels with cheap surplus electricity, factories saved on their heating costs. For example, the construction of the Imatra power plant in the 1920s was accompanied by the installation of the second largest electric steam boiler in the world at the nearby chemical pulp mill of the Enso-Gutzeit Oy which was capable of consuming 40 MW of secondary hydroelectricity.[14]

On the national scale, the annual consumption of secondary or surplus hydroelectricity fluctuated considerably, by between 1 per cent and 26 per cent of the gross electricity consumption, depending on hydrological and other factors.[15] The extensive use of off-peak steam boilers was a special Finnish solution for utilising the occasional surplus capacity productively and for improving the overall load factor. However, owing to the irregularities in its supply, this cheap secondary power could not generally provide a basis for any larger electricity-intensive industry, such as electrochemical manufacturing.

Despite the extending use of electricity for various purposes, Finnish industry and the Finnish economy utilised electric energy predominantly for mechanical drive. In 1937, electric motors accounted for 78 per cent of

electricity consumption in industry and 74 per cent of the total electricity consumption (excluding generation and transmission losses).[16]

After World War II, the pattern of electricity utilisation changed fairly slowly. For example in 1950 - 1954, mechanical drive accounted for 73 per cent of the total industrial electricity consumption. Steam boilers used 14 per cent, electrometallurgical furnaces 7 per cent, and electrochemical processes only 3 per cent. The remainder, 3 per cent, was accounted for lighting and space heating.[17] If we exclude steam boilers which were heated with secondary electricity, the onesidedness of the industrial utilisation of electric power is highlighted: industry consumed as much as 85 per cent of its primary electricity for mechanical drive, and the electric motors of industry used over half of all the electricity in the country. This phenomenon was, of course, a reflection of the imbalanced structure of Finnish industry and also of the modest extent of electricity use in the rest of Finnish society.

Industry's Proportion of the Total Consumption of Electricity

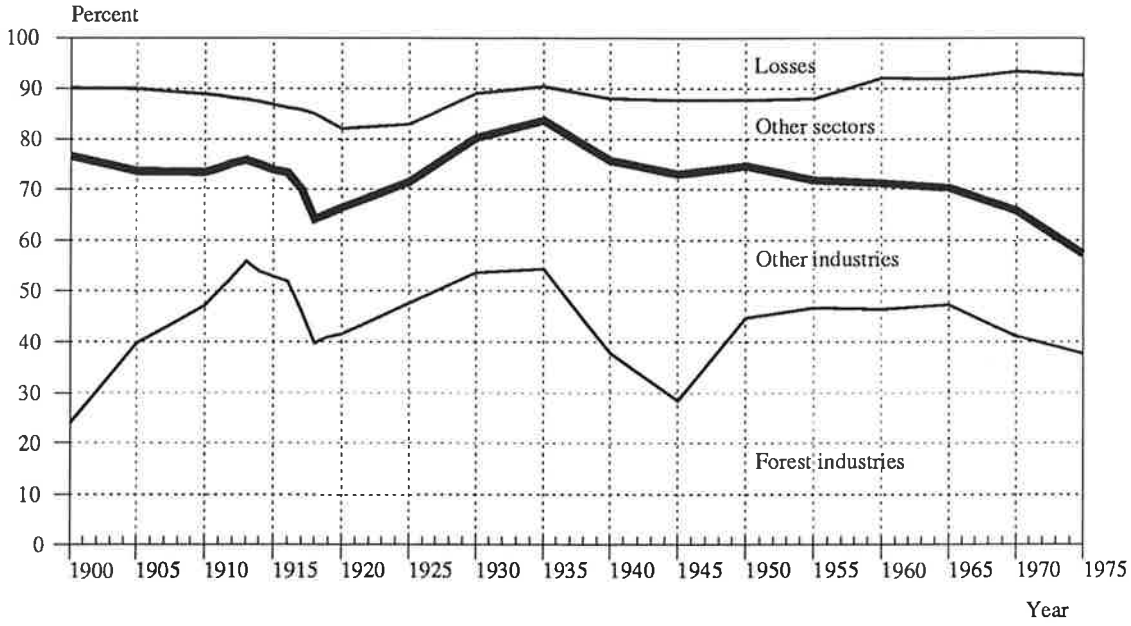
In the 1880s, Finland was still an agrarian country where industrialisation was just getting under way. The composition of its national output was markedly restructured only in the electrical era. Industrialisation led to a steep rise in electricity use, because modern industry was

much more power-intensive than farming, and as a latecomer, Finland as a rule chose the latest technology for meeting its mechanical drive needs.

Industry attained a dominant role in electricity consumption because it was the most modern sector in the economy, and in manufacturing, mechanical drive was fairly rapidly and extensively electrified. For many decades, the woodprocessing industry alone used about 40 - 50 per cent of the total electricity supply, while manufacturing and mining as a whole consumed about 65 - 85 per cent, as demonstrated in Figure 2.[18] It was only in the early 1960s that the share of manufacturing began to decline substantially.[19] In 1960, industry used 70 - 80 per cent of the total electricity consumption (including losses) in Finland and Belgium, whereas its share was less than 10 per cent in Switzerland. In other Western European countries, industry's share of electricity consumption was between these two extremes.[20]

Because manufacturing played such a decisive role, the growth rate of the total electricity consumption tended to slow down simultaneously as the growth rate of the industrial use of electricity started its gradual decline. In the 1920s, the latter was 19.3 per cent per annum, whereas its corresponding growth rate in the 1970s was 4.8 per cent.[21]

Figure 2. The composition of electricity consumption in Finland, 1900 - 1975.



Sources: *OSF 18A:17-76 Industrial Statistics of Finland 1900 - 1960* (Helsinki, 1902 - 1962); *Tilastokatsauksia* (1929) no 12, (Helsinki, 1929); *Sähkölaitostilasto v. 1930 - 1965* (Helsinki, 1931 - 1967); *OSF 42:6 Energy Statistics 1986* (Helsinki, 1987).

The Industrial Use of Electricity per Worker

The pre-eminence of pulp and other forest industries greatly enhanced the demand for electricity by Finnish manufacturing. This fact contributed to the rise of Finland to be among the top countries in industrial electricity consumption per worker in the interwar period. By 1938 Finland with its 11,850 kWh per worker had already slightly surpassed the Swedish level of 10,470 kWh.[22] Variations in this respect were then substantial even across Europe. For example, an Estonian industrial labourer used in his work on average less than a quarter, 2,300 kWh, of the annual amount consumed by his Nordic counterparts.[23]

Both in Finland and Sweden industrial electricity use per worker continued to grow in the 1940s and 1950s. By 1954, the rise had been slightly faster in Sweden which with its 12,630 kWh per worker had surpassed Finland (12,100 kWh). These amounts are higher than the corresponding figure for Switzerland, 5,180 kWh, but clearly lower than the figures for the USA (20,270 kWh) and for Norway (32,130 kWh per worker). In all these countries, some electricity-intensive sectors of production, such as chemical, metallurgical or forest industries, substantially increased the average electricity used per worker in manufacturing as a whole.[24]

The Total Consumption of Electricity: Growth and Structure

Industrialisation led to many other aspects which were also apt to boost electricity demand, such as rising living standards, urbanisation, the development of public transport, and the expansion of services. When the standard of living rose, the significance of the residential sector as a consumer of electricity increased. By 1930 its share grew to about 3 per cent and by 1975 to 19 per cent of the total electricity used in Finland.[25] .

Although by the end of the 1930s Finland surpassed some major industrial countries in the total electricity output per capita, its electricity use for non-industrial purposes remained relatively modest. If early twentieth-century Finland were to be ranked in international comparisons according to this indicator instead of the total output per capita, it would drop from a middle ranking nearly to the bottom. In the interwar period, no electricity-intensive country, in fact, used as low a percentage of its total electric energy for the civic consumption as Finland (See Table 3).

Table 3. **The total output of electric power and its consumption for civic purposes in various countries in 1936.**

Country	Total output TWh	Total output per capita kWh	Civic consumption* per capita kWh	Civic consumption as a percentage of the total output %
Norway	8.0	2,750	666	24
Canada	25.4	2,318	350	15
Switzerland	6.1	1,452	310	21
Sweden	7.4	1,187	135	11
USA	136.0	1,061	270	25
Finland	**2.3**	**645**	**46**	**7**
Germany	42.5	631	77	12
Britain	28.9	613	105	17
France	18.5	440	50	11
Italy	13.6	318	37	12

* Including the consumption by households, agriculture, handicrafts, small industries and private services plus street lighting and other public consumption (except transport).

Source: T. Myllyntaus, *The Electrification of Finland, 1877 - 1977* (Unpublished Ph.D. thesis, LSE, 1988), p. 146.

Before World War II when industry used 65 - 85 per cent of the total electricity output, the growth rates of the total and industrial electricity consumption were almost identical. Thereafter, the intensive

electrification of other sectors pushed the growth rate of the total consumption above that of industrial consumption, as indicated in Table 4.

Table 4. **The annual average growth rates of electricity consumption, the output volume of industry and the inflation-adjusted GDP in Finland, 1890 - 1977,** (Compound growth rates per year).

Period	Total electricity consumption %	Industrial electricity consumption %	Industrial output volume %	Real GDP %
1890-1913	25.3	25.3	5.3	3.0
1913-1920	6.8	6.5	-1.6	-1.4
1920-1938	14.1	14.0	7.9	4.7
1938-1949	1.2	0.3	2.8	2.1
1949-1973	9.2	8.3	6.4	4.9
1973-1977	2.5	0.0	0.5	1.2
1890-1938	18.2	18.1	5.2	2.9
1938-1977	6.2	5.1	4.7	3.7
1890-1977	12.7	12.1	5.0	3.3

Sources: T. Myllyntaus, *The Electrification of Finland, 1877 - 1977* (Unpublished Ph.D. thesis, LSE, 1988), Appendix tables A.5-A.6; S. Heikkinen et al., *Industry and Industrial Handicraft in Finland, 1860 - 1913* (Helsinki, 1986), pp. 120-22; R. Hjerppe, *The Finnish Economy, 1860 - 1985* (Helsinki, 1989), pp. 192-94.

The Self-Generation of Electric Energy

By 1890, the generation of electricity in total had risen to 1 GWh (million kWh) in Finland. In 1917, when the country gained its independence, the electricity output was 205 GWh and sixty years later, the net supply was 32,581 GWh (See Table 5). Between 1890 and 1977, the average annual growth rate per capita was 11.9 per cent for the net supply of electricity and 2.5 for GDP at constant prices. Hence, the generation of electric energy was one of the most expansive sectors of the national economy, because almost by a factor of five, the increase of the electricity net supply surpassed the growth rate of GDP.

In most of the years during the first four decades of the electric era (1882 - 1922), more electricity in Finland was generated by thermal power than by hydropower. Hydroelectricity was the leader only between 1899 and 1908, in 1913 and 1917 - 1918. In the early 1920s, the situation changed and hydropower became the primary source for electric energy for a long timespan. From 1921 to 1968 hydroelectricity accounted for 55 - 95 per cent of all electric energy produced in the country. Finland lost its membership in "the club of hydropower countries" in the late 1960s when almost all of its economically useable hydropower resources had been harnessed.

Thereafter, growing demand for electricity has in the first place been met by the means of thermal power: coal, oil and nuclear power plants.

At the turn of the century, Finland was clearly behind the most advanced countries, the USA and Switzerland, in the generation of electricity per inhabitant, but abreast with some major countries, for example Britain and Italy. Between 1900 and 1920, it fell behind most of the industrialised West-European countries. In interwar Europe - apart from the Soviet Union - the annual growth rate of electricity output was, in contrast, highest in Finland being 14.1 percent on average. By 1938, the country leapfrogged to the group of the leading producers of electricity per capita in the world. With its output of 850 kWh per capita, Finland then ranked seventh. In World War II, the country lost a third of its hydroelectricity capacity and it took a long time to restore the relative position of the late 1930s in electricity output. In 1975, the country was, however, again among the top ten consumers of electricity per capita.[26]

Table 5. The supply of electricity in Finland, 1890 - 1977

Year	Hydro-power GWh	Thermal power GWh	Total production GWh	Net supply* GWh	Supply per capita kWh
1890	0.3	0.7	1.0	1.0	0.4
1900	12	5	17	17	6
1910	44	46	90	90	31
1920	133	156	289	289	92
1930	868	338	1,206	1,206	350
1940	1,361	346	1,707	1,789	484
1950	3,650	516	4,166	4,164	1,039
1960	5,216	3,151	8,367	8,789	1,984
1970	9,354	11,860	21,214	21,742	4,720
1977	12,060	19,630	31,690	32,581	6,874

* Net supply = Production + Import - Export

Source: T. Myllyntaus, *The Electrification of Finland, 1877 - 1977* (Unpublished Ph.D. thesis, LSE, 1988), pp. 419-420.

From 1900 to the mid-1970s in terms of electricity output per inhabitant, the ranking order of countries remained surprisingly stable. The pathbreakers of electrical technology and electricity production preserved

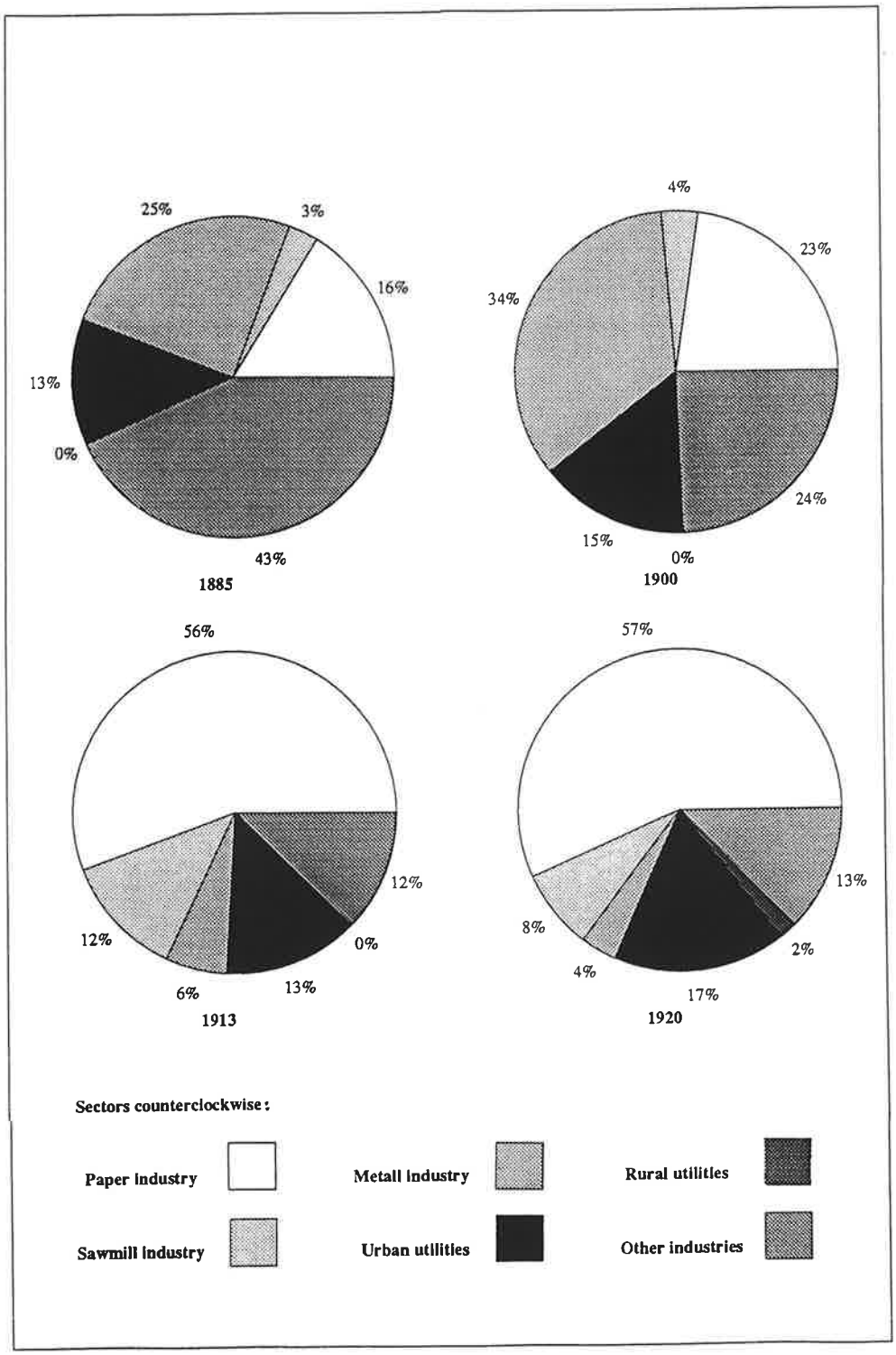
their leading positions. Of the latecomer industrialisers, only Iceland, New Zealand and Finland managed to rise and join the top ten electricity users between 1925 and 1975. As a rule, the top countries have had some common features: The extensive electricity use per capita has traditionally been concomitant to a highly developed economy and abundant indigenous energy resources (hydropower, geothermal energy, and/or coal) available for electricity generation. As in Norway and Sweden, the success of Finland is greatly attributed to the considerable hydropower resources and to dynamism in adopting appropriate technological know-how from abroad.

In Finland, industry was not only the prime consumer of electricity but also its major producer. Up to the mid-twentieth century, manufacturing companies, especially in the electricity-intensive industries, used a lot of electric power generated on their own premises.

A characteristic of Finland was that for a long time the electricity supply utilities played a minor role as suppliers of power for industry. The utilities mainly operated in the urban areas, whereas big factories were often situated in rural localities. Therefore, a considerable proportion of electricity was self-generated or purchased from another factory nearby. In fact, particularly from the 1920s, industrial plants began to supply electricity to urban and rural utilities on wholesale terms. For some woodprocessing companies, electricity developed into an important by-product which was generated by means of wastes or surplus hydropower capacity.[27]

Self-generation by industrial plants was not peculiar only to Finland, since in British industry, for example, 58 per cent of the capacity of electric motors was provided by self-generated electricity in 1912.[28] A year later, the corresponding percentage in Finnish industry was 65 per cent or more.[29] At the turn of the century, the output of industry's power plants greatly surpassed that of public power plants in various other countries. In 1891 in Germany, the capacity of industrial power plants was eight times larger than that of the public supply companies which managed to bridge the gap prior to World War I only very slowly. As late as in 1911 the industrial power plants possessed a generating capacity (6.7 million kW) which was four times larger than that of the public electricity supply utilities (1.5 million kW). In Germany, the public electricity supply utilities did not catch up with the self-generating plants of industry and mining in terms of output before the year 1928.[30]

Figure 3. **The production of electricity by industrial sectors in Finland, 1885 - 1920**



In Finland, the difference between self-generating plants and public power plants was not so large at the outset as in Germany but the convergence of the outputs of these groups was much slower. In 1885, the power plants of industry generated on estimate about 87 per cent of all electricity in Finland. In 1900, the corresponding figure was 85 per cent and still in 1920 about 80 per cent, i.e. four times that of the electricity supply utilities (Figure 3).[31] Unfortunately, there are no exact figures available for the subsequent years but in terms of output, power companies and electricity supply utilities presumably surpassed the industrial power plants only in the late 1930s.[32] While factories have gradually increased their purchases of energy from the public suppliers of electricity, several large industrial companies have continued to sell electricity to both power companies and supply utilities up to the present. Consequently, a brisk exchange of electricity has developed between these two sectors of the power business.

Conclusions

The experience of Finland shows that it was geographically fairly small local networks which dominated the production and consumption of electricity up to World War II. For half a century, most of the electricity was consumed within the same industrial company or within the same small local network where it was generated. Consequently, the develop-

ment of regional and national networks might not have had such an importance prior to 1940 as has been presumed. Although regional and national networks were commissioned in interwar-Finland, they gained a footing quite slowly.[33] If this notion proves to be true in other countries as well, historians should pay more attention to these small networks and to self-generation instead of large technological systems which became relevant only during and after World War II.

Another central point in my outline of the electrification of Finland is the dominant role of industry in both generation and use of electric energy. Manufacturing was the trail blazer and set the pace of the development. The electrification of services, transport, agriculture and households was a societally important phenomenon but its role was not decisive. From the introduction of the first permanent electric lighting plant in 1882 to the commission of the first nuclear power plant in 1977, industry consumed 60 per cent or more of all electricity in Finland. Hence, electricity was primarily industry's energy source.

The third point which I have tried to prove in the paper is the pivotal role of the electric motor as the promoter of electrification. Due to the above mentioned reasons, manufacturing in Finland required an exceptional amount of mechanical drive and for several decades, electric motors of industry consumed over half of all electricity. Applying electrical technology for mechanical drive gave a boost to the general electrification of the country and provided industrial production with many valuable

opportunities. The use of electricity as a power source had a great economic significance. It facilitated the increased exploitation of an indigenous energy source, hydropower, which is as a rule cheaper to produce than thermal power. In addition, the energy costs of the plants could be reduced by applying electric group and unit drive in the distribution of power to work places.

It should, however, be noted that overall energy costs in the main sectors of Finnish industry were clearly less than 15 per cent of the total production costs at the turn of the century, so that a saving of a quarter or a third in the cost of generating mechanical energy had a relatively slight impact on the total production costs. Thus it was not energy saving that was the weightiest reason for introducing electric motive power but the fact that the firms expected essential indirect cost savings from their investments in the new technology. A more flexible and functional layout of work stations on the factory floor was the aim of electric power distribution. The machines could be controlled with a higher degree of accuracy. The material losses and stoppages of production processes were diminished. Job safety was improved, while the maintenance chores of the workers were reduced, and the labour force was better able to concentrate on productive work. This resulted in a faster working tempo in the factories and improved productivity. Electrification thus made it possible to expand production at less extra cost than before.

Electricity was the essence of the power revolution in modernising Finland where industrialisation and the utilisation of electric energy mutually reinforced one another. Electricity was particularly suited to Finnish factor endowments. Efficient lighting enabled long working hours in wintertime and night-shift working all the year round. Electric motors were 'divisible' and easily operated without highly-skilled labour. Electric control systems provided opportunities for the large-scale automation of production processes and reducing labour costs. Electrification enhanced not only productivity but also profits and the international competitiveness of Finnish industry. The extensive electrification advanced Finland's endeavours utilising its main natural resource, timber, more efficiently and modernising its economy at a fairly brisk pace. Competitive forest industries and the voluminous consumption of electricity still constitute vital parts of the economic basis for the present Finnish welfare state.

NOTES

1. L. Hannah, *Electricity before Nationalisation* (London, 1979); T. P. Hughes, *Networks of Power, Electrification in Western Society, 1880 - 1930* (Baltimore, 1983); H. Ott, *Statistik der öffentlichen Elektrizitätsversorgung Deutschlands 1890 - 1913, Historische Energiestatistik von Deutschland - Band 1* (St. Katharine, 1986).

2. T. Myllyntaus, *The Gatecrashing Apprentice, Industrialising Finland as an Adopter of New Technology,* Institute of Economic and Social History, University of Helsinki, Communications no 24 (Helsinki, 1990), pp. 27-30.

3. In Japan for example, 2.2 per cent of all motive power in the printing industry was derived from electric motors in 1900 and 99.6 per cent in 1930. Thus printing became the first electrified industry in that country. R. Minami, "Mechanical Power and Printing Technology in the Pre-World War II Japan", *Technology and Culture* 23 (1982) no 4, pp. 610-11.

4. T. Myllyntaus, "Tekniset uudisteet graafisessa teollisuudessa 1800-luvun puolivälistä 1920-luvun alkuun", *Sanomalehtien taloudellinen tausta,* Suomen sanomalehdistön historia-projektin julkaisuja no 21 (Helsinki 1983), p. 65.

5. T. Myllyntaus, *Finnish Industry in Transition, 1885 - 1920, Responding to Technological Challenges* (Helsinki, 1989), p. 83.

6. The Archives of the Board of Industry [hereafter ABI] 1885 - 1930, The National Archives of Finland [hereafter NAF] and The Archives of Central Statistical Office of Finland [hereafter ACSOF]; *Official Statistics of Finland [hereafter OSF] 18 Industrial Statistics 1884 - 1977* (Helsinki, 1886 - 1979).

7. Cardboard and wallboard mills are here included in the pulp grinding industry. ABI 1900 - 1913, NAF and ACSOF; *OSF 18 Industrial Statistics 1925 - 1975* (Helsinki, 1926 - 1977).

8. *OSF 18:66 Industrial Statistics 1950* (Helsinki, 1953).

9. The author's estimate based on ABI 1900, NAF; W.D. Devine, Jr., "From Shafts to Wires: Historical Perspective on Electrification", *Journal of Economic History* 43 (1983) no 2, p. 351.

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11. A. Haapaniemi, "Kemian teollisuutemme historiaa: Tervanpoltosta teollisuudeksi", *Kemia-Kemi* 10 (1983) no 6, pp. 523-25

12. *OSF 42:5 Energy Statistics 1985* (Helsinki, 1986), pp. 80-81.

13. *Ibid.*, pp. 64, 80-81.

14. *Imatra Power Plant* (Helsinki, 1933), p. 12.

15. *Sähkölaitostilasto v. 1930 - 1965*, Electrical Inspectorate (Helsinki, 1931 - 1967).

16. *Sähkölaitostilasto v. 1937* (Helsinki, 1938) pp. xx - xxii.

17. *Voima ja valo* 25 (1952) no 9, p. 165, 27 (1954) no 10, p. 226, 28 (1955) no 10, p. 202.

18. In Sweden, industry utilised 94% of all electric energy in 1913 and 83% in 1928. V. Källström, "Den svenska industriens mekanisering", *Kommersiella meddelanden* 17 (1930) no 8, p, 429.

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20. *Voima ja valo* 35 (1962) no 12, p. 340.

21. *OSF 42:6 Energy Statistics 1986*, (Helsinki, 1987).

22. *SOS, Industri 1938* (Stockholm, 1940); *OSF 18. Industrial Statistics 1938* (Helsinki, 1940).

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24. *Elektrotechnische Zeitschrift*, B-Ausg., (1956) no 5, p. 221; *Voima ja valo* (1956) p. 170.

25. *Sähkölaitostilasto v. 1930* (Helsinki, 1931); *Energy Statistics 1986* (Helsinki, 1987).

26. T. Myllyntaus, *The Gatecrashing Apprentice*, op. cit., pp. 85-87.

27. T. Myllyntaus, "Sahateollisuus", in T. Myllyntaus, K-E. Michelsen and

T. Herranen, *Teknologinen muutos Suomen teollisuudessa 1885 - 1920* (Helsinki, 1986), pp. 75-76.

28. I.C.R. Byatt, *The British Electrical Industry, 1875 - 1914* (Oxford, 1979), p. 75,

29. ABI 1913, NAF and ACSOF.

30. H. Ott, "History of Electricity in Germany", *Un siècle d'electricité dans le monde 1880 - 1980*, ed. F. Cardot (Paris, 1987), p. 136.

31. ABI 1900 - 1920, NAF and ACSOF.

32. *Sähkölaitostilasto v. 1937* (Helsinki, 1938).

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