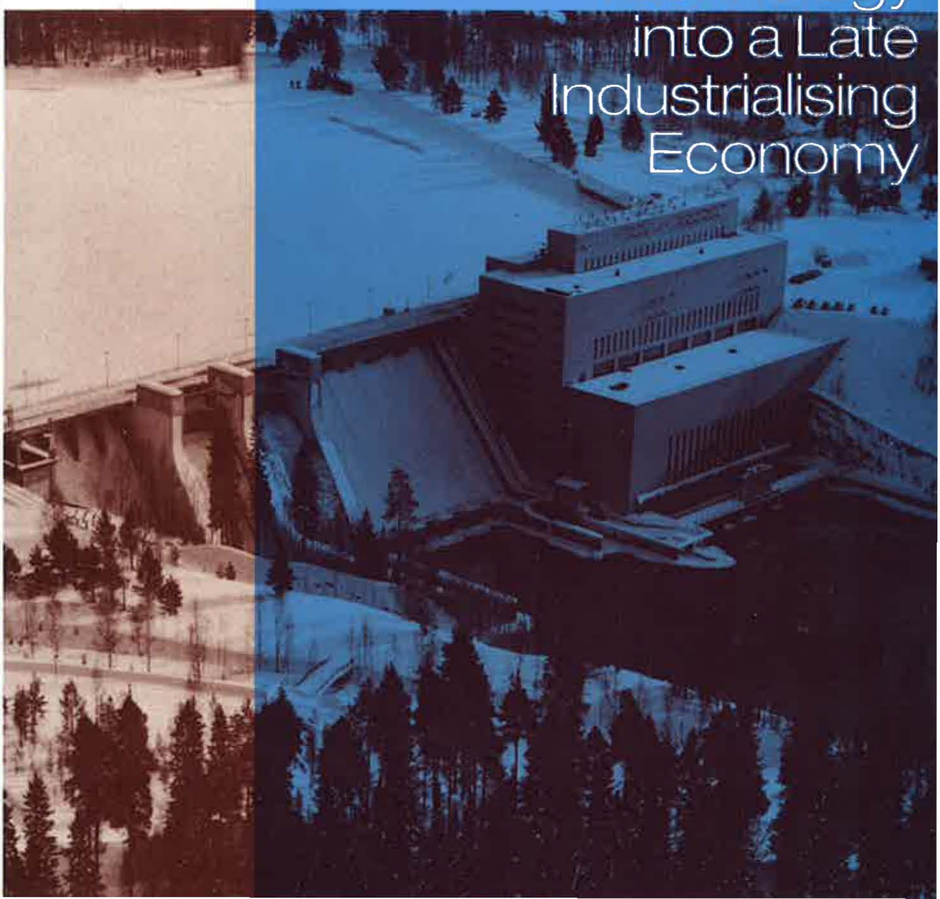
Timo Myllyntaus

Electrifying Finland

The Transfer of a New Technology into a Late Industrialising Economy



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Electrifying Finland

The Transfer of a New Technology into a Late Industrialising Economy

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M in association with
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To my parents

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Preface

When a few years ago I became a member of a research project dealing with the technology and economy of the Finnish energy sector I found myself with the interesting opportunity to study the history of technology from a multidisciplinary viewpoint. I had the privilege to be one of the pioneers in the history of technology in Finland and I took advantage of that by selecting electrification as the primary theme of my research. However, I did not find the selection easy because there were many unexplored themes within the energy sector. Inspiration from abroad, however, stimulated me to concentrate on electricity. While leafing through international research literature on energy, the studies on electricity fascinated me most. I noticed that in almost every country at least one historical outline had been published on the development of electricity supply. At the time there was no long-term account on that theme related to Finland. My first congress and research trips abroad sealed my decision to work out such an outline. The encouragement I acquired during visits to Britain, Sweden, Italy, Switzerland and Estonia was vital for my work; without those visits this book might never have been completed.

During a meeting of the project on the history of energy technology, an elderly professor of engineering was asked to write an article on steam engines. He promised to write about developments during the last eighty years, explaining this limitation for the research period by saying 'I remember the significant models of our steam engines only from the turn of the century but who could recollect the engines used before that.' I was one of the youngest in the project and my own experience on the stationary prime movers manufactured before the Second World War is very modest; nevertheless, I can vividly recall wood-burning stoves, horse-driven sledges, oil-lamps and steam locomotives which still, in the 1950s, were part of the everyday life in some parts of Finland. Although history-writing is not committing one's own personal memories to paper, these examples show how recent a phenomenon is large-scale electrification and how rapid technological change has been in Finland. As an undergraduate I was taught the old rule of the humanities that an historian should not deal

with the period after his/her birth. Breaking this rule has always tempted me, and in this research I have good reasons to break it. In the electrification of Finland, the climax took place during the post-war decades. By excluding those decades, a researcher would find only a prologue – although a promising prologue – of an epochal development.

I am deeply indebted to my teacher, Professor Leslie Hannah of the London School of Economics, who encouraged me during the work, read the whole manuscript, and let me draw on his wealth of knowledge. I also owe warm thanks to my two other supervisors, David G. Kirby and Jonathan Liebenau, whose advice greatly contributed to the study.

I wish to express my gratitude to Alan S. Milward, Kaj Pönni and Antony F. Upton for valuable criticism of the work. I am also indebted to Sven-Olof Olsson who read and improved some parts of the manuscript. In editing the text I have received substantial assistance from John Desborough which I gratefully acknowledge.

Special thanks are extended to Professor Emeritus Risto Keskinen of the Tampere University of Technology who backed me up to begin my studies in this field and from whose expertise I have greatly benefited. Other persons who have been involved in the project at various times also deserve recognition. The assistance of Timo Herranen, Timo Matala, Karl-Erik Michelsen, Seppo Mäki, Jyrki Ruutu, Satu Tuuva and Simo Vahvelainen in the tedious work of collecting the vast amount of information required for estimating the generating capacity, electricity output and consumption has been of vital importance. Meanwhile I wish to express my gratitude to all the others who participated in producing the book. Needless to say, any errors of fact or judgement are all mine.

My warmest thanks go to my parents. Both my parents were storytellers and my father's stories about his experience on the electrification of his home province aroused my early interest in the subject. Thanks to his wise advice I survived my first experiments on alternating current, and later under his direction I learned a practical trade which gave me a valuable insight into some parts of technology.

Nothing can exceed my obligation to my wife Tuija and my children Ojelvo, Pauliina and Marjukka, who, while suffering long periods of neglect, managed to prevent me from becoming absorbed in the dusky tombs of history for ever, and from time to time dragged me to the sunshine of the present to revive my energy resources.

For financial assistance, I gratefully acknowledge the fellowships and grants awarded by The Academy of Finland, The British Council, The Finnish Cultural Foundation, The Foundation of Imatra Power and Oskar Öflund's Foundation. In addition, I am pleased that ETLA is including this book in its series of thesis-type publications.

TIMO MYLLYNTAUS

Abbreviations

Ab	Aktiebolag (company with limited liability in Swedish)
AC	Alternating current
ACSOF	Archive of the Central Statistical Office of Finland
AEG	Allgemeine Elektricitäts-Gesellschaft (Berlin, Germany)
AG	Aktien-Gesellschaft (company with limited liability in German)
ASEA	Allmänna Svenska Elektriska Aktiebolag (Västerås, Sweden)
BBC	Brown, Boveri & Cie (Baden, Switzerland)
CBAF	Central Business Archives of Finland
CSOF	Central Statistical Office of Finland
DC	Direct current
FEAB	Finska Elektriska Aktiebolag (a subsidiary of the ASEA)
FIM	Finnish mark (equivalent to 100 pennies (FIP))
FRG	Federal Republic of Germany
GEB	Gesellschaft für elektrische Beleuchtung vom Jahre 1886 (St Petersburg, Russia)
GDP	Gross domestic product
GDR	German Democratic Republic
GNP	Gross national product
HBL	*Hufvudstadsbladet* (a newspaper, Helsinki)
HD	*Helsingfors Dagblad* (a newspaper, Helsinki)
HEP	Hydroelectric power plant
hp	Horsepower (equivalent to 736 watts)
HS	*Helsingin Sanomat* (a newspaper, Helsinki)
IVO	Imatran Voima Osakeyhtiö (Imatra Power Ltd)
KHM	Kansanhuoltoministeriö (Ministry of Supply)
KM	Komiteanmietintö (Committee Report)
MESUH	Municipal Electricity Supply Utility of Helsinki
MNC	Multinational company
NAF	National Archives of Finland
NOS	Norges offisielle statistikk (Official Statistics of Norway)
NPP	Nuclear power plant
ORKA	Eesti NSV Oktoobrirevolutsiooni ja Sotsialistliku Ülesehituse Riiklik Keskarhiiv (a central archive in Tallinn, Estonia)

OSF	*Official Statistics of Finland*
Oy	Osakeyhtiö (company with limited liability in Finnish)
p.a.	Per annum
rpm	Revolutions per minute
SOS	Sveriges officiella statistik (Official Statistics of Sweden)
SPTE	Société St Petersbourgeoise de transmission electrique de la force des chutes d'eau (St Petersburg, Russia)
STVAiFF	*Svenska Tekniska Vetenskapsakademien i Finland, Förhandlingar* (a series of publication, Helsinki)
SYF	*Statistical Yearbook of Finland*
TAik	*Teknillinen Aikakauslehti* (a journal, Helsinki)
TFiFF	*Tekniska Föreningen i Finland, Förhandlingar* (a journal, Helsinki)
toe	Ton oil equivalent
TVO	Teollisuuden Voima Oy (Industrial Power Company Ltd)
UKAEA	United Kingdom Atomic Energy Authority
UN	United Nations
US	*Uusi Suomi* (a newspaper, Helsinki)
V	Volt
VV	*Voima ja valo* (a journal, Helsinki)
W	Watt
wh	Watthour

Multiple units

T	tera	=	1 000 000 000 000
G	giga	=	1 000 000 000
M	mega	=	1 000 000
k	kilo	=	1 000

1 Introduction

1.1 THE SCOPE OF THE STUDY

The purpose of this research is to investigate the adoption process of a new technology in a latecomer economy. Electrical technology is well suited for this kind of examination, because electric power has been a catalyst of the key technological change in the modern industrialised economies during the last hundred years.[1]

In its early decades, electricity represented a new type of technology which had been recently innovated and developed with science and several international inventions as its basis. The international exchange of electro-technical innovations provided a stimulus for the use of this very flexible and versatile energy form in all the industrialised countries as well as for the rise of big transnational electrical engineering companies. Consequently, commercial electrical technology having start-up in the nineteenth century represents one of the earliest fields of modern high technology. Studying the long experience of the inter-country diffusion process of electrical technology might help us understand the corresponding processes and future impact of more recent technologies such as electronics, industrial robots, and optical fibres.

Finland, a peripheral North European region with long traditions of isolation from the heart of the Continent, is considered a relevant case for studying a developing economy transferring foreign technology to promote its industrialisation. In this research, the electrification of Finland is examined in an international perspective in order to identify its general and specific characteristics.

Finland is studied as a national and territorial entity defined by its current borders at any given time. Therefore during the period under study, the country has consisted of three, geographically somewhat different areas: that of the Grand Duchy of Finland and its successor up to 1920, that of the 'first republic' between 1920 and 1939, and the area of postwar Finland.[2]

The study covers the period from 1877 to 1977. In the year 1877, electric lighting with a steam-driven dynamo was experimented with for the first time in Finland. The history of heavy current engineering in the country began with the public demonstrations of electric illumination in Helsinki using imported French arc-lighting equipment.

Gradually, the use of electricity for different purposes spread all over the country. Urban areas and nearly half of the rural households were wired for electricity by 1940. By the mid-1970s, practically all citizens had some dealings with this energy form in their everyday lives. Finland had developed into an electrified, industrialised society where electricity had become a necessity, an integral element of its economic and technological base. At the same time, Finnish society decided to take a new step in energy technology: the first nuclear power station was to be put in operation in 1977. In the Finnish energy economy, that event meant the beginning of a new era which is excluded from this study.

1.2 THE BUILD-UP OF A NEW TECHNOLOGY: SOME THEORETICAL NOTES

A country could obtain new technology[3] by creating it or by transferring[4] it from abroad. For independent creation, a country needs favourable preconditions and sufficient back-up resources. Innovating and developing a new technique usually requires a lot of time and funds. Many less developed countries are, therefore, unable to create an indigenous technology. They mainly rely on imported technology, but its transfer is neither without cost nor trouble-free. Although less developed countries can adopt technology in a fully developed form from the advanced countries, they cannot avoid problems. For those countries, the introduction of a new technology generally means a greater change per decade than for highly industrialised countries. The introduction of a new technology can be defined as a process with four phases:

(1) transfer of a new technology;
(2) adoption, application and diffusion;
(3) use;
(4) direct and indirect effects.

From the viewpoint of a recipient country, there are two types of technology transfer: general and controlled. General technology is fairly easily available and inexpensive. It is not, as a rule, bought from the first-hand innovators but through middlemen or obtained from commonly accessible sources. In this case, the recipient makes the decisions on technology transfer; he chooses from whom he buys and what.[5] In the controlled transfer of technology, there is always a deliverer and a recipient who both make decisions. In this case, the object of transfer is clearly defined and its price is fairly high. This type of technology cannot generally be freely purchased on the world market because it includes at least some secret or somehow protected components of technological expertise. In the controlled transfer of technology, the deliverer has the upper hand; ultimately it is he who decides when and where his technology is transferred.[6]

In the eighteenth and nineteenth centuries, innovative activities in technology were concentrated in a few major industrial countries: first in Britain and France, and later also in Germany and the USA. A great number of other countries attempted to follow the example of these forerunners and to adopt their up-to-date technology. New technology can be transmitted through various channels from the industrial centres to the periphery. The most important channels can be listed as shown in Table 1.1.

Table 1.1 indicates that, as a rule, the role of the recipient is rather passive in those kinds of technology transfer which are more strictly controlled by the deliverer. In addition, it is frequently claimed that the efficiency of the channels mentioned in Table 1.1 decreases from no. 1 to no. 8. The controlled channels are regarded as more direct and as quicker means for transferring technology from one economy to another. Turn-key deliveries, joint-ventures and direct foreign investments supplemented with the training of native personnel, and the importation of capital goods are evaluated by the OECD as the most efficient ways to transfer technology. They are considered to facilitate the building of a modern production capacity in the recipient economy in a short period of time and to boost competitive and profitable manufacturing with little risk of setbacks.[7]

General transfer of technology greatly depends on the activity of a recipient society and it is regarded as a more inefficient, uncertain and roundabout method. However, it preserves the sovereignty of the recipient country and its autonomous efforts to gain technological self-sufficiency, while the hazards of dependence are involved in the case of controlled transfer of technology. Despite some advantages of controlled transfer and the direct involvement of foreign companies, less developed countries fear the consequences of technology imports on their aspirations for self-reliant growth and self-rule over resources.[8]

Technological change and the transfer process can also be classified as an *embodied* or *unembodied* type. Embodied technological change always emerges in the form of tangible equipment and material

Table 1.1 Channels for the inter-country transfer of technology

Role of the recipient	*Channels of transfer*	*Type of transfer*
Passive	1. Receiving direct foreign investments	Controlled
	2. Importing foreign machinery and equipment	Controlled
	3. Acquiring turn-key plants	Controlled
	4. Acquiring foreign licences and patents	Controlled
	5. Setting up joint-ventures with foreign companies	Controlled
↓	6. Recruiting skilled workers, artisans, engineers, teachers and consultants from abroad or permitting mass immigration	General
	7. Encouraging and supporting own nationals' journeys abroad for studying at foreign schools and universities, or training in factories visiting international congresses and trade fairs, making contacts with foreign experts, etc.	General
Active	8. Utilising 'the low cost diffusion of easily accessible technology': the spread of know-how through trade and scientific publications, analysing foreign products, etc.	General

inputs. The new technology characteristic of each period is regarded as built *into* production machinery. The capital stock of each industry consists of technically different vintages, the productivity of which is graded according to their age. New technology is, however, not entirely embodied in capital goods. Novel technological expertise, know-how, can also be utilised by developing the organisations of production, raising the educational standards of managers and the labour force, and simply by training the personnel to carry out its tasks better than formerly. 'Learning by doing' is one form of unembodied technological change. Erik Lundberg's example of this kind of change has become world-famous. He has stated that the Horndal Iron Works in Sweden had no new investment, and presumably no important change in its methods of production, for a

period of fifteen years; yet the output per worker increased on average by 2 per cent a year. By studying manufacturing processes elsewhere as well, steadily improving performances have been found that can only be attributed to learning from experience on the job.[9]

Formally, the transfer of technology from one economic area to another would seem to be simple. In the industrial centres general know-how is available almost free of charge, and since the mid-nineteenth century, the importation of the most modern machinery seems to have been only a financial problem. But in practice, the transfer and diffusion of technology is generally a difficult and slow process. Technology transfer is not merely a matter of transporting a piece of hardware from one location to another. Frequently, the importation of modern machinery was preceded and accompanied by the adoption of an adjacent, unembodied technology.

Besides the market situation and the production environment in the recipient country, the local natural resources, together with capital and labour markets have an important influence. The success of technology transfer also greatly depends on the social and institutional framework of the recipient country: the level of education, the craftsmanship of its labour force, the attitudes and social objectives of the community, and political circumstances, legislation, etc.[10]

If a recipient country has a sufficiently good educational infrastructure and domestic R & D capabilities, after some time it can proceed from importing to creating technology. Imported technology may serve as a base and starting point in gradually developing indigenous know-how. Table 1.2 demonstrates different levels of this development.

Table 1.2 Methods for creating technological capability

1. Imitating foreign technology
2. Learning by doing
3. Adapting foreign technology to domestic circumstances
4. Improving foreign technology
5. Making original inventions and innovations

Building up a modern electricity supply in a country requires the development or transfer of an entire technological system containing an enormous amount of different components. Installing and maintaining these components demands a great deal of technological knowledge. Therefore, an electricity supply system is very technology-intensive.

It is not enough that a new technology is made available in a recipient country through transfer. In order to become useful and economical, a foreign technology generally needs adaptation to the local circumstances. The practicability of a foreign innovation might be hazardous if a recipient country has very different price relations, for example between labour and capital, and dissimilar raw materials, fuels or other inputs than the supplier country. There are also many products which have needed modifications in some countries because of climatic, cultural, legal or other regional reasons. The adaptation of a new technology in a less developed economy often requires innovative activity which has to be carried out in the recipient country. Frequently, only a successful application opens up the way to efficient diffusion, and this process defines the macro-economic significance of a new technology. In diffusion, there is not only a question of technical feasibility but also of socio-economic preconditions.

The electricity supply system presents a technology which demands an adaptation of various details into the local conditions. The diffusion period of electrical technology has proved to vary considerably between and within countries. There are also differences in the forms and methods of electrification. Nevertheless, electricity is a technology which has penetrated into all kinds of twentieth-century societies. Owing to its universality and flexibility, electricity supply technology is well suited for comparative international case studies on the diffusion of a new technology.

Use is the principal purpose of any innovation. How an innovation carries out its tasks and how the opportunities provided by it are utilised have an important bearing on its effect on an economy. Electrical technology has proved to be a success: it suited outstandingly its first commercial function, lighting; although a century has lapsed, it is still the pre-eminent illuminant. In addition, new functions have continually been found for electricity, which keeps on pushing other energy sources aside.

Electricity is an exceptional commodity. It must be produced and consumed at the same instant. It cannot be stored economically on a large scale. Electricity is also a very homogeneous product and it can be transmitted long distances with low costs. It is easily and efficiently converted into the other forms of energy – heat, light or motion.[11] Electricity can be generated in units with very different sizes. The trend has, however, been nearly everywhere towards large, interconnected power plants. Because of its nature as a rather homogeneous commodity, electricity and its supply are well suited for testing various hypotheses of economic theory.

In studying the transfer process, the final phase is an evaluation of the impact and significance of the new technology on an economy. As a rule, it is difficult to measure the effects of an innovation. This is particularly true in the case of electricity which penetrated everywhere. In studying the impact of an industry based on new technology, we can apply 'Hirschman's linkages'.[12] According to this approach, an expanding sector, which is generally assumed to be an export industry, generates earning opportunities in other sectors, both at home and abroad, when its increased income is spent. These income flows inducing production in other sectors are classified into three linkage effects: backward linkage, forward linkage and final demand linkage.[13]

Melville Watkins defined backward linkage as a measure of the inducement to invest in the home-production of inputs, including capital goods, for the expanding industry. If the domestic economy is not able to supply the inputs needed, the inducement will leak abroad, because the inputs have to be imported. By contrast, the expanding industry is supporting the growth and diversification of the economy in a developing country if all or a substantial part of inputs are purchased from domestic suppliers.[14]

Forward linkage is a measure of the inducement to invest in industries using the output of the expanding industry as an input. Increasing the valued added in an export industry has been portrayed as the most representative example.[15]

Final demand linkage consists of the inducement to invest in domestic industries producing consumer goods for the factors of production of the expanding industry. The rise of the factors' income in the thriving industry promotes the growth of the home market and gives a boost to the domestic production of consumer goods. A crucial point is how much of the factors' earnings, primarily capital income and wages, is spent in the home market and to what extent domestic production can satisfy this demand. Final demand linkage is reduced by the amount that foreign factors, investors or migratory labour, expatriate their income or that is consumed in imported goods by domestic or foreign factors.[16]

By applying the linkage approach to studying the multiplier-effect of the electricity supply industry, we can suppose that this industry has potentially relatively strong backward and forward linkages, but a weak final demand linkage. Building up the electricity supply industry might support both the engineering industry and fuel production in a country, if inputs are supplied domestically to a large extent. Forward linkages are generally even bigger: electricity is utilised as an input throughout the economy. It is used in industry, transport and construction as well as in the service sector, in agriculture and households. Albeit that the intensity of electricity in industries varies, electricity is presumed to have a substantial impact on the rise of productivity and the decrease of production costs throughout the economy.[17]

Final demand linkage is modest, because electricity supply is generally a comparatively small, capital-intensive industry in a national economy. Even its potential impact on the home production of consumer commodities for its factors has to be estimated as weak. The demand for consumer goods is at its highest during the construction of big hydropower or nuclear power plants when a considerable amount of labour is employed. Running the electricity supply industry, in contrast, demands only a relatively small personnel.

1.3 THE OBJECTIVES OF THE STUDY

In studying the transfer of electrical technology, two aspects are underlined in this research: the viewpoint of a recipient country and a survey of long-term development. First, attention is paid to the channels and agents of transfer, and the role of the Finns in this process. Evaluating the measures and reactions of a recipient society is preferred to assessing the implications to the suppliers of technology. Second, instead of separate events, long trends of development and structural changes are examined. An aim is to study whether it is possible to outline the Finnish model of technology adoption and sketch its key features.

This research aims to describe and analyse electrification and the concomitant industrialisation process. Electricity was introduced fairly early in Finland and its use began to grow steadily from the 1880s. On the eve of the First World War, electricity production per inhabitant had already risen almost to the same level as the average of the corresponding figures for Italy and France, as shown in Table 1.3.

In the last quarter of the nineteenth century, Finland was still among the most markedly agrarian countries in Europe.[18] In 1880, 75 per cent of its total population were employed in the primary sector

Table 1.3 Annual electricity output in various countries, 1910–15

Country	*Year*	*Output* GWh	*Output per capita* kWh	*Mid-year population* 1000
1. Norway	1913	2201	900	2447
2. Switzerland	1913	1600	414	3864
3. USA	1912	24752	260	95331
4. Sweden	1913	1449	258	5621
5. Belgium	1913	1300	172	7541
6. Germany	1913	8000	119	66978
7. United Kingdom	1912	4140	91	45436
8. Czechoslovakia[a]	1913	964	73	(13214)
9. Italy	1913	2200	63	35192
10. Finland	**1913**	**(183)**	**(60)**	**3026**
11. France	1913	1800	45	39770
12. Japan	1915	2217	42	53124
13. Australia	1910	172	39	4375
14. Denmark	1913	(97)	(34)	2833
15. Spain	1913	500	25	20275
16. New Zealand	1911	18	17	1058
17. Russia[a]	1913	1945	14	139300[b]

[a] With 1937 frontiers.
[b] End-year population.
() Author's estimate.

Sources: Appendix Table A.5; B. R. Mitchell, *European Historical Statistics 1750–1970* (London, 1978); A. Maddison, *Phases of Capitalist Development* (Oxford, 1986) pp. 182–5; *OEEC, Statistical Bulletins, Industrial Statistics 1900–1959* (Paris, 1960) table 46; *Historical Statistics of the United States, Colonial Times to 1970, Part 2*, US Department of Commerce (Washington, D.C., 1975); *Økonomisk utsyn, 1900–1950* (Oslo, 1955) p. 51; Walter Wyssling, *Die Entwicklung der schweizerischen Elektritätswerke und ihrer Bestandteile in den ersten 50 Jahren* (Zürich, 1946) p. 500; V. Lacina, 'Die Entwicklung der Elektrifizierung in der Tschechoslowakei bis zum Jahr 1938', in *Energy in History*, ed. by J. Purs (Prague, 1984) pp. 165–8; *Statistika rocenka ceskoslovenské sosialistické republiky 1986* (Praha, 1986) p. 91; R. Minami, 'The Introduction of Electric Power and Its Impact on the Manufacturing Industries', in *Japanese Industrialization and Its Social Consequences*, ed. by H. Patrick (Berkeley, 1976) p. 303; *Anuario estadistico de España 1980* (Bilbao, 1981) p. 55; G. T. Bloomfield, *New Zealand: A Handbook of Historical Statistics* (Boston, Mass., 1989), pp. 41, 206; R. A. Clarke and D. J. I. Matko, *Soviet Economic Facts 1917–81* (London, 2nd end, 1983) pp. 2, 86.

Table 1.4 GNP per capita in various countries, 1906–13

Country	*Indices of GNP per capita (Finland = 100)* Clark 1913	Craft 1910	Bairoch[a] 1913	Maddison[d] 1913	Krantz 1906–10	Laurila 1913
Canada	300	..	..	186	..	..
UK	288	232	186	180	..	..
USA	276	..	..	227	..	..
Denmark	242	187	166	146	181	229
Netherlands	211	170	145	151	..	..
Belgium	171	198	171	182	..	..
Germany	168[c]	171	143	80	..	..
Switzerland	159	177	185	164	..	..
Ireland	158[b]	..	–	..	..	..
France	145	157	133	154	..	..
Sweden	144	136	131	124	159	198
Norway	124	126	144	107	124	205
Austria	113[b]	143[f]	(96)[e]	133	..	..
Poland	108[b]	..	–	..	..	..
Czechoslovakia	103[b]	..	–[e]	..	..	..
Finland	**100**	**100**	**(100)**	**100**	**100**	**100**
Spain	..	98	71	..	..	..
Bulgaria	89	..	(51)	..	..	..
Italy	88	98	85	106	..	..
Russia	88[b]	71[b]	63	..	..	..
Greece	81	81	(62)	..	..	..
Japan	79	..	..	60	..	..
Hungary	60	(107)[g]	–[e]	..	..	..
Portugal	59	98	(56)	..	..	..

[a] With 1913 frontiers.
[b] With 1937 frontiers.
[c] With 1950 frontiers.
[d] With 1979 frontiers.
[e] The Austro-Hungarian Empire.
[f] The area of Cisleithania.
[g] The area of Transleithania.
.. No data available.

Note: The figures in parentheses have a higher margin of error than other figures estimated by the same author.

Sources: C. Clark, *The Conditions of Economic Progress* (London, 3rd edn, 1957) pp. 88ff; N. F. R. Crafts, 'Gross National Product in Europe 1870–1910: Some New Estimates', *Exploration in Economic History*, 20 (1983) pp. 387–401; P. Bairoch, 'Europe's Gross National Product, 1800–1975', *Journal of European Economic History*, 5 (1976) no. 2, pp. 273–340; A. Maddison, *Phases of Capitalist Development* (Oxford, 1986) pp. 161, 178–85; O. Krantz, 'Productivity Changes in Scandinavia in the 19th and 20th Centuries', a paper for Productivity-Conference in Bellagio (mimeograph, 1986); E. H. Laurila, *Consumption in the Finnish Economy in the Years 1900–1975* (Helsinki, 1985) pp. 66ff.

(agriculture, forestry and fishing), while only 5 per cent were attached to industry and handicraft.[19] Consequently, compared on the basis of the distribution of labour force, Finland was then roughly 200 years behind Britain and about 30 years behind Denmark, Sweden and Norway, its nearest Western neighbours.[20]

Table 1.5 The top twelve electricity-consuming countries in 1976 (in per capita terms)

Country	*Production* Total TWh	Per capita kWh	*Consumption* Total TWh	Per capita kWh	Per GDP-unit kWh/$1000	*GDP per capita, at market prices* US $
1. Norway	82.2	20420	75.0	18620	2400	7767
2. Canada	293.4	12680	248.2	12340	1500	8410
3. Luxembourg	1.5	4310	4.1	11520	1810	6102
4. Iceland	2.4	11030	2.4	10910	1750	6612
5. Sweden	86.4	10510	86.4	10510	1170	9029
6. USA	2123.4	9870	2133.0	9910	790	7912
7. Finland	**27.8**	**5880**	**31.9**	**6750**	**1120**	**5950**
8. New Zealand	20.9	6660	20.8	6670	1590	4184
9. Switzerland	36.2	5710	34.3	5400	610	8864
10. Australia	76.6	5500	72.3	5190	770	7387
11. West Germany	333.7	5430	314.4	5110	700	7249
12. United Kingdom	277.0	4950	357.9	4610	1190	3937

Sources: OSF 42:6 Energy Statistics 1986 (Helsinki, 1987); *UN, Statistical Yearbook 1976–1977* (New York, 1977–8); *Statistical Yearbook of Finland 1978* (Helsinki, 1979); *Statistical Abstract of Sweden 1979* (Stockholm, 1979).

As late as 1913, the country's GNP per capita was about the same as the average for Eastern Central Europe and the Balkans. At the same time, Finland had only two-thirds the GNP per capita of Denmark or the Netherlands and only half of that of Britain, as indicated in Table 1.4.

A small, poorly industrialised Grand Duchy, as Finland was a century ago, could not develop a modern indigenous technological base; it had to import technology for its industry. Taking into account the agrarian economy of Finland, the country managed to increase its electricity production to a relatively high per capita level by the year 1913. Its electricity output per capita was then already on a higher level than would be expected from its GNP per capita. During the following six decades, Finland rose to join the top seven countries in electricity consumption per inhabitant, shown in Table 1.5, although its primary sector remained as the main source of livelihood for the population up to the 1940s. It was not until the postwar period that Finland achieved the final breakthrough in modernising its economic structure. Since the 1970s, its economic structure has differed only to a small degree from that of other OECD societies which had industrialised decades earlier than Finland.[21]

Since the second quarter of the present century, the Finnish economy has grown exceptionally fast. During the 1960s, its GNP per capita surpassed that of Britain. In 1976 Finland's GNP per capita was the eleventh highest in Europe and the eighteenth in the world. It was roughly by a factor of 2.5 higher than the average GNP per capita of Eastern Central Europe and the Balkans[22] and 40 per cent higher than that of Britain. Nonetheless, it was still 9 and 25 per cent lower than the respective figure for the Netherlands and Denmark.[23] Measured by GNP per inhabitant, Finland leapfrogged from the bottom third up to the top third of European countries in six decades.

From various statistics, for example from Table 1.5, we can notice a positive correlation between GNP per capita and consumption of electricity. Hence, this study attempts to find an answer to the question of what role electrification played in the rapid growth process of the Finnish economy. This problem is studied by evaluating the repercussions of electrification.

The emphasis of this research is laid on the analysis of the connections between electrification and industrialisation. These two phenomena are often considered interrelated. At least a moderately industrialised economy, a stable institutional framework and sufficient educational prerequisites are supposed to be necessary for wide-scale electrification which, in turn, is seen to speed up industrial and economic growth and stimulate the overall modernisation of society.

Generally, those few countries, such as Switzerland, Germany, the USA and Sweden, which had a fairly well-developed institutional and educational infrastructure supplemented with a very dynamic, science-orientated industry as early as the third quarter of the nineteenth century proved to become early and rapid electrifiers. Brisk electrification is seen to be tied up in high standards of living, an advanced system of technical education, active indigenous research and development, and many other characteristics of a modern industrialised society. Nineteenth and early twentieth century Finland was not such a society: it lacked a great number of those vital characteristics. Nevertheless, it turned out to be a rapid electrifier.

The central question in this research is why did Finland succeed in transferring and adapting foreign electrical technology so early and so efficiently, although it remained a predominantly agrarian country for such a long time.

2 An Outline of Finnish Electrification

2.1 A BACKGROUND VIEW

The Political Status of Late Nineteenth Century Finland

Among the areas under the rule of the Russian Tsar in the nineteenth century, Finland in some respects enjoyed a privileged position. Its political autonomy was wider than that of other border areas including the Baltic Provinces, Poland and Caucasia. Despite the country being incorporated into Russia in 1809, it preserved its former Swedish legal system and administrative institutions. Furthermore, at the Diet of the Estates in Porvoo in 1809, the representatives of the Finns were given the right to build up a national central government to attend to the internal affairs of the Grand Duchy. However, the laws and statutes prepared by the Finnish government, called the Senate from 1812, had to be confirmed by the Tsar. Additionally, the Russian government answered for military matters and foreign policy.

The Diet, a legacy of the pre-1809 Swedish system, met regularly only from 1863 and included representatives from four estates: the nobility, clergy, burghers, and landowning peasantry. At the close of the nineteenth century, quite a small number of men, under 10 per cent of the adult male population, were eligible to vote in the Diet elections. In 1905 a peaceful, anti-tsarist Great Strike gained universal suffrage for the Finns. For the first time in Europe, women obtained the equal right to vote. In 1907 the Diet of the Estates was replaced by a modern unicameral Parliament with several political parties.[1]

During the nineteenth century, the Finns managed to get on with the tsarist regime reasonably well. A Polish-style separatism did not emerge. The national goals included the use of constitutional means to defend the achieved autonomous political status and to develop their own self-governing institutions. Finnish attitudes changed quickly, however, with the implementation of several russification measures under governor-general Nikolaj Bobrikov. These included the February Manifesto of 1899, which effectively eliminated local control over legislation; a decree in 1900 to introduce gradually the use of Russian as the language of administration; and the Military Service Law of 1901, which disbanded the Finnish army (founded in 1879) and required Finnish recruits to serve outside the Grand Duchy.[2]

The Great Strike caused the postponement of Russian aspirations for abolishing the autonomy of Finland for a couple of years, but the tsarist policy of absorption continued in the Grand Duchy after 1907. The Finns' response to russification, known as the years of oppression (1899–1914), was split. The conservatives tended to co-operate with the tsarist regime, whereas the constitutionalists organised strong passive resistance. The struggle for autonomy and democratisation gave the Finnish politicians a crucial incentive to develop their national ideology and to consider total separation from the Russian Empire. Simultaneously, the struggle awakened the masses to political activity.[3]

The strained Russo-Finnish relations threw their shadow over the whole political and cultural life of the Grand Duchy during the two decades before the First World War. They had clear repercussions on the economy as well, although the turnover of mutual trade between Finland and the Empire was growing rapidly, by an average of 3.9 per cent a year between 1900 and 1913. At the time, Finnish exports to the Empire increased by 105 per cent and the corresponding imports rose by 41 per cent.[4]

From the beginning of its autonomous Grand Duchy status, Finland constituted its own customs area, separate from the Russian Empire with a customs border and its own tariffs. Finland thus had limited opportunities to pursue a separate customs policy, partly defined to its economic interests. To some extent, it was also entitled to export its products to Russia with much lower tariffs than foreign countries. On the import side, the most significant factor was that Russia could export grain and flour to Finland duty free. This hampered Finnish grain production, but stimulated the rise of husbandry and manufacturing by keeping grain prices low.

Since 1860 the Grand Duchy had its own monetary unit, the markka/penni (1 mark = 100 pennies), the value of which became independent of the Russian rouble in 1865 when its value was based on silver. In 1879 the gold standard was adopted in Finland; in value the gold mark was equal to the French gold franc. The central government had financial autonomy as well; it had a separate tax system and income from taxation was used only for expenditure within the Grand Duchy. Because the national armed forces were very small, military expenditure was modest.

Population

The Finnish population has never been large: 1.6 million in 1850, 2.7 million in 1900, 4.0 million in 1950 and 4.7 million in 1975. At the turn of the century, 55 per cent of the people inhabited the four southern provinces which covered merely a quarter of the total area.[5] Most people then lived in the countryside and all 38 towns were fairly small.[6] Town-dwellers accounted for just under 13 per cent of the total population, which was rather a modest figure compared to Western Europe or even to Scandinavia (see Table 2.1).

Table 2.1 The largest towns at the turn of the century and urban population in four Nordic countries in 1900–1 and 1975–6 (1000 inhabitants)

Finland	*31 Dec. 1900*	*31 Dec. 1975*	*Sweden*	*31 Dec. 1900*	*1 Nov. 1975*
Helsinki	94	497	Stockholm	301	665
Turku	38	164	Gothenburg	131	445
Tampere	36	166	Malmö	61	244
Viipuri*	32	–	Norrköping	41	119
Oulu	16	92	Gälve	30	87
Urban pop.	342	2.780	Urban pop.	1.104	6.789
D:o of total	13%	59%	D:o of total	22%	83%

Norway	*31 Dec. 1900*	*1 Jan. 1976*	*Denmark*	*1 Feb. 1901*	*1 Jan. 1976*
Kristiania/Oslo	229	463	Copenhagen**	477	709
Bergen	72	213	Århus	52	246
Trondheim	39	135	Odense	40	168
Stavanger	30	87	Ålborg	31	155
Drammen	23	51	Horsens	22	54
Urban pop.	628	2.715	Urban pop.	959	4.191
D:o of total	28%	68%	D:o of total	39%	83%

* Ceded to the USSR in 1944. ** Including Frederiksberg, Sundbyerne and Gentofte.

Sources: *Statistical Yearbook of Finland 1903 and 1975* (Helsinki, 1903, 1976); *Historical Statistics of Sweden I, Population 1720–1950* (Stockholm, 1955); *Annuaire statistique de la Norvége 1901* (Kristiania, 1901); *Statistique du Danemark, Annuaire statistique 1901* (København, 1901); *Statistical Abstract of Sweden 1976* (Stockholm, 1976); *Statistical Yearbook of Norway 1976–1977* (Oslo, 1976–7); *Statistical Yearbook of Denmark 1977* (København, 1977); *Yearbook of Nordic Statistics 1976–1978* (Stockholm, 1977–9).

Although Finland became urbanised quite rapidly during the first three-quarters of the twentieth century, it could not by the late 1970s completely bridge the gap between it and the other Nordic countries. Nevertheless Greater Helsinki, the capital district, developed into a notable urban agglomeration which was with its population of 0.9 million equal to its Norwegian counterpart, but a third smaller than Greater Stockholm or Greater Copenhagen.[7]

The country had two religions with official status: Lutheran, which was professed by 98.0 per cent of the population, and Greek Orthodox with the corresponding share of 1.9 per cent in 1880. In that year, the great majority (85.2 per cent) of the population spoke Finnish as their native language, and 14.3 per cent were Swedish-speakers who were living in the area around Helsinki and the southern and western coastal regions. The proportion of other minorities was insignificant: 0.2 per cent were Russian speakers, 0.1 German speakers and 0.1 per cent spoke Lappish or other tongues as their first language.[8]

Up to the 1860s Swedish was the only official language used in the administration, in justice and in education excluding primary schooling. Gradually towards the end of the century, Finnish became the second official language. Bilingualism was later included in the constitution of the new Republic after Finland had proclaimed its independence on 6 December 1917.[9]

Internal Politics and Culture

Up to 1809, Finland had been a remote province in the Kingdom of Sweden. After gaining the status of an autonomous Grand Duchy, the prerequisites for a national identity developed and nationalism became the central issue in Finnish internal politics and culture during the nineteenth century. Most conspicuous was the division of the national movement from the 1840s into two trends, the Suecomans and the Fennomans. A Finnish national identity was the basic goal of both trends, but one wanted to support the Swedish language and the other the Finnish language.

Culturally, ordinary Swedish-speaking and Finnish-speaking working-class people did not substantially differ from each other. Both groups shared similar customs and a way of life. Their members were predominantly Lutheran farmers, fishermen or craftsmen living in wooden houses and loving the sauna, coffee and distilled spirits.[10]

The social structure of the two language groups was, however,

completely different. Because the nobility, the bourgeoisie, the civil servants and the educated people (except a great many clergy) were Swedish-speakers at the beginning of the nineteenth century, the minority's social structure resembled almost a high, slim rectangle. At the same time, native Finnish-speaking upper and middle classes were almost non-existent, and therefore the majority's social structure was similar to a triangle with a long, horizontal hypotenuse and a low, obtuse angle above it.

The short-run objective of the Fennomans was to create a Finnish nation in which the Finnish speakers had the same rights, opportunities and positions as the Swedish speakers. They aimed at a mass movement and public enlightenment as the central means of developing the national spirit, and raising the educational and cultural level of the people. The ultimate goal of the radical Fennomans was condensed in the slogan 'One nation – one language', and this brought the language division to the centre of Finnish internal politics for many decades.

The press became an important weapon in the struggle between nationalist factions. As a rule, all political movements founded their own newspapers as soon as they could. In the second half of the century, the number of newspapers increased by a factor of ten and the growth rate of the printing industry was one of the highest of any industry in the economy. In 1900 there were 58 Finnish and 28 Swedish papers. Only five small towns out of 38 then lacked a local newspaper, while even many medium-sized population centres had two or more competing papers. The extent of the press can be measured by the number of inhabitants per newspaper or periodical published. At the turn of the century, this indicator was in Russia 137 000 and in Sweden 7000. The vigour of Finnish development is illustrated by the fact that the value of this indicator for the Grand Duchy precipitated headlong in a fifty-year period (1850–1900) from an East European number of 117 000 to a comparatively low West-European number of about 12 000.[11]

In late-nineteenth-century Finland, the mass-media sector was fairly well advanced compared with the rest of the economy. This was a significant factor from the viewpoint of technology transfer. The viable press provided a potential channel for diffusing information on new developments in technology.

To secure efficient communication, an active press should be complemented by a high rate of literacy of the population. During the entire nineteenth century, the ability to read was common in Finland.

In the 1850s, over 70 per cent of the population could read, and between 1880 and 1900 this percentage rose from 97.5 to 98.5.[12] The problem was at first that the majority of people could only read poorly and could not write at all. The reason for this, internationally quite untypical, situation was that since the late seventeenth century the state church had required of everyone who was going to marry the formal and superficial ability to read.[13] Because of the low requirements of the education system, only 13 per cent of the population over 9 years old in 1880 could both read and write.[14] Thanks to the new elementary school system, the advance in education was swift. In 1900, 39 per cent could read and write and by 1930 the figure had risen to 84 per cent.[15]

Economy

The variety of Finland's natural resources was small, consisting only of agricultural land, timber, the waterpower of rivers and some modest mineral deposits (copper and iron). Due to the large area of the country, the volume of arable land, and forest and waterpower resources has, however, been quite considerable and the Finns attempted to build their economy on the basis of these gifts of nature. Agriculture was the traditional primary occupation, although grain production is very risky in the country – situated north of the 60th latitude – due to the short and cool summers. Finland had no history of serfdom and the number of large landed estates was very modest. The landholding nobility was weak and the landowning peasantry had the central role in agricultural production. In the nineteenth century there was a notable shift from grain growing to dairy and meat production. This development also meant the transition from traditional self-sufficient farming to partly commercial production. Consequently, butter, cheese and milk rose to become important export products.

In the pre-industrial period, tar (produced from wood by burning) was one of the main export products. Wood-processing was also among the key sectors in later Finnish industrialisation. The production of the sawn timber, pulp and paper industries began to expand markedly after the Crimean War (1853–6). Sawn timber was shipped to Britain and other West European countries. Pulp and paper products were, in contrast, mainly exported to Russia up to 1917. Iron works, engineering workshops, and textile and glass industries were set up and grew on the basis of the Russian market, owing to insufficient purchasing power in the tiny home market.

The mutual 'free trade' with the Tsarist Empire was advantageous to Finland, because up to the 1890s Russian industry was, as a whole, modestly developed and uncompetitive. The Grand Duchy was not, however, transformed into 'the workshop of the Empire', although it achieved a strong footing as a supplier of some staple products (newsprint, printing paper). In the nineteenth century, southern Finland was certainly not an equally significant industrial region as the largest and most modern manufacturing centres of the Empire, such as St Petersburg, the Baltic Provinces, or big industrial towns in Russia and Poland. In respect of the level of education, political participation, personal freedom, and living standards, the Grand Duchy could, by contrast, well compete with other regions under the Tsar's rule.

Compared with Western Europe, the Finnish economy was strikingly agrarian at the turn of the century. The total population occupied in the primary sector increased by a third (i.e. half a million people) between 1880 and 1920, for urbanisation and emigration could not absorb the swiftly growing population. The rising number of the landless masses became a serious social problem and constituted an ingredient for the Civil War of 1918 between the 'Reds' and the 'Whites'. Consequently, Finland, a country with backward agriculture, faced a traumatic paradox of a large, sparsely inhabited territory and soaring rural over-population burdened with underemployment.[16]

Before the 1920s, Finland could not get rid of the stigma of being a latecomer; on the contrary, its role as the laggard was then even accentuated among the Nordic countries, because its occupational structure remained exceptionally rigid, as indicated in Table 2.2. In addition, up to the early postwar period, the proportion of the labour force engaged in manufacturing, in handicraft, and in construction remained substantially smaller in Finland than in the Scandinavian countries which were themselves no forerunners of industrialisation in Europe.

Finland was, however, in good company when it attempted to follow Sweden, Denmark and Norway in economic development, as these countries were among the most rapidly growing economies in the late nineteenth century.[17] After the 1880s, Finland gradually managed to narrow the lead of the other Nordic countries in living standards, because it outperformed them slightly in the growth of GDP per inhabitant in the long run.[18]

Gaining political independence as an aftermath of the Russian

Table 2.2 Population by occupation in the Nordic Countries, 1880–1970 (in per cent)

Occupation	*Country*	*1880*	*1890*	*1910*	*1930*	*1950*	*1970*
Agriculture, forestry and fishing	**Finland**	**74**	**70**	**70**	**66**	**46**	**20**
	Sweden	68	62	49	39	20	8
	Norway	52*	49	39	36	26	11
	Denmark	54	49	36**	30	24	11
Industry, handicraft and construction	**Finland**	**6**	**8**	**10**	**13**	**28**	**36**
	Sweden	17	22	32	36	41	40
	Norway	18*	22	25	27	37	38
	Denmark	26	28	28**	29	35	37
Transport and communication	**Finland**	**2**	**2**	**2**	**3**	**5**	**7**
	Sweden	..	..	6	7	8	7
	Norway	8*	7	7	8	10	10
	Denmark	..	..	6**	7	7	7
Services and other occupations	**Finland**	**18**	**20**	**18**	**18**	**21**	**37**
	Sweden	..	..	13	18	31	45
	Norway	22*	22	29	29	27	41
	Denmark	..	..	30**	34	34	45

* 1875 ** 1911 . . No data available.

Finland: Economically active population 1880–1970
Sweden: Total population 1880–1930; econ. active pop. 1950–70.
Norway: Economically active population 1875–1970.
Denmark: Total population 1880–1950; econ. active population 1970.

Sources: Population by Industry and Commune in 1880–1975, Statistical Surveys no. 63, CSOF (Helsinki, 1979) p. 331; *Historical Statistics 1968, Norges Offisielle Statistikk XII 245*, Central Bureau of Statistics of Norway (Oslo, 1969) pp. 36–7; Lennart Jörberg, 'The Industrial Revolution in the Nordic Countries', in *Fontana Economic History of Europe vol. 4:2*, ed. by Carlo M. Cipolla (Glasgow, 3rd imp. 1976) p. 392; Olle Krantz, *Die Skandinavischen Länder: Schweden, Norwegen, Dänemark und Finnland von 1914 bis 1970*, Handbuch der europäischen Wirtschafts- und Sozialgeschichte, Hrsg. von Herman Kellenbenz, Teilveröffentlichung (Stuttgart, 1980) p. 28.

Revolution in 1917 gave justification to considering Finland as a really detached national economy and greatly improved the opportunities of the Finns to pursue such an economic policy which supported both economic growth and the transfer and application of new technology in various sectors.

Energy Supply Before Electricity

In any economy, the characteristics of energy use are derived from energy needs and supply. Demand for energy depends on climate, production structure, level of industrial development and living standards. The availability of indigenous and imported energy sources, and their price relations define the basic features of supply.

In the late nineteenth century, the Finns used mainly the same energy sources as during the previous 400 to 500 years. The principle energy source was firewood. Wood resources in Finland were indeed ample. Forest accounted for 74 per cent of the total land area and the forest area per capita was the largest in Europe – 11.4 hectares in 1885.[19] In the mid-nineteenth century, firewood made up over 95 per cent of the total energy supply and its share decreased only to about 90 per cent by the First World War. Other indigenous sources were waterpower, wind, peat, wastes of the wood-processing industry and animal energy. Of this group, animal energy, waterpower and windpower were the most important. The use of peat encountered technical and economical difficulties. The price of energy was so low that the utilisation of wastes was regarded as uneconomical. The country lacked and still lacks coal, brown coal, oil shale or oil deposits.[20]

In a cold climate such as that of Finland, energy was, first of all, needed for *space heating* and *cooking*. Firewood was the dominant fuel. In the countryside, where 92 per cent of the population lived in 1880, there was no shortage of firewood.[21] Even the landless could cut their firewood almost free of charge in the private or common forests up to the second half of last century. Urban dwellers generally bought their fuelwood from peasants. Coal was introduced only in a number of blocks of flats with central heating in some big coastal towns.

Up to the mid-nineteenth century, indigenous fuels were also used for *lighting*. In peasant houses, lighting was modest in the evenings; often it consisted only of a burning fireplace which dimly illuminated the main room. Of the proper illuminants, hand-made coniferous splints (päre) about 14 inches long were the most common up to the 1870s. It is estimated that a peasant household needed lighting for just over 1300 hours a year. If the rooms of a farmhouse were illuminated by four splints burning at the same time, each for about 15 minutes, the annual consumption was over 20 000 splints. Making this amount of splints required a labour input corresponding to one man's work for twelve days.[22]

Although splint lighting consumed valuable pine trunks, it was regarded as cheaper than tallow candles or lamps burning on animal or vegetable fat, the use of which required at least some cash expenditure. In the peasant households, candles were used only on festive days or on special occasions. Candles and lamps fuelled by animal fat or vegetable oil were more common among the upper class and urban dwellers who had more cash income to spend.[23]

Paraffin (kerosene) lamps were introduced in some coastal towns in the 1860s, but it took nearly two decades before they began to spread to the remote inland peasant houses in the eastern part of the Grand Duchy.[24] In Finland, electric lighting came to compete with paraffin lamps both in the rural and urban areas, because gas utilities were working only in three big coastal towns. The market situation was, therefore, advantageous for electricity, for the price of paraffin remained rather high and the availability of lamp oil was often rather uncertain in the inland areas.

Climatic and social circumstances seemed to be favourable to the introduction of electricity in late nineteenth century Finland. Contemporary feelings and attitudes are aptly described in an article published in the liberal newspaper *Helsingfors Dagblad* during the darkest time of the year in 1883:

> Electric lighting indoors – one can really be electrified by this novelty.
>
> It brings about more than mere increased luxury and convenience. It brings health, satisfaction and a sense of well-being.
>
> Our Nordic habitat is not a blessing for the people whom destiny has thrown here. It is not the cold, snow nor ice which is the worst: it is darkness. The darkness oppresses vitality, blunts the mind and lays a weight of lead over the heart. Darkness is the enemy of life.
>
> The severe Nordic climate during the winter forces people to stay indoors for most of the 24 hours. To let fresh air flow in means allowing the cold to rush in, too. Therefore, in wintertime most dwellings are more or less unhealthy due to the lack of continuous ventilation . . .
>
> The drawback of obstructed ventilation in wintertime is increased by the necessity to burn lamps or candles most of the day. They fill the air with their carbon particles and harmful combustion gases which affect health and damage the blood. This is a dark disadvantage of our wonderful Nordic winter.
>
> Electric light will bring a radical change to all this. No smoke, no dirt, no more vapour of paraffin! . . .
>
> Finally, the practical side of the matter. No fuss in buying candles or paraffin, no troublesome maintenance of candelabra and lamps, no broken lamp cylinders, no stains of stearin on the carpets and clothes – no waste of matches.
>
> Just turn on the switch on the wall and instantly, you have light.[25]

Horses were a multipurpose energy source of *agriculture*. They worked in field works, in forestry, for transport, for threshing and even provided by their presence in farm buildings heating for livestock in wintertime. Watermills and windmills ground crops to flour, sawed boards and battens for household use and ran the machines in a blacksmith's shop. In 1890, there were about 4500 watermills and 10 000 windmills grinding flour.[26] Their total capacity was approximately 50 000 hp. Moreover, about 600 household sawmills powered by a waterwheel or hydroturbine were in use with a capacity of 3000 hp. Taking account also of the 200 power-driven dairies which had their 800 hp, we can estimate that agriculture with its subsidiary trades had a mechanical capacity of nearly 55 000 hp. This capacity was, however, utilised only seasonally during a few weeks a year.[27]

Finnish *industry* also pre-eminently relied on indigenous energy sources: firewood, waterpower, waste, peat and horses. During the last century, only ironworks used coal and coke. In 1890, motive power in industry totalled 40 000 hp of which hydroturbines accounted for 49 per cent, reciprocating steam engines 35 per cent and waterwheels 15 per cent. The four biggest industries using the capacity of motive power were paper and pulp production with 14 300 hp, sawmilling with 9000 hp, metallurgy and engineering with 7300 hp and textile production with 5500 hp. Apart from prime movers in seasonally worked sawmills, industrial motive power was generally running nearly all year round.[28]

The *transport* system on land was not very well developed by the last quarter of the nineteenth century despite moderate development during the previous ten decades. The extent of main roads grew from 22 180 km to 26 260 km between 1875 and 1900 and then to 73 340 km by 1975. In the same periods, the extent of railway lines grew from 680 km to 2930 km and furthermore to 5920 km.[29] Steam locomotives were run on firewood; the regular use of coal began only from 1897.[30] In seafaring, Finland had long relied on wooden sailing vessels. Only 12 per cent of Finnish merchant shipping (2470 ships) was driven by steam in 1900.[31]

Because of the low level of development, the growth potential of both the communication system and industry was considerable. In the late nineteenth century, industrialisation was just taking root in Finland. In some respects, the country had an opportunity to derive benefit from its late start. For instance, electricity did not have any serious, technically modern competitor with an established position. The direct-coupled hydroturbines of mechanical pulp factories might be mentioned as the only example of this kind of technology.

For electricity, there thus opened up a market gap to be filled; Finland's industrialising society lacked modern energy supply systems to satisfy the various power needs of its economy.

2.2 THE FORMATIVE YEARS

Experiments and Demonstrations

During the initial phase of applied electrical technology, individuals played an important role in making and transferring innovations. Three kinds of men influenced the introduction of electrical technology into new countries:

(1) *Advocates* who could inform and persuade public opinion, the authorities, and industrialists about the pre-eminence of electricity as a source of lighting and power;
(2) *Businessmen* who could make concrete sales agreements for electrical supply equipment; and
(3) *Technicians* who knew how to install and operate electrical equipment.

In nineteenth-century Finland, only some of the pioneers in electrical engineering were competent in all three tasks, but a few learned to master one or two of them.

Lighting was not the first field of electrical technology to be introduced in Finland. It is noteworthy that electric lighting was preceded by two forms of electrical communication engineering: the telegraph and telephone. These painted an image of the principles of an electric system, provided practical training opportunities for a few future Finnish electrical technicians and improved both national and international communication.

In Finland, telegraphy was demonstrated for the first time by Adolf Moberg, professor of physics, at the annual meeting of the Science

Society in Helsinki in 1850. Building a telegraph line from St Petersburg to Helsinki in 1855 was a direct investment by the Russian government stimulated by the Crimean War (1853–6).[32] Later on, lines were built over other parts of the country and in 1860 the network was connected to the Swedish network and thus to other European telegraph systems. Although the network was primarily built for military purposes, it soon became extensively used in the service of the Finnish economy. A good number of Finns were employed by the Telegraph Board which remained as a Russian institution in the autonomous Grand Duchy.[33]

From December 1877, experiments and demonstrations were made in Finland on the telephone machines invented by the American-Scot Alexander Graham Bell in 1876. The earliest commercial telephone business was the five-kilometre line built by a merchant between the City Hall of Kokkola and the outer harbour of Ykspihlaja, made available to the public at a fee. The first telephone exchange in Finland began operating in Turku in October 1881. Proper telephone companies were founded in six cities in 1882.[34]

Along with the telephone, electric lighting became known in Finland. The first demonstration of electric lighting was made by the temporary professor in physics, *Karl Selim Lemström* and engineer *Martin Wetzer* at the engineering works of the State Railways in Helsinki on 10 December 1877. For one and a half months, these men made successful experiments with a Gramme dynamo and a Serrin arc-lamp which Lemström had acquired from Paris.[35]

The two men clearly perceived the practical potential of electricity in lighting, but they were, first of all, interested in it scientifically. Lemström was aiming for the post of full professor in physics which he received in February 1878. Wetzer, in turn, worked as the head of the mechanical institute at Helsinki University. In a newspaper article, the latter, however, announced that he could also provide and install electric lighting equipment 'with Mr Lemström's scientific assistance'; unfortunately, he appeared to receive no orders.[36] Lemström and Wetzer were technicians who could demonstrate the technical opportunities of electric lighting. There were other men who were able to turn it into a commercial success.

Commercial Applications of Electric Light

On the 'high nameday of Her Majesty Empress', Maria Aleksandrovna, on 3 August 1878, a new series of demonstrations was begun.

This time, electric light was applied for commercial purposes when the businessman Carl Kämp hired the arc-lamp powered by a portable steam engine and the Gramme dynamo of Lemström and Wetzer to light the garden of his restaurant at Kaivopuisto (Brunnsparken), a seaside park in Helsinki.[37] These demonstrations, each of which was supplemented by an outdoor concert, a 'musikalisk soirée', were continued for nearly two months.[38] In the late summer of 1879, electric light was again used to light outdoor concerts and some other public entertainments.

Another application of electricity was introduced in Finland in the late 1870s. After a couple of years of using big chromic acid batteries for galvanising small metal objects, 28-year-old engineer and M.A., *Daniel Johannes Waldén* (1850–1930), imported a small hand-turned dynamo from Germany in 1878. Later on, he coupled the dynamo, which was probably the second one in Finland, to a steam engine at his electrical workshop in Helsinki.[39]

Dan. Joh. Wadén was a son of an assistant vicar from the Swedish-speaking coast of southern Finland. In 1874 he took a Master's degree in philosophy at Helsinki University and became a school teacher in mathematics, German and French languages. He had financed his university studies by working as a telegraphist. After graduation he continued working in the Telegraph Board and this provided him with an opportunity to study in St Petersburg, where in 1875 he passed the examination of engineer-mechanic. Five years later, he returned to St Petersburg to study heavy current engineering.[40]

After marrying a Finnish baroness of Swedish descent in 1876, Wadén, while working as a junior mechanic in the Telegraph Board, set up an electrical workshop which started producing and installing electric bell systems. He read articles about telephones with enthusiasm in the Swiss *Journal Télégraphique* in 1877 and by New Year's Eve he had installed a telephone line between his flat and workshop nearby.[41] In the following year, his workshop began to install telephone lines in various towns and, soon after, also manufactured telephone sets.[42]

In late 1879, Wadén bought some new electrical equipment from the branch of Siemens & Halske in St Petersburg: one Hefner-Alteneck AC-dynamo with a DC-exciter and six Jabločkov arc-lamps.[43] Lighting with 'Jabločkov's candles' was publicly demonstrated for the first time on the balcony of a Russian secondary school in Helsinki in March 1880.[44] Consequently, the Finns were quite abreast of the

times in electrical technology, although in Helsinki electric lighting was not used on as wide a scale as in the big European metropolises. By 1880 sixty Jabločkov lamps were in operation in London.[45] In St Petersburg-Kronstadt there were about 400 'Jabločkov candles' in use in 1881, while in the whole Russian Empire, their number totalled up to 700.[46] In Sweden the first commercial arc-lamp installations were made in 1876 at the sawmills of Korsnäs and Marma. 'Jabločkov's candles' were introduced in Blanch's Café in Stockholm in the autumn of 1878.[47]

'Jabločkov's candle' was the most used arc-lamp in Russia as well as all round Europe in the 1880s. Its unsuitability for the lighting of smaller rooms was one of its serious disadvantages. Several inventors, such as the Russian Aleksandr Lodygin, the Englishmen Joseph Swan and St George Lane-Fox, and the Americans Hiram S. Maxim, Thomas Alva Edison, Moses Farmer and the inventor partners William E. Sawyer and Albon Man, and the German Werner Siemens tried to invent a lamp for interior lighting.[48] Of these men, Edison, 'the noted inventor of the telephone, the phonograph and the microphone', was the best known in Finland even before the introduction of incandescent filament lamps.[49] Actually, he was the most famous and most popular American in Finland in the last quarter of the nineteenth century; hardly a month passed without at least one news item on Edison in the Finnish press.[50]

When the great inventor 'with 150 patents' was developing his incandescent lamp, the Finnish press reported on almost every step of his progress, about the experiments with filaments of platinum, carbonised paper, bamboo, etc. These news reports were published only some days later in Finland than in the British, German or Swedish press.[51]

Probably the great fame of Edison was responsible for tempting a man from Finland to Menlo Park in New Jersey, while Edison's lighting system was being created. That man, *Carl Samuel von Nottbeck* (1848–1904) became a pioneer in transferring Edison's technology into Europe. Although born in Finland, Nottbeck was not a Finnish subject; he was the eldest son of the Baltic-German director and co-proprietor of the Finlayson Cotton Mill at Tampere. He spent his childhood in Finland, went to school in St Petersburg, studied at the University of Dorpat (Tartu, in present Estonia) and took a degree in civil engineering at the Federal Technical Institute (ETH) in Zürich, Switzerland.[52] He persuaded his kinsfolk to accept Edison's lighting system in the long weaving-hall of the cotton mill which

Table 2.3 The first Edison lighting installations in Europe

Building	*City*	*Country*	*Opening date*
Paris electrical exhibition	Paris	France	Aug. 1881
Railway station	Strassburg	Germany	5 Jan. 1882
Public lighting plant* at Holborn Viaduct	London	England	12 Jan. 1882
Crystal Palace exhibition	London	England	14 Jan. 1882
Railway station of St Lazarre	Paris	France	31 Jan. 1882
La Scala Opera	Milan	Italy	11 Feb. 1882
Finlayson Cotton Mill	Tampere	Finland	15 Mar. 1882
Stock Exchange	Berlin	Germany	15 May 1882

* Officially the plant opened on 12 April 1882.

Sources: Brian Bowers, *A History of Electric Light & Power* (London, 1982) pp. 139ff; *Bulletin*, The Edison Electric Light Company (1882–3) no. 1–16, cited by Esko Sarasmo in 'Lisävalaistusta Finlaysonin sähkövalojen alkuvaiheisiin', *Yhdyslanka* (1957) no. 2, pp. 5–6.

was then the largest textile factory in the Nordic Countries.[53] After visiting the Paris electrical exhibition in 1881, he arrived in Tampere to install five dynamos for 300 'A-lamps' with another former Edison employee, the Hungarian Istvan von Fodor.[54]

Electric lighting at Finlayson was one of the earliest installations with Edison's incandescent lamps. Apart from exhibitions, it was the fifth permanent installation in Europe, coming just after those in the important commercial centres of London, Paris, Milan and Strassburg (see Table 2.3). The installation at the Finlayson cotton mill preceded even Edison's earliest central station in the USA which opened at Pearl Street in New York City on 4 September 1882. This was the first electricity supply utility in America.[55]

At the same time, in the early 1880s, several demonstrations and installations were, however, also made by using other incandescent filament lamps, such as those of Swan, Maxim and Lane-Fox.[56] In Finland, the first installation of Swan's filament lamps was carried out by the Swedish firm Elektriska A.B. from Stockholm at a sawmill in Parainen in the summer of 1883, which indicates an early adoption of British technology as well.[57]

Carl von Nottbeck's role in the transfer of electrical technology was, above all, that of a technician. He managed to install in a big factory a practical electrical lighting system which was later gradually

expanded. He was also an advocate who could convert his sceptical father to a totally new kind of electric lighting. Under a pseudonym, Nottbeck suggested novel practical applications for electricity in the Finnish press. His unprecedented proposals to electrify the country by means of its abundant hydropower resources and to use electricity for motive power in industry for railway traffic and for domestic lighting, cooking and space heating were pioneering in Finland. He published these far-seeing ideas in Finnish as early as September 1881.[58]

As a businessman, Nottbeck was not very successful although he was the general agent for Edison electric equipment in both Russia and Finland. Soon after installing electric lighting at Tampere, he started an advertisement campaign in the press with Dan. Joh. Wadén who acted as the local agent in Finland.[59] Nottbeck himself lived primarily in St Petersburg.[60]

The partners received only two orders in 1882: from G. Riek's wallpaper factory in Helsinki and from Julius Johnson, a sawmill owner in Jyväskylä.[61] Nevertheless, a little later, incandescent lamps came into much wider use than arc-lamps, the commercial utilisation of which was still for some years rejected by all except for a few restaurateurs and organisers of public entertainment.[62] In fact, arc-lamps never became as popular in the Grand Duchy as they did in some other countries. By the end of 1885 only 25 arc-lamps were operating in permanent installations in Finland. At the same time, approximately 3600 incandescent lamps were in use and of these about 1000 were at the Finlayson cotton mill in Tampere alone and 800 in various houses in Helsinki.[63] Wadén and his mechanics installed many of these lighting systems generally using Edison and later AEG lamps and dynamos of the German Schuckert Company. His most significant achievement in the field of heavy current engineering was setting up the first electric utility in the country, a public supply plant selling electricity to 31 consumers with about 300 lamps at first. This plant, called the 'Elektriska Centralbelysningen i Helsingfors', was opened in November 1884: in fact the same year as the first German electricity supply utility in Berlin and its Swedish counterpart in Gothenburg.[64]

Dan. Joh. Wadén mastered the tasks of advocate, businessman and technician, although heavy current engineering was his secondary occupation. When he resigned from the Telegraph Board, he primarily kept on working in the telephone business. Up to the year 1900, his firm continued to install electric lighting equipment. When competition became ever sharper, Wadén gradually gave up heavy current engineering. His electricity supply plant in the centre of Helsinki was merged with other local utilities between 1890 and 1891. Consequently, he concentrated on his prospering telephone business, especially inter-urban communication.[65]

Wadén's toughest competitor in the utility business was *Fritz C. G. Wilén* (1857–99) who was also an energetic and versatile Swedish-speaking Finn from a lower-middle-class family. Wilén was born in Britain as the son of a shipmaster and came to Finland at the age of seven when his family returned to Turku. He became interested in technology at the lyceum in Turku. Owing to disagreements between the teachers and students, Wilén, the chairman of the Student Union, was dismissed from the school for a term – just before the final exams – and was expelled from the town. While living in the archipelago of Turku, he was struck down by a long-lasting pneumonia and could never complete his studies. After recovering, he began his career as a journalist working in various newspapers in Turku, Helsinki and Tampere. Later on, he became the chief editor of *Tammerfors Aftonblad*, but was forced to resign in 1886 due to his sharp opposition to the coalition of his pro-Swedish party and some pro-Finnish groups in the local elections.[66]

There was a great deal of idealism in Wilén's philosophy of life including a strong belief in technology as a positive development factor. He was especially interested in electrical technology, and as a master of foreign languages he eagerly followed its development through the foreign press. As editor-in-chief, he actively joined in the newspaper discussion on street lighting in Finnish towns and he became a prominent advocate for electricity.[67]

After his resignation, Wilén continued working as a journalist, frequently writing long, knowledgeable articles on electric lighting in newspapers both in Swedish and Finnish under the pseudonym 'Bonifacius' (benefactor). In 1886 he made contact with the American firm Thomson-Houston International Electric Light Company which in the next year appointed this English-speaking man as its general agent for Finland, and for Russia for two years as well. Wilén set up his agency in Helsinki and launched an impressive advertisement campaign. In 1890 the company's head office for Europe, which was situated in Hamburg, asked for copies of Wilén's exemplary advertisements and catalogues telling him that 'our friends in other continents would find them interesting'.[68]

In the mid-1880s, Thomson-Houston made a breakthrough in the

Nordic Countries: its lighting system was chosen for municipal street lighting in Härnösand, a town on the eastern coast of Sweden. In Finland, Wilén's campaign had a decisive impact on similar plants, ordered by the municipal government, in Tampere in 1888 and in Oulu in 1889, which were the first electric street lighting installations in the country.[69]

Owing to Fritz Wilén's marketing talents, the sales of Thomas-Houston products got off to a good start. By 1 February 1890 this firm had delivered equipment for fifteen installations with 118 arc-lamps and 5140 incandescent lamps in Finland.[70] Wilén had also made plans to build a big electricity supply utility for indoor lighting in the centre of Helsinki. The parent company, Thomson-Houston, was not interested in making any direct investment in Finland, but the project easily found financiers within the country. The only problematical matter concerned the new technology he intended to apply. All earlier electricity supply plants built in Helsinki for single houses or for whole quarters were working on direct current. Wilén planned to use alternating current of 1000 volts in transmitting electricity from a single thermal power plant to several quarters and distribute it to lamps after transforming the tension down to 50 volts.[71]

The Helsinki city council granted the franchise to the new company, 'Helsingfors Elektriska Belysning Aktiebolag', after deliberating for twelve months. This untypically long delay was caused by the uncertainty of the authorities and by public debate on the new high-tension technology. According to the regulations, an electric supply company needed a franchise only if it constructed overhead or underground cables outside the buildings of the estate owner. Many laymen and even some experts opposed using a tension of 1000 volts in overhead cables running along the streets. In the public debate on the safety of these cables, Wilén needed all his journalistic talents. Finally in June 1890, the franchise was given to the company and it started to deliver electricity only a few months later. In the following year, Wadén's DC-plants were merged with Wilén's new company supplying alternating current.[72]

The triumph of Helsingfors Elektriska Belysning Ab did not, however, bring with it personal success to Wilén. After two pioneering years, he resigned from the post of managing director of the supply company. When in 1892 Thomson-Houston was merged with the Edison Company, disagreements broke out between Wilén's agency and the parent company.[73] As a result, Wilén decided to withdraw from the electricity business altogether. Presumably the basic problem was that he lacked the technical and practical knowledge required for the rational management of a considerable agency. At the same time, Wilén's health was again weakening, and he gave up his agency: in 1894 he bought a newspaper business in Tampere and returned to the profession of journalist. Soon thereafter, the American electrical engineering industry lost its foothold in the Finnish market.[74]

Fritz Wilén was above all an advocate who promoted the introduction of electric lighting systems. As a journalist and politician, he knew how to influence local governments and public opinion. Every new technology needs a supporting mental infrastructure, and by opening new visions Wilén laid the basis for the adoption of a novel energy form and its applications. He also contributed in transferring new kinds of innovations. His American connections supplemented the inflow of European, especially German, technology which was soon gaining strength in Finland as well as on the Continent. In many installations, Wilén had to lean on the foreign engineers of Thomson-Houston and still he could not avoid technical problems in the operation of the installed plants. Insufficient technical expertise became fatal to his career in the business of electrical equipment.

The Nascent State of Finnish Electrical Engineering

Fritz Wilén was not the only Finnish pioneer of electrical engineering who failed after a promising beginning. A similar fate – even if for different reasons – was experienced by *Carl A. Wahl* who belonged to the third generation of a successful Finnish merchant-industrialist family of German descent. Carl Wahl took a degree in engineering, specialising in electrical technology, at the Hanover University of Technology in 1887, returned to Finland and set up an electrical workshop in a former sauna of his family's ironworks at Warkaus in central Finland. In the following year the workshop, a subsidiary of his family's concern called 'Paul Wahl & Co:s elektriska verkstad', was moved to Viipuri, the coastal centre of East-Finland. It became the first firm in the country to manufacture dynamos, arc-lamps, electrical meters and, later on, electric motors and transformers. Most of these devices, as well as special steam engines coupled with dynamos, were designed by the firm's own engineers. Moreover, the firm started to supply electricity to customers from its power plants in Viipuri and Helsinki.[75]

Carl Wahl and his staff had a great deal of ambition. In 1889 he travelled to London in order to obtain from the English 'Electrical Power Storage Company' a comprehensive licence including all the most important accumulator patents at that time, and a monopoly to produce and sell 'E.P.S.'-accumulators for the Finnish, Swedish, Norwegian, Danish and Russian markets. Owing to this sole right, many other manufacturers in these countries, for example Dan. Joh. Wadén, had to give up making accumulators.[76]

The production of power storage equipment secured the workshop's prosperity for many years. That was, however, not enough, for Carl Wahl who managed to employ very competent electrical engineers. With men like Gerhard Renfors and Johannes Sohlman, Wahl developed new types of dynamos, electric motors, incandescent lamps, regulators for accumulators, and other devices. In Finland patents were granted for a dozen of their innovations.[77] Wahl's electrical workshop was the forerunner in the introduction of electricity for motive power: it made an experimental electric boat of 4 to 5 hp in 1892 and in the following year it supplied the first electric motor in Finnish industry for a local printing shop, Wiipurin uusi kirjapaino.[78] In 1895 the firm built one of the earliest tramway lines in Russia over the frozen Neva river in St Petersburg. In 1900, a three-phase transmission line of 33 kilometres with 15 000 volts was opened from the Lavola hydropower plant to the company's electricity supply utility in Viipuri. Generators and transformers were designed and manufactured by the firm, which was reorganised in the form of a limited company in 1898.[79] In a few years, Wahl's workshop rose to become the biggest supplier of electrical equipment in the country. By 1 August 1889 it had produced 29 dynamos for about 5000 incandescent and arc-lamps, and accumulators for 1100 incandescent lamps. Products were sold mainly in Russia and Wahl's mechanics travelled round the Empire installing lighting plants, for example in sawmills along the coast of the White Sea as well as in ships in the Caspian Sea. The firm's machines won a gold prize in the big Nižnij-Novgorod Exhibition in 1896. The number of workers rose from 49 in 1889 to 208 in1900.[80]

At the turn of the century, the downturn began. When the accumulator patents expired, corresponding devices were produced in Russia, and Carl Wahl's company had to reduce its output. At the same time, German companies intensified their sales activities of electrical equipment in the Russian and Finnish markets. They continually introduced new models, while Wahl's company, now losing its dynamism, stuck to its old dynamo and motor constructions.

In addition, in the late 1890s, tariff reforms in both Finland and Russia deprived the Finnish electrical manufacturers of a part of the privileged customs protection enjoyed in their main markets. Finally, the recession of 1901–3 seriously affected all engineering works in both Finland and Russia.[81]

The company had to give up the modernisation of the electricity supply utility and engineering works, because a new issue of shares failed at the turn of the century. When the company's output and employment at the same time drastically dropped to nearly half, in 1905 Carl Wahl resigned from the post of managing director. An embittered man, he moved to Charlottenburg in Berlin. He was especially disappointed with the parent company controlled by his relatives who refused to increase investments in the subsidiary. The development of the engineering works stagnated to the level of 1904 (about 120 employees) until it was taken over by the AEG in 1910. After that it functioned for some years as a mere repair workshop.[82]

Carl Wahl's firm was not only the first and leading Finnish manufacturing enterprise specialising in heavy current engineering, it also competed with foreign companies and supplied electricity producers with domestic equipment; it was also a notable training place for many young Finnish electrical engineers. Among these were, for example, the first Finnish professor in electrical technology, Johannes Sohlman, and the successful entrepreneur, Gottfrid Strömberg. Carl Wahl and his engineers were so gripped with innovation that they neglected to derive benefit from their innovations through rational and profitable management. The firm was neither properly organised nor financed to deal with almost every possible aspect in the field of electrical engineering.

In contrast to Carl A. Wahl, *Axel Gottfrid Strömberg* (1863–1938) represented a different type of pioneer: success in business was more important to him than trailblazing innovations. Strömberg's social background was more modest; he was born as the seventh child of a foreman in an ironworks in northern Finland. His main language was Swedish even if he learnt fluent Finnish at an early age. In his boyhood, he liked to wander around and watch men working in Paul Wahl & Co's rolling mill at Varkaus where his father was then employed. He was also busy making various mechanical devices by himself. In 1880–1, at the age of 17, he constructed a DC-dynamo of 65 V and 8 Amp for an arc-lamp, with the assistance of his younger sister. That was the first dynamo made in Finland.[83]

After completing his studies at the Polytechnic Institute of Helsinki with distinction, he was granted a government scholarship for studying electrical engineering in Germany. Between 1885 and 1887 he studied for one year at the Charlottenburg University of Technology in Berlin and for another year together with Carl A. Wahl he attended the lectures of the famous professor, Wilhelm Kolrausch, in the Hanover University of Technology.[84] Back home, Strömberg became the first qualified lecturer in electrical engineering at the Polytechnic Institute of Helsinki and an agent of Wahl's new workshop for two years. In 1889 he set up his own firm, the second Finnish electrical workshop starting its operation in a former sauna.[85]

The growth of Strömberg's firm was slower than that of Wahl's and he concentrated on supplying primarily the domestic market with electrical equipment and exported only smaller quantities of dynamos to Russia.[86] Strömberg did not attempt to produce everything. At first he bought steam engines from a domestic company, Kone- ja Siltarakennus Oy, for driving his dynamos. Later he became a general agent for the Swedish firm Ab de Laval (steam turbines and Jandus-incandescent lamps), the Dutch firm Philips (electric bulbs) and the German firms Kölner Accumulatoren-Werke (batteries), and Elektrizitätszählerfabrik H. Aron (electricity meters).[87]

During the late nineteenth century, Strömberg's firm confined itself to manufacturing only dynamos and electric motors and carrying out various kinds of installations. Its products then represented rather conventional technology. Strömberg and his staff were not active in inventing and patenting. His firm was even slow in adopting and applying other manufacturers' new innovations, like asynchronic three-phase motors and the methods for the serial production of machines.[88]

Like Wadén, Wahl and Wilén, Strömberg decided to provide electricity to the public. His innovation was to supply electricity to the lower classes of the capital city. In 1898 he established his new factory near a residential district of working-class people in Helsinki and began to distribute direct current to this northern Helsinki quarter which other suppliers, limiting their activities to the city centre, had neglected.[89]

Gottfrid Strömberg was a calculating businessman and a pragmatic technician who concentrated on running his firm. In this goal he succeeded. Moreover, he also managed to create a favourable image for his enterprise. In the early twentieth century, his company was considered essential for the defence of the national interests in the field of the electrical equipment trade. Almost all that was written about him in the Finnish press was very positive.[90] Soon after Wahl's company was taken over by the AEG, the government, following Strömberg's application, increased the customs protection for domestic electrical engineering.

Remarks

It is important to note that during the early years it was the Finns who held the initiative in transferring electrical technology to their country. At that time, the role of foreign experts or companies was secondary. The reason for the Finns' activity can be found in the intellectual and social atmosphere of late nineteenth-century Finland. The people, who had long been frustrated by their everyday troubles, had begun to find that with entrepreneurship as well as appropriate education in modern methods and technology they could improve the quality of their life. Optimism and belief in a better future constituted the dominant way of thinking among the intellectuals. The establishment was not wholeheartedly in favour of developing the technological bases of society, but a group of young men was, in contrast, enthusiastically interested in new innovations. One of them, John Didrik Stenberg (1841–86), was so motivated that he ran away from home for Germany at the age of sixteen in order to become an engineer.[91]

The above-mentioned pioneers of electrical engineering, Lemström, Wetzer, Wadén, Nottbeck, Wilén, Wahl and Strömberg, had some common features. First, all of them had a good knowledge of foreign languages. In addition to the national tongues, Swedish and Finnish, they knew between two and four foreign languages: German, French, Russian or English. Second, as active persons they read foreign publications more than the average person in their position. They also quite often travelled abroad on business visiting exhibitions, factories and meetings. Third, all except Wilén studied abroad – three in Germany, one in Russia, one in both Russia and Switzerland, and one in Sweden, France and Russia. The level of their education was fairly high: of the seven men, five were engineers with a university qualification and one even had a doctor's degree in science. Owing to these features, they had a good insight into what was happening in electrical engineering abroad and were capable of applying new innovations in their home country.

The adoption of electric lighting did not only depend on these capable agents of transfer; it also depended on the public. Owing to

the fairly active and internationally minded press and a high rate of literacy, people were generally aware of new electrical innovations. The acquisition of electric lighting for industrial plants, street lighting, shops, offices and homes above all depended on purchasing power and attitudes to new energy technology. In principle, technical novelties evoked a favourable response in Finland, and sometimes even idealistic admiration, while the social prestige of engineers and mechanics was reasonably high. However, the friction in moving psychologically from traditional means of lighting and motive power to modern technology was considerable. From the 1880s, when the structure of the traditional society was in any case transforming, new ideas and attitudes were given a chance to emerge.

The price of electric lighting was one of the most vital aspects in the discussion on electricity in the press. The majority considered the costs of an illuminant more important than the quality of its light, cleanliness, and easy-care. In a poor country, there were very few who could afford any luxury. The lack of purchasing power decisively restricted the diffusion of electric light and power in Finland.

The second point that might have delayed the acceptance of electric lighting was the uncertainty of its safety. Frequently, fatal electricity accidents abroad were reported in the Finnish press and people were very worried about that aspect of this technology. The providers of electrical equipment had to do their best to persuade the people that their electrical installations did not endanger the health of consumers. The third issue, the fire hazards with electrical installations, was also a persistent topic in the debates. The authorities quite early on saw it as a necessity to inspect installations, although a functioning inspection system was not set up before the interwar years. Defects were, however, continuously found and discussed, and this stimulated the improvement and safety of installations.

It was more the entrepreneurial spirit than profound scientific knowledge and technical expertise which spurred Finnish electrification at the outset. An important feature in the adoption of electrical technology was that local inhabitants were initiators in the transfer process. By international standards, the rapid adoption of the latest technology can be explained by the fact that there were qualified and well-informed local men taking care of marketing, installing and maintaining electric lighting equipment. Without these energetic transfer agents and a receptive societal atmosphere, the adoption of electrical technology would have taken place much later.

2.3 DIVERSIFICATION

Production

Electrical installations, at first, consisted of only small lighting plants for a house or a group of houses. Apart from some small technical differences, they were basically similar to each other. In the course of time, as the use of electrical technology expanded, diversification both in the supply and use of electricity took place. Various kinds of prime movers became coupled with a great many types of generators. Besides lighting, electricity was applied to several other purposes. Not only did the technology change, but big transnational companies emerged to compete with the early local electrical workshops in the manufacture and installation of electrical equipment. Side by side, there were set up both industrial autogenerating plants and electricity supply utilities whose capacity began to vary considerably. Different models of organisation and forms of ownership were developed for supplying electricity. Gradually, the modern systems of the electricity business began to take shape at the close of the nineteenth century.

As in other countries, Finland experienced the diversification process of the rising electricity business. In the 1870s and early 1880s, experiments and plans abroad promised a good future for street and room lighting by electricity. On the basis of historical experience, one might, however, have supposed that the adoption of these novelties in Finland would take a long time. Publicly organised street lighting in particular was introduced very late in Finland. It was only in the autumn of 1805 that the first stationary candle lanterns began to light the streets of Turku, the largest town in Finland in those days. In comparison Copenhagen was lit with 1200 street lanterns at the time.[92] In Helsinki, the new capital of the Grand Duchy, public street lighting was set up in 1818 with 80 hempseed oil lamps.[93]

It took many years before public street lighting with stationary candle lanterns spread to smaller towns. A few of them, such as Tammisaari on the southern coast, installed municipal street lighting as late as the 1860s. At that time the administrative centres gradually replaced candle lanterns and vegetable oil lamps with paraffin lamps and these became common in the street lighting of provincial towns in the 1880s. Some latecomers were still farther behind; for instance, the tiny town of Iisalmi in Savo moved from darkness direct to street lighting with 12 paraffin lamps in 1896.[94]

Fortunately, this dilatoriness was not a lasting feature of Finnish

town life. Things changed faster when economic activities gained strength. The growth of the urban population was accelerating and social life was picking up; people demanded better lighting on the streets in the evenings. In these circumstances, the proposals for electric lighting often evoked a favourable response. In fact, Finnish towns could derive benefit from their backwardness, since, as they generally lacked a gas lighting system or even decent paraffin street lighting, they did not have to think about the possible scrapping costs of previous investments in illuminating equipment when planning electrification.[95] Only three Finnish towns, Helsinki, Turku and Viipuri, lit their streets by gas, whereas in the early 1920s gas supply utilities in Norway lit 17 towns, in Sweden 37 towns and in Denmark over 70 towns and several rural municipalities as well.[96]

Gloomy roads stimulated some middle-sized Finnish towns without gas to become exceptionally active in bringing electric lighting to their streets. By the year 1900, at least a few main streets in nine towns were lit by electricity. Finnish town councils were generally rather inflexible institutions, but some of them were very enterprising even by international standards. The first two Finnish street lighting plants with arc-lamps, situated in Tampere and Oulu, were among the earliest electricity supply utilities in Europe owned by local governments, as shown in Table 2.4. The model for these plants was taken from the pioneering application of the American Thomson-Houston street lighting technology in Härnösand in Sweden, which some Finnish local politicians visited to make a closer inspection of a municipal electrical undertaking.

Some Finnish towns lacking the necessary technical expertise, funds or entrepreneurship gave temporal concessions of between 5 and 40 years to private electricity utilities, as did many cities abroad. In Europe, the great majority of electricity utilities were private: according to an incomplete list published in *Offizielle Zeitung der Internationellen Elektrotechnischen Ausstellung* in 1891 there were 218 electricity supply utilities, the biggest of which were coupled with 90 000–100 000 incandescent lamps. Only 4 per cent of these utilities were municipal.[97] Nevertheless, in Finland the municipal electricity utilities of Tampere and Oulu became models for other towns wishing to aim at a similar organisation.

By the autumn of 1914, at least one electricity utility was established in all 38 Finnish towns, 24 of which had a municipal distribution network. During the next eleven years, all the remaining private urban utilities except two, Viipuri and Kemi, were taken over by the

Table 2.4 The first municipal electrical undertakings in Europe

Year of opening	*Town*	*Country*	*Number of lamps**
1885	Härnösand	Sweden	35 arc-lamps
1887	Växjö	Sweden	. .
1888	**Tampere**	**Finland**	**30 arc-lamps**
1888	Västerås	Sweden	. .
1889	Bradford	England	. .
1890	**Oulu**	**Finland**	**30 arc-lamps**
1890	Königsberg	Germany	. .
1891	Sundsvall	Sweden	. .
1891	Brighton	England	. .
1892	Stockholm	Sweden	1024 incandescent lamps
1892	Zürich	Switzerland	135 arc-lamps and 20 000 incandescent lamps
1892	Hammerfest	Norway	. .
1892	Kristiania	Norway	. .
1892	Brussels	Belgium	. .
1892	Paris	France	. .
1892	Dublin	Ireland	. .

* The number of lamps connected to the system when the plant was commissioned.
. . No data available.

Sources: I. C. R. Byatt, *The British Electrical Industry 1875–1914* (Oxford, 1979) p. 105; G. R. Dahlander, *Elektriciteten och dess förnämsta tekniska tillämpningar* (Stockholm, 1893) pp. 514–37; G. R. Dahlander, *Elektriciteten, Nyaste uppfinningar och forskningar* (Stockholm, 1901) pp. 267–71; Yrjö Raevuori, *Tampereen kaupungin sähkölaitos* (Tampere, 1938) pp. 34–5, 98–105; *Svenska Dagbladet* (Stockholm) 3 Oct. 1909; Bengt Svensson, 'De första kommunala industriföretagen', *Hundra år under kommunalförfattningarna 1862–1962* (Stockholm, 1962) p. 142; Fritz Wilén, *Några upplysningar om den elektriska belysningen och dennas nuvarande ståndpunkt* (Åbo, 1888) pp. 18–22; Johan Vogt, *Elektricitetlandet Norge* (Oslo, 1971) p. 13; Johan Åkerman, *Ett elektriskt halvsekel, Översikt över ASEAs utveckling 1883–1933* (Västerås, 1933) p. 42.

local government (as indicated in Table 2.6). Unreasonably high sale prices of electricity, frequent technical malfunctions in distribution, the reluctance of private companies to expand their networks from the well-to-do city centres to the outskirts, and the fortuitous muddle of the overhead lines of competing companies above the streets provided the town councils with arguments against private electricity utilities.[98]

With experience, it became evident that after a few years of well-managed operation an electricity supply utility might become a profitable investment, and this fact also spurred from the 1910s the municipalisation of private companies. The private owners were as a rule satisfied with the financial compensation they were offered as well as with the other terms of sale, and consequently municipalisation did not usually get bogged down by serious conflicts in Finland.[99] Frequently the main problem was how to finance the municipal acquisition of the utility; generally it could not be funded by the ordinary income from taxation. As a solution, town councils used other revenues such as the profits on the sales of alcohol or of timber from the municipal forests.[100]

In Britain and on the Continent at the turn of the century, there was a vivid debate about private and municipal electricity utilities. Privately owned utilities were claimed to be more dynamic and more efficient. Municipally owned utilities were said to be inflexible and able to supply only expensive electricity to the public. For example, it was claimed that during 1898 and 1899 in the German cities of over 100 000 inhabitants municipal utilities charged on average a 12 per cent higher retail price for electricity for lighting and a 10 per cent higher price per kWh for power uses than did the privately owned.[101]

In Finland the opposite situation prevailed: municipal utilities sold electricity for lighting on average at 7 per cent and for power uses at 13 per cent lower than privately owned, as shown in Table 2.5. Abroad, the involvement of municipal governments in the electricity supply business was sometimes claimed as restricting free enter-

Table 2.5 The average basic rates of electricity for households, shops and small-scale industry in Finnish towns in 1914

Type of utility	*For lighting*		*For power*	
	*no.**	*pennies/kWh*	*no.**	*pennies/kWh*
Municipal	22	58.4	20	31.0
Private	13	62.7	11	35.5
Total	35	60.0	31	32.6

* The number of the utilities providing the exact information on their rate of kWh.

Sources: Selostus Suomen kaupunkien sähkölaitosten virranhinnoista, Kunnallinen Keskustoimisto (Kotka, 1915); *Sähköasian käsittely Käkisalmen kaupungin valtuustossa* (Käkisalmi, 1913) p. 12.

prise.[102] In Finland, by securing a reliable supply of electricity and water, the municipal governments were, on the contrary, seen to promote local private enterprise and to attract new firms to the town.[103] Municipal electricity supply utilities were regarded as a part of the local infrastructure. Consequently in Finland, as in the Scandinavian countries, there was early on a strong trend away from privately owned utilities towards municipal utilities.

Table 2.6 shows great differences in the electricity consumption per capita between Finnish towns, but even in Viipuri, the town ranked first, the consumption (65 kWh) was very low compared to that in the industrial metropolises abroad. In 1913 the use of electricity was 110 kWh per capita in London, 170 kWh in Berlin and 310 kWh in Chicago.[104] By contrast, the Finnish figures do not substantially differ from those in the industrial centres of the Russian Empire. Together the three electricity supply utilities in St Petersburg distributed 48 kWh per inhabitant in 1913.[105] Nor were the larger Finnish towns many years behind some significant West European cities: in 1908 the electricity utility of Stockholm distributed 41 kWh per inhabitant; the corresponding figure for Copenhagen and Hamburg was 39 kWh, for Bremen 36 kWh, for Amsterdam 24 kWh and for Breslau 20 kWh.[106]

The deliveries of the above-mentioned utilities to the Finnish urban population of half a million did not constitute the total supply of electricity. The consumption of the big factories was not included in the figures in Table 2.6. Factories, such as pulp- and paper-mills, were not generally situated in the towns and did not buy their electricity from the urban utilities at that time. From the very beginning, industry had the central role in both the generation and consumption of electricity in Finland. Big wood-processing factories started selling their surplus electricity to the nearby urban and rural utilities.

The first electric lighting installations were powered by small reciprocating steam engines. Later on, other prime movers entered the scene. The first dynamos of Finlayson & Co. drew their power from the hydroturbine-driven line shaft of the factory. In 1883 the Wärtsilä Iron Works in eastern Finland installed electric lighting, also using a hydroturbine as a power source for its dynamo.[107] Problems in building large hydroelectric plants and in the transmission of power over longer distances hampered the utilisation of hydropower for electrification in the nineteenth century. Nevertheless, in 1913 the total capacity of prime movers in hydroelectric plants was 30 MW, whereas that in the thermal electric plants with reciprocating steam engines was 24 MW.[108]

Close to the turn of the century steam turbines were introduced to drive electricity generators in Finland. The first steam turbine coupled with a dynamo was set in the steam tugboat *Mercur* in December 1892 and the second one was put in operation in the lighting plant of the fashionable restaurant *Kämp* in Helsinki in the following year.[109] Mainly owing to the great many imported German steam turbines, the total capacity of thermal power grew by a factor of 14.5 between 1900 and 1920, as shown in Appendix Table A.3. In 1913 about 75 steam turbines with a capacity of 28 MW were engaged in the production of electricity.[110]

At the turn of the century, internal combustion engines, too, were set to run generators. For many small electricity power plants, diesel engines were considered the most suitable and inexpensive prime mover. Petroleum motors and suction gas engines fuelled by gas from firewood, wood waste or peat were also in use. Over 50 combustion engines with the total capacity of 4 MW were coupled with generators in 1913. Diesel motors accounted for about 30 of these engines.[111]

Transmission: Direct and Alternating Current

Both the earliest electric lighting equipment and electric motors operated on direct current. The special advantage of direct current for lighting was that electricity could be stored in accumulators during the daytime and released in the evening, i.e. during peaks in consumption. In this way load fluctuations could be counteracted and disturbances in the production of electricity diminished. The benefit of direct-current electric motors was that they were readily available from the 1890s in a wide range of capacities and speeds, manufactured both in Finland and abroad. The speed of the direct-current motors could be cheaply and easily varied, which was a useful feature with some applications, e.g. with trams. Furthermore, these motors were not very sensitive to fluctuations in voltage. Direct current was thus the most favoured alternative for those firms producing the electricity they used and who did not have to cope with a long distance between the generators and the place of work. Direct-current generators and motors constituted the clear majority of electric machinery by number purchased up till the end of the 1910s.

The great drawback of direct current lies in the considerable energy losses in transmission of electricity over longer distances.

Table 2.6 The urban electricity supply utilities in Finland in 1914

Town	*The owner of the principal utility in 1914*	*Date I*	*Date II*	*Sales* 100 kWh*	*Consumption per capita kWh*	*The supplier of the first dynamo*
1. Helsinki	MG	1884	1909	9,617	56	Schuckert
2. Viipuri	AEG	1887	1936	1,916	65	Wahl
3. Tampere	MG	1888	1888	2,808	62	T-H
4. Oulu	MG	1890	1890	938	43	T-H
5. Kuopio	MG	1892	1907	741	42	Strömberg
6. Porvoo	MG	1893	1911	235	42	Strömberg
7. Vaasa	Vasa Elektriska Ab	1893	1919[a]	529	22	Oerlikon
8. Kotka	Kotka Järn Ab	1897	1922	255	21	Wahl
9. Joensuu	MG	1897	1897	75	14	Wahl
10. Turku	AEG	1898	1919	2,797	52	Strömberg
11. Pori	MG	1898	1907	245	14	Strömberg
12. Hämeenlinna	AEG	1899	1918[b]	168	25	ASEA/FEAB
13. Kristiina	Ab Lumen	1899	1925	30	9	AEG
14. Rauma	MG	1900	1900	202	29	Strömberg
15. Lappeenranta	MG	1901	1901	102	30	AEG
16. Hamina	MG	1901	1901	35	11	AEG
17. Mikkeli	MG	1901	1911	139	31	ASEA/FEAB
18. Pietarsaari	MG	1901	1901	177	24	Strömberg
19. Jyväskylä	MG	1902	1902	145	31	AEG
20. Uusikaarlepyy	J. W. Nessler	1903	1925	26	20	AEG
21. Kokkola	MG	1905	1905	69	17	Strömberg
22. Sortavala	T. Lehtinen	1906	1921	42	12	AEG
23. Heinola	El. belysning Ab	1906	1920	1	1	AEG
24. Raahe	Raahen Sähkö Oy	1907	1919	103	25	AEG
25. Lahti	MG	1907	1907	225	37	ASEA
26. Savonlinna	MG	1907	1907	44	9	Strömberg
27. Hanko	MG	1907	1910	122	19	AEG
28. Loviisa	Oy Strömberg Ab	1907	1922	78	20	Strömberg
29. Maarianhamina	AEG	1909	1919	24	17	(AEG)
30. Tammisaari	MG	1909	1909	104	33	Strömberg
31. Uusikaupunki	MG	1909	1909	34	8	Siemens
32. Iisalmi	MG	1910	1910	45	15	AEG
33. Kajaani	MG	1911	1911	(49)	(14)	**
34. Kaskinen	Kaskö El.verk Ab	1911	1917	14	9	..
35. Kemi	Kemin Sähkö Oy	1912	1939	43	17	ASEA
36. Tornio	MG	1912	1912	40	22	Strömberg
37. Naantali	MG	1912	1912	(9)	(10)	**
38. Käkisalmi	Ruben Peterzens	1914	1917	(9)	(4)	..
Grant total and average				22,233	44	

Date I The first central station was put in operation in the town.
Date II The electricity utility of the municipality was put in operation.
a The majority of the capital stock to the municipality in 1919.
b In 1908 the municipality hired its old plant to the AEG.
MG Municipal government.
T-H Thomson-Houston.
* Transmission losses excluded.
** No own dynamo, only a distributive utility.
.. No data available.

Sources: The Archive of the Board of Industry in the Archives of the Central Statistical Centre of Finland; The Archive of Strömberg Oy; *Teknikern* 1891–1918; various works in local history.

Urban central stations were, however, distributing direct current produced by their power plants to areas comprising of only a few blocks. In industry short DC-transmission lines were also erected; for instance, in 1901 a line one-kilometre long was built at the Inha Iron Works to transfer 30 hp of direct current at 450 volts.[112] Another problem with DC motors was that they required regular maintenance, a point to be considered when installing one. They were not very good at maintaining their standard speed, while the load fluctuated. It was also difficult to produce direct current at voltages high enough for large electric motors.[113]

The key factor stimulating industrial electrification was, however, alternating current. From the 1880s, AC technology had been intensively developed in several countries. In 1882 Lucien Gaulard, a Frenchman, and James Gibbs, an Englishman, filed for a British patent on an induction coil system, later known as the transformer principle. The American–Croatian Nikola Tesla constructed a two-phase asynchronous motor in 1887, and the Russian-born Mihail O. von Dolivo-Dobrovol'skij patented the principle of his three-phase cage induction motor in Germany in 1889.[114] The first practical application of polyphase technology to the generation of motive power was the 175 kilometre three-phase power transmission line, from the waterfalls at Lauffen to the fair in Frankfort-on-Main in 1891, on which 300 hp at 25 000 volts were transmitted from hydro-turbines to electric motors with an efficiency of 74 per cent.[115] In Sweden Jonas Wenström applied for several patents for the three-phase principle in 1889–90. On the basis of his discoveries the Swedish company ASEA built, in 1893, the first polyphase power transmission line in Sweden from the Hellsjö hydroelectric power plant to the Grängesberg mines, a distance of 13 kilometres.[116] Pioneers in this field in the United States were Westinghouse and General Electric. In 1895 these companies jointly manufactured the power generating equipment for the first large polyphase AC power station in the world, at Niagara Falls.[117]

The new AC technology was soon also introduced in Finland. In the autumn of 1890 Helsingfors Elektriska Belysning Ab, the utility founded by Fritz Wilén, opened its new thermal power plant of 1840 kW which then supplied alternating current at 1000 volts through transformers to the 1800 incandescent lamps of various subscribers.[118] In September 1891 the municipal electricity utility in Tampere began to illuminate public buildings in the city with a two-phase dynamo, powered by a line shaft driven by hydroturbines. The length of the

main line was 7 kilometres and the power was transmitted at 1100 volts.[119] Two years later Gottfrid Strömberg announced that he had started to manufacture AC dynamos and transformers.[120]

In both Sweden and Finland, the introduction of three-phase power transmission was pioneered in ore mines. It was of special importance for these firms to be able to make use of the benefits of electric power transmission, because transporting a bulky, cheap raw material to a distant power source was not economically possible. The breaking, transporting, crushing and classifying of ore required a great deal of energy. Compared with the previously used power sources, electrically driven conveyors, pumps, boring machines and electric lighting offered great advantages and new opportunities. In 1898 a 30-kilometre power transmission line was built in Karelia. It extended from the three hydroelectric power plants of the Uuksu river to the Ristioja smelting plant and the Pitkäranta iron mine. The line was financed by a Russian firm, and Swedish engineers contributed decisively to its planning. Another St Petersburg firm built the next power transmission line which ran from the Läskelä rapids to its iron mines at Välimäki, north of Lake Ladoga. The length of the line was 8 kilometres and the tension 6000 volts. As with the first power transmission line, the three-phase generators for this one were bought from the ASEA. The line was completed in 1899, but the mine had to be closed due to unprofitability in 1907.[121]

In 1900, a power transmission line leading from the Lavola rapids to Viipuri was completed by the company headed by Carl A. Wahl. This company both manufactured electrical equipment and ran a not insignificant electricity supply utility in the town of Viipuri, but more electricity was needed to serve all its customers. The owner company designed and manufactured the equipment for the Lavola power plant itself. The plant's two three-phase generators fed 300 hp of current at 15 000 volts over a distance of 33 kilometres.[122] After the turn of the century the metallurgical and engineering industry lost a great deal of its earlier importance for the building of power lines, while the paper industry became, for several decades, the leading organiser and financier of new power transmission projects.

Between 1900 and 1920 metallurgical and engineering firms built only two large power transmission projects, i.e. the Saarionkoski and Åminnefors power plants, which with their transmission lines, were completed in 1909 and 1910 respectively. The sawmill industry was represented by Pankakoski Ab, when the firm opened a power transmission line from its hydroplant to its sawmill at Lieksa in 1913.

Companies of the paper industry, in turn, built four substantial hydroelectric power plants at Klåsarö, Lahnasenkoski, Nokia and Pitkäkoski. The most efficient power plant in Finland was the Nokia hydroelectric plant, which was expanded in 1913. About 4200 hp of the power produced by its turbines were converted into electricity. A 13-kilometre, 33 000 volt transmission line connected this plant with the suburbs of Tampere.[123]

During the first decades of the twentieth century, Finland, however, clearly lagged behind Sweden and Norway, where several hydroelectric power plants of over 10 000 hp were being built at that time. Several hypotheses have been put forward to explain Finland's slower development, such as the relatively low heads of the rapids, a shortage of variety in raw materials, a scarcity of capital and a lack of co-operation within the private sector and between the industry and the government as well as unsettled political conditions and legislative problems.[124]

After the introduction of AC technology, it was no longer necessary to build the factories next to the prime movers; energy could be transmitted at a low cost over dozens of kilometres. This fact alone gave industrial enterprises new opportunities. Furthermore, it was fairly cheap to produce energy with hydroturbines, and a plentiful supply of energy made the intensive mechanisation of production possible. Three-phase asynchronous motors had several advantages as power sources for production machinery. Their speeds remained nearly constant at varying loads. A standard speed was an essential precondition for the perfect functioning of certain machines, e.g. paper-making machines. Owing to their simple construction, AC-motors were potentially cheap to produce and did not require very much maintenance.[125] Consequently, the electrification of manufacturing spurred on the rise of productivity.

Consumption

Not only the production of electricity but also its consumption became more diversified. The users of electricity began to utilise this versatile energy form, in addition to lighting, for electroplating, motive power and other purposes, too. In the Finnish metallurgical and engineering industry, electricity was first used for electroplating. This was an electrolytic method of coating metal and non-metallic articles with a thin metal layer, discovered during 1837–8 by the German Moritz Jakobi in St Petersburg and patented in 1840 by the

Englishmen George R. and Henry Elkington. In 1878 Daniel Joh. Wadén introduced electroplating into Finland.[126] Later, electroplating became a method commonly used in other engineering works and precision mechanics shops in Helsinki, Viipuri and Tampere during the 1880s and 1890s.[127]

In Finland, the printing industry was the pioneer in using electricity as a power source. Electric motors were first introduced in this sector in 1893 and by 1920 virtually the whole printing industry was electrified.[128] In the other sectors of manufacturing, electrification did not proceed so rapidly. The second swiftest was the metallurgical and engineering sector where the first electric motors were put in operation in 1896. In this sector, the share of electric motors of the installed power coupled mechanically with the working machines rose from 18 to 45 per cent between 1900 and 1913. In the latter year, the corresponding percentage was 20 in the sawmill industry, only 11 in the paper and pulp industry and 14 in manufacturing as a whole.[129]

More sophisticated uses of electricity were introduced. The technical director of the Pitkäranta mine, a Swede called Gustav Gröndal, empirically developed an electromagnetic concentration method in Finland for separating iron from copper and other substances in iron ore. This method was applied in 1891 into mining practice and at the same time patents for it were granted in several countries.[130] Gröndal also invented a multiple-phase process facilitating the retrieval of iron from poor ores. The process was based on an electromagnetic concentration of finely crushed ore where the concentrate was pressed into briquettes before it was placed in a furnace. Gröndal also patented his briquetting method, and it was widely applied in Europe and North America. In Finland, Gröndal's electromagnetic concentration and briquetting method was applied, both at Pitkäranta, and in the neighbouring Välimäki iron mine at the close of the nineteenth century.[131]

The Russian Nikolai Benardos patented in 1885 his electric arc welding method in many industrial countries. Characteristic of this method was the use of an electric arc springing up between the carbon electrode and the objects to be welded. Both this 'Elektrogefest' technique and the other welding method developed in 1892 by another Russian, Nikolaj Slavianov, were rapidly adopted in Russia and elsewhere. The Slavianov method is still today one of the leading welding methods; a bare metal wire, used as an electrode, is melted with an electric arc into the seam between two objects, jointing them as one.[132]

The available sources suggest that neither of the above-mentioned methods was introduced into Finland before the electric welding technique developed by the Swede Oscar Kjellberg. In this method the metal wire used as an electrode was coated with a substance which stabilised the arc. The welded seams made by this technique proved slightly firmer than those produced by the other two. Kjellberg visited Finland in the winter of 1906 and presented his innovation at the Hietalahti shipyard in Helsinki and at the Pori Engineering Works. Both these firms acquired the sole right to apply this technique in Finland.[133]

Electric welding has been one of the great innovations in the engineering industry in the twentieth century, because it has made possible significant savings in raw materials and labour. Welding greatly facilitated for example the building of ships as it eliminated the need to join hull sections by riveting. In Finland the expansion of electric welding was hampered partly by the distrust felt towards it: there were, for instance, statutes long in force demanding that steam boilers be built by riveting. Engineering experts also recommended the use of electric welding only for repairs to damaged steam boilers and other broken equipment. At the beginning of the twentieth century, protection of the best method by sole application rights slowed down the diffusion of electric welding in Finland and forced the engineering works to resort to oxyacetylene welding. Improved opportunities for the wider spread of this method were created when the Swedish gas welding equipment manufacturer AGA founded a general agency in Finland in 1910.[134]

The Finnish paper and pulp industry discovered the usefulness of electricity in the production of chemicals. At the turn of the century the Kuusankoski sulphite cellulose factory in south-eastern Finland experimented with the electrolysis process for converting a table salt or sodium chloride solution into sodium hypochlorite. This product proved an effective bleacher for pulp and was cheaper than imported chemicals. The results achieved by the use of sodium hypochlorite were encouraging and the first chlorine factory was founded at Kuusankoski ten years later.[135]

There were a few other important applications of electricity such as electric traction, electric furnaces, and automatisation. The above-mentioned examples might, however, serve to illustrate the multitude of purposes to which electricity was beginning to be applied between 1877 and 1919. Although this period was only the initial stage in the use of electricity in Finland, its practical use was enough to hint at the

revolutionary changes electricity promised to bring about and increasingly encouraged firms to apply electric power to their equipment and processes.

2.4 THE EMERGENCE OF FOREIGN INVOLVEMENT

In electrical engineering, the 1870s and 1880s constituted the time of pioneers. New inventions, innovations and modifications were made all over Europe and North America. Various kinds of dynamos, arc-lamps, incandescent lamps and other electric devices were developed. All round the world, people became interested in electricity, and they perceived it to have great potential as a source of lighting, motive power, heat, etc., but the means to utilise this potential were not yet found. Therefore, dozens of men in various countries innovated, developed and also manufactured electrical equipment. During these decades of pioneering national workshops, modern transnational companies were almost unknown. Some manufacturers, however, succeeded to the extent that they could start exporting their products through foreign agencies, and some eminent patents began to be utilised by independent companies in several countries.

A great change took place from the 1890s. In one country after another the sales and manufacturing subsidiaries of big transnational companies sprang up beside the national workshops. The electrical equipment business was swiftly internationalised and a world market for these products arose. Worldwide competition for market shares began between a few giant transnational companies. Minor manufacturers relying primarily on their own national markets often found themselves overpowered by the rivalry of the transnational companies which had much bigger resources. The general framework of the modern worldwide electrical business was established by the year 1905.

American electrical companies were the pioneers in setting up subsidiaries abroad. In England the Anglo-American Brush Electric Light Corporation was organised in 1880 to exploit British rights for the arc-lighting system innovated by the American Charles F. Brush whose company in the USA was then thriving. Thomas A. Edison became an entrepreneur in the electrical equipment business in the late 1870s, and a few years later he founded subsidiaries abroad as well. These subsidiaries, such as the Edison Electric Light Company Ltd set up in England in 1881, were to exploit the Edison system through the licensing, sale and manufacture of system components and through supplying light.[136]

The transformers and dynamos designed by the American professor Elihu Thomson laid the foundation for the Thomson-Houston Electric Company in 1883 and soon subsidiaries and agencies were opened abroad. One year later, George Westinghouse began to build up his corporation with dependent companies in major foreign countries. The American companies soon strengthened their position in the world market by merging. In 1889 Thomson-Houston bought the Brush company, while various Edison companies consolidated into the Edison General Electric Co. Only three years later, the latter was merged with Thomson-Houston under the name General Electric.[137]

Many of the big transnational electrical engineering companies emanated in the countries where rapid industrialisation and a large home market provided a good basis for growth, a strong demand for electrical equipment and a developed capital market. In the late nineteenth century, these characteristics prevailed in the USA and also in Germany where several transnational electrical engineering companies emerged. The earliest of these companies, Siemens & Halske, had specialised in electrical communication engineering since the 1840s, and later also gained a strong foothold in heavy current engineering.[138] The company significantly grew under the management of the Siemens family.[139] In 1875 it employed about 600 people. In Germany, there were then an additional 80 electrical firms with about 560 employees in total. One of them, Schuckert & Co, founded in Nuremberg in 1874, swiftly developed into another considerable international supplier of dynamos. Schuckert's was the first foreign electrical firm to use a local agent, namely Dan. Joh. Wadén, in Finland. However, in the same year, 1882, its Swedish agent, Luth & Roséns Elektriska Ab from Stockholm, also installed its equipment in the Grand Duchy.[140]

The Edison subsidiary, Deutsche Edison Gesellschaft, founded in 1883, was reorganised four years later and became an independent giant corporation under the strong German–Jewish businessman Emil Rathenau (1838–1915). Under the name of the Allgemeine Elektricitäts-Gesellschaft (AEG) it evolved from an installation firm to a prominent transnational electrical manufacturer. A link between the AEG, and the Edison corporation and its successor prevailed for several decades. Their mutual agreements included, among other things, the delivery of sole sales rights for some geographical areas;

thus North America went to the Edison corporation and Europe east of Germany and the whole of Russia to the AEG. Consequently, Finland fell into the AEG's sphere of influence.[141]

Among the other German electrical firms actively engaged abroad were Felten & Guilleaume in Mühlheim, Helios AG in Cologne (est. 1882) and Lahmeyer & Co in Frankfort-on-Main (est. 1890). Furthermore, in 1892 Thomson-Houston and AG L. Loewe & Co jointly founded the Union Elektrizitäts AG in Berlin to exploit the patents of the former, especially in the electrification of tramways in Europe. All these German electrical firms were severely hit by the depression just after the turn of the century. Helios AG went bankrupt, Schuckert & Co was merged with Siemens & Halske AG, and the Union with the AEG in 1903. About seven years later the AEG also took over Lahmeyerwerke from Felten & Guilleaume AG.[142] The AEG and Siemens & Halske AG evolved as two true transnational giants of the electrical business, becoming the biggest and fourth biggest electrical companies in the world by 1911.[143] British, French, Belgian and Dutch electrical manufacturers had only limited significance outside their own countries and colonies. By contrast, some notable transnational companies sprang up from a few smaller but rapidly industrialising countries. The Swiss electrical firms, Oerlikon Maschinenfabrik founded in 1882 in Zürich and Brown, Boveri & Co set up in 1891 in Baden, soon extended their business activities abroad from their comparatively limited home market. In northern Europe, the Swedish company, Allmänna Svenska Elektriska Aktiebolag (ASEA), grew into an important manufacturer of electrical equipment. This company was established in 1883 in Aalborga to exploit the patents and innovations of the Swedish inventor Jonas Wenström (1855–93).[144]

Up to the early 1890s, several Finnish firms imported and installed foreign electrical machinery as appointed agents. The world market for electrical equipment was transformed at the close of the nineteenth century when oversupply and sharp competition emerged. When demand in the home market became saturated in countries such as Germany, the USA, Switzerland and Sweden, the big electrical firms directed their sales efforts more actively abroad.

The earliest foreign electrical firm to set up a subsidiary in Finland was the Swedish ASEA company in 1897. Four years earlier the ASEA had appointed its first agent abroad in Helsinki with a branch in St Petersburg. The ASEA and its Finnish agent, Gustaf Zitting, decided to establish a manufacturing subsidiary to produce generators and motors under licence both for the Finnish and Russian markets. After a promising start, this joint-venture, known as the Finska Elektriska Aktiebolag (FEAB), did not manage to make a real breakthrough either in the Finnish or Russian market.[145] In 1904 tough competition in these depressed markets forced the closure of FEAB's factory in Helsinki and installation workshop in Tampere. For the next ten years, the engineering office Zitting & Co represented the ASEA's products in Finland. In 1913 the parent company opened up its new sales subsidiary, namely Allmänna Elektriska Aktiebolag i Finland, in Helsinki.[146]

In the late 1890s, German firms started a strong penetration into countries with a weak domestic electrical engineering industry such as Britain and Russia. American, Swiss, French and Belgian electrical firms also attempted to gain a foothold there.[147] The German firms were, however, superior in Russia which Emil Rathenau, for example, came to see as 'ein Land der Zukunft' (a country with a future). In 1898 the AEG changed its policy in Russia from appointing agents only, to establishing its own 'installation office' in St Petersburg.[148]

In 1898, the subsidiary of Siemens & Halske in Russia was reorganised as a limited company (Aktiengesellschaft) with a nominal capital of four million roubles, and in the same year its parent firm set up a new sales subsidiary in Finland under the name of 'Siemens & Halske AG, Teknisk byrå, Helsingfors'.[149] This subsidiary immediately gained a considerable market share and between 1901 and 1905 it was probably the leading provider of generators and electric motors in Finland. Its biggest delivery was the installation of two Zoelly-turbogenerators, both of 500 hp, in a textile factory in Tampere in 1905–6.[150]

In April 1900, the other German electrical giant, the AEG, opened its first subsidiary in Finland, the 'Elektriska Aktiebolaget AEG'. The significant new operations of the AEG in Finland were organised by the company's subsidiary in Stockholm and not directly by the parent company in Berlin. In early advertisements, the subsidiary in Helsinki was presented as a branch corresponding to those in the Swedish towns of Gothenburg, Malmö, Örebro and Sundsvall.[151] Its principal working language was Swedish. During the first few years, Swedish nationals had at least as central a role in the management of this company as German and Finnish directors and the same was true of the Siemens & Halske subsidiary in Helsinki.[152]

The AEG's engineering office, as it was called, broke into the market by the sale of small central stations with new Nernst-lamps

and ordinary incandescent lamps at a very competitive price.[153] Between 1899 and 1914, the AEG delivered nearly a half of the installations of the new urban electricity supply utilities (see Table 2.6), and after the recession of 1901–3, it also managed quite well as a provider of industrial generation plants and electric motors.[154]

According to announcements made by Siemens & Halske and the AEG, both companies had delivered generators and electric motors with a capacity of nearly 30 000 hp in Finland by the end of 1907, whereas the domestic company, Strömberg, had sold similar electrical machinery with a capacity of about 15 000 hp between 1899 and 1907.[155] Immediately after that period, Siemens & Halske lost its position as the market leader in Finland to Rathenau's engineering office. From 1906 the AEG was the most important supplier of turbogenerators, while it also became the biggest electrical firm in the country, as demonstrated in Table 2.7. The AEG set up more branches in the major towns than any other electrical firm; in

Table 2.7 The number and capacity of generators and electric motors installed annually by various suppliers in Finland, 1900–6

Supplier		*1900*	*1901*	*1902*	*1903*	*1904*	*1905*	*1906*
Wadén	no.	5	–	–	–	–	–	–
	hp	**120**	–	–	–	–	–	–
Wahl	no.	46	20	26	35	29	18	18
	hp	..	..	..	..	..	..	..
Strömberg	no.	79	72	..	81	141	185	..
	hp	**981**	**684**	..	**1365**	**1600**	**2700**	..
Electron	no.	..	..	26	..	..	..	..
	hp	..	..	**530**	..	..	..	..
ASEA/FEAB	no.	22	25	..	..	..	..	..
	hp	**1000**	..	..	..	..	..	..
Siemens & Halske	no.	..	..	..	..	109	153	198
	hp	..	..	**1805**	..	**1250**	**4250**	**4580**
AEG	no.	..	73	72	68	128	174	331
	hp	..	**1250**	**1160**	**1580**	**1200**	**2500**	**5880**
Mercantile*	no.	–	–	–	–	–	..	..
	hp	–	–	–	–	–	..	**1400**

* The importing company, Ab Mercantile, was appointed as Finnish general agent by Felten & Guilleaume und Lahmeyerwerke A.G., Mühlheim-on-Rhein and Frankfort-on-Main in 1905.

.. No data available.

Source: *Teknikern*, 1901–7.

addition to the company in Helsinki, branches were set up in Oulu in 1905, in Tampere and Turku in 1906, and in Viipuri in 1907.[156]

In Turku, the AEG bought in 1907 Ab Electron, a local private electricity utility with a notable installation department. The company was renamed in a German fashion 'Elektricitätswerk Åbo Aktiengesellschaft' and it built a new thermal power plant to deliver electricity to the town of Turku, the municipal utility of Naantali and a nearby rural utility.[157] Its board of governors was led by Walther Rathenau and the direction of the company was retained in Berlin – only the operational management worked in Turku.[158] This was the start of the AEG's direct involvement in the Finnish electricity utility business. In 1910 it took over 'Elektricitets- och gasaktiebolag Paul Wahl & Co' in Viipuri with its manufacturing plant, gas and electricity utilities. As in Turku, the AEG built an electrified tramway network in Viipuri under a concession agreement with the town council.[159]

The companies taken over in Turku and Viipuri were among the four largest electricity utilities and among the three leading domestic installation firms in the country.[160] In 1908 and 1913 the AEG, moreover, gained control of two other urban utilities in Hämeenlinna and Maarianhamina. In a short time span, it became the most prominent private owner of urban electricity utilities in the country. The AEG accounted for 81 per cent of the sales of the private urban electricity utilities and 22 per cent of the sales of all the urban electricity utilities in Finland, as indicated in Table 2.6.

The First World War interrupted the rapidly growing influence of the AEG, while the wartime crisis accelerated the plans of town councils to municipalise the private electricity utilities in their area. During the war, German property was confiscated by the Finnish government and put under special control. After the Peace of Brest-Litovsk (March 1918), the property was returned to its former German owners, but many of them were ready to sell their possessions in Finland because of the internal turmoil in the country and anxiety for the Allies' final decisions about German property in neutral countries. In this respect, the AEG was not an exception; it was also willing to negotiate seriously on the municipalisation of its utilities.

In Turku, Viipuri, Maarianhamina and Hämeenlinna, it was considered that although the AEG had brought new technology and capital to local electrification, co-operation with the company did not fulfil all hopes. The prices of electricity sold to the municipalities and to the public were criticised as being unreasonably high.[161] The AEG was also said to be an inefficient distributor of electricity, and too

inflexible in its relations with the town councils and stiffer than its Finnish private counterparts in other towns. Hence, three of the town councils were anxious to municipalise the utilities immediately after the war. In Viipuri, the town council did not accept the terms of the AEG's tender and so the municipalisation of the very profitable utility in that town was postponed to a particularly late date, 1936; only the municipalisation of the supply utility in Kemi in Lapland came later.[162]

There was a coinciding between the attempts of the Finnish government to facilitate electrification by reducing import tariffs on electrical equipment in 1897, the penetration of foreign electrical firms into the Grand Duchy's market and the increase of electrical installations. Causal relations seem to be quite evident between these phenomena. From the electricity producers' viewpoint, it was clear that after 1897 prices of electrical equipment were substantially lower, while the quality and capacity of the available machinery rose. Together these factors boosted investments in electrical technology.

One can, therefore, claim that the entry of foreign electrical firms accelerated the electrification in Finland. At least in the short run, electricity producers and consumers benefited from the sharper competition between the providers of electrical equipment. Bearing in mind the Finns' initial enterprising disposition, it is, however, not correct to claim that 'it was Berlin which started Finland on the road to electrification', paraphrasing Guenter Holzer's statement about Russia.[163] Nor did Berlin become the capital of the Finnish electrical industry as it did that of the Russian. However, the German firms had, undoubtedly, a technological and marketing lead in electrical engineering, as the Russian engineer P. Gurevič pointed out in 1915 in a Swiss journal: 'No other country could deliver at so low a price such a variety of electrical goods.'[164]

Fortunately, the intrusion of foreign electrical firms and products into the Finnish market did not crush the domestic electrical engineering industry completely, even if the engineering works of Paul Wahl & Co fell into the hands of the AEG. The activities of both the domestic electrical industry and the Swedish companies balanced the German involvement, and this fact prevented Finland from becoming completely dependent on the transnational companies of German origin.

The trend of the change was, however, threatening to domestic firms. Between 1895 and 1905 the market share of Finnish generators and electric motors dropped from about two-thirds to one-quarter, while their exports shrunk to a modest amount. During this process, Finland lost some part of its potential backward linkage effects but gained a considerable amount of forward linkage effects which were probably more important for its national economy. The ideal situation would, of course, have been for the domestic electrical firms to have preserved a competitive level through this period of technological leaps and economic recession, but this does not seem realistic if considered in an international perspective.

At the turn of the century, a strong increase of German influence took place in Finnish industry in general, as well as in academic and technical education, technical R & D, management practice and various technical norms. For example, the installation rules of nearly all electricity supply utilities, whether municipal or private, required that contractors should follow the technical norms and safety regulations as decreed in the 'latest edition of *Die Sicherheits-vorschriften des Verbandes Deutscher Elektrotechniker*' in all planning, in drawings and in the installation of main systems and appliances.[165]

It was not a question of mere imitation but partly of rational international standardisation, because the German electrical standards were widely adopted on the Continent. In Finland, as in many other European countries, for example, the distributive current of 50 Hz and 220 volts for one-phase-AC or 380 volts for three-phase-AC gradually established its position as the universal distribution standard all over the realm.

It did not cause great difficulties to adapt the Finnish electrical engineering industry to German standards but it might have hampered imports of some equipment from countries with different standards such as the USA and also Britain to some extent. By imposing their technical standards on various foreign countries, the Germans secured for themselves facilities to produce their machinery and appliances in huge numbers and sell them at all points of the compass. At the same time, they also erected a technical protection barrier around the area under their influence, against outsiders who refused to adopt German standards in their countries.

2.5 FINNISH HYDROPOWER, THE RUSSIAN MARKET AND FOREIGN BUSINESS

The increasing inflow of imported goods, and the admittance of foreign businessmen and sales subsidiaries raised conflicting feelings among the Finns at the turn of the century. A great many of them preferred imported consumer and capital goods to domestic products and evaluated their quality more highly: 'Not only unthinking, vain fools kept on boasting that they owned such and such imported from Berlin or Paris, but even many men of sense behaved so as well.'[166] On the other hand, the nationalists, who had a strong influence on society, were worried and annoyed at the influx of imported goods and foreign economic influence which were seen as a significant threat to the nascent nation.[167] By the close of the nineteenth century, the Finnish market had essentially developed and purchasing power in the economy was on the rise. When the world recession broke out owing to overproduction in about 1900, big foreign manufacturers became much more interested in new exporting opportunities, even in such a marginal periphery as Finland.

The deficit of Finnish foreign trade soared. That caused serious anxiety in the society. The average annual surplus of imports over exports almost trebled from FIM 40 million to FIM 111 million from the periods 1903–6 to 1907–10. During the latter period, the value of exports covered only 70 per cent of the value of imports, while in the former period it had been equivalent to 86 per cent. During 1911–13, the average annual trade deficit rose to FIM 118 million, but the export/import ratio slightly improved, being 75 per cent.[168]

The lavish advertising and aggressive marketing of imports irritated domestic manufacturers who found it quite easy to gain political support for their sentiments of patriotism. Due to their political victories in national affairs from 1905, the self-reliance of the Finns was increasing and they sought new means for expressing it. Around 1910, Finnish reactions against imported goods and foreigners' economic activities strengthened. In fact, these responses were in no way extraordinary: for some time, requests to support domestic production at the expense of imports had been common in neighbouring countries, such as Scandinavia and Russia, as well as in the leading advocate of free trade, England.[169] What made the Finnish case special was the manner and intensity with which these sentiments were intertwined with nationalism and the defence of the Grand Duchy's political autonomy.

The reactions developed into a substantial campaign which reached its climax in connection with the General Businessmen's Meeting in Pori in August 1911. The methods introduced to create a popular mass movement in support of domestic production were, primarily, adopted from Sweden. They included active advertising, public lectures, articles in journals, and exhibitions – all related to Finnish manufacturing.[170]

Slogans such as 'Suosi kotimaista teollisuutta!' (Favour domestic industry!) and 'Köp inhemska varor!' (Buy domestic goods!) appeared in the press.[171] This campaign became a permanent feature of the Finnish way of life – in successive waves it has continued over seven decades. The aim was to convince people that 'it is the patriotic duty of every citizen to favour domestic products'.[172]

At the time of the Businessmen's Meeting, the thoughts of two pioneering champions of Finnish nationalism, J. J. Tengström and J. V. Snellman, were reiterated. These men had regarded a sound domestic industry as a precondition for the existence of the Finnish nation. 'Unless Finnish industry is able to mature to independence, the Finnish language and the Finnish-speaking nation have no future', opined Snellman pessimistically. The role of industry and commerce was emphasised in Snellman's nationalist thinking by the quoting of such extracts from his writings as: 'Patriotism can be expressed in all activities. [Besides the press and literature] there is no other branch of activity which could better maintain Finnish nationalism and language than strong domestic industry.'[173]

The journal *Kauppalehti* considered that the industrial sophistication of a major country is apt to oppress the culture and language of dependent, less developed nations. For instance, France was seen to oppress Belgium, and western Switzerland; and correspondingly domineering German culture trod down vernacular languages and customs in western Poland and in many parts of the Austrian Empire:

> The British colonies are the best example. Hardly any industrial power has destroyed so many small unique nations and tribes and assimilated them into its own civilisation and language as England. . . .
>
> To destroy a small nation, political dominance by a more powerful country is not needed. The latter's industry is enough for that. But even a small industrialised nation can surprisingly resist the oppression of a powerful country.[174]

According to Snellman, Finland might fall into such a miserable situation as had the Baltic provinces where more than three languages were spoken: German was the language of culture, Russian was the language of trade, and vernacular languages were spoken only in

agriculture, which was the shrinking traditional sector. 'Similarly, some new language might intrude here between Swedish and Finnish and completely extinguish the languages inherited from our ancestors.' The threat was, first of all, seen to come from Russia but also major industrialised countries were considered ominous as well.[175]

Only the rise of a modern domestic sector could save Finland, because industry 'together with commerce is able to create a vital element for modern civilisation, i.e. a wealthy middle class with both political power and social authority. That is the best safekeeper and supporter of any nation.'[176]

Furthermore, a strong nationalist sentiment can be observed in *Kauppalehti*'s warning against attracting foreign capital and immigrant craftsmen into the country. 'It is true that they bring economic profit for the country, but simultaneously they break up the national culture. With them we have to accept foreign habits and languages the damaging impact of which on a nascent nation just creating a modern, distinguishing culture using its own vernacular is perhaps impossible to evaluate.'[177]

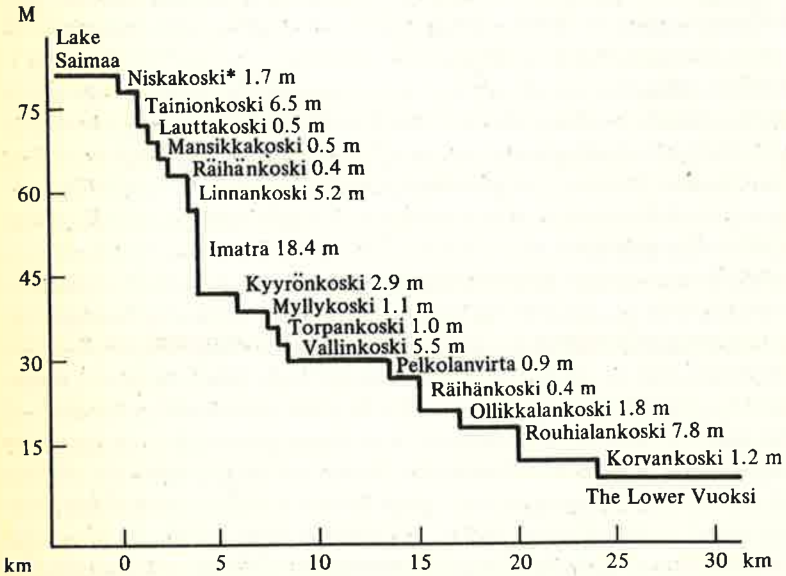
The national subsistence was seen resting on three cornerstones. 'It is a positive fact that to preserve their national integrity and survive in the struggle of existence, nations need a solid ethical philosophy of life, high intellectual enlightenment and independent economic welfare. . . . All these cornerstones support each other in securing the subsistence and future of a nation.'[178]

On the eve of the First World War, Finnish economic nationalism was markedly reflected in the field of the electrical equipment business and in electricity supply as well as in other industries. The most extreme forms of economic nationalism, however, were manifested in the utilisation of hydropower resources. Unlike the case of the introduction of electric light, the Finns were not very active in adopting long-distance electricity transmission in order to exploit their remote hydropower resources. When foreigners took over the initiative in this respect, the Finnish authorities preferred to retard the building of any large-scale transmission project. This resistance by the Finnish government, which might seem rather peculiar at first glance, was derived from nationalist thinking and political calculations connected to the strained Russo-Finnish relations.

In the 1890s, foreign investors became interested in the hydropower of the River Vuoksi in south-eastern Finland for three reasons. First, the river was situated in the vicinity of the fifth largest European city, St Petersburg. The Imperial capital of two million inhabitants was a potential consumer of huge amounts of electricity, but high cif-prices and high import tariffs on English coal made electricity from local thermal power stations rather expensive.[179] Second, technical facilities had been developed for transmitting electricity economically over the 165 kilometres from the banks of the River Vuoksi to St Petersburg. Third, the hydropower resources of the river were extraordinarily substantial and their harnessing required only a comparatively small investment per kilowatt owing to the favourable natural conditions.

The River Vuoksi is about 160 kilometres long and connects Lake Saimaa to Lake Ladoga. As shown in Figure 2.1, in its natural state – before development – the upper stretch of the river had very steep banks and numerous rapids. For the first 25 kilometres, the total

Figure 2.1 The profile of the Upper Vuoksi in its natural state



M Metres above the sea level in the Gulf of Finland.
m The head or fall of rapids in metres.
* Rapids are called *koski* in Finnish and *fors* in Swedish.

Sources: *Förteckning och beskrifning öfver i Finland befintliga mera betydande vattendrag, farleder, och större vattenfall äfvensom forsar vid hvilka industriella verk redan finnas anlagda* (Helsingfors, 1889); *Bidrag till Finlands hydrografi I, Vuoksenfloden* (Helsingfors, 1908); *Selostus Suomen koskivoimasta ja sen käyttämisestä ynnä Imatran voimalaitosyrityksestä* (Helsinki, 1922).

vertical drop between water surfaces in the river was about 64 metres, whereas in the next 135 kilometres downstream, the drop was only 6.3 metres. The mean flow of the river, 556 cubic metres of water per second, was sizeable and its seasonal variations were much smaller than those in the other Finnish rivers. Apart from the canal between Lake Saimaa and the Gulf of Finland,[180] the river was the only outlet of the watercourse of Lake Saimaa which was, with an area of 4400 square kilometres, the fourth largest lake in Europe. Even in the natural, unregulated state, the annual discharge of the river was outstandingly constant due to the good storage capacity in the considerable catchment area of 61 560 square kilometres of which as much as 21 per cent was covered by lakes.[181]

The Russian engineer Veniamin Feodorovič Dobrotvorskij was the first to put forward a suggestion for using the hydropower of the surrounding region for the energy needs of St Petersburg. He presented his 'grandiose programme' for harnessing the River Narva in Estonia and the River Vuoksi in the Karelian Isthmus at a meeting of the Russian Technical Society (Russkoe Tekhničeskoe Obščestvo) in May 1894. The proposal was based on the recent models of the power plants at Niagara Falls in the USA and the 175-kilometre transmission experiments with three-phase AC-current between Lauffen and Frankfort-on-Main. St Petersburg and its outskirts were to receive 24 MW from the two hydroplants transmitting electricity at 15 kV. The proposal was criticised for its technical uncertainties and unrealistic economic assessment.[182]

Nevertheless, a new company was set up under the name 'St Petersburger Gesellschaft zur elektrischen Transmission von Wasserfallkraft' with a capital of 4 million roubles (10.7 million Finnish marks). As early as September 1894 it submitted an application to the Finnish Senate for utilising the state-owned rapids at Imatra for electricity generation. The Finnish Board of Industry did not favour the granting of the request. A hydroplant of 15 MW would decrease the outstanding natural beauty of the waterfall and consequently depress tourism revenues. The Senate decided to turn down the application, using the reason that a franchise could not be granted to a foreigner. V. F. Dobrotvorskij, the head of the company, strongly objected. According to his opinion, he could not be labelled as a foreigner in Finland as he was a Russian.[183]

Dobrotvorskij's plan was not only technically and economically hazardous, it was also politically sensitive, because both the proposed plants would have been situated in the special administration districts of ethnic minorities. Ethno-political disagreements were presumably not the only big obstacle; the later proposals to utilise the hydropower of rivers in Russian territory, such as those on the Rivers Volkhov, Svir' and Mst were also submitted without success during the era of the tsarist regime.[184]

The Finnish government decided not to hurry the industrial utilisation of hydropower on the River Vuoksi. In 1896 the Senate granted funds for a scientific research project to study the river's natural conditions. Incomplete information about the local hydrography was considered to be an impediment to the rational utilisation of the river for different purposes. The research was carried out meticulously, but it took twelve years before the results were finally published.[185]

During 1897–9 two Russian companies built transmission lines of 30 and 8 kilometres respectively to supply electricity for their mines on the north-western coast of Lake Ladoga. At the same time, the Danish engineer William Waern and the Swedish businessman Theodor Höffding established a limited company, the Siitola Actien-Gesellschaft, to utilise the hydropower of the Linnankoski rapids on the River Vuoksi. Their intention was to build two power plants: that on the left bank was to generate electricity with a capacity of nearly 12 MW to be transmitted to St Petersburg at 30 kV, and the 2.2 MW capacity of the plant on the right bank was to be used for the manufacture of calcium carbide and phosphorous on the spot.[186]

The company could not get a concession from the Finnish Senate for transmission. However, it managed to raise the capital of about 5 million Finnish marks through Russian private banks for building the smaller power plant and the calcium carbide factory, and they were put in operation in 1900. In the following year, the factory was destroyed by fire. At the same time, the price of calcium carbide slumped and plans to rebuild the factory were dropped. The whole company went bankrupt and the power plant of 1.1 MW was left idle for 14 years.[187]

In 1904 the society of Swedish-speaking Finnish engineers (Tekniska Föreningen i Finland) proposed to the Senate that it should examine the use of hydropower for the electrification of the Finnish State Railways.[188] In the following year, the Senate set up a committee for identifying the technical and economic problems of railway electrification. A year later, another governmental committee began to research new opportunities for using domestic energy sources, primarily hydropower and peat. By 1908, both committee reports were

completed, but not published; their proposals for electrification, however, led to no practical measures.[189]

When the long recession of the Empire's economy turned to a boom in 1908–9, the Finnish Senate received increasing numbers of proposals and applications from Russians and other foreigners for the transmission of electricity from the planned hydroplants on the River Vuoksi. Some were related only to the transmission of electricity to St Petersburg and others to the building of electrified express railway lines to the Karelian Isthmus which was developing as a popular summer resort for the wealthy people of the Imperial capital. Some plans, like that of the Englishman Charles Henry Steward, included both these aims.[190] The Finnish authorities were worried about these plans, while the War Ministry of Russia supported those for constructing electrified railway lines from the Empire to Finland. Foreign businessmen and banks began to buy up the rapids along the River Vuoksi, and this brought a great deal of money and new people to the valley.[191]

The Finnish Senate for various reasons systematically rejected all concession applications for electricity transmission and the electrification of railway lines.[192] It generally appealed to the legal and proprietary problems in building hydroplants and in obtaining wayleaves. In fact, the Finnish law on riparian rights was rather strict for the builders and owners of hydropower plants, as explained in Chapter 3.3.

When the pressure of the applicants, nevertheless, increased, the Senate set up a new committee in January 1913 to examine the possibility of using the rapids for electricity production for the Finnish State Railways.[193] Almost at the same time, Dobrotvorskij's reorganised company, 'Société S:t Petersbourgeoise de transmission electrique de la force de chutes d'eau' (SPTE), began to prepare its own plan for the utilisation of the hydropower of the River Vuoksi.[194] The German engineering office 'Gebrüder Hallinger' from Munich worked out a well-grounded and quite carefully calculated application for the company, and it was handed to the Senate in late December 1913. The idea of the plan was to close the natural bed of the Upper Vuoksi by an upstream dam, to build a canal of 18 kilometres from Lake Saimaa in the neighbourhood, and to concentrate all the water of the river in one big waterfall with a 64-metre drop at a natural precipice of granite in the valley of Kuurmanpohja. The tailrace canal of 12 km was to lead water back to the original bed of the Lower Vuoksi. Similar proposals had earlier been unsuccessfully submitted to the Senate by the Finnish novelist Sigurd Wetterhoff-Asp in 1909 and by the Englishman C. H. Stewart in 1911.[195]

The Russian representative of the company, the Councillor of State P. I. Rattner (who was also the former head of the Helios company, the largest electricity utility in St Petersburg), could produce the necessary technical calculations and drawings as well as an affirmation of proper financing. The construction was to be started in April 1914. This hydropower plant of 300 000–400 000 hp (221–294 MW) would then have been the largest in the world; larger than the Niagara hydroplant with its 40 m waterfall. The electricity generated was to be transmitted for lighting and motive power to St Petersburg.[196]

The whole plan was a clever countermove by the Helios company in the struggle between the three electricity utilities in St Petersburg. The Helios–SPTE group was not in the lead in the preparations for taking advantage of the cheap hydropower of the River Vuoksi. Ahead were two other utility companies, namely 'Gesellschaft für elektrische Beleuchtung vom Jahre 1886' (GEB-1886), controlled by the AEG and Siemens & Halske with Swiss and German banks, and the company of Belgian origin backed by 'Société Générale de Belgique', a bank from Brussels. Through their subsidiaries, the latter companies had already acquired some rapids on the Upper Vuoksi and were ready to continue work on the staked wayleave from St Petersburg to the Upper Vuoksi.[197]

The SPTE had recently been reorganised by five Russian banks (with the 'Russo-Asian Bank' in the lead) and some French, English and Belgian banking houses. Its goal was to cut off the German–Swiss concerns from the hydropower resources in the surroundings of St Petersburg and finally push them out of the capital itself. The resistance of the German–Swiss vested interests forced the Helios–SPTE group to give up this goal just before the First World War and to make an agreement which gave the majority position to GEB-1886 and the Belgian utility company in the new co-ordinated commission of the three parties.[198]

As compensation for the utilisation of Finnish natural resources, the SPTE offered the Finnish government electricity at a negligible price for the railway traffic between Viipuri and St Petersburg. It also offered an annual rent increasing by steps to 1.5 million Finnish marks after the first six years and the assignment of the whole plant without charge after 90 years' operation.[199]

The plan created a vivid debate in the Finnish press. The majority of articles were against it. First, there were doubts about the

profitability of the power plant. The estimated investment cost of FIM 157 million was regarded as too small, whereas the possibility of selling the annual energy output of 1.6 GWh in the area of St Petersburg was seen as very improbable for many years.[200] Second, the compensation of FIM 1 to 1.5 million to the Finnish government was considered too small a remuneration for using Finnish natural resources. Building a state-owned hydroplant at the Imatra rapids was claimed to yield a bigger net income.[201] Third, the plan was considered to break the Finnish law of riparian rights.[202] Fourth, the project was seen as politically risky, leaving the whole hydropower of the River Vuoksi 'in Russian hands'.[203]

The Senate asked for an opinion from the committee of 1913 and the Swedish engineering office 'Vattenbyggnadsbyrån i Stockholm' and ordered a comparison of the Kuurmanpohja project with the series of hydroplants along the natural bed of the River Vuoksi. In its statement of June 1915, the Swedish engineering office criticised the calculations of 'Gebrüder Hallinger' and claimed that although the Kuurmanpohja project had technical advantages it was economically a hazardous enterprise owing to its enormous overcapacity. The SPTE's project would have been almost as economical as would a group of four or five smaller hydroplants on the River Vuoksi, *if* the maximum capacity corresponding to the whole mean discharge of Lake Saimaa, 294 MW, could have been utilised right from the beginning.[204]

According to the Swedish engineering office, it would be impossible to sell 1.6 GWh in Petrograd[205] and its surroundings, and to the railway lines of south-east Finland during the next 20–30 years. It forecast that the electricity consumption in Petrograd would be only 0.93 GWh in 1940. Because of the high investment costs and limited demand, the unit price of electricity would be high and interest losses unbearable. As the best solution, it recommended the successive building of four or five hydroplants on the River Vuoksi at a pace corresponding to the development of industry and electricity demand in the region.[206]

The interesting thing was that the committee of 1913 and the Swedish engineering office did not include in their forecasts for electricity consumption the demand of industry and population centres in south and central Finland. They stuck to the opinion of the committee of 1905 that it was unprofitable to transmit electricity further than 200 kilometres. They could not foresee the future development of electrification in Finnish industry, agriculture and other sectors.[207] Nor did they consider the probable emergence of a new electricity-intensive industry near the new power plants, as had happened in other countries.

The suggestions of the committee and engineering office reveal how distrustful an attitude they took in the opportunities to electrify Finland. They proposed to build the Imatra hydroelectric plant of 84 MW at first and reserve 26 MW of its capacity for the canal of Saimaa and the electrification of the State Railways in south-eastern Finland and 14 MW for consumption in the town Viipuri and its surroundings. The remainder, a surplus of about 23–44 MW, could be sold to Petrograd at most for twenty years.[208]

It seems that in Finland the plan of the SPTE was opposed more for national and political than economic reasons. With the support of the tsarist government, the Kuurmanpohja project might have been carried out had not the outbreak of the war halted its planning. The Finnish nationalists were relieved when the SPTE's plan was rejected from several sides by early 1915.

Although the construction of the canal with the giant hydroelectric plant was not to be carried out, the situation along the natural bed of the River Vuoksi was not developing favourably for the Finns. When the war broke out, the hectic bargaining about the rapids, however, quietened down for a while. The ownership of the hydropower resources at the time are shown in Table 2.8.

At the outbreak of the First World War, the SPTE owned a considerable share, about 29 per cent, of the main hydropower resources in the River Vuoksi. By late summer 1914, the German vested interests under the leadership of the Deutsche Bank managed to accumulate a great many of the SPTE company's shares and in the following September representatives of the Deutsche Bank were appointed to the Board of the SPTE. Thereafter, the company was managed by a German bank consortium up to the confiscation by the Russian authorities.[209]

Aktiebolaget Force, founded in 1908, was officially a Finnish company with its domicile in Viipuri but in practice the most of its shares were owned by foreign firms. It was at least a co-owner in four rapids possessing about 12 per cent of the total hydropower potential in the river. From 1912 the majority of the company's shares had been taken over by the new Belgium-based firm, 'Elektricitetsbolag Imatra'.[210] The main promoters of the latter were two utility firms from St Petersburg, the Belgian–Russian company 'Gesellschaft für die elektrische Beleuchtung Petersburgs' and the German–Russian

Table 2.8 The main rapids of the river Vuoksi with their head, capacity and owners in late 1914

Name of the rapids	*Head m*	*Capacity MW*	*Owners*
Niskakoski	1.7	7	Ab Tornator
Tainionkoski	6.5	27	Ab Tornator
Linnankoski	5.2	22	SPTE
Imatra	18.4	77	The State of Finland
Kyyrönkoski	2.9	12	East bank: SPTE West bank: Peasant communities of Meltola and Korpikanta, Ab Force, The State of Finland
Myllykoski	1.1	5	Ab Force
Torpankoski	1.0	4	Ab Force
Vallinkoski	5.5	23	Ab Force, 89% of the capacity; SPTE, 11% of the capacity
Räikkölän- or Ensonkoski	8.7	37	Oy W. Gutzeit & Co
Ollikkalankoski	1.8	8	SPTE
Rouhialankoski	7.8	33	SPTE
Korvankoski	1.2	5	SPTE
Total	61.8	260	

* Approximate capacity in the unregulated mean flow conditions.

Sources: *Kauppalehti*, 13 Jan 1915, p. 18; *Mercator*, 7 May 1915, p. 285; 4 June 1915, p. 342; 19 Jan 1917, pp. 38–40; *Uusi Suometar*, 20 Jan. 1914; *Selostus Suomen koskivoimasta ja sen käyttämisestä ynnä Imatran voimalaitosyrityksestä* (Helsinki, 1922), App. 2; The Archives of Enso-Gutzeit Co in the CBAF, *Saimaan säännöstelysuunnitelma 1948, I Vesistön kuvaus*, Koskitoimikunta, Vesistöjen säännöstelytoimisto (mimeograph, n.d.) pp. 147–53.

company 'Gesellschaft für elektrische Beleuchtung vom Jahre 1886'. The latter (GEB-1886) had been formed to continue the operation of the central station of Siemens & Halske on the Nevski Prospect in the Imperial capital.[211] Later, the thriving GEB-1886 had grown markedly and set up electricity supply utilities in other towns, such as in Moscow, Sosnovec and Łódź, the industrial town known as 'the Manchester of Poland'. Like the SPTE, a competing firm, the GEB-1886 was keen to obtain hydroplants to complement its thermal plants in St Petersburg. Through two firms, 'Ab Force' and 'Electricitetsbolag Imatra', it had a strong grip on the rapids of the Upper Vuoksi.[212] When the GEB-1886 was put under special control by the

Russian authorities at the beginning of the war, it appeared that this company was controlled by the Deutsche Bank as well.[213]

A quarter (27 per cent) of the hydropower of the Upper Vuoksi was owned by two wood-processing companies working with West European capital and under Norwegian direction. Enso Ab was founded by a Finnish industrialist in 1887 to produce groundwood pulp and cardboard, but it was sold to the big Norwegian corporation Ab W. Gutzeit & Co owing to over-investments in 1911. Similarly to avoid bankruptcy, the majority of capital stock in the Finnish company Tornator Ab was taken over by a group of Norwegian businessmen in 1908. The factories both in Ensonkoski and Tainionkoski utilised only a fraction of the hydropower in their possession. They had good opportunities to expand their energy production for their own use or for sale.[214]

In the period from the mid eighteenth century to 1870 the rapids of Imatra became internationally famous as an outstanding beauty-spot thanks to at least 63 travel accounts in various languages.[215] From the opening of the first hotel in 1870, they developed into a popular tourist attraction as well.[216] Imatra constituted the highest waterfall on the River Vuoksi: the head was 18.4 metres in a stretch of 1300 metres. Imatra together with other, much smaller, possessions of the State comprised about 31 per cent of the main hydropower, economically exploitable resources of the Upper Vuoksi.[217] The remaining 1 per cent was owned by peasant communities, private landowners, local parishes and municipalities. Consequently, the Finns possessed hardly more than one significant waterfall in the middle of the Upper Vuoksi in 1914, while foreigners owned two-thirds (68 per cent) of the total hydropower potential of the river.[218]

During the First World War, the Finns could not obliterate their fear of losing the hydropower of the River Vuoksi to foreigners. In 1915 the SPTE applied for a new concession. This time it planned to build a hydroplant at Rouhialankoski for transmitting energy to St Petersburg which was suffering a marked shortage of energy owing to blocked coal imports. Again the Finnish authorities began making hydrographical inquiries and calculations, and the project was postponed.[219] The Finns' long-lasting examinations and frequent bureaucratic dawdling began to irritate the Russian side, although administrative efficiency was not characteristic of the tsarist regime either. Moreover, hydropower technology and its use was even more poorly developed in the Empire; in Russia there was no substantial hydroelectric plant before the October Revolution.[220]

When the fuel shortage in the region of Petrograd developed into a chronic crisis during 1916, the Minister of War proposed to confiscate for the Russian State the private rapids on the Upper Vuoksi and to build a hydroelectric plant in one and half years for producing energy for the Imperial capital.[221] The nightmare of the Finns, the worst of all the alternatives, was, it seemed, about to come true. The Finnish Senate worked out several letters of protest, the basic idea of which was that the Russian government did not have the legal right to confiscate Finnish private property even for military purposes. In its counter-proposal, the Finnish government was ready to confiscate for itself the Vallinkoski rapids and to build in three years its own hydroelectric plant to alleviate the energy needs of Petrograd and the Finnish State Railways. The Russian government decided to approve both these schemes, but rejected a third submitted by the SPTE.[222]

Owing to the March Revolution in Russia in 1917, both hydroelectric projects in Karelia came to grief. The Finns could not, however, easily forget this traumatic experience. Even before the declaration of independence, the Finnish government set up a new hydropower committee in October 1917 to carry out various tasks, for example to plan and build state-owned hydroelectric plants. Having in mind the events before the Russian Revolution, the committee concentrated on working out means to prevent foreign control of Finnish hydropower. One of the results was the law passed in August 1919 which stated that 'no one is permitted to transmit electricity generated with indigenous energy sources over the Finnish border'.[223] The prohibition was categorical: except for the rivers on the border, the export of electricity from any rapids was forbidden on any terms. No opportunity was left to negotiate on the export prices of electricity nor for interconnecting power plants with foreign plants however profitable that might have been for Finland.[224]

After passing this law, the government did nothing to promote the construction of private or state-owned hydroelectric plants. Considering the sequence of events from the 1890s up to the early 1920s, it seems that the main objective for the Finnish government was to foil foreign direct investments and prevent aliens from profiting from Finnish natural resources, rather than to utilise the indigenous hydropower potential on a large scale for the development of the national economy. The government regarded large-scale electrification and the utilisation of hydropower more as a political than an economic or technological question.

Building foreign-owned hydroelectric plants and using them to produce electricity for St Petersburg or for Russian railways was seen to contain such big political risks that they would definitely eliminate all possible economic returns for Finland. The Finns feared that the transmission of electric power could also lead to the further transfer of political power to St Petersburg. At that time, it was self-evident that if there was any conflict between the intact political status and higher national income, they preferred the former. Under these circumstances, the political instability of autonomous Finland delayed the large-scale utilisation of electrical technology in the country.

When the government of the new republic proved to be as incapable and reluctant to electrify the country on its own initiative as the government of the Grand Duchy had been, Parliament decided at last in 1921 to start building a state-owned hydropower plant at Imatra for supplying electricity for the industrial and other needs of southern Finland. In the same year, the State decided to confiscate the Linnankoski rapids from the SPTE, because the head of these rapids was to be jointly used with the Imatra rapids in the new hydroplant. The company (with a new domicile in France) was not satisfied with the financial compensation offered. The court of arbitration which considered the case, following requests by the French and British ambassadors, did not change the amount of compensation.[225]

The SPTE sold the Ollikkalankoski, Rouhialankoski and Korvankoski rapids as early as 1918 to the Finnish businessman Eugen Wolff.[226] That year the State of Finland bought the majority of shares in the Ab W. Gutzeit & Co and Tornator Ab, but refused to buy the three above-mentioned rapids of the Upper Vuoksi which Eugen Wolff offered to sell at the price of FIM 18 million.[227]

The property of Ab Force constituted the only part of the Upper Vuoksi which was still in foreigners' hands in the early 1920s. Consequently, quite soon after the declaration of Finland's independence most of the rapids in the Upper Vuoksi were restored to the possession of the Finns. The foreign direct involvement in the utilisation of Finnish hydropower was quickly approaching its end.

2.6 THE WARTIME ENERGY CRISIS

During the First World War, Finland avoided becoming a battlefield and the Finns were not mobilised to fight in the Russian Army.

Nonetheless, the Grand Duchy was involved in war indirectly; for example, the Russian government, by declaring a state of war, restricted the political rights of the Finns. The main effect of the war on the Finns was economical. Trade relations with Germany, which had recently risen to the main trading partner, were completely broken off. The German navy closed the Sound in the Baltic Sea and cut Finnish exports to Britain and other allied Western countries. Consequently, a great many sawmills stopped work. Butter exports to the West were rerouted via Sweden up to late 1915, while increasing amounts of butter, cheese and milk were exported to Russia. Unlike the two Finnish staples, sawn timber and butter, the output of paper production kept on growing because its principal market had traditionally been in Russia.[228]

The structure of the economy changed swiftly. Workers moved from contracting industries to expanding sectors such as engineering and the fortification work which was started in 1914.[229] The tsarist regime expected German landings in Finland and increased the number of its troops there to 50 000 soldiers by late 1915. The Russian government bought a lot of goods and services for these troops in the Grand Duchy thereby boosting local demand.[230]

At the very beginning of the war, Russia gave up the gold standard and started financing its warfare by issuing notes. The value of the Finnish mark became tied to the rouble with an administered, unfavourable exchange rate. In Finland this led to the abandonment of the gold standard, a big inflow of Russian roubles and marked inflation.[231] The authorities of the Grand Duchy tried to hold down inflation by fixing maximum prices for necessities. The Finnish government's policy was ill-founded and contributed to imbalances between the demand and supply of commodities. When supply decreased, the rationing of some goods was adopted and illicit trading emerged.[232] After the March Revolution in 1917, the economic situation got worse, war material deliveries were reduced, fortification works were discontinued and imports of Russian grain stopped. In the late summer accelerating demand-inflation was accompanied by rising unemployment and aggravated food shortage.[233]

The declaration of independence on 6 December 1917 was followed by the Civil War from January to May 1918. The revolt of the leftist armed guards against the new bourgeois national government failed when the rightist armed guards, the 'Whites', with German military intervention defeated the rebelling 'Reds'. At least 34 000 lives were lost in the Civil War and its aftermath.

Germany, the supporter of the 'Whites', could not provide much-needed necessities for Finland, and neither Britain nor the USA afforded aid. Although there was rationing, and food supplies were confiscated by the State, sufficient food could not be distributed to everyone. The daily flour ration per person was cut to 80 grams in the summer of 1918.[234] The food shortage deteriorated right up to the collapse of Germany in the following autumn. During the winter of 1918/19, Finland received food supplies from Scandinavia and the USA.

The late 1910s are known in the literature on Finnish economic history above all as the time of food shortage and swift inflation.[235] These years also witnessed the first energy crisis in the country during which lighting problems became especially sharply pronounced. The prime cause of the crisis was a slump in the importation of fuels and of energy-related technical equipment. In the prewar years, the main imported fuels were English coal and Russian paraffin oil (kerosene). Coal imports began to dwindle soon after the outbreak of war, and in the years 1915–17 they were on average only 2 per cent of the level in 1913, and in 1918–19 just under 6 per cent.[236] Coal and coke received from Russia were in the first place reserved for the ironworks and other factories producing war materials.[237] For space heating and locomotives, firewood was used as a substitute. The biggest technical problems emerged in the gasworks where the gas production from wood was more inefficient and troublesome than from coal. Gas deliveries to private clients were not rationed, although street lighting was reduced.[238]

In 1914 the annual import of paraffin oil and petrol decreased by a quarter from 39 000 tons in the previous year to 29 000 tons and continued quite steadily at that level for the subsequent three years. In 1917–18 it dropped from 25 000 tons to a mere 2 tons, rising to 44 000 tons in the following year only to fall again to 15 000 tons in 1920.[239] Although the lighting crisis came to a climax in 1918 it was felt more acutely for a longer period than the statistics of foreign trade show. Problems in distribution and the increase of prices markedly affected the opportunities for obtaining illuminants and matches. Hoarding and speculation worsened the situation. They were induced by the news and rumours of shortages in the other regions. These factors accentuated the psychological anxiety and fear of dark, cold homes.

Before the war, paraffin oil was not very expensive in the Finnish ports compared with major European cities. As stated in the official

statistics of foreign trade, its average cif-price was 18 Finnish pennies (FIP) per kilogram in 1913.[240] In Helsinki, the retail price of first-class Russian paraffin oil was 24.9 pennies per kg.[241] According to the exchange price quotations in late April 1913, American paraffin oil cost FIP 21.3 in Hamburg, FIP 23.1–25.9 in London, FIP 23.5 in Antwerp and FIP 27.1 in Amsterdam, while Russian paraffin oil was sold at the price of FIP 22.4 in London and Liverpool. In Russia, paraffin oil prices varied considerably: FIP 7.7 in Baku, FIP 18.3 in Astrakhan, FIP 25.2–26.0 in Moscow, FIP 29.3 in Odessa and as much as FIP 33.8 in St Petersburg.[242]

Up to 1916, the price increase was slower for paraffin oil than for foodstuffs on average in Helsinki, but in 1918 its price soared more than that of other necessities. It then cost a factor of 46 more than in 1913.[243] From January 1918, paraffin oil began to vanish from lawful trade all round the country: the authorities could no longer gather reliable data about its prices. By May, nearly all the paraffin oil stocks of the merchants were sold out, hoarded or had fallen into the hands of blackmarketeers.[244] In the next year, paraffin oil was again sold publicly and its price slumped, but in the period 1919–21 the price still prevailed at a very high level. Compared to prewar prices, only hard rye bread was more expensive on average in those years.[245]

In Finland, wartime economic crisis and rationing were ascribed to inflation which was even according to the official indices the highest in Western Europe between July 1914 and June 1921.[246] Furthermore, we must take account of the fact that official indices did not indicate accurately the prices of rationed goods like paraffin oil. Calculating on the basis of official maximum prices in the fourth quarter of 1918, the weighted cost of living index (with the base year 1914 = 100) was 774, whereas using the prices of illicit trade it was 1304.[247] In addition, paraffin oil was a product the price of which varied considerably in different parts of the country. Even before the war, in the northernmost town of Rovaniemi, it could cost twice as much as in Helsinki.[248]

Between 1918 and 1921 paraffin oil was presumably one of the goods most in demand. In the countryside and small towns, it was difficult to find any proper substitute for a paraffin oil lamp. To make coniferous splints by hand was wearisome work. Candles were a more handy illuminant, but internal production could not satisfy the demand. In 1917, large imports of candles were to foil rumours of a candle shortage. Where candles were available, however, their price was very high. Similarly, the price of matches increased by a factor of

11.5 even in lawful trade between early 1914 and late 1918.[249] The fear of a shortage of matches, which was unfounded according to the authorities, caused a still steeper increase in their price in illicit trade.[250] To provide still further substitutes for paraffin oil lamps, the government in 1918 ordered carbide lamps abroad, supported the setting-up of two calcium carbide factories and made agreements for the production of domestic carbide and turpentine lamps.[251]

In the circumstances of the late 1910s, the advantages of electricity clearly emerged. Its use was quite independent of import blockades, because it could be generated by various indigenous energy sources, such as firewood, wood waste, peat or hydropower. Unlike other substitutes, the intensity of its light was even stronger than that of a paraffin oil lamp. It was also a clean, hygienic and fireproof means of lighting and precious matches were not needed. The most important advantage was that the relative price of electricity was steeply decreasing, while the prices of other illuminants soared. Compared with electricity, the price of paraffin oil more than quadrupled by 1921 as indicated in Table 2.9. Moreover, electricity and gas did not vanish from the market owing to hoarding and they were not sold at high illicit prices like paraffin oil. When some electricity supply utilities began to charge unreasonably high rates, the Senate decided to regulate electricity and gas prices by a statute in the autumn of 1918.[252]

As a result of the energy crisis, electricity became considerably more attractive. For industries producing civil goods it was almost impossible to obtain imported fuels, although they managed to get various raw materials from abroad. Firewood had to be substituted for coal, but as numerous factories, the State Railways and houses with central heating all began to use billets, even they became difficult and expensive to purchase in sufficient quantities.[253] Moreover, the annual billet export to Petrograd and Tallinn trebled between 1913 and 1916, thereby aggravating the firewood shortage in Helsinki and provincial centres on the coast. The fixed maximum prices on billets had to be abolished, because they proved to discourage supply; hence, the average price of billets quadrupled in major towns between 1913 and 1917.[254] During the first war years, the transfer from coal and coke to wood nearly doubled the fuel costs of firms in Helsinki, and later on, these costs grew rapidly as they followed steeply rising billet prices. Consequently, many companies became customers of electricity supply utilities owing to the scarcity and high price of fuel.[255]

Table 2.9 The price changes of some energy forms in Finland, 1911–21

Year	*Electricity*[a] *FIP/kWh*	*Paraffin oil* *FIP/litre*	*Gas*[b] *FIP/m³*	*Coniferous firewood* *FIP/m³*	*Wholesale price index* *1911 = 100*
Nominal prices					
1911	64	19	25	1766	100
1914	60	26	25	1908	106
1917	. .	71	32	7048	342
1918	. .	(522)	52	8737	603
1921	316	418	180	23493	1302
Index at constant prices					
1911	100	100	100	100	
1914	89	129	94	102	
1917	. .	109	37	117	
1918	. .	(406)	34	102	
1921	38	169	55	102	

[a] Only utilities in towns included.
[b] The retail price of gas for lighting, the Municipal Gasworks in Helsinki.
. . No data available.

Sources: Revue de statistique ouvrière (1912–17); *Revue sociale* (1918–22); *Björneborg Tidning*, 14 June 1911; *Selostus Suomen kaupunkien sähkölaitosten virranhinnoista* (Kotka, 1915); *Neuvoja ja ohjeita sähkövirran käyttäjille*, Sortavalan kaupungin sähkölaitos, Julkaisu no. 1 (Sortavala, 1921); *Kertomus kaasulaitoksen hallinnasta vuosina 1911–1921* (Helsinki, 1912–22).

The lighting crisis, 'Egyptian darkness' as the contemporaries biblically called it, was felt most acutely in the countryside where a paraffin oil lamp was the most common illuminator.[256] Public discussion on lighting problems made electricity well-known even in the remotest districts and created an enthusiastic interest for moving to electric lighting in various parishes. People joined their efforts and at village meetings decided to set up a limited company or co-operative to distribute electricity. In some parishes, separate small electricity utilities were put in operation in two or more nearby villages.

The number of rural electricity utilities had begun to grow substantially from about 1910 and by a rough estimation there were 130 rural electricity distribution utilities in 1917.[257] The following two years were exceptional, when over 90 new rural electricity distribution utilities were established. Between 1918 and 1923, the distribution of electricity was set up by independent utilities or local industrial plants at least on a small scale in over 200 rural municipalities and by the mid-1920s the total number of rural utilities rose to over 450.[258]

In the literature on Finnish history, the food shortage of 1917 is considered to be one of the most important acute causes for the Civil War.[259] Reactions to the fuel shortage were, in contrast, constructive: people concentrated on solving their energy problems technologically, not politically. The rural electrification of the late 1910s attained the scope of a mass movement which was initiated and organised mostly by laymen. In the 'electrification frenzy', as it was called, mistakes could not be avoided. Often the village utilities were too small to deliver electricity economically and at reasonable prices. During the early postwar boom, electrification became extraordinarily expensive owing to the high prices of scarce electrical equipment, especially copper wire. Installations were carried out in a hurry and without proper plans, materials and craftsmanship. Owing to the lack of appropriate materials, even barbed wire was used as leads and bottlenecks as insulators in extreme cases.[260] For these reasons, transmission losses might be well above half of the electricity supply and that fact undermined the economy of these utilities. Moreover, because subscribers at first consumed electricity very sparingly, almost exclusively for lighting, the load and sales income of utilities remained insufficient.[261]

Ilmari Killinen complained that in the 'frenzy', rural capital was foolishly wasted on indebted, unprofitable enterprises supplying electricity so expensively that farms could not use it rationally. According to him, electrification could have been carried out more reasonably and economically in normal times with the same capital.[262]

Surprisingly many utilities, which laymen had founded spontaneously, managed to survive for a longer period. This indicated the need for large-scale rural electrification and constituted the base for it. By merging village utilities, more economical distribution units were created in the following decades. Many of these utilities developed into the mixed companies owned by municipalities, with private firms and individuals. It is noteworthy that the central government was not involved in the early rural electrification of Finland. Before the 1930s, it did not provide the credits and supply electricity at low wholesale prices to rural utilities, as did the Swedish government.[263] Considering the early electrification of Finland as a whole, the government played a passive role; it lacked both interest and plans to introduce modern electrical technology in the country.

2.7 REGIONAL POWER SYSTEMS IN THE INTERWAR PERIOD

The Government and Electricity Supply

Gaining political independence in 1917 gave new opportunities and incentives for the government of Finland to pursue a target-oriented and nationwide economic policy. One of its most urgent goals was to increase the rate of self-sufficiency in agriculture, energy supply and in other fields. The late 1910s provided a hard lesson on the extent of dependence on imported necessities. Active support for agriculture and forestry well suited the political constellation of the young republic where the agrarian population was the largest, and politically a very influential social group. There were also other, more urgent reasons why it was necessary to increase self-sufficiency in energy supply by substituting indigenous fuels and hydroelectricity for imported fuels. Owing to a shortage of currencies, the government had to limit importations very tightly in the early 1920s. Furthermore, in the first postwar years exceptionally high international prices discouraged the importation of fuels, especially coal.

In the young republic, economic nationalism was underlined more than in the Grand Duchy. The policies of successive governments reflected this sentiment and made it clear that the country's natural resources would in the future serve only Finnish industry and other domestic economic activities. The interwar governments took a discouraging attitude to enquiries on concessions and investment tenders which foreign companies and investors made for exploiting Finnish hydropower resources. On the contrary, the state took over some of those industrial companies which were exposed for sale through the withdrawal of foreign capital. The government also itself set up new companies, such as a fertiliser factory, in order to improve economic independence.

A strong impact on the energy political outlines of the interwar governments was made by Bernhard Wuolle, the conservative transport minister of Lauri Ingman's cabinet (1918–19).[264] According to him, the primary energy problem of independent Finland was to secure a rational and inexpensive electric power supply in the more industrialised southern part of the country. His grand idea was to build chains of interconnected hydroelectric plants on the rivers Vuoksi, Kymi and Kokemäki and couple these chains together with a trunk line. He considered this the best way to create a reliable supply system which would both save energy and capital, and facilitate low energy prices. Sub-themes in his programme included building a state-owned hydroplant at Imatra and the electrification of the railways.[265]

Between 1905 and 1940, Bernhard Wuolle was one of the leading Finnish experts in electrical technology. As an internationally minded man, he knew West European countries quite well and was keen to adopt new innovations from them. In interwar Finland, hardly any important project related to electricity was then put forward without his being involved. As an initiator and knowledgeable man he set up various enterprises, such as the Municipal Electricity Supply Utility of Helsinki (MESUH), a regional power company in southern Finland (Etelä-Suomen Voima Oy in 1917), the government-owned broadcasting company (Oy Yleisradio Ab in 1926) and the government-owned Technical Research Centre of Finland in 1941. Moreover, he served on various committees and acted as a consultant in several projects.[266]

In electrical technology, the Swedish language had been more important than Finnish in the period of the Grand Duchy. Due to the rise of nationalism and the Finnish-speaking educated class, the latter language soon became dominant in the electrical business of the republic. A sign of Wuolle's conciliatory character and high prestige was that he was the only person who has held the pivotal posts in the societies of both Swedish and Finnish-speaking engineers. The heated 'battle of the languages' in the early years of the republic did not favour his line of compromises. Wuolle belonged to the minority which in 1919 attempted to change a prominent technical journal in Swedish (*TFiFF*) to become bilingual. The defeat of his line made him concentrate his efforts on working for the Society of Finnish-speaking Technicians.[267]

From the mid-nineteenth century, Finnish has been one of the very few European languages which has used vernacular words for electricity and related concepts, such as *sähkö*, instead of loanwords and derivatives from the Greek *elektron*.[268] In the 1920s, efforts were increased to find Finnish substitutes for the 'ugly, unpronounceable foreign loan-words' of electro-technical terminology.[269] This was not done only out of nationalist enthusiasm, but also as an attempt to make electro-technology understandable to ordinary people. For example, an electrical device would become familiar and more smoothly acceptable if it had a name derived from a word of Finnish origin, such as from a common verb explaining the function of the device. Presumably, the translating of electro-technical terms, making

know-how Finnish, really removed some of the prejudices and negative feelings against this new technology which was no longer felt to be strange and foreign.

The electricity law of 1901 was regarded as obsolete in the 1920s. A new law was passed in 1928. It cancelled the previous requirement of having to apply for a franchise. The right was given to every Finnish citizen to establish an electricity utility. The new law was worked out in co-operation with electrical engineers. It was more liberal than its counterparts in many European countries.[270]

A statute of 1929 gave the duty for controlling and inspecting electric power undertakings to a new semi-official organisation, *Sähkötarkastuslaitos ry* (The Electrical Inspectorate) which was set up according to the Swiss model. It was a registered association the board of which included representatives of private and municipal electricity utilities, and of the government. Among other matters, this organisation began to compile new, detailed, nationwide statistics for electricity production, the lack of which had been criticised for three decades.[271]

The Imatra Power Plant

Bernhard Wuolle considered that Finland had benefited from the disagreement and direct mutual struggle of various Russian and international vested interests which had finally impeded the transmission of the hydropower of the river Vuoksi to St Petersburg. In contrast, independent Finland ought to find a consensus for utilising that natural resource for the domestic economy.[272]

Wuolle opined in 1921 that there were generally five ways to organise an electricity supply system:

(1) to refrain from any government intervention leaving the whole business for private enterprise (the model of the former Grand Duchy);
(2) to nationalise the whole electricity supply sector (the current Soviet model was one variant of this);
(3) to grant the government the right to control and inspect the electricity supply sector (the German model);
(4) to authorise the government to supply electric power for its own needs (the Swiss model);
(5) to permit 'loyal competition' between the government-owned and private supply companies (the Swedish model).[273]

From the early 1910s, Wuolle had preferred the fifth alternative – the Swedish model – which, in fact, also included the third ownership category, that of municipal supply undertakings in addition to those of private firms and central government. Later, having ascended to key posts in Finnish society, he had the chance to influence the introduction of this model into the country. In the autumn of 1917, the Senate invited him to lead a three-man committee, called *Koskivoimatoimikunta* (The Commission for Hydropower) whose tasks was to plan the construction of state-owned hydroelectric power plants.[274]

The decisive initiative to commence the construction of the Imatra power plant did not, however, come from the government but it was three conservative members of Parliament who used their right to propose the motion. On 1 April 1920, the leading economist of the Conservative Party and bank manager Juhani Arajärvi, the farmer Artturi Hiidenheimo and professor Hugo Suolahti proposed that Parliament should ask the government to work out a bill on the introduction of state-owned hydropower.[275] Although the government did not take a serious view of this motion, a great majority in Parliament supported it.

After waiting nearly a year for the government's bill without success, the Standing Committee of Supply headed by Risto Ryti proposed that Parliament should include an appropriation of FIM 10.5 million in the supplementary budget of 1921 for the preparation and construction of the Imatra and Anjalankoski hydropower plants. The Committee gave the following reasons for its proposal:

> The supply of cheap electricity provides new opportunities for the country's industries, increases their international competitiveness and improves economic welfare. The utilisation of hydropower for electricity generation reduces the use of both imported and indigenous fuels, and consequently yields national savings. In pursuing the common interest of the country, the state must, therefore, act in such a way that electric power is available within as large an area as possible, in sufficient quantities and at a reasonable price, and that the rapids capable of supplying cheap power will be harnessed for useful purposes as promptly as possible.[276]

In the parliamentary discussion, the proposal had only three opponents: Magnus Lavonius, the transport minister of the acting government (the Rafael Erich cabinet of 1920–1), Georg Schauman, an MP of the Swedish Left, and Karl Laurén, an MP of the Swedish People's Party. Lavonius based his counter-arguments on the difficult

situation of the state's finance and unaccomplished plans on railway electrification.[277] Nevertheless, Parliament accepted the proposal and in the same year (1921) the preparatory building works started at the Imatra rapids.[278]

Parliament's decision to build a power plant at the Imatra rapids – the biggest one in the country – with a total capacity of 150 MW led to a radical change in Finnish electricity supply. Firstly, the planned power plant was enormous compared with the existing total generating capacity of about 138 MW in the country. To utilise fully the new production potential, the construction of transmission lines of 400–600 kilometres across the whole of southern Finland was required. This meant introducing new dimensions to the Finnish electricity supply.

Secondly, the Imatra scheme also meant an extensive participation of the state in electricity supply.[279] In principle, public opinion and all parties supported the scheme. The opposition of private undertakings was disunited. Similarly, the protests of contemporary environmentalists were rather faint, although the Imatra rapids was the most famous beauty spot in the country.[280] In technical aspects, the Commission for Hydropower was well prepared for criticism. It used several foreign consultants in the planning of the plant and published their references on its plans. The referees were highly esteemed experts in the hydroelectric field, such as the Germans E. Dubislav, Adolf Ludin and W. Petersen as well as the Swedes Axel Ekwall and N. K. Sundblad and W. Borgquist.[281]

By May 1929 – in the first building phase – the state had invested about FIM 344 million in the Imatra Power Plant and affiliated transmission lines. This amount was covered by tax revenues and foreign loans. According to the director of the building project, Hugo Malmi, the final costs exceeded the estimate worked out in 1923 only by 4 per cent.[282]

The three first hydroturbines as well as the fourth unit installed in 1930 were jointly manufactured by the Finnish Tampella Oy and the Swedish Ab Karlstads Mekaniska Verkstad. The generators were ordered from the Swedish ASEA. The transformers were supplied by the ASEA, the Swiss BBC and the Finnish companies Strömberg Oy and Sähkö-Osakeyhtiö Dynamo.[283] Nevertheless, the Finnish inputs played the major role in the project, because the purchases of foreign equipment accounted for only a quarter of the total investment costs amounting to FIM 404 million by May 1932.[284]

The construction of the plant took the relatively long time of eight years. Finally, in early 1929, the plant began to deliver electricity to Viipuri, Helsinki and Turku. However, no major delay occurred, for the scheduled start-up was only about half a year late. Three years later, the power plant with its transmission lines was transferred into a state-owned limited company Imatran Voima Oy (Imatra Power Ltd), giving the directors of the power plant a lot more independence to do business than they had as the heads of a governmental office. The company succeeded. Its sales grew steadily, and the generation capacity of the plant increased from 56 MW to 125 MW between 1929 and 1937.[285]

Hydropower in General

In Finland, there are six big rivers with considerable waterpower potential: the rivers Vuoksi, Kymi and Kokemäki in the south, and rivers Oulu, Ii and Kemi in the north. Before 1917, only rather small hydropower plants utilised the potential of these rivers. The resources of the three southern rivers were harnessed on a large scale between 1919 and 1938. The incentives for this were the swift industrialisation of the country, the concurrent steady growth of demand for electricity and the technological development in the construction of dams and hydroplants. In 1922, Finnish industry attained the same output level as in 1913. Between 1922 and 1938, the industrial output grew on average by 7.8 per cent annually, while the volume of GDP grew by 4.4 per cent p.a.[286]

After the First World War, a few years passed before the development of hydropower took off. Finnish industry was then in a new, uncertain situation and it was mainly interested in immediate changes in production lines and technology in the short run. It was trying to obtain reasonable market shares abroad and at home. When the Finnish export industries gained a firm grip on the market in the mid-1920s, they began to expand and modernise their production. At the same time, they became more interested in electricity supply and hydroelectric plants.

In the early 1920s, only two medium hydroelectric plants were completed at Äetsä (10 MW) and Anjala (15 MW). These, like half a dozen smaller ones, were built by wood-processing companies to supply energy for pulp and paper factories. In the 1920s, two more hydroelectric plants with capacities of 10–20 MW were set up in addition to the Imatra power plant. By contrast, in the 1930s, nearly twenty hydroelectric plants were completed. The largest were at

Harjavalta (74 MW) on the river Kokemäki, and Rouhiala (100 MW) on the river Vuoksi.[287] From the mid-1920s, hydropower was built up very rapidly. In 1925, the hydroelectric capacity was 100 MW and in the following fifteen years it increased fivefold. Due to this exceptionally swift growth, Finland caught up with many major European industrial countries in electricity output per capita. The average capacity of Finnish hydroplants was, however, fairly small; mostly less than 5000 horsepower (3.7 MW).[288]

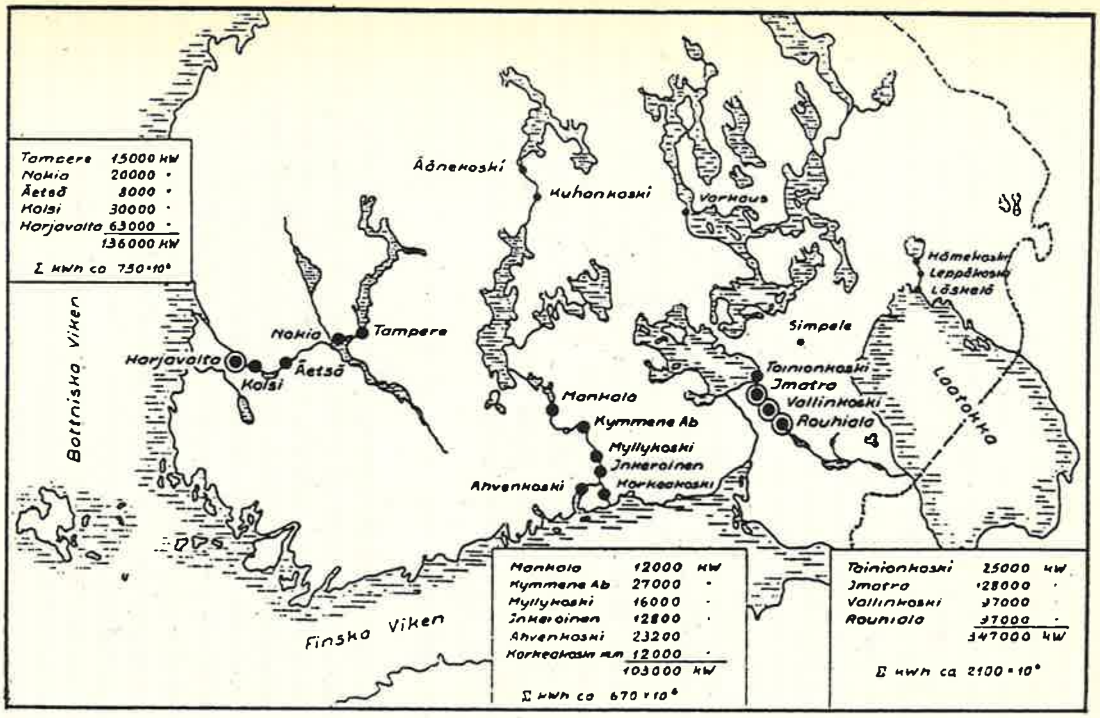
By 1939 almost all viable rapids were exploited in the three main watercourses of southern Finland. There were still some undeveloped heads in the minor rivers, but their total power potential was rather modest. For this reason, more attention was paid to the possibilities of regulating watercourses and utilising the resources of northern rivers.[289] Before the outbreak of the Winter War in November 1939, plans were made for building several hydropower stations on the river Oulu.

From the turn of the century, hydroplants had constituted the vital part of the Finnish electricity supply. In the interwar years, their contribution rose from a half to three-quarters of all generated electricity. They carried the basic load and supplied most of the energy for transmission lines. Thus within two decades Finland changed from a thermal power country into a hydropower country.[290]

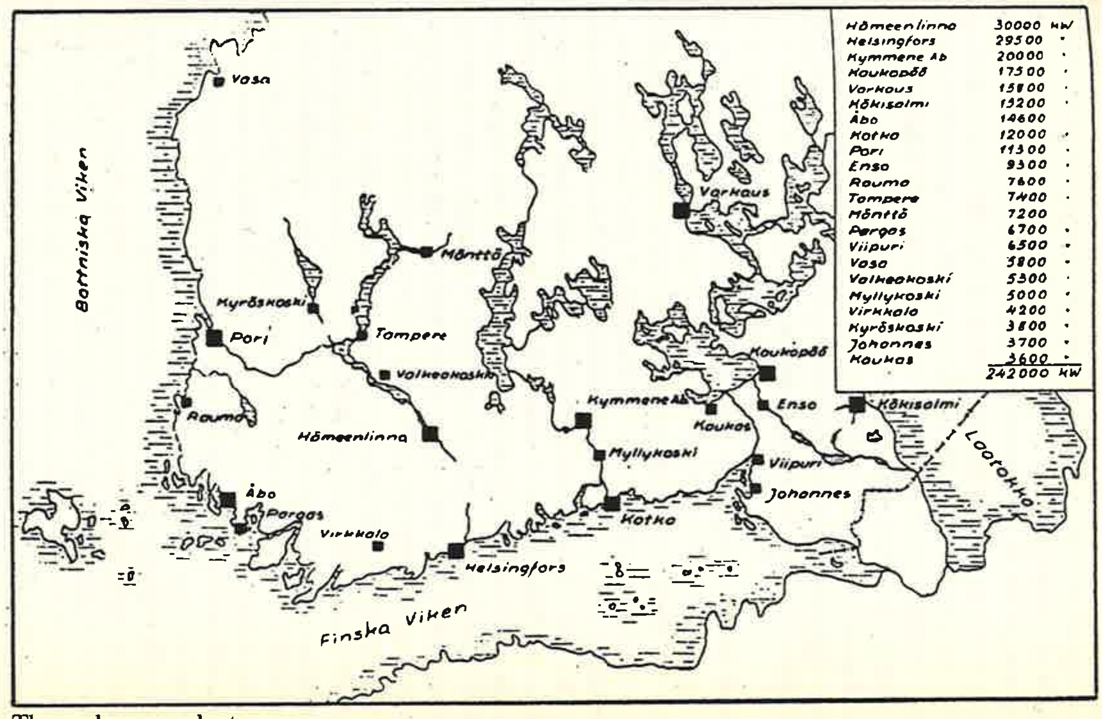
Thermal power

Thermal power plants were built at the same rate as hydropower in the interwar years and the relation of capacities between these prime movers remained roughly 1:1. Thermal power plants were situated in the big towns or in the same river valleys as hydropower plants. The wood-processing industries had definite reasons for building thermal power plants alongside hydroplants. Nearly all of these industries had a great deal of cheap fuel in the form of wood refuse. Furthermore, most of them needed a large amount of steam for their processes. For these industries, the construction of thermal power plants was profitable, because the building and operating costs of thermal power plants were relatively inexpensive. Moreover, the necessary steam could be obtained from the back-pressure steam turbines as a by-product. The efficiency of back-pressure plants was very high due to the joint production of electricity and heat in the form of steam. About 600 GWh of the entire electricity supply in the country (2300 GWh) was generated by steam in 1936. About three-quarters of

Map 2.1 The largest power plants in southern and central Finland in 1937



Hydroelectric power plants



Thermal power plants

Source: V. Veijola, 'Yleiskatsaus Suomen sähköistykseen', *Voima ja valo*, 10 (1937) no. 11, p. 224.

steam-generated electricity was supplied by cheap back-pressure power. The rest was produced by conventional condensation steam power.[291]

The biggest condensation power plants were built between 1909 and 1929 at Suvilahti (29.5 MW) by the MESUH and in 1937–39 at Vanaja (30 MW) by the Imatran Voima Oy.[292] Condensation power plants served as reserve power sources for peak loads and for the periods of drought. In electricity production, the total installed capacity of steam power engines rose from 68 to 427 MW between 1920 and 1938. The capacity of combustion engines and hydro-turbines grew from 5 to 13 MW and from 66 to 429 MW respectively. The average growth rate of the overall generator capacity in the same period was relatively high, 10.8 per cent per annum.[293]

Regional Power Companies

Before the First World War, electricity supply utilities generally delivered power only to one municipality. It was very rare for transmission distribution lines to cross the borders of municipalities. From the late 1910s regional undertakings emerged. Usually their distribution areas merely covered some nearby rural municipalities. The organisational structures and operations of new regional power undertakings varied widely. There were wholesale and retail enterprises, undertakings with or without their own power plants, companies and co-operatives, etc.

At the outset, regional power networks were distant from each other and were not interconnected. At the time, the chairman of the Commission for Hydropower, Bernhard Wuolle, strongly urged that the electricity supply of southern Finland ought to be structured with an interconnected trunk grid and efficient co-operation between hydropower and thermal power plants. He proposed that the state, municipalities and private companies should jointly build the trunk grid in order to achieve a highly developed interconnection. His conciliatory proposal was not supported either within the Commission for Hydropower or among the conflicting interest groups outside it. As a result, he resigned from the Commission in the autumn of 1923. In the following spring, Parliament decided that a trunk grid across southern Finland would be erected by a state-owned undertaking with funding at a cost estimate of FIM 170 million.[294]

By 1939, various interconnections had been realised, but no proper rational interconnected system of electric power was created. Only

the transmission lines of some private companies were interconnected. Although a few wholesale customers were coupled to both Imatran Voima's grid and the private lines, the state-owned and private power systems were not directly connected with each other.

Table 2.10 includes the power companies with transmission lines of 100 km or longer covering two or more municipalities and transmitting more than 1500 MWh in 1937. It shows that these 23 regional power companies played a rather important role in the Finnish electricity supply system which consisted of 374 companies in total. They owned almost half of the transmission lines with a voltage of 3 kV or more and generated about the same proportion of all electricity output. Furthermore, they transmitted nearly two-thirds of the electricity output of the country and owned as much as 87 per cent of the high-tension transmission lines (21–120 kV).

Among the largest power companies, there were several industrial companies which transmitted and/or sold electricity as a supplementary business. Such companies included Kymin Oy, Nokia Ab, G. A. Serlachius Ab and Oy Rauma Wood Ltd. Trading on electricity was the main business for such companies as Imatran Voima Oy, Rouhialan Voimansiirto Oy (RVO), Etelä-Suomen Voima Oy (ESVO) and Oy Hämeen Sähkö which were wholesalers of electric power. Kymenlaakson Sähkö Oy, Lounais-Suomen Sähkö Oy, Jyllinkosken Sähkö Oy, Sähkö Oy Korpelan Voima were, in turn, retailers. RVO was a private company for transmitting the power of the Rouhiala hydroelectric plant on the Vuoksi to factories in the valley of the river Kymi. Etelä-Suomen Voima Oy (Southern Finland Power Ltd) was, in turn, a nearly twenty years older transmission company, founded in 1917. From the beginning of the next decade, ESVO transmitted electricity from the hydroelectric plants on the river Kymi to its biggest shareholder, the City of Helsinki, and to other wholesale customers. It did not possess its own power plants but was a co-owner of the Abborfors (Ahvenkoski) hydroplant.[295]

In the 1920s the general manager of ESVO, Gösta Nordensvan, was the most energetic opponent of the Imatra hydroplant and its affiliated long east–west trunk line. In November 1923 he insisted on reducing the size of the Imatra power plant project to only that of a provincial undertaking. When the original, interprovincial project was built despite the resistance of private power companies, Imatran Voima Oy started to compete sharply with ESVO and some other undertakings over wholesale power deliveries in southern Finland.[296]

Although the Finnish regional transmission networks had greatly

Table 2.10 Major regional power companies in Finland in 1937

Undertaking	Own generating capacity	Transmission lines					Power supply		
		110–129kV	21–70kV	10–20kV	3–9kV	Total	Self generation	Purchased	Total
	MW	km	km	km	km	km	GWh	GWh	GWh
Imatran Voima Oy	123.0	811	218	1	–	1030	823.2	0.7	823.9
Rouhialan Voimansiirto Oy	–	180	–	–	–	180	–	224.2	224.2
Kymin Oy	42.1	–	141	158	–	299	199.5	23.1	222.6
Etelä-Suomen Voima Oy	–	–	198	119	46	363	–	154.5	154.5
Nokia Oy	19.0	–	87	98	12	197	120.7	0.9	121.6
Porin Voima Oy	15.8	–	59	451	43	553	63.2	–	63.2
G. A. Serlachius Ab	13.1	–	68	22	8	98	28.5	6.9	35.4
Oy Rauma Wood Ltd	7.6	–	–	89	28	117	26.7	–	26.7
Lojo Elektricitets Ab	–	–	32	84	273	389	–	11.4	11.4
Riihimäen Saha Oy	1.5	–	4	208	40	252	1.6	9.3	10.9
Oy Hämeen Sähkö	–	–	–	479	–	479	–	8.5	8.5
Ab Värtsilä Oy	3.0	–	42	64	10	116	6.6	1.1	7.7
Kymenlaakson Sähkö Oy	–	–	–	672	189	861	–	7.7	7.7
Lounais-Soumen Sähkö Oy	2.5	–	88	806	–	894	4.3	0.8	5.1
Iloniemen Saha Oy	1.0	–	–	146	–	146	4.6	0.0	4.6
Kosken Sähkö Oy	0.4	–	–	145	–	145	1.7	1.0	2.7
Maarian Sähkö Oy	–	–	–	125	9	134	–	2.6	2.6
Esse Elektrokraft Ab	0.4		–	120	–	120	1.1	1.0	2.1
Jyllinkosken Sähkö Oy	2.0	–	–	364	–	364	2.0	0.0	2.0
Sähkö Oy Alku	–	–	–	108	–	108	–	2.0	2.0
Sähkö Oy Korpelan Voima	1.2	–	–	456	–	456	1.9	–	1.9
Viipurin Kaasu ja Sähkö Oy	0.5	–	–	131	63	194	1.3	0.4	1.7
Sallilan Sähkölaitos	0.6	–	–	144	51	195	1.5	0.1	1.6
Sum	233.7	991	937	4990	772	7690	1288.4	456.2	1744.6
National total	**804.1**	**1018**	**1211**	**10195**	**4831**	**17255**	**2786.2**	..	**2786.2**
The sum of the national total	29%	97%	77%	49%	16%	45%	46%	..	63%

.. No data available.
Source: *Sähkölaitostilasto v. 1937* (Helsinki, 1938).

advanced since the 1910s, they were a quarter of a century later still quite underdeveloped. In many rural power companies, e.g. in Korpelan Voima, the amount of transmitted electric power was strikingly small compared with the length of their transmission and distribution networks. The heavy capital costs of networks and transmission losses had a substantial impact on electricity prices.[297]

Transmission Lines and Distribution Networks

In 1919 transmission lines extended for only short distances in Finland and transmitted a small amount of electricity. The only substantial line was between the Nokia hydropower plant and the town of Tampere. Its tension was 30 kV, and soon after the First World War, electricity distribution was set up from Nokia to many rural areas in Häme province via the network of Hämeen Sähkö Oy. Elsewhere, the extent of the transmission lines also began to increase considerably. In 1923 there were about 300 corporations and private individuals owning high-tension lines. Nevertheless, the number of proper transmission lines – those carrying at least 5 GWh per year for a notable distance – grew to six and their length to 400 km.[298]

The expansion of transmission lines was carried out without any national plan in the early 1920s. Because no standard tensions were applied, many different voltages were used. At the time, the most frequently adopted tensions were rather low, namely 0.3–20 kV. Non-standard tensions and transformers increased construction costs and the expense of interconnection. The Finnish electricity supply sector was, however, not just a jungle of countless numbers of different technical standards as was its British counterpart.[299] Nearly all transmission lines were supplied with a 3-phase alternating current at a frequency of 50 Hz. In 1937, the five most widely used voltages (3, 6, 10, 20, and 110 kV) accounted for 88 per cent of the length of all transmission networks of 3 kV or over.[300]

Power companies regarded transmission lines as considerable investment, and therefore, they attempted to find means to build their lines without unbearable expenses. The Finns developed their own cheap, light pylon structures and efficient erecting methods. The most characteristic feature of the Finnish transmission lines was the guyed single-circuit pylon (*harustettu pylväs*) with wooden legs and steel cross-arms. As a result, the building costs of transmission lines per kilometre were considered substantially lower in Finland than elsewhere in Western Europe. Some Canadian and Hungarian

Table 2.11 Transmission lines in Finland, 1919–38

Voltage kV	*1919 km*	*1923 km*	*1931 km*	*1935 km*	*1938 km*
110	–	–	541	722	1056
70	–	60	223	259	257
30–50	13	106	545	799	1156
10–20	. .	4110	8327	9481	10722
3–6	. .	3130	4330	4760	4825
Total	. .	7406	13966	16021	18016

. . No data available.

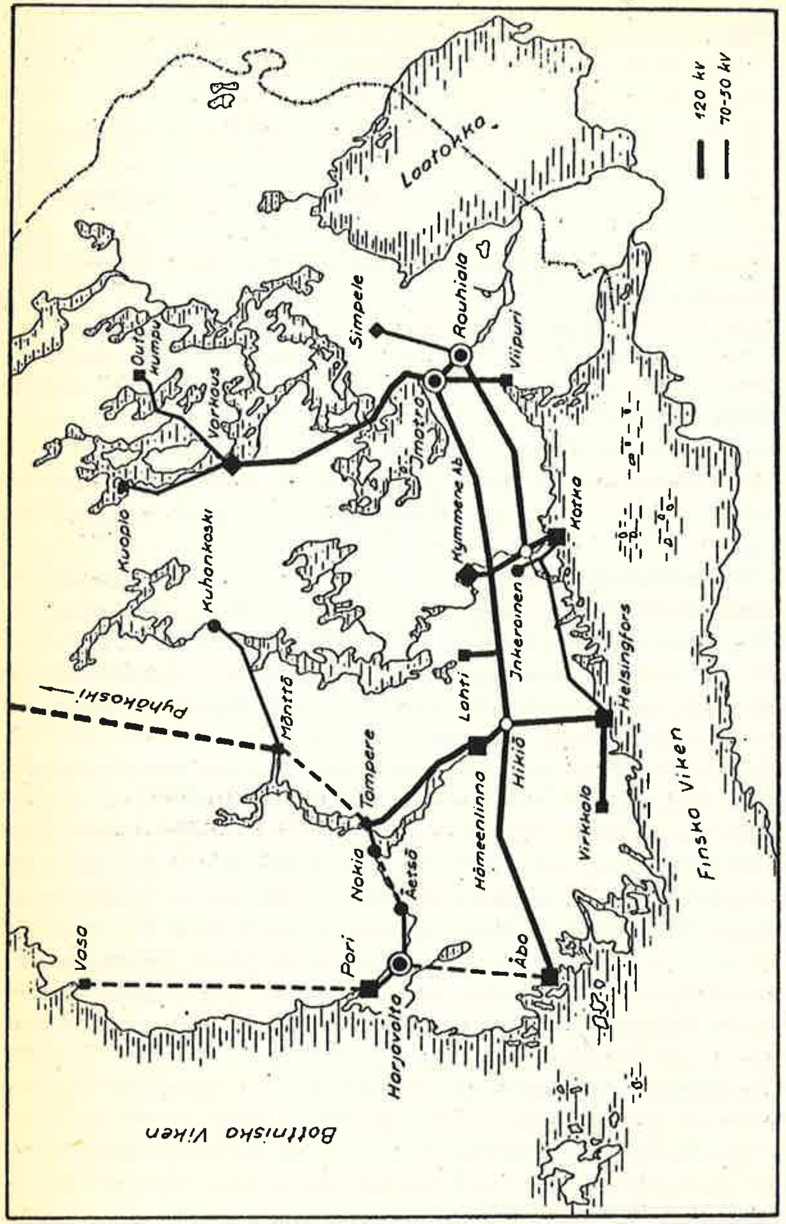
Sources: G. Christiernin, *Finland's Water-power and Electrification* (Helsingfors, 1924) p. 7; G. M. Nordensvan, 'Suomen voima- ja sähköistys-oloista', *TAik*, 13 (1923) no. 10, p. 345; *VV*, 6 (1933) no. 5–6, pp. 122; *VV*, 12 (1939) no. 5–6, p. 123.

studies after the mid-1940s proved that the construction costs of guyed pylons were 25–30 per cent cheaper than those of self-supporting pylons.[301]

The long-distance transmission of electricity made a breakthrough in interwar Finland. The length of transmission lines with a voltage of 3 kV or over grew by a factor of 2.5 between 1923 and 1938, as shown in Table 2.11. Most of them were situated in industrial, rather densely populated Southern Finland, although some extended up to the central parts of the country.

In the first interwar years there were huge differences in the lengths of the Swedish and Finnish transmission networks. In 1928, the former had about 50 000 km of lines over 0.4 kV and the latter only 11 000 km. The spatial density of these lines was 121 km per 1000 square kilometres in Sweden and 31 km per 1000 square kilometres in Finland.[302] By 1938 the density of Finnish transmission lines over 0.4 kV had risen to 53 km per 1000 sq. km in the whole country and to about 103 km per 1000 sq. km in southern and central Finland. In this respect, Finland was, however, clearly ahead of such countries as Norway and Estonia.[303]

Through the Imatran Voima Oy the state owned 41 per cent or 2560 km of the high-tension lines over 30 kV and 70 per cent of all 110 kV lines in 1939.[304] In Sweden the state owned about 9000 km of high-tension lines.[305] All the Finnish high-tension lines of 110 kV equalled only one-third of the length of the 132 kV British National Grid at the time.[306]



Map 2.2 High-tension transmission lines in Finland in 1937

— Completed lines --- Planned lines

Source: V. Veijola, 'Yleiskatsaus Suomen sähköistykseen', *Voima ja valo*, 10 (1937) pp. 11–2, 225.

At first, Finnish high-tension lines were point-to-point transmission lines. Later, they developed into regional distribution networks. A significant feature in the development was that in the late 1920s the three largest towns, Helsinki, Turku and Viipuri, were supplied with electricity through the same transmission system from the Imatra hydroplant. In the 1930s this system was extended to Tampere and some other important industrial areas in southern and central Finland.

By the outbreak of the Winter War, many Finnish towns were only partly wired for electricity. Urban distribution networks were quite small, on average 120 km in 1937. Only in three towns (Vaasa, Viipuri and Helsinki) did local networks total between 500 and 700 km, while twenty-one of the thirty-eight towns had a distribution network of less than 60 km. In a third of the towns, the length of the utilities' distribution lines was under 35 km.[307] Although in total about a dozen different DC and AC distribution voltage systems were in use in the Finnish utilities during the interwar period, there was a powerful tendency to adopt the AC distribution tension of 380 volts for power uses and 220 volts for lighting throughout the country.[308] At the time, rural utilities were ahead of urban undertakings in the standardisation of distribution voltages. By 1937 nearly a half (18) of the towns had completely switched to this system. The rest were still in the transition phase apart from four towns which had not yet begun the process at all. Two different voltage systems were used in thirteen towns, while in four towns three systems were applied in electricity distribution.[309] In all urban electricity supply utilities – except for the one in small Iisalmi – had then a distribution system of alternating current in operation, and in all these undertakings as well as in those rural utilities and industrial plants which were supplied with an AC-system, the frequency was 50 Hz.

In Helsinki and in two other towns, the transition to the system of 380/220 V took several decades. It was not until the mid-1960s that this system became the sole voltage standard in all towns.[310] Nevertheless, the change from several distribution voltages to the present standard system took place more quickly in Finland than in many other countries in Europe, for example in Sweden and Switzerland, neither of which can be called laggards. In this respect, Finland benefitted from its position as a latecomer: its greater interwar electrification boom took place just after the foreign leaders of electrical technology decided in the late 1910s to adopt the uniform standard of 380/220 V.

Finland in Comparison

In interwar Finland, the state did not directly intervene through legislation in the generation, interconnection, transmission or pricing of private undertakings as was the case for example in Britain, Germany and France. It was considered that there was no need for this, for the free market mechanism was claimed to work well enough. From 1929, the state could, however, influence the pricing of electricity, supply conditions, etc. by participating in the business through the Imatra Power Ltd (IVO) and competing with private undertakings. Consequently, state intervention in Finland was milder than in the most contemporary West European countries in the interwar years.[311] In the interwar period, the Finnish electricity supply system organisationally began to approach the so-called Swedish model where government-owned, municipal and private undertakings competed but still co-operated with each other.

In Finland between 1920 and 1938, the total output of electric power increased by a factor of eleven, or on average 14.1 per cent per annum. This rate of growth was the highest in interwar Europe except for the Soviet Union.[312] Although Finland surpassed some major industrial countries in the total electricity output per capita, its electricity use for non-industrial purposes remained relatively modest. Many contemporaries considered that by evaluating in per capita terms, the civic consumption of electricity was a more interesting indicator than the total electricity output, because it was seen to be a good measure of the population's living standards.[313] The reason for this viewpoint was that households and other retail consumers generally accounted for the main part of the civic consumption. If early-twentieth-century Finland was ranked in international comparisons according to this indicator instead of the total output per capita, it would drop from the middle position of Table 2.12 (and Figure 4.2) nearly to the bottom rank. 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.

While manufacturing used 70–85 per cent of all electricity output in interwar Finland, households consumed merely 5–7 per cent. The countrywide average for the domestic use per capita rose from a modest 23 kWh to 42 kWh between 1930 and 1938, whereas the total electricity consumption per capita grew from 350 kWh to 850 kWh. Regional differences were also pronounced: for example, the civic consumption per capita in urban areas (138 kWh) was treble that of

Table 2.12 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	2750	666	24
Canada	25.4	2318	350	15
Switzerland	6.1	1452	310	21
Sweden	7.4	1187	135	11
USA	136.0	1061	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).

Sources: *Sähkölaitostilasto 1937* (Helsinki, 1938) pp. xv–xxiii; J. Larho, 'Distribution of Electric Energy Abroad', *TAik* (1938) pp. 384–92; *NOS XII.291 Historical Statistics 1978* (Oslo, 1978) p. 243; *Canadian Statistical Review, Historical Summary 1970* (Ottawa, 1970) p. 89; *Historical Statistics of the United States*, Part 2 (Washington D.C., 1975); *Kommersiella Meddelanden*, 26 (1939) no. 18, pp. 701–4; *Sommario di statische storiche dell'italia 1861–1975* (Roma, 1976) p. 101; B. R. Mitchell, *European Historical Statistics, 1750–1970* (London, 1978) pp. 292–3; A. Maddison, *Phases of Capitalist Development* (Oxford, 1986) pp. 183–4.

electrified rural areas (48 kWh) in 1938. Electrification was most advanced in the four southern provinces. In the eastern and northern parts of the country, it was generally limited only to towns and boroughs.[314]

To sum up the developments of interwar Finland, it can be said that electrification was regionally quite disproportionally spread and the use of electric energy was unbalanced. While electric power was intensely utilised in some modern sectors, especially in manufacturing, there were large sectors of the economy, such as agriculture and households, which consumed electricity very sparingly relying primarily on other forms of energy and with traditional technology. Furthermore, Finland was one of the few European countries where not a single kilometre of the railways proper was electrified. The ample use of firewood, unstimulative tariff structures and relatively high retail rates, hampered the growth of the non-industrial consumption of electricity in the country.[315]

2.8 ELECTRICITY SUPPLY IN DISTRESS

The Power Economy during the War

In late November 1939, war broke out between the Soviet Union and Finland. Although the obstinate resistance of Finland in fighting against heavy odds amazed the Soviet supreme military command as well as the outer world, for the Finns the result of the short war, losing nearly one-tenth of their territory, was a painful blow. In March 1940 the peace treaty of Moscow terminated this so-called Winter War.

The period of reconstruction was of brief duration. After fifteen months of peace, the Continuation War broke out between the two countries. Finland fought alongside the Axis Powers against the Soviet Union for three years and three months. In September 1944 a truce was made with the Allies (the USSR and the UK) in which territories were again ceded in the East. In addition, the truce forced Finland to turn its weapons against the German troops located in Lapland. The withdrawing Germans burned down Lapland before they were finally pushed into Norway by April 1945.

Paradoxically, Finland was the smallest but the only one of the Axis Powers whose heartland was not occupied by enemy troops in the Second World War. During the war and its aftermath, the country also managed to preserve its political and economic system. This too was not common among the countries involved in the war.

Warfare, the crisis in foreign trade and consequent shortages strained the economy of Finland in the 1940s. The electricity supply industry could not avoid problems in these circumstances. Routine prewar plans and arrangements prepared for all contingencies were soon found insufficient for securing a reliable and efficient electricity supply. In September 1939, before the outbreak of the Winter War, an Energy Office was founded under the Ministry of Supply (Kansanhuoltoministeriö) to organise a nationwide electricity supply. It created a very centralised organisation which gave an almost 'dictatorial authority' to the head of the Energy Office. This post was held by engineer Väinö Veijola from September 1939 to September 1940. He was succeeded by engineer Harald Frilund for the following nine years. In 1941, an impressive title, *Valtakunnan voimapäällikkö* (The National Energy Chief) was conferred on him.[316]

Harald Frilund (1889–1969) played the key role in designing and executing the strategy for the electricity supply system of the 1940s. In many respects, his background was in no way untypical of Finnish electrical engineers of his generation. He was a son of a Swedish-speaking master builder in Helsinki. He graduated from the Helsinki University of Technology in 1914. After the First World War he made study tours in Sweden, Germany and Switzerland while working for Finnish firms.[317]

When Frilund was nominated for the post of national energy chief, he was the technical director of EKONO, the Association of the Energy Economy, which was a technical co-operation organ of the industry. The nomination was not surprising because he had participated in crisis planning of national energy supply in the Council of Economic Defence between 1936 and 1939. Frilund was an esteemed expert who was a member of many domestic and foreign associations of his trade – for example, of the Engineers' Science Academy of Sweden and of the Verband Deutscher Elektrotechniker.[318]

The main task of the national energy chief was to secure the electricity supply of Southern Finland which was divided into three main power regions: Imatra, South Finland, and Nokia-Harjavalta. These regions were, in turn, subdivided into 21 power districts. The central and northern parts of the country, which were outside the area of the trunk grid, were covered by three special power districts: Jyväskylä, Oulu, and Kemi-Petsamo. These regions and districts were governed by a system of local energy chiefs. All local energy chiefs worked under the leadership of the national energy chief who also was the head of the Energy Office in the Ministry of Supply.[319]

Building up the centralised, hierarchial organisation led to some radical changes in electricity supply. In order to secure an electricity supply for war-material factories, the Energy Office considered it desirable that electricity should be delivered to them from at least two separate power plants. For this purpose, some new interconnected transmission lines were built and further plans to interconnect southern power plants were implemented. The networks of the vital regional power companies, Imatran Voima Oy (Imatra Power Ltd), Etelä-Suomen Voima Oy (Southern Finland Power Ltd), Länsi-Suomen Voima Oy (Western Finland Power Ltd) were interconnected with few links. As a result, the Energy Office created a co-operating network covering the important, densely populated industrial centres of southern Finland. The form of the new grid resembled a horseshoe: one end in Kokkola on the western coast and the other in Outokumpu in the east, while the front curve extended down to Helsinki. Even in the first few years, the new grid supplied electricity cheaper and more reliably to many small utilities and industrial plants than their own uneconomical power plants.[320]

War conditions and the actions of the government compelled the power companies to co-operate with each other and for the first time in Finland they began to utilise the advantages of interconnection and economic mix on a large scale. The power chiefs had the right to set running first the most economical power unit regardless of who owned the unit and who needed the electricity. The general rule was that first hydropower was utilised as much as possible, and then thermal power plants were started up in order of efficiency.

During the Continuation War, the electricity supply industry faced several problems caused partly by the climate and partly by wartime conditions. From autumn 1939 to spring 1943, Finland suffered exceptional droughts and the discharge of the principal rivers varied between about 10 and 70 per cent of their long-run average, as shown in Table 2.13. The crisis was aggravated by the fact that winters at this time were extraordinarily cold. The generating capacity had to be augmented by thermal power plants, but they had problems obtaining fuel. The importation of coal from the areas controlled by Germany could not meet the entire demand. The Third Reich supplied Finland with such small quantities of fuel that they generally just sufficed to satisfy the needs of the following few weeks. The lack of labour, in turn, limited the chopping of firewood. The most serious problem was, however, the shortage of internal transportation facilities for coal and indigenous fuels.[321]

In the winter of 1941/2, the situation became critical: some factories had to stop due to the lack of electricity, and the electric lighting of public and private buildings was temporarily reduced.[322] The primary factor which saved the electricity supply from serious overload and power shortages was the severe decrease in the output of the wood-processing industries. The war had cut off export routes for paper, pulp and timber to all major markets except Germany. Consequently, at the turn of the years 1941/2, for example, only one paper-making machine was producing newsprint. The lack of labour and raw materials also slowed down industrial production. Because of this deep slump, the total demand for electricity in the principal

branches of industry decreased by a third, from about 3000 to 2000 GWh per annum or lower.[323]

Finland lost 24 per cent of its installed hydropower capacity and 10 per cent of its thermal power under the Moscow peace treaty of March 1940. During the Continuation War, Finland reconquered these plants and managed to get some of them working again. In the period 1939–44, some new power plants were also put into operation. In consequence, the capacity of power plants in 1943 was nearly as large as before the war and electricity output slightly higher. More new hydroelectric plants could have been completed if all turbines and generators ordered from Germany had been received.

In the beginning of the Continuation War, Finland not only conquered its prewar territories, but also quite considerable Soviet areas in the Olonets region. Its troops cut traffic on the important Leningrad–Belomorsk railway line. Some warmongers were then looking forward to the utilisation of the hydropower resources in occupied East Karelia at least partly for the needs of 'Nucleus-Finland'. East Karelia was estimated to possess a technically exploitable hydropower of about 750–1100 MW, of which roughly 200 MW was already harnessed.[324] In fact, the Finns did not really attempt to utilise East Karelian hydroplants, although, for example, the three largest local hydroelectric power plants on the river Svir' (Syväri) were occupied by them for two and a half years.[325]

In summary, electricity did not become a critical commodity in Finland during the war. Despite various problems between November 1939 and September 1944, the country could secure a continuous electricity supply. Bombings, overload or accidents did not destroy any of the major power plants. Soviet air raids damaged some transmission lines, but no long-lasting shortages took place and the wartime electricity supply system was not put to a severe test.[326]

Although almost all consumer goods, from bread to stockings, were available only with ration cards (or through the black marketeers), electricity was not put on ration at all during the war years as, for instance, was the case in occupied Denmark and even in neutral Sweden.[327] Harald Frilund with his Energy Office considered that electricity supply and the fighting spirit of the nation were closely connected. He believed that through maintaining an electricity supply the authorities could efficiently influence the morale of the population. Various arrangements for electricity supply were seen to provide instruments for rewarding or disciplining the people.

During the war, electricity supply was used for rewarding the population under heavy pressures. Meanwhile, there was no need to ration electricity distribution; indeed, an essential rise in the electricity consumption of households and services was permitted. Nominal prices of electricity were strictly regulated from late July 1941 for nearly seven years. When inflation was accelerating, this meant a considerable decrease in the real price of electricity. The Ministry of Supply rejected the demands of some local authorities, for example in Helsinki, for the rationing of electricity. It did not unnecessarily want to 'string the nerves of the population' even on a local scale and reveal that the Finnish electricity supply was in trouble.[328]

The Culmination of Crisis after the Armistice

In the Second World War, Finland preserved its independence, but lost 2.2 per cent of its population, 12 per cent of its territory and 13 per cent of its national wealth. Furthermore, the armistice of the year 1944 with the Soviet Union and the new war against the German troops in Lapland caused serious setbacks for the energy supply of the country. A third (1250 GWh p.a.) of the existing hydroelectric capacity and hydropower resources of about 550 GWh p.a. under construction were ceded to the Soviet Union under the truce agreement.[329] The Germans destroyed three medium-sized hydroelectric plants (totalling 200 GWh p.a.) in Lapland in 1944–5. Meanwhile, the importation of German coal was cut off, and a coal supply from other countries was also out of the question.[330] For these reasons, electricity problems were expected to intensify in the following few years and the wartime organisation for electricity supply continued to work until the end of December 1949.[331]

In late 1945 the coal stock was almost at zero. Early in the following year, the operation of thermal power plants was secured only by emergency oil deliveries from Sweden. Because of fuel shortages, the use of electric cookers and electric fires for space heating increased rapidly. Consequently, all uninstalled electric and gas cookers were confiscated by the government.[332] Domestic electrical appliances were said to have caused a sharp rise in the load of electric supply utilities in autumn 1945, while the wood-processing industries were still working at only half of their capacity.

In the latter half of the 1940s, the power requirements of Finland increased substantially. The country had to provide goods (with the value of $226.5 million at 1938 prices) for war reparations to the Soviet Union between 1944 and 1952, home market industries started to expand and the exports of timber, pulp and paper began to recover.[333] At the same time, a boom took place in the electrification of the countryside and of thousands of new houses in the population centres. However, serious obstacles slowed down the expansion of electricity distribution. There was not enough electrical equipment available, such as generators, transformers and cables. Furthermore, because of difficulties in foreign trade, the consumption of oil and coal had to be strictly rationed.

The most serious problem was attributed to the climate. In autumn 1946 a new period of exceptional drought broke out and it continued until 1949. For this reason, the Ministry of Supply forbade the use of electric fires and the lighting of display windows.[334] In the distribution of electricity, priority was given to the factories producing goods for war reparations. Alongside this production, it was decided to boost export industries by all possible means and secure an electricity supply for them, because they could acquire badly needed foreign currency for the country.

In winter 1947/8, the electricity supply crisis was becoming increasingly critical. The water stock in the main rivers again decreased to an extraordinarily low level, while electricity demand grew ever more steeply. Table 2.13 illustrates the drop in the discharge of the three main rivers. The power plants of these rivers produced about 90–95 per cent of the total hydroelectricity in the country.

On 1 October 1947, the Energy Office headed by Harald Frilund began the rationing of electricity throughout the country. Nearly all sectors of the economy, except the factories producing goods for war reparations, and the wood-processing, cement, electrochemical, electrometallurgical and textile industries, were fined for exceeding their monthly rations of electricity. For industrial plants, monthly rations varied from 60 to 90 per cent of their consumption in the corresponding month of the previous year. A ration of 30 kWh per month was imposed for ordinary households irrespective of the number of their members and lodgers. An extra rate of FIM 10, equivalent to an increase of about 180 per cent to the average kWh-rate for households, was the fine for each kWh exceeding the ration.[335]

The Energy Office considered that merely rationing was not enough to curb consumption. The use of electric cookers was prohibited in households with alternative cooking facilities.[336] Between November 1947 and May 1948, the Ministry of Supply spent FIM 8 million in the first modern advertisement campaign for

Table 2.13 The discharge of the main rivers, 1901–49

Situation on the 1st of December in each year	*Vuoksi* m^3/s	%	*Kymi* m^3/s	%	*Kokemäki* m^3/s	%
Average, 1901–30	600	100	300	100	230	100
Minimum, 1901–30	321	54	101	34	62	27
1939	420	70	120	40	90	39
1940	330	55	120	40	140	61
1941	**280**	**47**	**70**	**23**	**30**	**13**
1942	260	43	140	47	450	65
1943	700	117	490	163	500	217
1944	640	107	420	140	360	157
1945	630	105	230	77	140	61
1946	470	78	205	68	250	109
1947	**325**	**54**	**105**	**35**	**55**	**24**
1948	370	62	170	57	180	78
1949	700	117	150	50	100	43
Average, 1939–49	466	78	202	67	181	79

Sources: 'KHM:n voimatoimiston toiminta 1939–1944', *KHM, Teollisuusosasto Ja XVIII.1*, The Archive of the Ministry of Supply in the National Archives of Finland; Harald Frilund, 'Kraft- och bränsle krisen 1939–1949', *Kraft- och bränsleekonomi 1911–1961* (Helsingfors, 1961) p. 106

electricity conservation. The campaign's practical goal was to decrease electricity consumption in the non-industrial sectors by 50 per cent. The people responded positively. According to opinion polls, 77 per cent of the population was willing to follow even tighter rationing. Furthermore, the great majority of the press supported the campaign and reiterated the catchwords of the Energy Office as well as launching some of their own which might sometimes be even more imperative, like 'Let not a single bulb be switched on for futility's sake'.[337] In the subsequent year, both Frilund and the press claimed that roughly half the goal was attained.[338]

The campaign also included the idea about disciplining the people whose morale was supposed to be declining as a result of war-weariness. 'The primary aims of this campaign were (a) to explain the necessity of rationing, and (b) to create a common atmosphere of most tight thriftiness through electricity conservation.'[339] At the time, all efforts were needed for paying war reparations, increasing exports and reconstructing the economy. The Energy Office's advertisements designed under Frilund's supervision expressed this objective clearly. 'By reducing electric lighting and halving non-industrial consumption (with 50 MW), we can use a third more electricity for manufacturing. Citizens! Think *Soteva* [the Mission of the Industry for War Reparations]. Think wool, grain, cotton, sugar, fats, tobacco – to pay for our imports, we need kilowatts.'[340] The campaign of thriftiness and rationing of electricity was, first of all, aimed to spur the people to work harder and to check rising leisure time entertainment and private consumption. By means of its regulations, the Energy Office most heavily hit restaurants, hotels, cinemas, dance halls, petrol stations, jewellers' shops, etc. They had to pay an extra rate of FIM 12 for each kWh consumed. Consequently, the electricity bills of these consumers more than trebled.[341]

Frilund's rationing system with seven different consumer categories was based more on puritan ethics than on the reality of the economy. Therefore, it was soon found complicated and inflexible. For example, it did not sufficiently take account of wartime changes in price relations. Between 1939 and 1947, the general cost of living index had risen by 480 per cent and the average nominal price of birch billets by 645 per cent, but the regulated average nominal price of electricity only by 80 per cent. The imposed monetary sanctions could not level out this disproportional change.[342] Finally, the Energy Office admitted that changed price relations gave an inducement for using electricity instead of fuels. In addition, low rates slackened the rate of investment by electricity supply utilities. As a result, the prices of electricity were freed from price controls in February 1948. In many towns in March, electricity became about one-quarter more expensive in money terms.[343]

The forceful propaganda campaign and the rationing of electricity were criticised for many reasons. First, the campaign was concentrated on non-industrial consumption, especially that of households, even though the share of the latter was only about a tenth of the total consumption in 1946. Halving this amount would have meant only a decrease of a marginal 5 per cent of the total consumption. Nevertheless, the Energy Office insisted that even such a decrease would save valuable timber resources for industry and currency needed for coal imports.[344] Second, the opportunities to save electricity in industry were not scrutinised carefully enough, although they were there much larger and more promising than in other sectors.[345] Apart from the copper producing company, Outokumpu Oy, industry did not pay sufficient attention to the conservation and rationalisation of its electricity use. Consequently, during the worse period, from August 1947 to March 1948, nearly all exporting groundwood pulp mills had to stop production.[346] It was claimed that the wood-processing industry then lost income from export equivalent to nearly current FIM 1000 million per month because of energy and raw material shortages.[347] Third, the national energy chief was accused of depressing people with statements which were too pessimistic.[348] Fourth, the insufficient rations of electricity unevenly and unjustly hampered the production of industrial firms and disturbed the normal, everyday life of ordinary people.[349]

Electricity supply became a decisive bottleneck for the economic recovery of Finland, despite the rationing of electricity consumption, the conservation campaign and the positive response of ordinary people to both. As shown in Table 2.14, after the war, electricity output recovered much more slowly than industrial production to its prewar level. It is striking that in devastated, war-weary Europe, there was no country where the restoration of the pre-war electricity output level took such a long time as in Finland.[350]

Although the wood-processing industries were privileged consumers, the electricity crisis hit the biggest users, groundwood pulp

Table 2.14 Volume indices of electricity supply and industrial production, and the average load of generating capacity in the early winters of 1939–49

Year	*Actual load* *MW*	*Load estimate for the normal water conditions** *MW*	*Electricity output* *1938 = 100*	*Industrial output* *1938 = 100*
1939	. .		100	95
1940	200		58	72
1941	220		57	78
1942	240		62	79
1943	290		101	92
1944	210		93	86
1945	410		95	89
1946	380		95	104
1947	300	(410)	92	114
1948	360	(430)	95	130
1949	460		114	135

* Average load in the week beginning 1 December.
. . No data available.

Sources: Appendix Table A.6; H. Frilund, 'Kraft- och bränsle krisen 1939–1949', *Kraft- och bränsleekonomi 1911–1961* (Helsingfors, 1961) p. 106; S. Heikinen *et al.*, *Industry and Industrial Handicraft in Finland, 1860–1913* (Helsinki, 1986) p. 121.

mills, hardest. Some iron works, cement factories, construction projects and other firms stood idle for shorter periods, as well. Furthermore, about 100 firms were compelled to shorten their working hours. The shortage of electricity did not, however, cause unemployment, because the employers were generally ready to arrange occasional work for the employees of closed factories.[351] In the main grid of southern Finland, the capacity of postwar hydroelectricity would have been at least 240 MW in normal water conditions. In winter 1947/8 only about 140 MW was available. The lack of hydroelectricity could not be fully made up by thermal power, although all thermal power plants were in full use. The maximum capacity of thermal power was on average 170 MW. Hence, there was a persistent deficit of 100–110 MW.

In 1944 the government approved a scheme for building nine new hydro and thermal power plants with a total capacity of 400 MW and for expanding some old ones. In autumn 1948 the first substantial new plants began to mitigate energy shortages. Then electric power also started being transmitted from the river Oulu in the north to southern Finland via a new high-tension line (470 km) of 110 kV, later 220 kV.[352] The Ministry of Supply eased the rationing of electricity in autumn 1948 and cancelled it altogether on 1 February 1949. Hence, the crisis was overcome.[353]

The postwar shortage of electricity was an international phenomenon. In Finland, it did not cause such severe measures in rationing and limited consumption as it did in some other countries. The distribution of electricity to households and the service sector was not purposely interrupted in the country in any phase of the crisis. By contrast, in Austria, and even in Norway, electricity to households might be cut off for 5–10 hours a day during the first postwar years.[354]

Nevertheless, the events of the 1940s meant a serious setback to the Finnish energy economy; electricity production in the country substantially fell behind Sweden, for example. During that decade, Britain succeeded in surpassing Finland in electricity output per capita.[355] The electricity shortage caused by the war, the loss of power plants and the exceptional droughts hampered the functioning of the Finnish economy and retarded its postwar reconstruction. The lack of electricity reduced industrial output, particularly in the important wood-processing industries. The extensive programme of building new power plants consumed scarce domestic financial and material resources for investments, while economic assistance from abroad was very restricted; there was no Marshall-aid, for instance.

As a result, both industrialisation and urbanisation were retarded, whereas agriculture had to be expanded. Hence, the electricity crisis did not only have acute negative impacts, but it indirectly checked the structural transformation of the whole Finnish economy.

2.9 THE POSTWAR HYDROPOWER BOOM

Power Policy

The reconstruction of the economy and the payment of war reparations were the emergency tasks facing Finland after the armistice of September 1944. One of the major obstacles in carrying out these tasks was a shortage of energy. The importation of fuels had to be restricted to small amounts due to limited currency resources and indigenous fuels were also not sufficiently available. The scarcity of a generating capacity hampered electricity output, and owing to the absence of intercountry transmission lines the deficit could not even technically be made up by the importation of electricity. Besides this acute problem there was another, long-term task: the reorganising of the electricity supply sector after the centralised wartime system was to be abandoned. How did Finnish society tackle these problems?

The years 1939–49 developed into an epoch-making period for the relationship between the government and the energy economy in Finland. Before the war, the government's interference in the power sector was limited only to imposing safety regulations for installations, setting customs tariffs for electricity equipment and building the Imatra hydroelectric power plant with its transmission lines. During the war and its aftermath, the government interfered in almost all aspects of the power economy. Consequently, the government came to play the crucial role in solving the problems of acute energy shortages as well as developing the electricity supply system.

The government's measures for mitigating the electricity shortage were to reduce consumption, to find means for utilising the whole thermal capacity, and to raise the country's hydroelectric capacity to the level of demand for electricity in the off-peak periods. It launched an emergency five-year programme (1946–50) for building new hydroelectric generating capacity equating to 2100 GWh per annum which meant that the current capacity was to rise by 84 per cent over the five-year period.[356]

Putting forward this scheme only aimed at presenting guidelines for the short-term solution of the power shortage. For organising the electricity supply industry in the long run, the government set up a committee in November 1944 which published a report in early 1947. The committee considered six alternatives for organising the nationwide electricity supply system. Four of these alternatives won support from different interest groups. These four were briefly as follows:

(1) To nationalise all noteworthy power plants and transmission lines over 50 kV.
(2) To merge private, municipal, and state-owned power plants and transmission lines into a mixed 'Giant Group' (Suuryhtymä).
(3) To form a new nationwide transmission company, 'Trunk Line Company' (Valtajohto Oy), which would oversee and operate all the transmission lines with a voltage of 100 kV or over.
(4) To preserve the existing ownership structure and organise the interconnection voluntarily.[357]

The main features of these reform alternatives are described in the Table 2.15. Nationalisation would have meant a radical change, while returning to the interwar conditions required abolishing the centralised management system created on the eve of the Winter War, 'Giant Group' and 'Trunk Line Company' were two different half-way-solutions based on some kind of mixed ownership between private and publicly owned companies. Each of these alternatives was claimed by their supporters to have advantages which would promote national targets. According to the committee, the national power system had two main aims during the following decades; first, the rapid growth of electricity generation, and second the flexible and economical interconnection between the major power plants.

The majority on the Power Committee regarded the 'Trunk Line Company' as the best alternative. Meanwhile, this proposal was a compromise between the other, sharply contrasting alternatives. Its most influential opponent was the government-owned power company Imatran Voima Oy (IVO) which had the most to lose in this option and would gain hardly anything. Imatran Voima Oy had the longest network of high-tension lines in the country, and it already controlled a large proportion of electricity supply. The managing director of IVO, Alfons Alftan, preferred the mixed 'Giant Group' as the best solution. The minority of the committee, representatives of private electricity producers (H. Frilund, G. M. Nordensvan, L. Paavolainen and V. Veijola), opposed all state intervention in the

Table 2.15 Reform alternatives for the electricity supply system in the 1940s

	Type of reform			
Key factors	*Nationalisation*	*'Giant Group'*	*'Trunk Line Company'*	*Return to the interwar conditions*
Ownership	State-owned	Mixed ownership but the majority of shares for the state	Mixed ownership but the majority of shares for the state	Separate private and publicly owned companies
Market structure	Monopoly in large-scale production and transmission	Monopoly in production and transmission	Monopoly only in high-tension transmission	Oligopolistic competition in production and transmission
Interconnection	By adjustment inside the centralised system	By adjustment inside the centralised system	By agreement between producers and Trunk Line Co.	By voluntary procedure
Proponents	Leftist political parties and socialisation Committee of 1946–50	State-owned power company IVO	Power Committee of 1944–7	Private electricity producers and political parties on the right
Claimed advantages of the reform	– Planned and sufficient growth of electricity generation – An annual increment of 65 TWh due to interconnection	– Annual growth of 65 TWh due to interconnection – Nationwide equal prices for electricity	– Flexible interconnection: annual growth of 65 TWh due to interconnection	– Safe solution: good experience during the interwar years – Low electricity prices because of competition

Source: KM 1947:3 Voimatalouskomitean mietintö (Committee Report) (Helsinki, 1947) pp. 61–8.

business of electricity supply. They wrote a common dissenting opinion to the committee report, while Alftan worked out his own.[358]

In early postwar Europe, demands to nationalise industry and the energy sector gained strong support in many countries. France and Britain, in fact, nationalised their electricity supply industry between 1946 and 1948.[359] These kinds of aspirations also affected the Finnish political climate; even before the Power Committee had published its report, the government nominated a new committee 'to study and plan the taking into public possession appropriate sectors of the economy'. This committee is known as the 'Socialisation Committee', although the committee itself regarded this name as theoretically incorrect. By contrast, it preferred some other, more appropriate concepts, such as 'nationalisation' or 'compulsory purchase for public needs'.[360]

In its report, the new committee presented a much more radical scheme than the compromise proposal of the Power Committee. It put forward the nationalisation of hydropower resources, private power plants, transmission lines with 100 kV or over and inefficiently managed private distribution utilities. Nearly all electricity generation and high-tension transmission were to be centralised under the control of the new company, 'State Power Company' (Valtion Voima Oy). The government was to own at least 75 per cent of its shares.[361]

Neither of the two committees received sufficient support for their proposals. Neither 'Trunk Line Co.' nor 'State Power Co.' was ever set up. In late 1949, when the centralised wartime electricity supply system was abandoned, the existing ownership relationships remained unchanged. In late 1952, with a vote of 96 against 89, Parliament rejected the bill which sought to nationalise the power sector and establish 'State Power Co'. The bill was put forward by the Social Democratic MP Vilho Väyrynen and 29 other MPs.[362]

Although the proposals of the committees were not carried out, they were not unimportant for later development. Both state-owned and private power companies followed some of the committees' recommendations as precepts in their practical activities for more than a decade.[363] For example, owing to the rapid expansion of the Imatran Voima Oy and its affiliated firms, the government-led companies managed to gain control of most of the functions planned for 'Trunk Line Co'. By 1963 the IVO-group had acquired 51 per cent of the 110 kV lines and all the lines with a higher voltage (220 kV and 400 kV).[364] In the mid-1960s, the government-controlled companies also generated over half, about 52 per cent, of all electricity output in Finland.[365]

By the mid-1960s, all Finnish power plants were interconnected. The threat of nationalisation very likely stimulated the development of the significant co-operation and interconnection between private and state-owned power companies.[366] The ownership of power plant capacity was still divided among several producers, but a system of agreements between them was claimed 'to ensure an almost optimum utilisation of the total capacity. Overall schedules were planned to ensure that as great a part of the consumption as possible was covered by hydroelectric production.'[367]

The Building Programmes for Hydropower

To replace the generating capacity ceded to the Soviet Union and meeting the predicted growth of electricity demand, the Power Committee of 1944–7 proposed that the current hydroelectric capacity of 2500 GWh p.a. should be increased to 4600 GWh p.a. by the end of 1950.[368] The committee report showed that eight hydroelectric plants were already under construction and they would increase electricity generation by 1847 GWh p.a. Four of these building projects (at Kolsi, Kuusankoski, Merikoski and Pyhäkoski) had been begun during the war and the rest immediately after the armistice. The committee proposed starting two new, large hydroelectric projects in 1948–50. Moreover, they recommended that extra hydroturbines should be installed in a dozen plants and the regulated flow of watercourses should be extended. Finally, the committee suggested the building of two thermal power plants with 30 MW turbogenerators in each, and an efficient nationwide interconnection between power plants.[369]

The programme could not be carried out punctually according to the schedule, for by the end of 1950 the generation potential of hydroelectric plants had only grown to 4160 GW per annum. However, in February 1952, the objective of the programme, an output potential corresponding to 4600 GWh p.a. was achieved. By then twelve new hydroelectric plants and the extension of the Imatra power plant were in operation. In total, 27 new turbine units with a capacity of nearly 390 MW were completed, as indicated in Table 2.16.[370]

According to plans of 1944–5 it was expected that by 1951 at the latest the supply and demand of electricity would be in equilibrium. As a result of unfortunate coincidences, the country was then, nevertheless, on the brink of a new crisis. In November 1951, concurrently with a long-lasting drought, the three large outdated steam turbines broke down at the Suvilahti power plant in Helsinki.[371] Hence, the municipal electricity utility (MESUH) was deprived of almost all its local generating capacity. Because the rest of the country could not fully compensate for the lost capacity, street lighting was cut by half and the electricity consumption of trams was reduced. The rationing of non-industrial electricity consumption was planned to begin from 1 January 1952.[372] To conserve electricity for other purposes, ten of Finland's dozen groundwood mills (all but two small units) discontinued their operations, owing to the national electricity shortage, which was estimated to cause the loss of export income totalling about current FIM 918 million during October–December.[373]

Thanks to abundant rain, a mild winter and the repair of broken steam turbines, the crisis was fortunately passed as early as December 1951.[374]

The economic planning council prepared for the government two or three more building programmes for hydropower for the 1950s. Being targeted schemes, they were not as detailed as the first one. In the course of time, the government increasingly began to delegate the planning and responsiblity for a sufficient electricity supply to the state-owned and private power companies. The development of the supply system depended on oligopolistic competition between private and state-owned companies, and continually increasing demand. The government and its credit institutions, however, continued to support the building of new power plants.[375]

Because nearly all big rapids in southern Finland had been harnessed for power generation during the interwar period, the postwar construction of new hydroelectric plants concentrated on the three northern watercourses: Oulu, Kemi and Ii. By 1957 seven plants had been built between lake Oulu and the Gulf of Bothnia, and by 1963 nine other plants were commissioned on the upper tributaries of the watercourse Oulu. Together, these plants could produce 2550 GWh per annum. To increase power generation, an efficient regulation of the whole watercourse was introduced. The natural conditions for this were good, because lake Oulu contained a large water reservoir of 2340 million cubic metres. The flow of the watercourse could be fully adjusted to follow the annual variations of the load. Between 1940 and 1954 the city of Oulu built the Merikoski power plant at the mouth of the river. All the others were set up by Oulujoki Oy, a subsidiary of Imatran Voima Oy.[376]

The river Kemi is 600 km long and has a huge catchment area of 51 000 sq. km in Finnish Lapland. It was the largest single source of energy in the country. Its estimated hydropower resources are 5700 GWh a year, but owing to the small lake area, the flow varies greatly.[377] Because of its remote location, no attention was paid to the river Kemi by power companies before the Second World War. The power plants in southern Finland could supply enough electricity for industry during the interwar years. The power potential of the north was, however, researched and evaluated. When the fortune of the Finns in the Continuation War changed, the potential of the river

Kemi was reconsidered. From the winter of 1942–3, some 'farsighted directors in the wood-processing industries' anticipated territorial losses in south-eastern Finland. They saw that new power plants in the north could compensate for the cessions in Karelia. The director general of Yhtyneet Paperitehtaat Oy (United Paper Mills Ltd), Rudolf Walden, was then acting as Finland's defence minister. He sent the head of the building department of the company, Erkki Aalto, to buy domains with riparian rights on the river Kemi for the company. 'On the dark winter days, but in a short period, Erkki Aalto with two companions, surveyor Väinö Taskinen and forester Jarl Sundqvist, bought nearly all the rapids between Rovaniemi and lake Kemi. The men rode by horse-drawn sleigh with a suitcase full of bank notes and briskly did good business.'[378]

With seven other wood-processing companies, Yhtyneet Paperitehtaat Oy established a new private power company, Pohjolan Voima Oy (Northern Power Ltd) in July 1943. Erkki Aalto was nominated its managing director and during the following decade he became famous as a vocal advocate and industrious planning engineer of hydroelectric power plants.[379] The company, however, built only two hydroelectric plants on the river Kemijoki. The first, at Isohaara, was another example of good business. The company applied for permission to build a dam which would form a framework for both a power plant and a traffic bridge at the spot where the German troops destroyed an important railway and highway bridge in October 1944. The company had to pay only for the machine house and plant machinery (310 GWh p.a.), because the government decided to finance the construction of both the dam and traffic routes at Isohaara at the mouth of the river. The other plant, at Jumisko (98 GWh p.a.) was completed five years later in 1954 in the upper tributaries of the river Kemi.[380]

All the other eight power plants on the watercourse were built by a government-owned company, Kemijoki Oy, by the year 1976.[381] This company was set up in 1953 after a heated debate in Parliament. On the one hand, it was defended as a rational building and operational scheme utilising the state's 37 per cent ownership of all rapids along the river Kemi. On the other hand, the company was seen as a plot 'to infiltrate socialism into the country'.[382] The most influential proponents of Kemijoki Oy were the chairman of the former Socialisation Committee and acting social democratic minister of trade and industry Penna Tervo, and the prime minister and the member of the central board of the Agrarian League, Urho Kekkonen.[383] Their

pivotal argument for the government's involvement was that private companies did not have enough capital to build such a series of power plants in reasonable time.[384]

Proponents denied similarities with the development in the Soviet Union, but by contrast they referred to experiences of 'the thoroughly capitalist country, the USA, where the government has been carrying out large building projects of power plants', such as in the Tennessee Valley, Grand Coule and Bonneville. In a parliamentary debate, Kekkonen cited a recent statement of the contemporary democratic governor Adlai Stevenson: 'Such projects were unattainable for private enterprise. If the government had not built these, they would not have been built at all.'[385]

With sharp irony, Kekkonen made fun of the obstinate opponents of 'the rational, co-ordinate utilisation of the river Kemi', arguing that 'Vladimir I. Lenin was still terrifying them with his slogan: *Communism is Soviet power plus the electrification of the whole country*.[386] And of course, any bright political thinker easily deduces from such a slogan that the electrification of the country leads to communism.'[387]

The Pohjolan Voima Oy bartered its riparian rights on the river Kemi with the government's riparian rights on the river Ii and built five hydroelectric plants each with an average capacity of 32 MW in the 1950s and 1960s. The annual hydropower resources of this river are 1500 GWh p.a. of which about 900 GWh p.a. became harnessed by 1970.[388]

In Finland as a whole, hydropower capacity increased between 1945 and 1965 from 430 MW to 1925 MW; that is, by a factor of 4.5, and hydroelectricity output by a factor of 3.4. The annual growth rate of hydroelectric production was 6.3 per cent on average, while the total electricity generation grew as much as 8.1 per cent per annum.[389]

Problems of Hydropower Building

The construction of the first postwar power plants faced many difficulties. First, there was a lack of building materials and machines, and even of skilled labour. Second, the power companies found it hard to raise funds for their projects. Third, the acquisition of electrical machinery, especially generators and transformers, constituted problems, too.

The years of reconstruction meant an epoch-making period in the technological reorientation of Finland. Instead of going to its former main suppliers of technology, Germany and the rest of the Continent, the country turned its interest to the USA and Britain. Finnish power companies were willing to import versatile and efficient American and British building machinery for hydroelectric projects. They started by purchasing big trucks from the surplus stocks of the US Army in Europe. Not until 1947 were they able to acquire the most modern universal excavators, drilling machines, dredging machines, dump trucks, bulldozers, etc. Earlier American authorities had opposed the exportation of up-to-date technology to Finland claiming that the machines would be reshipped to the Soviet Union.[390]

Finnish builders quickly learnt to use imported machines which they proudly presented to journalists and other visitors.[391] In 1950 the Oulujoki Oy, for example, bought a universal excavator from the American Marion Power Shovel Co. This machine with the weight of 545 tons was claimed to be the largest of its kind in Europe at the time. Bruce Leeper, the American engineer who came to Finland to direct the installation of the giant excavator, recognised the efficiency of the Finns. According to him, they managed to assemble the excavator in one and a half months, whereas a similar job had taken three months in the USA and five months in France.[392] Due to the up-to-date machinery and the rational organising of the construction works, the building of northern power plants was said to proceed 'at the American speed'.[393] Power plants were built in a series, by moving specialised teams of skilled workers and machinery from one construction site to another after the completion of each building phase according to co-ordinated schedules. Despite the more severe conditions and greater earthmoving tasks, the building of postwar hydroelectric power plants took only 3–5 years compared with eight years spent in erecting the Imatra plant in the interwar period.[394]

Delays in the deliveries of generators, transformers and other electrical equipment constituted the principal reason for the postponement of hydropower projects in the 1940s.[395] For those plants, the building of which was commenced during the war, the generators were orderd from Germany, but they were not received before the rupture of relations in 1944. This caused a lot of trouble for the Finnish power economy. In Europe just after the war there was a great demand for electrical equipment and it was hard to find a generator supplier capable of delivering a unit in a short period. Finnish power companies invited bids from several countries and sometimes generators for the same power plant had to be ordered

Table 2.16 The acquisition of generators for the hydroelectric plants of the first postwar building programme in Finland

Power plant, and its owners*	*Unit*	*The year of completion*	*Capacity MW*	*Manufacturer*	*The country of origin*
Kolsi, Nokia Oy and Ahlström Oy	1.	1945	12	Strömberg Oy	Finland
	2.	1949	12	Skodawerken	Czechoslovakia
Kuusankoski, Kymin Oy	1.	1946	10	Siemens/Strömberg	Germany/Finland
	2.	1949	10	ASEA	Sweden
	3.	1951	10	,,	,,
Merikoski, Municipality of Oulu	1.	1948	11	ASEA	Sweden
	2.	1950	11	Strömberg	Finland
	3.	1953	11	AEG	West Germany
Isohaara, Pohjolan Voima Oy	1.	1948	20	Westinghouse	USA
	2.	1949	20	,,	,,
Tainionkoski, Enso-Gutzeit Oy	1.	1949	13	Metropolitan-Vickers	England
	2.	1949	13	,, ,,	,,
	3.	1950	13	,, ,,	,,
Pyhäkoski, Oulujoki Oy	1.	1949	36	ASEA	Sweden
	2.	1951	36	General Electric	USA
	3.	1951	36	,, ,,	,,
Jylhämä, Oulujoki Oy	1.	1950	16	Oerlikon	Switzerland
	2.	1951	16	,,	,,
	3.	1952	16	,,	,,
Mankala, Municipality of Helsinki**	1.	1950	8	Strömberg Oy	Finland
	2.	1951	8	,,	,,
	3.	1952	8	,,	,,
Hartolankoski, Tyrvään Voima Oy	1.	1950	6	Strömberg Oy	Finland
	2.	1951	6	,,	,,
Katerma, Kajaani Oy	1.	1950	7	(Westinghouse)	USA
Imatra, Imatran Voima Oy	7.	1951	26	General Electric	USA

* The programme also included two smaller plants, Valkeakoski (3 MW) and Mustio (3 MW) both of which were completed in 1951.
** Tampella Oy, Enso-Gutzeit Oy and the municipality of Kotka owned together 34 per cent of Mankala's shares.

Sources: *Waterpower in Finland*, ed. by R. Salokangas (Tampere, 1969) pp. 22–7; *TAik* (1946) p. 136; *Talouselämä* (1947) pp. 265–76, (1947) p. 799; *Finnish Trade Review* (1947) no. 48, p. 20; *VV*, 23 (1950) no. 2, p. 30; *Vapaa Sana* 2.11.1952.

from different manufacturers, as shown in Table 2.16.[396] Nor was it rare for bids to be reinvited, because the government's Licence Board refused to grant an import licence to some power companies on the basis of their first application. The problems in gaining import licences for foreign equipment impeded most of all the municipal Merikoski hydroelectric plant in Oulu.[397]

The realisation of the first hydroelectric building programme cost FIM 30 000 million at the current prices. About one-quarter of this sum consisted of outlays in foreign currency needed for the importation of machines, steel and other materials. Because of the depressing shortage of currency and Finland's weak position on the international credit market, various arrangements were applied to finance the acquisition of foreign machinery. In many cases, foreign credits were obtained for the orders of vital machinery placed in the USA, Britain, Switzerland and Sweden. For example, a part of the American loan totalling $35 million was used to purchase US-made generators and turbines for the Isohaara power plant. The British generators and transformers for the Tainionkoski and Pyhäkoski power plants were, in turn, paid for by exporting mainly sawn timber to the UK according to the intergovernment trade agreement.[398]

During the 1950s, the sole Finnish manufacturer of generators, Strömberg Oy, was able to extend its production, while the importation of machinery was also eased. The acquisition of machinery gradually ceased being a serious obstacle in hydropower projects. About 33 per cent of the hydroelectric generating capacity in use in 1965 was manufactured in Finland. The Finnish company, Tampella Oy, supplied most of the hydroturbines installed in the country during the postwar period. From the mid-twentieth century, all kinds of power plant machinery could be made in the home country except steam turbines.[399]

In Finland, foreign trade was strictly controlled up to the late 1950s. Imports were limited owing to the lack of foreign currency. This kind of rationing also influenced hydropower projects. However, the financing of new plants gradually became their central problem. Between 1945 and 1965, the main credit sources were the direct financing from the state's budget and loans from the government's financial institutions. The electricity undertakings received more than three-quarters of all their loans from these sources. The role of private credit institutions was modest. Similarly, the proportion of foreign loans was small; only about 2 per cent of the total loans.[400]

Besides credit institutions, the government granted so-called construction and unemployment loans to state-owned as well as private power companies.[401] In the government's policy, northern hydropower projects had three objectives: (i) to increase the electricity supply in the country, (ii) to recruit local people in these projects thereby alleviating high unemployment in the north, and (iii) to promote industrialisation in the provinces of Oulu and Lapland.

State-owned plants increased their share of generated hydroelectricity from 30 per cent to 50 per cent between 1945 and 1957. The rapid growth of the government-led power companies was partly caused by the fact that the government had owned a large share of the country's unharnessed water power resources for decades before the truce. The government-led companies also had better credit facilities than private enterprises and this gave the former the opportunity to build several power plants simultaneously.[402]

The Formation of the Big Power Companies

In the mid-1940s, Finland had only two substantial companies whose primary task was electricity generation. These were the government-owned Imatran Voima Oy and the private company Länsi-Suomen Voima Oy (West-Finland Power Ltd). The plant of the third big interwar power company, Oy Rouhiala Ab, was ceded to the Soviet Union in 1944. The majority of electricity undertakings were mainly power distributors. Many wood-processing concerns were, in contrast, considerable electricity producers and sellers as well. The extensive building on northern rivers led to co-operation between the major electricity consumers and the setting-up of large power companies.[403]

The Imatran Voima Oy (IVO) was founded in 1932 to operate the hydropower plant on the river Vuoksi in south-eastern Finland. The government has wholly owned it from the outset. Over the decades, IVO developed into a large parent company with many affiliated firms. The operations of subsidiaries were quite tightly co-ordinated with IVO's activities.[404]

Harnessing the river Oulu began after a long preparation. Since the beginning of this century, the utilisation of the river's hydropower had been studied, planned and recommended. The government slowly continued to buy domains along the river, while resolutions were passed in Parliament urging the building of the Oulu power plants with public funds.[405] The Winter War gave a new impetus to this project. A new company, Oulujoki Oy, was established in 1941 and it started to construct the Pyhäkoski power plant. From the very beginning, Imatran Voima Oy was the biggest shareholder of the new company and during the four decades prior to 1980, its proportion of

Oulujoki Oy's shares rose from two-thirds to 91 per cent. The rest has been owned by private industrial concerns, Tampella Oy, A. Ahlström Oy and Yhtyneet Paperitehtaat Oy according to their domain assets on the river.[406]

The Pohjolan Voima Oy (Northern Power Ltd) was set up in 1943 to supply electricity to its share-holding wood-processing companies. By 1977 it had built ten hydroelectric power plants. At the end of the 1940s nine companies possessed equal portions of its capital stock. In the 1970s, seven private and three state-owned companies owned each about 10 per cent of the Pohjolan Voima Oy's capital stock.[407]

In 1953 the Kemijoki Oy was established by three share holders; the state (51 per cent) and two government-owned companies, Imatran Voima Oy and Veitsiluoto Oy. Later, Yhtyneet Paperitehtaat Oy, the Municipality of Helsinki and Tampella Oy obtained minor portions of its capital stock. They bought their shares by selling their riparian rights on the river to Kemijoki Oy. In the late 1970s the government directly owned 82.5 per cent and the Imatran Voima Oy 16 per cent of the company's capital stock.[408] Kemijoki has regularly sold 80 per cent of its output to IVO, whilst Oulujoki Oy has correspondingly sold 85 per cent. Therefore, the Imatran Voima Oy has for a long period transmitted over a half of the country's electricity.

The coppermining company Outokumpu Oy and the wood-processing concern Enso-Gutzeit Oy together established the Pamilo Oy in 1943 to build and utilise two hydroelectric plants on the river Koitajoki in eastern Finland. The project met many obstacles and the construction of power plants was not even started. The power company was reorganised ten years later. Then its capital stock was redivided between the share holders as follows: Enso-Gutzeit Oy 60.5 per cent, Imatran Voima Oy 27.3 per cent Outokumpu Oy 6.6 per cent, and a private company, Oy Kaukas Ab, 5.6 per cent. The building scheme was also revised and instead of two power plants the company completed in 1955 one larger plant, the Pamilo, with the potential of 230 GWh in average water conditions.[409]

To sum up, four groups of electricity producers have emerged in Finland as a result of the growth of electricity supply:

(1) The government-led companies, such as Imatran Voima Oy, Oulujoki Oy, Kemijoki Oy and Pamilo Oy.
(2) The power companies owned primarily by private industry, e.g. Pohjolan Voima Oy and Etelä-Suomen Voima Oy.

(3) Self-generation by wood-processing industries which possessed their own hydroelectric plants and thermal electricity generation linked to waste burning and the production of steam for their processes.
(4) The electricity utilities of municipalities. Among the largest of these are the electricity utilities of Helsinki, Tampere, Oulu, Lahti and Kuopio.[410]

Many of the electricity undertakings set up since the 1930s are, however, not purely privately or government-owned, most of them being mixed companies. Who possesses the majority of capital stock in the mixed companies decides whether they are called privately-led or government-led companies in Table 2.17.

Since the 1910s, there has been a clear trend towards concentration in the Finnish electricity supply industry. From the 1930s to 1965 hydroelectric production has been rather concentrated: the three largest companies have produced about a half of the total hydro-

Table 2.17 The ten largest thermal power and hydropower producers of electricity in Finland in 1965

Hydropower			
Company	*Owner*	*Output* GWh	*Of the total output* %
Oulujoki Oy	G	2285	22.4
Kemijoki Oy	G	2098	22.4
Imatran Voima Oy	G	840	9.0
Pohjolan Voima Oy	P	837	8.9
Enso-Gutzeit Oy	G	377	4.0
Kymin Oy	P	368	3.9
Länsi-Suomen Voima Oy	P	320	3.4
Pamilo Oy	G	264	2.8
The Municipality of Oulu	M	182	1.9
Kajaani Oy	P	164	1.7
Sum		7733	82.7

Thermal power			
Company	*Owner*	*Output* GWh	*Of the total output* %
Enso-Gutzeit Oy	G	514	11.3
The Municipality of Helsinki	M	447	9.8
Kymin Oy	P	337	7.4
Outokumpu Oy	G	313	6.8
Oy W. Schauman	P	197	4.3
Oulu Oy	P	165	3.6
Oy Kaukas Ab	P	165	3.6
Kemi Oy	P	157	3.4
A. Ahlström Oy	P	155	3.4
Veitsiluoto Oy	G	154	3.4
Sum		2059	61.7

G= Government-led company.
M= Municipal utility.
P = Private company.

Source: *Sähkölaitostilasto v. 1965* (Helsinki, 1967).

electric output. In thermal electric production, the ten largest companies generated 50–64 per cent of the total. The government-led companies rose to the dominant position: their share was 64 per cent of hydroelectricity, 29 per cent of electricity generated by thermal power plants and 52 per cent of the total generation in 1965.[411]

Thermal Power

In early postwar Finland, indigenous hydropower and the back pressure plants of industrial companies were preferred to condensing power plants which were using primarily imported fuels. Nevertheless, it was necessary to build new condensing power plants for reserve in case of drought and for peak periods. At the time, the price of coal and other fuels was, however, so high that thermal power plants were not competitive with hydroelectric plants. This fact hampered investments in those plants. Among the first few condensing power plants were the units of IVO (Vanaja) and of the Municipality of Helsinki (Salmisaari), both 30 MW, commissioned in 1952 and 1953 respectively.

When in the second half of the 1950s the world prices of fossil fuels suddenly fell to as low as a half of their average level in the immediate postwar years, condensing power capacity began to grow rapidly in Finland.[412] The most important was IVO's condensing power plant in Naantali; its first turbogenerator of 125 MW became operational in 1960 and the second unit of 133 MW in 1964.[413] Consequently, the average fuel costs per kWh of thermal power rose, because electricity was generated in condensing power units at a lower thermal efficiency than in back-pressure plants which were formerly primarily used for the generation of thermal electricity. Since their thermal efficiency was merely 20–25 per cent in the 1940s and 1950s, the condensing power plants were still mainly used in the last resort. The preference to utilise hydropower and back-pressure power led to the very low load factor of condensing power which was one of the features which long characterised the Finnish electricity supply system.[414]

Since the early twentieth century, Finland has been one of the leading utilisers of back-pressure technology in the world. During the late interwar years, for example in 1938, about 80 per cent of electricity was produced by hydropower, 15 per cent by back-pressure and only 5 per cent by condensing power. The respective percentages were 84 per cent, 8 per cent and 8 per cent in 1946 when the recession of the wood-processing industry hampered the exploitation of back-pressure power. In the 1950s and 1960s, that particular

industry heavily invested in new back-pressure plants. In 1964, which was abnormally dry, the corresponding percentages were 63 per cent, 26 per cent and 6 per cent of the total electricity supply. The rest, 5 per cent, consisted of electricity imports.[415]

In the mid-1960s, when fully utilised, the generation capacity of back-pressure plants would have sufficed to cover a third of the country's power demand. The large amount of back pressure available is due to the predominance of the wood-processing industries in the Finnish economy. These industries require great quantities of low-pressure steam. The custom was to generate steam in the high-pressure boilers and feed it into the production plant through back-pressure turbines. In the early 1960s, 60–120 atmosphere pressures were introduced in most boiler plants in the wood-processing industries. Technological change of this kind together with the swift growth of the industries in question caused the steep rise in back-pressure capacity, the total thermal efficiency (70–80 per cent) of which was even triple compared to that of condensing plants.[416]

District heating is another characteristic application of back-pressure technology in Finland. In the 1950s, a change began from central-heating plants serving one house or a group of houses to the district-heating of larger areas. Technologically, this meant a shift from hot-water boilers to high-pressure steam boilers. The steam produced by these was led through back-pressure turbines into heat exchangers in which it yielded its heat by condensation to the water circulating in the buildings. This heating system allowed considerable savings in fuel costs. If we compare combined heat and power (CHP) with normal condensing power, which generates electricity only, and then allows heat to be lost by transferring it to cooling water, the economies of CHP are clearly seen from the energy balance shown in Table 2.18.

Like many other Finnish district heating experts of the 1970s, Gunnar Smeds, the deputy mayor of Helsinki, claimed that the thermal efficiency of conventional condensing power production was 38 per cent, while that of CHP was as high as 85 per cent if electricity generation and district heating are summed up (see Table 2.18). In the district-heating plants, a given amount of fuel provides heating with a high efficiency and also produces a substantial quantity of electricity. This fact, together with the opportunity to use cheaper fuels, has enabled district heating to compete successfully despite heavy investments in plants and distribution networks. The production of district-heating power led to a highly centralised system in an area. Due to the opportunities of multifuel combinations, it is, *Table* 2.18 The thermal efficiencies of condensing and back-pressure power in Finnish district heating plants in the 1970s

	Condensing power %	*Combined heat and power* %
Energy input from fuel to the power plant	100	100
The distribution of energy use in the plant:		
Boiler losses	10	10
In-plant consumption	5	5
Power yield for electricity generation	38	27
Heat yield for district heating	–	58
Heat losses through cooling water	47	–

Source: G. Smeds, 'District Heating and Energy Conservation', *Finnish Trade Review* (1979) no. 1, p. 10.

however, more flexible than, for example, a central-heating system with oil, coal or gas firing limited to one fuel only.[417]

The National Grid and International Co-operation in Transmission

During the decade of the 1940s, there were two separate long-distance transmission systems, private and government-owned grids, which both extended from south-eastern Finland to the western coast. Although they had parallel lines with branches crossing the other line in few places, they did not constitute a proper interconnected system.

Alongside the other inducements, the electricity shortage and the construction of hydroelectric power plants in the north acted as a spur to developing a real interconnected national grid. These plants demanded an extensive power transmission to the south where the electricity deficit and the growth of demand were most swift. Consequently, the Finnish transmission system began to develop rapidly from 1949. In that year, a new line connected Pyhäkoski, the second power plant on the river Oulu, to the high-tension network of the Imatran Voima Oy in south and south-eastern Finland.

The private transmission system jointly owned by wood-processing concerns and private power companies also expanded substantially from 1949. Its trunk line then extended along the western coast from the new Isohaara power plant through Oulu–Kokkola–Harjavalta–Helsinki to Kyminlinna in the south. The trunk line was augmented

by many branch lines. Besides Isohaara (310 GWh p.a.), other big hydroelectric power plants connected to the system were Merikoski (190 GWh p.a.), Harjavalta (400 GWh p.a.), Kolsi (150 GWh p.a.) and Abborfors (110 GWh p.a.).[418]

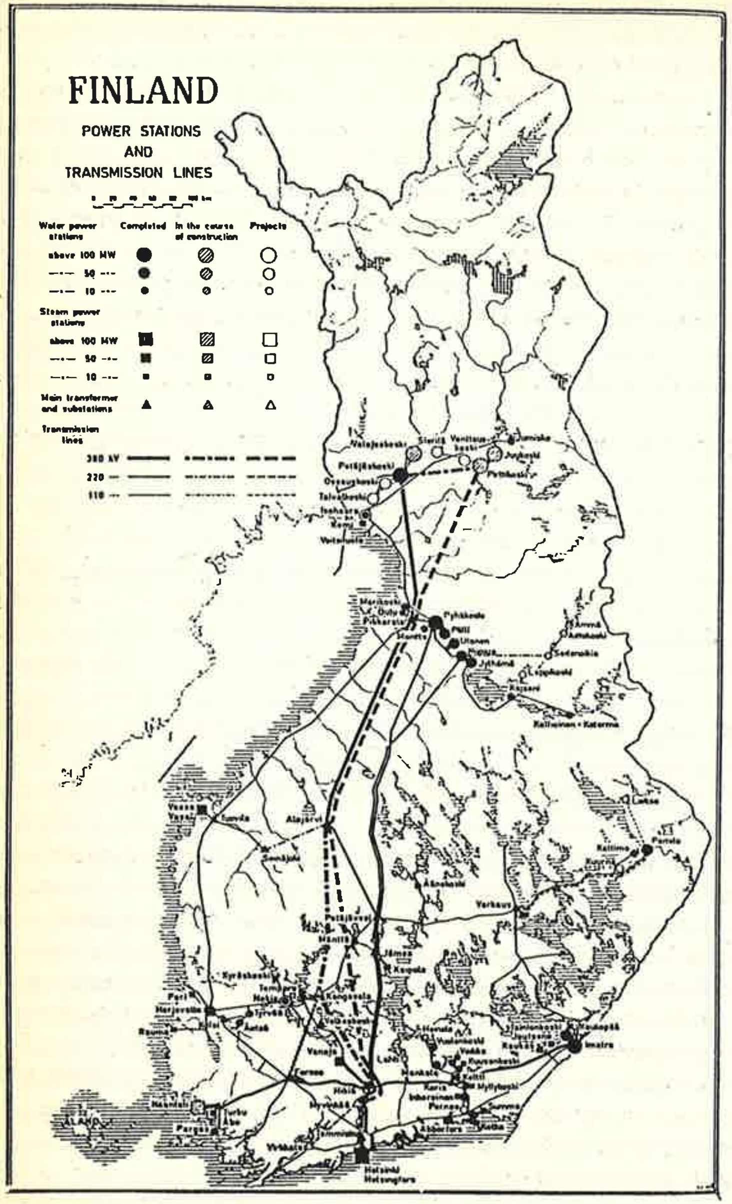
Up to the early 1950s, there was only one direct link between the government-owned and private grids and that was at Koria near the mouth of the river Kymi. This was for a long time based on a temporary installation, but was still considered functional. The two grids, however, had few indirect links through major consumers such as the municipal electricity supply utilities of Helsinki and Tampere, and such large industrial plants as Kymi and Myllykoski, i.e. these could buy electricity from both grids and in an emergency also transmit power from one grid to the other by means of using an intermediate voltage.[419]

The entire long-distance transmission system was operated at 110 kV up to September 1951 when a new higher tension of 220 kV was introduced into the north–south line between the Pyhäkoski hydroelectric plant and the Petäjävesi sub-station. Technologically, this was a demanding move; at the time such high voltage had been adopted in only a few countries. Apart from one exception, 220 kV had, in fact, been the highest transmission voltage in the world for thirty years.[420]

Transmitting electricity from the Arctic Circle to the industrial centres in southern Finland was a new challenge for the country's technological expertise because there were considerable quantities of energy to transmit, and the distance of 500–800 kilometres was one of the longest transmission spans in Europe at the time. Imatran Voima Oy estimated that the annual volume of energy to be transmitted from the north to the south would grow to 6.5 TWh and the transmission peak to 1300 MW by 1970. On these premises two comparable transmission systems were simulated. One was completely based on the voltage of 220 kV, and other on a mix of 400/200 kV. The calculations were checked by engineers of the French national power company in Paris with an experimental network model in 1953. The results indicated that in the alternative of 400/220 kV investments were 20 per cent lower and annual operation costs about 25 per cent lower due to smaller transmission losses. On the basis of the research, Imatran Voima Oy decided to build a new north–south high-tension line at 400 kV in 1954.[421]

Finland was only the sixth country to decide to adopt the tension of 400 kV for transmission. At that time, operational experience abroad with high-tension lines of this kind was very limited. However, the

Map 2.3 Major power plants and transmission lines in Finland in 1959



Source: Gunnar Lax, 'Suomen rakennettu vesivoima', *Voima ja valo*, 32 (1963) no. 7–8, p. 152.

Finns extensively exploited R & D results from foreign experimental lines. It was only in 1953 that Sweden, the pioneer in this endeavour, had put its own 400 kV line in operation at full voltage. In the Soviet Union, the first line of this kind was introduced in 1956. Similar lines were also under construction in France, West Germany and Switzerland.[422] In Finland, the first line was completed in 1956. For four years, however, it operated with a tension of 220 kV. When the entire line of 760 km from the Petäjäskoski power plant in Lapland to Hyvinkää in the vicinity of Helsinki was completed in August 1960, the full tension of 400 kV was switched on.[423]

The length of high and medium tension lines trebled between 1945 and 1965, as shown in Table 2.19. The average growth rate of mileage

Table 2.19 Medium and high tension lines with overhead cables in Finland, 1945–65

Voltage kV	1945 km	1950 km	1955 km	1960 km	1965 km
400	–	–	–	758	758
220	–	–	1040	1429	1635
110	1677	3060	4012	4620	5547
70	260	181	159	157	108
35–45	1035	1964	2458	2878	3202
10–20	12471	23628	37357	44270	53425
3–6	4888	4751	3691	2853	1913
Total	20331	33584	48717	56965	66588

Source: *Sähkölaitostilasto v. 1946–1965* (Helsinki, 1947–67).

was annually 6.1 per cent. During this period all major industrial and population centres were connected to the national grid. At the same time, operational security improved. In southern Finland, the inter-war radial transmission network of 110 kV was replaced by a loop structure; by this means sub-stations could receive electricity via two or more lines. Occasional damage or disturbances to high-tension lines, therefore, did not cause a break in distribution.[424]

The threatened shortage of electricity in the mid-1950s led to negotiations with Sweden about the exchange of power. When the grids were extended northward in both Finland and Sweden, they closely approached each other, and connecting them became possible without great expense. In Finland, some juridical obstacles had first to be removed, for the law of 1919 prohibited the export of electricity on a large scale. The required amendment passed through parliament in December 1957, and in the following February, Imatran Voima Oy and the Swedish Kungliga Vattenfallstyrelse (The Royal Board of Waterfalls) signed an agreement on the exchange of electricity for up to 150–300 GWh annually.[425]

One of the reasons for the agreement was that occasionally Swedish hydroelectric plants had earlier been forced to drain off surplus water through spillway gates, while Finland had suffered from power shortages due to drought. By exchange, Swedish surplus resources could be utilised for Finnish energy needs, and conversely a part of the Swedish demand could be met by the Finnish surplus. The sub-station at the Petäjäskoski power plant was connected to Kalix in Sweden with a new high-tension line of 220 kV over the river Tornio on the border. The interconnection of the Finnish and Swedish national grids started when this transmission line was commissioned in April 1959. As time passed, the volume exchanged increased greatly.[426]

The ties between Finland and Scandinavia were intensified by a new agreement in 1963. The largest power companies (not governments) of the five Nordic countries founded NORDEL, an organisation to promote mutual technological and economic co-operation in electricity supply. By means of NORDEL power exchange was extended to cover four countries: Denmark, Finland, Norway and Sweden. The exchange of electricity produced by a surplus generating capacity and the joint utilisation of the power plants with the lowest costs have produced savings and mutual benefits in the Nordic countries ever since. Nordic interconnection also enabled them to economise on investment in reserve capacity; and NORDEL-co-operation has increased the safety and stability of electricity supply in the member countries. A failure, even in a large power plant, no longer endangered the functioning of the national grid.[427]

Soon after Finland and Sweden interconnected their power systems, the former also made an agreement for electricity importation from the Soviet Union. In 1961 a 110 kV transmission line was completed from the power plants (formerly called Enso and Rouhiala) in Svetogorsk to Imatra. In the 1960s, Finland imported an 180–630 GWh annually through this line. To secure a sufficient supply, Imatran Voima Oy made a new agreement in 1975 on electricity importation (up to 4 TWh p.a.) with the Soviet firm V/O Energomashexport. In 1979 a 400 kV line between Vyborg and Lappeenranta (Yllikkälä) was completed. The power transmission began first with island operation. Only a few years later were the

Soviet and Finnish grids properly linked when a special substation between them was completed after some delay. The substation connected two large AC networks together by converting alternating current to direct current and then back to alternating current. Finnish engineers considered this operation necessary due to safety and the quality of electricity in the Finnish grid. Due to this transmission line Finland became the fourth country (alongside West Germany, Austria and Italy) through which the Western and Eastern European power systems were interconnected.[428]

Concluding Remarks

The postwar hydropower boom in Finland was facilitated by the ample importation of up-to-date Western technology. The orders could be paid for without long-term international loans, because the country was able to export products, such as sawn timber and paper, which Europe under reconstruction badly needed. In the transfer of electrical technology, the domestic power companies and machinery importers had a centre role. Due to the tight regulation of the economy and the co-ordinated building programme of hydropower, the government was also closely involved in the transfer of technology. It can be claimed that nearly all relevant spheres of society were engaged in carrying out large building programmes and in acquiring badly needed technology from abroad for this nationally vital task.

During the interwar years and in the early 1940s, Finland had orientated technologically to German-speaking Europe. For the postwar 'Second Republic', the USA became, by contrast, the primary model country for various technological and organisational solutions such as the construction methods of hydroelectric power plants, the regulation of watercourses, the maintenance of fish stock in harnessed rivers, the organising of government-led power companies, etc. Besides the UK and neutral Sweden and Switzerland, the USA was also an important supplier of building machinery and electrical equipment.

New hydro and thermal power plants were built and owned by domestic companies. By contrast, turn-key deliveries by foreign firms or concessions for direct foreign investments in the electricity supply did not suit the Finnish conduct of the economy. The period 1945–65 not only saw a rapid increase in hydroelectric and thermal capacity, but also a great development in co-operation between electricity producers. All Finnish power plants became interconnected via the national grid, but also the country's entire electricity supply system was interconnected with that of three other Nordic countries. During the same time-span, imports of electric power from the Soviet Union were, in addition, started to supplement the domestic and Nordic electricity supply.

During the period, an intense shortage of power was replaced by quite a balanced electricity supply system with interconnections, an economic mix, the rapid expansion of generation capacity and annual regulation of watercourses. The sufficiency of electricity supply with decreasing real prices boosted the structural transformation and economic growth of the country. Despite the plans inspired by the foreign models, the electricity supply system was not nationalised in postwar Finland. Mixed ownership structure was preserved in the power economy. Nevertheless, Finnish power supply became very concentrated and the government-owned Imatran Voima Oy with its affiliated companies acquired the upper hand in the generation of hydroelectricity and a near-monopoly in high-tension transmission.

2.10 RESTRUCTURING ELECTRICITY PRODUCTION

From a Power and Fuel Policy to a General Energy Policy

In Finland, the generation of electricity was for a long time closely associated with hydropower, because electricity was mainly produced by hydroturbines from the 1920s up to the mid-1960s. Increased demand was met by harnessing new rapids. But ultimately, the most profitable potential hydroelectric sites ran out and thermal power grew in importance. Formerly, the Finnish energy policy was split into separate sections. The utilisation of hydropower was only loosely connected to the fuel supply as a means of ensuring the peak generation of electricity. An adequate fuel supply was related to the problems of foreign trade, indigenous fuels and employment. Furthermore, electricity and space heating were considered to be unrelated to each other. When thermal power plants became increasingly important, electricity generation and fuel problems began to be seen as a single energy issue. A consequence was that a new approach was made in energy policy: electricity supply and the fuel economy were seen as a joint problem for the first time.

After the chronic shortage of electricity was overcome in the 1950s, a new way of thinking evolved in the electricity supply industry. From the 1960s up to the early 1970s, the objectives of the Finnish electricity policy were formulated as follows:[429]

(1) Electricity should be supplied at as low a price and as reliably as possible. As a major consequence of this aim, imported coal and later oil largely replaced the indigenous fuels of wood and peat. An ever larger share of the annual felling volume was utilised as an industrial raw material. The price ratio between indigenous fuels and imported energy was rapidly increasing.

(2) Larger generation units should be built in order to achieve objective 1. Big power plants, it was asserted, supplied electricity at a lower unit price. This objective directed the interest of the supply industry to large condensing plants fired conventionally by coal. In the 1960s oil-fired condensing power plants were favoured, because oil became increasingly cheap. However, the basic solution envisaged to meet the growing demand for electricity was the introduction of nuclear power plants.

(3) Co-operation in the planning and timing of new power plant projects should be developed. Following the American models of 'power pooling', it was proposed that by taking turns at building new generation units, power companies could build larger power plants than without any co-operation. In this way, they could alternately exchange the roles of electricity sellers and buyers.[430]

(4) The country's supply system should achieve an appropriate mix of different types of power plants. Formerly, power companies aimed to build only highly efficient units which generally meant high capital costs. It was soon realised that expensive steam power plants were too costly as idle reserve units. The goal was to build various types of power plants the range of which would be well suited for the fluctuations of the load. By so doing total costs could be optimised. For reserve capacity and peak hours, electricity undertakings should build thermal power plants with capital costs as low as possible. This would be economically profitable although their technical efficiency ratio would be lower. For this reason, gas turbine power plants were built as reserve capacity. The first gas turbine was commissioned in 1962. The total capacity of these prime movers and combustion engines increased from 30 MW in 1962 to 872 MW in 1976 when gas turbine power was also introduced for the longer generation than normal peak load periods due to the shortage of base load capacity.[431]

(5) The volume of the reserve capacity should be optimised. The relative decline of hydropower was automatically decreasing the need

for reserve capacity. Owing to high investment costs, it was reasonable to avoid surplus back-up power plants and the simultaneous construction of large units. The first step was to develop interconnection between Finnish power plants. The second was to derive benefits from international co-operation with other Nordic countries.

The risks of a split approach to energy policy came out strikingly in the early 1970s. The growing share of thermal power compelled the decision-makers to understand the connection between electricity and fuel policy. An urgent need for an integrated energy policy and macroeconomic problem-setting emerged. Then the unexpected oil crisis of 1973/4 came as a shock for Finnish energy policy-makers who had concentrated on a single overriding aim, that of minimum energy costs. In retrospect, the former policy proved to be inadequately formulated. The unbalanced target-setting endangered the security of the national energy supply, narrowed the scope for flexibility and left little room to redirect resources on sudden changes of prices.

The oil crisis led to a reformulation of the objectives of Finnish energy policy. The security of energy supply and rational consumption became essential targets. Without forgetting economy and efficiency, the government set the following new objectives for its energy policy:[432]

(a) the conservation of energy;
(b) increasing the share of indigenous energy sources in the total supply;
(c) improving the efficiency of the management and planning of the national energy economy.

In practice, the government attempted to substitute peat and industrial wastes for imported fuels in the production of heat and electricity. Second, it tried to support the co-generation of heat and electricity, because this method efficiently saved primary energy sources. Third, it reconsidered the options for increasing hydropower production. Fourth, the government started to collect taxes on electricity consumption in order to constrain the growth of electricity use. Finally, in 1975 the Department of Energy was set up in the Ministry of Trade and Industry to plan and control the function of the energy sector in the economy.[433]

The Changing Roles of Hydropower and Thermal Power

In the mid-1960s, specialists estimated the technically exploitable hydropower resources of Finland to be about 18.5 TWh per annum.

By that time, nearly 10 TWh p.a. were already being used for power generation and only another 3 TWh p.a. were regarded as economically viable.[434] When the large hydroelectric projects in progress were completed during the following ten years, virtually all the more profitable building sites for power plants had been utilised. The rest of the exploitable resources situated on rivers were on the national borders or in nature parks or were too expensive to harness. By 1977, the built-up hydropower capacity in average water conditions had increased to 11 TWh p.a.[435]

Hydropower carried the base load in Finland up to the 1960s, while thermal power served as a complementary power source. The demand for electricity, however, increased more rapidly than the supply of hydroelectricity. Gradually, thermal power was used to provide a part of the base load. In 1969 – for the first time since 1920 – more electricity was produced by thermal power than by hydropower. This development changed the use of the hydropower capacity from supplying the base load to acting as a reserve for peak hours. The function was well performed by hydroelectric power plants which were economical for the purpose and very rapidly brought into operation.[436]

With the growth of electricity consumption, daily peaks in demand also rose. The main reasons for this change were the switch to a working week of five days, the relative diminution of shift work and the growth in household consumption. Space heating by night electricity had the opposite impact. The need for a flexibly governed generation capacity, however, considerably increased during the 1970s. It was estimated that the annual duration of the high demand shortened from 5900 hours in 1967 to 5500 hours in 1975.[437]

In 1967 half of Finland's hydroelectric capacity of 2000 MW was in reserve to satisfy the peak demand, while half still generated the base load. The new role for hydropower increased the need for the closer regulation of watercourses and the building of artifical lakes. The country's largest lake, Saimaa, had been regulated since 1948. The best possibilities for regulation were, however, on the rivers Oulu, Emä and Kemi. According to regulation orders, the uppermost and lowest power plants on the river Oulu had to run continuously at least 50 cubic metres per second, but five other plants could be closed at night. This arrangement provided about 100 MW of surplus capacity for twelve hours. The hydroelectric plants on the river Emä, too, were allowed to be closed at night as well. The plants on the river Kemi could be loaded twelve hours by day at a capacity which was

40 per cent higher than the average load. This, in turn, gave 80 MW more capacity for peak hours.[438]

Because the decision to build nuclear power plants met difficulties, the government asked Imatran Voima Oy in co-operation with other power companies in July 1968 to secure the country's electricity supply by conventional technology up to 1975. As a result, IVO built gas turbine power plants in Vanaja, Huutokoski, Loviisa and Naantali, the last of which was completed by 1974. Moreover, the company's advisory board decided in April 1970 to construct a conventional condensing power plant of 1000 MW in Inkoo. Three units, each 250 MW, were completed in the years 1974–6. Between 1965 and 1977, the total capacity of thermal power trebled. It grew from 2000 MW to 6200 MW. All forms of steam turbine power increased rapidly; the most outstanding growth took place in co-generating district heating plants.[439]

The expansion of thermal power in the 1970s proved to be miscalculated: at the end of the decade, Finland had a huge overcapacity. While two big conventional condensing power plants at Naantali (completed between 1960 and 1972) and Inkoo were under construction, preparations were made to start building four nuclear power plants. Power companies could not anticipate the oil crisis and its consequences the most dominant of which was slower economic growth. Together with conservation campaigns, the slackening performance of the economy stopped the increase of electricity consumption for two years (1974–5).

The investment schemes of the companies were planned on much faster growth rates of consumption. In early 1978 heavy oil-fired thermal power plants with a 500 MW capacity (or 9 per cent of the total thermal capacity) stood idle. When nuclear power plants were brought into operation, the new coal-fired Inkoo plant of 1000 MW was left practically unused for some years, while idle plants together accounted for at least a quarter of the total thermal capacity. They were investments yielding a nil return. The situation was opposite to that during the reconstruction period. Now over-investment in the electricity supply, not a lack of power, troubled the sound development of the national economy.[440]

The Extension of the National Grid and Interconnection

The several hydropower plants constructed in the north required extensive high-tension lines to connect the power sources to the main population centres. The north–south high-tension lines began to dominate the Finnish transmission network in the 1950s. In the postwar years, industry gained strength and spread in the country's central districts as well. New thermal power plants were built near the consumption centres and big coal-fired condensing power plants were located on the coast next to import harbours for coal. Nuclear power plants were planned to be situated on the southern and south-western coasts, too. Consequently, within a few years the recently created pattern of the national north–south transmission system no longer corresponded to the emerging new situation. There arose the need for west–east transmission lines as well.

Imatran Voima Oy planned a new high-tension line of 400 kV. This circular line, called the 'Atomic ring', was to connect the most important population and industrial centres in south and central Finland with new condensing, gas turbine and nuclear power plants in that area. The ring was coupled with three 400 kV lines to the plants in northern Finland, and from there by two lines to the Swedish national grid.[441] In the south–east, electric power was also imported from the Soviet hydropower plants near the Finnish border.[442] The opportunities to import electricity both from West and East provided an additional option to secure the reliable functioning of the Finnish supply system.

When conventional condensing and nuclear power caught up with and surpassed hydropower and back-pressure power in terms of capacity in the 1960s and 1970s, the Finnish system of interconnection again needed reforms. Earlier, the exchange of electric power between big electricity producers had occasionally taken place on a rather limited scale, but in the emerging new situation – when thermal power plants began to produce great quantities of reserve power more regularly – the interconnection procedures required special additional costs. To set clear rules for co-operation, Imatran Voima Oy initiated a new solution, the so-called Y/73 system of interconnection based on bilateral agreements between the power companies. This system was set in operation at the beginning of 1973. Furthermore, two years later electricity producers founded the new organisation *Sähkön tuottajien yhteistyövaltuuskunta* (STYV) (The Co-ordinating Council of Electricity Producers). It consists of representatives of government-owned power companies, private industrial firms, private power companies and municipal power companies. The purpose of STYV is to promote and co-ordinate the rational development of the national generation and transmission system.[443]

Upon its creation, STYV promptly recommended the adoption of the Y/73 system in the whole country. By 1976, all substantial electricity suppliers complied with the recommendation and joined the system. As a result Finland, – after a long transitional period – introduced a formal and rather flexible system of interconnection which included extensive opportunities for an economic mix of various power plant types and for co-operation between government-owned, municipal and private power companies.[444] Thus the model the basic idea of which had been proposed by Bernhard Wuolle in the 1910s and 1920s was finally carried out in the unprecedented societal atmosphere of consensus of the 1970s.

The Bumpy Road to Nuclear Power

The year 1955 opened a new era. It was then that the Finns learnt the potential of nuclear technology for energy production. Before 1955 only a handful of scientists in Finland were aware of recent development in nuclear physics.[445]

The whole year was full of events relating to nuclear technology that attracted the attention of the government, businessmen, the press and the public at large. These events culminated in the participation by a Finnish delegation in the first large conference on nuclear power arranged by the United Nations in Geneva in August 1955.[446] 'The International Conference on the Peaceful Uses of Atomic Energy' was epochal for the energy production of the whole world, because the great powers of both East and West revealed a considerable number of formerly tightly concealed research results which were indispensable for planners of nuclear power plants (NPP).[447]

In March, well before the Geneva Conference, the Nobel prizewinner and acting principal of the Academy of Finland A. I. Virtanen proposed an initiative to the government for providing facilities for young scientists to study nuclear physics abroad and for 'setting up a committee for attending to the all-round development of nuclear power technology in our country'.[448]

The government quickly responded. In the same year, it founded the first post of professor of nuclear physics and set up a committee, presided over by professor Erkki Laurila, to investigate the options to meet the country's demand for energy in the future, paying special attention to the utilisation of nuclear power. 'The Energy Committee' presented its report in September 1956.[449] In the following year, Parliament passed a law on nuclear power which gave the right to

Finnish citizens and domestic companies to build and run a nuclear power plant providing it met stipulations on safety.[450]

The Energy Committee considered Finland's own energy resources to be very poor. Limited hydropower resources could meet the growing demand for electricity only up to 1967. The country lacked any fossil fuel deposits. The range of indigenous fuels was composed merely of two basic energy sources: peat and timber. The economic utilisation of peat on a large scale, however, remained an unsolved problem. In 1955 the estimated aggregate fuel consumption corresponded to 9.4 millions tons of coal (i.e. 5.9 Mtoe). Imported fossil fuels, coal and oil, accounted for about 40 per cent, whereas indigenous fuels, wood and wood waste, totalled 60 per cent of the total fuel consumption. An increase in the use of timber as fuel seemed unlikely, partly because wood and wood waste were becoming increasingly valuable as industrial raw materials. The growing fuel consumption was thus expected to be met by imported fossil fuels thereby laying a heavy burden on the country's trade balance.[451]

The committee claimed that fuels were more expensive in Finland than in any other country in Europe. In 1956, industrial fuel costs in Finland were claimed to be about 1.25 times higher than in Sweden, 1.5 times higher than in Britain and 2.5–3.0 times higher than in the USA. Transportation was one of the major reasons for these burdensome costs. Energy problems were relevant to the industry, because in the manufacture of the main export articles, paper and pulp, the fuel costs amounted to about 10 per cent of the selling price. Consequently, nuclear power was seen to offer a promising option for the future energy supply.[452]

The Committee proposed that in the first phase Finland should concentrate on expanding education in nuclear technology. As a result, the government substantially increased teaching in this field in the Helsinki University of Technology and set up a system of research assistantships for postgraduates. Between 1958 and 1962, 38 postgraduates had held these posts. Meanwhile, dozens of students, engineers and scientists were trained abroad in Scandinavia, Britain, the USA, Canada, the Soviet Union and some other countries. Opportunities to undertake research in nuclear power technology improved at home when the first research reactor, the American Triga FiR 1, was commissioned in 1962. Four years earlier, Finland had become the first elected member country of the International Atomic Energy Agency (IAEA) and this facilitated the importation of refined uranium for the reactor.[453]

The year 1955 also boosted Imatran Voima Oy's (IVO) interest in nuclear power. In the late 1950s it attempted to excavate and refine uranium from one of the Finnish deposits, but soon found it unprofitable. In the beginning of the following decade, IVO joined its efforts with Canadian General Electric Ltd to determine the investment and operational costs of a 275 MW Canadian-type power plant under Finnish conditions. The reactor type under research was fuelled with natural uranium, moderated and cooled by heavy water.[454]

The Finns contributed roughly 5000 man-days to this feasibility study and published results in a report of three volumes. The project provided an opportunity for a large number of power engineers in different fields to familiarise themselves with nuclear power technology. The cost analysis of the study indicated that nuclear power might be a competitive form of energy production in Finland, provided the plant could achieve an adequate load factor.[455]

The results increased interest in nuclear power in Finland. Simultaneously in 1965, two companies, Imatran Voima Oy and the private Kotkan Höyryvoima Oy, sent out invitations for tenders for a nuclear power plant to suppliers in various countries. By the deadline (15 November 1965), the IVO received tenders from eight suppliers (AEG, ASEA, Canadian General Electric, General Atomics, General Electric, Siemens, UKAEA and Westinghouse). On the basis of cost analysis, the tenders of AEG, Canadian General Electric and Westinghouse were accepted in the final competition. Besides these three, the Soviet V/O Technopromexport, the British UKAEA and the Swedish ASEA also sent their tenders to the final competition by the due date of 1 November 1966. The management of IVO could not make a final decision. It wavered between the West German AEG's and the American Westinghouse's tenders. It submitted the decision to IVO's owners, the Ministry of Trade and Industry and the government.

The government was irritated that IVO had prepared the building of nuclear power plants up to the final decision before consulting the owners and political decision-makers. In spring 1967, the government decided to abandon the acquisition of nuclear power on the basis of the received tenders. A crisis in mutual confidence broke out between the government and IVO.

The Prime Minister and the chairman of the Social Democratic Party Rafael Paasio ran down the IVO's managers because of their narrow, technical approach. 'Not a single issue has been handled more stupidly: only idiots do business in this way.'[456]

The IVO 'had behaved like a common industrial company ordering a paper-making machine.' It was obsessed with technical details and calculations on the direct costs of the tendered plants. It had not asked for the government's or Parliament's consent for such a major issue as the introduction of nuclear power. At the time, Finland had not made the necessary international agreements on the utilisation of nuclear power. The deliveries of nuclear fuel and the processing of wastes were not included in the request for tenders; these questions were unanswered at least in the AEG's tender. Finally, IVO had requested 'turn-key' tenders, although existing researchers had proved that the domestic industry could supply inputs equal to half of the total value of the plant.[457] To find the best solution on the question of foreign trade policy, the government decided in March 1967 to give up the turn-key option and to invite tenders for building the first nuclear power plant as a joint project of Finnish and foreign companies. Tenders were invited and received from Sweden, Britain and the Soviet Union.[458]

Then, in early 1968, the issue flared up. While the British Parliament debated how to support UKAEA's tender for a nuclear power plant in Finland, a series of high-ranking delegations from the three countries concerned visited Finland.[459] In July 1968, the government again decided that for the time being no nuclear power plant would be built. The Prime Minister Mauno Koivisto explained the decision:

> By means of tender competition we cannot acquire a nuclear power plant for Finland. If we try to get the great powers to compete with each other, if we try to wag the issues, so they begin to wag us. It proved to be impossible to solve the tender competition on the nuclear power plant in a way which satisfies all participants. In this significant matter, Finland does not want to risk its good trade relations with any competing country.[460]

Although the government intervention twice prevented IVO from ordering an NPP, the company did not give up its intentions. From 1967 IVO had been preparing a long-term national plan for electricity supply. In January 1970 it finally published an ambitious plan whereby, by 1990, ten NPP-units with the total capacity of 7400 MW were to be built in five locations. One of these locations was Helsinki, where two units (2 × 300 MW) were to be erected for the co-generation of electricity and district heating by 1983.[461]

Soon after rejecting the tender competition in summer 1968, the government decided to commence talks on nuclear power plants with the Soviet Union. In September 1969, with the inter-government agreement, Finland ordered a plant from the Soviet Union. The Soviet government granted 20 years' credit worth about 54 million roubles to its Finnish counterpart which guaranteed the overall financing of the project.[462] Meanwhile, Imatran Voima Oy and V/O Technopromexport concluded a technical and economic agreement on supplying two turbogenerators and a 420 MW nuclear reactor with pressurised water cooling.[463]

The construction of Loviisa 1 nuclear power plant was a rare instance of international collaboration. The Soviet nuclear power technology was interwoven with Western control and safety systems. Swiss consultants were involved in general planning, and the Soviet V/O Atomenergoexport was responsible for nuclear design and the supply of machinery and equipment. The main circulation pumps, transformers and other electrical equipment were of Finnish manufacture. Instrumentation came from the West German firm Siemens and computers from joint British and Finnish (Nokia Oy) sources. Quality control of structures and components as well as the coordination of the entire project were the responsibility of Imatran Voima Oy. Unlike the current Soviet NPPs, the reactor of Loviisa 1 was covered with a gastight shield. Imatran Voima Oy and Wärtsilä Oy jointly erected a steel shield building with cooling equipment under an American Westinghouse licence.[464]

The Loviisa 1 NPP was completed one and half years behind schedule, because the Soviet manufacturer failed to deliver the reactor pressure vessel in time. In February 1977, both turbogenerators of the Loviisa 1 supplied electric power for the first time to the national grid, while its commercial operation commenced in May 1977. Its identical twin unit, the Loviisa 2 NPP, was put into commercial operation in January 1981 being nearly three years late due to problems with the pressure vessel. The Finnish contributions to both the Loviisa 1 and 2 plants accounted for about 70 per cent of their total value and the final costs of the latter plant were more than double the estimated costs (FIM 500 million) at the time of order in 1969.[465]

In total, 23 private, state-owned and municipal firms of industry founded a power company called Teollisuuden Voima Oy (TVO) (Industrial Power Ltd) in 1969. In 1974 and 1975, it started to build two nuclear power plants with boiling water reactors supplied by the

Swedish company Ab ASEA-ATOM as turn-key deliveries. In October 1979 and July 1982, they were commissioned.[466] Consequently, the total capacity of Finland's four NPPs rose to 2160 MW.[467]

In the press, the IVO's NPPs were considered a good bargain for Finland. Per MW, the final price of the Soviet plants was about a third lower than that of the Swedish plants. Together two Loviisa NPPs (2 × 440 MW) cost FIM 2000 million, whereas the two TVO's plants (2 × 660 MW) at Olkiluoto cost over FIM 4600 million.[468] During the past decade, all of Finland's four NPPs have worked quite satisfactorily. Their average annual productivity ratio (the actual output against the maximum output potential) was the highest in the world between 1982 and 1986.[469]

The inter-country transfer of nuclear power technology has seldom been as successful as in the case of Finland. For example, the Yugoslavians were disappointed with their ill-fated first nuclear power plant at Krsko in Slovenia. The unit was planned and built by the American Westinghouse Company, while the value of the Yugoslavians' contribution to its construction rose to 65 per cent. The reactor of 664 MW was for the first time synchronised in October 1981. The plant was completed two years later than originally agreed and its final costs rose manifold compared to the planned total costs. Nevertheless, it could not be driven to the maximum capacity, because even at 75 per cent load, vibration caused damaging effects. In early 1982, Westinghouse reconstructed the piping systems of the steam generators. As a result, vibrations were eliminated. Between 1982 and 1986, the Krsko NPP operated with a load factor of only 69 per cent, while the average figure for all Finnish NPPs was 89 per cent.[470]

The building of the first NPP was the largest single transfer project of technology ever carried out in Finland. Some of its features reflected quite closely the pattern of technology transfer which the Finns had followed for a century. The transfer of nuclear power technology was prepared with numerous study tours abroad and the active adoption of technology through the diffusion of easily accessible know-how (see Table 1.1). The Finns played a vital role in the planning and preparation of the whole project. A pivotal objective was to produce as many components in the home country as economically rational and technologically possible. In aiming at high quality and safety, the Finns were apt to adopt technology from a number of suppliers and from various countries and were also willing to modify the foreign technology to fit Finnish requirements.

In the case of the first NPP, the Finns rejected the easy, shortcut way, i.e. purchasing a turn-key delivery from a foreign manufacturer. By contrast, they preferred a difficult, roundabout method with a strong Finnish involvement and with domestic management of the project. Right from the outbreak of the electric era, one significant feature in building power plants in Finland was the desire to avoid contracts of purchase with foreign companies on the deliveries of completely equipped power plants. In the construction of power plants, an important goal was to strengthen the Finns' own expertise in the field. A 'Finnish way' to build power plants emerged. From the very beginning to the end, plants were projected by Finnish engineers in whose designs as much domestically produced equipment as possible was used. Generally only those components, such as turbo-generators, which were not produced in the country were imported.[471] In the way the first nuclear power plant was built, there was a question of both rational strategy and national self-esteem. The Finnish viewpoint of this matter is described in a recent book as follows:

> Western and Eastern nuclear power know-how was assimilated under the command of Kalevi Numminen in IVO's bureau in Helsinki where Soviet, Finnish, American and West German engineers met each other in the same room constructing the very same nuclear power plant.[472]

The Rise of the Conflict on Electric Power Generation

The environmental movement arose much later in Finland than in other Western countries. The initial phases of country-wide electrification did not meet opposition; all political parties considered that the rapid increase of electric power supply was indispensable for the growth of overall welfare. It is peculiar to Finland that the earliest and strongest protests were directed at building hydroelectric and not at thermal power plants. From the late nineteenth century, it was known that the construction of hydropower plants had a negative effect on the stock of fish and crayfish in rivers. In Finland, fishways (designed to allow fish to migrate upstream) have regularly proved to be useless; the stocks of migratory fish (salmon, trout and whitefish) shrank to a negligible level in all harnessed rivers. During this century, many fishermen and farmers had to give up their traditional source of livelihood and find a new occupation. From the 1950s, hydroelectric plants began to meet increasing opposition from local people, because the Water Act did not properly protect their rights. The expropriations and undervalued compensations of riverside domains and farming plots as well as the strong fluctuations of regulated water levels embittered fishermen and farmers of various river valleys. Some of the trials between these people and the power companies on riparian rights have lasted for more than three decades.[473]

In the 1920s, the Imatra power plant was opposed, because it compromised the aesthetic values of a national beauty spot.[474] In the postwar years, environmentalists began to support fishermen and other local people in their fights against hydropower companies. The issue became connected with the debate on regional policy, and on the utilisation of northern Finland's natural resources for the needs of the industrialised southern part of the country. Northerners claimed that not only did they lose their hydropower to the south, but also municipal tax revenues. Big power companies, such as Oulujoki Oy and Kemijoki Oy, paid the bulk of their taxes in Helsinki where they had their head offices. Furthermore, northerners, the neighbours of big hydroplants, had to pay a higher price for their electricity than far-off southerners, because IVO's tariff policy favoured distribution utilities with large wholesale purchases.[475]

The most impressive anti-hydropower protest took place in October 1979. Then the so-called 'Fur Cap Delegation', a few dozen representatives of riverside people and municipalities on the river Kemi, arrived in Helsinki and occupied the Ministry of Justice demanding a special law on the payment of compensation for the lost catches of fish. The demands of these non-violent protesters were later fulfilled.[476]

As late as the 1960s, Finnish environmentalists considered that nuclear power would rescue the rapids of the country and conserve its nature unspoiled. They recommended the hastening of the introduction of this 'nearly inexhaustible and unpolluting energy source'.[477] It was not until the mid-1970s, just before the first NPP in Loviisa was started up, that Finnish environmentalists realised the risks of nuclear power.[478] The favourable consensus of opinion began to fade and by 1982 the majority (54 per cent) of the population was against new NPPs.[479] In fact, it was not before the turn of the 1970s and 1980s that the actual disadvantages (such as acid rain) of conventional coal- and oil-fuelled thermal power plants became public issues in Finland. Consequently, it is striking how insignificant was the political debate on environmental aspects of electricity generation during the period under study (1877–1977) compared with the time after it.

Conclusion

The year 1977 was notable for Finnish energy production. The Imatran Voima Oy then commissioned the fourth 250 MW unit at its Inkoo 1000 MW coal-fired thermal power plant. A considerable extension of the Finnish 400 kV transmission network was also completed in the same year. The most important event was, however, the start-up of the Loviisa 1 NPP. President Urho Kekkonen and the Soviet prime minister Aleksei Kosygin inaugurated the plant on 23 March 1977.[480]

At 7 a.m. on the following morning, electric lights went out in many homes around Finland. A lot of people were left without their regular breakfast coffee and quite a few unsuspecting people on their way to work became stuck in lifts. Factory workshops were plunged into darkness and machines quietened down. Recurrent interruptions in the electricity supply continued up to 12 May. Industrial action had broken out.[481]

The striking technical personnel of power plants taught the public two things. First, sudden and unsuspecting interruptions in power supply tangibly pointed out how numerous activities of modern society were dependent on electricity. When electricity distribution was switched off nearly the whole of society stood still.[482] Second, the Finnish electricity supply system proved to be extremely centralised. An occupational group of 1900 persons was able to paralyse industrial production and to bring the rest of society to its knees.[483] A hundred years earlier there was no group totalling only 0.04 per cent of the total population and no technological failure which could halt the working of the entire nation and darken houses all over the country in a few seconds. Since the 1880s, electricity has influenced economic and societal development, but a great deal of this influence has remained invisible in normal conditions. The dependence of modern society on electricity is only revealed when the power supply is suddenly cut off for some reason. Electrification had created a new kind of society which was interdependent on national technological systems and vulnerable to sudden technical disturbances.

According to the general technological standards of the time, the Finnish generation and distribution system had, nevertheless, advanced to a very high level, comparing well with other West

European supply networks. As international statistics indicate, electricity consumption per worker in industry and per inhabitant in the national economy had risen to comparatively high levels. In fact, Finland had developed as one of the most electricity-intensive countries in the world (see Table 4.2). Although electricity prices in Finland were somewhat higher than the average prices in Western Europe, they had nationally become competitive with alternative energy forms (see Table 4.8). By the mid-1970s, practically the whole of Finland was electrified; 99.5 per cent of all households were wired for electricity.[484] This energy form became involved in almost all kinds of human activities. A new technology had completed its breakthrough and firmly established its position in Finnish society.

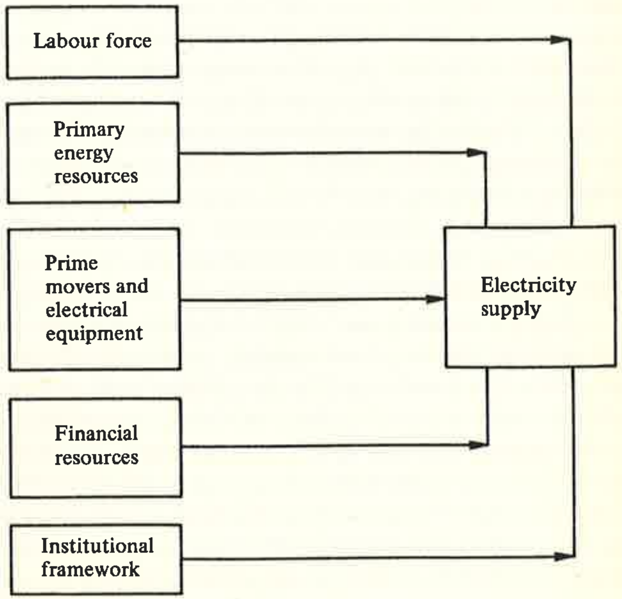
3 Electricity Supply

3.1 SUPPLY FACTORS

When erecting an electricity supply system, there are several prerequisites. A latecomer economy cannot provide them all from indigenous sources. It is inevitable and reasonable that some production factors should be obtained from abroad. For example, any latecomer country has to adopt electrical technology from abroad in some form or another.

An electricity supply system is composed of various factors. At the same time, it is a technological, economic and societal system. These aspects are an integral part of the system. As depicted in Figure 3.1, five basic factors can be mentioned. The work force is a vital factor of electricity supply, although the business does not constitute any labour-intensive economic sector. Especially in modern times, the routine technical operation of the supply system requires only a small

Figure 3.1 Supply factors of electricity production



number of personnel. Much more labour is needed for the construction and maintenance of the system. A noteworthy point is that the significance of qualified personnel is fairly high in this business, the operation of which depends a great deal on well-trained technological expertise. Primary energy sources constitute the second important supply factor. The availability and price of indigenous or imported energy resources are essential elements for electrification. Pre-1977 Finland possessed only three indigenous primary energy sources – firewood, peat and hydropower – which could be utilised for the large-scale generation of electricity. The qualities of the indigenous energy sources were more than modest, but their unit prices per one generated kWh were not low. For this reason, imported fuels could frequently compete successfully with indigenous energy in electricity generation.

The third factor consists of equipment needed for an electricity supply system. The acquisition of equipment presupposes imports and technology transfer in various forms. Applied technology affects the function and development of an electricity supply system in various aspects. Although the Finnish market was small, it nonetheless enabled the rise of a domestic electrical engineering industry. The competition between Finnish manufacturers and importers of electrical equipment has promoted rather than hampered the electrification of the country.

Financial resources for electrification constitutes the fourth supply factor. Financial resources played an important role in the Finnish case, particularly in the construction of large hydroelectric plants or a series of them. Generally, both domestic and foreign resources were available. Although some projects were backed with a considerable share of foreign financing, the Finnish electricity supply system was, as a rule, built up with domestic capital.

An institutional framework, the fifth factor, contains a set of various elements from the political climate to riparian rights. It differs country by country and might radically change within one country over time. Because the electricity supply system is a capital-intensive and natural-resource-intensive business as well as a vital sector of the economy, its activity is tightly controlled in many countries by jurisdiction and political supervision. In various countries, the institutional framework has essentially affected the development of the electricity supply system. Finland was not an exception, although any sudden, dramatic changes, such as nationalisation, did not take place. In the Finnish case, the critical points were the option

of direct foreign investments in the electricity generation, the issues related to riparian rights, and the government's involvement in electricity supply.

As a branch of secondary production, electricity generation requires various inputs from other industries. Its outstanding advantage is, however, that it is possible to choose many different combinations of inputs: a number of primary energy sources, several types of prime movers, etc. the choice of an electricity supply system can be made on the bases of quantities, qualities and prices of available primary energy sources and machinery. Electricity generation is an industry which is not exclusively bound by local endowments.

If a required input is not supplied from domestic sources, it can be imported. In fact, in many regions of the world, electricity supply can be characterised as an 'enclave import industry'. For example, in St Petersburg, both electrical machinery and fuel were imported from abroad, without any substantial backward linkages to the local economy: utilities just converted these inputs into electricity which was distributed to the consumers. Before 1914, this was also the case in other cities on the Baltic coast, e.g. Riga, Tallinn, Helsinki and Turku. The enclave nature of utilities in these cities was emphasised by the location of the power plant close to a convenient port for unloading coal and other imported materials. Furthermore in some of these cases, the direct involvement of foreign capital and immigrant engineers stressed the image of an 'enclave import industry'. The reliance on imported fuels and machinery had a tendency to limit electrification to these big coastal cities. Moreover, its development impact was restricted to forward linkage effects.[1]

On an opposite development path with various backward linkages, electrification could give rise to new 'satellite industries' providing inputs for the electricity supply industry. In many countries, electrification led to the utilisation of indigenous primary energy sources and to the development of a cable industry and the production of generators, motors, batteries, transformers, household appliances and other branches of the electrical engineering industry. The combined stimuli of the electricity-related industries supported the development of some other industries such as prime-mover engineering, the production of copper, brass, lead and aluminium, the manufacturing of insulating materials, cement production, fuel supply, etc. These cumulative effects give a basis for explaining the acceleration of industrial growth. The supply of indigenous primary energy sources accelerated the spread of electrification throughout these countries before the advent of the large-scale transmission network. The use of indigenous energy for the generation of power connected the electricity supply industry to the domestic economy with at least some backward linkage even if the supply of domestic electrical equipment was fairly modest.

For the profitable operation of electricity generation, it is important that both fixed and variable costs are reasonable. Investments in power plants and a transmission network should not be too expensive. The choice between primary energy sources, power plant alternatives, distribution systems and technical standards influence the level of fixed and variable costs. The kind of interests and goals that are dominant in the building of an electricity supply system also have an impact on the price of electricity. The availability and price of both primary energy sources and power plants are very important for decisions on electricity generation units. National and local circumstances greatly affect these factors. The development of the economy and technology can radically change the supply conditions of energy sources and equipment as well as their price relations. In every decade, decision-makers might face a new constellation of opportunities when they choose the best alternatives for the expansion of the existing generating capacity.

From the macroeconomic viewpoint, a country's own energy resources and potential to manufacture prime movers and electrical equipment are significant. The bigger the backward linkage effects of electrification are on the national economy, the better are the opportunities to use domestic inputs. In certain situations, these inputs might reduce the price of electricity as well. When the costs of foreign inputs rise too high, domestic inputs may be the cheaper choice. Indigenous primary energy sources and technical equipment might be better suited for a country's micro- and macroeconomic needs than their imported counterparts. Moreover, in cases of international crises and economic disturbances, sufficient domestic inputs can secure a continuous and trouble-free operation of an electricity supply system. In all times, they support the economic independence of the country.

If the supply of domestic inputs is not internationally competitive and is, therefore, protected by various sanctions, there might arise a conflict between the electricity supply industry and the suppliers of domestic inputs. For example, substantial protection of domestic primary energy and machinery production by import tariffs might increase the price of electricity and retard electrification. Consequently, the forward linkage effects of electrification would be smaller. The benefit of using domestic inputs cannot be an end in itself. Policy-makers of the state administration and decision-makers in industry have to find a rational balance between backward and forward linkage effects.

3.2 LABOUR FORCE AND TECHNICAL EDUCATION

Trained personnel and technological expertise are more important for electrification than an army of unskilled labour. This makes a workforce with a technical education a key factor for development. In an international research, Göran Ahlström has pointed out that highly qualified engineers have great importance in industrial growth in general.[2]

How did Finland acquire its experts in electrical technology? The Grand Duchy of the late nineteenth century had a polytechnic institute in Helsinki, where mechanical engineers, civil engineers, chemists, architects, as well as land-surveyors were educated.[3] From 1883 the teaching programme included courses in electrical technology. In 1908 the polytechnic was transformed into a modern university of technology.[4] Three years later it was possible to take the degree of graduate engineer in electrical technology in Finland. Before that the country had to rely on the education of nationals abroad or on the immigration of foreign specialists. Both means were used but students' studies abroad and postgraduates' educational visits to other countries was the preferred method.

From the mid-nineteenth century, Finnish students interested in electrical engineering travelled abroad to study it. Knowledge about the first generation of electrical engineers and electricians is scanty. However, detailed information on the subsequent generations can be found from the membership books, rolls, of the Association of Electrical Engineers in Finland (AEEF, established in 1926). Unfortunately, these sources do not cover all the early electrical engineers who practised their trade in the Grand Duchy and in the young republic.

If we consider the age groups of the AEEF members who had the opportunity to take the engineer's degree before the First World War, the clear majority (59 per cent) had studied abroad at least one year. At the time, it was usual to take the engineer's degree in Finland first and then continue one's studies abroad. About 32 per

Table 3.1 The education of early Finnish electrical engineers

	Born between 1858 and 1889 *no.*		*Born between 1890 and 1899* *no.*		*Total* *no.*	*%*
Technical studies without examination						
in Finland	1		2		3	1.5
abroad	1		2		3	1.5
Lower Finnish degree of engineer	15		14		29	13
Finnish degree of graduate engineer	18		100		118	53
Lower Finnish degree of engineer plus supplementary studies abroad	22		1		23	10
Finnish degree of graduate engineer plus postgraduate studies abroad	4		6		10	4
Engineer's degree from abroad	21		16		37	17
Total	82		141		223	100
Studies by country:		*%*		*%*		*%*
Only in Finland	34	41	116	82	150	67
At least partly abroad	48	59	25	18	73	33
Total	82	100	141	100	223	100
Studies abroad by country:						
Germany	36		18		54	62
Sweden	5		7		12	14
France	3		2		5	6
Switzerland	3		1		4	5
Austria (Vienna)	3		0		3	3
USA	1		5		6	7
Russia (St Petersburg)	1		2		3	3
Total	52		35		87	100

Source: Suomen sähköinsinööriliitto ry, Matrikkeli 1926–1951, ed. by Ole Fraser (Helsinki, 1951).

cent of these AEEF age groups followed that practice. A quarter (26 per cent) went abroad straight after matriculation from a Finnish higher secondary school and graduated from a foreign university, as shown in Table 3.1.

The German universities of technology attracted most of the early Finnish students of electrotechnology who went to study abroad. Two-thirds of the studies abroad took place in Germany. The most popular schools were the famous universities of technology in Karlsruhe and Charlottenburg-Berlin and the Ingenieure Technicum Mittweida. Nearly half of the Finnish students in the German technical schools chose one of these three institutions. Technical schools in other countries played a minor role. Many of those who studied in Sweden were actually Swedes who had immigrated to Finland after graduation. In the United States, Finns took rather short courses and none of them graduated in electrical technology there.

The number of engineers has been considered an important indicator of a country's technological capacity. Unfortunately, it is not possible to make a case study on electrical technology. However, we can compare the total number of engineers in Finland with some industrialised countries on the eve of the First World War. The comparison is presented in Table 3.2

If we take account of the students' studies abroad, differences between these countries somewhat narrow. The ratio between engineers

Table 3.2 The number of engineers with higher technical education from the domestic universities of technology in Finland, France, Germany and Sweden in 1913

	Germany	*France*	*Sweden*	*Finland*
Number of engineers	64109	41674	3427	1569
Total labour force, in thousands	17638	20225	2631	1338
Number of engineers per 1000 economically active people	3.6	2.1	1.3	1.2

Note: As in the case of the three other countries, Ahlström's method is here applied to Finland: The figure is based on the number of examined students. The death rate is taken to be 17 per thousand and the active period of an engineer is assumed to be 40 years.

Sources: Göran Ahlström, *Engineers and Economic Growth* (London, 1982), pp. 107–8; Angus Maddison, *Phases of Capitalist Development* (Oxford, 1986) p. 209; *Berättelse öfver Polytekniska Institutets i Finland verksamhet 1882–1908* (Helsingfors, 1883–1908); *Suomen teknillinen korkeakoulu, Vuosikertomus 1908–1913* (Helsinki, 1909–14).

and the total labour force for both Finland and Sweden rises to about 1.5, whereas it drops to about 3.0 for Germany.[5] Grand Duchy was behind the technologically most developed countries in Europe, but the difference was not huge. Finland cannot be called a proper latecomer in respect of the number of engineers, although, relatively speaking, Germany had twice as many engineers. A comparison with Britain provides another dimension. At the time of the First World War, the total number of full-time students in science and technology at British universities, colleges and technical institutes was only about 3000. During the academic year 1915–16, the number of students in these fields at Finnish universities and polytechnics was 1800. If these figures are related to the total labour force, Finland had eight times more students in science and technology than Britain.[6]

Despite the great increase in engineers, Finland still lacked various specialists in the early interwar years. There were not enough qualified hydrographers, consultant engineers or designers of large hydroelectric plants, or construction engineers for these plants and transmission lines. For these tasks, a number of Swedish and German experts were employed. This aroused a heated debate between Finnish engineers on the sensible limits of self-sufficiency. By launching the slogan 'Let our own engineers electrify the country', radical nationalists demanded the increase of students' studies abroad and an improved technical education at home. 'Only in this way, shall we get rid of foreigners in hydro development and sever the mockery of our undevelopment and inefficiency.'[7]

Over the course of time, the number of electrical engineers increased, but studying abroad declined. In the case of those engineers born in the 1890s or later, three reasons reduced the studies in foreign institutions. First, undertaking studies for a higher engineering degree became possible in the home country in 1911. Second, the opportunities and level of education at home improved and the Finnish government cut down grants for studies abroad. In 1930, only 13 Finns were studying at the German universities of technology, while the number of students at the Helsinki University of Technology (HUT) was 686.[8] A modern electrical laboratory was opened at the HUT in 1926. Electrical technology was included in the department of mechanical engineering until its own department was founded in 1941.[9] Third, the outbreak of the First World War greatly limited Finns' opportunities for studying abroad. In addition, economic and political instability in Germany discouraged Finns from going there for studying after the war. Consequently the proportion of electrical engineers with foreign studies fell to 18 per cent in the age group born in the 1890s. The most conspicuous decline took place in postgraduate studies abroad.

By 1940 the number of all graduate engineers and architects had increased to about 3000. The quantity and quality of Finnish electrical engineers had also reached a comparatively high level. Therefore, a shortage of qualified graduate engineers did not substantially impede the realisation of the demanding postwar hydropower programme. Meanwhile, the development of the education of electrical engineers was, however, neglected and students seldom went abroad to study. Compared to the Scandinavian countries, postwar Finland was left further behind in this field than in any other field of technology. In 1964 the number of entrant students and professors in electrical technology was 4.5 times higher in Sweden than in Finland. In other fields of technology, the corresponding ratios were generally 3:1 or 2:1.[10]

A swift change then took place. In 1965 the total number of students enrolling annually in electrical engineering doubled from 90 to 180 when the departments of electrotechnology were opened at the University of Oulu and at the new Tampere University of Technology. Moreover, the number of posts for professors rose from six to eleven in two years. Electrical engineering was to become the largest branch of technology in the Finnish universities, because industry's need for graduate engineers was claimed to be particularly acute in electrical technology. This development plan was, however, hampered by a lack of qualified teachers and well-equipped laboratories. Therefore, it was not until the 1970s that Finland started catching up with Scandinavia and other Western industrialised countries in the new fields of electrotechnology, such as electronics and teleinformatics.[11]

Between 1911 and 1975, 2360 students took graduate electrical engineer's degree in Finnish universities, while 121 qualified as licentiates and 47 as doctors in the subject. In addition to the university level, electrical technology was also taught at the intermediate level, i.e. at technical colleges and schools as well as at vocational schools. In these respects, development was rapid in the postwar decades. The education of electrical engineers at technical colleges actually outnumbered that of graduate electrical engineers. Between 1915 and 1975, as many as 5740 lower-level electrical engineers and nearly 9000 electrical technicians passed the examinations.[12] The total number of graduate engineers and architects working in their trade amounted to 13 700 in 1980, while the corresponding figure for all technical college engineers was 26 800 and for technicians 54 600.[13]

If we compare the Nordic countries in 1977, technical education at the vocational schools was largest in per capita terms in Denmark and Finland. In the latter country, 44 600 pupils were studying in trade, craft and industrial programmes, and around 21 600 pupils of two-year education programmes completed their studies. About 3100 electricians then passed the examinations at the vocational schools.[14]

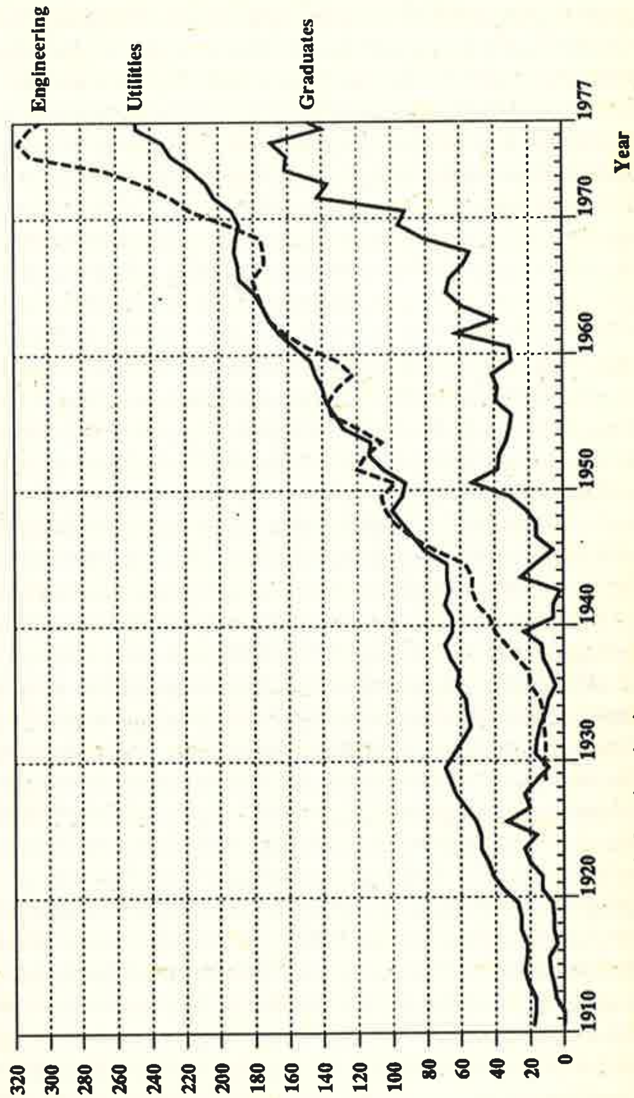
There seems to have been quite a stable relation between a higher education in electrical engineering and the development of employment in the electricity supply utilities. In the period 1911 to 1969 per each 1000 employees of these utilities, on average three graduate engineers annually took their degrees. In the 1970s, the figure rose to 6.5 new graduate engineers annually. Rather a similar relationship prevailed between graduating electrical engineers and the employment of electrical engineering from the 1940s to the late 1960s.

Both the electricity supply utilities and electrical engineering were rather small industries in Finland. In 1938 they accounted for 6900 and 3400 employees respectively. In 1977, the corresponding figures were 25 200 and 29 900 as shown in Figure 3.2. During that time-span, their joint proportion of total industrial employment increased from 3.3 per cent to 10.3 per cent.[15]

In the electricity supply utilities, engineers constituted a minor, but rapidly growing occupational group. For example between 1950 and 1962, the number of engineers and other technical personnel doubled, while the total workforce of these utilities increased only by 39 per cent. In the latter year, 3 per cent of 14 700 people working at the utilities were engineers and just under 10 per cent other technical personnel.[16]

Although shortages of qualified personnel became apparent in the electrification of Finland from time to time, we cannot speak about any fatal and chronic 'unmet need' of engineers and electricians. Taking account of both Finnish-educated personnel and employed foreign specialists, the country's pool of a qualified labour force was quantitatively quite satisfactory compared to most European countries. Consequently, the relatively large number of electrical engineers and technicians can be considered an asset which boosted the electrification.[17]

Figure 3.2 Employment in the electricity supply utilities and the electrical engineering industry, and the number of electrical engineers graduating from the universities of technology annually, 1910–77



Graduates in electrical engineering in persons.
The employment in the electrical engineering industry and electricity supply utilities in 100 persons.

Sources: OSF 18 Industrial Statistics 1910–1977 (Helsinki, 1912–79); *Annual Reports of the Helsinki and Tampere Universities of Technology and the University of Oulu, 1911–1977.*

3.3 HYDROPOWER

Resources

The hydropower resources of a region depend on two main factors: *discharges* and *altitudes* of watercourses. The volume of a discharge is influenced by the size of the catchment area, precipitation, and evaporation. Moreover, geographical characteristics have a great impact on what kind of watercourses gather the rainfall. An important feature of Finland's hydrology is that the eight largest catchment areas cover almost the whole territory of the country and concentrate the vast majority of the country's precipitation in eight watercourses.[18] Two of them, the rivers Tornio and Paats, are situated in the present border areas, and they are not available for the power generation of Finland.

On the southern coast of Finland, the annual rainfall is the most abundant, over 700 mm. The precipitation decreases on moving north, and the average in northern Lapland is less than 400 mm p.a. It rains all the year round, but the seasonal maximum occurs in summer and the minimum in late winter. The precipitation consists of snow in southern Finland for four months in the year and in northern Finland for seven months. Snow stores water which is later released from forests, marshes and fields into watercourses in April and May.

Not all of the precipitation flows through rivers into the sea; a part of it evaporates on the way. Although the Finnish climate cannot be regarded as dry and hot, evaporation is quite considerable. Evaporation is lowest in Lapland where it may annually be less than 150 mm p.a. It is quite natural that the highest values, over 350 mm, occur in the Lake Region of central Finland, since there is an abundance of open water surfaces and temperatures are relatively high.[19] Therefore, in Lapland about one-third of the precipitation evaporates and in southern Finland over one-half evaporates from vegetation, the soil and watercourses. Notwithstanding the considerable evaporation losses, a very large amount of water flows in Finnish rivers. A rough total of 100 000 million cubic metres of fresh water flows annually from the mainland of Finland into the Baltic Sea and about 10 000 mm^3 into the Arctic Ocean.[20] Sixteen of the twenty-two largest rivers are situated entirely within the territory of present-day Finland. The remainder cannot be fully utilised for the country's power needs, because they flow partly in the border areas or their main rapids are situated in foreign territory.

Despite the vast catchment areas, the hydropower resources of Finland are relatively modest. Before the Second World War, the amount of exploitable hydropower capacity in Finland, calculated on the average hydrological circumstances, was approximately three million kilowatts, corresponding to an average energy output of nearly 25 TWh per year. After the truce with the Soviet Union about 3 TWh of this potential energy was lost in 1944, so that there was left a technically exploitable hydroelectric potential of about 22 TWh. Using modern technology, the economically utilisable potential is estimated to be about 20 TWh per year in average circumstances.[21] Almost a half of these resources are situated in northern Finland, in the province of Lapland, while more than 90 per cent of the population and industry are centred in the southern half of the country.

Although by area postwar Finland is roughly as large as Norway and three-quarters the size of Sweden, the country's hydropower resources are only 14 per cent of Norway's and 27 per cent of Sweden's hydroelectric potential assessed as technically exploitable. This is partly due to the considerably lower annual precipitation in Finland than that of Sweden and Norway, which are situated nearer the Atlantic Ocean, and partly to the fact that the country is far flatter than Sweden and still more so than mountainous Norway. The mean altitude of Finland is 150 metres which is less than a half of the European average. The technically exploitable potential of its hydropower resources is only the thirteenth in rank among the European countries, as indicated in column 2 of Appendix Table A.2.

Territorially, Finland with its 337 000 square kilometres is the fifth largest country in contemporary Europe, and about 10 per cent of its extensive area is occupied by inland watercourses including about 188 000 lakes. The central lakes of the country are, however, situated not more than 80 metres above sea level. Consequently, the heads of fall at the hydropower plants are very small, usually 5–10 metres, which is only a quarter of the corresponding Swedish heads.[22] Historically, Finland has, nevertheless, benefited at least from two advantageous features. Firstly, the country was sparsely populated; thus available hydropower potential was for a long time fairly satisfactory in per capita terms. Secondly, the technical exploitability of its annual gross surface hydro potential has been estimated to be higher and more accessible than that of any other country in Europe, as shown in column 7 of Appendix Table A.1. In the past, this was a very important factor. From an early date, it was possible to harness hundreds of small rivers and their low rapids for power production using quite unsophisticated technology. Later, the multitude of natural lakes linked by sounds and rivers to voluminous watercourses offered suitable geographical prerequisites for regulation and for the use of relatively large amounts of water.

Legislation and Social Counterforces

The Finnish legislation governing the use of rivers and watercourses is derived from the provincial laws which prevailed during the thirteenth century in the Kingdom of Sweden.[23] This legislation was based on two main principles. Firstly, the unchanged basis of the law relating to watercourses was stated in the provincial law of Swedish Helsingland: 'He owns the water who owns the land'. In the early centuries this principle meant that lakes and rivers belonged to the village owning the forests which surrounded them. The landowners in a village had the right to control and to possess lakes and rivers in proportion to the area of land they owned around the village. But since the Middle Ages, many lakes and rivers became private property when the jointly owned areas of villages began to be split into parts. In the nineteenth century, villages and private persons owned the great majority of lakes and rivers in southern Finland. The waters owned by the State were primarily situated in the northern half of the country where notable state-owned land areas were also located.

Secondly, the private proprietary rights of watercourses did not, however, mean an exclusive right to use them; instead, the owners' right to utilise their watercourses was limited by common interests. According to Swedish–Finnish laws, an open mainstream serving common needs should be kept at the deepest spot of all rivers excluding minor ones. The function of the mainstream was to secure the free flow of water, the movement of migratory fish (salmon, trout and whitefish), guarantee the prerequisites for ship and boat traffic and, later, the proper conditions for timber floating. The width of a mainstream varied depending on the natural conditions and common needs. Pursuant to the Code of 1734, it was permitted to be as narrow as one-sixth of the width of the river when it was only intended to serve as a passage for boats and fish; if it served all of the above-mentioned functions, it was to be a third of the width of the river or a minimum of 7 metres. The mainstream was to be kept open the year round, but for the rest of the river two-thirds of the width of an

average water surface could be freely dammed or otherwise used by its owner.

Although the mainstream was called *kungsådra* (king's vein) in Swedish, it did not belong to the State in the traditional Swedish–Finnish jurisdiction. The State only had the duty of ensuring that the proper rights of different population groups to the mainstream were secured in accordance with the laws.[24] Therefore, the established Swedish and Finnish laws of watercourses differ considerably from those of southern and central Europe which are based on Roman jurisdiction.[25] According to both Roman and German law all important and navigable rivers are public (*usus publicus*) and, as such, the property of the State. Only small and exhaustible rivers could be private property. On the Continent, the central or local government grants private persons or companies concessions for river traffic, hydropower plants, timber floating, etc. after a comparison of the economic benefits and disadvantages of different project applications.

In Finland, the comparison of different interests is a comparatively new phenomenon – an addition to a law dating from the 1930s. The utilisation of watercourses was determined in the first place on the basis of proprietary rights, and in the second place on the basis of legislation and its interpretation. During the course of history five interest groups have struggled for the use of rivers:

(1) *Farmers* defended the free flow of water and the dredging of rivers and creeks.
(2) *Fishermen* demanded the preservation of an unobstructed passage for migratory fish and the right to build and use fishing equipment in rivers.
(3) *Plyers* claimed the right to maintain free traffic on lakes and rivers.
(4) *Timber-floaters* wanted to develop the passability of watercourses for their purposes and the right to use all rivers for floating if necessary.
(5) Besides the utilisation of the hydro-potential of rivers on both sides of the mainstream, *millowners and electricity producers* aimed at the damming and regulation of entire watercourses for the needs of power production.

During the past two centuries, the power and prestige of these five groups have varied substantially. The most serious conflicts have generally arisen between millowners, pro-dammers, and other groups, anti-dammers. A technological factor contributing to the fierce struggle for the use of the watercourses was prompted by the introduction of hydroturbines. There was a conspicuous tendency for Finnish industry to utilise more and more efficiently and extensively the waterpower resources of the country using the opportunities provided by the new technology.

When hydroturbine technology was adopted in Finland in the 1840s, the legal position of the mills with waterwheels was weaker than ever before.[26] During the first half of the nineteenth century, agricultural interests dominated the use of waters. It was then a fashionable trend to clear fields by dredging creeks and rivers, and draining lakes. During the period between the years 1810 and 1860, legislation relating to waterpower plants was made more strict. The construction of nearly every kind of watermill – for industrial or household use – was forbidden without an official permit, and the demolition of existing watermills was facilitated by new decrees for the promotion of agriculture.[27]

After the Crimean War (1853–6), the economic policy of Finland was liberalised and modified in a more pro-industrial direction. The new trend found its way to the law relating to watercourses as well. In 1868 the first decree in the country aiming at the complete arrangement of watercourses was prescribed.[28] In its basic principles, it followed the earlier legislation so that rivers remained the property of villages and private persons, but a third of the width of a river was to be kept open for public use.

The new decree facilitated the construction of waterpower plants. Among other things, it gave the owner of rapids the unhindered right to construct a power plant and a dam in minor rivers which did not have boat traffic or timber-floating. In the larger rivers an official permit was still necessary before the construction could start. The freedom to construct in small rivers was important, and many seized the opportunity, since large rivers could rarely be harnessed using the damming and hydraulic technology available in Finland at that time.

Although the Diet had made the decree of 1868 quite liberal from the standpoint of waterpower plants, it is noteworthy that the authorities, having pressure exerted on them by the Senate, interpreted it strictly under the old tradition. By contrast, industrial entrepreneurs hastened to express their dissatisfaction even with the text of the new decree. They continued to oppose it during the following decades. They wanted to utilise the power of rapids more freely and to regulate the wide seasonal fluctuations of water amounts

in the watercourses by using dams.[29] By strongly stressing the inconvenient shortage of water in wintertime, industrialists, especially from the 1880s, began to demand that the Diet should reform the law regarding watercourses and allow a more extensive utilisation of water resources for power production. In 1889 the authorities complied under pressure, and the Diet granted those industrial enterprises which had hydropower plants the right to dam the river for an emergency during periods of drought.[30] Later, two Committees were set up to prepare a bill on water rights.

The representatives of different interest groups participated in both the working of the Committees and the hearings in the Diet in 1900. In the preparation of the law, an attempt was made to reach a compromise by arbitrating different points of interest. This indicates that some kind of balance prevailed between conflicting groups. Agriculturalists were compelled to relinquish a part of their traditionally strong position in the Diet, because millowners and timber-floaters were gaining more power and support owing to the rapid expansion of industry. Unfortunately, the attempts to arbitrate made the Water Act of 1902 complex and unclear, and this allowed for diverse interpretations.

The builders of hydropower plants gained many concessions under the new law. First, they were granted more extensive rights to dam than earlier, although certain limitations were set. A basic principle in the law was that a hydropower plant should not be detrimental to a 'valuable head' or substantially inconvenient to other parties.[31] Causing minor inconvenience was then permitted.

Second, the builders of hydropower plants were given better opportunities to obtain the right to use the shares of rapids owned by others. The ownership of rivers is vitally important for the utilisation of hydro-potential. The Water Act of 1902 stipulated anew the rights to ownership of a river shared by two or more villages. This cleared up the situation only partially. Rapids, like water areas, were generally not parcelled, but rather were the common property of the farm owners. Villages were often large, comprising of hundreds of farms, each of which had its own share of the village's water areas. It has been stated that one great obstacle to developing hydropower resources in Finland was the time-wasting and troublesome process of acquiring all the shares of water rights for the ownership or use of the developer.[32] The third concession was that the regulation of a watercourse was allowed inside the builder's own water area, but nowhere else.

Not only the builders and owners of hydropower plants, but also the timber-floaters used efficient organisations to expand their activities and improve their status during the latter half of the nineteenth century. Therefore, the Water Act stated that mainstream channels had to be maintained on all waterways for timber-floating, navigation, and the passage of fish. This actually meant a restriction on the former freedoms of millowners. Because all rivers were now considered to be potential channels for timber-floating, all hydropower plants were required to have an official permit in advance. Thus it was ensured that the authorities had opportunities to secure the interests of timber-floaters.

The rights for damming and regulation granted for hydropower plants remained comparatively restricted, resulting particularly from the demands of the agriculturalists. During the 1890s, heavy floods had caused damage to farmers' fields, and they therefore wanted to preserve the unobstructed flow of water in watercourses.[33] The Water Act of 1902 also stated that the loss of a benefit or any other damage caused by a hydropower plant was to be compensated at a rate of one and half times its full value.[34] Additionally, the Water Act aimed to protect farmers' rights of ownership with respect to rivers and their banks.

When the Water Act was under preparation, the relative importance of fishing was clearly decreasing. The interests of fishing were looked after very ambiguously. Large rivers abounding in salmon, trout and whitefish were, however, protected so that a permanent dam was only allowed to be constructed in those parts where migratory fish did not usually rise. This applied primarily to the rivers flowing into the Gulf of Bothnia where salmon and whitefish were most numerous. It has been claimed that this provision of the Act in the course of time became a major obstacle for the construction of hydropower plants in the large rivers of northern Finland, until it was amended in the 1930s.[35] The builders were obliged to make a natural or artificial passage for fish in all dams, but the Water Act did not define how well it should function. Therefore, many dams became equipped with useless fishways.

Like timber-floating, navigation was regarded as one form of the common use of the waters. To a great extent the interests of river navigation were neglected in the Water Act, because the use of rivers for traffic was then considerably diminishing, while the road and railway networks were expanding.

Although the Water Act of 1902 was quite strict, its application to

hydropower projects was mitigated as the need for hydropower grew. On the one hand, this was the result of a tendency on the part of industrialists to interpret it deliberately in the way they had hoped it would have been explicitly stipulated.[36] On the other hand, the stand of the State with respect to the construction of hydropower plants became more positive than it had been previously. The State itself started to plan and promote the utilisation of rapids for electricity production. Generally, interest in electricity generated by hydroturbines increased vigorously during the 1910s. This was stimulated to a great extent by the shortage of import fuels, particularly coal and paraffin, during the First World War. After 1916 the construction of hydropower plants was substantially facilitated by the new decree concerning the parcelling of land.[37] It allowed for the free division of rapids and riverside lots from larger estates into separate pieces of land.[38]

The end of the turbulent period of 1914–18 and the attainment of political independence for Finland created new circumstances favourable for hydroelectric power plants which gradually began to assume the upper hand with respect to other interest groups. The country was then starting a deliberate programme of electrification utilising its hydropower resources. The central factor in carrying out the programme was the active participation of the State. The government built a power plant at the largest rapids in the country. This Imatra hydroelectric plant was one of the biggest in Europe when four turbines of its first and second section (together 75 MW) were put into operation in 1929–30.[39]

The resistance of other interest groups, anti-dammers, began to weaken as industrialisation proceeded. At the same time, more larger rapids could be brought technically and juridically under construction. 'The sheer necessity, the economic interest of the country and the enlightened era caused the comparative free interpretation of the restricted Water Act', wrote a civil engineer.[40] The boom in the development of hydropower was not restrained by the rise of a new pressure group, the conservationists, in the 1920s. The early conservationists did not aim at a mass movement against power plants, but they were content to protest against the new energy technology in the newspapers and journals in the national romantic tendency.[41]

The initially cautious attitude towards electricity was replaced by general enthusiasm from the mid-1910s. Rapids at famous beauty spots were harnessed for energy production, and it was considered to be an unfortunate matter of necessity. The construction of power plants and distribution networks for electricity soon developed into important projects for employing a part of the labour force no longer engaged in agriculture. During the big slump of the 1930s, industrialists again began to demand the moderation of legislation related to watercourses by referring to the need to find work for the vast number of unemployed. For this reason, in 1934 two essential modifications were made in the law of riparian rights.

Firstly, the regulation of watercourses was allowed. An official permit for a private hydropower company could, however, only be granted on fairly strict conditions. The State was, in contrast, authorised to regulate watercourses, even if the regulation would be detrimental to a 'valuable head' or substantially inconvenient to the other parties. A new contribution to the Finnish law of riparian rights was the comparison of different interests. By regulation the State had to receive a benefit, the value of which was at least twice as large as the amount of detriment and inconvenience.[42] Secondly, hydropower projects could be declared urgent, and then the consideration of the application for a construction permit was hastened by establishing a special watercourse commission.[43]

The persistent applications made by a state-run power company to construct plants at major rapids on the river Oulu, a large stream rich in salmon in northern Finland, led legislation relating to watercourses to a new phase in the interwar years. The government's new argument was that river fishing was unimportant compared with hydropower and should not be allowed to hold up hydro development. As a result, a new amendment was made in May 1939 to the Water Act of 1902. It gave permission for the construction of a permanent dam across the mainstream, even on large rivers, if the loss to fishing was clearly smaller than the benefit gained by the hydro development.[44]

The growing demand for power for the increasingly influential industry as well as the development of hydropower technology towards ever powerful units put repeated pressure on the government and Parliament to reform the law of riparian rights to keep it consistent with the interests of energy production. Up until the 1930s, one of the main principles in the legislation relating to watercourses was that hydropower plants should cause only minor disadvantages or no inconvenience at all to other parties. Practical interpretations of the law could not always follow this ideal, and some substantial injustices to the other parties were committed in the construction projects of hydropower plants particularly after the stipulation of the Water Act of 1902.[45]

The law of riparian rights and the development of hydropower entered a decisive epoch in the year 1940. The loss of one-third of the built-up hydroelectric capacity in the Winter War of 1939–40 combined with a simultaneous drought and a fuel shortage compelled the industry to produce the maximum output from the remaining hydroelectric plants. In July 1940, therefore, an Act was passed permitting temporary licenses to be granted for regulating watercourses before the final permits were granted.[46] It soon became necessary to speed up the construction of new hydropower plants as well, and in March 1941 an Emergency Act for power plant construction was passed.[47] Under this Act, a power company which possessed a building site and at least two-thirds of the hydro potential of the rapids could be granted a temporary licence to build a power plant before the final decision on its case was made. The Acts of 1940 and 1941 not only accelerated the handling of applications, but they opened up entirely new opportunities for future hydroelectric projects. These two temporary amendments of the Water Act of 1902 made energy production the most important aspect in the utilisation of rivers, for they gave the right to exclude the other forms of use, even though these might have produced as large a benefit as energy production. Thus, within the span of a century, millowners achieved dominance in the use of Finnish rivers, while hydroturbine technology executed a complete breakthrough in the competition with other prime movers.

The Emergency Act of 1941 was due to expire at the end of 1945, but it was subsequently extended to April 1962 when the new Water Act took effect. In twenty years, 61 hydropower plants were constructed. Together they generated about 5400 GWh or a half of the average hydroelectric output between 1966 and 1976.[48]

After a lengthy preparation, a new Water Act was passed by Parliament in May 1961. This Act stipulated who was entitled to build a hydropower plant and on what conditions. Technological changes in hydropower building had made it possible to concentrate several successive heads into a single plant. There were, however, practical difficulties in acquiring the ownership of the whole stretch of a river related to power generation. For this reason, a permit could also be granted to the holder of the utilisation rights. In contrast to the former legislation, the new Water Act specified the procedures for obtaining a utilisation right by agreement and the legal conditions for starting a project. Under the new Act, an applicant who owns or holds the right to use at least one-fifth of the hydro potential of a certain stretch of river could be entitled to use permanently the hydro potential of the other co-owners against payment of fully adequate compensation. The regulations concerning the mainstream and its closing were roughly similar to those in earlier laws. One-third of the width of a river must be kept open to allow the free flow of water, and permit timber-floating, navigation and the passage of fish. Despite the prohibitive wording, the new Water Act was not so strict in the closing of the mainstream as the Act of 1902 had been. But definitely prohibited was the closing of the channels of navigation and timber-floating without an official permit.[49]

One of the conditions for granting a legal permit for the closing of the mainstream was the developer's obligation to construct the necessary floating equipment. Actually, the new Act secured better facilities for timber-floaters than the earlier legislation. The new provisions were to ensure that the effectiveness of timber-floating would not substantially deteriorate. The Act of 1961 did not make new concessions to other interest groups, such as farmers, fishermen and plyers. The Act consolidated the wartime 'temporary' position of hydropower companies to their permanent dominance.[50]

Engineers and power companies have considered the laws of riparian rights at any given time a serious obstacle to building hydropower plants. In the festschrift of the Finnish Water Power Association, the political scientist Reino O. Hinkka expressed an opposite view in his retrospective survey: 'All this bears out the old saying: where there is a will there is a way. Hydro development has gone ahead without excessive difficulty, despite the tardiness of systematic codification and the impediment of superannuated laws, even at a time when development was at its most intense.'[51] To consider the era of hydroelectric power objectively, some restrictive effects of juridical matters cannot, however, be denied. First, the Finnish laws and their tightly nationalist interpretation were used for filibustering and even prohibiting direct foreign investment in the hydroelectric plants, as described in Chapter 2.5. Second, before the interwar period juridical aspects partly restricted the opportunities of the Finnish millowners to dam, regulate water levels and extensively utilise the hydropotential of rivers for the generation of power. At the time, the regulations on the 'king's vein' required operators to drain large amounts of water past hydroturbines. Third, the complexity of the legislation postponed the hydroelectric projects before the Emergency Acts of the 1940s. By contrast, under these new acts the rights of some other interest groups were violated.

To sum up, legislation and the conflicting interests of political

pressure groups partly caused the retardation of hydro development in Finland up to the interwar period. These obstacles were gradually removed, and from the 1940s, hydroelectric projects received the generous support of legislators and political decision-makers.

The Technology of Dam Building

Hydropower resources and the institutional framework of their utilisation were not the only factors influencing the construction of hydropower plants. The country's technological potential had a great impact on what kind of building sites could be utilised and how. It was the task of power companies and their technical specialists to apply the available technology to the local physical and societal circumstances. In dam-building, the consideration of these circumstances was particularly important. Dams are at the same time technical, environmental and societal objects. They had to suffice for various purposes.

Before the First World War, there were not only legal but also technological problems in dam-building. The shortage of both know-how and competent personnel meant that in Finland the planning of a hydropower plant took many years. There were difficulties in finding economical and technically reliable ways for building hydroelectric power plants. Even if all the legal restrictions have been revoked, the harnessing of big rivers would have met serious technical problems before 1910. Traditionally, wood had been the principal building material for regulating dams in Finland. In small rivers, simple dam structures were erected with wooden piers, buttresses and gates. This technique was not suitable for damming big rivers, because wooden piers were too weak. Dam-walls of stone had to be founded on rock – an expensive task considering nineteenth-century equipment.[52]

The lack of knowledge of soil mechanics and proper equipment made the construction of earthfill dams too costly. To create reliable compacting was a serious technical problem with those dams. Therefore, big dams were not built in Finland before the introduction of concrete dams in the 1920s. Concrete technology was adopted rather late in Finland. Artificial Portland cement, the central element of concrete, was patented by the Englishman Joseph Aspdin in 1824.[53] Soon afterwards, the industrial production of artificial cement was set up in Britain. The first proper concrete dam was built at San Mateo in California between 1887 and 1888.[54]

Although domestic production was small, the importing of cement to Finland was almost negligible in the nineteenth century.[55] By 1901 it had increased to 15 tons per year. On the eve of the First World War its importation had risen by a factor of eight. After a severe wartime slump, cement consumption grew to 125 000 tons by 1923 when the prewar peak was reattained.[56] During the next five years, consumption almost trebled. A significant cause for the growing use of concrete structures was that cement production began from indigenous raw materials in two Finnish factories in 1914 and 1919. On the international scale, cement consumption was modest in Finland. In 1923 it was 34 kg per capita compared with 85 kg in Denmark and 204 kg in the USA.[57]

Before the introduction of ferroconcrete technology, cement and concrete were generally used as only minor supplements to other principal building materials. In Finland, the first notable concrete structures reinforced by iron were built by the German construction firm Adhaesion, Gesellschaft für Eisenbetonbau in 1904.[58] In the following two years, German companies such as Meyer & Sohn, the big firm Wayss & Freytag AG and Swedish engineering offices including August Kiökemeister's, also began to build concrete structures in Finland.[59] For many years concrete technology was primarily applied to houses and bridges. As a result of visiting the Paris World Exhibition in 1900, studying in German universities and reading German technical literature, Finnish engineers learned novel ferroconcrete methods.[60] In 1907 they started designing and building their own small-scale ferroconcrete structures. These first projects were headed by the lecturer Jalmar Castrén at the Polytechnic of Helsinki. Contemporaries claimed these projects were more important for the diffusion of this new technology than were the projects carried out by foreigners. Foreign construction firms brought entire calculations and drawings from abroad; the Finns had no access to the methods by which they were worked out.[61]

The use of concrete for hydropower projects swiftly spread after the First World War. By the late 1920s, the Finns learnt to master concrete technology and gave up the old masonry technique such as rock facings for the dams. The development of dynamite technology also decreased the costs of water passage building by the early interwar period.[62]

In Finland, the heyday of massive concrete gravity dams and buttress dams was from the 1920s to the late 1940s. Thereafter, earthfill became the principal dam structure. Ferroconcrete technology, which was swiftly adopted in interwar Finland, still maintained its position in the construction of machine stations and spillways in the dams.[63]

The development of modern compacting and earthmoving equipment started from the invention of the claw roller in 1904. This together with advances in soil analysis and soil mechanics brought earthfill and rockfill dams in favour. Lower building costs were the main advantage of these types of dam. Motorised earthmoving machines were introduced in Finland from about 1910. In the 1920s, workers called new steam shovels *Hullu-Jussit* (Mad-Johnnys), because they could excavate a couple of cubic metres of earth from the water passage at a time and load railway wagons unceasingly with spoil. However, it was only from the late 1940s when the extensive use of excavators, cranes, rock-drilling machines, bulldozers, and trucks revolutionised Finnish dam construction just as ferroconcrete technology had done about thirty years earlier.

Finnish dams are rather small even though the maximum height was doubled and the capacity of the biggest dam grew by a factor of 136 after the completion of the dam at the Imatra power plant (Table 3.3).

Table 3.3 'Big' dams in Finland in the 1970s

Type	*Name*	*Height m*	*Capacity 1000 m³*	*Year of completion*
MCD	Imatra	20	19	1929
MCD	Pälli	16	21	1953
MCD	Utanen	16	29	1956
BCD	Harjavalta	26	26	1939
BCD	Mankala	15	15	1949
BCD	Pyhäkoski	36	150	1949
BCD	Kaltimo	19	475	1958
MED	Pamilo	19	1110	1955
MED	Petäjäskoski	18	2600	1957
MED	Aittokoski	29	463	1960
MED	Seitenoikea	25	450	1961
MED	Seitakorva	22	1400	1963
MED	Pitkämö	29	175	1969
MED	Porttipahta	38	1170	1970
MED	Melo	33	150	1971

MCD = Massive concrete dam; BCD = Buttress concrete dam;
MED = Massive earthfill dam.

Source: Jaakko Holm and Antti Leskelä, 'Padot', *Vesirakenteiden suunnittelu*, RIL 123 (Helsinki, 1979) p. 58.

In the 1970s the highest dam in the world, Rogunsky in the USSR, had a height of 325 metres, and the most voluminous dam, the New Cornelia Tailings-dam in the USA, had a capacity of 210 million cubic metres.[64]

The most common type of Finnish hydroelectric power plant is the run-of-river power plant with low water pressure (see Table 3.4). This type can regulate the discharge only in the very short run owing to its small water reservoir. A Finnish power plant is most often built as part of a dam.

A plant with a considerable lake as a headwater basin serves as a storage power plant. This is also general in Finland. The Jylhämä hydroelectric plant on the Oulu watercourse is the best example of this type of power plant.

Owing to the development of rock-digging technology and reinforcing methods, tunnel power plants became competitive with traditional power plants. Their water passages and machine stations

Table 3.4 General classifications of hydroelectric power plants

By regulation	*By structure*	*By water pressure*
Run-of-river power plant (*Laufkraftwerk*) – for daily regulation	Dam with an integrated power plant	Low pressure plants Head: <10 m – turbines: tubular, ordinary Kaplan or Francis
Storage power plant (*Speicherkraftwerk*) – for annual regulation	Plant with a pressure tube – dam with a separate machine station	Low medium pressure plants Head: 10–40 m – turbines: ordinary Kaplan or Francis
Pumped storage plant (*Pumpspeicherwerk*) – for daily regulation – circulates water between two reservoirs	Tunnel power plant – machine station inside a bedrock tunnel	High medium pressure plants Head: 40–400 m – turbines: Francis
Tidal power plant (*Gezeitenkraftwerk*) – daily regulation – double acting		High pressure plants Head: 400–1800 m – turbines: Pelton

Source: Risto Keskinen. 'Vesivoimalaitosten laitos- ja koneistotyypit', *Vesivoimalaitokset*, INSKO 45–78 (Helsinki, 1978) pp. 65–8.

can be situated in underground tunnels away from the dams. Earth and rockmoving works can be carried out on a much smaller scale than in the case of an open river power plant. The amount of concrete structures is also much smaller, partly because in the Finnish bedrock the lining of tunnels is not always necessary. In Sweden and Norway, tunnel power plants are general, but in Finland there are only three of them, at Jumisko, Pirttikoski and Pamilo.[65]

Due to the rapid development in dredging, quarrying and other earthmoving methods, the low heads of several successive rapids could be concentrated into a single hydroplant. It became economical to carry out such projects which were considered impossible during the interwar period.[66] New construction methods and equipment enlarged the scope of technically exploitable hydropower resources. Technological factors and building costs were decisive also in the choice of rivers, building sites and dam designs for power plants.

In summary, among the reasons for the delayed start in the construction of regulating dams and large hydroelectric power plants was the Finns' modest knowledge of ferroconcrete technology and modern power plant designing. Moreover, they were reluctant to accept 'turn-key' solutions tendered by foreign companies and they categorically opposed concessions for foreigners to build and operate hydropower plants. They considered that learning to build hydropower plants themselves was the only way to solve the problem. However, it took over two decades at the beginning of this century before Finnish firms and engineers were competent to design and construct large hydroelectric power plants.[67]

Turbine Technology

The use of hydropower technology had long traditions before the hydroelectric era. For centuries, Finnish flourmills, sawmills, iron works and other small factories were run by wooden water wheels. The introduction of the so-called Scottish reaction wheels in 1847 opened up a new era in Finnish hydropower technology. In the 1850s proper hydroturbines, the Fourneyron machines, were put into operation. From the next decade, the Jonval hydroturbines began to dominate waterpower installations in Finland.[68]

The majority of the installed hydroturbines were of Finnish manufacture up until the early 1870s. Large factories like pulp and paper mills increasingly imported their big hydroturbines. Technological change in working machines favoured fast-revolving and efficient power machines. In these respects, American Francis turbines became famous and gained a notable market share in Europe, too.[69] They were also imported into Finland from the 1890s. While foreign competition became keener, Finnish machine shops had to continue manufacturing older and less efficient turbine types, because they had poor facilities for research and development.

German and Swedish manufacturers had better opportunities to respond to the American challenge. They succeeded in developing competitive versions of the Francis turbine. In 1901 the German firm Briegleb Hansen & Co attempted to prove by empirical experiments that its own turbine surpassed the 'New American' hydroturbine advertised as by far the best. The advance of European turbines was reported in Finnish technical journals.[70] Consequently, German firms including Briegleb Hansen & Co and J. M. Voith, and the Swedish AB Karlstad Mekaniska Werkstad (KMW) gained a strong foothold in the Finnish markets. The Finnish manufacturers could survive only by producing small and medium hydroturbines for flourmills, minor factories and rural electricity supply utilities. In order to keep up with the accelerating development of turbine technology, they decided to buy licences and technological know-how in other forms as well. The lack of both a modern hydraulic laboratory and of other resources for competitive R & D compelled Tampella, the largest Finnish hydroturbine manufacturer, to accept a co-operation agreement with KMW, the leading Swedish hydroturbine producer, in 1913 (see Table 3.5). Owing to successful laboratory experiments and design, the speed of the Francis turbines made by Tampella increased from 124 to 420 rpm during the period 1897 to 1917. This increase signified a definite development towards a level on a par with international standards.[71]

Between 1904 and 1918, four medium-sized Finnish machine shops had to give up the production of hydroturbines. One notable manufacturer, the Onkilahti machine shop, was set up in 1904. From the outset it started with a Francis turbine. It did not, however, begin to produce its own design, but an imitation of the 'Success' turbine of the American S. Morgan Smith. Neither enabled Onkilahti to continue production by its own efforts. In order to produce turbines bigger than 500 kW, it made a co-operation agreement with the Swedish machine shop, Nyqvist & Holm Ab (Nohab) in 1928.[72]

The 1910s was a turning-point for Finnish turbine manufacturing. The First World War blocked the import of both German and American hydroturbines and the fuel for oil lamps. Soon demand

began to grow for turbines for small and medium size hydroelectric power plants all over the country. Domestic machine shops were busy; they managed to regain the dominant position in the home market, and maintained it during the whole interwar period, as shown in Table 3.5.

During this century, the Francis machine has been the most widely used hydraulic turbine in the world. Between 1900 and 1930 it also dominated the installations of new hydroturbines in Finland. In due course however the Francis turbine, too, failed to satisfy the growing requirements of the power producers: higher capacity, velocity, and efficiency. In that respect, it faced a serious competitor in 1913 when Viktor Kaplan, an Austrian professor in Brünn (Brno), patented a new, rapidly revolving hydroturbine with an efficiency of 85 to 95 per cent.[73] While the turbine types of the mid nineteenth century had, in practice, a maximum velocity of 100 to 200 rpm under an average waterfall and the developed Francis machine had one of 200–450 rpm, the Kaplan turbine, in contrast, attained a velocity of up to 500–1000 rpm. The newcomer also had excellent characteristics with respect to speed regulation: both its stationary guide vanes and the vanes of its propeller could easily be governed.[74]

Because the Kaplan turbine was well suited to the low heads of the medium and large rivers in Finland, Tampella bought a licence through its Swedish partner, KMW, in 1923. It delivered the first propelturbine in the following year, and the first proper Kaplan turbines to the power plant of a papermill at Simpele in 1925.[75] Since the late 1930s, when the production of small hydroturbines slackened and efforts were concentrated on large hydroelectric power plants, the Kaplan turbine has been the leading type manufactured by the Finnish hydroturbine industry.

The postwar reconstruction period came as a shock to the Finnish hydroturbine manufacturers which had dominated their home market during the interwar years. The Onkilahti machine shop went bankrupt in 1946. Tampella lost a considerable market share to foreign companies from Switzerland, West Germany and the USA. The main reason for this was that Tampella's relatively small capacity was engaged in the production of war reparation materials for the Soviet Union. In the background, there were, however, other reasons. Finnish companies using hydropower were dissatisfied with the technological level of domestic turbines. For many years, Tampella had continued to manufacture unchanged models designed by its Swedish partner. KMW had been a pioneer in developing early

Table 3.5 The net supply of hydroturbines in Finland, 1847–1975

	1847–95		*1896–1912*		*1913–55*		*1956–75*		*1847–75*	
	no.	*MW*	*no.*	*MW*	*no.*	*MW*	*no.*	*MW*	*no.*	*MW*
A. Tampella's production	150	6	200	14	1645	1520	105	1270	2100	2810
B. Production of other works	375	7	570	12	400	20	0	0	1345	39
C. Total Finnish production	525	13	770	26	2045	1540	105	1270	3445	2849
D. Export	9	0	2	0	140	315	17	125	168	440
E. Import	350	16	420	40	105	240	36	175	911	471
F. Net supply (C−D+E)	886	29	1188	66	2010	1465	124	1320	4188	2880
G. Rate of self-sufficiency (100×C/F)		45%		39%		105%		96%		99%

Sources: Risto Keskinen, *Transfer of Water Turbine Technology to and from Finland*, a paper delivered in 'The Nordic Symposium on the History of Technology', 14–16 June 1988 (mimeograph, 1988) p. 12.

Kaplan machines and one of the leading hydroturbine producers in the 1920s, but it had later lost its dynamic spirit. The company lacked resources for competitive R & D and it was reluctant to make even small improvements.[76]

To regain its competitiveness, Tampella first sought partners from elsewhere, such as Th. Bell & Cie from Switzerland. Second, it created proper conditions for indigenous R & D by completing a modern hydraulic laboratory in Tampere in 1954. In the following year, the company gave up its co-operation with KMW and began to rely on its own expertise in designing and manufacturing. As a result, the structure of Tampella turbines was substantially reshaped.[77]

One of the new types was a tubular turbine which made it profitable to build even for small and very low heads. For these conditions, the Francis turbines were too slowly revolving and the ordinary Kaplan turbine with a vertical axis required expensive concrete structures and a special generator. The tubular turbine is a modification of the original Kaplan turbine with a horizontal axis. In Central Europe, the tubular turbine had been in commercial use since 1940. Tampella developed three versions of its tubular turbine:

the tube, the bulb, and the pit type. The first one was designed for small power plants and it became the most common. Its structure saved building costs in two ways. The water passages were made of plate steel instead of the more expensive ferroconcrete structures and the installation of a standard generator was possible.[78]

Owing to investments in R & D and the production capacity, Tampella succeeded in regaining its dominant position in its home market in the 1950s. At the same time, the company caught up with the international standard of turbine manufacturing. Before 1917, Finnish turbines were exported to Russia and the Baltic provinces. In the interwar period, turbines were shipped only to the Baltic republics. Shortly after 1944, Finland produced 74 hydroturbines for the Soviet Union as war reparations and then exported about two dozen others to that country. Between 1950 and 1965, turbines were also shipped to Spain, Poland, Turkey, Iceland, Norway and Sweden.[79]

Later exports were more orientated to the demanding Western markets. Between 1965 and 1982, Tampella shipped 16 hydroturbines to Sweden and Norway, which had formerly supplied both turbines and know-how to Finland. Nevertheless, the future prospects of hydroelectric manufacturing looked rather meagre in the 1960s; there was a steep slowdown in the construction of hydroelectric power plants both in Finland and Europe in general. The Finnish companies were so pessimistic that in 1966 Strömberg Oy decided to finish the production of generators for hydropower plants and Tampella announced its abandonment of hydroturbine manufacturing. The oil crisis of 1973, however, restored faith in hydropower and Tampella and Strömberg continued to produce machinery for new Finnish and foreign hydroelectric power plants. At the same time, old plants were modernised with up-to-date, more efficient equipment.[80]

3.4 STEAM POWER

Fuel supply

Because Finland does not possess resources of coal, brown coal, oil or natural gas all fossil fuels have had to be imported. Transport costs have substantially increased the prices of these energy sources. Traditionally, coal has been a competitive fuel on the coast, but only a few dozen kilometres from the ports its price was for a long time almost the same as that of firewood, the most common indigenous fuel.[81] Up to the 1960s, coal was mainly a reserve fuel which was used in electricity generation during droughts, economic boom years and shortages of indigenous fuels at competitive prices. This caused severe fluctuations in the volume of coal consumption. Most years, the needs of coastal steam power plants kept the share of coal of all fuels consumed for generation at over 20 per cent up to the mid-1970s. Oil was introduced in steam power plants in the 1940s. Emergency oil deliveries from Sweden were crucial during the exceptional drought of 1946–7. In normal circumstances, oil became an important fuel in electricity generation only from the late 1950s.[82]

A high price limited the use of firewood in electricity generation. This fuel was, however, greatly used between 1940 and 1947, when there was a lack of both hydropower and imported fuels. After the reconstruction period, firewood rapidly lost its significance as a fuel in electricity supply, as shown in Table 3.6.

Table 3.6 The proportions of fuels consumed by the electricity-producing steam power plants in Finland, 1930–75

Year	*A* *Coal* %	*B* *Oil* %	*C* *Natural gas* %	*D* *Firewood* %	*E* *Saw waste* %	*F* *Peat* %	*G* *Other fuels* %	*H* *Indigenous fuels (D+E+F+G)* %	*I* *Total* %
1930	26.3	0	0	14.2	59.5	0	0	73.7	100.0
1935	30.9	0	0	8.7	60.4	0	0	69.2	100.0
1938	42.1	0	0	7.1	48.5	0	2.3	57.9	100.0
1940	23.4	0	0	30.4	44.1	0.5	1.6	76.6	100.0
1942	46.9	0	0	19.9	32.9	0.3	0.0	53.1	100.0
1945	13.0	0	0	32.9	41.6	0.2	12.3	87.0	100.0
1947	32.3	13.2	0	22.3	21.3	0.6	10.3	54.5	100.0
1950	35.2	2.1	0	8.2	27.6	0.1	26.8	62.7	100.0
1955	15.0	7.1	0	2.6	26.7	0.1	48.5	77.9	100.0
1960	46.6	11.4	0	1.8	8.6	0.2	31.4	42.0	100.0
1965	22.0	29.6	0	0.3	11.6	0.2	36.3	48.4	100.0
.....									
1970*	45.6	35.0	0	..	..	..	..	19.4	100.0
1975*	39.6	37.4	8.7	..	..	..	..	14.3	100.0

Conversion factors: Coal 1 ton = 0.63 ton of oil equivalent (toe); Oil 1 ton = 1.0 toe; Natural gas 1000 m^3 = 0.855 toe; Firewood 1 m^3 = 0.111 toe; Saw waste 1 m^3 = 0.0496 toe; Peat 1 ton = 0.128 toe; black and sulphite liquor 1 ton = 0.315 toe.

* In 1970 and 1975, the statistics also include the fuels of gas turbines.

. . No data available.

Sources: Sähkölaitostilasto 1930–1965 (Helsinki, 1931–66); *OSF 42:4 Energy Statistics 1984* (Helsinki, 1985).

Since the 1910s, industrial waste has been a central fuel in Finnish electricity generation. Because of its cheapness, it could easily beat other fuels. The refuse of the sawmill industry, such as strips of wood, bark, chips, and sawdust, was for a long time the most important fuel for steam power plants. The amount of saw waste consumed was rather steady up to the 1970s, while its relative share gradually declined. Other branches of the wood-processing industry utilised their waste in electricity generation as well. The scale of generation with this waste remained quite modest up to the 1950s when Swedish methods of burning liquid wastes of the pulp industries were adopted in Finland. In a few years, black and sulphite liquors became notable primary energy sources for electricity supply.

Up to the early 1960s, the energy self-sufficiency rate of the Finnish electricity supply (including hydropower) was very high, over 74 per cent.[83] The main primary energy source, hydropower, was based totally on the country's own natural resources, and more than half of the thermal electricity was generated with indigenous fuels. The wide use of industrial waste and firewood caused some special technical requirements for the steam generation equipment. The conventional hearths of coal-burning boilers did not suit these fuels well. This fact had an effect on the demand for steam boilers. The unconventional circumstances required a technology to be applied to these specific needs. Therefore, Finnish machine shops had a good chance to compete with importers in this field.

Steam Boilers

The boiler is an integral part of a steam power plant. It must be adapted to the requirements of both the available fuels and prime movers. Following the advance of the prime movers, boilers have also experienced a radical technological change.

Before the era of electrification, old 'haystack' or 'wagon' type boilers were displaced by Cornish and Lancashire boilers in new installations in Finland.[84] The universal development of boilers during the age of electricity can be divided into four phases, as follows:[85]

During the first phase, in the period up to the turn of the century, three main characteristics can be identified: (i) the manual fuel feeding on the horizontal fire bars of the furnace; (ii) a thick riveted cylinder with one or more flues and a big water tank; and (iii) steam generation for reciprocating engines.

The second phase took place roughly during the first quarter of the twentieth century with the following improvements:

(1) Mechanical fuel stokers replaced manual feeding.
(2) Stepwise hearths or a rotating chain of fire bars were adopted.
(3) Cornish and Lancashire boilers were superseded by multiple fire-tube boilers in the smaller installations and by water-tube boilers in larger ones. Owing to the smaller diameter of the water tank, the steam pressure could be increased.
(4) Reciprocating steam engines were supplanted by steam turbines. The capacity of a single boiler was insufficient for a steam turbine, because burning fuels on fire bars of a furnace did not generate enough heat. Big turbines required several boilers to fulfil their requirement of steam. Boiler technology was clearly behind the development of the steam turbine and was regarded as a bottleneck for the efficient utilisation of turbogenerator technology.

The adoption of coaldust heating opened up the third phase (1925–55). This innovation increased the capacity of a single boiler so much that one boiler was enough even for a big steam turbine. This meant an epoch-making change in boiler technology. The abandonment of the water tank was the dominant feature of the fourth phase (1955–75). The new type was a boiler where water flowed through pipes coupled serially or in parallel. Water boiled directly to dry steam without an intermediate stage of wet steam. The pressure and flow of steam could, therefore, be increased without great difficulties.

In respect of steam boilers, Finland had a very high rate of self-sufficiency. In nineteenth-century Finland, most domestic steam boilers were small and simple. They were mainly imitations of foreign models made domestically under the supervision of foreign engineers. Multiple fire-tube boilers and water-tube boilers were introduced in Finland by the 1890s. The structure of these types was more complicated. Finnish machine shops, therefore, preferred to buy foreign licences for their production. For example, in the early 1910s the machine shop Kone ja Silta Oy, bought a licence for the American Babcock & Wilcox boiler through the latter company's associate in London. This boiler type with inclined rows of hollow cast iron tubes and natural circulation was patented in 1867 in the USA.[86] It became the most common water-tube boiler in Finland in the early twentieth century.[87]

In the 1920s, boilers with coaldust heating were first installed in some of the largest Finnish power plants. Their heating surface could produce twice as much steam per square metre as the Lancashire boiler. Moreover, a cold boiler of this type could be heated quickly, in an emergency even in 15 minutes, and it worked efficiently.[88]

Various means for the transfer of developed boiler technology can be illustrated from the case of the domestic company Tampella which began to manufacture water-tube boilers. Firstly, the company set up a department for boiler production in 1933. In the next year, the company nominated as the department's director the Finnish engineer Carl af Hällström who had worked in the USA for several years and was well-versed there in boiler manufacturing. The department started to produce boilers with vertical water-tubes under licence from Yarrow & Co Ltd from Glasgow. Between 1933 and 1951, Tampella made 49 Yarrow-boilers; some of them were the biggest boilers in Finland at the time. Moreover, Tampella hired the Swedish engineer Carl Thomas Carlson and also began to manufacture boilers to his design. Between 1935 and 1939, in total 28 so-called Tampella-Carlson boilers were produced for the home market and export.[89]

Despite the acceleration of technological change, Finnish machine shops could keep their strong foothold in the home market for both small and big steam boilers. In interwar Finland, the great majority of stationary boilers were the multiple fire-tube type with a heating surface of 20 to 200 square metres. This type accounted for about two-thirds of the total number of boilers. It was popular in small Finnish power plants, because it was very suitable for heating with firewood and saw waste. With a few exceptions, all multiple fire-tube boilers were made in Finland.[90] Large water-tube boilers with a heating surface of 200 to 1500 square metres were frequently manufactured under foreign licence or imported. Because fuel, coal, coke and firewood were relatively expensive in Finland at the time, boilers in use were generally modern and efficient.

After the Second World War, Finnish machine shops began to design steam boilers of all sizes for themselves. They gave up buying licences for whole boilers but, instead, purchased licences for special components, such as economisers, superheaters and spreader stokers. In the 1950s, a rapid development started in Finnish boiler design. Water-tube boilers totally supplanted both the boilers with flues and multiple fire-tube boilers. Since the early 1960s, Finnish machine shops have mainly relied on their own R & D in boiler manufacturing. Some of them have developed prominent multifuel boilers which could burn coal, oil, woodchips, peat, etc. at the same time. Boiler manufacturers, like Finnish engineering firms in general, have traditionally been owned by the citizens of the country. None of them was a subsidiary of transnational companies during the period under research.

During the present century, at most nearly 300 steam boilers have been made annually. In the mid-1960s, there were over 7000 registered boilers working in Finland. Thereafter, their number decreased to 4800 in fifteen years due to the centralisation in the generation of steam and thermal power. In the postwar era up to the 1970s, Finland's self-sufficiency was strengthened and it exported a great many steam boilers, mainly to the Soviet Union, but also to other Comecon countries, as well as China, Brazil, Sweden, etc.[91]

Reciprocating Steam Engines

In industrialised countries, the reciprocating steam engine developed very rapidly between 1850 and 1870. It seemed to displace all other prime movers. From the 1880s its position was, however, challenged by various competitors. Internal combustion engines proved to be more economical than small steam engines. The rapid development of electrical engineering, especially three-phase transmission, gave new promising opportunities for the hydroturbine which had formerly met serious difficulties in preserving its market share. The most threatening competitor was, however, the steam turbine independently invented by the Swede Carl Gustav de Laval in 1883 and the Englishman Charles A. Parsons in 1884.[92]

At the time, a great many people continued to believe in the future of the reciprocating steam engine. Nevertheless, some improvements were seen to be necessary. The rivalry between various prime movers led to their accelerated technological development from the late 1890s to the 1920s. Consequently, all aspects of steam power technology took a big leap forward.[93]

In the last quarter of the nineteenth century, high-speed engines were increasingly needed to drive dynamos. But the unfortunate disadvantage of reciprocating steam engines was that they ran desperately slowly. Attempts were made to solve the problem with belts, gears and even with greatly improved engine types. In spite of everything, the decline of the large reciprocating steam engine began in electricity generation about 1900. As a prime mover of locomotives and ships, the steam engine maintained its position much longer.

Up to the 1910s most of the thermal generation capacity in Finland was run by steam engines. Small engines were mainly made in the country and larger ones were imported. The principal foreign suppliers were firms from Sweden, Germany, Switzerland and Britain. Many of the nineteenth-century Finnish-made engines were designed by immigrant engineers or they were local modifications of Western models. Although the Finns manufactured reliable small engines, they did not manage to make any substantial contributions to steam power technology apart from minor improvements. From 1837 to 1957, over 15 000 reciprocating steam engines were produced in the country for stationary installations, portable steam engine-units, locomotives and ships. In Finland, steam turbines gradually supplanted reciprocating engines in electricity generation between 1900 and 1940.[94]

Steam Turbines

The emergence of electricity supply decisively influenced the development of the steam turbine. In fact, big steam turbines were designed specifically to run generators.[95] Compared with the reciprocating engine, the steam turbine had several advantages, as follows:[96]

(1) The most important was that it revolved fast enough for generators. A reciprocating engine with more than 600 rpm was a rarity. The velocity of 1000 to 30 000 rpm was, in contrast, no problem for a turbine. It could be coupled directly to a generator without any gears.
(2) It made building big units possible. For a single steam engine, approximately 5 MW was the maximum capacity. In the 1970s, the biggest turbogenerator provided 1000 MW.[97]
(3) After the first few years, the rate of efficiency of the steam turbine surpassed that of the reciprocating engine. With the same amount of steam, it generated more electricity than the reciprocating engine.[98]
(4) It was cheaper than a reciprocating engine with the same capacity.
(5) It required considerably less space.
(6) It needed less supervision and service.
(7) It ran much more smoothly and caused no flickering in lamps.

Although a condensing steam turbine unit is regarded as an economical prime mover, it wastes most of the energy supplied for it.

In the modern condensing turbine plants, only 35–40 per cent of primary energy is transformed to electricity; the rest is lost in the various phases of the process.

Steam turbines have never been manufactured in Finland. This has been considered an indication of Finland's persistent backwardness in high technology. For example, the Finnish emeritus professor of thermodynamics Per-Holger Sahlberg has claimed that Finland should have set up steam turbine production in the early twentieth century. In the postwar era, these kind of plans were too late: a jump directly from scratch to modern complicated turbines was difficult to carry out without tremendous financial sacrifices.[99] From a retrospective viewpoint, such a goal looks rather over-ambitious. In the 1960s, steam turbines were manufactured only in fourteen countries; Table 3.7 depicts the situation in the middle of the decade. Generally, these countries had big, developed economies. Among them there were only four small countries with a population of less than 15 million inhabitants. They were Switzerland, Sweden, Czechoslovakia and Belgium; all of them had a stronger industrial base in the early twentieth century than Finland. Consequently, the present situation in the latter country is quite understandable. Nevertheless, three East European countries, Poland, East Germany and Hungary, started to produce steam turbines in the postwar era. In Western countries, the production of steam turbines became markedly concentrated from the mid-1960s to the mid-1970s when the number of Western manufacturers operating transnationally decreased to eight companies.[100]

The absence of a Finnish production did not seem to hamper the diffusion of steam turbines in the country. The negative aspect was that the domestic industry lost some of the important economic and technological backward linkages which would have been the case with thermal power plants equipped with Finnish steam turbines.

The first steam turbines for generators were imported into Finland in the early 1890s.[101] These were rather small Swedish de Laval action turbines. The installation of two Zoelly-turbogenerators, each with 500 hp, by Friedr. Krupp AG opened up the new era of large thermal units in the Finnish electricity supply. These turbines, with the manufacturer's serial numbers 2 and 3, were put into operation in the wool factory Ab F. Klingendahl & Co Oy in Tampere in 1905.[102] In the following few years, big German and Swedish firms delivered several turbogenerators to Finland. By means of their sales subsidiaries, the German AEG and Siemens & Halske got a strong

Table 3.7 The steam turbine manufacturers in the world in the mid-1960s

Country	*Manufacturer*	*Licenser*
Belgium	ACEC (Westinghouse's subsidiary)	Westinghouse
Britain	AEI, English Electric, GEC, Parsons	
Czechoslovakia	Skoda/Ersten Brünner Maschinenfabrik	
France	Ahlsthom, Rateau, CEM	
East Germany	Bergmann-Borsig	
West Germany	AEG, Siemens-Schuckert Werke, Brown Boveri & Cie, Bloom & Voss, MAN	
Italy	Ansaldo,	General Electric
	Franco Tosi	Westinghouse
Poland	Zamech	General Electric
Soviet Union	LMZ in Leningrad, A factory in Khar'kov	
Sweden	Stal-Laval	
Switzerland	Escher Wyss, Brown Boveri & Cie	
Japan	Hitachi, Toshiba,	General Electric
	Mitsubishi,	Westinghouse
	Fuji	AEG/Siemens
China	2 factories	Skoda
USA	General Electric, Westinghouse	

Sources: Matti Lajunen, *Höyry- ja kaasuturbiinit* (Tampere, 1972) pp. 59–60; B. Epstein and K. R. U. Mirow, *Impact on Developing Countries of Restrictive Business Practices of Transnational Corporations in the Electrical Equipment Industry: A Case Study on Brazil*, UNCTAD (New York, 1977) pp. 19, 26.

foothold in the Finnish market. They supplied the larger turbogenerators, while the Swedish firm de Laval with other companies could compete only in the field of smaller units.[103]

In the interwar period, the Finnish steam turbine market was again shared by foreign manufacturers. The AEG and Siemens & Schuckert lost a good deal of their former stronghold as turbogenerator suppliers. The Swiss Brown, Boveri & Cie (BBC) expanded its market share in the country at the expense of de Laval.[104] Moreover, other companies, such as the English Metropolitan Vickers, the German Maschinenfabrik Augsburg-Nürnberg AG and the Swiss Oerlikon AG, managed to sell their products through their Finnish agents.[105]

After the Second World War, Finland ordered at first mainly back-pressure turbines. Later the number of conventional condensing turbogenerators increased. At first nearly all steam turbines were ordered from West German, Swedish or Swiss companies, but later tenders from new suppliers were seriously considered. For example, in the 1960s, of twelve back-pressure turbines installed in municipal power and district heating plants nine were West German and three Swedish. By 1965, AEG had delivered 48 per cent of the total capacity of all installed or ordered turbogenerators in Finland.[106] In the 1970s, East European firms supplied eleven units, and Parsons Co., a British company, one steam turbine for similar plants. Thus Finnish power companies were not dependent on only a handful of transnational companies but derived benefit from their freedom of choice between several competitors. The Finnish engineers' innovative task became one of fitting Western and Eastern components to work together in the same plants.

3.5 OTHER PRIME MOVERS

The first German gas engines were imported into Finland in the 1870s.[107] The domestic manufacture of petrol engines started in 1895 and of diesel engines in 1903. Apart from motors for automobiles, motorcycles and tractors, Finland was almost self-supporting in internal combustion engines during the interwar period. By the mid-1970s, over 80 firms had produced these motors. At that time, about 6000 diesel engines had been manufactured mainly for ships, trucks, tractors and power plants.[108]

In electricity production, internal combustion engines had a minor role in Finland. The main cause for this was the high price of oil. The low investment costs and high efficiency rate (40 per cent or more) of the combustion engines did not compensate for this defect. In the early twentieth century, Finnish engineers hoped that the problem could be solved by so-called suction gas motors, i.e. combustion engines using gasified indigenous fuels, such as sawing waste, firewood or peat. Many plants of this kind were built, but they were small and unreliable. In the 1950s these motors were abandoned.

In postwar Finland, dozens of diesel power units were installed for reserve generation capacity in hospitals and other public buildings, and large factories. From 1942 big marine diesel engines of over 100 hp were produced in Finland under licence from famous manufacturers such as Krupp, Nohab, Sulzer and Burmeister & Wain.

Some types of these engines were employed for driving generators as well. In the 1970s Wärtsilä, a Finnish manufacturer, began to receive international recognition for big diesel engines of its own design.[109]

After a very long research period by many innovators, Brown Boveri & Cie was the first to introduce a successful gas turbine for electricity generation in the Neuchatel power plant in Switzerland in 1939.[110] In Finland, imported gas turbines have been installed in power plants since 1962.[111] By 1975 the share of gas turbines rose to 10 per cent of the nominal capacity of all electricity-producing prime movers.[112] Unlike reciprocating combustion engines, gas turbines have not been manufactured in Finland. This is another example of high technology in energy production which had gone beyond the power of Finnish industry.

3.6 ELECTRICAL EQUIPMENT

Total Supply

The expansion of electricity production and consumption presupposed a supply of electrical equipment. The demand could be fulfilled by imports or domestic production. The import of these products directly accompanied the adoption of electrical technology. In fact, the marketing efforts of foreign manufacturers and their local agents were very important factors in the diffusion of electrical technology in Finland. At first, they had to take pains in order to prove that their products worked properly and were economical.

The imports of electrical equipment into Finland reflected the situation in the world market and the general pattern of the Finnish import trade. In the early twentieth century, Germany dominated the export of electrical equipment in the world. On the eve of the First World War, its share had risen almost to half, as shown in Table 3.8. Despite sharper competition, Germany still remained the largest exporter in the interwar period, although the USA managed to surpass its export value for two or three years.[113]

The net supply could be derived by adding imports to home production minus exports. Calculating the long-term time-series for Finland is not easy for practical statistical reasons. The official statistics include so many inconsistencies and incommensurable aggregations that a complete harmonisation is impossible. The time-

Table 3.8 The market shares of the eleven biggest exporters of electrical equipment, 1913–39

Country	*1913* %	*1925* %	*1928* %	*1939** %
Germany	46.6	26.2	29.4	28.7
USA	15.8	25.6	24.7	23.1
Britain	22.0	25.6	20.5	20.8
Holland	1.7	3.8	5.8	7.3
Japan	0.2	0.8	1.0	5.3
Sweden	2.0	2.9	4.5	3.8
France	4.2	5.6	3.8	2.9
Belgium	1.4	1.3	2.1	2.7
Switzerland	3.4	3.4	3.6	2.6
Italy	1.2	0.9	0.9	1.5
Hungary	1.5	3.9	3.7	1.3
Total	100.0	100.0	100.0	100.0

* During the first half of the year.

Sources: *Voima ja valo*, 3 (1930) p. 133; *Voima ja valo*, 12 (1939) p. 316.

series in Appendix Tables A.7–A.8 are thus only approximations, but they are good enough to indicate the main trends of changes.[114]

The growth of the supply of electrical equipment can be divided into six periods, as shown in Table 3.9. In addition to variations in the growth rates, there are interesting changes in the structure of supply. In the late nineteenth century, the supply of electrical equipment made a good start. Its volume expanded swiftly. Domestic production began comparatively early, in the late 1880s, and grew more rapidly than imports. Its share of the total supply was unexpectedly high; for some years in the 1890s, the value of domestic production was nearly the same as that for imports. For Finland at that time, Germany was the most important machinery supplier in general. Therefore, it is not surprising that the Wilhelmine *Reich* was also the principal exporter of electrical equipment to Finland. As a premonition of coming events, the market share of Germany rose from 38 to 66 per cent of electrical imports between 1890 and 1900. Sweden managed to keep its corresponding share of 20–25 per cent, while Denmark and Britain were pushed aside.[115]

The first decade of the twentieth century brought a slowdown in the growth rate of Finnish electrification and a severe crisis in electrical engineering in the Grand Duchy. The recession was

Table 3.9 Average annual growth rates of the supply of electrical equipment in Finland, 1890–1976

Period	*No. of years*	*Production** %	*Export** %	*Import** %	*Net supply** %
1. 1890–1900	10	14.1	5.0	11.9	13.3
2. 1900–1913	13	1.9	– 4.7	10.5	7.9
3. 1913–1920	7	2.4	–24.3	5.0	4.6
4. 1920–1939	19	16.3	31.4	8.5	10.8
5. 1939–1957	18	6.7	9.3	0.7	4.0
6. 1957–1977	20	7.3	15.2	8.9	6.8
1890–1977	87	8.6	9.1	7.3	7.8

* Calculated from the value at constant prices.

Source: Appendix Table A.8.

preceded by the decrease of import customs duties for heavier electrical machinery in 1897 and a slump both in the home and main export market, Russia, in 1901–3. The paramount cause for the crisis in Finnish electrical engineering was tightening competition with those foreign manufacturers who became interested in the Finnish market.[116]

German electrical engineering greatly advanced in the 1890s. It had started to mass-produce three-phase equipment. Soon its home demand fell behind the quickly growing supply of generators, motors and appliances. Consequently, at the turn of the century German firms began to sell mass-produced electrical machinery at very low prices abroad.[117] From 1905, after an economic recession, the demand for electric equipment picked up markedly and a period of brisk expansion of three-phase technology began in the Finnish industry. This meant a permanent drop in the general price level of electric motors for, being lighter and less complicated than DC-motors, the AC-motors were also cheaper. German electrical machinery was then superior to the heavy and clumsy Finnish machinery and even to Swedish machinery. Paul Wahl & Co and Gottfr. Strömberg, the only Finnish manufacturers of generators, transformers and electric motors, were late in starting the production of three-phase machinery. The domestic production of AC-motors in series began in 1906–7. AEG eliminated the largest Finnish electrical engineering works by taking it over from the collapsing Wahl concern in 1910. Only the minor company, Strömberg, was left to compete with giant foreign companies. As a result, Germany's share of electrical imports to Finland grew to 71 per cent by 1913, while its share of the net supply of electrical equipment rose to 52 per cent.[118]

In the period 1913–20, the growth rate of the supply of electrical equipment slowed down somewhat and was radically restructured. German imports were interrupted, and domestic production began a sluggish recovery. A big change took place in Swedish imports. Their share of all electrical imports surged from under 19 per cent up to almost 90 per cent.[119] In the interwar period, the supply of electrical machinery expanded very rapidly, German imports recovered, while domestic production became more versatile and competitive.

The First World War had a permanent impact on the world trade in electical equipment; Germany could not completely restore its former market share. In the early 1920s, Finland imported about 43 per cent of this kind of product from the Weimar Republic. Between 1929 and 1936, Germany shipped on average 45 per cent of the total imports of electrical equipment to Finland. During the Second World War, its proportion rose to 75 per cent. This trade was significant for Germany as well. In the mid-1930s, Finland with its share of 12.3 million Reichsmarks a year was among the seven largest buyer countries of German electrical equipment in the world. The value of German imports to Finland was then nearly the same as those to France.[120]

Sweden, the nearest Western neighbour, was the second biggest supplier of electrical equipment; its share of Finnish electrical imports was on average 27 per cent between 1929 and 1936. By their joint import proportion of just above 70 per cent, Germany and Sweden dominated the Finnish market for electrical machinery. Other countries could compete only in some special items: Holland with electric bulbs, Denmark with batteries, the USA with cables and Switzerland with certain electrical equipment.[121] For the largest Swedish electrical engineering company, ASEA, Finland was from 1904 to 1923 the foremost foreign trading partner apart from Norway. In this respect, this country surpassed even Britain, Canada, Denmark and the Russian Empire. During the interwar period, Finland came third in rank just after the British Commonwealth and the Soviet Union. Later, the country's share diminished relatively, but nevertheless, it stayed among the main buyer countries for ASEA's electrical equipment.[122]

The period 1939–57 was an exception. During the war and the later

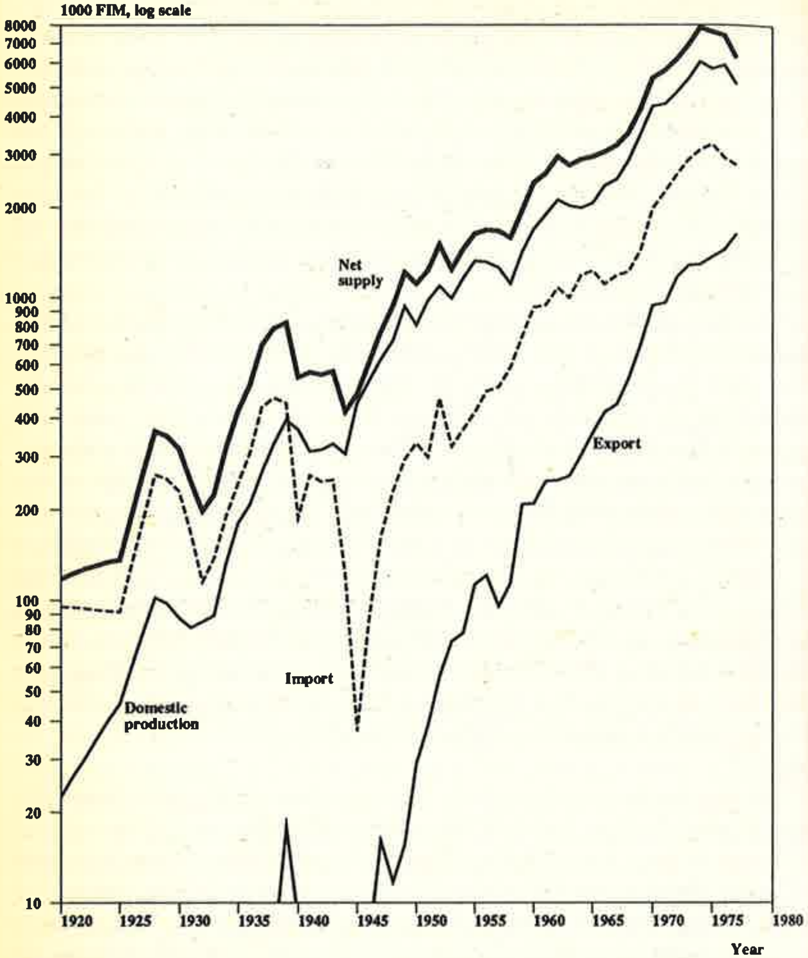
reconstruction, the foreign trade of Finland was tightly controlled. Foreign currency was spent only for the most vital items. This state of affairs gave a marked protection to domestic electrical engineering. Rising demand created a good base for import substitution even if the net supply grew at the slowest annual rate in the whole electrical era. Considering the overall strained circumstances, it was, however, quite satisfactory, because Germany could provide some of the equipment in demand. The domestic electrical industry developed fairly rapidly both technologically and economically. For the first time in this century, the value of its production surpassed that of imports in 1940. During the reconstruction period, its position was strengthened still further.

In 1957, following a large devaluation, the convertibility of the Finnish mark was eased and import tariffs were greatly reduced. This was the epoch-making step in the gradual liberalisation of the importing of Western products to Finland. From that year, the postwar free trade era began.[123] The buyers of electrical equipment progressively obtained unregulated access to imported goods, while domestic production lost its protection. The Finnish electrical engineering industry managed to survive despite successive reductions of import tariffs due to special agreements with the EFTA and the EEC. The boom of the net supply during the free trade period continued up to the oil crisis when it was interrupted for some years. In the time-span 1957–74 the net supply of electrical equipment grew annually as much as an average of 9.5 per cent. Over the following three years its value at constant prices, by contrast, fell by 20 per cent.[124]

During the free trade period, domestic production grew somewhat more slowly than imports of electrical equipment. The annual average growth rate of the net supply was, however, lower than both that of domestic production and imports, as indicated in Figure 3.3 (and Table 3.8). The exceptionally rapid growth rate of exports reflects the technological development of Finnish electrical engineering and its high standards in some fields.

West German electrical manufacturers, with Siemens and AEG leading, regained a firm foothold in the Finnish market in the 1950s. Their market share, however, shrank from 45 per cent in 1960 to 25 per cent in the years 1974 to 1976. The Finn-EFTA agreement of 1961 and Nordic co-operation markedly benefited Swedish manufacturers whose share rose from 13 per cent to 26 per cent during the same period. Consequently, Germany and Sweden still dominated

Figure 3.3 Supply of electrical equipment in Finland, 1920–77 (at constant prices of 1913)



Sources: *OSF 1A Foreign Trade 1889–1976* (Helsinki, 1893–1977); *OSF 18 Industrial Statistics 1890–1976* (Helsinki, 1892–1979).

the Finnish market although the dependence was considerably reduced. In 1976 the five largest supplier countries, including Britain, the USA and Japan, accounted for two-thirds of the total electrical machinery imports to Finland.[125]

When considering Finland in an international perspective, electri-

fication indeed generated the domestic production of electrical equipment quite early. During the first four decades of the electric era, the country, however, lost a great deal of the positive backward linkages of this new technology to the industralisation process, because the domestic production of electrical engineering products could not cope with foreign competition.

The gaining of political independence, and the two World Wars were external factors which mitigated the pressure of imports on the Finnish electrical engineering industry and gave it the opportunity to improve its position. Over the years, Finland did not develop into a tiny superpower of electrical engineering like Sweden, Holland or Switzerland. It is, however, not a negligible fact that, despite external pressures, Finnish electrical engineering could survive and preserve its independence in the midst of large transnational companies. Although there were faults in the interaction of nationwide electrification and the domestic electrical engineering industry, domestic production could provide the equipment and technological solutions which were adapted for Finnish circumstances. This supported the efforts to build the electricity supply industry on a sound and economical basis. Forebodingly, between 1900 and 1913 the rapid increase of coal-consuming steam power, which was not the best possible trend from the viewpoint of the contemporary national economy, coincided with the strongest dominance of the German electrical manufacturers in the history of Finnish electrification.

The Sectors of Finnish Electrical Engineering

In the era of electrification, the production of generators, transformers, alternators, and electric motors was the most important sector of the electrical engineering industry. This sector, unfortunately, faced successive setbacks. It was the branch where foreign competition had the most pressing impact. At the turn of the century, Finnish manufacturers were slow to adopt mass-production methods and failed to create efficient sales organisations. As a result, they remained too small to compete on equal terms even in their home market. Nevertheless, some Finnish manufacturers thrived and a few notable of them are listed in Table 3.10.

Technologically, the standard products of Strömberg Oy, the prominent domestic manufacturer, were still not old-fashioned in the 1920s and 1930s, although they could have been more reliable and durable. The company's problems were – if anything – economic. It

Table 3.10 Some notable manufacturers of electrical equipment in Finland

Firm	*Est.*	*Products*	*Years of production*	*Control*
Paul Wahl & Co	1887–1910	Generators Accumulators Transformers	1887–1910 1887–1910 1899–1910	**Finnish** until in 1910 merged with AEG
Strömberg	1889–	DC dynamos Electric motors AC generators Transformers Cookers	1889– 1898– 1906– 1914– 1936–	**Finnish** until 1929 the majority of the stock to ASEA; in 1930 29% of it to ASEA and 29% to BBC; in the 1940s back to the Finns
Finska elektriska AB	1897–1904	Generators Electric motors	1898–1904 1898–1904	**Swedish,** a subsidiary of ASEA
Kone Oy	1910–	Lifts Electric motors	1918– 1933–	**Finnish,** subsidiaries abroad
Suomen Kaapelitehdas Oy	1912–	Electric cables Telecom. cables Electronics	1913– 1929– 1960–	**Finnish,** in 1967 merged with Oy Nokia concern
Suomen sähköteollisuus Oy	1918–1921	Generators Electric motors	1918–21 1918–21	**Finnish,** in 1921 merged with Strömberg
Turun porsliinitehdas Oy	1918–	Insulators	1918–	**Finnish,** in 1925 merged with Arabia Oy
Suomen sähkölampputehdas Oy, later by Oy Airam	1921–	Electric bulbs Batteries Fluorescent lamps	1925– 1938– 1950–	**Finnish**
Osram Oy	1921–	Electric bulbs	1933–51	**German** up to 1944
ASA Radio Oy	1925–	Radio receivers B&W TV-sets Colour TV-sets	1925– 1958– 1969–	**Finnish**
Salora Oy	1928–	Radio receivers B&W TV-sets Colour TV-sets	1928– 1958– 1968–	**Finnish**
Kemppi Oy	1949–	Welding machines	1949–	**Finnish**
Rosenlewin Konepaja Oy	1868–	Refrigerators	1951–	**Finnish**
Oy Nokia-Elektroniikka	1867–	Radiotelephones Prof. electronics Microcomputers	1961– 1967– 1973–	**Finnish**

did not have the resources to conquer the home market or to grow by exporting. The Finnish market was so small that hardly any electrical manufacturer has survived without substantial exports. Owing to Strömberg's difficulties, the Swedish ASEA managed to get this largest Finnish manufacturer under its control in 1929. In the next decade, Strömberg Oy was a pawn in the game of competing Swedish, Swiss and German transnationals (see Table 3.10). The Finnish government was more interested in the wood-processing industry than domestic electrical engineering. By the bilateral trade agreements of the 1930s, it granted selective import quotas of electrical equipment to certain countries to promote the export of sawn timber, pulp and paper products. These agreements favoured mostly Germany and to some extent also Switzerland but discriminated against Sweden which was highly self-sufficient in wood-based products.[126]

During the Continuation War (1941–4), the Finnish government forbade foreigners by law to use their voting majority in Strömberg Oy, which was considered an important company for military production. Moreover, ASEA and BBC lost their majority when the group of five Finnish companies purchased the new issue of Strömberg's shares. After the war, BBC sold its shares to the Finns, but ASEA from time to time attempted to get Strömberg Oy back under its control.[127]

Heavy electrical engineering derived bigger benefits from the general regulation of the economy between 1939 and 1957 than the rest of this sector; the value of its output at constant prices grew by an annual average of 12.4 per cent. In the conditions of free trade (1957–74), its average growth rate, in turn, slowed down to 8.9 per cent p.a. which is less than the growth rate (9.7 per cent) of the entire electrical engineering industry at the time.[128]

The lift industry was one of the most flourishing branches of the Finnish electrical engineering industry. The electric lift was innovated by Siemens & Halske for the Mannheim Exhibition in 1881, and ten years later the device was introduced in Finland.[129] The first electric lifts were made in Finland at the turn of the century. A specialised firm for lift repair, Kone Oy, was established in 1910. This company started manufacturing lifts and joisting devices in 1918 and obtained a market share of 80 per cent in Finland by the early 1930s. From the mid-1940s it dominated the home market with the state-owned lift factory, Valmet Oy. Because house building grew strongly owing to swift urbanisation, the number of lifts installed increased from 3400 to 29000 p.a. between 1934 and 1975 or on average 5.4 per cent annually.[130] In the 1960s, Kone Oy greatly increased its exports and started to found subsidiaries abroad. In the 1970s, it had become a true transnational company, and one of the largest European lift manufacturers.

The cable industry was another successful branch. The earliest cable factory, Suomen Kaapelitehdas Oy, was set up in Finland in 1912. It concentrated on import substitution. After many difficulties, the company managed to conquer the leading position from the German firms in the home market in the 1930s. At the end of that decade, it supplied about 80–85 per cent of demand for cables in the country and, in addition, exported notable amounts, mainly to Estonia, Holland and Sweden. Cables were made of imported raw materials until 1943 when the Finnish mining company, Outokumpu Oy, could supply all the copper demanded. Consequently, the degree of domestic raw materials increased from barely 20 per cent to over 50 per cent.[131]

Suomen Kaapelitehdas Oy participated in the production of goods for war reparations to the Soviet Union. This provided an opportunity to expand its production capacity. In 1948, when the production of cables for war reparations ended, the company's capacity greatly surpassed the demand of the home market. The export of Finnish cables began again. The Soviet Union was the principal purchasing country and its share of the total sales rose from 15 to 23 per cent in the 1950s.[132] Within half a century, the enterprise developed into a large company even by international standards. In 1964 its sales totalled over FIM 150 million, of which exports accounted for about 35 per cent. In the same year, the first foreign subsidiary was set up in Turkey. The Finnish cable industry, consisting of five companies, exported 33 per cent of its total sales, while exports accounted for a mere 18 per cent of the Finnish metal industry's sales in general. Besides the Soviet Union, important clients were some Third World countries such as India, Colombia and Iraq.[133]

The technological expertise of the Finnish cable industry was claimed to be good from the late 1930s. Nearly all cables needed by the home market could be manufactured domestically. The dynamic and quality-conscious home market promoted development. Among the Nordic countries, postwar Finland was a pioneer in the introduction of new cable types such as aluminium cables and hanger spiral cables. The latter was partly a result of Finnish R & D.

Thomas Alva Edison started the factory production of incandescent lamps in the USA in October 1880. During the next ten years, mass production of electric bulbs was also established in Germany, England, Austria, Hungary, Sweden, and the Netherlands. From the turn of the century, the bulb manufacturing of the world developed into a cartellised industry and new, independent factories were rarely set up. Nevertheless, an independent Finnish workshop, specialised in repairing electric bulbs, decided to start production of incandescent lamps in the mid-1920s.[134] The case of Suomen sähkölampputehdas Oy is an example of problems in independent technology transfer from the centre to a periphery. At first, the firm had difficulties in employing foreign engineers specialised in bulb production. Equally, it was impossible for Finnish engineers to gain experience through training in the factories belonging to the worldwide *Phoebus* cartel. However, the factory managed to hire one German glass engineer. He started production with one Finnish engineer, two German foremen and ten local girls. The first model, 'Suomi'-bulb, was a complete failure and the whole batch had to be destroyed. The enterprise thus nearly broke down. But a vigorously growing demand for bulbs encouraged the founders to keep on trying. Hardly a year later, the next model, 'Airam', appeared on the market and it did not raise a storm of clients' complaints as did its predecessor.[135]

About 80 per cent of the raw materials for bulbs had to be imported. The problems of acquiring these foreign inputs prevented the expansion of production for three years. In 1929, production was, however, in full swing at last. Then bulb importers initiated their counteractions. They joked: 'Is the Airam-lamp really Finnish? The only Finnish thing about it is the air in the bulb, but even that is evacuated.' Importers were not satisfied with mere defamation. By 1931 Airam-bulbs had developed into a serious competitor whose production had doubled in a couple of years due to new machinery and improved foreign technical assistance. In a short period, the *Phoebus* cartel considerably cut its wholesale and retail prices in Finland. The former prices decreased by 35–40 per cent in Finnish marks. Because of great simultaneous changes in the exchange rates, the 'battle of bulbs' hit the cartel more severely than the Finnish factory. The prices of bulbs decreased by 67–70 per cent in foreign currency. Consequently, all small bulb manufacturers had to give up their exports to Finland and only one trademark continued competition. Osram, a big German company, chose to set up its own bulb factory in Finland. Between 1929 and 1933, bulb importation into Finland diminished by nearly 80 per cent, while the domestic

production of bulbs managed to treble despite the Great Depression. The market share of domestic bulbs rose from 9 per cent to 40 per cent. Over the same time-span, however, the total value of bulb consumption decreased from FIM 23 to 11 million.[136]

In the postwar period, the Finnish bulb industry grew considerably and still preserved its independent position. The pressure of bulb imports was a cause of continuous concern, whereas imports and exports of lighting fittings more or less balanced one another out. Due to the large exports of lamp ballasts, the balance of trade for the whole Finnish industry of lighting equipment was in favour of exports in the early 1970s. The annual turnover of this industry totalled about FIM 100 million, of which exports accounted for 30 per cent in 1971.[137]

The manufacture of electrical heating devices and household appliances developed into an important industry in Finland. Big steps were taken in the postwar period. In the early 1970s, Finland produced and exported quite a range of appliances such as refrigerators, cookers, washing machines, room heaters and sauna stoves. By contrast in the field of electronics, Finland was a latecomer but managed to catch up somewhat with the forerunners by the mid-1970s. The early products of this sector were radio receivers. The manufacturing of them was set up few months before the beginning of regular domestic broadcasts in 1924. The growth of the industry was in no way negligible. In 1938 about 80 000 radio receivers were sold in the country, and 38 per cent of them were Finnish-made.[138] Similarly, the domestic production of TV-sets accompanied the beginning of experimental Finnish broadcasts in 1955. Regular broadcasts started in January 1958, seventeen years later than in the USA. Although the adoption of television technology took place late in Finland, its diffusion was rapid. By 1965 half the households possessed television licences. In 1956, Finnish-made TV-sets accounted for only 20 per cent of the total sales. Ten years later, their share was already 80 per cent. The domestic production of colour TV-receivers was begun in 1968 with a modest batch of ten sets. In 1975, colour TV-sets were the largest single sales of the entire Finnish electrical industry apart from cables. The production value of 170 000 colour TV-sets surpassed that of welding machines, telephone switchboards, radio receivers or three-phase AC-motors.[139]

Generally, Finland's position in the field of home electronics and professional electronics was not particularly strong. It was still decisively behind the standards of other industrial countries. In 1969, the total value of electronics output excluding telephone devices was in Sweden FIM 1260 million or five to six times bigger than that of Finland. The output of Denmark was four times that of Finland.[140] In the 1970s the Finnish electronics industry, however, developed rapidly. Moreover, at the same time the country's telephone industry made a breakthrough in the field of radiotelephones and trebled its personnel. As a whole, electrical engineering came to be one of the most important growth sectors in the economy of postwar Finland. Between 1928 and 1975, the share of this sector rose from 9 to 26 per cent of the production value of the whole engineering industry. In the latter year, it accounted for about 17.3 per cent of the export of engineering products and 4.1 per cent of the total export. The majority of Finnish electrical products, however, presented standard technology. All high-tech exports of the country in 1973 accounted for about 2.5 per cent of the total exports of industrial goods. The corresponding average figure in the OECD countries was distinctly higher being slightly below 14 per cent.[141]

The development of domestic electrical engineering had a substantial significance on the national economy. It added a vital growth sector to the one-sided production structure of the country. It created thousands of jobs and boosted technical education. For customers, the starting up of domestic production often meant cheaper products. This effect was clear in the prices of bulbs, cables and also other products.

The growth of electrical engineering was not a result of a well-planned industrial policy. This industry was hardly mentioned in the Finnish programmes for industrial policy which emphasised the wood-processing industries, the traditional export sector of the economy. Moreover, the government and municipalities have not consistently supported domestic electrical engineering, for instance, with their orders. In the home market, the industry has, however, benefited from its favourable prestige and the marked tendency of economic nationalism.

From the late 1950s, Finnish industrial policies followed a non-selective market-oriented approach instead of a planning approach. In contrast to, for example, Sweden and Norway, it was not necessary to resort to the extensive subsidising of firms or industries. Furthermore, apart from the period of war and reconstruction, the Finnish government has not been tightly involved in the transfer of technology. It has mainly concentrated on creating the general basis for industrial development like taking care of education with very low fees for students. Responsibility for technological change was on the micro level in Finnish firms.

3.7 THE FINANCING OF INVESTMENTS

An important question is what kind of role financing played in electrification. This issue would be worthy of a separate research. Here it is possible only to sketch some outlines. Before the 1920s, investments in electricity supply were rather small. Industry financed its power plants by self-financing and bank loans. Private power companies and distribution utilities acquired their capital by means of issuing shares. Municipalities built their utilities with tax revenues or their other sources of income. Presumably, financing was then not the main obstacle for carrying out large-scale projects of electrification.

The hydropower projects of the interwar period were rather large and required considerable sums of capital. Despite many problems, the financing of the Imatra plant did not face such agonising difficulties as did the corresponding project in the republic of Estonia at the same time where plans to build the Narva hydroelectric power plant (44 MW) were finally given up due to financial and political problems.[142] In the early 1920s, the Finnish government could not raise foreign funding for the construction of the Imatra power plant with acceptable terms, because the international financial centres tightly controlled their lending, especially to such a new state as Finland the capability of which to pay its debts was not highly trusted. Those foreign credits which the government managed to obtain were used for other, more urgent purposes. When the construction was already in full swing, the government negotiated a bond loan of two million pounds from Britain in 1924; this loan would have covered all the estimated costs (FIM 330 million) of the first section with three hydroturbines. The negotiations, however, failed. The construction was continued despite financial problems. In 1925 and 1926 the government received loans through American credit institutions and of these about FIM 170 million were used for purchasing foreign machinery and equipment for the power plant. The first two sections (75 MW) of the Imatra hydroelectric plant, completed by autumn 1930, together cost FIM 412 million of which the main part, 59 per cent, was covered by the government's ordinary budget funds and 41 per cent by foreign loans.[143]

There was much more private capital invested in the electricity supply in the 1930s than during the preceding decade.[144] The largest project of this kind was the Rouhiala hydroelectric plant of 100 MW, commissioned in 1937.[145] In the previous year, a total of 1700 million marks was invested in hydropower plants and affiliated transmission lines. This sum accounted for about 9 per cent of the total value of capital invested in Finnish industry.[146]

During the postwar reconstruction period, financing was regarded as the main obstacle in hydro development, because the construction of hydroelectric plants required considerable capital inputs.[147] Concurrently, there were many other investment objects, while financial resources were exceptionally scarce owing to the repercussions of the lost war. Financial problems limited first of all private investments in the electricity supply. The public sector, which controlled 40 per cent of the total saving in the economy in the mid-1950s, was mainly responsible both for financing and constructing power plants and transmission lines.[148]

The postwar programme for the expanding of the electricity supply system was mainly funded by credits. While self-financing had accounted for about 70 per cent of the total investment costs in the 1930s, it comprised only about 20 per cent in the 1950s. During the first two postwar decades, the National Pensions Institute (NPI), the government and its bank, Postipankki (Post Office Bank) were the most important financiers of hydro development. The former granted over 60 per cent of all credits to the investments of the electricity supply between 1951 and 1965. The NPI was not only a creditor but it also became a co-owner of some government-owned power companies.[149]

The government granted credit to power companies from its budget funds from 1948 onwards. It expanded its financing after 1957, when the NPI had to decrease its lending according to the new national pension law. In addition, the government supported both its own and private power companies with so-called employment loans as well as with increments of its companies' share capital.

In financing new power plants, Postipankki was the most prominent among the banks and other credit institutions. Other domestic creditors were the central bank, commercial banks, saving and co-operative banks, insurance companies, mortgage banks and municipalities. The significance of foreign credits was very modest, being only 1–3 per cent. The primary foreign credit institution was the International Bank for Reconstruction and Development (World Bank) which granted nine loans, altogether 48 700 million old marks (about 150 million dollars), to Finland between 1949 and 1962. Almost half of these loans was used to develop the electricity supply sector.[150]

Table 3.11 illustrates a rather ordinary financial year in the 1950s

Table 3.11 The financial structure of the total investments in the electricity supply sector of Finland in 1954 (at current prices)

	1000 million FIM	*%*
Self-financing	3.4	23.1
National Pensions Institute	7.0	47.6
Government and municipalities	3.5	23.8
Post Office Bank and the Bank of Finland	0.4	2.7
Private Finnish credit institutions	0.2	1.4
Foreign credit institutions	0.2	1.4
Total	14.7	100.0

Source: H. Lehtonen, 'Voimatalouden kasvun rahoittaminen', *Voima ja valo*, 29 (1956), no. 11, p. 235.

when an overwhelming share, about three-quarters, of all investments in the electricity supply was financed by the credits from the public sector.

In terms of constant prices, investments in electricity supply increased up to 1960. Then they declined for some years as the construction of hydroelectric plants slackened. In the late 1960s many conventional thermal power plant projects were started and the value of investments began to grow. Large inputs in conventional thermal power, nuclear power and the transmission network boosted investments steeply in the 1970s, as indicated in Table 3.12. Two time-series related to the electricity supply can be calculated from the official statistics. Because their great differences in the 1970s can hardly be explained with large investments in the gas and water utilities, they ought to be interpreted with great caution.

Contrary to postwar hydroelectric power plants, nuclear power plants were extensively financed by foreign credits. We can take the financial structure of TVO (Industrial Power Company Ltd) as an example. By the end of 1979, when the commercial production of the Olkiluoto I NPP started, the company had invested FIM 4026 million in its construction project of two NPPs. As much as 59.4 per cent of the total costs was financed by foreign credits, 18.6 per cent by Finnish bank credits, 4.4 per cent by other domestic credits and only 17.6 per cent by shareholders' equity. TVO had obtained about half of the foreign credits from Swedish banks (Sveriges Investeringsbank Ab, Ab Svensk Exportkredit, Skandinaviska Enskilda Banken, PK-Banken, etc.) and the company raised the other half by issuing bond

Table 3.12 The investments in electricity supply in Finland, 1952–77 (at current prices, in new FIM, millions)

Year	*Electricity supply*						*Net investments in electricity, gas and water supply*	
	Hydro-power	*Nuclear power*	*Other thermal power*	*Transmission and distribution network*	*Total* *At current prices*	*Index* *At constant prices 1975=100*	*At current prices*	*Of total net investments %*
1952	. .	–	. .	. .	100	17	. .	. .
1953	. .	–	. .	. .	132	17	. .	. .
1954	. .	–	. .	. .	147	20	. .	. .
. . .								
1959	120	–	54	80	254	28	. .	. .
1960	133	–	99	97	329	35	. .	. .
1961	134	–	60	76	270	28	230	5.4
1962	94	–	65	108	267	27	275	5.2
1963	81	–	66	98	245	24	211	4.0
1964	78	–	44	113	235	22	221	3.7
1965	23	–	38	125	186	17	315	4.5
1966	. .	. .	. .	. .	. .	. .	257	3.9
1967	. .	. .	. .	. .	. .	. .	296	3.6
1968	. .	. .	. .	. .	. .	. .	549	4.5
1969	. .	. .	. .	. .	. .	. .	363	3.7
1970	. .	. .	. .	. .	. .	. .	736	4.5
1971	. .	. .	. .	. .	. .	. .	1107	5.6
1972	30	55	580	310	975	60	1125	4.7
1973	40	210	710	415	1375	72	2430	6.3
1974	95	590	895	490	2070	88	4342	6.1
1975	69	912	1046	655	2682	100	4631	8.2
1976	16	1040	1201	710	2967	99	4088	8.3
1977	16	946	878	720	2560	78	3501	6.1

. . No data available.

Sources: Electricity supply: *Mercator* (1956) p. 606; *Voima ja valo* (1960–6); *OSF 42:6 Energy Statistics 1986* (Helsinki, 1987). Net investment in electricity, gas and water supply: *Capital Stock in Finland, 1960–1986*, Tilastotiedotus KT 1988:4, CSOF (Helsinki, 1988).

loans and drawing other credits on the international markets in North America, Europe and the Middle East. At the time, the opportunities of Finnish companies to obtain foreign credits were good. The main obstacle was internal – the regulative policy of the central bank, the Bank of Finland.[151]

During the 1950s, the construction of the electricity supply system was estimated to constitute 9–10 per cent of all net investments in the Finnish economy. This figure is the same or slightly higher than in other Western countries at the time.[152] According to another source, electricity, gas and water supply accounted on average for 4.3 per cent of the total investments in fixed capital in the 1960s and 6.0 per cent in the 1970s. At highest, their share was 8.3 per cent in 1976 – a year before the first nuclear power plant was completed and three others were under construction. Between 1960 and 1980 the growth of investments in the electricity, gas and water supply lagged behind the expansion in the rest of the economy and therefore the proportion of these industries decreased from 7.4 per cent to 5.8 per cent of the total net fixed capital in Finland.[153]

The substantial construction costs of power plants and transmission lines were partly the cause for the rather high prices of electricity in the international context. The main result of the financing problems was, however, the extensive involvement of the public sector in the electricity supply sector. Before the 1960s, the high capital requirements frequently hampered the private sector in carrying out large projects. Consequently, in Finland the public sector obtained its eminent share of the electricity supply not by the policy of nationalisation but through its financial operations and entrepreneurship.

3.8 ELECTRICITY GENERATION

Generating Capacity

The total national generating capacity represents a country's potential for producing electricity. It also roughly reflects the total investments in electricity supply. Generating capacity and its technical composition form a framework for the operation of a whole supply system.

The growth of the generating capacity indicates the expansion opportunities that have presented themselves in the various sections of electricity distribution and use. The generating capacity, in turn, is

generally increased on the basis of the expected future demand for electricity. Most countries have had a surplus generating capacity from the very beginning of their electrification. Utilities must provide for a fluctuating load and especially for peaks which occur quite regularly within certain intervals. Electricity generation must match demand more closely than other energy forms, because of the lack of storage by users and the instantaneous nature of the delivery system. The decisions of most consumers about the timing and volume of use can only be influenced indirectly by utilities. Utilities build a new capacity for various reasons, for example:

- to meet anticipated increases in demand;
- to minimise the costs of meeting demand;
- to meet environmental and other standards; and
- to improve the security of supply.

The Finnish economy was in a slump when experiments with electric lighting started at the end of 1870s. Alongside the economic recovery, electric lighting began to spread during the next decade. Generators needed for the electric lighting of a single house, a city block or a residential quarter were small and technically simple. The diffusion of electrical technology was, nevertheless, comparatively rapid up to the turn of the century. After 1900, its pace, however, slowed down. This was surprising because internationally generation and transmission technology was just then developing by leaps and bounds. Furthermore, the price of electrical equipment was decreasing and machinery was more easily available.

In per capita terms, Finland was almost at the same level (0.15–0.16 kW per 1000 inhabitants) as Sweden in its generating capacity in 1885. During the following fifteen years, capacity grew annually in Finland on average 28 per cent; nevertheless, it was within this initial period when Finland was left behind its Western neighbours. In 1900 its generating capacity was not more than 13 MW, whereas Sweden's was 66 MW and Norway's about 110 MW.[154]

During the first two decades of the present century, the annual growth rate of generating capacity in Sweden and Norway dropped to 14.1 per cent and 10.4 per cent respectively.[155] With a growth rate of 12.6 per cent, Finland could not substantially improve its relative position.[156] In the interwar years, Finland's supply sector was, by contrast, booming. Its generating capacity grew by 11.1 per cent p.a., which was an extraordinarily swift pace in the international context of that period. The growth was 4.9 per cent in Sweden and only 1.8 per cent in Norway where dramatic setbacks in electricity supply were met at the time.[157] After the losses in the war, post-1944 Finland increased its generating capacity at quite a stable and swift rate. From 1945 to 1975, the annual growth rate was 7.1 per cent on average. This was slightly higher than Sweden's corresponding figure of 6.9 per cent p.a.[158]

Between 1885 and 1975, the annual growth in the generating capacity in Finland was on average 11.8 per cent and the respective growth rate of the net supply electricity was 13.7 per cent. By 1975, the total generating capacity had increased to 7200 MW or to 1525 kW per 1000 inhabitants, while the corresponding figures for Sweden were essentially higher, 23 135 MW and 2823 kW. Hence, favourable development in interwar and postwar Finland was not enough to level out all its setbacks during the other periods.[159]

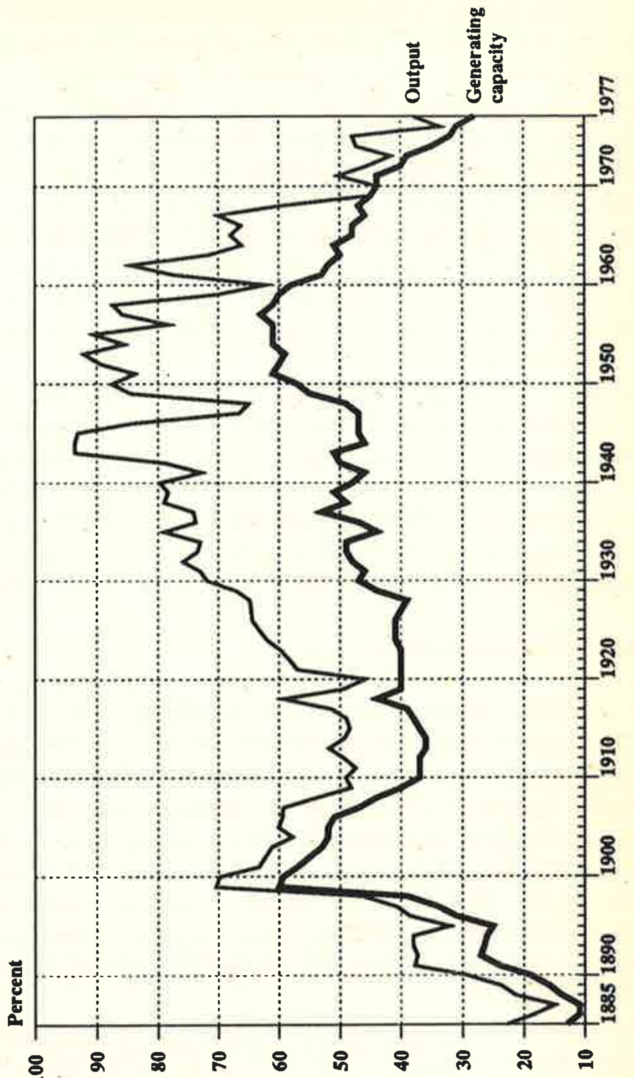
The Output, Import and Export of Electricity

The amount of electricity output quite closely followed the variations in the generating capacity. Discrepancies were mainly caused by business cycles, economic crises, the restructuring of the economy, and climatic circumstances. The development of the electricity supply in various periods is dealt with in Chapter 4.1.

The structure of electricity supply, the mix of primary energy sources, was an important element in electrification. Thermal power and generation on the spot were dominant in the beginning. With the breakthrough of transformer and transmission technology, hydropower rose to become the main primary energy source of electricity at the turn of the century, as shown in Figure 3.4. Shortly afterwards, some initial experiments with hydroelectricity failed due to the slump of the whole Finnish metallurgical industry. Another reason for the recession was the rapid development of the steam turbine as a competitive prime mover.

High fuel prices boosted the revival of hydro development in the 1920s and hydroelectricity generation began to grow steeply. As indicated in Figure 3.4, right from the beginning a characteristic of hydroelectric plants has been that their annual operation times have generally been longer than those of thermal power plants. Therefore, the contribution of hydroelectric plants to electricity output has been larger than their proportion of generating capacity. Due to new technological opportunities, the difference increased in the interwar period.

Figure 3.4 The proportion of hydropower of generating capacity and electricity net supply in Finland, 1885–1977



Source: Appendix Tables A.5–A.6.

The large-scale introduction of hydroelectricity has greatly boosted the electrification of Finland. Between 1898 and 1920 the contribution of hydroelectricity fluctuated around 50 per cent of the total generation. From the early 1920s the production of hydroelectricity grew faster than generation by means of thermal power. In 1932 for the first time, more than 75 per cent of electricity was generated by hydropower. According to Ingvar Svennilson's terminology, that percentage is the threshold for joining the club of 'hydro countries'. Finland remained in this club of privileged large-scale users of renewable, unpolluting energy until the early 1960s when it fell back among the thermal countries. By then Finland had reached the limits of its economically exploitable hydropower resources. By 1977 the contribution of hydropower to net electricity supply declined to under 40 per cent.[160]

Foreign trade in electricity was minimal before the year 1959 except for the war years of 1940 and 1944. Since then, it gradually grew to considerable figures. Imports generally overruled exports. At their highest in 1973, imports constituted as much as 15.5 per cent of the net supply of electricity. Thereafter, first a slackening demand due to the oil crisis and then the completion of the Loviisa 1 NPP cut electricity imports to a relatively low level, as depicted in Figure 3.5.

Capacity Utilisation Ratio

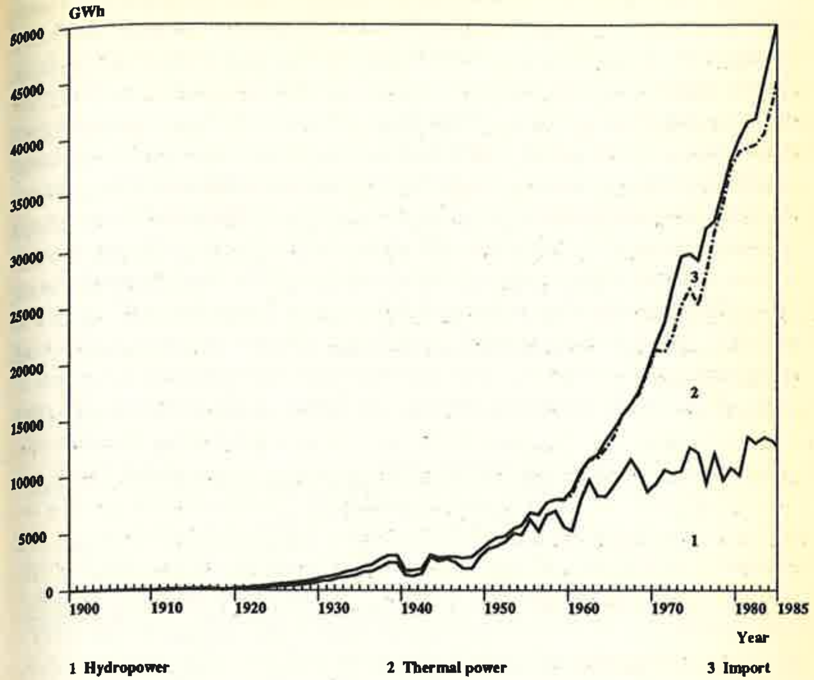
From the 1890s, electricity supply undertakings have had an acute need to measure how successfully they had utilised their generation potential in a certain period of time. Load factor measurement, introduced by the Englishman R. E. Crompton in 1891, spread in various countries as an instrument for measuring the capital productivity of electricity supply undertakings.[161] The load factor can be defined as the ratio between actual electricity output during a specified period and the potential which would have been produced if the maximum load had been maintained throughout the period.[162] Thus:

$$\text{Load factor} = \frac{\text{Actual output in kWh during a year}}{\text{8760 hours} \times \text{Maximum load in kW}}$$

Maximum load means the largest volume of electricity demand at any moment in a given period, e.g. in half an hour or one hour.

Owing to the lack of statistical data, I have used a substitute for the load factor called the capacity utilisation ratio (CUR). The main

Figure 3.5 Net supply of electricity in Finland, 1900–85



Source: Appendix Tables A.5–A.6.

difference between these two indicators is that in the latter the nominal maximum generation capacity estimate has been used instead of the maximum load. The nominal capacity of a generating unit as a rule denotes the maximum capacity which its manufacturer has stated.

$$\text{CUR} = \frac{\text{Actual output in kWh in a year}}{\text{8760 hours} \times \text{Nominal generating capacity in kW}}$$

An interesting question is how close the value of CUR is to that of the load factor. These two indicators can be compared on the basis of Swedish data for the years 1921–34. According to that data, the value of CUR was on average 9 per cent less than the value of the load factor. At least in the Swedish case, the capacity utilisation ratio was a reasonably good surrogate for the load factor.[163]

By estimation, the average CUR of the Finnish electricity supply rose from about 10 per cent to 29 per cent between 1885 and 1913.[164] For the interwar period, there is data available for comparing Finland with its nearest neighbours, Sweden and Estonia. The year 1920 can be regarded as a starting-point for the period of peace lasting almost twenty years in these countries. However, postwar crises disturbed their economies at first. Therefore, the swift implementation of ambitious electrification plans had to wait, but the expansion of the electricity supply was in each country considered necessary for a rapid economic growth. Raising the capacity utilisation ratio was a convenient way to increase the electricity supply without investment. Between the years 1920/1 and 1937/8 Finland improved its CUR by 68 per cent. For Sweden, the increment was 49 per cent and for Estonia 41 per cent. The level of the Swedish CUR had remained high for a long time and was still continuously better than that of the other two countries, as Table 3.13 indicates. In the

Table 3.13 The capacity utilisation ratio in electricity supply of various countries, 1925–38

Country		*1925* %	*1929* %	*1931* %	*1933* %	*1935* %	*1938* %
Finland	b	28	29	29	36	39	41
Sweden	b	38	43	37	36	42	42
Estonia	b	21	31	23	24	26	23
USSR	b	24	31	31	34	43	50
USA	b	36	37	30	27	32	36
Italy	a	. .	29	26	28	. .	. .
Germany	a	25	25	20	21	. .	. .
,,	b	27	28	23	23	. .	. .
France	a	. .	22	19	17	. .	. .
Britain	a	15	15	15	16	21	25

a Public utility plants.
b All the electric power plants in the country.
. . No data available.

Sources: Appendix Tables A.3–A.6; Eesti NSV Riiklik Ajaloo Keskarhiiv (*RAKA*), Fond 3842 N.1. s.ü. 81 and 87; *ORKA*, Fond 1011, nim, 1, s.ü. 85 and 87, and Fond 1831 nim. 1, s.ü. 4082 and 4089; *SOS, Industri 1925–1935* (Stockholm, 1927–37); B.I. Weitz *et al.*, *Electric Power Development in the USSR* (London, 1937) p. 108; R. A. Clarke and D. J. I. Matko, *Soviet Economic Facts 1917–81* (London, 2nd edn, 1983) p. 86; Leslie Hannah, *Electricity before Nationalisation* (London, 1979) pp. 426–34; *Historical Statistics of the United States*, Part 2 (Washington D.C., 1975).

1930s, the Finnish CUR was, nevertheless, reaching the level of its Western neighbour. The outbreak of the Winter War in November 1939, however, caused a severe crash of the Finnish CUR in 1939–40.

In Sweden and Finland, a relatively high and even load of electricity supply could be maintained because of continuously running pulp and paper mills. Moreover, industrial electric boilers were heated with inexpensive surplus electricity during off-peak periods. Compared to these two countries, the Estonian pulp and paper industry was much smaller. The republic of Estonia lacked the metallurgical and electrochemical industries which were also noteworthy consumers of electricity in the other two countries. The Estonian CUR remained rather low, although the country could not carry out its large hydropower building scheme. Its main power plants, such as the peat-using Ellamaa and Ulila, utilised only a fraction of their capacity.[165]

Table 3.13 is an attempt to show the northern Baltic countries in a comparative context.[166] Internationally, the Swedish capacity utilisation ratio of the interwar period was in the top rank, and Finland, too, appeared there in the 1930s. One reason for this is that at the time, the 'hydro countries' tended to have higher CURs than 'thermal countries'. This is particularly the case in countries having watercourses with a rather even discharge throughout the year. The other reason is that the electricity-intensive industries had a dominant position in the economies of Sweden and Finland. Both these factors contributed to raise CUR in those countries.

According to official statistics, postwar Finland's capacity utilisation ratio (41 per cent) has been only slightly below the average of West European countries (42 per cent), as shown in Table 3.14. By contrast, its economic mix greatly varied from the West European average but resembled the mix of other 'hydro countries'. Particularly between 1950 and 1967 Finland relied heavily on hydropower, and the utilisation ratio of thermal power, serving partly only in a reserve capacity, was merely a third of the ratio for hydropower. During about a quarter century, 1950–76, only Iceland (59 per cent) and Norway (57 per cent) utilised their hydroelectric capacity more intensively than Finland (55 per cent) which was the eleventh largest producer of hydroelectricity in Europe in the mid-1970s. The country strived efficiently to benefit from its hydropower resources which occupied a middle position in European rankings, as shown in Appendix Table A.2. All this highlights the importance of

Table 3.14 The utilisation of the installed generating capacity in Finland, Sweden and Western Europe, 1950–76 (kWh/kW/annual average)

Period	*Hydropower*		*Conventional thermal power*		*Total**	
	hours	*CUR in %*	*hours*	*CUR in %*	*hours*	*CUR in %*
Finland						
1950–67	5250	60	1743	20	3711	42
1968–76	4150	47	3047	35	3454	39
1950–76	4842	55	2225	25	3615	41
Sweden						
1950–67	5092	58	1372	16	4280	49
1968–76	4036	46	2369	27	3481	40
1950–76	4701	54	1741	20	3983	45
*Western Europe***						
1950–67	3997	46	3726	43	3837	44
1968–76	3124	36	3646	42	3526	40
1950–76	3673	42	3696	42	3722	42

* Including hydropower, conventional thermal power and nuclear power.
** The averages of 17 countries (Austria, Belgium, Denmark, Faeroe Islands, Finland, France, West Germany, Iceland, Ireland, Italy, Luxembourg, the Netherlands, Norway, Portugal, Sweden, Switzerland and the UK).

Sources: *World Energy Supplies 1950–1974*, Statistical papers ser. J.19, United Nations (New York, 1976); *World Energy Supplies 1973–1978*, Statistical papers ser. J.22, UN (New York, 1979).

hydropower in the Finnish electricity supply up to the era of nuclear power.

3.9 DISCUSSION

Supply factors were of vital importance in the development of the electricity supply in Finland. The key factors were a qualified workforce and indigenous primary energy sources. They provided a basis for building a supply system which corresponded to the needs of the economy. In the Finnish case, native engineers and electricians were significant transfer agents of electrical technology. Domestic technical education and studies abroad facilitated the country's catching up with the industrialised countries in this field. Unlike for example in Britain, electrical technology has widely been taught at

several levels of the Finnish education system and the number of students developed fairly satisfactorily. Although there were many shortcomings in the education of Finnish engineers and other personnel, the level of their technological expertise more often constituted an asset rather than a bottleneck for electrification.

Adopted expertise could be applied in practice on a large scale when indigenous energy resources were deployed. The country was fortunate to have reasonable resources of hydropower and timber, the deployment of which boosted electrification. To put it simply, the rise of electricity generation from the late 1890s up to the 1960s was based on new power generating technology, hydropower, and wood wastes of the forest industries. Finland was technologically dependent on foreign countries, but in terms of primary energy, the self-sufficiency of its electricity generation was rather high. Up to the late 1950s, over 90 per cent of electricity was generated by means of indigenous primary energy. During the following decade, the figure declined to about 50 per cent where it remained up to the introduction of nuclear power.[167]

A marked characteristic of Finnish electrification is various backward linkages to the domestic economy. Despite the small size of the home market, a versatile electrical engineering industry emerged. Electrification, backed by the ideology of economic nationalism, stimulated the engineering industry even more generally. The Finnish engineering industry was able to produce all kinds of prime movers for generating capacity other than steam turbines and gas turbines. The rate of self-sufficiency was particularly high in the fields of hydroturbines and generators coupled to them, steam boilers, transformers and cables.[168] Such a state of affairs was not a very typical phenomenon for late industrialised countries at the time. Postwar Australia represents a more common but contrasting case. Its 'supply authorities relied on overseas suppliers of generating equipment to meet most of their requirement, since no manufacture of large generating equipment took place in Australia'.[169]

Efforts to attain high self-sufficiency in the respect of know-how, labour, equipment and capital as well as concurrent juridical, technical and financial problems somewhat delayed the development of the electricity supply in the Grand Duchy and the interwar republic. Nevertheless, the nationalist approach created quite a balanced base for further advancement. In the postwar period, Finland had fairly passable technological and economic prerequisites to narrow the gap with leading industrialised countries. Consequently, the Finnish approach to electrification did not lead to isolation and backwardness but to modernisation on the basis of domestic resources and active technology transfer.

Electricity supply utilities did not form an 'enclave import industry' in Finland. They became interwoven in many ways in the country's economy feeding its growth by both backward and forward linkages. Electrification created a market for a new industry, electrical engineering, some branches of which managed to develop from home market industries into exporting industries. As a result, Finland transformed from an adopter of technology into a deliverer. This kind of change can be regarded as a sign of a successful technology transfer.

4 Demand for Electricity

4.1 DEMAND FACTORS

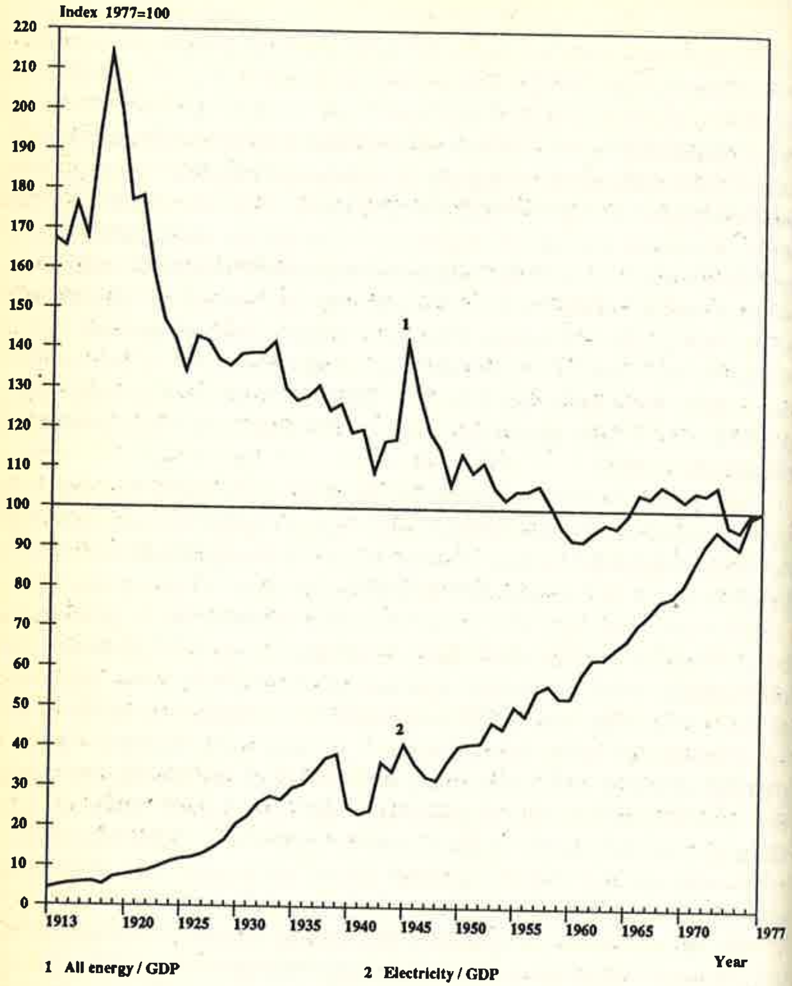
As a commodity, electricity has several unique properties which make the relation of its supply and demand unusual: such as the instantaneous transmissibility from a production site even to a remote consumer and the necessity that that supply must immediately meet demand. Electricity supply is expected to satisfy the consumers' needs without interruption at any time in the 365 days of the year. Although in practice electricity supply utilities possess many means to manipulate demand within certain limits, there are numerous other important factors they cannot control. Consequently, demand has a very great impact on the fluctuations and growth of electricity output.

This section deals with the problems of how electricity use depends upon various economic, societal and technological factors, called in economics demand factors. It also treats the changes that have taken place in those interdependent relationships over a time-span.

Electricity use and the gross domestic product have historically been strongly correlated in many countries. In pre-1973 Finland, this relationship took a simple functional form (linear) so that one principal variable, the GDP, was capable of explaining much of the variation in the other, electricity use, as they both changed with the passage of time. Unlike the case with the total energy requirement, the annual growth rate of electricity use has steadily been greater than that of the GDP, as indicated in Figure 4.1. Year after year, each unit of the GDP required more electricity, but less non-electrical energy than in previous periods of time.

The World Wars conveniently divided the electrical era into three periods and the oil crisis of 1973–4 might represent the third turning-point. Within each of these periods, the relationship of electricity use and the GDP has been stable and linear. The transitional wartime years shook their former relationship severely and served as starting-points for a new one. The ratio of percentage electricity growth to percentage GDP growth fell from an average of about 7.0 between 1890 and 1913 to 3.1 between 1920 and 1938 and further down to 1.8 between 1949 and 1973. After the oil crisis, it continued to fall. The ratio was declining because the electricity growth rate went down

Figure 4.1 The ratios of total energy use/GDP and electricity use/GDP in Finland, 1913–77



Sources: Appendix Tables A.5–A.6; *OSF IA:33–80 Foreign Trade* (Helsinki, 1915–63); *OSF 42:6 Energy Statistics 1986* (Helsinki, 1987); *Voima ja valo*, 19 (1946) no. 1, pp. 13–14; *Talouspolitiikan perusohjelma* (Helsinki, 1954) pp. 109–16; R. Hjerppe, *The Finnish Economy, 1860–1985* (Helsinki, 1989) pp. 192–4.

simultaneously as the GDP growth rate went up until 1973, as shown in Table 4.3.

Internationally, electricity use as a rule grew faster than the GDP, and the ratio of these two quantities kept on falling. Apart from some exceptions, a high growth rate of the GDP seems to imply a swiftly expanding electricity supply. However, countries with rapid growth rates frequently have a lower electricity output growth-rate/GDP growth-rate ratio than countries with slow growth rates. It is likely that the former could utilise their electricity output more efficiently than the latter.

In Finland, as in many other latecomer industrialising nations – Japan, Australia, Denmark, Spain, Portugal, Greece, etc. – electricity production expanded at a rapid pace, around 7–11 per cent a year, between 1925 and 1975. Because the expansion of electricity production was accompanied by an outstandingly high GDP growth rate, Finland's electricity-output/GDP ratio was, however, lower than the average ratio of the 16 industrialised countries included in Table 4.1.

In the period under study, the GDP was by far the most important factor in explaining electricity consumption. Nevertheless, an interesting question is to consider what factors contributed to push the growth of electricity demand well above GDP growth. As a hypothesis, it can be claimed that this tendency was influenced by a set of factors including the industrialisation process, the formation of households, the prices of electricity and competing energy forms, technological change and improved efficiency in electricity use, and the continuous penetration of electricity in the economy. Another problem is to consider why the growth rates of electricity consumption and the GDP gradually converged over time. This tendency was not peculiar only to Finland, but was a universal feature for other Western economies listed in Table 4.1.

As shown in Table 2.2, Finland was an agrarian country in the 1880s. The composition of its national output was deeply restructured only in the electrical era. Because industry was much more electricity-intensive than farming, industrialisation led to a steep rise in electricity use. Furthermore, manufacturing consumed an exceptionally large share of electricity supply in Finland as late as the early 1960s when its share began to decline substantially.[1] For many decades, the wood-processing industry alone used about 40–50 per cent of the electricity supply, while manufacturing and mining as a whole consumed about 60–80 per cent, as demonstrated in Figure 4.2. Thereby, the growth rate of the total electricity consumption tended to slow

Table 4.1 Annual compound growth rates of electricity production and gross domestic product in various countries, 1925–75

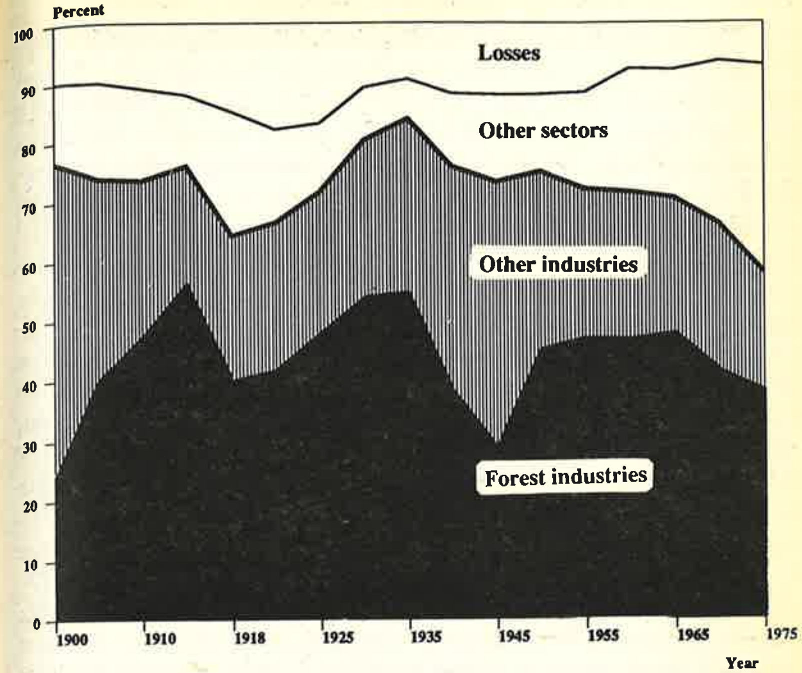
Country	*A* Electricity %	*B* GDP %	*C* Ratio *A/B*	*D* Electricity %	*E* GDP %	*F* Ratio *D/E*
	1925–75			*1950–75*		
Finland	**7.43**	**3.97**	**1.87**	**7.46**	**4.71**	**1.58**
Sweden	6.37	3.40	1.87	6.14	3.73	1.65
Norway	4.93	3.63	1.36	6.28	4.05	1.55
Denmark	7.97	3.14	2.54	8.62	3.61	2.39
Netherlands	7.70	3.32	2.32	8.28	4.51	1.84
Belgium	5.93	2.46	2.41	6.40	3.89	1.65
Austria	5.76	2.81	2.05	7.09	5.07	1.40
Switzerland	4.83	2.94	1.64	5.74	3.88	1.48
United Kingdom	6.26	2.22	2.82	5.69	2.64	2.16
France	5.71	2.97	1.92	6.98	4.85	1.44
Italy	6.48	3.22	2.01	8.20	5.06	1.62
West Germany	–	–	–	7.81	5.46	1.43
Canada	6.99	4.39	1.59	6.77	4.93	1.37
USA	6.62	3.05	2.17	6.76	3.37	2.01
Japan	8.23	4.82	1.71	9.77	8.92	1.10
Australia	8.05	3.43	2.35	8.55	4.52	1.89
Average	6.65	3.30	2.06	7.28	4.57	1.66

Sources: B. R. Mitchell, *European Historical Statistics 1750–1975* (London, 2nd rev. edn, 1981); A. Maddison, *Phases of Capitalist Development* (Oxford, 1986); J. Darmstadter *et al.*, *Energy in the World Economy* (Washington, 1971); *United Nations, Statistical Yearbook 1975* (New York, 1976); R. Hjerppe, *The Finnish Economy, 1860–1985* (Helsinki, 1989) pp. 192–4.

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.[2]

Industrialisation implied 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 residential sector became an important consumer of electricity. By 1930 its share grew to about 3 per cent and by 1975 to 19 per cent of the total electricity used in Finland.[3] Important background factors were also the

Figure 4.2 The composition of electricity consumption in Finland, 1900–75



Sources: *OSF 18A:37–76 Industrial Statistics of Finland 1920–1960* (Helsinki, 1922–62); *Tilastokatsauksia* (1929) no. 12 (Helsinki, 1929); *Sähkölaitostilasto v. 1930–1965* (Helsinki, 1931–67); *OSF 42:6 Energy Statistics 1986* (Helsinki, 1987).

population growth and other demographic changes, of which the formation of households was the most crucial. Between 1950 and 1975, the number of households increased by 47 per cent, whereas the population grew only by 17 per cent.[4] The rapid rise in the number of separate households boosted electricity demand, because in households a lot of electricity is consumed collectively, not individually. For example, a refrigerator consumes practically the same amount of electricity in a year independently of whether it is used by one person or a family of five.

On average, the total consumption of electricity per capita increased by 12.7 per cent annually in Finland between 1890 and 1977. A striking feature in this internationally comparably rapid development was, however, the considerable fluctuations in the growth rates during this time-span. A comparison with steadily developing Sweden, a top-ranking country in electricity use per capita, is illuminating. There are two good reasons for this comparison. Firstly, the composition of the national output in Sweden and Finland resembled each other, but the former country was not burdened by such hardships of the two World Wars and a civil war, as was its eastern neighbour. Secondly, the official Swedish statistics for electricity output, starting from 1912, are relatively reliable, and they are compiled using rather similar methods as their Finnish counterparts.[5] Figures 4.3 and 4.4 also include the British electricity output per capita which fluctuated fairly close to 50 per cent of the Swedish per capita level for several decades.[6]

Despite a good start, Finland lagged behind both Sweden and the United Kingdom in electricity use per capita between 1885 and 1900 and its development was retarded even more during the next two, politically turbulent, decades. From the early 1920s to the oil crisis of 1973–4, Sweden and the UK expanded their electricity supply quite steadily maintaining the mutual ratio of 2:1. In Finland the development was, in contrast, very irregular. After a fluctuating growth rate of the years 1900–19, its electricity consumption expanded swiftly and steadily in the interwar years and surpassed the British per capita level by the Second World War. In the early 1940s, however, Finland was again left far behind. It then took nearly thirty years to catch up with the UK again and restore the relative position of the late 1930s which the republic had lost due to the war and territorial losses. In Finland, electricity supply has been more vulnerable to political crises, but has proved to have a great ability to grow swiftly during the periods of peace.

In Chapter 2, Finland was compared with various other countries. The conclusion was drawn that from the 1880s, the country had not stumbled along with the European latecomer industrialising nations but almost kept abreast with the major industrialised economies in respect of electricity consumption per capita. Another striking feature, demonstrated in Table 4.2, is that from 1900 the ranking order of countries remained quite stable for the ensuing 75-year period. Of the latecomer industrialisers, only Iceland, New Zealand and Finland managed to rise and join the top ten electricity users between 1925 and 1975 (see also Table 1.5). In contrast, Japan and the Soviet Union, both known as two exceptionally rapidly growing economies, did not reach the level of the top ten electricity users by the mid-1970s. The most extensive electricity users per capita have tradition-

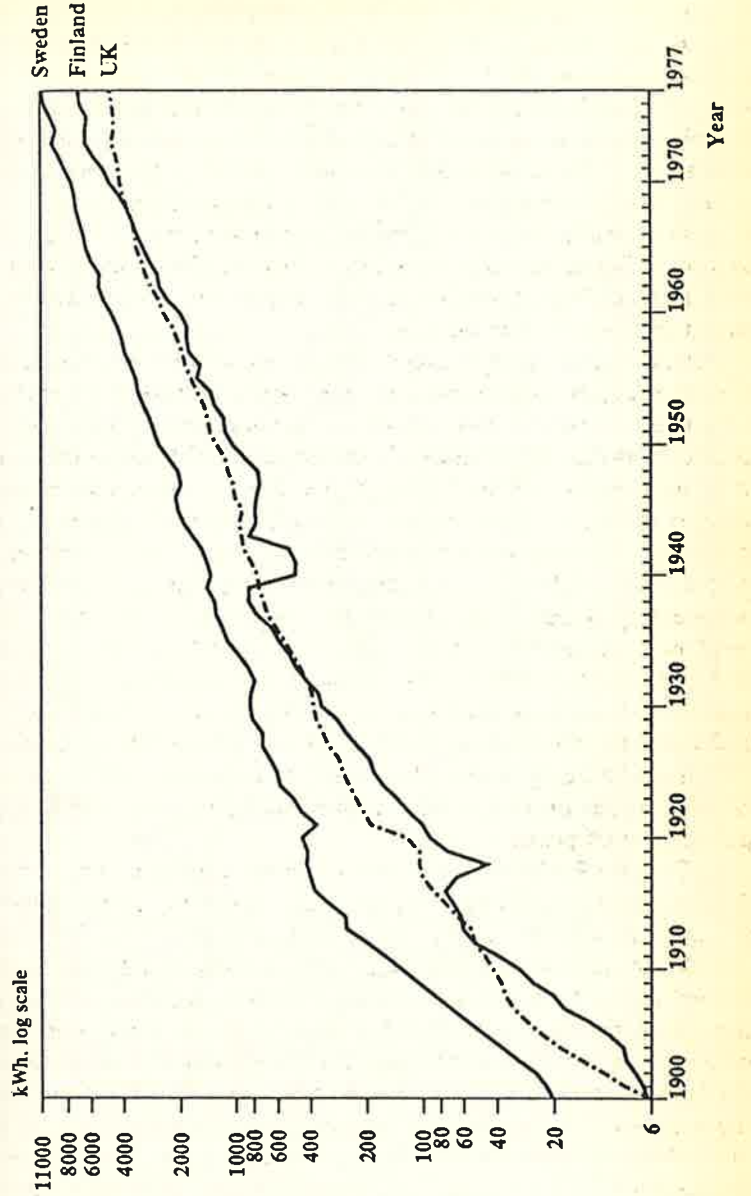


Figure 4.3 The total electricity output per capita in Finland, Sweden and the United Kingdom, 1900–77

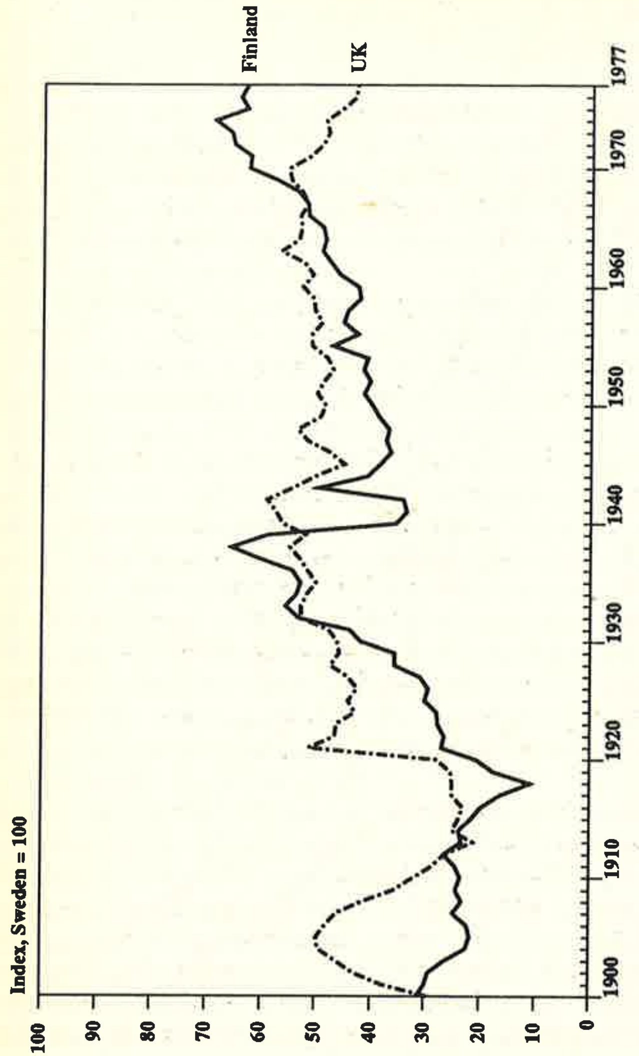


Figure 4.4 The relative position of Finland and the United Kingdom to Sweden in relation to electricity output per capita, 1900–77

Sources: Appendix Tables A.5–A.6 and the sources of Table 4.1.

Table 4.2 Electricity consumption per capita in various countries, 1900–75 (production in 1900 and 1913)

Country	*1900 kWh*	*1913 kWh*	*1925 kWh*	*1938 kWh*	*1950 kWh*	*1975 kWh*
1. Norway	24[a]	900	2230	3064	4538	16144
2. Canada	. .	. .	977	2339	3873	11718
3. Switzerland	61	414	767	1324	2123	5194
4. USA	75[b]	260[d]	701	1092	1092	9293
5. Sweden	21	258	608	1296	2566	9713
6. Germany	18	119	330	807	.	.
FRG	.	.	.	.	948	4716
GDR	.	.	.	.	973	4571
7. Austria	. .	. .	321	389	816	3936
8. Belgium & Luxembourg	. .	172[f]	283	662	797	4137
9. Australia	. .	39[c]	259	631	1163	5094
10. France	9[a]	45	254	506	797	3434
11. United Kingdom	5	91[d]	250	540	1115	4515
12. New Zealand	. .	17	246	883	1617	6520
13. Finland	**6***	**60***	**184***	**850***	**1042****	**6181****
14. Netherlands	. .	. .	181	425	729	3784
15. Italy	5	63	170	362	532	2589
16. Czechoslovakia	. .	73*	144*	277*	759**	3863**
17. Japan	. .	42[e]	138	463	541	4067
18. Denmark	. .	34	111	302	561	3646
19. Spain	. .	25	72	108	247	2189
20. Poland	. .	. .	57*	117*	375**	2641**
21. Hungary	. .	. .	53	121	321	2161
22. Ireland	. .	. .	. .	121	304	2311
23. Iceland	. .	. .	. .	. .	193	10555
24. Yugoslavia	. .	. .	31	71	147	1797
25. Greece	. .	. .	23	38	88	1676
26. Russia/USSR	. .	14*	19**	208**	505**	4037**
27. Romania	. .	. .	18	74	135	2260
28. Portugal	. .	. .	18	56	110	1126
29. Bulgaria	. .	. .	6	37	113	2969
30. Turkey	. .	. .	6	18	38	371
World	. .	. .	100	207	378	1583

[a] 1901 [b] 1902 [c] 1910 [d] 1912 [e] 1915 [f] Belgium only
* With the interwar borders ** With the post-1945 borders
. Category not applicable . . No data available

Sources: 'Statistics on electricity output, 1912–1925' at the Archive of the Central Statistical Office of Sweden; *OSF 42:6 Energy Statistics 1986* (Helsinki, 1987); *Historical Statistics of the United States*, Part 2 (Washington D.C., 1975); F. Hjulström, *Sveriges elektrifiering* (Uppsala, 1940) pp. 279–81; J. Darmstadter *et al.*, *Energy in the World Economy* (Baltimore, 1971) table XI; T. Liesner, *Economic Statistics 1900–1983* (London, 1985); A. Maddison, *Phases of Capitalist Development* (Oxford, 1986); R. Minami, 'The Introduction of Electric Power', in *Japanese Industrialization and its Social Consequences*, ed. by H. Patrick (Berkeley, 1976); *Annual Bulletin of Electric Energy Statistics for Europe 1978*, UN, ECE, vol. 24 (New York, 1979) table 2; *Demographic Yearbook 1984*, UN (New York, 1986) (See also the sources of Table 1.3).

ally been those countries which have both a highly developed economy and abundant natural resources (hydropower, geothermal energy, and/or coal) for electricity generation.

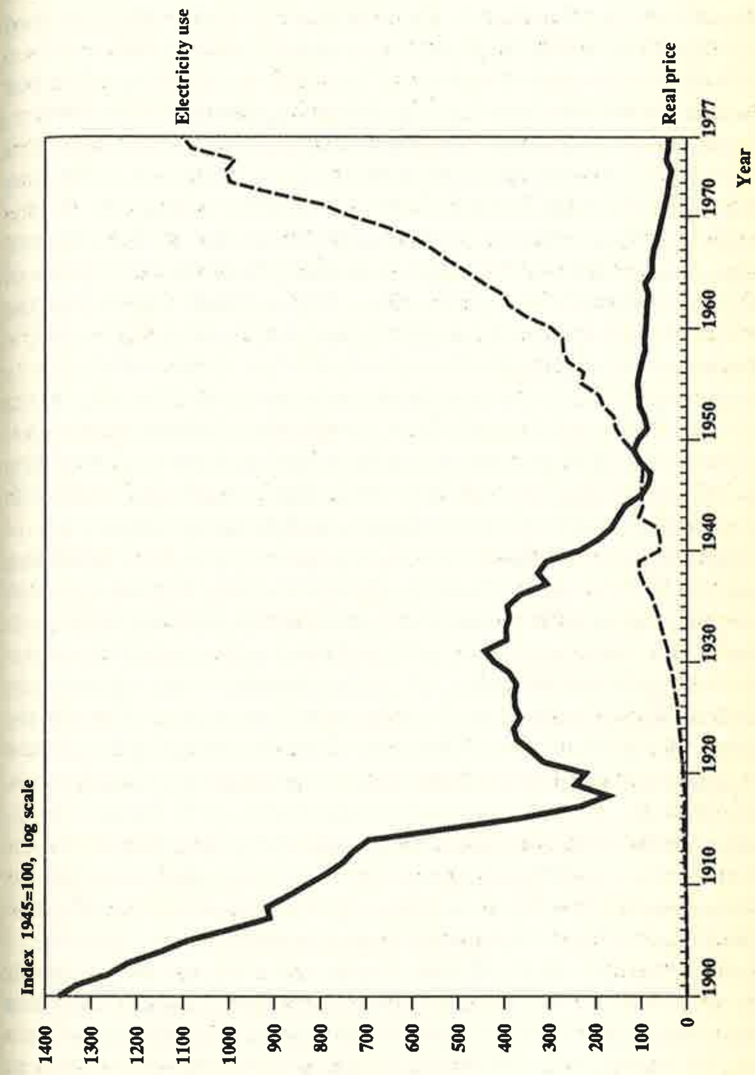
During the period 1925–38, Finland leapfrogged from the fourteenth to seventh place in electricity consumption per capita, rising between New Zealand and Germany. In 1950, after the lost war, Finland ranked ninth only after Norway and seven industrialised economies which had been either neutral or unoccupied Allied countries during the war. In the following quarter of a century, Finland, which had been the only unoccupied country of the Axis Powers, again moved up to the seventh place in the table, this time between New Zealand and Switzerland. That was another epochal transition, because the latter country had been one of the principal models for Finnish electrification since the late nineteenth century.

Changes in electricity prices have had a great impact on the demand for this energy form. For Finland, long time series can be estimated on the average, inflation-adjusted retail price of electricity from the beginning of the first supply utility in 1884. This price series is characterised by a steeply decreasing trend. Converting nominal retail prices to the constant 1977 marks, households paid FIM 13.86 per kWh for electric lighting in 1885, FIM 2.29 in 1925, FIM 0.67 in 1950 and FIM 0.25 in 1977.[7] Nominal retail prices of electricity have not been so apt to fluctuate as rapidly as other prices in general; in a country of high inflation consumers have as a rule benefited from this. Especially during both World Wars, the inflation-adjusted retail price of electricity slumped considerably and it did not return to its former level in the postwar periods.

It seems that changes in real electricity rates have not affected very strongly demand in the short run. It takes some years before consumption patterns are adapted to changes in real prices, because the changes in electricity use often require some preliminary investments, in wiring and appliances for example. The long-term character of the inverse relation between the real price and demand for electricity is demonstrated in Figure 4.5. The index series of these quantities are almost like mirror images of each other.

In the shorter periods of time, many irregularities can be found. Between 1900 and 1913, the inflation-adjusted price of retail electricity went down by half and the total consumption of this energy form quite predictably rose by a factor of ten, whereas between 1918 and 1938 the price increase of nearly 90 per cent did not prevent consumption jumping even more swiftly, by a factor of 22 (or by 2100 per

Figure 4.5 The real retail price and total consumption of electricity in Finland, 1900–77



Electricity rates deflated by the official wholesale price index.

Sources: Appendix Tables A.5–A.6; *Revue de statistique ouvrière* (1912–17); *Revue sociale* (1918–67); *Statistical Yearbook of Finland 1940–1977* (Helsinki, 1941–78), *OSF 42:6 Energy Statistics 1986* (Helsinki, 1987).

cent). During the two periods of war and economic crisis, 1914–18 and 1939–47, the growth of the total electricity consumption stagnated, although the real price fell by three-quarters both times. In the period 1947–77, the growth of electricity consumption by a factor of 11.4 was encouraged by a further fall of 51 per cent in real retail price.

Manufacturing, the biggest electricity consumer, partly generated the power it needed within its own plants and partly purchased from supply utilities at wholesale prices. Although not much electricity was purchased at the basic retail price, the retail price time-series reflects the trend of both production costs and wholesale prices reasonably well in the long run. In the case of industrial consumption, there is no commensurable data available for the average cost price or the average wholesale price of electricity from the late nineteenth century to the 1970s. Although it is likely that the real price of electricity consumed in the manufacturing industry fell in the long run, it did not drop by 98 per cent between 1885 and 1977 as did the average real retail price.[8]

Electricity prices have also had an important influence on the degree and rate of improvement in efficiency of electricity use. Competition with fuels has provided another incentive for innovating new electricity-using technologies for industry, transport and buildings. Over the decades, technological change has greatly increased the efficiency rate of electricity-using equipment. The most significant improvement has taken place in electric motors, but an essential advance has occurred in light fixtures and various electrical appliances as well. The electric devices of the 1970s accomplished the same output as their predecessors of earlier decades with substantially smaller amounts of electricity – a fact which tended to diminish the demand for electric energy. The steep rise of electricity prices in the 1970s gave a special stimulus for developing electricity-saving equipment.

Along with technological change, electricity has frequently received new functions and applications. It has not only been replacing muscle power and fuels in final energy consumption, but has also reduced the need for raw materials and capital. The penetration of electricity throughout the economy has caused a good deal of saving in the total costs but has simultaneously increased demand for electric power. From the 1940s to the 1970s, a great contribution to the expanded use of electricity was the acceleration in appliance penetration driven by rising living standards and the declining real prices of various electrical appliances.

4.2 INDUSTRY

Industry's Role in Electricity Use

At the turn of the century, mining and manufacturing still formed only a small sector in the Finnish economy. Nonetheless, they consumed the overwhelming share of all electricity generated in the country, as demonstrated in Figure 4.2. The development of total electricity use followed quite closely the variations in the growth rate of industrial output. During the whole period under study, the connection between the GDP, industrial output and electricity use was close: in the 1970s it was discovered that the beginning of a recession could be detected earlier from short-term statistics of electricity consumption than from corresponding statistics of the national output.

Why did the industrial sector have such a dominant role in electricity use in Finland? First, it was the only notable modern sector in the Finnish economy, and second, it needed a lot of mechanical power and process heating owing to its energy-intensive composition. The pre-eminence of pulp and other forest industries greatly enhanced the demand for electricity by Finnish manufacturing. For this reason, Finland rose to become 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.[9] Variations in this respect were then substantial even in Europe alone. For example, an Estonian industrial labourer used in his work on average less than a quarter, 2300 kWh, of the annual amount consumed by his Nordic counterparts.[10]

Both in Finland and Sweden industrial electricity use per worker continued to grow in the 1940s and 1950s. In 1954, it was 12 100 kWh in Finland and 12 630 kWh in Sweden. These amounts are higher than the corresponding figure for Switzerland, 5180 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 production sectors, such as certain chemical, metallurgical and forest industries, substantially increased the average electricity used per worker in manufacturing as a whole.[11]

Before the Second World War when industry used 80–90 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

Table 4.3 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

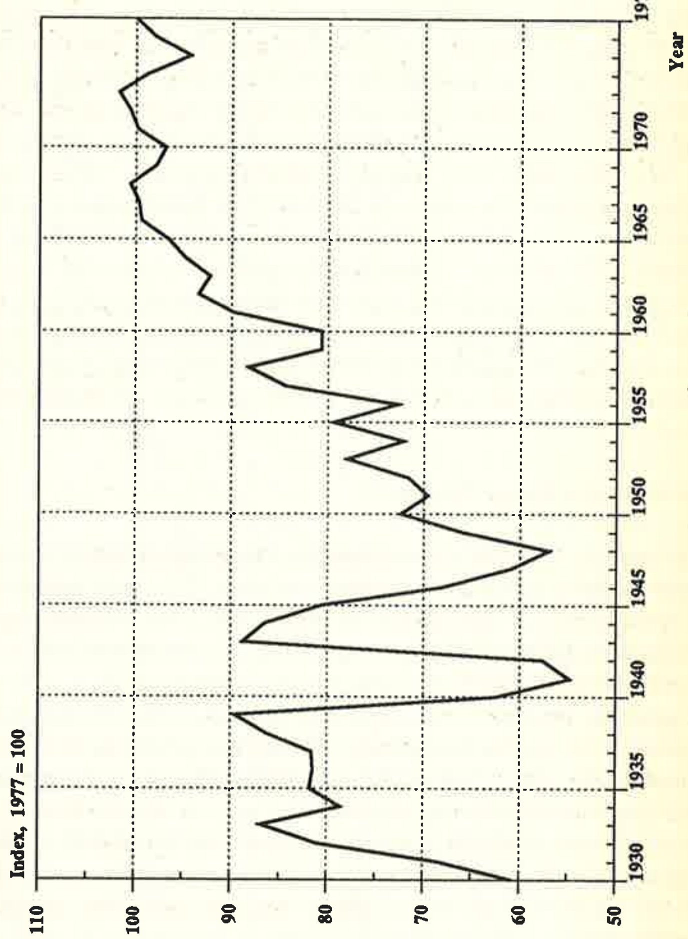
Sources: Appendix tables A.5–A.6; S. Heikkinen *et al.*, *Industry and Industrial Handicraft in Finland, 1860–1913* (Helsinki, 1986) pp. 120–22; R. Hjerppe, *The Finnish Economy, 1860–1985* (Helsinki, 1989) pp. 192–4.

the total consumption above that of industrial consumption, as indicated in Table 4.3.

Industrial electricity use has followed quite closely the ups and downs of the production volume of this sector. At the time when electricity pushed aside other energy forms and when the forest industries rapidly expanded, electricity use grew much faster than industrial output. In the postwar period, when the industrial structure changed to become less electricity-intensive, the growth rates of electricity use and of industrial output converged even before the oil crisis and the ensuing conservation campaigns. Increases of industrial output by 1 per cent were accompanied by a growth in electricity use of 3.5 per cent between 1890 and 1938 and by a growth of 1.3 per cent between 1949 and 1967. In the late 1960s, the rise in the electricity-intensity of Finnish industry halted; thereafter, industrial output grew slightly faster than electricity use.

According to Figure 4.6, there were considerable annual fluctuations in the ratio between electricity use and industrial output. They were partly caused by hydrological conditions. The peak years were generally years of abundant water and slump years were those of drought. The electricity-intensity of industrial output rose in good

Figure 4.6 The electricity intensity of Finnish industry, 1930–77 (electricity consumption per unit of output volume)



Sources: Appendix Tables A.5–A.6; S. Heikkinen *et al.*, *Industry and Industrial Handicraft in Finland, 1860–1913* (Helsinki, 1986) pp. 120–22.

years, because surplus electricity was utilised for heating the steam boilers of pulp mills and other process heating instead of fuels. The lowest points in the curve roughly reflect the use of electricity for primary purposes, such as power and lighting.

Up to the mid-twentieth century, manufacturing companies, especially in electricity-intensive industries, used a lot of electric power generated on their own premises. Formerly, this was not peculiar only to Finland, for in British industry 58 per cent of the capacity of electric motors was provided by self-generated electricity in 1912.[12] A year later, the corresponding percentage in Finnish industry was 65 per cent.[13] 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 part of electricity was self-generated or purchased from another factory nearby. In fact, especially from the 1920s, industrial plants began to supply electricity to urban and rural utilities on wholesale terms. For some wood-processing companies, electricity developed into an important by-product.[14]

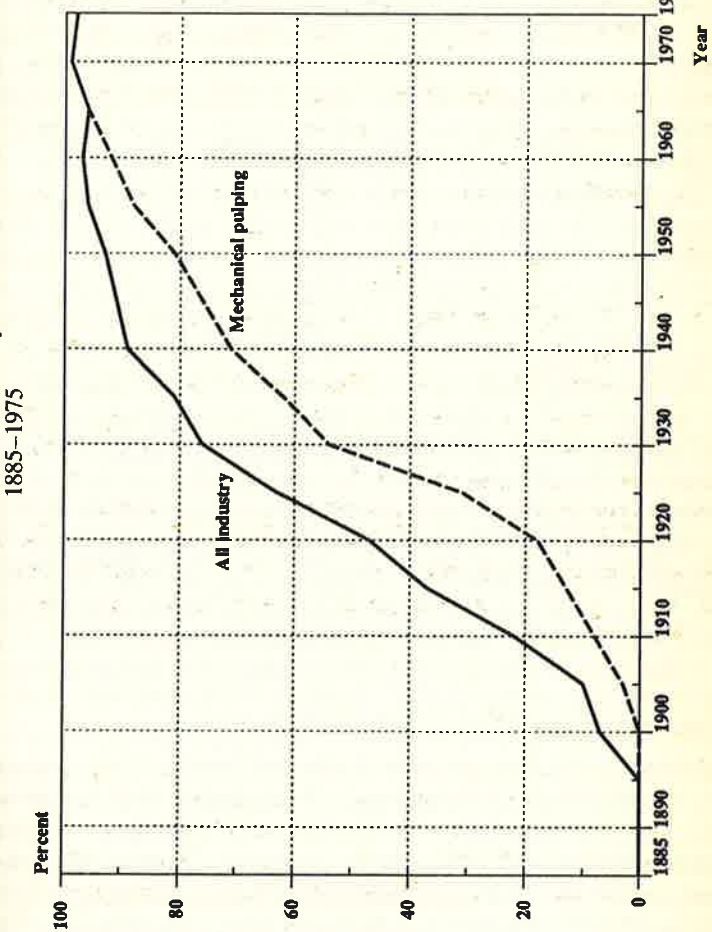
Electricity as a Power Source

In Finland, as in many other countries, the printing industry was the pioneer in using electricity as a power source.[15] Electric motors were first introduced in this sector in 1893. By 1904, electric motors accounted for as much as 40 per cent of its motive power and by 1920 virtually the whole printing industry was electrified.[16]

In general, electric motors were introduced in Finnish manufacturing around the turn of the century. Half of the motive power installed in industry was electrified by the mid-1920s. The diffusion process 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 4.7, 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 in just under 70 years. The process was somewhat prolonged by the rather slow electrification of the pulp-grinding industry which was the largest user of mechanical energy.[17]

Surprisingly, Finland was not a latecomer in the electrification of mechanical drive in industry even if it did not participate in experi-

Figure 4.7 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, *NAF and ACSOF; OSF 18 Industrial Statistics 1885–1975* (Helsinki, 1887–1977).

Table 4.4 The capacity of electric motors as a percentage of total motive power installed in industry in various countries, 1911–51

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		..
Denmark	1914	19	1925	42		..		..
Poland		..	1925	27		..		..

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

Sources: ABI 1913, ACSOF; *OSF 18 Industrial Statistics 1925, 1938, 1950* (Helsinki, 1927–52); R. Minami, 'The Introduction of Electric Power', in *Japanese Industrialization and its Social Consequences*, ed. by H. Patrick (Berkeley, 1976) pp. 304–5; *SOS, Industri 1913–1950* (Stockholm, 1914–53); S. H. Schurr, 'Energy Use, Technological Change, and Productive Efficiency', *Annual Review of Energy*, 9 (1984) pp. 409–25; *Italian Industrial Censuses of 1911–1951*; *NOS XII:245, Historical Statistics 1968* (Oslo, 1969); I. C. R. Byatt, *The British Electrical Industry, 1875–1914* (Oxford, 1979) pp. 75–6; *The Electrical Industry of Great Britain*, British Electrical and Allied Manufactures Association (London, 1929) p. 132; *Industrie, Donneés du recensement économic de 1937* (Tallinn, 1939); Statistical Centre of Denmark, *Erhvervstællingen 1925* (København, 1924).

mental and pioneering projects in this field in the 1880s and early 1890s. From the turn of the century, the proportion of electric motors in the total installed power was moderately high by international standards. In the USA, the capacity of electric motors accounted for 4.8 per cent of the total mechanical drive in manufacturing establishments in 1899; in Finland the corresponding percentage was 6.7 in 1900.[18] In 1913 Finland was in an intermediate position according to Table 4.4, but was left somewhat behind between 1913 and 1925. By 1938, the industry of the country had leaped close to the leading electrifiers abroad and preserved – and even improved – its position during the time of the Second World War and reconstruction.

The rapid electrification of mechanical drive in manufacturing partly explains why industry attained such a dominant role in electricity consumption. Since the early 1890s, the pulp-grinding industry used mechanical drive more than any other sector of industry. The electrification of this sector had a marked impact on the overall degree of electrification in industry. In 1900 pulp-grinding mills accounted for about 25 per cent of the total capacity of mechanical drive coupled with working machines of industry. In 1913 the figure was 39 per cent, in 1925 20 per cent, in 1950 17 per cent and in 1975 11 per cent.[19] Directly coupled Francis-hydroturbines and grinding machines fitted well into the technological requirements of the Finnish pulp mills in the early twentieth century. They were simpler and often cheaper than an electrically applied drive. Later, they were replaced by the latter, because they strictly limited the location and rational layout of pulp mills. Over time, the price relations of electrical and non-electrical equipment changed to the favour of electric drive as well.

Because the other sectors of wood-processing were also fairly energy intensive, the demand for electricity 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.[20] The favourable, export-led growth of wood-processing boosted the expansion of both other industries and overall electricity consumption through its various economic multiplier effects.

The Electrochemical Industry

Since the 1880s, large-scale electricity production offered numerous opportunities to the chemical industry. Utilising both electrothermal and electrolytic processes, hundreds of new plants were set up in a few decades in various industrialised countries, especially in those with advantageous hydropower resources. In the electrochemical industry, Finland failed to follow the path of the major industrialised countries and its Scandinavian neighbours, although from early on there were intentions and plans to establish electrochemical factories which would utilise Finnish hydropower resources. For example, in 1892 the engineer Pierre Twardowski planned to build an aluminium factory working with Russian raw material at the Myllykoski rapids on the river Vuoksi.[21] However, no aluminium factory was ever brought into operation in Finland during the following nine decades.

The first boom in the Finnish electrochemical industry began in the late 1890s. Along the river Vuoksi, two factories were founded to produce calcium carbide and one to make chlorate, mainly for the Russian match manufacturers. A sharp decline in prices on the world market from the year 1900 forced one of the carbide factories, Hämekoski, to convert into a pulp-grinding mill and the other one, the Linnankoski plant, was destroyed by fire.[22] Only the chlorate factory, Finska Elektrokemiska Ab, managed to continue in production.[23] After losing the Russian market, the Finnish owners of the factory sold it to a Scandinavian transnational, Swedish Match, in the early 1920s.[24]

The profitability of electrochemical production requires well-chosen raw materials, profound know-how, and cheap energy. Finland did not have many good raw material resources for this kind of production, but Norway and Switzerland also had rather limited resources yet they still managed to develop a thriving electrochemical industry mainly on the basis of imported raw materials. Finland also lacked the technological expertise and experience; the diffusion of foreign electrochemical know-how was obstructed by many patents, expensive licences and the tight cartels of transnational companies.

Another critical aspect was the shortage of cheap electricity. Before the Imatra power plant became operational, there was not enough inexpensive energy available for a larger factory. In the early 1920s the lowest electricity prices for the Norwegian electrochemical industry were just under 3 current Finnish pennies (FIP) per kWh and for the Swedish corresponding industry between FIP 4 and 6. At the same time in Finland, some electrochemical factories were closed after the First World War, because they were required to pay FIP 12–18 per kWh for their energy.[25] More favourable geographical and hydrological conditions made hydroelectricity cheaper in Sweden as well as in mountainous Norway and Switzerland than in flat Finland. Furthermore, in those countries, abundant hydropower resources stimulated the building of power plants especially for the electrochemical industry, which consumed nearly half of the hydropower produced in Norway, 30 per cent in Sweden but only 2 per cent in Finland in the early 1920s.[26]

The extensive requirement for bleaching chemicals in the pulp and paper industry led to four chlorine factories being started by 1939.[27] All these factories applied the electrolytic method in production. The

most important of them was Finnish Chemicals Oy, a joint-venture of the big transnationals, the British Imperial Chemical Industries Ltd (ICI), the German I. G. Farbenindustrie AG and the Belgian Solvay & Cie. During the war, two plants were lost but Finnish Chemicals Oy, under the leadership of the ICI, increased its chlorine production by a factor of 20 between 1945 and the late 1970s. The company continually purchased substantial amounts of electricity from private power companies and the state-owned IVO, because the British parent company rejected suggestions for building its own power plant as well as proposals for generation co-operation with private Finnish industry.[28]

The Finnish chemical industry developed comparatively slowly and worked only for the home market; its rapid expansion started only in the early 1960s. The most pivotal single reason for the accelerated growth was the beginning of oil refining by Neste Oy, a new national company, in 1957.[29] In 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, as shown in Table 4.5. By 1977 the chemical industry had increased its share to 13 per cent of the total industrial electricity consumption.[30]

The Electrometallurgical Industry

The experimental production of iron and steel in electric furnaces was introduced in many countries at the turn of the century. Within a few years, the production of steel in electric furnaces began on a commercial scale in various parts of Western Europe. Even though the total annual worldwide output of steel produced in electric furnaces remained rather modest until the early 1930s, this method proved significant, because the use of electricity enabled the production of several kinds of steel alloys, above all special steels for machine and hand tools. For instance, by making the cutters for high-speed cutting machine tools of electric steel containing tungsten, the cutting speed could be raised 20-fold compared to tools with cutters made of normal steel. Due to electric steels, engineering works were thus able to produce higher-quality goods more rapidly than before.[31]

In Finland, Elektrometallurgiska Aktiebolaget began to produce foundry pig iron at their Vuoksenniska and Nokia melting plants in 1916–17. The necessary technology was bought from Sweden, where the first so-called *Elektrometall* furnaces had been built in 1910. In the contemporary wartime crisis, the electric furnaces made important contributions to Finland's self-sufficiency, because domestic charcoal could be used in the *Elektrometall* process and indispensable energy was produced by hydropower.[32] At the same time, the electric furnace reached a new turn in the country's basic metal industry, which had for three decades been declining, mainly due to its obsolete technology.

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 and Vuoksenniska was then the only company in the country producing iron from ore. By 1945, electric steel furnaces were operating in three companies.[33]

The state-owned mining company Outokumpu Oy opened a very modern, fully electrified copper melting plant which was the third biggest in Europe in 1936. Its furnace was only the second industrial electric copper furnace ever built. Six years later, Outokumpu also built an electrolytic copper mill at Pori to refine its raw copper.[34] The profitability of both plants depended upon abundant and cheap electricity. That is why the energy crisis of 1946–8 turned out to be a very traumatic experience for the management of the company, which did not receive enough electricity from the strictly regulated national grid and faced rising power prices. In producing anodic copper, the share of electricity of the total production costs increased from about 18 per cent in 1946 to 40 per cent in 1948.[35] The event produced two consequences: a search for a new energy-saving melting method and a determined drive for an extensive self-generation of electric power. Both aims were achieved. In the 1970s, Outokumpu, however, gave up its tight self-generation policy, but its indigenous flash melting method, put in operation in 1949, met a more permanent success. The method, utilising the exothermic chemical reactions of the melting process, was immediately patented in many countries and became one of the most significant inventions in copper technology. Owing to the introduction of the new method, electricity consumption decreased from 3000–5000 kWh per ton of anodic copper in 1936–48 to 2000–3000 kWh in 1949–53 and to only 1000 kWh in 1954–6. The innovation had a remarkable impact, for it caused a substantial drop in Outokumpu's share of the national electricity use. Between 1939 and 1946 the company's share had

Table 4.5 Electricity consumption by sectors in Finland, 1960–77

Sector	*1960*	*1965*	*1970*	*1973*	*1977*	
	GWh	*GWh*	*GWh*	*GWh*	*GWh*	*%*
Mining and quarrying	151	235	365	510	540	1.7
Food, beverages and tobacco	235	325	505	630	740	2.3
Textile	170	203	310	370	350	1.1
Wood products excl. furniture	259	341	499	690	713	2.2
Furniture excl. metal	27	36	31	50	77	0.2
Paper and paper products	3863	6405	8455	10416	9398	28.8
Printing, publishing and allied ind.	37	43	60	89	112	0.3
Chemical excl. oil refining	541	992	1545	2010	1995	6.1
Oil refining	35	70	215	265	340	1.0
Non-metallic mineral products	200	310	415	500	510	1.6
Metallurgy	361	528	1145	1590	2115	6.5
Engineering and metal products	282	425	700	895	1090	3.3
Other manufacturing	6	7	10	20	20	0.1
Industry outside ind. statistics	99	92	81	169	224	0.7
INDUSTRY	**6266**	**10012**	**14336**	**18204**	**18224**	**55.9**
TRANSPORT	33	32	35	59	135	0.4
ELECTRIC HEATING	5	10	600	1497	2225	6.8
OTHER CONSUMPTION	1789	3040	5335	7516	9885	30.4
SUBTOTAL	8093	13094	20306	27276	30469	93.5
LOSSES	696	1148	1511	2206	2112	6.5
GROSS CONSUMPTION	**8789**	**14242**	**21817**	**29482**	**32581**	**100.0**

Source: *OSF 42:5 Energy Statistics 1985* (Helsinki, 1986) pp. 64, 80–81.

increased from about 2 to 5 per cent. By 1954 it had dropped to 2.3 per cent despite ever-growing production volume. The expansion of the company's activities raised its share to about 4 per cent of the total electricity consumption by 1982.[36]

The metallurgy's share of the total industrial electricity consumption increased from 6 up to 12 per cent between 1960 and 1977. The sector was thus catching up with the chemical industry. Together with engineering, it accounted for nearly 18 per cent of the industrial electricity use and about 10 per cent of the total electricity consumption for 1977, as indicated in Table 4.5.

Electric Boilers

In the interwar electricity supply system, there were considerable diurnal, 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 and for saving fuel. For example, the construction of the Imatra power plant 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.[37]

On the national scale, the annual consumption of secondary hydroelectricity fluctuated considerably, by between 1 and 26 per cent of the gross electricity consumption, depending on hydrological and other factors.[38] 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.

Concluding Remarks

To sum up, Finnish industry used electricity predominantly for mechanical drive. For example in 1950–4, 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 rest, 3 per cent, was consumed for lighting and space heating.[39] If we exclude steam boilers which were heated with secondary electricity, the onesidedness of industrial utilisation of electric power is highlighted: industry consumed as much as 85 per cent of its primary electricity for mechanical drive. This phenomenon was, of course, a reflection of the unbalanced structure of Finnish industry.

4.3 TRANSPORT

In the field of transport, electricity has a long international history, but its use has not expanded as steadily as in many other sectors. In Finland particularly, electricity has played rather a volatile role in the development of traction. In transport, existing electrical applications have frequently been challenged by other non-electrical technologies, above all by vehicles powered by internal combustion engines. One of the main problems has been that despite countless attempts, engineers have not succeeded in innovating a practical, competitive electric car.

Experimental electric locomotives were built in Europe and the

USA as early as 1835–42. All these locomotives were powered by galvanic batteries.[40] The year 1879 saw, however, the actual birth of electric traction. In that year, Siemens & Halske presented a satisfactory electric locomotive which circulated on a track 300 metres at the Berlin Trade Fair. A stationary power station supplied electricity for the locomotive's direct current motor of 3 hp.[41]

In May 1881 the first electric tramway in the world opened at Licherfelde in Berlin.[42] It was, however, not Germany but the USA which developed as the world leader in electric traction. There the promotion also started at an exhibition, held in Chicago in 1883. It took some years before the great expansion of practical electric traction got going. In 1888 Frank J. Sprague constructed a tramway system which laid many basic standards for American tramways such as the overhead trolley as a contact wheel.[43] As early as 1890, 28 per cent of American tramways were electrified; thereafter a very rapid expansion of tramway networks and a speedy changeover from horse trams began. Between 1890 and 1895, the length of electrified tramway lines in the USA grew from 4 060 km to 13 000 km and up to 44 660 km by 1903.[44]

In Europe, development was slower. For example, in Germany only three electric tramway lines were in operation in 1891. The situation was rather similar elsewhere on the Continent. In Britain, electric traction was first used at a beach track in Brighton in 1882. The second electric underground line in Europe was opened in London in 1890.[45] In Russia, electric trams were introduced in Kiev before any other cities of the Empire. This was in 1892, but in the capital, St Petersburg, electric traction did not come into regular use until 1907.[46]

Electric traction began to spread more rapidly through Europe only after 1895. In Germany, tramway routes expanded from 410 km to 3700 km between 1895 and 1903. Development in France and Britain was even slower. During the same period, the total route length increased from 130 km to 2000 km in the former and 90 km to 2350 km in the latter.[47]

The earliest experiment with electric trams made by the Finns took place in St Petersburg in 1895, as mentioned on page 33. In Finland, the use of electric traction began at the very end of the nineteenth century. The three earliest applications were narrow gauge railways for industrial purposes: at the sawmill of Halla Ab in Kotka in 1896, at the Forssa Cotton Mill in 1898 and at the Kymi Paper Mill in 1899. By 1913 about ten industrial electric railways were built; the total length of their tracks was approximately 40 kilometres.[48] The first four regular electric tramway routes in Helsinki were opened in autumn 1900. Compared with a horse-driven tramway, this doubled the number of tramway passenger fares in four years.[49] The concurrent decrease in ticket prices made tramway journeys accessible for workers and not just the middle class.[50]

In the early adoption of electric traction, Finland was not very far behind some developed European countries and quite abreast of Scandinavia. The earliest narrow gauge electric railway in Sweden was commissioned for industrial purposes in 1890. The first 'tramway-like train', a narrow gauge railway for passenger traffic, was opened at Djurholm in Stockholm in 1895, whereas proper trams started to operate on the streets of Stockholm only in late 1901.[51] In Copenhagen, the electrification of tramways was initiated by an accumulator-operated tram in 1897. It was followed by conventional electric trams two years later.[52]

Because towns were very small in Finland, as in Denmark, railborne urban transport was introduced only in two provincial centres besides the capital. The AEG built tramways in Turku in 1908 and in Viipuri in 1912. The total length of Finnish electrified tramway tracks grew from 13 km in 1901 to 60 km by 1929.[53]

From the 1940s the total tramway network and the number of passengers started to decrease. In the Second World War, the town of Viipuri was ceded to the Soviet Union. In 1950 the tramway lines of Helsinki and Turku totalled 114 km. The corresponding figure was 103 km in October 1972 when the municipal tramway of Turku was closed. In Helsinki, the growth of the tramway system stagnated: the length of tracks varied between 79 and 92 km in the years 1950–77. Nevertheless, the number of tramway passengers began to rise again in the 1970s and the Helsinki city council decided to modernise its tramway transport.[54]

In general terms, the Finnish case resembled the common downward-sloping trend of tramway transport and public urban transport on the Continent in the postwar period. From the mid-twentieth century, private cars and diesel-buses gained the upper hand in urban transport almost everywhere. In the mid-1970s, in Western Europe there were 100 conurbations with a population of over 300 000, of which 60 still had a tramway system. France, Britain, Italy and Spain had disposed of most of their electric trams by then.[55]

The electric trolley-bus was invented by Werner von Siemens in 1882. It was introduced in many countries before 1913 and English companies developed as the leading manufacturers of these vehicles.[56] In Finland, urban transport services became interested in trolley-buses only during the Second World War when the sharp shortage of oil-based fuels limited their bus traffic. Trolley-buses were introduced first in Tampere in December 1948 and then in Helsinki two months later. In May 1976 Tampere disposed of its municipal trolley-bus system.[57]

In 1974 after twenty-five years' operation, the Municipal Transport Board of Helsinki also decided to replace its outdated trolley-buses with diesel-buses on the single route they had ever worked. However, under pressure of public opinion, the Board was compelled to study and experiment with different modern types of this noiseless and unpolluting transport form for eleven years until it rejected trolley-buses altogether claiming that their annual total costs were about 10 per cent higher than the costs of diesel-buses.[58]

In the postwar period, electricity has been applied in two other areas in the field of urban transport: in traffic control and underground railways. From October 1951 traffic lights diffused widely not only within Helsinki but also in small towns all over the country.[59] The population of the Greater Helsinki District steeply increased owing to accelerated migration from the countryside in the 1950s and 1960s. This actual development, together with some overestimated population forecasts, motivated the city council to start building an underground railway system in 1969.[60]

In Finland, the big issue in electric traction has been the electrification of railways. The idea was presented and researched early on, but was put into practice only exceptionally late. From the very beginning to the final realisation, it was not a technological problem but a political and economic issue.

Technical problems were solved abroad quite early. In 1899 there were just over 100 km of electrified railways built or under construction in Europe. By 1910 this figure had risen to 2500 km. Norway was the front-runner of electrified railways in the Nordic countries; there the first broad gauge railway line with an electric drive was put in operation in 1899 and in Sweden it was achieved in 1906.[61] In the latter country particularly, the government soon became interested in building electrified railways. Its pioneer project, carried out between 1910 and 1917, was an electrified line of 129 km in the northern mining area of Kiruna.[62] The electrification of the Danish State Railways opened with the first electrified suburban line in Copenhagen in 1934.[63]

By 1936, nearly 7 per cent or about 18 000 km of the total length of European railway lines (excluding the Soviet Union) was electrified. Finland was then among the nine poorest Eastern European and Mediterranean countries which had no public electrified railways of broad gauge at all.[64]

In 1950 Switzerland was the leader in this field. Its electrified lines accounted for 80 per cent of the total length of the railway network and 98 per cent of transported goods. It was followed by the Swedish State Railways with the corresponding figures of 36 per cent and 86 per cent. Italy came third with 34 per cent of its total network electrified. All these three countries had two things in common. First, their parallel economic and political reason for railway electrification was the aim to be independent of foreign coal. Second, they all generated a major part of the electric power needed for locomotives by cheap, indigenous hydropower. Difficult topography in Switzerland and Italy and harsh climatic conditions in northern Sweden were also considered to favour electrification.[65]

The first two Finnish technical committees which researched railway electrification between 1905 and 1907 supported the idea. But 'non-technical experts whose opinion was not asked', quoting Bernhard Wuolle, 'opposed railway electrification for strategic reasons'.[66] Who were the opponents? These 'non-technical experts' were probably Finnish nationalists, because the Russian Ministry of War, which was responsible for the military strategy for the whole Empire, warmly supported these electrification plans.[67] When Finland gained its independence, the political constellation of railway electrification also changed. Engineers still supported electrification for the same reasons as before but the opposition of some politicians was partly based on new causes. The 'strategic reasons' had lost most of their weight, while economic factors and the interests of farmers had come to the forefront. In the interwar period, Finnish steam locomotives were mostly fired by indigenous firewood and not by imported coal. Therefore, steam engines were not the security risk during international crises as they were in the above-mentioned countries.

The second point which favoured steam locomotives was that a great many farmers and forest workers earned an essential part of their annual income by supplying firewood to the State Railways. The centrist Agrarian League which participated in most of the interwar governments naturally defended the economic interests of its supporters by opposing railway electrification.

The third reason lay in the saving in capital costs. Because since the

late nineteenth century, investments in railways were regarded as unreasonably expensive, the electrification of the State Railways would have been too big a burden for taxpayers.[68] As early as 1907, in per capita terms Finland's railway network of 3336 km was the second longest in Europe.[69] The frequency of traffic was not, however, as high as in the densely populated countries. Consequently, the high capital costs and the low transport volume strained the economy of the Finnish State Railways. The tax reform of the 1920s increased taxes, particularly for farmers, and the MPs of the Agrarian League wanted to cease all further plans to increase the existing tax rate, especially if new expenditures would not directly benefit the interest of the rural population.

The result of these factors was that the electrification of the railways was not linked to the building project of the state-owned Imatra power plant, as was originally planned. Professor Bernhard Wuolle, the most prominent proponent of railway electrification at the time, wrote a lengthy technical committee report on the subject in the mid-1920s.[70] His calculations and proposals were, however, bitterly criticised by some representatives of the State Railways.[71]

After the Second World War, the political situation changed again. Most politicians, even the Agrarians, had to admit that steam locomotives were no longer economical. The steam engines of the State Railways were then worn out, and even when they were fired by rather cheap coal, they were more expensive than diesel or electric locomotives.

By the early 1960s, many research reports had proved that the electrification of at least 1000 km of the most frequently operated lines and the use of diesel engines on the other lines was the most advantageous solution both technically and economically. Personal disputes within the State Railways and political divisions in the government, however, postponed electrification for several years. Opponents preferred complete dieselisation to partial electrification.

Finally, in 1961 Parliament decided to start partial electrification of the State Railways and to order locomotives and other necessary equipment from domestic manufacturers. However, it took four years before the construction work was begun on the lines north and west from Helsinki. In 1969 the traffic on the first two local routes was opened with Finnish-made motor-coach trains.[72]

The selected electric system was the same as that proposed by Bernhard Wuolle in the 1920s, namely a one-phase alternating current with 50 Hz and 25 kV.[73] Thereby, the Finns gained nothing technologically by waiting forty years. Erecting the system took a relatively long time, because the planning and building work as well as nearly all the equipment were made by Finnish companies. To compensate for their lack of experience, these companies had to buy technological know-how from abroad, mainly from the English firm British Insulated Callender's Construction Ltd.[74]

Orders for long-distance electric locomotives caused another sharp political struggle in the late 1960s and early 1970s. The rightist parties and engineering companies still favoured the planning and construction of domestic engines. The leftist and central parties supported new proposals for ordering the engines from the Soviet Union for two reasons. First, according to the manufacturers' tenders, the price of a domestic engine would have been current FIM 1.6 million, whereas a corresponding Soviet engine would have cost FIM 1 million. Second, Finland imported mainly oil, coal and raw materials from the Soviet Union at the time; therefore, for trade and political reasons, electric engines as rather sophisticated engineering products were considered very suitable for diversifying imports from the Soviet Union to Finland.[75]

In December 1968, Parliament decided by 117 votes to 51 to give the government the right to order Soviet engines, but required it first to carry out a new research on railway electrification. A new committee was set up to study the problem once again. This committee, headed by the social democrat Jussi Linnamo, proposed the traditional solution: postponing electrification and repairing old steam engines instead. Nevertheless, the government ordered 27 Soviet electric locomotives in November 1970. The President Urho Kekkonen, the Premier Mauno Koivisto and the Director General of the State Railways Esko Rekola supported the importation of Soviet electric engines, which were improved by supplementing them with modern Finnish technology such as a thyristor control system.[76]

The largest locomotive factory in the world, at Novosherkassk in the Ukraine, supplied the first four engines of 3100 kW in 1973. The first electrified long-distance route, which connected Riihimäki to Seinäjoki, was opened in March 1975. After the satisfactory experience with the Soviet engines, the electrification of the railways proceeded without opposition. At the end of 1977, electrified lines accounted for 515 km or 8.5 per cent of the total length of lines in use.[77]

In Finland, transport has never been a significant customer in the demand for electricity – at the highest its share has been only 3–4 per

cent of the total electricity consumption. It was, however, an important factor in the early phases of general electrification. The committee reports of 1907 opened up visions of opportunities made possible by the transmission of electricity. The plans for railway electrification directed attention to the country's hydropower resources. Later, these plans motivated the government to expropriate the Linnankoski rapids, and to connect its head with the next downstream rapids, thereby increasing the capacity of the Imatra power plant.[78]

The electrification of railways suffered the drawbacks of politics more than any other sector. It is obvious that the lack of technological and economic knowledge also hampered the electrification of the railways. Incompetence in making reliable and convincing economic calculations of both costs and benefits was one of the main pitfalls of various plans and committee reports on this topic. Only in a rather late phase did the originators of these economic calculations begin to note the several positive direct and indirect effects of railway electrification, such as a bigger transport capacity, higher efficiency, and a rising demand for transport services due to greater competitiveness.

4.4 AGRICULTURE AND RURAL ELECTRIFICATION

Finland is a country where industrialisation led to urbanisation only very slowly. In 1910, 2.5 million inhabitants or 85 per cent of the total population lived in the countryside. At the time as many as 70 per cent earned their living in agriculture, forestry or fishing, as shown in Table 2.2.[79] Over half of the population lived in rural municipalities up to 1969.[80] Potentially, this population comprised a sufficient basis for a viable electricity supply, but in practice, rural dwellers played a minor role as electricity consumers. The agrarian composition of the labour force and national product, in fact, delayed the whole electrification process in Finland.

Rural electrification has, in general, been expensive for consumers and not very profitable for the utilities. This was especially true in Finland, because it was a sparsely populated, small-farming country with some disadvantageous geographical features. Moreover, the purchasing power of the rural population was, as a rule, modest until the 1960s. Rural electrification was not evaluated or motivated only for its direct economic returns but also for its indirect economic effects as well as social, political and parochial reasons. Only the combination of these factors can explain the relatively large investments in rural electrification.

The first three officially registered electricity utilities which supplied rural areas began operations between 1900 and 1903.[81] The broad expansion of rural utilities started only in the following decade. The shortage of paraffin gave a strong impetus to electrification in the late 1910s. The utility was often backed by a local mass movement; decisions on starting electricity distribution were made in open village meetings or ordinary men. Various forms of ownership and organisations were applied. There were joint-stock companies, co-operatives, municipal utilities, ordinary partnerships, one-man firms, etc.[82] Most utilities, especially in the southern part of the country, were joint-stock companies. Co-operatives were most popular in northern Pohjanmaa (Österbotten). Purely municipal utilities were rather rare, but municipalities often became substantial co-owners of joint-stock companies.[83]

Local power plants and distribution networks were frequently built hastily and incompetently. Floods carried away new dams, portable steam engines were unreliable, transmission losses might rise up to 50 per cent of the total supply, bulbs flickered, and motors stopped owing to a low voltage. Many rural electricity utilities lacked sufficient technological know-how and materials for constructing a proper and economical supply system. They generally were too small to be viable enterprises and able to employ competent personnel to run them efficiently.[84]

In the interwar period, not many rural utilities were thriving and a few went bankrupt. Despite applications from the Association of Rural Electricity Supply Utilities, the government did not support electrification in the countryside financially or technologically, apart from some exceptions which were as a rule related to the Imatra power plant project. Rural utilities had to rely on the funds they could raise by bank loans, selling their shares, collecting so-called membership fees, and invoicing their clients for both consumed kilowatt-hours and a basic fee. In this respect, Finland distinctly differed from Sweden where the government supported rural electrification by means of grants and loans.[85]

As sparing people, farmers were not good consumers from the viewpoint of utilities. In the 1920s, nearly half of the rural electricity consumers used this energy form only for lighting. The rest also used some electricity for threshing, pumping water and ironing their Sunday clothes but hardly for anything else.[86] The annual load factor

of utilities might stay as low as 4 per cent for several years. A sharp peak load took place only on the few autumn days when many farmers wanted to thresh at the same time.

During the Winter and Continuation Wars, rural electrification was discontinued, but it was resumed after the demobilisation of the Army in autumn 1944. Again the shortage of paraffin was a strong incentive for modernising the power supply of farms. During the time of great social changes, other reasons were also put forward. Firstly, it was said that electricity should be used for raising agricultural productivity and easing the farmers' toil. The second set of reasons was related to social justice: electricity should be available to rural dwellers, as it was to townspeople. An increasing amount of hydro-electricity was transmitted from remote areas to population centres. For this reason, it was argued that rural people should not be left without the benefits of the natural resources of their own local area.[87]

Thirdly, a political and economic goal of the first postwar governments was to discourage emigration from the countryside to towns. It was considered that rural electrification was one way 'to bind the labour force to its plots'.[88] Electricity was expected to raise the living standards of rural dwellers, and this, in turn, would decrease their wish to move to the towns. The centrist Agrarian League was still the leading party in the government and it preferred to have a lot of satisfied voters in the countryside.

A parliamentary committee on rural electrification, sitting in 1947–50, found that in the former year as many as 82 000 rural households or 1.4 million inhabitants were still without electricity. The general degree of rural electrification was then only 50 per cent. The committee put forward an ambitious goal: with the government's financial support, 170 000 households should be electrified and the degree of electrification raised to 80 per cent by 1955.[89] The committee did not predict the growth in the number of rural households correctly; and their target percentage was attained only by 1960 after 250 000 households had been electrified.[90]

Regional differences were substantial. Since the 1910s, electrification was more extensive in the more densely populated and wealthier areas of the south and of the south-west coast than in the provinces of central and northern Finland. By 1939 about two-thirds of the rural households in the Province of Uusimaa were electrified, while in the eastern and northern parts of the country electrification was just being introduced. In 1947 the average degree of electrification was 63 per cent in the five southern provinces with a population of 1.7

million rural inhabitants, whereas the corresponding figure was only 22 per cent in the four northern provinces with 1 million rural inhabitants. The density of population was low in both areas: 7.5 inhabitants per square kilometre in the former area and for the latter area the corresponding figure was 4.9.[91] The postwar electrification programme could level out the regional differences only slowly. In 1960 the degree of rural electrification was 95 per cent in the Province of Uusimaa and 50 per cent in the Province of Kuopio. In the course of electrification it was found that the patterns of settlement had a great impact. As mentioned earlier, electrification positively correlated with the population density – the higher the density the greater the percentage of electrification. The riverside districts, however, differed from other sparsely populated areas. The degree of electrification was notably higher in the provinces of Oulu and Lapland than in the provinces of Kuopio and Mikkeli, though the population density in the north was much lower. This was because the population in the former has settled mainly along the rivers, while in the latter it had scattered throughout the countryside, between many lakes and woods. Building numerous, ramified transmission lines made electrification much more expensive in the lake district than erecting a few lines along the riverside settlements which wound like strings of pearls from the hinterland towards the sea.[92]

Despite the central government's electrification programme, most of the investment costs were paid by the rural supply utilities and their consumers. Between 1947 and 1964 about FIM 250 million were invested in rural electrification and the government's grants covered just under FIM 50 million or a fifth of the total. These grants have been criticised for being only nominal, because the government first collected over FIM 50 million as purchase tax on the whole investment programme and then with some delay returned a part of it as grants.[93] In the 1970s, the government's grants greatly increased when the very last areas were electrified. Between 1947 and 1977 the state's financial support to rural electrification totalled FIM 403.3 million at constant 1977 prices.[94] The government's postwar rural electrification programme functioned as a catalyst for local entrepreneurship, distributed technological know-how, promoted technical standardisation and levelled regional differences.

A significant feature in the rural electrification of Finland was that initiatives came from local people. The government had no leading role in the process. There were two main waves of electrification. The first sprang up in the late 1910s and the second began in the late 1940s. Common features of these waves were that in both cases supply systems were planned and built mainly by Finnish engineers and firms, although in the 1920s some German and Swedish companies constructed a minor part of rural supply systems. The post-1945 electrification was, however, much better planned, organised and financed.

Standardised equipment and technical norms were adopted; here the Finns benefited from the achievements and mistakes of the rural electrification of Sweden. Rural utilities gradually became connected to the national grid. Projects were led by competent personnel. The average size of utilities grew. Many former small utilities were merged to bigger units. New provincial utilities, which were almost exclusively locally owned joint-stock companies, were set up. After a few difficult years, the economy of independent rural utilities was much stronger in the postwar years than in the interwar period. In short, 'the Finnish model for rural electrification' became established.

There have been big differences in the forms and diffusion rates of rural electrification among European countries. As early as 1925, Switzerland had wired 95 per cent of its rural households. Denmark, the Netherlands and Norway had by then electrified 50 per cent or more, and most of the European countries had reached the figure of 20 per cent. With about 18 per cent, Finland was among the laggards.[95] In 1945 the degree of rural electrification had risen to 70 per cent in Norway and 84 per cent in Sweden, but it still remained under 50 per cent in Finland.[96] By the mid-1970s all developed Western European countries had completely electrified their rural areas, while Finland was still undertaking electrification of its eastern and northern parts and its archipelagos, as shown in Figure 4.8.[97]

Internationally, Finland was a latecomer in rural electrification. Because of the extraordinary economic geography of Finnish farming, very rapid and early electrification might not have been even rational or economical. Nevertheless, if from the very beginning, planning, standardised systems and larger utility units had been applied, as was the case in the postwar period, electrification could have been carried out with much lower costs. In economic terms, electrification became sensible only when the rise of relative fuel prices and wages made the use of various electric machines remunerative. The electrification of very remote and sparsely populated areas was not carried out on the basis of purely direct economic returns but primarily for social, regional, political or other reasons.

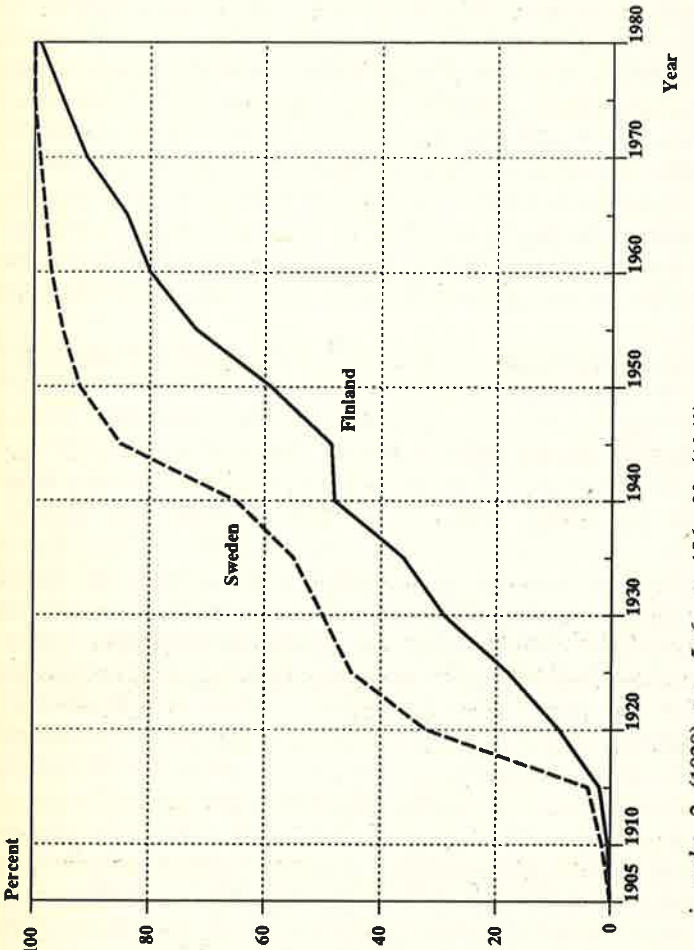


Figure 4.8 The degree of electrification of rural households in Finland and Sweden, 1905–80

Sources: Voima ja valo, 2 (1929) no. 5–6, p. 136; 23 (1950) pp. 65–6; *KM 1950:9* (Helsinki, 1950); *Maaseudun sähköistämistyöryhmän mietintö* (Helsinki, 1978) p. 7; Hans Modig, 'El på landsbygden', *Vattenfall under 75 år* (Stockholm,

In the postwar years, some new electric machines became general in Finnish farms, including the water pump, the milking machine, the milk refrigerator, the household flour mill, the grain dryer, and the circular saw for cutting billets into small firewood. Agriculture with its associated occupations, nevertheless, remained quite a modest electricity consumer. Despite the large relative size of the rural population, its share of the total electricity consumption never rose as high as 10 per cent.[98] In the early 1960s, agriculture and dwellings accounted for 40 per cent, rural small and medium-size industry for 34 per cent, handicrafts for 14 per cent, and the public sector for 12 per cent of the total electricity consumption in the countryside.[99]

Since the 1950s, the mechanisation of agriculture and the growing demand from individual farms and other rural consumers increased electricity use, but these factors were counteracted by the consequences of a sharp decrease in the rural population. Electrification succeeded in raising productivity of viable farms and improving living standards in the rural areas in general, but it could not prevent underemployed country people from migrating to the towns.[100]

4.5 THE TERTIARY SECTOR AND HOUSEHOLDS

Regular Customers of Supply Utilities

The tertiary sector and households comprise a heterogeneous, residual group of electricity consumers. For a long time the various parts of this group had at least one common feature – they used electricity predominantly for lighting. In many Finnish towns, electrification was started with the lighting of shops, restaurants, or streets. In addition, electric lighting was also introduced into the dwellings of some well-to-do people.

Electricity supply utilities were set up to meet the demand from these sectors and from small-scale industry. Despite a fairly steady growth in demand, the clients of utilities consumed quite a modest amount of electricity before the 1910s. The utilities considered it necessary to persuade consumers to use electricity also for other purposes – not merely for lighting. Contemporary specialists considered that the very limited use of electrical appliances was caused by the following factors: the relatively high price of electricity and of household appliances, low living standards, lack of knowledge, and the negative attitudes and social values of consumers. It was thought that utilities could primarily influence the three last factors, the impact of which they could counteract by advertising and information campaigns, or 'electricity propaganda' as these activities were called in the interwar years. Models for 'electricity propaganda' were adopted from Switzerland, Germany, Sweden and Norway. The main reason for launching these campaigns was that the load factor of the generating capacity was considered to be too low in the Finnish utilities.[101]

In 1929 the Municipal Electricity Supply Utility of Helsinki (MESUH) established the post of 'propaganda engineer' whose tasks included drafting advertisements and information bulletins, writing articles for family and other journals, and delivering public lectures and radio talks.[102] However, Finnish utilities did not in general hire and/or sell appliances to their clients, as was the regular custom for promoting electricity sales in Britain.[103]

Households

It is often claimed that electrical household appliances spread rather slowly in Finland.[104] We must, however, differentiate between the adoption and diffusion of an innovation. Even before the 1980s, information on and specimen copies of new innovations reached Finland with only a short time-lag. New appliances, nevertheless, only became available and were accepted by ordinary customers after a lag of some years, but when they had made an initial breakthrough into the market they spread at a moderately rapid pace all over the country.[105] For those appliances innovated before 1945, the average time-lag was 15–20 years between the introduction of an innovation in a pioneering country and its introduction in Finland. In the postwar period, this lag greatly shortened.

Before and during the interwar period, the Finns did not favour those appliances, such as electric cookers, boilers and radiators, which consumed a lot of electricity annually and were therefore the most important from the viewpoint of the utilities. By contrast, in European comparison they fairly early started to buy appliances which consumed quite modest amounts of electricity and fitted well into their life-style. Such devices were irons, vacuum cleaners, coffee makers and heating pads, as indicated in Table 4.6.

Unfortunately, the figures in Table 4.6 are not fully comparable, since the rate of electrification varied among the areas concerned. The figures for Helsinki, Oslo and Switzerland fit best together

Table 4.6 The diffusion of various electric appliances in Helsinki, Oslo, Berlin, Switzerland and the USA, 1928–30 (percentage of the number of wired households)

Appliance	*Helsinki Nov. '30*	*Oslo Dec. '30*	*Berlin Oct. '28*	*Switzerland Dec. '29*	*USA Dec. '29*
Iron	37.5	68.0	56.0	80.5	94.0
Vacuum cleaner	20.7	17.0	27.5	. .	43.6
Heating pad	6.8	2.1	16.3	. .	. .
Kettle, coffee or tea maker	11.3	3.6	5.9	23.5	27.5
Radiator	2.2	44.0	7.4	32.3	16.1
Cooking plate	1.3	59.0	. .	. .	. .
Cooker	0.0	11.0	1.6	17.4	4.4
Hair drier	1.1	0.4	8.6	. .	. .
Sewing machine	0.8	0.4	2.1	. .	15.0
Boiler	0.5	18.5	0.2	10.8	. .
Fan	0.4	2.4	1.6	. .	29.4
Refrigerator	0.4	0.1	0.2	. .	9.4
Washing machine	0.06	0.2	0.5	. .	33.4

. . No data available.

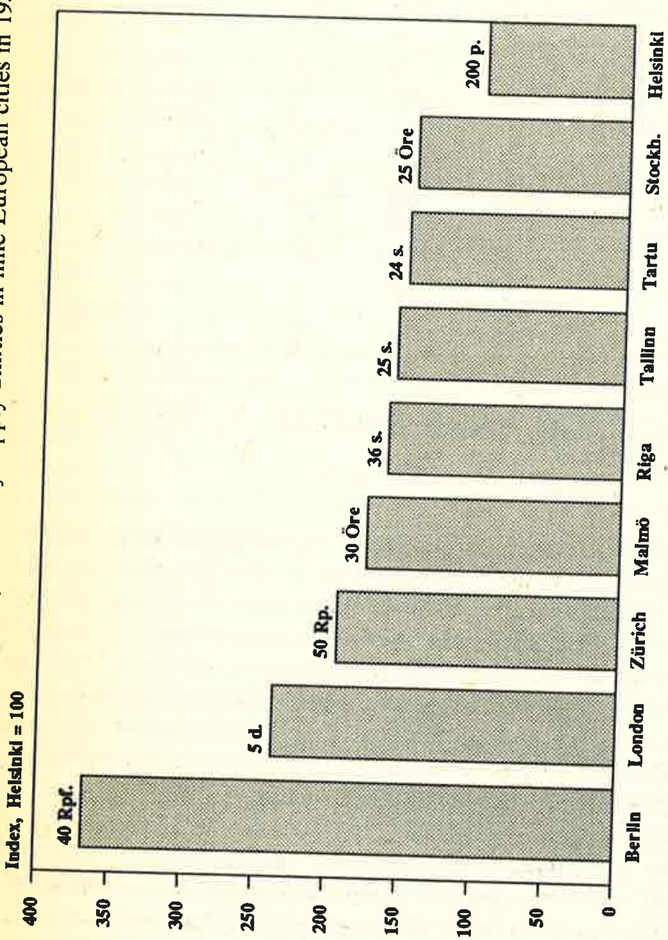
Source: Sigmund Schalin, 'Tilastoa taloussähkökojeista', *Voima ja valo*, 4 (1931) no. 2, pp. 41–4.

because these areas were nearly completely electrified. In Berlin, by contrast, only 55 per cent of households were wired for electricity and in the USA the percentage was somewhere between 65 and 85.[106]

The price of electricity was the main reason why appliances consuming a lot of electricity did not spread at the same pace in Finland as in Norway or Switzerland both of which had access to extraordinarily cheap hydroelectricity. Finnish consumers regarded their electricity rates as too expensive and they had cheaper alternative energy sources for various kinds of heating.

Was electricity really expensive in Finland? It is not easy to evaluate this objectively. First, electricity prices varied a lot over time. Second, electricity prices ought to be judged relative to some other economic variable such as the disposable income of households. This kind of comparison is made in Table 4.9. Third, intercountry comparisons of electricity rates might be a handy method for evaluation, unless significant fluctuations in exchange rates would distort them. Figure 4.9 illustrates an international comparison in the late 1930s.

Figure 4.9 The highest kWh-rates charged by electricity supply utilities in nine European cities in 1937



Notes:
For defining the heights of the bars, the electricity rates of non-Finnish cities are changed to Finnish marks by using official exchange rates.
Electricity rates in original currency are marked above the bars.

Sources: 'Tallinna linna elektrijaama tegevuse ülevaade', Eesti Rahvuslik Jõukomitee, *ORKA* F. 1011, Nim. Arh. nr (s.ü) 88, p. 15; *Kertomus Helsingin kaupungin sähkölaitoksen toiminnasta vuonna 1937* (Helsinki, 1938) p. 11;

Applying official exchange rates, Finnish electricity prices varied between nearly the top and almost the bottom of the European price scale before the 1980s. At the turn of the century, a kWh for lighting cost about FIM 0.75 in Germany and FIM 1.00 in Helsinki.[107] In 1910, the basic electricity rate for lighting was almost the same in Helsinki (0.6 FIM/kWh) as in more affluent Berlin (0.5 RM = 0.62 FIM/kWh).[108]

If we, in turn, compare European cities of the late 1930s, the electricity rates in Helsinki were clearly below the average. Figure 4.9 contains the maximum rates which electricity supply utilities charged in some European cities in 1937.[109] This comparison deals with the time just after the MESUH had reduced its maximum rate, which was applied to most households, from FIM 2.50 to FIM 2.00. The fact that the average income level was then somewhat lower in Helsinki than in Berlin, London, Zürich, Malmö or Stockholm, narrowed the differences in the ratios between electricity rates and earnings. The official nationwide statistics on the average retail prices of electricity support the data of Figure 4.9. According to them, households paid 20 per cent less for their electricity in Finland than in Sweden in 1937, while the corresponding difference between the two capitals was 31 per cent in favour of Helsinki.[110]

The spread of electrical appliances slowed down during the Second World War and the reconstruction period. The government strictly controlled foreign trade with import and export licences up to 1957 and consumer goods could be imported only in very modest quantities annually. Radio receivers, electric kettles and electric fires, which were mostly Finnish-made, were then probably the best-selling household appliances.[111]

In the 1950s, when the Finns had again opportunities to buy foreign-made electrical household appliances, they were far behind many countries. Under tight protection, the domestic production of electrical devices, however, got off to a good start. The manufacture of washing machines, refrigerators, etc. was often commenced under foreign licences, but quite soon appliances of domestic design were introduced. Later, when import restrictions were alleviated, some Finnish products succeeded in competing with imports, although consumers were offered a chance to choose from quite a wide variety of West European appliances. Rising living standards made it possible for the Finns to start catching up with the lead of industrialised countries.

The participation of women in the labour force has always been relatively high in Finland.[112] Before the Second World War, single women generally worked outside the home. During the war and after it, the contribution of women to the labour force greatly increased and many married women also participated in the labour force. Consequently, in Finland this increase antedated or was concurrent with the rapid spread of electric appliances. When an employed wife returned home for work in the evening, she had a great deal of work to do in a few hours. Therefore, she often needed the help of her husband or children with the housework. This was going to change the traditional divison of labour in the family. The growing disposable income of households with two or more earning members, however, enabled them to buy labour-saving household appliances. Wives saw electrical household appliances as 'dream machines which stimulate the husband to do housework'.[113] Finnish men, in turn, became interested in purchasing electrical household appliances, because they wanted to avoid or at least reduce their share of the housework.[114] As a result, the electrification of the home was partly carried out in order to preserve the traditional family roles intact despite both parents being gainfully employed. Thanks to electrical appliances, an employed wife could do the regular housework almost alone without the husband's or children's help.

An average Finnish couple with children spent just under three and a half hours per day in housekeeping (cooking, dishwashing, cleaning, laundry work) in 1979. The mothers' contribution was 90 per cent or about three hours. Mothers spent five hours per day or twice as much time as fathers for all domestic work (housekeeping, shopping, child care), but they used for gainful employment only half the time fathers did. Consequently, the mothers' total workday was just 9 per cent longer than fathers'. In Finland, domestic work is divided between sexes according to the similar pattern of the other Nordic countries. Because the full-time employment of Finnish mothers outside the home is more general, they work daily somewhat longer hours than mothers in Scandinavia, but at home they spend 8–12 per cent less time in housework.[115]

In the USA, where a much smaller proportion of women participate in the labour force, the popular notion on the time-saving effects of electrical household appliances has been challenged. Various studies claim that time spent on specific tasks has been reduced only negligibly when modern equipment is used, but this lack of time-saving may well mask an increase in the quality or quantity of the work or both.[116] According to this hypothesis, families with, for

example, a washing machine or electric floor polisher, tend to wash clothes and polish floors more frequently than families without those appliances. Hence, the total annual time used for those activities does not differ crucially between the two types of family. Nonetheless, in the USA as well as elsewhere, employed women who had limited time for carrying out necessary daily housework improved their productivity by means of electrical appliances.[117]

The use of electrical household appliances also depends on cultural and climatic factors. For example, electric can openers, electric shoe polishers, air conditioners and some other typical American equipment were practically unknown in Finnish homes before the mid-1970s, whereas the number of electric sauna ovens was already steeply rising, and electrical coffee makers became the best-selling electrical household appliance.[118]

A large proportion of appliances were imported or their production technology was transferred from Germany, Sweden, Britain and other European countries, as well as from the USA in the early postwar years. Import substitution managed to expand strikingly in the case of some appliances, such as radio receivers, cookers, washing machines, mangles, refrigerators, freezers, and tv-sets. After foreign trade was liberalised, a notable part of electrical household appliances sold was still manufactured domestically and predominantly by Finnish-owned companies; transnational companies set up only a few assembly plants in Finland. Private domestic companies had a significant role in transferring electrical household technology into Finland, while the central government through the Electrical Inspectorate, the Licence Board for Foreign Trade and other institutions controlled and regulated the importation of electrical appliances. Despite protective measures and a narrow variety of supplied goods, prices of electrical household appliances were claimed to be reasonably low compared with the rest of Western Europe in the late 1950s.[119]

Electricity prices had decreased by the mid-1970s to such a low level that many consumers did not even think of the probable rise in the electricity bill when they were considering buying smaller appliances. Electricity expenses were quite moderate for an urban dweller with a centrally fuel-heated flat which was equipped with various appliances. In the average Finnish family, electricity accounted for about 3 per cent of total annual expenditure in 1966.[120]

Electricity made much housework physically lighter and more convenient. If we compare producing the same output before the 1870s and one hundred years later, there is a substantial saving of

Table 4.7 The diffusion of household electrical appliances by 1973 (data on the introduction into the market and ownership level in the USA, West Germany and Finland)

Appliance	*USA* A	*USA* B %	*FRG* A	*FRG* B %	*Finland* A	*Finland* B %
Iron	1893	100	1889	93	1911	94
Refrigerator	1910	100	1912	87	1927	86
Freezer	1940	38	1957	32	1958	20
Washing machine	1907	80	1919	98	1929	57
Autom. washing machine	1937		1958		1958	
Dish washer	1914	34	1929	7	1962	3
Cooker	1909	64	1908	64	1912	75
Radio receiver	1921	100	1923	100	1923	100
B&W TV-set	1939	100	1938	73	1956	77
Colour TV-set	1954	67	1967	21	1968	4
Vacuum cleaner	1908	..	..	..	1928	62

A The date when the appliance was introduced on the market.
B The ownership level as a percentage of all households in 1973.
.. No data available.

Sources: Wolfgang Dotzentrath, 'Einige Gedanken zur rationellen Elektrizitätsanwendung', *Elektrizitätswirtschaft*, 75 (1976) no. 20, p. 654; *Sähköviesti*, 37 (1975) no. 4, p. 7.

time and effort. The change in time spent to supply lighting is a good example of rising productivity. In the mid-nineteenth century, lighting a country house with four simultaneously burning splints for 1300 hours per year demanded twelve days' drudgery from a man to make splints for the whole year (see page 21). In 1975, for lighting a home with four electric bulbs of 60 watts each for 1300 hours per year required eleven hours' labour input from a man who worked on the minimum wage, seven and a half hours' work from an average farmworker and only five hours twenty minutes' work from an average worker in industry.[121] This calculation, however, excludes the capital costs of both modes of lighting; the difference between splint and electric illumination would somewhat diminish if capital costs had been included in the calculation.

Before the Second World War, such durable consumer goods as the washing machine, refrigerator or electric cooker were rare in Finnish households. Thus Table 4.7 suggests that during three postwar decades, the diffusion of electrical household appliances was

not slow in Finland.[122] In the ownership levels for these devices, the country caught up with such highly industrialised economies as the United Kingdom and France by 1970, although it was still behind the USA, West Germany and the Scandinavian countries.[123]

The use of electricity in Finnish households closely resembled the pattern in other industrialised countries of Western Europe by the early 1970s. When space heating is excluded, electricity was primarily used for cooking, accounting for 26 per cent of the total household consumption. The category of lighting and minor appliances ranked second with 21 per cent, refrigerating and freezing consumed, 19 per cent, entertainment electronics (TVs, radios, record players, etc.) 12 per cent and the rest, 22 per cent, was divided between ventilation, laundry, sauna-ovens and other equipment. In 1973 the average household in Helsinki consisted of 2.8 persons and consumed 1540 kWh yearly. This amount fitted well in the West European consumption pattern which in the same decade ranged from 1200 to 2500 kWh p.a., compared with 4600 kWh p.a. in the USA.[124]

The decrease in the real retail electricity price was an important factor which stimulated Finnish households to increase their consumption of electric power in the postwar period. Abruptly in 1974, the price trend was disrupted. On 1 February of that year, the wholesale price of electricity rose by about 55 per cent, and in early 1975 it was 80 per cent higher than in early 1973. Finland was not the only country where electricity rates nearly doubled between 1973 and 1976 owing to the oil crisis, as demonstrated in Table 4.8. The noteworthy point is, however, that Finnish electricity rates for both households and industry were above the West European average in the 1970s. Although 30–40 per cent of electricity was generated by hydropower, electricity rates were in Finland just as high as in many coal- and/or oil-using countries.[125] For industry, Finnish electricity rates were the second highest in the sample and for households they ranked fifth in 1976.

In order to eliminate the effect of exchange rates, we can compare the ratios between the retail electricity price and the hourly income of an average worker. Unfortunately, data is available for comparing Finland only with West Germany for two decades. According to Table 4.9, this ratio has been quite similar at various points of time and decreased almost at the same pace in both countries. Only in the 1960s does electricity seem to have been essentially more expensive in Finland than in West Germany, which country, alongside Belgium, Italy and France, used to have the highest electricity prices on the

Table 4.8 Electricity rates in some West European countries on 1 January 1973 and 1976 (in current Finnish pennies (FIP) per kWh)

Country	*Rate for households consuming 3500 kWh annually*			*Rate for industrial plants consuming 10 million kWh annually*		
	FIP/kWh 1973	*FIP/kWh 1976*	*Index 1976*	*FIP/kWh 1973*	*FIP/kWh 1976*	*Index 1976*
Belgium	18.4	28.0	130	8.8	14.3	92
West Germany	11.4	26.1	121	11.3	16.2	104
Italy	14.5	25.7	120	7.5	14.2	91
France	16.3	23.1	107	7.6	11.2	72
Finland	**12.7**	**21.5**	**100**	**7.5**	**15.6**	**100**
Denmark	10.3	20.2	94	5.8	11.4	73
Netherlands	10.6	20.0	93	7.0	14.1	90
Austria	11.5	17.6	82	8.1	12.6	81
UK	11.0	16.9	79	7.4	11.7	75
Switzerland	9.3	16.6	77	7.8	12.5	80
Sweden	9.9	13.2	61	5.5	9.2	59
Norway	4.4	11.1	52	4.9[a]	8.7[a]	56
Average	11.7	20.0	93	7.4	12.6	81

[a] Applying the annual consumption of 2 million kWh.

Source: Energy Statistics 1980, Ministry of Trade and Industry, Energy Department (Helsinki, 1981) p. 84.

Continent.[126] Table 4.9 supports the suggestion that in postwar Finland up to the late 1970s, electricity was more expensive than in Western Europe on the average.[127]

Space Heating

During the fuel shortage of the Second World War, electric space heating began to spread in Finland, but after the war its use was forbidden for a few years. With a prohibitive tariff policy, the Finnish Association of Electricity Supply Undertakings attempted to obstruct the use of electricity for space heating from 1949 to 1961.[128] Thereafter, a new rise started owing to the decrease of general electricity prices and special heating tariffs marketed by the supply utilities. At first, with their tariff policy the utilities favoured accumulating electric space heating (which consumed power only at night), but later, they started to apply special reduced rates to small houses with a direct electric heating system. The positive experiences of

Table 4.9 The average working time required from an industrial worker to purchase 10 kWh of household electricity in Finland and West Germany, 1938–77

Year	*Finland**		*West Germany*
	Hours	*Minutes*	*Minutes*
1938	3	50	. .
1955		52	58
1965		27	19
1970		15	12
1973		10	9
1977		9	9

* Male workers only.
. . No data available.

Sources: Revue sociale (1939–65); *Statistical Yearbook of Finland 1939–1978* (Helsinki, 1940–79); *Energy Statistics 1978–1986* (Helsinki, 1979–87); Horst Magerl, 'Zukunftsaufgaben der Elektrizitätswirtschaft', *Elektrizitätswirtschaft*, 78 (1979) no. 1, p. 2.

Scandinavian and Scottish utilities and a wish to level down great daily variations in the load caused the radical change in the tariff policy of Finnish electricity supply utilities.

The number of electrically heated dwellings grew from a few hundred to 13 000 between 1960 and 1968 and then up to about 160 000 in 1977. The volume of electricity consumed for electric heating jumped from 5 GWh to 2190 GWh p.a. in the period 1960–77.[129] Although electrically heated dwellings still accounted for only a small fraction of the total dwelling stock, for instance 7 per cent in 1973, it meant an important increment for the electricity consumption of households.[130]

Before the energy crisis of 1973–4, oil heating was cheaper than electric heating, but after the crisis the cost relationship reversed. In a few years the great majority of new small houses were equipped with electric heating. In addition to a cheaper price, the advantages of electricity were tidiness and convenience, whereas its disadvantages included the great dependence on the local supply utility. In densely populated areas, some small houses, however, became connected to a district heating system which steadily expanded its market share as a heating system for blocks of flats. In the 1970s the market share of oil-fired central heating sharply declined in all types of dwellings under the pressure of both electric heating and district heating.

The Tertiary Sector

From the 1910s, households perceptibly contributed to the growth in demand for electricity. Their share increased from 10 per cent to 21 per cent of the total consumption of electricity between 1960 and 1980, while industry's share decreased from 71 per cent to 57 per cent. This increase was caused by a fall in the real electricity price, the growth of households' disposable income, a great diffusion of various electrical household appliances and a rising number of households.[131]

The tertiary sector was the other group which steadily expanded its proportion of the total electricity consumed. As shown in Table 2.2, the tertiary sector was the most rapidly growing section of the Finnish economy in the postwar period.[132] Another cause for the substantial rise in demand for electricity was a strong drive for mechanisation in this sector as well; various kinds of electric and electronic equipment were introduced in shops, hotels, restaurants, banks, offices, etc. The price relation between electrical machinery and labour was steadily changing in favour of the former.

The non-industrial and non-transport sectors accounted for quite a stable share, about 10–13 per cent, of the total electricity consumed from 1900 up to 1950. Thereafter, their share began to grow and by 1970 it had risen to 28 per cent of the total consumption of electric power, as indicated in Table 4.10. This change reflects the deep structural transformation which took place in the economy of postwar Finland.

4.6 PRICE COMPETITION BETWEEN FUELS AND ELECTRICITY

The demand for electricity partly depends on available alternatives, their qualities and prices. As a versatile energy form, electricity intruded into the territories of various fuels and power sources. In lighting, it had to compete with paraffin, candles, gas, wood, etc. In industrial motive power, it challenged the dominance of directly-coupled hydropower, and wood- or coal-fired steam power, and wood gas- or oil-using combustion engines.

Table 4.10 The composition of electricity consumption in Finland in 1970

Sector	%	*GWh*
Residential space heating	3	600
Dwellings without space heating	12	2590
Agricultural production	1	200
Services and building construction	12	2580
Forest industries	41	8985
Mining and other industries*	24	5351
Transmission losses	7	1511
Total	100	21817

* Including transport (0.2% of the total consumption).

Source: Jorma Kattelus, 'Sähkön tarve Suomessa 1970–85', *Sähköviesti*, 36 (1974) no. 1, pp. 4–5; *OSF 42:5 Energy Statistics 1985* (Helsinki, 1986) pp. 64, 80–81.

The competetiveness of electricity depended on both its capital and operating costs. If an industrial company decided to buy its electricity from a utility or from another factory nearby, it certainly saved some of its capital costs compared with the alternatives: building its own directly-coupled or electricity generating hydropower or steam power plant. In lighting, electricity was, in turn, burdened by higher capital costs than with paraffin or candle lighting, but that was not the case when compared with gas lighting. Electric drive had many advantages and these led to many bigger industrial companies deciding to build their own hydro or steam power plant delivering the generated energy around the factory in the form of electricity.

The lack of coherent statistical data restricts the opportunities to compare the total costs of competing energy sources in the long term. From about 1910, we can, however, compile nationwide data on the average retail prices of electricity, paraffin, gas, birchwood and coniferous firewood. Unfortunately, there is no data on average retail prices for coal or coke. These fuels rivalled with firewood, and changes in their prices used to correlate with the fluctuations in the prices of birch billets up to the 1950s. Although the operating costs of electricity continuously went down compared with the operating costs of energy production from solid fuels, up to the 1960s firewood and also coal in certain areas had lower total costs for space heating. In choosing a technology for mechanical drive, the operating costs of different power systems often played a minor role in the decision-making process.

Table 4.11 The operating costs of some lighting methods in Helsinki in 1909 (costs for the luminous intensity of 10 normal candles per hour, in current Finnish pennies)

Light fixture	*Costs FIP/h*
Stearin candle	18.4
Paraffin lamp	1.05
Electric bulb with a carbon filament	2.2
Electric 'Nernst-bulb'	1.0
Electric 'Tantal-bulb'	1.0
Ordinary electric arc-lamp	0.7
Gas lamp with open flame	4.0
Gas lamp with an Auer-burner	0.46

Source: Lauri Loimaranta, *Sähkö ja sen käytäntö* (Helsinki, 1909) p. 149.

In lighting, operating costs did matter. In Helsinki, the operating costs of ordinary lighting methods were repeatedly compared.[133] It was reported that by 1909 electric lighting with up-to-date filament lamps had become essentially cheaper than candle illumination and had reached the level of paraffin lamps in operating costs, but was still more expensive than modern gas lighting, as shown in Table 4.11.

In the following decades, tough price competition took place between electricity and gas in the three Finnish cities with gasworks. Outside Helsinki, Turku and Viipuri, electricity became on average the cheapest illuminant as early as in the first half of the 1910s, when only the operating costs are compared. Paraffin positively lost its competitiveness in population centres during the First World War, although it remained an important illuminant in sparsely populated areas up to the beginning of the post Second World War period.

From the early 1940s, the prices of paraffin and gas began to soar and electricity gained a superior footing in price competition. After the war, electricity became available for most households in the country at reasonable cost. Figure 4.10 indicates that the nominal electricity retail price remained very stable both in the interwar period and from the early 1950s to the late 1960s. This must have strengthened the confidence of consumers in the electricity supply system and increased demand. The supply utilities also derived benefit from this stability in their sales promotion, launching advert-

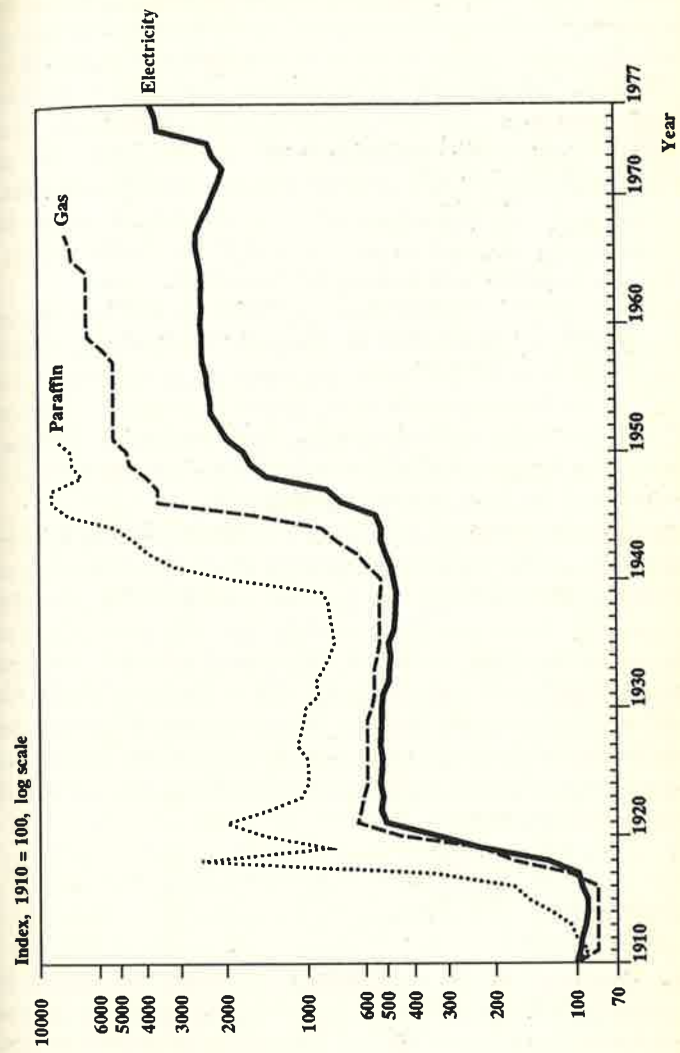


Figure 4.10 Nominal retail prices of electricity, lighting gas and paraffin in Finland, 1910–77 (index 1910 = 100)

Note: Between 1910 and 1919, gas prices include only tariffs in Helsinki. In the years 1918 and 1943–4, paraffin was generally not traded legally; for those periods its prices are estimates.

Sources: Revue de statistique ouvrière (1912–17); *Revue sociale* (1918–67); *Statistical Yearbook of Finland 1960–77* (Helsinki, 1961–78); *Kertomus Helsingin kaupungin kaasulaitoksen toiminnasta 1910–19* (Helsinki, 1911–20).

isement slogans such as 'all prices go up but electricity rates permanently remain low'.[134]

Figure 4.11 demonstrates how inflation-adjusted electricity rates slumped during both World Wars but decreased only slowly in the periods of peace. The competitiveness of electricity steadily strengthened, whereas billet prices tended to rise faster than prices in general. The use of billets in energy production continued to decline. This indigenous energy form started to play only a minor role from the late 1960s when billet prices jumped up strikingly. As an imported item, paraffin proved to be very sensitive to economic crises and it managed to regain its price competitiveness very slowly in the interwar period. By contrast in the post-1945 years, its pre-war position in price relations was quite quickly restored.

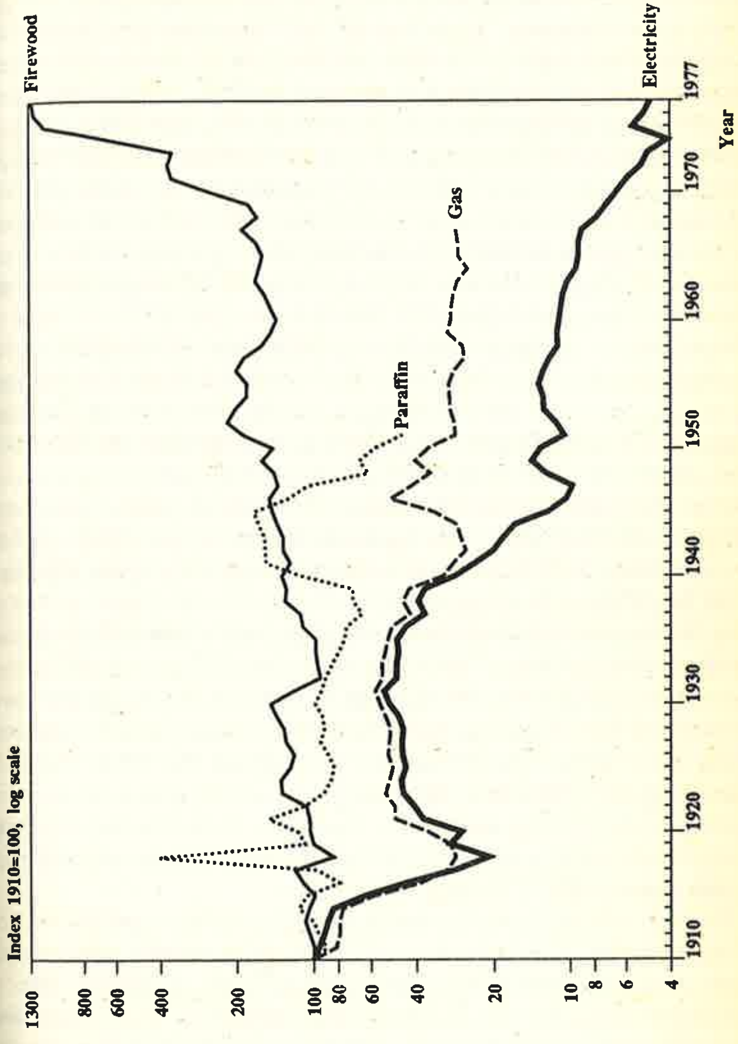
In Finland, the price competitiveness of electricity was very strong in lighting. It did not meet real challengers, because gas supply utilities, the providers of the most serious rival in lighting, were working only in two or three cities. In addition to a competitive price, electricity also had other valuable qualities which made it an attractive choice. It was a clean, versatile energy form, the use of which could conveniently be controlled and automated.

In mechanical drive, electricity became competitive during the first quarter of the twentieth century. Successive changes in both capital and operating costs favoured the position of electricity. Finally, electricity gained a footing in space heating, too. The slow diffusion of electric space heating, however, depended primarily on the purposeful tariff policy of supply utilities. Up to the early 1960s, the regular use of electric space heating was discouraged by the discriminative pricing of electricity. The need to improve the load factor made power companies and distribution utilities change their tariff policy in favour of space heating.

4.7 DISCUSSION

In Finland, the demand for electricity was closely connected to industry and industrialisation. Other sectors of the economy, except for households in the postwar period, were quite insignificant consumers of electricity. The main single reason for the rapid rise in demand for electricity was the energy-intensive structure of Finnish industry: electric power was needed primarily for the rapidly growing forest industry.

Figure 4.11 Inflation-adjusted electricity and fuel retail prices in Finland, 1910–77



Notes: Deflated by the official wholesale price index (1910 = 100). Firewood denotes the real retail price of birch billets.
Sources: The same as in Figure 4.10.

Up to the 1940s, the demand for electricity grew almost at the same pace as the output of industry. Thereafter, industry's exceptionally high proportion of total electricity consumption began to decrease, while households and other sectors expanded their shares. In Finnish industry, the electrification of mechanical drive rose rapidly: by 1913 32 per cent of installed motive power was electrified and by 1950 the percentage had risen to 93. The predominance of agriculture in the economy and the dispersed pattern of farm location retarded the electrification of households in Finland. Both towns and rural areas were electrified by municipal or private initiative; before the late 1940s the government's role was very modest. Nevertheless, by 1938 just under 60 per cent of all households were wired for electricity which was quite a reasonable achievement in the rather unfavourable circumstances. By 1960 the degree of household electrification had risen to 90 per cent and by 1977 to 99.5 per cent.[135]

The price was, undoubtedly, an important determinant in the demand for electricity. However, the international level of the retail electricity price was not so crucial as the relative price of electricity compared with fuels and other costs as well as with the income of consumers. Electricity developed into a very competitive energy source, because it possessed versatile technical properties and its inflation-adjusted price fell considerably from the 1880s. Seizing markets from fuels helped the volume of electricity consumption to grow faster than the GNP.

In European terms, electricity was generally not extraordinarily cheap in Finland before 1977; the swift electrification of the country had to be explained by other factors. Compared to other countries on the basis of the official exchange rates, electricity prices decreased to a low level in the late 1930s, but rose above the West European average in the 1950s and 1960s when the construction of extensive hydroelectric systems had to be financed. Nevertheless, the great growth in electricity demand for non-industrial purposes took place in just those postwar decades.

The use of electricity for multiple purposes was considered convenient and rational in various sectors of the economy, while labour costs and fuel prices increased. Households developed into an important consumer group when living standards rose; housewives began to work outside the home and families wanted to increase their leisure time at the expense of housework.

In addition to the favourable economic growth, the energy-intensive composition of Finnish industry and the lack of competitive

alternatives, there was another important reason for the fairly rapidly increasing demand for electricity: Finnish society was generally receptive to electrical technology. A number of electrical innovations were experimented with early in Finland. After they were initially accepted by some key interests groups, such as various governmental institutions, supply utilities, import trade companies, appliance manufacturers or opinion-leading consumers, they were diffused at a moderate speed all over the sparsely populated country. The only major exception in the diffusion pattern was electric traction on railways which was accepted grudgingly and slowly. In that case, different economic and political interests clashed strongly. Rural electrification was, in turn, delayed owing to the characteristics of Finnish economic geography and the high investment expenses in transmission and distribution networks – not because of suspicions or the limited interest of local people. The successive governments of Finland had a rather cautious and indecisive attitude toward electrification and certainly did not include it in its top priorities in industrial or economic policy.

Disputes at the national and parliamentary level did not necessarily make an impact on the local level where a great deal of electrification was carried out. A concensus between municipalities and local industry frequently prevailed which enabled mutual co-operation in electricity supply. In fact, localism was characteristic of the Finnish electricity supply system, particularly before the Second World War, and this phenomenon had both its advantages and drawbacks.

5 The Interaction of Electricity and the Economy

5.1 LINKAGES

In many countries, electrification is considered a key process in creating a modern industrialised economy. Electricity plays a vital role in the modern economy because it interlocks with all industries. Measured by the value of gross output, electricity supply represents a small contribution to GNP. Nevertheless, its linkage effects and stimuli to the economy are considerable. Electricity has become a necessity for almost all economic activities in industrialised societies.

Finland has not been an exception. Electricity has been closely interwoven with the country's industrialisation since the 1880s. From the beginning, electricity supply induced attempts to provide, through domestic production, inputs needed for electrification. Despite the small size of the Finnish market, electricity managed to call forth some new industries and stimulate some others. Thus, electrification widened and strengthened the base of the Finnish economy with its backward linkage effects.

The first induced industry was heavy electrical engineering which began with the manufacturing of dynamos in 1887. The production of various kinds of electrical machinery was expanded over time and supplemented by the manufacturing of cables, insulators, electric bulbs, lighting fixtures, etc. A domestic industry for making electric appliances sprang up during the interwar years. It was, however, only in the post-Second World War period that this import substituting industry began to boom. Although the import trade was gradually liberated, international competition did not make Finnish electrical engineering companies wither but forced them to specialise.

In the late 1970s, Finnish TV-set manufacturers had the most promising growth prospects, whereas heavy electrical engineering had to work under the pressures of hard competition. By that time, the home market had become too small for Finnish electrical engineering. Only those companies capable of exporting had a chance to survive.

Electricity supply stimulated some other industries, although it could not be credited with setting up these industries. The expansion of electricity generation stimulated the development of domestic hydroturbine and steam boiler production, the mining and refining of copper ore, the utilisation of wood-processing wastes, and the excavation of peat. The main backward linkages of electrification are shown in Figure 5.1, with the names of some companies involved.

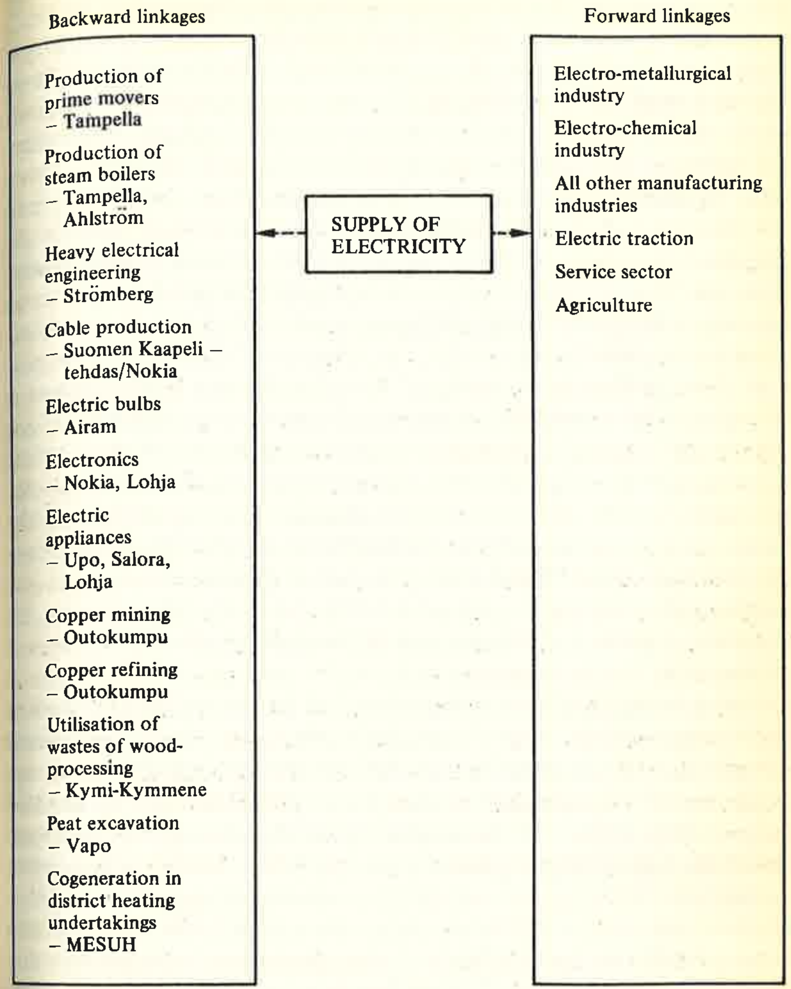
Attempts have been made for some countries to estimate the interdependence of economic sectors by measuring purchases from and sales to other sectors. According to Albert Hirschman, these input–output ratios indicate the ratios of backward and forward linkages. Data for Italy, Japan and the United States suggests that the forward linkages of electricity supply were much higher (59 per cent) than its backward linkages. (27 per cent).[1]

Backward linkage might have been just as low in Finland as in those three countries. Forward linkage, however, tended to be much higher, because only a small fraction of electricity in Finland was supplied for final demand, for consuming households. By contrast, electricity supply had a very high forward linkage to manufacturing. If we exclude transmission losses from the calculations, manufacturing accounted for about 85 per cent of the total net electricity consumption in 1900, and in 1975 the percentage was still 62. Therefore, in Finland electricity was primarily an input for manufacturing. The rise of electricity supply spurred a general expansion in manufacturing, and the rapid growth of industrial sectors, such as pulp and paper production, required rapid development of electricity supply. It was an important factor for the general growth of the economy in Finland that the country's electricity supply avoided becoming a bottleneck of development. The satisfactory advancement of electricity supply stimulated the whole Finnish economy.

5.2 THE REPERCUSSIONS OF ELECTRIFICATION

During the century under research, electricity came to be used for versatile purposes and its use has had numerous economic and societal effects. Although electric lighting was one of the first and widest-spread applications of electrical technology, it did not have a revolutionary impact on industrial production. The greatest benefit it brought was improvements in working conditions and safety from fire in the factories.

Figure 5.1 The linkages of electricity supply in the Finnish economy, 1882–1977



The electrical device which had revolutionary repercussions in manufacturing as well as some other sectors was the electric motor. Electric power transmission and the electric motor radically transformed the utilisation of mechanical drive in industry. Direct mechanical power transmission through line shafts, pulleys and belts was replaced by electric group and/or unit drives. The application of electrical technology brought more flexibility in industrial power systems and opened unprecedented opportunities for mechanisation.[2]

As the unit drive gradually became more common in factories, their layout was thoroughly reorganised. Machines could be freely placed anywhere, according to efficiency requirements and not only where they could be reached by the power shaft and its belts. Thus the functions that organisationally belonged together could be placed next to each other. Formerly those work phases which required motive power had to be concentrated near the prime mover or the line shaft and the rest of the phases farther from the power source. Now that the individual work phases could be integrated into an organisational whole, preconditions were created for genuine mass production and assembly lines.[3] Furthermore, due to the electrical unit drive, the machines could be controlled with a higher degree of accuracy, and standstills and material losses were diminished. Job safety was improved, while the maintenance chores of the workers were reduced, and they were better able to concentrate on the productive work. This resulted in a faster working tempo in the factories. Electric drive, plus the functional division of motive power distribution and rational decentralisation in accordance with the requirements of each work phase improved the efficiency of the production process. Thus the unit drive contributed to the growth of productivity in Finnish industry.[4]

Not only electric motors but electrical automatic control devices such as thermostats, pressostats, relays, electromagnetic switches and valves, had significant effects on manufacturing. Their introduction might not have caused a great change in capital costs but they enabled large savings to be achieved in labour costs. Some of the workforce could be replaced by quite simple electrical devices which often consumed only negligible amounts of electricity. A great advantage of electrical control systems was that they could work with low costs continuously twenty-four hours a day. Another advantage was that electric devices could be connected into instantly operating, automatic control systems which could carry out quite complicated sets of operations. Automatic control systems facilitated the organisation of the work process in more rational ways and an essential rise in efficiency.

The possibilities offered by electricity encouraged new designs in production machinery. The markets began to abound with more efficient, individually driven machines which the firms with electric

power were willing to buy. One characteristic of electrification was that it helped launch a remarkable new period of mechanisation in industry.

The adoption of electric drive generally caused a reduction in the energy costs of a firm, but cost reduction was often so small that it was not the primary cause for electrification. Firms frequently expected essential indirect cost savings from their investments in new technology. Some important direct savings, however, resulted from electrification: (i) Transmission and distribution of electric power facilitated an increase in the exploitation of an indigenous source of energy, hydropower, which was generally cheaper than thermal power. (ii) The economies of scale in the larger, centralised power plants enabled a price reduction in electricity. (iii) The opportunity to purchase power from electricity supply utilities was advantageous for many medium-sized and small industrial plants. Thus, they could avoid relative high capital costs needed for installing their own prime movers.

In the service sector, the repercussions of electrification gained a foothold only gradually in the early decades. In the postwar period, by contrast, development clearly accelerated. Like in industry, some savings in capital and labour costs resulted from electrification. The greatest effects have, however, taken place in the quality improvements in services and the introduction of new opportunities. For instance, consumers received fresher food because of refrigeration and freezing equipment. X-rays and other applications of electrical technology changed medical care. Cinemas and ice-hockey halls with artificially frozen ice are examples of new opportunities for leisure-time activities.

In agriculture, electrification led to labour saving and productivity increase. As mentioned in Section 4, electricity was, however, used only sparingly in Finnish agriculture and its consumption remained quite modest. In the residential sector, electrification stimulated demand for durable consumption goods. At the same time, it facilitated labour saving and many other household conveniences. Electrification was also involved in social changes. In family life, the spread of electric household appliances promoted housewives' working outside the home and the participation of husbands in housework.

5.3 ELECTRICITY AND ECONOMIC GROWTH

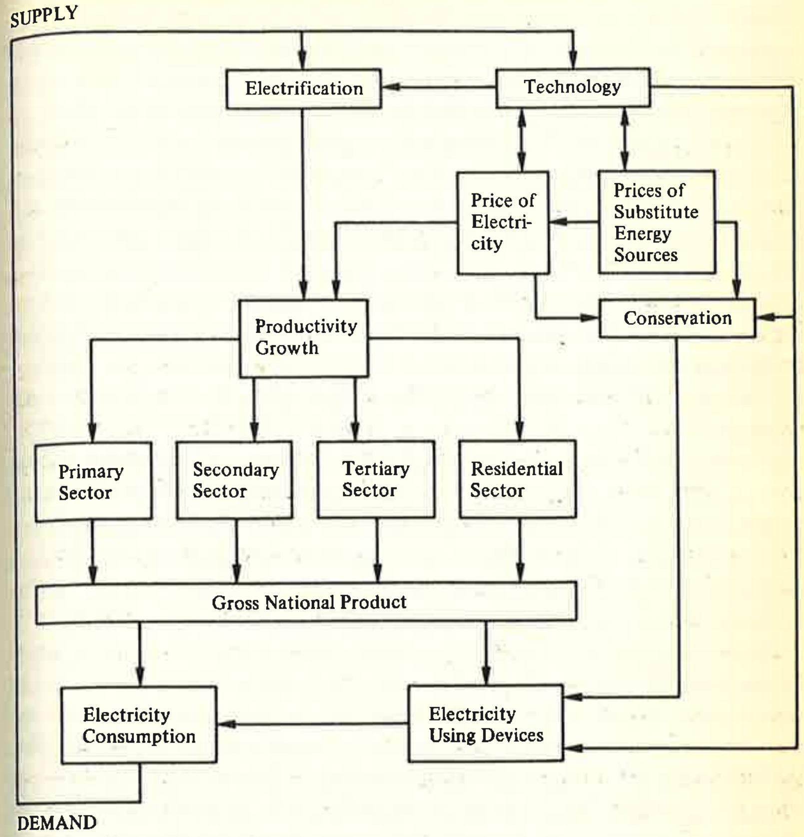
Electrification is one ring in a chain of reactions through which technological change affects economic growth. There are three basic preconditions for electrification: technological opportunities, a functional economy and demand for electricity. Prerequisites for electrification gradually mature. Its rapid advance depends upon the smooth co-operation of various sections of the economy. Thus, together with various other factors the generation and consumption of electricity form an interacting subsystem in an economy.

As mentioned earlier, electricity is interlocked with almost all activities of the economy. There is, however, an extra link to connect electrification with economic growth. As the Americans Sam Schurr and Nathan Rosenberg have pointed out, in the industrialised economy electrification and productivity growth are related.[5] The rise of productivity, which means the increase of output per unit of input, is one of the main sources of economic growth along with the change in the composition of the national output and the quantitative increments of inputs such as capital and labour. At least in the long run, productivity growth is more cost-saving than the other sources.

During the last hundred years, technological change has favoured the applications of electrical technology. Electricity has, in turn, enabled firms to reduce the total costs of producing a certain volume of commodities or to produce more commodities with similar costs. Not only technological characteristics of electricity but also the economic effects through its price have effects on productivity growth. Due to its relatively lower price, electricity has partly replaced fuels, on the one hand, and labour, capital and materials on the other. Productivity growth boosts economic expansion and investment. Favourable economic development tends to stimulate the introduction of electricity-using devices and the consumption of electricity which both, in turn, feed the rise of electricity supply. Figure 5.2 illustrates the relationships of this spiral-like, interacting system the central elements of which are electrification, productivity growth, GNP, and electricity consumption. Several additional factors are also depicted there, the contributions of which are vitally important for the function of the system.

Over the period under research, technological change related to electricity was ample and profound. Two features became preeminent. First, the thermal efficiency in converting fuels into electricity improved radically. It is likely that the average thermal efficiency of Finnish conventional condensation steam-electric power plants rose from 5 per cent to 35 per cent between 1913 and 1960. After that date, it is thought to change only little.[6] Second, 'the unusual characteristics of electricity had helped to raise the overall economic

Figure 5.2 Interrelationships between electrification and economic growth



efficiency by making it possible to perform tasks in altogether different ways than if fuels had to be used directly'.[7] The advantages of electricity came out the most clearly in manufacturing. The contributions of electricity included: (i) much greater flexibility in applying energy to industrial production; (ii) facilitating the introduction of new techniques and new arrangements in the existing industries; and (iii) promoting the rise of new industries.

Primitive farming and self-sufficient country life characterised the Finnish economy during the whole nineteenth century. Urbanisation proceeded slowly; even still at the turn of the century, in no other country in Europe did urban dwellers account for a lower proportion of the total population than in Finland (13.9 per cent in 1906).[8] The first signs of modern industry sprang up in the country only during the 1840s. Notwithstanding, the features of a latecomer industrialiser remained distinctive; the turnover of commercialised agriculture and the output of handicrafts was modest, internal transport was small and the whole monetary economy underdeveloped. After the Crimean War (1853–6), industrialisation accelerated. Because the point of departure was humble, the total output of industry and handicraft showed very satisfactory growth rates straight from the first decades of their expansion. The growth rate of industrial output increased up to the First World War. After the setbacks related to the wartime economic crisis and the Civil War of the year 1918, industrial output attained its prewar level in 1922. In the interwar period, the Finnish economy probably achieved the highest growth rate in Europe. Between 1922 and 1938, industrial output grew at 7.3 per cent per annum.[9]

From the 1880s, the fairly high growth rates of industrial output and GDP were surpassed by the rapid expansion of electricity production. Between the mid-1880s and 1939, the electricity sector was one of the most dynamic and fast-growing sectors in the Finnish economy. The Second World War hit the electricity supply sector heavily. No other industry experienced such a massive setback.

Industrial output regained its prewar volume as early as 1946, while it took three more years before the electricity supply sector could equal that. From the beginning of the reconstruction period, the former pattern was restored: electricity supply again began to grow more swiftly than industrial output or GDP. The main difference was that the growth rates somewhat converged. The composition of industrial output was diversifying. The electricity-intensive wood-processing industry was losing ground to engineering and light industries. The service sector, too, expanded outstandingly. The fact that these new, leading growth sectors of the economy were less electricity-intensive than the old ones slowed down the rise in demand for electricity.

Considering the period 1890–1977 as a whole, we can see from Table 5.1 that the growth rate of electricity consumption in industry exceeded the growth rate of industrial output by a factor of 3.8 and the growth rate of total electricity consumption surpassed that of real GDP by a factor of 2.4. No main economic indicator experienced such a growth as electricity consumption. Furthermore, taking account of the various linkage effects of electrification and its

Table 5.1 Annual average growth rates of various economic variables in Finland, 1860–1977 (compound growth rates per year)

Variable	*1860–1890* %	*1890–1913* %	*1913–1920* %	*1920–1938* %	*1938–1949* %	*1949–1977* %	*1890–1977* %	*1920–1977* %
Population								
– Total	1.0	1.1	0.5	0.9	0.8	0.6	0.8	0.7
– Urban	2.6	3.3	1.1	2.6	1.3	3.8	2.9	2.9
GDP at constant prices								
– Total	2.3	3.0	−1.4	4.7	2.1	4.2	3.3	4.0
– Per capita	1.2	1.9	−1.9	3.8	1.3	3.7	2.5	3.3
Industrial production								
– Output volume	5.0	5.3	−1.6	7.9	2.8	5.5	5.0	5.7
– Employment	2.6	3.5	2.1	3.4	1.4	1.6	2.5	2.1
Total installed power in industry								
– Total	6.3	7.9	3.5	8.0	2.4	7.1	6.6	6.5
– Per employee	3.5	4.2	1.4	4.4	1.0	5.4	4.0	4.2
Capacity of electric motors in industry								
– Total	.	.	9.3	11.7	3.1	7.3	.	7.8
– Per employee	.	.	7.1	8.0	1.6	5.5	.	5.6
Electricity consumption in industry								
– Total	.	25.3	6.5	14.0	0.3	7.1	12.1	7.9
– Per employee	.	21.1	4.3	10.2	−1.1	5.4	9.4	5.6
Gross electricity consumption*								
– Total	.	25.3	6.8	14.1	1.2	8.2	12.7	8.6
– Per capita	.	24.4	6.3	13.1	0.5	7.5	11.9	7.9

* Unlike in Table 4.1, the figures here are equal to those for the supply of electric power including, namely, both the domestic generation of electricity and its net import.
. Category not applicable.

Sources: Appendix Tables A.5–A.6; *Statistical Yearbooks of Finland 1950–1981* (Helsinki, 1950–81); Sakari Heikkinen *et al.*, *Industry and Industrial Handicraft in Finland, 1860–1913* (Helsinki, 1986) pp. 120–22; Riitta Hjerppe, *The Finnish Economy, 1860–1985* (Helsinki, 1989) pp. 192–6.

repercussions on productivity, one cannot deny the critical contribution of electricity on economic growth in Finland. Electrification served as a catalyst for modernisation and for the introduction of new technology in various sectors of the economy.

Unfortunately, we have no time-series for capital input in Finnish industry and no estimate for the growth of total factor productivity. From Table 5.1 we can, however, calculate that half of the output increase between 1890 and 1977 was ascribed to factors other than the increment of labour input. During the period 1920 to 1977 their contribution was even higher, nearly two-thirds. This suggests that the increase of capital inputs, mechanisation, and productivity growth gained rising importance in industrial development.

From the very beginning, electrical technology was exploited in Finland primarily for boosting the efficiency of various industries. Its use for luxury purposes, such as for lighting of palaces and clubhouses, or for other non-productive ends as an energy source in homes of ordinary people, gained a foothold rather slowly. The industrially orientated utilisation of electricity emphasised its significant role in accelerating the rise of productivity and in promoting economic growth.

6 Conclusion

6.1 THE THEME OF THE STUDY

The main theme of this work is electrification as a transfer process for a new technology. I have analysed the characteristics of Finland as an adopter and applier of technological know-how. A comparative international approach has been used to identify those national factors which affected electrification. I have attempted to examine how technology transfer and electrification were connected with the economic, political and cultural life of the country. Here, electrification is not regarded only as an economic and technological investment project but also as a factor in the modernising of Finnish society. When electricity became an important tool in industrialisation and in restructuring the whole economy, marked societal questions on the application of electrical technology emerged. In consequence, the aims of society and the mutual relationships of the interest groups defined the general framework of electrification.

6.2 THE PACE OF ELECTRIFICATION

Earlier literature has generally understated the pace with which Finland was electrified. Often these statements referred to the first quarter of the present century when electrification did not advance in Finland as briskly as in some leading countries. The Finns had set their goals high in the case of electrification and had picked out Germany, Switzerland, Sweden and Norway for their model countries.[1] Compared with these advanced and rapidly electrifying countries, Finland's achievements might not look extraordinary. That is true, but we might ask whether such a comparison is justified. If we, by contrast, compare Finland with such countries as the United Kingdom and France, or with the countries with rather similar status in Eastern and Southern Europe, the situation appears to be quite different.

If we choose another approach and take account of the available prerequisites, the electrification of Finland again looks unexpectedly satisfactory. In fact, there seems to be a contradiction between the modest level of economic development and the early adoption of electrical technology. A striking phenomenon is that, while a number of Finnish farmers, even in the 1880s, lived by the archaic means of slashing and burning-over woodland for cultivation and lit their houses with wooden splints, their compatriots in towns were at the same time pioneering the installation of most modern electrical lighting systems in Europe. In a way, Finland leapfrogged over some phases of development, direct from an archaic subsistence economy to hectic industrialisation.

In Chapter 4, it was claimed that Finland had reached approximately the same level of electricity consumption per capita in 1900 as Britain or some major Continental countries, such as France and Italy. After some setbacks between 1900 and 1925, Finland rose to be among the top ten electricity consumers in per capita terms during both the interwar years and postwar period. This performance was fairly exceptional, because of the late industrialising countries only Iceland, New Zealand and Finland managed to enter the group of the top ten electricity users (in per capita terms) between 1925 and 1975.

The central question of this work is why Finland succeeded so early in catching up with some leading industrialised countries, such as Britain and France, in the degree of electricity consumption and why Finland carried out the electrification faster than some other European latecomer economies with similar initial per capita income levels, such as Greece, Italy, Spain and Ireland (see Tables 1.4 and 4.2).

The success of Finland was not based on significant, indigenous inventions. The country had not a single great inventor in heavy current engineering.[2] By contrast, Italian scholars such as Luigi Galvani (chemical reaction as a source of electricity), Alessandro Volta (battery), Antonio Pacinotti (ring-shaped armature) have left an indelible impression on the history of electrical technology.[3] France, an early centre of electrical technology, had many notable contributors, including A. M. Ampère (mathematical formulation of relationships between magnetic fields and electric current) and Hippolyte Pixii (DC-motor with commutator). The group of British inventors in electrical technology is equally impressive. We can mention such first-class pioneers as Humphry Davy (arc-light), Michael Faraday (electromagnetic induction), C. F. Varley (self-exciting generator) and Joseph Swan (incandescent filament lamp).[4]

Strikingly many of the nineteenth-century key pioneers in this field were brought up in the European periphery, Scandinavia and Eastern Europe. Hans-Christian Ørsted (magnetic field around a conductor carrying an electric current) and Søren Hjorth (contribution to the principle of self-excitation) are examples of Danish inventors. Jonas Wenström (three-phase motor), Gustaf de Laval (turbogenerator), Birger and Fredrik Ljungström (turbogenerator) and Oscar Kjellberg (electric welding with coated metal electrodes) can be mentioned of the Swedish pioneers.[5] The great Russian inventors included, for example, Alexander Lodygin (incandescent filament lamp), Pavel Jabločkov (arc-lamp), Nikolaj Benardos (electric welding with carbon electrodes) Nikolaj Slavianov (electric welding with metal electrodes), and Mihail Dolivo-Dobrovols'kij (three-phase motor). Among the Hungarian pioneers were the inventors of the parallel connection of transformers, Otto Blathy, Max Déri and Karl Zipernowsky. Nikola Tesla, the inventor of the alternating-current motor, was a Croatian. Therefore, the peripheral location of Eastern Europe could not smother inventive activity, but it delayed electrification. In Finland, economic, cultural and geopolitical factors seem to have hampered inventing more than electrification.[6]

In some countries lacking indigenous innovations, entrepreneurship and capital, electrification was markedly boosted by foreign involvement. Although foreign companies, investors and technical specialists were involved in the electrical business in Finland, their activities were far less significant than, for example, in Norway or Eastern Europe.

What caused, then, the atypically brisk development in Finland? We can compare the promoting and obstructing factors of electrification.

First, in industrialisation, cultural and societal factors are important. Cultural tensions can crucially impede technology transfer. Some Anglo-American scholars suggest 'that the recipient culture functions only as a hindrance to technological progress and makes no positive contributions to transfer whatever'.[7] For example, John Jensen and Gerhard Rosegger describe the transfer of Western transport technology to Romania in the late nineteenth century, as follows:

> The bulk of the local people were passive onlookers or, at best, menial participants in the work forces of the development projects. Their technological knowledge proved irrelevant to the tasks at hand. They were unable to take an active part in the transformation of their own country until they had formed new social groupings to conform to Western models of labor-management relations, and until they had acquired working skills, habits, and outlooks which satisfied the requirements of modern technology.[8]

In Finland, general opinion early took a positive attitude towards industry and new technology. There was no such aversion to industry and capital among the native population as in Bulgaria, Romania and some other East European countries.[9] Finnish peasants readily accepted and adopted the capitalist way of thinking. Local people did not resign themselves to 'passive onlookers' when it was a question of the electrification of their own country.

The ideology of Finnish nationalism did not oppose but supported industrialisation and the adoption of new technology. It even encouraged nationals to take over all sectors of the economy. Entrepreneurship and the introduction of new innovations were made virtues and a national duty. A strong industry and a self-managed economy were seen as a foundation of the national identity and a guarantee for national existence. Electrification was an integral part of Finnish economic nationalism.[10] Various interest groups in Finland considered electricity as a new technology which was in harmony with their objectives. Particularly in the early twentieth century, electricity inspired not only engineers, millowners and businessmen but also local politicians and artists. Electricity was even seen as a mystical power with which the Finns could raise their welfare and promote their national goals.[11] The famous Finnish poet Eino Leino expressed the idea of the omnipotent power of electricity in his poem 'The Melody of Electricity' with the words:[12]

> I am a singing law surging through the sea of life,
> I am a glowing spirit flowing through all matter,
> I have rugged reason and boundless intelligence,
> My power is supreme and sacred, I am the lofty one[13]

Connected to the generally favourable attitude to technology the consensus of various interest groups on the matter substantially contributed to the rapid advance of electrification in the country. The cultural receptivity to adopting new power technology, which from time to time even developed into a frenzy for electrification, was able to alleviate the retarding effects of high investment costs caused by the dispersion of settled areas and other disadvantages of the country's economic geography, and the relatively low purchasing power of the population.

Second, despite its modest living standards, Finland had some valuable spiritual and cultural resources. The basic educational level was not totally unsatisfactory; for example at the turn of the century practically all adults could read. During the period under research, the Finnish mass media were not underdeveloped. The press was active, widely circulated and generally internationally minded. In a fairly short time, news about major inventions was distributed all over the country. The masses, not only the elite, were kept abreast of the times.

The teaching and research of electrical technology in Finland developed rather slowly before the First World War. This drawback was, however, mitigated by a comparatively large number of students studying abroad. Technology adopted from the best German universities of technology has had a great impact on the electrification of Finland. From 1911 it was possible to take an engineer's degree in electrical technology in the home country with the opening of the Helsinki University of Technology. Nevertheless in many other European countries, technical education was much better organised in the late nineteenth and early twentieth century. For example in 1910, Germany had eleven universities of technology, while Austria-Hungary and Russia both had seven. In Sweden, it was possible to read for an engineer's degree in two institutions.[14] Beginning with the late 1910s, education in electrical technology on various levels greatly expanded in Finland. The ample supply of engineers and other trained labour offered a valuable asset for electrification, although one might doubt the quality of education and its appropriateness for the needs at any given time.

Education and favourable opinion formation by mass media significantly alleviated the introduction of electricity into Finland. When electrical technology was adapted to the local circumstances by trained nationals, it did not meet such an opposition as would the sheer duplication of Western technical systems by foreigners. Among the important means for breaching the cultural barrier were the utilisation of existing Finnish organisation models and business ownership structures as well as the translation of electrical terminology into Finnish. Education contributed to building a viable technological support network for electrification.

Third, although Finland lacks coal and oil deposits, it has some other indigenous energy sources. Theoretically, this indigenous primary energy potential is quite satisfactory. In per capita terms, Finland's timber resources are the largest in Europe, peat resources the second largest and the hydropower potential comes the sixth. In practice, timber has for some decades been too valuable to be used merely for fuel and the deployment of peat for electricity generation also contains some economic, technical and environmental problems.[15] Therefore, renewable hydropower constitutes the main indigenous energy source for electricity generation in Finland. Its mediocre hydropower resources did not comprise such a key factor for electrification as in the cases of Norway and Sweden, which have had the privilege of benefiting from the extraordinary gifts of nature. The capacity of Finland's technically exploitable hydropower resources was estimated in the mid-1960s to be only a third of Italy's, Yugoslavia's or Spain's potential and approximately the same as the resources of Romania and Greece.[16] In addition, it is noteworthy that the initial phase of Finnish electrification in the nineteenth century was significantly not based on the country's 'white coal'. Hydropower became an important energy source for electricity generation only at the turn of the century. A significant fact is, however, that the steep rise in electricity output in interwar and postwar Finland was primarily based on the extensive utilisation of hydropower.

Fourth, by utilising its ample timber resources, Finland succeeded in producing and exporting sought-after products (sawn timber, pulp and paper) for the world market; the demand for these products was quite steadily increasing and their terms of trade tended to develop favourably. For several decades, the Finnish economy was strengthening and industrialisation advanced at a good pace. These phenomena provided a favourable basis for rapid electrification. When investments were made frequently, there were good opportunities for introducing the latest electrical technology embodied in new machinery. Fifth, the composition of Finnish industry was very energy-intensive. The wood-processing industries needed a lot of mechanical energy. Except in groundwood pulping, the mechanical transmission of power was fairly briskly replaced by electric drive in Finnish industry. Sixth, the interaction between rapid industrialisation and electrification supported each other.

There were also some obstructing factors which delayed electrification. First, the Grand Duchy of Finland had a narrow modern sector and a low standard of living. The purchasing power of the people was modest, while electricity was expensive. In international terms, the average price of electricity supplied by electricity utilities continued to remain rather high after Finland became a republic. A fairly low average level of income restricted the demand for electricity for other than industrial purposes. Therefore, it was not until the postwar period that the price of electricity was no longer a major obstruction

for the versatile use of electrical appliances in households, agriculture and the service sector. Second, in Finland the fixed costs of the electricity supply system were rather high for several reasons. Due to long distances, the sparse population and the great multitude of watercourses, the construction of extensive transmission networks has in per capita terms been more expensive in Finland than on average elsewhere in Europe. At the same time, the shortage of capital has delayed these investments.

6.3 THE CHANNELS FOR TECHNOLOGY TRANSFER

Because the Finns were not indigenous inventors of electrical engineering, they had to obtain the technology they needed from abroad. For that purpose, they exploited many channels, the importance of which varied from one period to another. The transfer of electrical technology began quite early during the period of the Grand Duchy. Then technology was transferred through all the channels mentioned in Table 1.1. The main channels were students' studies abroad and other personal interactions and the importing of equipment.

The other five channels complemented the contributions of the main channels, but their potential was not efficiently utilised. The unfavourable geopolitical location and linguistic barriers impeded the extensive utilisation of the 'low cost diffusion of easily accessible know-how', whereas insufficient technological and manufacturing preconditions discouraged the exploitation of licence and patent imports. For various reasons, the significance of direct foreign investments and foreign experts in electrical technology was, in turn, much smaller in Finland than in many other peripheral countries of Europe.

In the interwar period, studying in foreign universities declined, but still various other tours abroad remained important. The annual imports of electrical equipment rose to considerable amounts. A number of foreign engineers were working in Finland, because the country still lacked qualified specialists to plan, design and construct up-to-date power plants and transmission lines. As a consequence of the First World War, direct foreign investments sharply decreased in the late 1910s. Afterwards they were strongly discouraged, because public opinion and the government persistently opposed them. Legislation made it difficult for foreigners to own power plants or distribution utilities in Finland.

In the postwar years, contacts with foreign countries greatly increased. Advances in international communication, education and various information services accelerated the transfer and diffusion of know-how. Technology imports through licensing rose to a significant position. The importing of electrical equipment remained a prominent transfer channel, while students' studies abroad and the recruitment of foreign specialists were comparatively modest. Direct foreign investments in electricity supply were negligible. The technological capacity of the country substantially developed. On a broad front, Finnish companies moved from the imitation and adaptation of foreign technology to the improving of it and to making original innovations. (see Table 1.2).

If we consider Finland's mix of transfer channels, we can observe that channels controlled by the deliverers of technology were under-represented in relation to the so-called general channels. Finland imported a great deal of electrical machinery and equipment. The significance of technology transfer through licences and patents rose only gradually, but apart from the period of 1898–1914, direct foreign investments remained modest. There was also a marked aversion to acquiring turn-key plants and setting up joint-ventures with foreign companies. The tendency to avoid direct foreign involvement is not unique among many late industrialising economies, but the persistent determination of Finland to pursue this kind of policy is rather atypical among small countries with a relatively high foreign trade/GNP ratio.

The Finnish way of adopting foreign know-how led to a model where technology transfer was controlled by the recipient country and aimed at avoiding the dangers of becoming too dependent on a few outside suppliers of technology. The 'Finnish model' emphasised the active role and initiative of nationals in the transfer process. Accordingly, the pronounced role of the Finns characterised the electrification of the country. Owing to their reasonably good education and mental preparedness to adopt new innovations, the Finns developed into eager and initiative-taking transferrers of electrical technology.[17]

Some present-day theories regard certain channels as better and economically safer than others for the recipient country. It is, generally, claimed that the efficiency of the channels mentioned in Table 1.1 decreases moving from no. 1 to no. 8; in other words, know-how which is successfully transferred through the top channels of Table 1.1 starts to boost the economy of the recipient country in a shorter period of time than know-how brought in through the bottom channels.[18] According to these theories, the Finns rejected the firm arms of rescuers and clutched at mere straws. The channels they favoured tended to boost the economy of the recipient with a longer lag and more meagre results, than technology transferred through channels controlled by the deliverer.

Was the electrification of the country delayed because the Finns chose rather slow-moving, roundabout and uncertain channels for technology transfer? Compared for example with the mountainous hydropower country Norway, which received a considerable amount of direct foreign investments in its electricity supply and power utilising sectors in the early twentieth century, Finland was really left behind at the time. Nevertheless later, in the interwar period, the growth rate of electricity supply in Finland was the second highest in Europe. In the postwar years, its growth rate was above the average of twelve major West European countries.[19]

A striking feature is that in the transfer of electrical technology, Finland relied mainly on channels other than direct foreign investments, and thrived. This fact sharply contradicts a common conviction on the critical role of multinational companies (MNCs). The Italian Antonio Murolo questioned the general belief that foreign-owned subsidiaries have made notable contributions to countries like Greece. 'The conviction that the presence of foreign subsidiaries is beneficial to the economy of the host country is one of the basic themes of nearly all the studies that have been written on the transnational corporation, but it is seldom asked whether these benefits outweigh the costs imposed on the local economy.'[20]

Some proponents of the conviction are as categorical as Roger Seymour (IBM) who formulated it with the words: 'This is purposeful – to underline the fact that, today, it is virtually only the MNCs that have state-of-the-art technology and the means of transferring it. . . . A basic fact in today's world [is]: Transfer of technology takes place as a result of the international investment decision, not without it and not in spite of it.'[21] The American Peter Cory drew an opposite conclusion comparing technology transfer into Yugoslavia and Mexico. He claimed that 'the principal proposition being considered in the dissertation – that MNC presence speeds the inflow of new technologies – does not receive any support at all. . . . In general, it appears that those technologies acquired by developing countries can be, and indeed are, introduced equally rapidly whatever the predominant transfer mechanism involved.'[22]

In an historical perspective, the lesson of the Finnish experience is that a self-controlled transfer of technology coupled with favourable economic development is not an impossible option for small, less developed countries. Consequently, for such countries there are also other opportunities for promoting the transfer of a new technology than lining up at the entrance gates of transnational companies in order to apply for direct foreign investments, as Arghiri Emmanuel seems to imply.[23]

Statistical Appendix

NOTES ON SOURCES AND METHODS

Table A.1 Relationships Between the Gross Surface and Technically Exploitable Hydropower Potential in European Countries

For assessing the hydropower potential of an area, the mean annual gross surface hydro potential is a basic concept. It expresses the theoretical volume of hydropower resources which the area possesses. Some parts of this theoretical potential are generally technically exploitable. In Table A.1, the mean annual productive potential is used to measure this.

In the course of technological change, the technically exploitable part of the hydropower potential tends to increase.[1] Many countries have found that not all of the technically exploitable hydropower is economically exploitable. Various factors, which may vary radically from country to country, affect the volume of the economically exploitable hydropower potential which can greatly fluctuate over time.

The figures in Table A.1 are based on national estimates from the 1960s. They have been gathered and worked out by the Economic Council of Europe.[2]

Table A.2 Technically Exploitable Hydropower Potential and the Production of Hydroelectricity in European Countries

In this table, actual hydroelectricity production is compared to an estimate of the technically exploitable hydropower potential. The figures for the year 1938, in column 4, are only suggestive, because production is compared to the potential for the year 1965. In some cases, this is even very misleading: first, because territorial borders substantially changed in Europe between 1938 and 1965; second, due to the above-mentioned reasons the technically exploitable hydropower potential substantially increased during that time-span.[3]

Tables A.3–A.4 Generating Capacity in Finnish Industry

Official Statistics on the Generating Capacity

The semiofficial organ *Sähkötarkastuslaitos* (The Electrical Inspectorate) began to compile and publish regular, annual statistics of electricity supply utilities from the year 1930.[4] Before that, some occasional attempts were made to work out special statistics for generating capacity and electricity production; the most complete set was produced by the one-year joint-project of the Central Statistical Office of Finland (CSOF) and the Association of Rural Electricity Supply Utilities in 1926.[5]

One might reasonably expect that the electricity generating capacity would have been included in the official industrial statistics from the outset, in 1884, but compilers of this annual statistical publication were unfortunately not abreast of contemporary technological developments.[6] Between 1884 and 1908, the official industrial statistics included meagre information on power generation. The only nationwide time-series related to energy use dealt with the total number and capacity of industrial steam engines. At that time, consistent statistics on industrial water wheels, hydroturbines, internal combustion engines, electric motors and electricity generators were not compiled, although the Board of Industry also asked about those power engines in its questionnaires.

As a result of the reform of 1909, the omitted categories of prime movers, electric motors and generators were introduced into the official industrial statistics. The methods for gathering and presenting information on these power engines were, however, rather confused and the new statistics did not specify the capacity and type of prime movers coupled with generators.

In 1920 the questionnaires and compiling methods for industrial statistics were again reformed. Although the methods became much sounder theoretically, the statistics on generating capacity remained unreliable, because they failed to cover all generators and their prime movers.[7] The defects were not remedied during the 1920s and even in the next decade the grand total of the generating capacity in the official industrial statistics was 15–25 per cent lower than that in the other official statistics compiled by the Electrical Inspectorate.

The third official statistical series on generating capacity covers the time from 1960 and is worked out by the Energy Department of the Ministry of Trade and Industry.[8] It is based on similar sources to those of the Electrical Inspectorate. It, however, differs from the two other time-series in some respects; for example it indicates the generating capacity at the beginning of each year instead of the end of the year, as do the other two.

The Compilation of Time-Series

Table A.4 is compiled by connecting the statistics of the Electrical Inspectorate for the period 1930–59 with those published in *Energy Statistics* for the period 1960–77. Table A.3 is, by contrast, one I have calculated by using information from various sources. For the period 1885–1908, the main source was the original questionnaires completed by the industrial companies for the official industrial statistics; they are at present available in the Archives of the Board of Industry at the National Archives of Finland. For the period 1909–29, the time-series is based on the so-called calculation forms of the Board of Industry. These forms are the only available documents from the first phase in compiling industrial statistics for those years. The forms are retained in the archive of the Central Statistical Office of Finland in Helsinki. For that period, the original questionnaires have been destroyed.

The data concerning prime movers and generation capacity in industry have been gathered from all questionnaires and calculation forms with intervals varying from two to seven years.[9] Some parts of the data are compiled by consulting the annual questionnaires of the Board of Industry

for the period under research. If possible, these data collected factory-by-factory from the official archives have been checked and complemented by means of other sources, such as business histories, industrial calendars and albums, technical and economic journals, newspapers, as well as some documents in a few business archives, for example 'Books of Delivered Dynamos' by the Strömberg-factory.[10]

In the original questionnaires, the capacity of steam engines coupled with dynamos and generators was expressed in one of the following three horsepower units. I have transformed these units into kilowatts using fixed coefficients:[11]

1 indicated horsepower	=	0.7	efficient hp	=	0.515 kW,
1 nominal horsepower	=	2.5	efficient hp	=	1.840 kW,
1 efficient horsepower	=	0.736	kilowatts.		

Table A.3 includes the generating capacity of mines and quarries, of manufacturing, and of electricity, gas and water supply utilities. Owing to lack of information, it excludes the non-industrial generating capacity, for example that of theatres, hospitals, churches and other single public buildings, as well as generators in manors and other private residences. Although in 1885 the non-industrial generating capacity constituted as much as about 10 per cent of the total generating capacity in Finland (in total 355 kW), its relative importance substantially declined by the turn of the century.

Table A.3 covers the generating capacity neither of flourmills nor dairies except for the very few flourmills registered officially among the rural electricity supply utilities. Being closely associated with farms, these production units worked only a few months a year on a seasonal basis. Reliable evidence on their machinery and annual operational hours does not exist for the period under research. At a low estimate, the generating capacity of flourmills and dairies was about 500 kW or nearly 1 per cent of the industrial generating capacity in 1913.

Tables A.5–A.6 The Supply of Electricity in Finland

Three decades elapsed after electricity began to be used on a commercial scale before the annual estimation of electricity output was started in Finland. However, in the early 1890s some Finnish electricity supply utilities began to use electricity meters and measure the volume of their generation. The first estimated figure (22 GWh) for the nationwide production of electricity was published in the official industrial statistics for the year 1912. This figure, like those for the following few years, underestimated the actual electricity output, because it included only the output of some well-known electricity producers which sold a considerable part of their generation. A serious fault was to exclude from the official statistics the production of electricity by industrial plants solely for their own use. Among the contemporary energy specialists, this was a generally acknowledged fact.[12]

The first attempt to cover the entire electricity production including self-generation was made in the above-mentioned statistics of 1926.[13] From 1930 the Electrical Inspectorate started compiling regular annual statistics which included electricity production for all purposes providing the generation took place on an industrial scale.[14] Table A.6 shows integrated time-series of these statistics from 1930 to 1959 and the production and supply series of the *Energy Statistics* from 1960 to 1977.[15]

The time-series of Table A.5 have been based on the work we carried out in the research project on the *History of the Finnish Energy Economy*. The national output series have been compiled under the guidance of the author from the statistics of six industrial sectors: (i) pulp and paper, (ii) sawmill, (iii) metallurgical and engineering industries. (iv) urban electricity supply utilities, (v) rural electricity undertakings and (vi) other industrial sectors.

The three largest sectors, the pulp and paper, sawmill and metal industries, on average generated 64 per cent of all industrial electricity between 1900 and 1913. In estimating their electricity generation, we started by calculating time-series for their production volumes and assessing the total consumption of mechanical energy. These series then served as the bases for the estimation of electricity output and consumption together with the generating capacity of these industries. In other branches, electricity output is calculated by multiplying the generating capacity by the estimated average annual operational hours. Various estimates of average annual operational hours were applied to each sector and they were derived from case studies of some sample firms. The technical efficiency of generators is rated at 90 per cent for the whole period 1885–1929. Their capacity by industrial sectors is derived from the work sheets used in compiling Table A.3.

Earlier, attempts at presenting statistics for the pre-1930 generation capacity and electricity output met with sharp criticism.[16] Statistics were generally argued to be incomplete or to be duplicating the same capacity. I have tried to correct the defective data utilised in previous estimates, to apply sound calculating methods and to aim to use as apposite estimates as possible. Because I have been cautious in my estimation, I believe my time-series are, however, rather under than above the unknown true figures. Nevertheless, my estimates for the period before 1920 are substantially higher than all earlier estimates due to my including electricity sales, autogeneration as well as losses.[17] For the 1920s, my estimates are still somewhat higher than the figures in the official industrial statistics, but near the estimates of some contemporary energy experts.[18]

To my knowledge, the reconstructed time-series for the electricity output of Finland are the second longest national series of this kind in the world; only the time-series of Italy, which start from the early 1880s, are longer.[19]

Tables A.7–A.8 The Supply of Electrical Equipment in Finland

In compiling these statistics, there were two major problems: first, how to work out a time-series the product range of which was consistent over the whole period under study; second, how to compile such production and foreign trade statistics which were at the same time as comprehensive and commensurable as possible. The practical difficulties originate in the basic sources, the *Official Statistics of Finland*.

In the Finnish industrial statistics, the classifications of the production of electrical equipment changed in 1909, 1920, 1954, 1964 and 1970. The major changes in foreign trade statistics, in turn, took place in 1918 and during 1960 and 1961. In both of these statistics, the product range included in the group 'electrotechnical equipment' have substantially changed over the decades. Moreover, the classifications of industrial and foreign trade statistics did not match each other. Therefore, I have attempted to harmonise the statistics of divergent periods and two different fields so that each time-series has been composed using a similar product range.[20]

The main groups which I have included are 'electric machines, devices and accessories and their parts' (called 'group 85' in both industrial and foreign trade statistics since the early 1960s) plus plain and insulated wires, cables and conductor rails of copper, aluminium or steel (codes 74.03, 74.10 and 76.10 in the later statistics). The production value of light fixtures (code 83.07), welding electrodes (83.15.1), kWh-metres (90.26.3) and electrical measuring devices (90.28) is also included. Furthermore, from 1920 to the reforms of the 1960s, the separate item category of 'electrotechnical porcelain' (insulators) is included in the production and foreign trade time-series. In addition to the official statistics, I have consulted various articles by the experts of the electrical engineering industry.[21]

Table A.1 Relationships between the gross surface and technically exploitable hydropower potential in European countries as a function of average density of the surface potential in the mid-1960s

(Countries arranged in decreasing order of column 3 – gross surface potential per square kilometre)

Country	*Mean annual gross surface hydro potential*		*Hydropower potential assessed as technically exploitable Mean annual productive potential*			*Exploitable potential as percentage of gross surface potential*[a]
			Total	*Related to the area*	*Related to the population*	
	TWh	*GWh/ square km*	*TWh*	*MWh/ square km*	*kWh/ inhabitant*	*%*
1	*2*	*3*	*4*	*5*	*6*	*7*
1. Switzerland	179	4.50	39.0	950.0	6550	21.8
2. Austria	153	1.82	43.9	523.0	6050	28.7
3. Norway	556	1.71	151.6	468.0	40720	27.2
4. Iceland	140	1.35	35.0	338.0	82390	25.0
5. Italy	341	1.13	76.5	254.2	1480	22.4
6. Yugoslavia	226	0.88	66.0	259.0	3383	29.2
7. Albania	25	0.85	5.0	173.0	2680	20.0
8. Greece	85	0.73	20.7	179.0	2421	24.3
9. Turkey	537	0.69	150.0	192.0	3200	18.7
10. France	314	0.57	82.0[b]	150.0	1676	26.2
11. Portugal	42	0.46	13.2	146.2	1435	31.5
12. Sweden	196	0.44	80.0	178.5	10344	40.7
13. Luxembourg	1	0.40	0.1	40.0	302	10.0
14. W. Germany	95	0.38	20.6	83.0	348	21.6
15. Romania	85	0.36	23.4[c]	98.0	1225	27.5
16. Bulgaria	35	0.32	15.8[d]	142.1	1925	45.0
17. Czechoslovakia	41	0.32	12.0	93.4	848	30.8
18. Spain	144	0.29	62.8	126.8	1995	43.6
19. United Kingdom[e]	63	0.28	11.5	47.1	216	18.3
20. Belgium	7	0.22	0.5	17.3	53	7.1
21. USSR[f]	972	0.17	314.0	56.3	1780	32.2
22. E. Germany	16	0.15	2.0	18.5	117	12.5
23. Finland	47	0.14	21.7	64.2	4700	46.1
24. Hungary	12	0.13	3.4[c]	36.5	332	28.3
25. Ireland	7	0.10	1.1	15.7	383	15.7
26. Poland	32	0.10	12.1	38.7	384	37.8
27. Denmark	4	0.09	0.0	0.6	6	0.7
28. Netherlands	3	0.09	0.0	0.5	1	0.5
Total or average	4358	0.39	1263.9	112.0	1937	28.9

[a] Column 4 in relation to Column 2.
[b] Including all projects considered possible.
[c] Excluding contiguous Danube potential.
[d] Minimum estimate.
[e] Great Britain only (excluding Northern Ireland).
[f] Refers to the total territory in Europe, including the Caucasus.

Table A.2 Technically exploitable hydropower potential and the production of hydroelectricity in European countries, 1938 and 1965

(Countries arranged in decreasing order of column 2 – mean annual productive potential)

	Country	*Mean annual productive potential*[a] *1965 GWh*	*Production of hydroelectricity 1938 GWh*	*Production as percentage of mean annual productive potential*[b] *1938 %*	*Production of hydroelectricity 1965 GWh*	*Production as percentage of mean annual productive potential*[c] *1965 %*
	1	2	3	4	5	6
1.	USSR	314000[d]	5091[e]	. .	81431[e]	. .
2.	Norway	151600	9918	6.5	49347	32.6
3.	Turkey	150000	1	0.0	2167	1.4
4.	France	82000[f]	10400	12.7	46893	57.2
5.	Sweden	80000	7307	9.1	46423	58.0
6.	Italy	76500	14783	19.3	44943	58.7
7.	Yugoslavia	66000	470	0.7	8985	13.6
8.	Spain	62800	2236	3.6	19550	31.1
9.	Austria	43900	2400	5.5	16083	36.6
10.	Switzerland	39000	7087	18.2	24279	62.3
11.	Iceland	35000	23	0.1	641	1.8
12.	Romania	23400[g]	127	0.5	1005	4.3
13.	Finland	21700	2456	11.3	9488	43.7
14.	Greece	20700	13	0.1	748	3.6
15.	West Germany	20600	(7299)[h]	(32.3)[i]	15365	74.6
16.	Bulgaria	15800[j]	141	0.9	2000	12.7
17.	Portugal	13200	127	1.0	3983	30.2
18.	Poland	12100	50	0.4	913	7.5
19.	Czechoslovakia	12000	600	5.0	4456	37.1
20.	United Kingdom	11500[k]	988	8.6	4625	40.2
21.	Albania	5000	. .	. .	250	5.0
22.	Hungary	3400[j]	20	0.6	75	2.2
23.	East Germany	2000	–[h]	–[i]	785	39.3
24.	Ireland	1100	296	26.9	939	85.4
25–6.	Belgium & Luxembourg	600	44	7.3	1187	197.5
27.	Denmark	28	–	–	25	89.3
28.	Netherlands	21	–	–	–	–
	Total	1263949	71877	. .	386586	. .

[a] Hydropower potential assessed as technically exploitable.
[b] Column 3 in relation to Column 2.
[c] Column 5 in relation to Column 2.
[d] Refers to the total territory in Europe, including the Caucasus.
[e] Refers to the total territory of the USSR with the present boundaries.
[f] Including all projects considered possible.
[g] Excluding contiguous Danube potential.
[h] Electricity production in the German territory of 1938.
[i] German electricity production of 1938 in relation to mean annual productive potential of both pre-1990 West and East Germany.
[j] Minimum estimate.
[k] Great Britain only (excluding Northern Ireland).
. . No data available.

Table A.3 Generating capacity in Finnish industry, 1885–1929

Year	*The capacity of prime movers coupled to generators*				*Generators*			
	Hydropower	*Steampower*	*Combustion engines*	*Total*	*Driven by hydropower*		*Total*	
	kW	*kW*	*kW*	*kW*	*no.*	*kW*	*no.*	*kW*
1885	40	280		320	5	30	34	278
86	..	..		370	..	..	..	330
87	..	..		460	..	..	..	410
88	..	..		590	..	..	..	520
89	..	..		740	..	..	..	660
1890	207	907		1114	15	185	94	1001
91	..	..		1270	..	..	..	1140
92	..	..		1430	..	..	..	1280
93	..	..		1610	..	..	..	1450
94	..	..		1800	..	..	..	1620
1895	512	1505		2017	32	457	139	1822
96	..	..		2660	..	..	..	2390
97	..	..		3600	..	..	..	3230
98	..	..		5000	..	..	..	4470
99	..	..		9050	..	..	..	8140
1900	7527	5315	24	12866	125	6732	323	11728
01	..	..	..	13830	..	..	..	12450
02	..	..	..	15080	..	..	..	13570
03	8814	7836	18	16668	141	7999	419	15225
04	..	..	..	18060	..	..	..	16260
1905	10608	9895	16	20519	141	9629	484	18537
06	..	..	..	24800	..	..	..	22300
07	..	..	..	31800	..	..	..	28700
08	..	..	..	36800	..	..	..	33100
09	..	..	..	45500	..	..	..	41000
1910	18746	30072	1500	50318	157	17045	608	45840
11	..	..	..	57700	..	..	..	52000
12	..	..	..	66000	..	..	..	59400
13	26506	44288	3277	74071	168	23884	656	67448
14	..	..	..	81300	..	..	..	73200
1915	..	..	..	89900	..	..	..	81900
16	..	..	..	96500	..	..	..	86800
17	..	..	..	98600	..	..	..	88800
18	..	..	..	101500	..	..	..	91300
19	..	..	..	116700	..	..	..	105000
1920	54750	75830	6369	136949	..	49262	..	123200
21	61471	85031	6648	153150	..	55324	..	137835
22	69018	95348	6939	171305	..	62116	..	154174
23	77491	106916	7243	191650	..	69742	..	172485
24	91004	124900	7561	223465	..	81904	..	201118
1925	97685	134435	7892	240012	..	87917	..	216011
26	109677	150746	8238	268661	670	98709	1173	241795
27	117557	169350	8355	295262	..	105801	..	265736
28	126003	190249	8474	324726	..	113403	..	292254
1929	172556	213727	8595	394878	..	155300	..	355390

.. No data available.

Table A.4 Generating capacity in Finnish industry, 1930–77

Year	*The capacity of prime movers coupled to generators*			
	Hydropower MW	*Steampower* MW	*Combustion engines and gas-turbines* MW	*Total* MW
1930	220	240	9	469
31	231	259	9	499
32	252	263	10	525
33	265	265	9	539
34	268	274	10	552
1935	268	328	10	606
36	296	327	10	633
37	424	369	11	804
38	429	428	13	870
39	512	478	14	1004
1940	404	430	14	848
41	408	463	17	888
42	495	468	19	982
43	507	469	18	994
44	416	466	16	898
1945	430	465	17	912
46	440	474	16	930
47	441	474	16	931
48	474	474	17	965
49	597	476	15	1088
1950	658	472	15	1145
51	788	481	15	1284
52	814	522	15	1351
53	857	577	15	1449
54	980	616	16	1612
1955	1077	682	17	1776
56	1118	704	17	1839
57	1293	729	18	2040
58	1339	845	18	2202
59	1419	947	18	2384
1960	1387	1009	12	2408
61	1531	1342	13	2886
62	1652	1474	30	3156
63	1688	1651	32	3371
64	1837	1712	32	3581
1965	1837	1959	32	3828
66	1905	1979	45	3929
67	1980	2253	46	4279
68	2060	2298	70	4428

Table A.4 *Continued*

Year	*The capacity of prime movers coupled to generators*			
	Hydropower MW	*Steampower* MW	*Combustion engines and gas-turbines* MW	*Total* MW
69	2087	2440	71	4598
1970	2087	2492	135	4714
71	2116	2511	162	4789
72	2240	2965	366	5571
73	2286	3381	268	5935
74	2293	3727	584	6604
1975	2292	4106	788	7186
76	2384	4506	872	7762
1977	2428	5260	985	8673

Table A.5 The supply of electricity in Finland, 1885–1929

Year	A Hydropower GWh	B Thermal power GWh	C Production (A+B) GWh	D Supply per capita kWh
1885	0.1	0.1	0.2	0.1
86	0.1	0.2	0.3	0.1
87	0.1	0.3	0.4	0.2
88	0.1	0.4	0.5	0.2
89	0.2	0.5	0.7	0.3
1890	0.3	0.7	1.0	0.4
91	0.5	0.8	1.3	0.5
92	0.6	1.0	1.6	0.6
93	0.7	1.1	1.8	0.7
94	0.8	1.3	2.1	0.8
1895	0.8	1.6	2.4	1.0
96	1.2	1.9	3.1	1.2
97	1.7	2.4	4.1	1.6
98	2.6	3.0	5.6	2.2
99	9.3	3.9	13.2	5.0
1900	11.9	5.2	17.1	6.4
01	11.3	6.5	17.8	6.7
02	12.3	7.4	19.7	7.3
03	13.6	8.6	22.1	8.2
04	13.5	9.9	23.4	8.5
1905	16.9	11.2	28.1	10.2
06	21.2	14.4	35.5	12.8
07	29.7	20.3	49.9	17.7
08	31.1	26.7	57.7	20.2
09	36.3	39.1	75.4	26.0
1910	44.3	46.0	90.3	30.8
11	55.5	61.6	117.1	39.5
12	78.5	80.4	158.9	53.0
13	94.9	88.0	182.9	60.4
14	93.9	96.6	190.5	62.4
1915	102.1	108.8	210.9	68.4
16	115.4	120.1	235.5	75.9
17	105.5	99.7	205.2	65.7
18	84.1	57.5	141.5	45.3
19	113.8	116.1	229.8	73.7
1920	132.7	156.4	289.1	92.3
21	182.2	137.4	319.6	100.8
22	223.7	160.0	383.7	119.5
23	268.6	180.6	449.2	138.5
24	332.2	203.6	535.8	163.8

Table A.5 Continued

Year	A Hydropower GWh	B Thermal power GWh	C Production (A+B) GWh	D Supply per capita kWh
1925	384.0	222.6	606.6	183.6
26	420.3	231.3	651.6	195.1
27	489.1	268.0	757.1	224.8
28	570.4	309.9	880.3	259.2
29	666.8	328.4	995.2	290.7

Table A.6 The supply of electricity in Finland, 1930–77

Year	*A* *Hydropower* *GWh*	*B* *Thermal power* *GWh*	*C* *Production* *(A+B)* *GWh*	*D* *Import* *GWh*	*E* *Export* *GWh*	*F* *Net supply* *(C+D−E)* *GWh*	*G* *Supply per capita* *kWh*
1930	868.1	338.1	1206.2	0.2		1206.4	349.8
31	922.6	339.9	1262.5	0.2		1262.7	363.3
32	1124.7	354.2	1478.9	0.2		1479.1	422.2
33	1244.0	447.7	1691.7	0.2		1691.9	479.8
34	1350.0	496.2	1846.2	0.2		1846.4	520.3
1935	1655.9	439.0	2094.9	0.2		2095.1	585.9
36	1713.8	608.0	2321.8	0.3		2322.1	644.8
37	2066.2	720.0	2786.2	0.3		2786.5	768.5
38	2456.2	651.8	3108.0	0.3		3108.3	850.2
39	2435.3	676.3	3111.6	0.3		3111.9	844.2
1940	1360.6	346.3	1706.9	85.7	4.0	1788.6	483.7
41	1294.6	484.2	1778.8	0.5	1.8	1777.5	480.1
42	1523.3	411.1	1934.4	0.8		1935.2	521.9
43	2945.3	196.4	3141.7	1.0		3142.7	844.6
44	2556.1	171.1	2727.2	198.0	24.7	2900.5	776.6
1945	2755.8	202.4	2958.2	1.5	0.9	2958.8	787.3
46	2483.2	459.2	2942.4	2.0	1.7	2942.7	773.2
47	1909.9	956.6	2866.5	2.3	2.4	2866.4	742.8
48	1923.4	1036.7	2960.1	2.6	2.2	2960.5	756.8
49	3008.9	545.9	3554.8	2.5	2.7	3554.6	896.9
1950	3649.6	516.3	4165.9	2.5	4.9	4163.5	1038.5
51	3864.7	744.9	4609.6	2.6	5.7	4606.5	1138.3
52	4261.2	507.8	4769.0	3.2	7.9	4764.3	1164.6
53	4979.2	423.8	5403.0	3.6	8.9	5397.7	1304.1
54	4876.1	817.8	5693.9	3.6	11.4	5686.1	1358.0
1955	6189.7	639.8	6829.5	3.9	9.3	6824.1	1611.4
56	5201.7	1443.2	6644.9	4.5	0.1	6649.3	1552.8
57	6616.5	1083.4	7699.9	5.5		7705.4	1782.0
58	6959.9	998.1	7958.0	4.2		7962.2	1826.2
59	5562.7	2349.0	7911.7	143.5	20.4	8034.8	1828.2
1960	5216.0	3151.0	8367.0	427.0	5.0	8789.0	1984.0
61	7943.0	2325.0	10268.0	184.0	4.0	10448.0	2342.1
62	9672.0	1761.0	11433.0	99.0	17.0	11515.0	2564.0
63	8289.0	3289.0	11578.0	341.0	4.0	11915.0	2634.3
64	8253.0	4208.0	12461.0	702.0	6.0	13157.0	2879.6
1965	9260.0	4354.0	13614.0	645.0	17.0	14242.0	3120.5
66	10277.0	5228.0	15505.0	165.0	260.0	15410.0	3363.9
67	11513.0	4887.0	16400.0	104.0	110.0	16394.0	3559.3
68	10384.0	6977.0	17361.0	563.0	279.0	17645.0	3814.3
69	8658.0	10623.0	19281.0	637.0	458.0	19460.0	4208.5
1970	9354.0	11860.0	21214.0	1339.0	736.0	21817.0	4736.3
71	10574.0	10459.0	21033.0	2590.0	0.0	23623.0	5122.1
72	10276.0	12259.0	22535.0	4219.0	0.0	26754.0	5765.9
73	10474.0	14689.0	25163.0	4556.0	237.0	29482.0	6318.5
74	12576.0	14019.0	26595.0	3615.0	475.0	29735.0	6338.7
1975	12087.0	13102.0	25189.0	4146.0	159.0	29176.0	6191.9
76	9387.0	18552.0	27939.0	4088.0	73.0	31954.0	6761.3
77	12060.0	19630.0	31690.0	1393.0	502.0	32581.0	6873.6

Table A.7 The supply of electrical equipment in Finland, 1890–1977, at current prices

Year	A Production 1000 FIM	B Export 1000 FIM	C Import 1000 FIM	D Net supply (A−B+C) 1000 FIM	Year
1890	3.1	0.6	4.6	7.1	1890
1895	3.5	1.2	3.5	5.8	1895
1900	13.0	1.1	16.1	28.0	1900
1903	8.9	1.2	4.0	11.7	1903
1905	7.1	0.4	17.7	24.4	1905
1910	7.2	0.4	38.9	45.7	1910
1913	19.1	0.7	67.5	85.9	1913
1915	22.3	1.1	47.7	68.9	1915
1920	266.2	1.4	1126.1	1390.9	1920
1925	513.4	6.9	1031.4	1537.9	1925
1928	1131.9	4.2	2901.0	4028.7	1928
29	1034.7	1.5	2677.0	3710.2	29
1930	849.8	1.3	2249.0	3097.5	1930
31	745.9	1.8	1531.8	2275.9	31
32	830.9	25.5	1129.3	1934.7	32
33	862.8	29.9	1340.2	2173.1	33
34	1300.7	33.3	1861.2	3128.6	34
1935	1774.8	30.1	2396.4	4141.1	1935
36	2120.4	28.4	3119.3	5211.3	36
37	3175.2	56.1	5181.2	8300.3	37
38	3687.3	74.8	5219.4	8831.9	38
39	4641.1	210.3	5279.3	9710.1	39
1940	5793.3	138.6	2964.0	8618.7	1940
41	6023.0	101.1	5034.8	10956.7	41
42	7524.6	147.4	5904.5	13281.7	42
43	8915.9	240.6	6805.7	15481.0	43
44	9137.8	121.2	3608.7	12625.3	44
1945	19342.9	230.5	1592.1	20704.5	1945
46	35571.5	485.9	5791.2	40876.8	46
47	50461.0	1311.0	13107.9	62257.9	47
48	76997.0	1258.6	24676.2	100414.6	48
49	100697.0	1682.5	31623.0	130637.5	49
1950	100367.0	3590.0	41079.0	137856.0	1950
51	173499.0	6842.0	52900.0	219557.0	51
52	192438.0	9788.0	81981.0	264631.0	52
53	168258.0	12372.0	54738.0	210624.0	53
54	196776.0	13141.0	62115.0	245750.0	54

Table A.7 *Continued*

Year	A Production 1000 FIM	B Export 1000 FIM	C Import 1000 FIM	D Net supply (A−B+C) 1000 FIM	Year
1955	222220.0	18900.0	70129.0	273449.0	1955
56	230179.0	21197.0	85934.0	294916.0	56
57	241537.0	18277.0	97166.0	320426.0	57
58	230518.0	23622.0	121869.0	328765.0	58
59	291645.0	42824.0	152622.0	401443.0	59
1960	362351.0	44854.0	198363.0	515860.0	1960
61	406557.0	53423.0	203062.0	556196.0	61
62	462696.0	54786.0	235688.0	643598.0	62
63	457120.0	58533.0	225705.0	624292.0	63
64	493359.0	74893.0	294333.0	712799.0	64
1965	532040.0	92101.0	317493.0	757432.0	1965
66	618847.0	109897.0	291438.0	800388.0	66
67	668340.0	119905.0	320154.0	868589.0	67
68	847309.0	159952.0	362255.0	1049612.0	68
69	1070133.0	213351.0	441129.0	1297911.0	69
1970	1382506.0	300830.0	633610.0	1715286.0	1970
71	1483452.0	323217.0	758177.0	1918412.0	71
72	1753602.0	425974.0	933699.0	2261327.0	72
73	2281139.0	549176.0	1230815.0	2962778.0	73
74	3234934.0	689187.0	1652889.0	4198636.0	74
1975	3486966.0	824712.0	1953864.0	4616118.0	1975
76	3998870.0	970605.0	1963558.0	4991823.0	76
1977	3822347.0	1211244.0	2061382.0	4672485.0	1977

Table A.8 The supply of electrical equipment in Finland, 1890–1977, at constant prices of 1913

Year	*A Production 1000 FIM*	*B Export 1000 FIM*	*C Import 1000 FIM*	*D Net supply (A−B+C) 1000 FIM*	*E Net supply index 1938=100*	*Year*
1890	4.0	0.8	6.0	9.2	1.2	1890
1895	4.8	1.6	4.8	7.9	1.0	1895
1900	14.9	1.3	18.5	32.2	4.1	1900
1903	10.7	1.4	4.8	14.1	1.8	1903
1905	8.7	0.5	21.6	29.8	3.8	1905
1910	7.6	0.4	40.9	48.1	6.1	1910
1913	19.1	0.7	67.5	85.9	10.9	1913
1915	16.4	0.8	35.1	50.7	6.4	1915
1920	22.5	0.1	95.2	117.6	14.9	1920
1925	45.5	0.6	91.4	136.2	17.3	1925
1928	101.8	0.4	260.9	362.3	45.9	1928
29	97.4	0.1	252.1	349.4	44.3	29
1930	87.0	0.1	230.2	317.0	40.2	1930
31	81.2	0.2	166.7	247.6	31.4	31
32	84.7	2.6	115.1	197.2	25.0	32
33	88.8	3.1	137.9	223.6	28.4	33
34	133.3	3.4	190.7	320.6	40.6	34
1935	180.4	3.1	243.5	420.8	53.4	1935
36	208.5	2.8	306.7	512.4	65.0	36
37	265.3	4.7	432.8	693.4	87.9	37
38	329.2	6.7	466.0	788.6	100.0	38
39	394.0	17.9	448.2	824.3	104.5	39
1940	366.4	8.8	187.5	545.1	69.1	1940
41	310.9	5.2	259.9	565.7	71.7	41
42	314.8	6.2	247.1	555.7	70.5	42
43	328.3	8.9	250.6	570.0	72.3	43
44	304.5	4.0	120.2	420.7	53.3	44
1945	448.6	5.3	36.9	480.2	60.9	1945
46	527.1	7.2	85.8	605.7	76.8	46
47	621.4	16.1	161.4	766.7	97.2	47
48	717.7	11.7	230.0	936.0	118.7	48
49	931.8	15.6	292.6	1208.8	153.3	49
1950	806.1	28.8	329.9	1107.2	140.4	1950
51	974.4	38.4	297.1	1233.1	156.4	51
52	1090.4	55.5	464.5	1499.5	190.1	52
53	989.9	72.8	322.0	1239.1	157.1	53
54	1159.7	77.4	366.1	1448.3	183.7	54

Table A.8 *Continued*

Year	*A Production 1000 FIM*	*B Export 1000 FIM*	*C Import 1000 FIM*	*D Net supply (A−B+C) 1000 FIM*	*E Net supply index 1938=100*	*Year*
1955	1322.7	112.5	417.4	1627.6	206.4	1955
56	1310.1	120.7	489.1	1678.6	212.9	56
57	1255.9	95.0	505.2	1666.1	211.3	57
58	1108.4	113.6	586.0	1580.8	200.5	58
59	1413.7	207.5	739.8	1945.9	246.8	59
1960	1690.3	209.2	925.3	2406.4	305.1	1960
61	1881.0	247.2	939.5	2573.3	326.3	61
62	2106.4	249.4	1073.0	2930.0	371.5	62
63	2013.7	257.8	994.3	2750.1	348.7	63
64	1984.9	301.3	1184.2	2867.7	363.6	64
1965	2056.7	356.0	1227.3	2928.0	371.3	1965
66	2347.6	416.9	1105.6	3036.3	385.0	66
67	2465.4	442.3	1181.0	3204.1	406.4	67
68	2848.5	537.7	1217.8	3528.6	447.4	68
69	3477.8	693.4	1433.6	4218.1	534.9	69
1970	4304.5	936.6	1972.8	5340.6	677.2	1970
71	4395.3	957.7	2246.4	5684.0	720.8	71
72	4797.0	1165.3	2554.2	6185.9	784.4	72
73	5306.1	1277.4	2863.0	6891.6	873.9	73
74	6048.9	1288.7	3090.7	7850.9	995.5	74
1975	5744.3	1358.6	3218.7	7604.4	964.3	1975
76	5918.9	1436.6	2906.3	7388.6	936.9	76
1977	5115.2	1620.9	2758.6	6252.9	792.9	1977

Notes

1 Introduction

1. Thomas P. Hughes, *Networks of Power, Electrification in Western Society, 1880–1930* (Baltimore, 1983) p. 1.
2. In 1809 Sweden ceded Finland to the Emperor of Russia, who gave the status of an autonomous Grand Duchy to this former province. When Finland gained its independence in December 1917, it preserved its existing area intact. According to the peace treaty of Tartu (Dorpat) in 1920, Soviet-Russia ceded Petsamo, an area of about 10 000 square kilometres in northeast Lapland, to the Republic of Finland. As a result of the Winter War (1939–40), Finland lost about 9 per cent of its total area to the Soviet Union. Roughly the same territories plus Petsamo were annexed to the Soviet Union according to the truce of Moscow in 1944. These three peacetime Finlands accounted for 373 600, 382 800 and 337 000 square kilometres respectively. *Statistical Yearbook of Finland 1916, 1940 and 1975*, Central Statistical Office of Finland (hereafter *SYF*, CSOF) (Helsinki, 1916, 1940, 1976).
3. Technology is here defined as knowledge to innovate, design, produce and use tools, machines and other commodities as well as expertise to organise and manage production and marketing. Similar definitions have been applied, for example, by Mira Wilkins, 'The Role of Private Business in the International Diffusion of Technology', *Journal of Economic History*, 34 (1974) no.1, p. 166; David J. Jeremy, *Transatlantic Industrial Revolution: The Diffusion of Textile Technologies between Britain and America, 1790–1830s* (Cambridge, Mass., 1981) pp. 5–9; A. G. Kenwood and A. L. Lougheed, *Technological Diffusion and Industrialisation before 1914* (London, 1982) p. 4.
4. Technology transfer is also defined rather broadly in this study. It is considered to include the transmission of systematic knowledge for the manufacture of a product, for the application of a process, or for the rendering of a service as well as the transactions involving the sale or lease of goods and the exchange of personnel. This definition differs from the narrower one applied recently, for instance, by UNCTAD. *Draft International Code of Conduct on the Transfer of Technology*, TD/CODE/TOT/33, UNCTAD (New York, 1981).
5. Sampsa Saralehto, *Teknologian kansainvälinen siirto kehitysmaiden teollistumisprosessiin* (Helsinki, 1986) pp. 91–109.
6. Ibid.
7. 'Teknologian siirto ja kansainvälinen työnjako, Teknologiakomitean mietinnön liite no 5'. *Komiteanmietintö 1980:55* (Helsinki, 1981) pp. 20–22; Saralehto, *Teknologian kansainvälinen siirto*, pp. 110–11.
8. Meheroo Jussawalla, 'Trade, Technology Transfer, and Development', in *The Trouble with Technology: Exploration in the Process of*

Technological Change, ed. by S. Macdonald, D. McL. Lamberton and T. Mandeville (London, 1983) p. 134.

9. C. E. Ferguson, *The Neoclassical Theory of Production and Distribution* (Cambridge, 1969) p. 293.
10. S. B. Saul, 'The Nature and Diffusion of Technology', in *Economic Development in the Long Run*, ed. by A. J. Youngson (London, 1972) pp. 36–61.
11. David S. Landes, *The Unbound Prometheus, Technological Change and Industrial Development in Western Europe from 1750 to the Present* (Cambridge, 1972) pp. 281–2.
12. Albert O. Hirschman, *The Strategy of Economic Development* (New Haven, 1959) pp. 98–119.
13. Melville H. Watkins, 'A Staple Theory of Economic Growth', *Canadian Journal of Economics and Political Science*, 29 (1963) no. 2, p. 145.
14. Ibid; Sanjaya Lall, 'Transnationals, Domestic Enterprises and Industrial Structure in Host LDCs: A Survey', *Oxford Economic Papers*, 30 (1978) no. 2, pp. 217–48.
15. Ibid.
16. Watkins, 'A Staple Theory', pp. 145–6.
17. Richard B. Du Boff, 'The Introduction of Electric Power in American Manufacturing', *Economic History Review*, 20 (1967) no. 3, pp. 509–18; Warren D. Devine, Jr., 'From Shafts to Wires: Historical Perspective on Electrification', *Journal of Economic History*, 43 (1983) no. 2, pp. 347–72; Arthur G. Woolf, 'Electricity, Productivity, and Labor Saving: American Manufacturing, 1900–1929', *Explorations in Economic History*, 21 (1984) pp. 176–91.
18. Dieter Senghaas, *The European Experience, A Historical Critique of Development Theory* (Dover, New Hampshire, 1985) p. 73.
19. 'Population by Industry and Commune in 1880–1975', *Statistical Surveys no. 63*, CSOF (Helsinki, 1979) p. 330.
20. N.F.R. Crafts, *British Economic Growth during the Industrial Revolution* (Oxford, 1985) pp. 11–17, 62–3; Fritz Hodne, *An Economic History of Norway 1815–1970* (Bergen, 1975) pp. 127–8; Lennart Jörberg, 'The Nordic Countries 1850–1914', in *The Fontana Economic History of Europe*, vol. 4.2, ed. by Carlo M. Cipolla (Glasgow, 1973) p. 392; Viljo Rasila, 'Kehitys ja sen tulokset', in *Suomen taloushistoria Vol. 2, Teollistuva Suomi*, ed. by J. Ahvenainen *et al.* (Helsinki, 1982) p. 155.
21. Senghaas, *European Experience*, p. 79.
22. Poland, Czechoslovakia, Hungary, Romania, Bulgaria, Yugoslavia, Albania, and Greece are included in this group. *World Bank Atlas; Statistical Yearbook of Finland 1978* (Helsinki, 1979).
23. Ibid.

2 An Outline of Finnish Electrification

1. Eino Jutikkala and Kauko Pirinen, *A History of Finland* (Espoo, 4th rev. edn, 1984) pp. 190–1, 215–16.

2. Jutikkala and Pirinen, *History*, pp. 202–13; D. G. Kirby, *Finland in the Twentieth Century* (London, 1979) pp. 25–8.
3. O. Jussila, 'From Province to State: Finland and the Baltic Provinces (1721–1920), A Comparative Survey', in *Les 'petit états' face aux changements culturels, politiques et économiques de 1750 à 1914*, sous la direction de D. Kosary (Lausanne, 1985) pp. 65–7.
4. Erkki Pihkala, *Finland's Foreign Trade, 1860–1917*, (Helsinki, 1969) pp. 66–137.
5. *SYF 1982* (Helsinki, 1983).
6. Some towns in the south and on the west coast officially have two names, one in Finnish and one in Swedish, such as Helsinki-Helsingfors, Turku-Åbo, Tampere-Tammerfors, Viipuri-Viborg, Oulu-Uleåborg, Pori-Björneborg, etc. In this work, only Finnish names of towns are generally used.
7. *Yearbook of Nordic Statistics 1976* (Stockholm, 1977).
8. *Official Statistics of Finland* (hereafter *OSF*) *6:45 Population de la Finlande au 31 décember 1910* (Helsinki, 1915).
9. Jutikkala and Pirinen, *History*, pp. 189, 224–5.
10. Although, linguistically, the two main languages belong to entirely different families, Swedish-speaking and Finnish-speaking populations, did not constitute different nationalities as did the Germans, on the one hand, and the Estonians and the Latvians, on the other, in the Baltic Provinces. During the centuries, the original ethnic Swedish and Finnish populations became mixed, and therefore it is proper to call them only language groups.
11. Timo Myllyntaus, *The Growth and Structure of Finnish Print Production, 1840–1900*, Communications no. 16, Institute of Economic and Social History, University of Helsinki (Helsinki, 1984) p. 14.
12. These figures are related to the population of 10-year-olds or over in 1880 and that of 15-year-olds or over in 1900. *OSF 6:29, 37, 45 Population* (Helsinki, 1899, 1905, 1915).
13. Egil Johansson, 'The History of Literacy in Sweden', in *Literacy and Social Development in the West*, ed. by Harvey J. Graff (New York, 1981) pp. 151–82.
14. *OSF 6:29 Population* (Helsinki, 1899).
15. These two percentages are related to the population of 15-year-olds or over. *OSF 6:37–76 Population* (Helsinki, 1905–33).
16. Kirby, *Finland*, p. 2.
17. Paul Bairoch, 'Europe's Gross National Product: 1800–1975', *Journal of European Economic History*, 5 (1976) no. 2, pp. 283–4, 308–9.
18. Between 1866/70 and 1976/80 the annual compound growth rate of GDP per inhabitant was 2.2 per cent in Finland, whilst it was 2.1 per cent in Sweden, 2.1 per cent in Norway and 1.9 per cent in Denmark. Olle Krantz, 'Productivity Changes in Scandinavia in the 19th and 20th Centuries', in *International Productivity Comparisons and Problems of Measurement, 1750–1939*, ed. by P. O'Brien, Publication B 6 of the Ninth International Economic History Congress (Bern 1986) p. 64.
19. L. Ilvessalo and M. Jalava, *Maapallon metsävarat*, Metsäntutkimus-

laitoksen julkaisu 16.2 (Helsinki, 1930) p. 353; *OSF 6:29* Population (Helsinki, 1899).

20. Timo Myllyntaus, *Suomen energian hankinta* (Helsinki, 1980) pp. 8–11.
21. *SYF 1982* (Helsinki, 1983).
22. *Tidning för landbrukare och näringsidkare* (1849) no. 39; Gösta Grotenfelt, 'Päreistä, pärepihdeistä y.m.s.', *Tiedonantoja valtion maanviljelys-kansatieteellisistä kokoelmista, Nide II*, Tiedonanto no. 4 (Helsinki, 1921) pp. 142–3.
23. Toivo Vuorela, *Suomalainen kansankulttuuri* (Porvoo, 1977) pp. 321–9.
24. In 1883 the novelist Juhani Aho wrote a vivid short story about the intrusion of new paraffin lighting technology into a traditional peasant village. 'When Father Brought Home the Lamp', in *Stories by Foreign Authors, Scandinavia* (New York, 1901) pp. 19–38.
25. *Helsingfors Dagblad*, 19.12.1883, no. 346 (translation by T. M.).
26. *OSF 2:6 Katsaus Suomen taloudelliseen tilaan 1886–1890* (Helsinki, 1894) p. 57.
27. The Archives of the Board of Industrial, Ej-series, the year 1890 in the National Archives of Finland (hereafter ABI, NAF).
28. Ibid.
29. *The Economic History of Finland, Vol. 3, Historical Statistics*, compiled by K. Vattula (Helsinki, 1983) pp. 272–3, 283.
30. There were 323 locomotives in use in the state and private railways. *Suomen Valtionrautatiet 1862–1912, vol. II* (Helsinki, 1916) p. 568; *Economic History of Finland, Vol. 3*, p. 276.
31. At the time, steam ships accounted for 16 per cent of the total gross register tons of the fleet. *Economic History of Finland, Vol. 3*, pp. 304–5.
32. The first public telegraph lines had been drawn in 1845 in the USA, in 1848 in England, in 1849 in Prussia and Austria, and in 1853 in Sweden and Russia. Ilmari Killinen, 'Sähkön käyttö ja sen kehitys Suomessa', *Voima ja valo* (hereafter VV) 2 (1929) no. 5–6, p. 154; Einar Risberg, *Suomen lennätinlaitoksen historia 1855–1955* (Helsinki, 1959) pp. 57–131.
33. The telegraph from the capital of Russia to Finland was built by the German firm, Siemens & Halske. One of the five Siemens brothers, Carl, was appointed head of the company's branch in St Petersburg. He was fond of Finland and became a Finnish subject in 1853. The new citizenship and a marriage with a Russian banker's daughter of German descent helped him to become a privileged merchant of the first guild in the Empire's capital. In December 1896 the tsar, Nikolas II, raised Carl Siemens to the nobility as a Finnish burgher of the town of Lappeenranta. Georg Siemens, *History of the House of Siemens, Vol. I* (Freiburg/Munich, 1957) p. 32; (Eino S. Repo), *Siemens 60 vuotta Suomessa 1898–1958* (Helsinki, 1958) pp. 12, 30; Joachim Mai, *Das deutsche Kapital in Russland 1850–1894* (Berlin, 1970) p. 95.
34. U. E. Moisala, Kauko Rahko and Oiva Turpeinen, *Puhelin ja puhelinlaitokset Suomessa 1877–1977* (Turku, 1977) pp. 34–80.

35. Applying in practice the discovery of Michael Faraday that the interaction of magnetic fields and mechanical motion produces electric current, the French instrument-maker Hippolyte Pixii invented a hand-turned AC-generator in 1832. The self-excited DC-dynamo was almost simultaneously innovated by the Englishman C. F. Varley, his countryman Charles Wheatstone, the German Werner Siemens and some others in 1866–7. All these dynamos were rather impractical owing to harmful overheating. In 1870 the Belgian Zenobe T. Gramme introduced an improved version, a dynamo with a ring-armature, which came into wide use in a few years.

    The principle of the arc-lamp was invented by the Englishman Humphry Davy in 1802. The first practical applications of arc-lamps originated in the mid-nineteenth century. The clock-regulated arc-lamp designed by the Frenchman Serrin in 1859 was one of the models which were put in operation in some lighthouse illuminations. *Helsingfors Dagblad* (hereafter *HD*) 10.12.1877, 11.12.1877, 19.1.1878, 31.1.1878; G. R. Dahlander, *Elektriciteten och dess förnämsta tekniska tillämpningar* (Stockholm, 1893) pp. 411–14; T. K. Derry and T. I. Williams, *A Short History of Technology* (Oxford, 5th impr. 1982) pp. 610–15.
36. Karl Selim Lemström (1838–1904), a Swedish-speaking Finn, graduated from Helsinki University in 1862 and then studied physics in Helsinki, Stockholm, Paris and St Petersburg. After the nomination for the post of full professor, he turned his interest from electricity to astronomy and meteorology. Lemström was an excellent experimentalist and nowadays scientists remember him as one of the founders of modern laboratory-based physics in Finland.

    Martin Wetzer (1816–82) was a German, born in Bavaria, later he became a Finnish subject. In 1840 he was invited to make scientific instruments at the observatory of Pulkova in Russia. Two years later, he was recruited to the post in Helsinki where he worked for forty years. *HD* 10.7.1882; *Finsk Tidskrift* (1904) 2, pp. 292–8; Tor Carpelan and L. O. Th. Tudeer, *Helsingin Yliopisto, Opettajat ja virkamiehet vuodesta 1828*, vol. I (Helsinki, 1925) pp. 534ff.
37. *HD*, 3.8.1878, 4.8.1878, 7.8.1878, 9.8.1879.
38. In late August, the equipment was transported to Turku where five similar electric lighting demonstrations were organised by the restaurateur Julius Lindgren. *Åbo Posten*, 22.8.1878, 25.8.1878, 26.8.1878, 29.8.1878, 30.8.1878.
39. Georg Christiernin, 'Elektroteknikens pioniärer i Finland', *Tekniska Föreningen i Finland, Förhandlingar* (hereafter TFiFF (Helsingfors, 1930) no. 2, p. 53.
40. Erik von Schantz, 'Dan. Joh. Wadén, Minnesteckning', *Svenska tekniska vetenskapsakademien i Finland, Förhandlingar* (hereafter *STVAiFF*) no. 6:4 (Helsingfors, 1932) pp. 35ff.
41. *HD*, 27.12.1877.
42. Before the turn of the century, Wadén's firm had produced 2500 telephone sets and they were even awarded a prize at the Paris exhibition in 1889. Schantz, 'Wadén', pp. 39–46.

43. Chief engineer F. von Hefner-Alteneck designed a dynamo with drum-armature in 1874, while working in the company of Siemens & Halske in Berlin. Driven by a steam-engine this dynamo could supply current continuously without overheating.

Pavel Jabločkov, a Russian army telegraph engineer, completed his 'candle'-invention in 1876 in Paris where his arc-lamps came into daily use in the next year. In London the application of the electric light was not to be seen in practice until late 1878. The technical properties of Jabločkov's invention and its diffusion round the world were described in the Finnish press from early 1877, for example in: *Uleåborg Tidning*, 31.5.1877; *Morgonbladet*, 27.9.1878; *Åbo Posten*, 12.10.1878; and *HD*, 4.3.1880. *Electrician*, 20.7.1878, p. 97; Derry and Williams, *Short History of Technology*, pp. 629ff.

44. In the nineteenth century the Russian inventor's surname was spelled 'Jablochkoff' or 'Jablochkov' in English, whereas the modern spelling of his name is 'Jabločkov'. Lev D. Belkind, *Pavel Nikolaevič Jabločkov* (Moskva, 1962); 'Elektriskt ljus efter Jablochkoffs system', *HD*, 4.3.1880.

45. I. C. R. Byatt, *The British Electrical Industry, 1875–1914*, (Oxford, 1979) pp. 16–17.

46. Belkind, *Jabločkov*, p. 180; 'Raznye izvestiya', *Električestvo* (St Petersburg) (1882) no. 5, p. 69.

47. Johan Åkerman, *Ett elektriskt halvsekel, Översikt över ASEAs utveckling 1883–1933* (Västerås, 1933) p. 33; Sigmund Schalin's archive in *The Archives of The Municipal Energy Supply Utility of Helsinki (AMESUH)*.

48. *HD*, 11.2.1880; Brian Bowers, *A History of Electric Light & Power* (London, 1982) pp. 113–20.

49. The Finnish press tended to exaggerate Edison's merits. He did invent the phonograph in 1877 and filament lamp two years later at the age of 32, but the invention of both the microphone and telephone is generally credited to A. G. Bell. Edison, however, improved telephone significantly. He introduced a separate mouthpiece with a more developed carbon microphone. *HD*, 2.8.1878; *HD*, 17.10.1878.

50. For example: 'Thomas A. Edison, Hans ungdom', *HD*, 18.8.1878; 'Edisons underskjorta', *HD*, 24.11.1882; 'Edisons yngre dagar', *Wiborgsbladet*, 11.4 .1890 and 12.4.1890.

51. *HD*, 18.8.1878, 17.10.1878, 2.1.1880, 9.1.1880, 11.2.1880, 16.2.1880, 13.4.1880.

52. Kyllikki Hirsjärvi, 'Ylhäistä elämää Tampereella, Muistitietoja Nottbeckien perheestä', *Tampereen historiallisen seuran julkaisuja 8* (Tampere, 1950) pp. 235, 251.

53. Väinö Voionmaa, *Tampereen kaupungin historia, vol. III* (Tampere, 2nd edn, 1932) pp. 28–33.

54. Later on, Fodor became an Edison-agent in Eastern Europe and then the managing director of the electricity supply utility in Budapest and the Royal Counsellor of the Court. Killinen, 'Sähkön käyttö', *VV* (1929) no. 5–6, p. 158; Yrjö Raevuori, *Tampereen kaupungin sähkölaitos ja sähkön varhaisvaiheet Suomessa* (Tampere, 1938) pp. 19ff.

55. John Winthrop Hammond, *Men and Volts, The Story of General Electric* (New York, 1941) p. 46; Thomas Hughes, *Networks of Power* (Baltimore, 1983) pp. 39–46; Bowers, *History*, p. 139.

56. The earliest Swan and Edison lamps and a small French electric motor were brought to Finland by Dan. Joh. Wadén from the Paris Exhibition in 1881 for experimental purposes. Christiernin, 'Elektroteknikens pioniärer', pp. 54–5.

57. The lighting of this sawmill owned by the Attu company took place two and half years after the installation of forty-five lamps at Cragside, near Rothbury, in Northumberland, the first house in England properly fitted with Swan's electric lamps. According to C. N. Brown, two other private houses might have been lit by Swan lamps in 1880 before Cragside. Raevuori, *Tampereen sähkölaitos*, p. 24; Bowers, *History*, pp. 113ff; C. N. Brown, *J. W. Swan and the Invention of the Incandescent Electric Lamp*, A Science Museum Paper (London, 1978) pp. 35–7.

58. *Tampereen Sanomat*, 10.9.1881; Raevuori, *Tampereen sähkölaitos*, pp. 71–4.

59. *HD*, 29.3.1882, 6.4.1882, 14.4.1882, 19.4 .1882, 22.4.1882, 29.4.1882.

60. Later on, Nottbeck moved to Paris where he died. Hirsjärvi, 'Ylhäistä elämää', p. 251.

61. *HD*, 21.11.1882; Raevuori, *Tampereen sähkölaitos*, p. 23.

62. *HD*, 31.7.1880, 25.7.1882.

63. *HD*, 4.2.1886; Sigmund Schalin's archive, AMESUH.

64. Edv. Bildt's central station in Gothenburg like that of Wadén in Helsinki supplied electricity for indoor lighting for the subscribers in the city centre. In Sweden, electric street lighting was introduced in Stockholm and Härnösand a year later. *HD*, 26.11.1884, 6.12.1884, 4.2.1886; Åkerman, *Ett elektriskt halvsekel*, p. 42.

65. *Nya Pressen*, 15.5.1891; Schantz, 'Wadén', pp. 38–48.

66. *Hufvudstadsbladet* (hereafter *HBL*) 17.1.1899; *Nya Pressen*, 17.1.1899; *Tammerfors Nyheter*, 19.1.1899.

67. *Tammerfors Aftonblad*, 14.9.1889.

68. Wilén published large and detailed advertisements of Thomson-Houston products in the daily press and also elucidatory booklets describing the development of electrical technology and explaining its basic principles in an easily comprehensible way. As examples of these can be mentioned an exceptional advertisement of a half page in *Nya Pressen*, 10.4.1890, and booklets *Några upplysningar om den elektriska belysningen och dennas nuvarande ståndpunkt* (Åbo, 1888), and *Det nya systemet för elektrisk belysning med växelström och transformatorer* (Helsingfors, 1890); Raevuori, *Tampereen sähkölaitos*, pp. 32ff.

69. K. I. Junnelius, *Oulun kaupungin sähkölaitos 1889–1939* (Oulu, 1939) pp. 7–26.

70. The biggest and oldest electrical firm in the country, Wadén's workshop, had installed 50 Schuckert-dynamos by the summer of 1889. Raevuori, *Tampereen sähkölaitos*, p. 102.

71. Sigmund Schalin's archive; Oiva Turpeinen, *Energiaa pääkaupungille, Sähkölaitostoimintaa Helsingissä 1884–1984* (Espoo, 1984) p. 34.

72. 'Helsingfors elektriska belysningsaktiebolags centralstation', *TFiFF* (1890) pp. 133–4.
73. In 1892, the Finnish engineer Gustaf Zitting was appointed the local general agent of 'Union Elektizitäts Gesellschaft' in Berlin which was a brand new joint-venture of Thomson-Houston and some German businessmen. *Teknikern* (1892) no. 48, p. 251.
74. After failing to get medical treatment for his pains, Wilén committed suicide in a deep depression in January 1899. *HBL*, 17.1.1899; *Nya Pressen*, 17.1.1899; *Tammerfors Nyheter*, 19.1.1899.
75. Francois Bertini, *Suomen teollisuus-sanakirja 1889* (Tampere, 1890) pp. D.3–4; Christiernin, 'Elektroteknikens pioniärer', pp. 61ff.
76. Ibid.
77. 'Patentförtekning', *TFiFF* (1889) pp. 154–6, (1891) pp. 136–42; Väinö Petterson, *Asialuettelo patenteista, joita on Suomessa myönnetty vuosina 1833–1903* (Helsinki, 1905) pp. 9–11, 118–24.
78. *Teknikern*, (1892) no. 40, p. 168; *Suomen teollisuuslehti* (1892) no. 16; *Suomen kirjapainolehti*, 31.10.1893, p. 75.
79. Killinen, 'Sähkön käyttö', p. 161; Ingwald Sourander, 'Ensimmäiset sähkövoimansiirtolaitokset Suomessa', *VV*, 14 (1941) no. 5–6, 143ff.
80. Bertini, *Suomen teollisuus-sanakirja*, pp. D.3–4; Christiernin, 'Elektroteknikens pioniäer', pp. 61–2, 82–3; *OSF 18 Industrial Statistics 1889–1900* (Helsinki, 1892–1902).
81. Christiernin, 'Elektroteknikens pioniärer', pp. 61–2, 82–3.
82. Ibid; 'Lyhyt kertomus yhtiön vaiheista vv. 1898–1923', in *Ohjelma: Wiipurin kaasu- ja sähköosakeyhtiön 25-vuotisjuhlassa* (Viipuri, 1923) pp. 3ff; P. H. Norrmén, *Toiminimi Ahlström 1896–1927* (Helsinki, 1927) pp. 88–116; Thorvald Sjölund, *Viipurin kaasulaitos 75 vuotta 1860–1935* (Viipuri, 1935) p. 9.
83. *Aktiebolaget Gottfr. Strömberg Osakeyhtiö, Juhlajulkaisu 1889–1919* (Helsinki, 1919) p. 5; V. J. Sukselainen, *Oy Strömberg Ab 1889–1939* (Helsinki, 1940) pp. 9–11.
84. During that session, Kolrausch's lectures were attended by altogether sixteen students of which four were foreigners: one Englishman, one Norwegian and two Finns. Under Kolrausch's supervision, Strömberg wrote a theoretical article which aroused international interest. A. G. Strömberg, 'Eine graphische Methode zur Bestimmung der Magnetwickelung einer Dynamomaschine unter Berücksichtigung der Rückwirkung des Ankerstromes', *Centralblatt für Elektroteknik* (1887) pp. 283ff; Dahlander, *Elektriciteten* (1893) pp. 269, 306, 469–70; Christiernin, 'Elektroteknikens pioniärer', p. 61.
85. Strömberg worked as a part-time lecturer for a decade up to spring 1896. Christiernin, 'Elektroteknikens pioniärer', pp. 82–5; *Ab Strömberg Oy, Juhlajulkaisu*, p. 27.
86. Between 1889 and 1896, Strömberg manufactured about 100 dynamos and electric motors, while Wahl made 450 corresponding machines with a capacity of 3500 hp in the period 1887–97. *Teknikern*, 15.11.1897, no. 166, p. 212; *Suomen Teollisuus* (1925) p. 467.
87. *Kauppalehti*, 17.3.1909, p. i; *Mercator*, 16.6.1911; Sukselainen, *Strömberg*, pp. 49–51, 114.

88. According to Sukselainen, at the turn of the century 'Strömberg was so tightly engaged in the practical management, especially organising finance for his firm, that he did not have time to modernise the models of machinery he was producing'. L. Paavolainen, 'Sähkökoneteollisuus', *50 vuotta Suomen teollisuutta ja taloutta* (Helsinki, 1946) pp. 279–80; Sukselainen, *Strömberg*, pp. 91–2.
89. Sukselainen, *Strömberg*, p. 53.
90. For example, a business journal called him 'the primary creator and developer of the electrical engineering industry in our country'. *Kauppalehti*, 17.12.1913, p. 730.
91. After graduation, he worked in some railway building projects in Finland and set up an engineering workshop of his own in 1876. His firm installed telephones and electric lighting plants and was going to start dynamo production. However, at the party thrown in honour of the electric lighting system of his new villa, he was struck by a heart attack and died at the age of 44. Jonatan Reuter, *John Didrik Stenberg, En minnesteckning* (Helsingfors, 1928) pp. 7ff.
92. Public street lighting was installed in Paris in 1667, whereas the first efficient system was applied in Amsterdam in 1669, in Hamburg in 1673, in the Hague in 1678, in Berlin 1679, in Vienna in 1687, in Bremen in 1698, in Leipzig in 1701, in Strassburg in 1727, and in London in 1736–7. *Åbo Tidning* (1809) nos 9 and 10; -o-z-n, 'Skola gas- eller elektricitätsverken vara privata eller kommunala?', *Teknikern* (1901) no. 244, pp. 37–9; Lettie S. Multhauf, 'The Light of Lamp-Lanterns: Street Lighting in 17th-Century Amsterdam', *Technology and Culture*, 26 (1985) no. 2, pp. 236–52.
93. Timo Herranen, *Kaasulaitostoimintaa Helsingissä 1860–1985* (Espoo, 1985) pp. 42–3.
94. Tauno Räisänen, *Iisalmen kauppala ja kaupungin historia 1860–1930* (Kuopio, 1959) p. 502; Johannes Cederlöf, *Ekenäs stads historia, Del III 1810–1930* (Ekenäs, 1964) pp. 204–7.
95. By the early 1880s, in England the equivalent of about 800 million current Swedish crowns were invested in gas utilities, in Germany 200 million crowns and in Sweden 10 million crowns. Adolf Ahlsell, 'Om förhållandet mellan elektrisk belysning och gasbelysning', *Ingeniörs-Föreningens Förhandlingar*, 1883 (Stockholm, 1883) p. 49, cited in Arne Kaijser, *Stadens ljus, Etableringen av de första svenska gasverken* (Malmö, 1986) p. 183.
96. Private gas utilities were founded in Helsinki and Viipuri in 1860 and in Turku in 1862. Herranen, *Kaasulaitostoimintaa Helsingissä*, pp. 32–3; Fritz Hodne, *The Norwegian Economy 1920–1980* (London, 1983) p. 47; Kaijser, *Stadens ljus*, p. 178; *Danmarks statistik, Statistiske Meddelelser*, 4 række, 50 bind, 7 hæfte (København, 1917) p. 15; *Danmarks statistik, Statistisk tabelværk*, 5 række, Litra A, nr 18 (København, 1929) p. 124.
97. Dahlander, *Elektriciteten* (1893) p. 515.
98. Jorma Tiainen, 'Sortavala Laatokan Karjalan nousun aikana n. 1880–1918', in *Sortavalan kaupungin historia* by Erkki Kuujo, Jorma Tiainen, and Eeva Karttunen (Jyväskylä, 1970) p. 191; *Historiikki*

Viipurin sähkölaitoskysymyksen tähänastisista vaiheista ja kertomus Viipurin kaupungin sähkölaitoksen ja raitioteiden toiminnasta v. 1936 (Viipuri, 1937) pp. 3–7; Oiva Turpeinen, *Energiaa pääkaupungille, Sähkölaitostoimintaa Helsingissä 1884–1984* (Espoo, 1984) pp. 56–61.

99. In Oulu, the influential Pro-Swedish (language) Party supported the building of a municipal electricity utility, while the Pro-Finnish Party and particularly its local organ, 'Kaiku', sharply criticised this unlucky street lighting project. This kind of clear political division has not, however, been observed in other Finnish towns. K. I. Junnelius, *Oulun kaupungin sähkölaitos*, pp. 14–23; Eero Hietakari, *Oulun kaupungin sähkölaitos vv. 1889–1964* (Oulu, 1968) pp. 16–22.

100. Kyösti Kaukovalta, *Uudenkaupungin historia, Neljäs osa 1875–1918* (Uusikaupunki, 2nd edn, 1962) pp. 199–200; E. A. Kannisto, 'Poimintoja valtuuston käsittelemistä, pääasiassa raha-asioita koskevista kysymyksistä v. 1890–1918', *Tornio 1621 12/5 1921* (Oulu, 1921) p. 179.

101. -o-z-n, 'Gas- eller elektricitätsverken', p. 38.

102. Ibid.

103. Tiainen, 'Sortavala', p. 191.

104. Georg Klingenberg, 'Electricity Supply in Large Cities', *Electrician*, 72 (1913) pp. 398–400; Thomas Hughes, *Networks of Power* (Baltimore, 1983) p. 228.

105. This figure is derived from the statement of the city prefect signed on 27 November 1914. P. Gurevič, in turn, mentioned the same figures for Berlin, Chicago and London but gave the figure of 63 kWh per inhabitant for St Petersburg. *Förslag till utnyttjande af vattenkraften i Wuoksen uppgjorda af vattenbyggnadsbyrån i Stockholm* (Helsingfors, 1917) pp. 230–5; P. Gurevič, 'Osnovnye voprosy električeskoi politiki v poslevoennuyu epokhu v Rossii', *Električestvo* (1917) no. 1, p. 10.

106. *Svenska Dagbladet*, 3.10.1909.

107. E. H. Furuhjelm, 'Öfvermasmästare berättelse för år 1883', *Tjensteförrättande Bergintendentens underdåniga berättelse för år 1883* (Helsingfors, 1884) p. 43.

108. The Archives of the Board of Industry (hereafter ABI), ACSOF.

109. Both were rather small Swedish de Laval-steam turbines. *Teknikern* (1892) no. 48, p. 262; (1894) no. 73, p. 4.

110. ABI in the ACSOF.

111. Ibid; *Mercator*, 16.1.1916, p. i.

112. *Teknikern* (1902) no. 265, p. 4.

113. Berhard Wuolle, 'Sähkön käyttäminen käyttövoimana teollisuuden palveluksessa', *Suomen Metalliteollisuuden Harjoittajain Liiton esitelmäsarja työnjohtajille*, no. 11 (Helsinki, 1910) pp. 1–7.

114. T. K. Derry and T. I. Williams, *A Short History of Technology* (Oxford, 1982) pp. 635–6.

115. *Teknikern* (1891) no. 20, p. 157; (1917) no. 1027, p. 53; Byatt, *The British Electrical Industry*, p. 68.

116. Filip Hjulström, *Sveriges elektrifiering, En ekonomisk-geografisk studie över den elektriska energiförsörjningens utveckling*, Geographica 8 (Uppsala, 1940) p. 80; Jan Glete, *ASEA under hundra år 1883–1983* (Västerås, 1983) pp. 34–7.

117. Byatt, *The British Electrical Industry*, pp. 68–9.

118. Sigmund Schalin's archive in the AMESUH; Turpeinen, *Energiaa*, pp. 36–49.

119. Raevuori, *Tampereen sähkölaitos*, pp. 81–3.

120. Sukselainen, *Strömberg*, p. 38.

121. J. A., 'Sähkövoimansiirtolaitokset Pitkärannan tehtailla', *Suomen teollisuuslehti*, 5 (1901) pp. 36–7; Ingwald Sourander, 'Ensimmäiset Sähkövoimansiirtolaitokset Suomessa', *VV*, 14, (1941) pp. 134–42.

122. Sourander, 'Sähkövoimansiirtolaitokset', pp. 143–4.

123. Ibid, pp. 144–7.

124. G. M. Nordensvan, *Etelä-Suomen Voima Osakeyhtiö 1916–1941* (Helsinki, 1941) pp. 10–15.

125. Wuolle, 'Sähkön käyttäminen', pp. 1–7.

126. Dahlander, *Elektriciteten* (1893) pp. 647–8; Christiernin, 'Elektroteknikens pionärer', *TFiFF*, 50 (1930) p. 53.

127. *Wiborgsbladet*, 22.3.1890; Sukselainen, *Strömberg*, pp. 65, 113.

128. ABI (1890–1900) in the NAF; *Suomen Kirjapainolehti*, 31.10.1893, p. 75; see also Timo Myllyntaus, 'Tekniset uudisteet graafisessa teollisuudessa 1800-luvun puolivälistä 1920-luvun alkuun', *Sanomalehtien taloudellinen tausta, Suomen sanomalehdistön historiaprojektin julkaisuja*, no. 21 (Helsinki, 1983) p. 65.

129. ABI (1900–13) in the NAF.

130. Gustav Gröndal, 'Anrikning af malmer', *TFiFF*, 16 (1896) pp. 113–16; Sourander, 'Ensimmäiset', pp. 134–5.

131. Sourander, 'Ensimmäiset', pp. 134–5.

132. Dahlander, *Elektriciteten* (1893) pp. 781–6; *Teknikern* (1895) no. 111, pp. 173–5.

133. Oscar Kjellberg founded Elektriska Svetsning Ab (ESAB) in 1904, and a patent for his electric welding method was granted in 1907. *Helsingfors Skeppsdocka, Aktiebolaget Sandvikens Skeppsdocka och Mekaniska Verkstad 1865–1935* (Helsingfors, 1935) pp. 66–7.

134. Gunnar Wasenius, *Oy AGA Ab 1917–1967* (Helsinki, 1967) p. 36. (AGA, abbreviation for Svenska Aktiebolaget Gasaccumulator, is a Swedish firm, founded in 1904.)

135. Veikko Talvi, *Pohjois-Kymenlaakson teollistuminen, Kymi Osakeyhtiön historia 1872–1917* (Kouvola, 1979) pp. 151–2.

136. Thomas P. Hughes, 'British Electrical Industry Lag: 1882–1888', *Technology and Culture*, 3 (1962) no. 1, pp. 29–30.

137. Malcolm MacLaren, *The Rise of the Electrical Industry during the Nineteenth Century* (Princeton, 1943) pp. 170–98; A. J. Körner, 'Den elektriska industriens historia', in *Uppfinningarnas bok III*, ed. by Sam Lindstedt (Stockholm, 1927) pp. 870–1.

138. Siemens & Halske founded manufacturing plants in Berlin in 1847, in St Petersburg in 1855, in London in 1858, in Paris in 1878, in Vienna in 1879, in Tokyo in 1887 and in Chicago in 1892. Ludwig von Winterfeld, *Entwicklung und Tätigkeit der Firma Siemens & Halske*

in den Jahren 1847–1897 (Hamburg, 1913) pp. 20ff; S. von Weiher, 'The Rise and Development of Electrical Engineering and Industry in Germany in the Nineteenth Century, A Case Study – Siemens & Halske', in *Development and Diffusion of Technology Electrical and Chemical Industry*, ed. by Akio Okochi and Hoshimi Uchida (Tokyo, 1980) p. 42.

139. The founder of the company, Werner Siemens, made theoretical contributions in dynamo-electric principles and constructed his famous dynamo in the years 1866–7. In 1888, the King of Prussia rewarded the achievements of Werner Siemens (1816–92) in electrical technology by raising him to the nobility. Werner von Siemens, *Lebenserinnerungen* (Berlin, 1897) pp. 252–3; (Eino S. Repo) *Siemens 60 vuotta Suomessa 1898–1958* (Helsinki, 1958) p. 15.

140. Georg Siemens, *History of the House of Siemens, Vol. I* (Freiburg/Munich, 1957) pp. 150–1; Körner, 'Den elektriska industriens historia', pp. 870ff.

141. Felix Pinner, *Emil Rathenau und das elektrische Zeitalter* (Leipzig, 1918) pp. 271ff; *50 Jahre AEG*, Allgemeine Elektricitäts-Gesellschaft (Berlin, 1956) pp. 77–111.

142. Ibid, pp. 223–50; Siemens, *History of the House of Siemens*, pp. 151–3.

143. With a turnover of 86 million US dollars, the AEG in 1911 surpassed for the first time the General Electric Co with a turnover of 70.4 million dollars. The turnover of the Western Electric Co was 66.2 million dollars. The Siemens & Halske had a slightly smaller turnover, 66 million dollars, while the Westinghouse Electric Manufacturing Co achieved 34.2 million dollars. *New-Yorker Handelszeitung* quoted in *Teknikern* (1913) no. 828, p. 152.

144. Johan Åkerman, *Ett elektriskt halvsekel, Översikt över ASEAs utveckling 1883–1933* (Västerås, 1933) pp. 17–33; Körner, 'Den elektriska industriens historia', pp. 875–83.

145. The ASEA owned 33.8 per cent of the FEAB's capital stock in 1903; the rest was owned by Gustaf Zitting and other Finns. Åkerman, *Ett elektriskt halvsekel*, p. 69; Glete, *ASEA under hundra år*, p. 38.

146. *Mercator*, 3.1.1914, pp. vi, 12.

147. I. C. R. Byatt, *The British Electrical Industry 1875–1914* (Oxford, 1979) pp. 71–2.

148. Walther Kirchner, 'Siemens and AEG and the Electrification of Russia, 1890–1914', *Jahrbücher für Geschichte Osteuropas*, 30 (1982) no. 3, pp. 406–9.

149. A year earlier, the parent company in Berlin had been reformed as a limited company with a nominal capital stock of 36 million Reichsmarks. Ibid, pp. 404–5; Körner, 'Den elektriska industriens historia', p. 872; (Repo), *Siemens*, p. 31.

150. *Teknikern*, 14.3.1906, no. 455, p. 67.

151. *Teknikern* (1901) no. 242.

152. 'Elektriska Aktiebolaget A.E.G.' and 'Siemens & Halske Aktiengesellschaft, Teknisk Byrå, Helsingfors', *Suomen kauppa, meriliike ja teollisuus, Helsinki I* (Helsinki, 1907–15) pp. 57–61, 81–6.

153. The Nernst-bulb was an incandescent lamp which had a filament made from rare earths (zirkonium and ytterbium) instead of carbon. The German professor Walther Nernst developed Pavel Jabločkov's invention into a commercial product and sold his patents to the AEG. The first Nernst-lamps were on sale in 1900. In Finland, they were used from 1901, for example in the supply utilities of the towns of Lappeenranta and Hamina. *Teknikern* (1902) no. 265, p. 4; K. J. Laurell, 'Det elektriska ljuset', in *Uppfinningarnas bok III*, ed. by Sam Lindstedt (Stockholm, 1927) pp. 191–2.

154. 'A.E.G.' and 'Siemens & Halske', *Suomen kauppa, meriliike ja teollisuus, Helsinki I* (Helsinki, 1907–15) pp. 57–61, 81–6.

155. Ibid, *Teknikern* (1900–8); 'Aktiebolaget Gottfrid. Strömberg Osakeyhtiö', *Kotimaisen teollisuuden albumi* (Helsinki, 1913) pp. 22–5.

156. *Teknikern* (1906) no. 447, p. 18; (1907) no. 504, p. 59; (1908) no. 558, p. 77.

157. Upon setting itself up, the company's nominal capital was announced to be 1.2 million German Reichsmarks (FIM 1.5m). *Teknillinen Aikakauslehti* (hereafter *TAik*) (1921) p. 317.

158. Walther Rathenau (1867–1922) followed his father, Emil, as head of the AEG in 1915. Ilmari Ekström, *Turun kaupungin sähkölaitos 1908–1958* (Turku, 1958) pp. 25–44; Hughes, *Network of Power*, pp. 179–80.

159. *Kontrahti Viipurin kaupungin ja Berliinissä olevan yhtiön Allgemeine Elektricitäts-Gesellschaftin välillä* (11.11.1910) (Viipuri, 1932); (Oskar Schultz), *Sähkölaitos ja sähköraitiotiet Turussa* (Turku, 1908).

160. Taken as a whole, the AEG's subsidiaries in Viipuri made up the second biggest employer in the town, the next only to the engineering works of the State Railways. 'Lyhyt kertomus yhtiön vaiheista vv. 1898–1923', *Ohjelma: Wiipurin kaasu- ja sähköosakeyhtiön 25-vuotisjuhlassa* (Viipuri, 1923) pp. 3–6.

161. To be fair, one must state that the retail prices of the AEG utilities were quite close to the average electricity prices in Finnish towns and certainly not among the most expensive. *Teknikern* (1911) no. 729, p. 133; *Selostus Suomen kaupunkien sähkölaitosten virranhinnoista* (Kotka, 1915).

162. The agreement between the town council of Viipuri and the AEG resembled the common German-type concession of agreement the unreasonable consequences of which had to be restricted later by law, for example in Switzerland and Germany. *Historiikki Viipurin sähkölaitoskysymyksen tähänastisista vaiheista ja kertomus Viipurin kaupungin sähkölaitoksen ja raitioteiden toiminnasta v. 1936* (Viipuri, 1937) pp. 1–8; Ekström, *Turun kaupungin sähkölaitos*, pp. 79ff; B. J. Palme, 'Näringarna', in Matts Dreijer *et al.*, *Mariehamns stads historia 1911–1961* (Helsingfors, 1962) pp. 243–4; Y. S. Koskimies, 'Hämeenlinnan kaupungin historia 1875–1944', in *Hämeenlinnan kaupungin historia IV* (Hämeenlinna, 1966) p. 385.

163. Guenter Sheldon Holzer, 'The German Electrical Industry in Russia: From Economic Entrepreneurship to Political Activism, 1890–1910' (unpublished Ph.D. thesis, Lincoln, Nebraska, 1970) p. 90; Kirchner, 'Siemens and AEG', p. 412.

164. P. Gurewitsch, in *Elektrotechnische Zeitschrift*, 36, 29 July 1915, no. 30, quoted in Kirchner, 'Siemens and AEG', p. 420.
165. It is noteworthy that electrical contractors were expected to know German. *Sähkölaitosasian käsittely Käkisalmen kaupungin valtuustossa* (Käkisalmi, 1913) p. 11; *Ohjesääntö sähköjohtoja varten jotka aiotaan yhdistää Savonlinnan kaupungin sähkölaitoksen sähköverkkoon* (Savonlinna, 1915) p. 6; *Kokkolan kaupungin sähkölaitoksen johtoverkkoon yhdistettäväksi tarkoitettujen sähkölaitelmien rakennemääräykset* (Kokkola, 1929) p. 1ff.
166. *Wiipurin Sanomat*, 9.3.1910; Santeri Pohjanpalo, 'Yleisön osa kotimaisen teollisuuden menestymisessä', *Kauppalehti*, 6.4.1910, pp. 4–5.
167. G. B., 'Ingeniörbyråerna och gynnandet af den inhemska industrin', *Mercator*, 20.10.1911, pp. 766–7.
168. *OSF I Foreign Trade 1912–1913*, CSOF (Helsinki, 1913–14); *TAik* (1912) no. 15, p. 108; *Kotimainen työ* 1 (1913) no. 1, pp. 1–5; (W. Walkama), *Kotimaisen työn ja teollisuuden merkitys kansallemme* (Kotka, 1913) pp. 3ff.
169. In Britain, the Merchandise Marks Act, passed in 1887, obliged all imports to bear a stamp of origin so that they were distinguished from domestic products. *Kauppalehti, Kotimaisen teollisuuden numero* 1911, p. 53; *Mercator*, 27.1.1911, p. 30; Sidney Pollard, '"Made in Germany" – die Angst vor der deutschen Konkurrenz im spätviktorianischen England', *Technikgeschichte*, 53 (1987) no. 3, pp. 183–96.
170. In addition, 'Kotimaisen työn liitto' (The Association of Finnish Labour) was set up in 1913 for promoting Finnish production and its prestige. It started to publish a journal and catalogues of domestic industrial products as well as organise 'Finnish Weeks' around the country. *Mercator*, 24.3.1911, p. 145; *Kotimainen työ*, 1 (1913) no. 1, pp. 1–5; *Suomalaisten teollisuustuotteitten yleinen hakemisto* (Helsinki, 1915).
171. The former slogan was used in the publications in Finnish, whereas the latter was frequently repeated in the press in Swedish, such as *Mercator*, which frequently printed it from 12 May 1911 on. *Kauppalehti*, 2.8.1911.
172. Pohjanpalo, 'Yleisön osa', p. 5; G. B., 'Ingeniörbyråerna', pp. 766–7; *Kotimainen työ*, 1 (1913) no. 1, p. 1.
173. 'J. V. Snellmanin mielipiteitä suomalaisesta teollisuudesta', *Kauppalehti*, 9.8.1911, pp. 473–4; see also Pohjanpalo, 'Yleisön osa', p. 4; (Walkama), *Kotimaisen työn ja teollisuuden merkitys*, pp. 4–9.
174. 'Snellmanin mielipiteitä', p. 474.
175. Ibid; 'Maamme nykyinen valtiollinen asema ja liikeelämämme', *Kauppalehti*, 12.1.1910, p. 1.
176. 'Snellmanin mielipiteitä', p. 474.
177. Ibid.
178. (Walkama), *Kotimaisen työn ja teollisuuden merkitys*, pp. 4–5.
179. *Prospect der Siitola-Actien-Gesellschaft, Gemeinde Ruokolahti, Gouv. Wiborg in Finnland* (Riga, 1898) p. 4; B. R. Mitchell, *European Historical Statistics 1750–1970* (London, 1978) pp. 12–15.

180. The canal was built by the Finnish Government in 1845–56. A. Rahkonen, *Der Wuoksi und dessen Wasserfall Imatra der bedeutendste in Finland und in ganz Europa* (Wiborg, 1874) p. 56.
181. *Erinäisten ulkomaisten ammattimiesten lausuntoja Imatran voimalaitosyrityksen suunnitelmista*, Koskivoimakomitean toimiston julkaisuja v. 1922 no. 3 (Helsinki, 1922) pp. 4–6; Lasse Nevanlinna and Gunnar E. Lax. 'Development of Hydro Power', in *Waterpower in Finland* (Tampere, 1969) p. 22; Heikki Simojoki, 'Hydrology in Finland', in *Waterpower in Finland*, pp. 38–42.
182. V. F. Dobrotvorskij, 'Soobrazheniia o peredače električeskoi energii ot vodapada na reke Narove v S-Peterburge' in 'Deiatel'nost Obščestva', *ZIRTO* (1894) no. 10, pp. 46–8; 'Snabženie g. S. Peterburga električeskoi energii, peredannoi ot vopopadov "Narvskogo" i "Imatra"', *Električestvo* (1896) no. 4, p. 54.
183. *Wiborgsbladet*, 12.10.1894, 5.6., 7.6., 12.9., 16.10., 1.11., 2.11.,1895, 1.2., 9.11.1896, 26.1., 8.9., 7.12.1897, 26.1.1898; Sven Hirn, *Imatran tarina* (Imatra, 1978) pp. 124–5.
184. N. M. Oznobin, *Elektrifikacija SSSR za 40 let* (Moskva 1958) pp. 12–43; Heiko Haumann, *Beginn der Planwirtschaft. Elektrifizierung, Wirtschaftsplannung und gesellschaftliche Entwicklung Sowjetrussland 1917–1921* (Düsseldorf, 1974) p. 39.
185. *Bidrag till Finlands hydrografi, I Vuoksen-floden*, Bilaga till Öfverstyrelsens för väg- och vattenbyggnaderna berättelse för år 1904 (Helsingfors, 1908) p. i.
186. *Prospect*, pp. 4–12.
187. *Einladung zur Aktienzeichung in der 'Siitola Aktien-gesellschaft'* (Riga, 1899); *Statut der Siitola Actien-Gesellschaft* (Riga, 1899); *Mercator*, 4.7.1913, p. 567; K. Heitto, 'Linnankosken voimalaitos, Imatran voima-aseman edeltäjä', *Voimaviesti* (1947) no. 2, pp. 16–18; Tuomo Polvinen, *Die finnischen Eisenbahnen in den militärischen und politischen Plänen Russland vor dem ersten Weltkrieg*, Studia Historica 4 (Helsinki, 1962) p. 199.
188. At the same time as the Finnish engineers prepared their proposal, a group of Russian businessmen had already submitted their own proposal to the Russian Ministry of Transportation about an electric railway line between St Petersburg and Imatra. *Viipuri*, 29.11.1901.
189. *Teknikern*, 25.4.1906, no. 461, pp. 108–9; Elna Kerkkonen, *Koskitoimikunta vuosina 1917–1947* (Helsinki, 1950) pp. 18–19.
190. *Nya Pressen*, 16.12.1909; *Wiborgs Nyheter*, 25.1, 19.5, 22.5, 31.5, 7.10.1911; *HBL*, 22.11.1911.
191. Local observers complained that the extra income and the construction works did not bring well-being but demoralisation to the riverside villages. 'The rapids were harnessed, new factories were set up, and big masses of labour arrived to the region . . . It was hectic and epochmaking activity like that in the Klondyke. Money and spirits flowed in . . .', *Wiipurin Sanomat*, 17.1.1900.

'A wandering mob is loafing here and spoiling the habits of formerly quiet villages. The dark sides of factory life appear. Machine-like factory work turns people to machines, blunts their mental abilities . . . Much of the material returns goes to foreigners. Finns have to move aside, often because of their own foolishness. They sell forests but, instead of using the income to improve their farming, the money is spent on vanity.' J. Koskinen, 'Jääsken kotiseutumuistoja', *Karjala*, 30.6.1914.

192. Despite numerous proposals, the electrification of railway lines was not carried out in Tsarist-Russia either. Haumann, *Beginn der Planwirtschaft*, p. 18.
193. Kerkkonen, *Koskitoimikunta*, p. 19.
194. The company used several translations of its name. Here the French name is used, because the company was generally called by it in the Finnish press. In the early 1910s, Belgian and French investors became substantial shareholders in the company; for example, the activities of the banking house T & F Mottart from Brussels were closely connected with the SPTE. The capital stock of the company was 6 million roubles (16.1 million Finnish marks) in late 1912. *Karjala*, 22.10.1912; *Kauppalehti*, 22.1.1913, p. 51.
195. *Teknikern*, 8.3.1911, no. 715, pp. 45–6; *Viborgs Nyheter*, 31.5.1911; *Uusi Suometar*, 18.1.1914; *HS*, 19.1.1914.
196. *Uusi Suometar*, 18.1.1914; *HS*, 19.1.1914.
197. *Uusi Suometar*, 20.1.1914; *Mercator*, 3.1.1913, p. 8; Urs Rauber, *Schweizer Industrie in Russland* (Zürich, 1985) pp. 202–11, 312.
198. E. P., 'Vuoksen vesivoiman käyttäminen', *Kauppalehti*, 4.1.1914, p. 17; *Mercator*, 9.1.1914, pp. 31–2; Valentin Djakin, 'Zur Stellung des deutschen Kapitals in der Elektroindustrie Russlands', *Jahrbuch für Geschichte der UdSSR und der volksdemokratischen Länder Europas*, Band 9 (Berlin, 1966) p. 134.
199. E. P., 'Vuoksen vesivoima', pp. 16–17; *Mercator*, 3.1.1913, p. 8; 9.1.1914, pp. 31–2; *Uusi Suometar*, 20.1.1914.
200. *Mercator*, 9.1.1 914, p. 32; 16.1.1914, p. 58; 23.1.1914, p. 74; *Kauppalehti* 21.1.1914, p. 32; *Teknikern*, 2.12.1914, no. 910, pp. 378–9.
201. *Kauppalehti*, 21.1.1914, p. 32.
202. *Mercator*, 23.1.1914.
203. *Mercator*, 16.1.1914, p. 58.
204. *Kommitténs för granskning af förslagen till utnyttjande af vattenkraften i Wuoksen handlingar, Del V Förslag till utnyttjande af vattenkraften i Wuoksen*, uppgjorda af Vattenbyggnadsbyrån i Stockholm (Helsingfors, 1917) pp. 219–29.
205. The name of St Petersburg was changed to Petrograd in late 1914 and to Leningrad in 1924.
206. *Kommitténs*, pp. 219–29.
207. The electricity consumption in Finland was 1.1 GWh in 1930 and it rose to 1.6 GWh by 1934. Terho Savolainen, 'Tilastotietoja sähköntuotannosta ja kulutuksesta vuonna 1975' *Sähkö* (1976) no. 12, p. 505.
208. Kerkkonen, *Koskitoimikunta*, pp. 19–20.
209. *Mercator*, 19.1.1917, pp. 38–40.
210. The company was set up to recruit international banks to join in the hydropower and transmission project. The most active investors were German, Swiss and Belgian banks. The German-speaking world called it 'Imatra AG für Erzeugung und Verteilung elektrischer Energie'. *Karjala*, 8.11., 9.11.1912; Rauber, *Schweizer Industrie*, pp. 206, 209, 312, 367.

211. Oznobin, *Elektrifikacija*, p. 9; Joachim Mai, *Das deutsche Kapital in Russland 1850–1894* (Berlin, 1970) pp. 199–201; Djakin, 'Elektroindustrie Russlands', pp. 124–6.
212. Ab Force was run with the nominal capital of 18 million Finnish marks, Electricitetsbolaget Imatra with 30 million francs and the GEB-1886 with 133.5 million marks (the values of a gold mark and a gold franc were almost equal up to mid-1914). Ibid; *Uusi Suometar*, 20.1.1914; Mai, *Russland*, pp. 197–203.
213. In contrast to Mai, Urs Rauber emphasises the leading role of Swiss banks in the GEB-1886. He states that in the general meeting of 5 May 1914, the Swiss accounted for 55.6 per cent, German 40.3 per cent, Russian 3.9 per cent and Dutch 0.2 per cent of the whole represented share capital. Mai, *Russland*, pp. 197–203; Rauber, *Schweizer Industrie*, pp. 203–4.
214. Victor Hoving, *Enso-Gutzeit Osakeyhtiö 1872–1958* (Helsinki, 1961) pp. 179–203, 274–329.
215. Sven Hirn, *Imatra som natursevärdhet till och med 1870* (Helsingfors, 1958) pp. 42ff.
216. Rahkonen's work *Der Wuoksi und dessen Wasserfall Imatra* was one of the first Finnish guidebooks for tourists.
217. *Bidrag till Finlands hydrografi I*, p. 3.
218. *Uusi Suometar*, 20.1.1914; *Mercator*, 7.5.1915, p. 285; 4.6.1915, p. 342.
219. *Mercator*, 4.6.1915, p. 342.
220. In 1913 only 40 GWh or 2 per cent of all electricity output in Russia was generated with 78 small hydroplants with the total capacity of about 8.5 MW. Haumann, *Planwirtschaft*, p. 19.
221. *Kauppalehti*, 17.1.1917, pp. 46–7.
222. Ibid.
223. 'Laki sähkövoiman siirtämisestä maan rajojen ulkopuolelle', *Suomen asetuskokoelma 1919*, no. 19 (Helsinki, 1919).
224. 'With a special permit from the government, electricity could be exported only from power plants situated not more than ten kilometres from the border.' In the south-eastern border of Finland there were no big hydropower resources within such a short distance. In the north-west the Finnish–Swedish border, in contrast, went along the Rivers Muonionjoki and Tornionjoki. Ibid.
225. Kerkkonen, *Koskitoimikunta*, pp. 36–42.
226. *Kauppalehti*, 16.10.1918, p. 532; *Mercator*, 18.19.1918, p. 628.
227. *Mercator*, 17.5.1918, p. 136; Hoving, *Enso-Gutzeit I*, pp. 354–6.
228. Erkki Pihkala, *Finland's Foreign Trade 1860–1917* (Helsinki, 1969) pp. 66–77.
229. In the beginning of 1917 about 40 000 people are estimated to have worked in war material production and 30 000 in fortification corps. Viljo Rasila, 'Kehitys ja sen tulokset', *Suomen taloushistoria 2* (Helsinki, 1982) p. 165.

230. Kari O. Virtanen, *Ahdistettu kansakunta 1890–1917, Kansakunnan historia 5* (Porvoo, 1974) pp. 403–4, 493–4.
231. The formal decree on the transfer to paper currency was promulgated on 15 April 1915. *Suomen asetuskokoelma 1915*, no. 19 (Helsinki, 1915); Leo Harmaja, *Effects of the War on Economic and Social Life in Finland* (New Haven, 1933) pp. 44–5; Paavo Korpisaari, *Suomen markka 1914–1925* (Porvoo, 1926) pp. 7–51.
232. Korpisaari, *Suomen markka*, pp. 7–51.
233. In Finland, the official cost-of-living index rose by 310 per cent between 1914 and 1917. Compared to Western Europe, this was rapid inflation. At the same time, the prices of necessities increased by about 150 per cent on the average in England, France, Italy and Sweden, and by 150–200 per cent in Germany, Hungary and Norway. *Kansanvalistusseuran Tietokalenteri 1919* (Helsinki, 1918), pp. 165–6; O. K. Kilpi, *Hinta- ja valuuttavallankumoukset* (Helsinki, 1921) pp. 15–16; *Revue sociale* (1925) no. 4, pp. 295–6.
234. Maija Tudeer, 'Laskelmia elinkustannusten vaihteluista Helsingissä vuosina 1917–1919', *Revue sociale* (1921) p. 774.
235. Harmaja, *Effects*; Leo Harmaja, *Maailmansodan vaikutus Suomen taloudelliseen kehitykseen* (Helsinki, 1940); J. Karhu, *Sota-ajan taloudellinen elämä Suomessa* (Helsinki, 1917); Heikki Rantatupa, *Elintarvikehuolto ja -säännöstely vuosina 1914–1921* (Jyväskylä, 1979).
236. *OSF 1 Foreign Trade 1913–1919* (Helsinki, 1915–22).
237. *Mercator*, 23.4.1917, p. 252.
238. Timo Herranen, *Kaasulaitostoimintaa Helsingissä 1860–1985* (Espoo, 1985) pp. 78–9.
239. *OSF 1 Foreign Trade 1913–1920* (Helsinki, 1915–22).
240. Ibid.
241. *Annuaire statistique de la ville de Helsingfors 1919* (Helsingfors, 1919) pp. 446–7.
242. 'Maailman naftamarkkinat', *Kauppalehti*, 14.5.1913, p. 297.
243. *Annuaire statistique de la ville de Helsingfors 1922* (Helsingfors, 1922) p. 285.
244. *Revue sociale* (1919) p. 148.
245. *Statistique de la ville de Helsingfors 1922*, p. 285.
246. In that time-span, the cost-of-living index in Finland jumped from 100 to 1214, while in Germany it went up to 1124, in Italy to about 635, in France to 307, in the Scandinavian countries to 236–302 and in England only to 222. Kilpi, *Hinta- ja valuuttavallankumoukset*, pp. 15–16; *Revue sociale* (1925) no. 4, pp. 295–6.
247. Tudeer, 'Laskelmia', p. 772.
248. *Revue de statistique ouvrière* (1912) pp. 1–49.
249. In comparison, the cost-of-living index rose by a factor of 10.6 from 1914 to 1918. *SYF 1920–1925* (Helsinki 1920–25)' *Kauppalehti* (1917) no. 50, p. 863, 27.11.1918 no. 36, p. 641.
250. Fixing the maximum prices too low for both stearin candles and matches was said to be the cause for the shortage of these items. *Mercator*, 10.11.1916, p. 778; *Kauppalehti*, 18.9.1918, p. 453.

251. *Kauppalehti*, 24.7.1918, p. 316; 21.8.1918, p. 390; 28.8.1918, p. 408; 27.9.1918, p. 471; *Teknikern*, 11.9.1918, no. 1107, p. 148; 18.9.1918, no. 1108, p. 152; (M. Ollikka), *Sääksmäen Sähkön osakeyhtiön toimintakertomus ajalta 1919–1944* (Sääksmäki, 1945) p. 3.
252. *Mercator*, 15.11.1918, p. 723.
253. A. Frey, 'Det ekonomiska läget, Metallindustrin', *Ekonomiska Samfundets Tidskrift* (1916) p. 19.
254. Karhu, *Sota-ajan taloudellinen elämä*, pp. 26–9; *Reveu de statistique ouvrière* (1914–18).
255. *Helsingin kaupungin sähkölaitos 1909–1934* (Helsinki, 1935) p. 49.
256. Gösta Grotenfelt, 'Landsbygdens elektrifiering', *Mercator*, 8.11.1918, p. 691.
257. The earliest rural electricity supply utilities were put in operation in the very first years of the twentieth century, *OSF 18. Industrial Statistics, 1910–1918* (Helsinki, 1912–22).
258. *OSF 18. Industrial Statistics, 1925–1926* (Helsinki, 1926–7); L. Konkonen, 'Sähkölaitostilastoa vuodelta 1926', *Tilastokatsauksia* (1929) no. 12 (Helsinki, 1929) pp. 36–8; Ilmari Killinen, 'Sähkön käyttö ja sen kehitys Suomessa', *VV*, 2 (1929) no. 5–6, p. 171.
259. Rantatupa, *Elintarvikehuolto*, p. 273.
260. (Antti W. Lehtinen), *Vilppulan sähkö-osakeyhtiö 1918–1943* (Tampere, 1943) pp. 3–9; Killinen, 'Sähkön käyttö', p. 171.
261. *Kertomus Oy Kangasalan Sähkön toiminnasta vuodelta 1939* (Kangasala, 1940) p. 1.
262. Killinen, 'Sähkön käyttö', p. 171; see also Grotenfelt, 'Landsbygdens elektrifiering', p. 691.
263. Gösta Grotenfelt, 'Landsbygdens elektrifiering', *Mercator*, 22.6.1917, pp. 551–3; 8.11.1918, p. 691; Viljo J. Varho, 'Maaseutusähköistyksestä maassamme viime vuonna', *VV*, 3 (1930) pp. 85–6; Hans Modig, 'El på landsbygden', in *Vattenfall under 75 år*, Statens Vattenfallsverk (Stockholm, 1984) pp. 161–99.
264. K. B. Wuolle (1876–1962), son of a joiner from Tampere, was bilingual, but sympathised more with Finnish-speakers. Like many others of his generation, at the turn of the century he changed his Swedish surname (Wennerblom) to a Finnish one. After taking the engineer's degree at the Helsinki University of Technology (HUT) in 1900, he received a scholarship from the Finnish State Railways to continue his studies in Germany. As a student of the Charlottenburg University of Technology and a trainee at Siemens & Halske AG, he specialised in electrical technology and railway electrification in 1902–4. In 1907 he was invited to lead the construction works of the thermal power plant of MESUH; later he acted as general manager of the utility in 1910–16. While working as the general manager of the State Railways in 1917–22, he became a diplomat posted in Berlin for a while in 1918. From 1922 to 1946, he held the post of professor of general engineering and industrial economy at the HUT. He was vice-chairman of Ekono's advisory board in 1910–16 and its chairman from 1917 to the 1950s. Representing the Conservative Party, he was a member of Helsinki city council in 1924–46. For over twenty years,

he worked as the editor-in-chief of *Voima ja valo*, the leading Finnish journal in electrical technology. He was also an esteemed business historian writing e.g. a history of the HUT. *Bernhard Wuolle 75-vuotias*, Työntutkijain Kilta ry (Helsinki, 1951) pp. 7–13; *Suomen sähköinsinööriliitto ry, Matrikkeli 1926–1951*, ed. by Ole Fraser (Helsinki, 1951) pp. 295–6; *HS*, 5.11.1962; *US*, 5.11.1962.

265. B. Wuolle, *Aktuella finska kraftproblem*, Ingeniörsvetenskaps akademiens meddelande no. 51 (Stockholm 1925) pp. 10–14.

266. *Bernhard Wuolle 75-vuotias*, pp. 7–13; *Suomen sähköinsinööriliitto*, pp. 295–6; R. S. Halonen, 'Kustaa Bernhard Wuolle Suomalaisten teknikkojen seuran kunniajäsen', in *Bernhard Wuolle, Juhlajulkaisu* (Helsinki, 1956) pp. 33–6.

267. TFiFF was the organ of the Swedish-speaking engineering society in Finland, set up in 1880. The society's Finnish-speaking counterpart, 'Suomenkielisten teknikkojen seura', was founded in 1896 to 'promote technical literature in Finnish by developing technical vocabulary, arranging lectures and discussions as well as by other means'. Halonen, 'Kustaa Bernhard Wuolle', pp. 33–9; *Suomen teknillinen seura 1896–1976* (Helsinki, 1976) p. 5.

268. Since the 1840s electricity has been called *sähkö* in Finnish. The word is derived from the verbs 'säkenöidä sähähtäin', sparkle with hissing. In Hungarian it has been called *villany* (lightning) since the 1830s, in Icelandic *rafmagn*, in Irish *leictreachas* and in Welsh *trydan*. In contrast to the situation in Europe, electricity is quite regularly denoted by a vernacular word in the Asian languages such as Arabic, Hebrew, Chinese, Japanese, Vietnamese, Tibetan, Korean, etc. *VV*, 8 (1935) no. 12, pp. 263–7; *VV*, 33 (1960) no. 1, pp. 10–17.

269. For several years, the club of electric technicians, a division of The Society of Finnish-speaking Engineers, worked out lists of recently created electro-technical terms in Finnish and their counterparts in German and Swedish. This activity was to supplement similar glossaries which were published in the trade journals of many technical fields from the late nineteenth century. *VV*, 1 (1928) no. 2, pp. 59–62.

270. Ilmari Killinen, 'Sähkön käyttö ja sen kehitys Suomessa', *VV*, 2 (1929) no. 5–6, pp. 153–77; V. Veijola, 'Maamme sähköistys ja sähkölaitoksia koskeva lainsäädäntö', *VV*, 3 (1930) no. 11, pp. 282–3; V. Veijola, 'Sähköolojemme kehityksestä kuluneina vuosina', *VV*, 9 (1936) no. 5–6, p. 148.

271. Niilo Honkala, *Sähköturvallisuus tavoitteena, Sähkötarkastuslaitos r.y. 1928–1978* (Jyväskylä, 1978) pp. 153–72.

272. Wuolle, *Aktuella finska*, p. 10.

273. B. Wuolle, 'Valtion ja yksityisten tehtävät voimakysymyksen ratkaisussa', *TAik*, 11 (1921) no. 3, pp. 162–5.

274. The other members were professor Axel Juselius, a Finnish engineer educated in Switzerland, and a Master of Law and an MP of the liberal Progress Party Risto Ryti. In 1918 Juselius was succeeded by the junior engineer of the National Board of Public Roads and Waterways Hugo Malmi. Hugo Malmi, *Imatra ja sen kahlehtiminen* (Helsinki, 1949) p. 20.

275. *Valtiopäivät 1920, Liitteet V.11* (Helsinki, 1921) pp. 249–50; *Maakansa*, 3.12.1952.

276. This argumentation greatly resembles the viewpoints highlighted in B. Wuolle's proposal for the postwar development programme presented in 1916. B. Wuolle, *Kotimaisen tuotannon lisääminen* (Helsinki, 1916) pp. 32–42; *Valtiopäivät 1920, Asiakirjat, II osa* (Helsinki, 1921) pp. 59–61.

277. In the government, Magnus Lavonius (1870–1948) represented the Progress Party. By occupation, he was a textile engineer educated in Reutlingen, Germany. For four decades, he worked as a manager of textile factories in Tampere. *Suomen liikemiehiä, Vol. I* (Helsinki, 1930); *Who's Who in Finland 1950* (Helsinki, 1948).

278. Schauman and Laurén opposed the proposal primarily for reasons of principle. Their standpoint, however, was based on misunderstandings and insufficient knowledge of both this particular issue and Finnish parliamentarism. Schauman claimed that in 'sound parliamentarism', single MPs' motion cannot overrule the government's viewpoint. *Valtiopäivät 1920, Pöytäkirjat III* (Helsinki, 1921) pp. 2948–68, 2973.

279. Its explicit foreign models were the Trollhättan hydroelectric plant of 40 MW (later 124 MW), which the conservative government of Sweden built between 1905 and 1910, and the subsequent state-owned plants put in operation in Scandinavian countries. Wuolle, *Kotimaisen tuotannon lisääminen*, pp. 38–42; Hugo Malmi, 'Vesivoiman käyttöönotto Norjassa ja Ruotsissa sekä valtion suhde siihen', *TAik* 10 (1920) no. 1, pp. 2–19; Emil Fitger, *Finska utsikter* (Göteborg, 1924) pp. 16–18; *Kungl. vattenfallsstyrelsen 1909–34* (Stockholm, 1934) pp. 31–60; N. Lucas, *Western European Energy Policies: A Comparative Study* (Oxford, 1985) pp. 107–9.

280. *Valtiopäivät 1920, Pöytäkirjat III*, pp. 2956–7; Juha Kylämäki *et al.*, *'Imatra, vallaton hurjapää'. Sosiologinen tutkimus Imatrankosken valjastamisesta*, Turun Yliopiston tutkimuksia no. 99 (Turku, 1980).

281. *Koskivoimakomitean toimiston julkaisuja v. 1922*, no. 3 (Helsinki, 1922); Elna Kerkkonen, *Koskivoimatoimikunta vuosina 1917–1947* (Helsinki, 1950) pp. 34–5, 57–8.

282. Hugo Malmi (1878–1952) was an engineer educated in Finland. As a state official he made research trips to various European countries from 1909. He was especially interested in hydropower developments in Sweden and Norway. He supported the idea that in the building of state-owned power plants and an extensive transmission network, the government should secure a sufficient and inexpensive supply of electricity for the country's economy. When the viewpoint of active state intervention in the electricity supply business gained the upper hand in Parliament, Malmi, one of its most prominent promoters, became the director of the Imatra project for the years 1923–9. After successfully completing the construction of the Imatra hydroplant, he was nominated the first general manager of Imatran Voima Oy, a post he held until 1949, Fitger, *Finska utsikter*, pp. 16–18; Malmi, *Imatra*, p. 35.

283. *Koskivoimatoimiston julkaisuja v. 1926*, no. 10 (Helsinki, 1927) pp. 6–7.
284. Malmi, *Imatra*, p. 33.
285. Malmi, Imatra, pp. 36–40; Jaakko Auer and Niilo Teerimäki, *Puoli vuosisataa Imatran Voimaa* (Helsinki, 1982) pp. 44–69.
286. Riitta Hjerppe, *The Finnish Economy 1860–1985* (Helsinki, 1989) pp. 192–4, 237–48.
287. Lasse Nevanlinna and Gunnar Lax, 'Development of Hydro Power', in *Waterpower in Finland* (Tampere, 1969) pp. 21–8.
288. See Appendices A.3–A.4; Bror Sjögren, *Water Power Development in Finland* (Helsingfors, 1936) pp. 1–10.
289. V. Veijola, 'Yleiskatsaus Suomen sähköistykseen', *VV*, 10 (1937) no. 11, p. 223.
290. Svennilson defines an economy as a 'hydro country' if it produces more than 75 per cent of its electricity by waterpower. Ingvar Svennilson, *Growth and Stagnation in the European Economy* UN, ECE (Geneva, 1954) p. 117.
291. Veijola, 'Yleiskatsaus', p. 225; Appendix A.6.
292. Veijola, 'Yleiskatsaus', p. 224.
293. Harras H. Porkka, 'Teollisuutemme voimakysymys, Tilastollinen katsaus', *TAik* (1937) pp. 225–8; *VV*, 12 (1939) p. 125.
294. Viljo Castrén, 'Valtio voimantuottajana maassamme', in *Bernard Wuolle, Juhlajulkaisu* (Helsinki, 1956) pp. 87–9.
295. The other 50 per cent of the capital stock in Ab Abborfors Oy was possessed by The Insulite Co of Finland, an American-owned company set up in Kymi in 1930. On the eve of the Winter War, Abborfors, started up in 1931, was the sixth largest power plant in Finland. Among the ten largest plants, there was then also another one built and controlled by foreign capital. That was the 13.7 MW thermal power plant of the German-owned Oy Waldhof Ab, a pulp mill in Käkisalmi on lake Ladoga. *Sähkölaitostilasto v. 1937*, p. xiii.
296. Gösta M. Nordensvan (1886–1959) was the son of a Swedish-speaking telegram branch manager in Kuopio. In 1907 he graduated from Ingenieur Technicum Mittweida in Germany. After working as a draftsman in Allis-Chalmers Co. and three other companies in the USA for five years, he returned to Finland and worked as an engineer in the MESUH from 1913 to 1917. While general manager of ESVO in 1917–37, he also became director of several other private power companies and a board member of many important organisations. He crowned his career with the post of general manager of the big Nokia-concern in 1929–58. As an amateur economic historian, he wrote some historical articles and two business histories on companies under his command. G. M. Nordensvan, 'Imatran voimalaitossuunnitelmasta', *TAik* (1924) pp. 132–6; *Suomen sähköinsinööriliitto*, pp. 187–8.
297. Eino Isohanni, *Korpelan Voima* (Kokkola, 1971) pp. 52–5; Toivo Rinne, *Lounais-Suomen Sähkö-Osakeyhitö 1912–1962* (Turku, 1962) pp. 51–6.
298. Georg Christiernin, *Finland's Water-power and Electrification* (Helsingfors, 1924) p. 6.

299. Thomas Hughes, *Networks of Power* (Baltimore, 1983) p. 227.
300. *Sähkölaitostilasto v. 1937*, p. viii.
301. Lauri Haro and Jaakko Laine, 'Guyed Towers in High Voltage Transmission Lines', *Sähkö*, 43 (1970) no. 1, pp. 19–24.
302. *VV*, 2 (1929) p. 139.
303. *VV*, 12 (1939) p. 123; J. Veerus, 'Eesti elektrifiseerimise sihtjooni', *Tehnika Ajakiri* (Tallinn) (1939) no. 5–6, p. 116.
304. Matti Haro, 'Suomen voimatalous' (unpublished master's thesis in economics, Helsinki University, 1953).
305. *Statens vattenfallverk under fyra decennier* (Stockholm, 1948) p. 213.
306. Leslie Hannah, *Electricity before Nationalisation* (London, 1979) p. 121.
307. *Sähkölaitostilasto 1937*, app. 2.
308. Veijola, 'Yleiskatsaus', p. 228.
309. *Sähkölaitostilasto 1937*, app. 2.
310. *Sähkölaitostilasto 1960 and 1965* (Helsinki, 1961, 1967) app. 2.
311. Tauno Bergholm, 'Energiataloudesta', *VV*, 15 (1942) no. 1, pp. 8–10.
312. Appendix A.5–A.6; Svennilson, *Growth*, pp. 114–16; B. R. Mitchell, *European Historical Statistics, 1750–1970* (London, 1978) pp. 290–4.
313. J. Larho, 'Distribution of Electric Energy Abroad', *TAik* (1938) p. 390; see also Wuolle, *Aktuella finska*, pp. 3–4.
314. *Sähkölaitostilasto 1940* (Helsinki, 1941) pp. 22–3.
315. Larho, 'Distribution', pp. 390–2.
316. Literally translated, the title was 'The Power Chief of the Realm'. 'KHM:n voimatoimiston toiminta 1939–1944', *KHM, Teollisuus-osasto, Ja XVIII:I*, The Archives of the Ministry of Supply in the National Archives of Finland (hereafter AMS, NAF); 'Fighting the Electricity Shortage – Proof of the Strength of Finnish Advertising', *Finnish Trade Review* (1948) no. 54, p. 33; Harald Frilund, 'Kraft- och bränsle krisen 1939–1949', in *Kraft- och bränsleekonomi 1911–1961* (Helsingfors, 1961) pp. 104–14.
317. Sven O. Hultin, 'Harald Frilund, Minnesteckning', *STVAiFF*, no. 19.6 (Helsingfors, 1970) pp. 49–50; *Suomen sähköinsinööriliitto ry, Matrikkeli*, ed. by Ole Fraser (Helsinki, 1951) pp. 72–3.
318. In 1943 Frilund became the general manager of a distinguished engineering office, Consulting Ab. Three years later, he was also elected general manager of EKONO. He held both these important posts up to 1963 when he retired at the age of 74. Throughout the critical period 1946–53, as the chairman he also had a lot of power in the official Commission of Machinery Supply for Power Plants. Between 1955 and 1956, he was a central figure of the government's Energy Committee and a member of the Commission for Atomic Energy for 1957–63. In 1953, Frilund was honoured with the title of professor. *VV*, 37 (1964) no. 11, pp. 332–3.
319. A separate Power Section was established under the Department of War Economy which was a military institution ruled by the General Staff of the Army. The task of the Power Section was to secure the electricity supply for the production of military equipment and material. 'KHM:n voimatoimiston toiminta', AMS; Erkki Kinnunen,

Kriisiajan teollisuushallinto Suomessa vuosina 1930–1955, Metalliteollisuuden kehityksen valossa (Helsinki, 1967) pp. 55, 60.

320. 'KHM:n voimatoimiston toiminta'; B. Wuolle, 'Voimantuotanto laajentuvan teollisuuden tarpeeksi', *Talouselämä* (1941) no. 12–13, pp. 265–6.
321. Very little petrol was supplied for civil vehicles. The few available trucks were rather inefficient because most of them were fuelled with gas generated from firewood or charcoal. 'Muistio maan sähkökattilatarpeesta', Pro memoria by Harald Frilund 25.8.1943. *KHM, Teollisuusosasto Ja XVIII:1*, AMS.
322. 'KHM:n voimatoimiston toiminta'; G. M. Nordenswan, 'Voiman tuotanto ja omavaraisuuden vahvistaminen sen alalla', *Talouselämä* (1942) no. 11–12, p. 157.
323. Harald Frilund, 'Suomen voimatilanne 1918–1950' (29.4.1946), Mimeograph, The Archive of Enso-Gutzeit Oy in the Central Business Archives of Finland (hereafter AEGO, CBAF).
324. The corresponding figures for Finland of 1942 were 1500–2000 MW and 660 MW. *OSF 18 Industrial Statistics 1942* (Helsinki, 1944); Viljo Castrén, 'Suomen vesivoimavarat', *TAik* (1938) pp. 382–4; Erkki Aalto, 'Suomen vesivoimavaroista ja niitten rakentamismahdollisuuksista', *VV*, 18 (1945) no. 10, pp. 139–45.
325. *Pikku Jättiläinen*, ed. by Yrjö Karilas (Porvoo, 10th edn, 1943) p. 482; Axel C. Gadolin, *Ostkarelen – det finska gränslandet* (Malmö, 1941) pp. 91–2.
326. During the Winter War, Soviet air raids paralysed the transmission of hydroelectricity from the river Vuoksi to Helsinki. For the capital, electric power was then supplied from the Harjavalta hydroplant through the brand-new 70 kV transmission line. Lauri Forsblom, 'Etelä-Suomen Voimaosakeyhtiö', in *Bernhard Wuolle, Juhlajulkaisu* (Helsinki, 1954) p. 80; *Voiman miehet*, compiled by Antti Tuuri (Oulu, 1986) pp. 162–3.
327. 'KHM:n voimatoimiston toiminta'; Hans Christian Johansen, *The Danish Economy in the Twentieth Century* (London, 1987) p. 75.
328. 'KHM:n voimatoimiston toiminta', AMS.
329. Before the Winter War, in 1939, Finland's hydroelectric capacity totalled about 3200 GWh p.a. By the end of the Continuation War, it rose to nearly 3600 GWh p.a. and after the truce, in September 1944, it was about 2350 GWh p.a. *KM 1947:3 Voimatalouskomitean mietintö* (Committee Report) (Helsinki, 1947) pp. 12–15.
330. *KM 1947:3*, pp. 12–15; Gunnar E. Lax, 'Suomen rakennettu vesivoima vuoteen 1947 mennessä', *VV*, 19 (1947) no. 12, p. 214,
331. Frilund, 'Kraft', p. 105.
332. (Statute of 15.11.1945): 'Asetus, Valtioneuvoston päätös kaasu- ja sähköliesien säännöstelystä', *Suomen asetuskokoelma 1945*.
333. Jaakko Auer, *Suomen sotakorvaustoimitukset Neuvostoliitolle* (Porvoo, 1956) p. 262; Bartell C. Jensen, *The Impact of Reparations on the Post-War Finnish Economy* (Homewood, Illinois, 1966) pp. 1–19.
334. (Statute of 9.10.46): 'Asetus, Kansanhuoltoministeriön päätös sähkövoiman säännöstelystä', *Suomen asetuskokoelma 1946*.

335. 'KHM:n hintaosaston kiertokirje no. 23848, KHM:n teollisuusosaston kiertokirje no. 17/28/1440', *AEGO; HS*, 5.10.1947; *Revue sociale* (1948).
336. (Statute of 27.9.1947): 'Asetus, Kansanhuoltoministeriön päätös sähkövoiman säännöstelystä', *Suomen asetuskokoelma 1947*.
337. *Lalli*, 14.11.1947.
338. 'In November the country saved 60 million kWh or, calculated according to production costs, about FIM 240 million mostly in foreign currency. This conservation, achieved primarily by reducing residential lighting in urban areas, benefited industry which was hungry for power.' H. Frilund, Pro memoria, 'Sähkön säästöpropagandan merkityksestä ja tähänastisista saavutuksista', *KHM, Teollisuusosasto Ja XVIII:1*, AMS; Jarl Sarvas, 'Sähkövoimatilanne', *Suomen Työ* (1947) no. 10–12; *Palkkatyöläinen*, 7.11.1947; *Ylä-Vuoksi*, 13.12.1947; *Vapaa Sana*, 14.12.1947; *Keskilaakso*, 16.12.1947; *Uusi Aika*, 4.1.1948, 9.1.1948; *Eteenpäin*, 24.2.1948; *Kansan Työ*, 19.2.1948; *HS*, 11.12.1948; *Finnish Trade Review* (1948) no. 54, pp. 33–4.
339. 'Alustava muistio syys – talvikauden 1948–9 sähkönsäästöpropagandasta', *KHM, Teollisuusosasto Ja XVIII:1*, AMS.
340. With his authority and public 'sermons on electricity', Frilund impressed upon the Finnish energy policy his view that electricity, the elixir of the exporting industries, was all too valuable to be wasted for residential space and water heating. This conception was not challenged until on the very eve of Frilund's retirement in 1963. *Palkkatyöläinen*, 7.11.1947; *Eteenpäin*, 20.11.1951; *HBL*, 13.3.1969.
341. 'KHM, kiertokirjeet no. 23848 & no. 17/28/1440', AMS and AEGO; *US*, 7.8.1948.
342. *Revue sociale* (1940–8); Ilkka Ruotsetsaari, *Energiapolitiikan päätöksenteon ja hallinnon kehityksestä ja nykytilasta Suomessa*, University of Tampere, Department of Political Science, Research Reports 85 (Tampere, 1986) pp. 24–5.
343. Electricity prices were again regulated from July 1951 to December 1955. *US*, 3.3.1948; *Savo-Karjala*, 16.3.1948; *Uusi Päivä*, 18.3.1948; Matti A. Paavonsalo, 'Vesivoimatalouden rahoittaminen Suomessa toisen maailmansodan jälkeen' (unpublished master's thesis in economics, Helsinki University, 1957).
344. T. Bergholm, 'Yksityinen sähkön kulutus ja säästö', *Sähköviesti* (1943) no. 3, p. 3.
345. *TAik* (1946) pp. 137–9.
346. In fact, the shortage of electricity explained only partly why groundwood pulping was discontinued in winter 1947/8. In the previous years, the stocks of logs had been burnt as fuelwood and there was not enough labour force available to supply new raw materials for the pulp mills.
347. *US*, 5.11.1947.
348. *Pohjolan Työ*, 29.1.1948.
349. *Turun Sanomat*, 15.2.1948; *US*, 7.8.1948.
350. B. R. Mitchell, *European Historical Statistics, 1750–1970* (London, 1978) pp. 292–4.

351. *Talouselämä* (1948) no. 10.
352. *VV* (1949) p. 159; (1950) pp. 237–8.
353. *VV* (1950) p. 237.
354. *Lalli*, 14.11.1947.
355. Appendix Table A.6; Leslie Hannah, *Electricity before Nationalisation* (London, 1979) p. 428.
356. *TPO, Lähiajan talouspoliittinen ohjelma*, Talousneuvosto (Helsinki, 1947) pp. 113–14; *Komiteanmietintö* (hereafter *KM*) *1947:3 Voimatalouskomitean mietintö* (Committee Report) (Helsinki, 1947) pp. 6–11.
357. *KM 1947:3*, pp. 61–8.
358. *KM 1947:3* pp. 82–7.
359. François Caron, *An Economic History of Modern France* (London, 1979) pp. 223, 299; Leslie Hannah, *Electricity before Nationalisation* (London, 1979) pp. 329–56; Leslie Hannah, *Engineers, Managers and Politicians* (London, 1982) pp. 7–40.
360. The Finnish word *kansallistaminen* literally corresponds to the English term 'nationalisation', but it is more vague due to its having two meanings. On the one hand, it is defined as 'taking some enterprise into State possession in a capitalist society'. This 'British meaning' was also used in postwar Finland. On the other hand, in Finnish this term also denotes transferring the ownership of property from foreigners to private nationals, to local authorities or to the host government. The term has continually been used in the connection of the decolonisation and business of the Third World, e.g. on the issue of the Suez Canal in the 1950s. In this sense of the word, there was nothing to 'nationalise', i.e. expropriate from foreign owners, in the electric power sector of Finland, because practically all power plants and supply utilities were already owned by Finnish private capital, municipalities or the government.

    Except in cases of political agitation, the term *sosialisointi* (socialisation) came to mean in Finnish usage 'taking some enterprise into State possession in a socialist society'. Therefore in the case of the reorganisation of the Finnish electricity supply, the most apposite term in Finnish for the scheme under study is *valtiollistaminen* (purchasing by the State) which was, in fact, used by the committee as a synonym for *sosialisointi* and *kansallistaminen*. *KM 1950:41 Mon. Sosialisointikomitean mietintö no 1*, Mimeograph (Helsinki, 1950) pp. 1–6; Yrjö Enne, *Kansallistamisen edellytykset Suomessa* (Forssa, 1948) pp. 1–2.
361. The proposal of the Socialisation Committee was more moderate than the nationalisation carried out in practice in Britain. For example, contrary to the UK, municipal electricity supply utilities and well-managed private distribution utilities were to be left outside the nationalisation scheme. *KM 1950:41*, pp. 155–204; Hannah, *Electricity*, p. 349.
362. *Valtiopäivät 1951, Liitteet I-XII* (Helsinki, 1951) pp. 24–33; *Valtiopäivät 1952, Asiakirjat V* (Helsinki, 1953) Lak. al. miet. no. 50; *Valtiopäivät 1952, Pöytäkirjat II* (Helsinki, 1953) pp. 2036–9, 2095–7, 2107–8; *US*, 12.11.1952; *Kansan Työ*, 25.11.1952.

363. Jaakko Auer and Niilo Teerimäki, *Puoli vuosisataa Imatran Voimaa* (Helsinki, 1982) p. 93.
364. IVO's share was 45 per cent of all 110 kV lines in 1945 rising to 52 per cent in 1950, but when a part of IVO's transmission lines was changed to 220 kV lines, its share dropped to 40 per cent of 110 kV lines in 1951. Matti Haro, 'Suomen voimatalous' (unpublished master's thesis in economics, Helsinki University, 1953) p. 65; Pekka Nyyssönen, 'Power transmission', *Finnish Trade Review* (1963) no. 133, pp. 16–17.
365. *Sähkölaitostilasto v. 1965* (Helsinki, 1967).
366. *Kauppalehti*, 1.3.1950.
367. Lasse Nevanlinna, 'Present Day Finnish Power Industry', *Sähkö*, 38 (1965) p. 34.
368. *KM 1947:3*, pp. 15–18.
369. Ibid, pp. 18–40; Bror Nordqvist, 'The Power Economy of Finland', *Finnish Trade Review* (1947) no. 48, pp. 16–23; Bror Nordqvist, 'Voimalaitosten rakennusohjelmaa vielä laajennettava', *Talouselämä* (1948) no. 40, pp. 803–11.
370. Paavo Harve and Bror Nordqvist, 'National Resources of Fuels and Water Power in Finland', in *The Transmission of the Fourth World Power Conference, 1950*, vol. 1 (London 1952) pp. 189–91; Bror Nordqvist, 'Onko Suomen voimatalous turvattu lähivuosina?', *VV*, 24 (1951) pp. 148–9; *Eteenpäin*, 9.2.1952; *Vapaa Sana*, 2.11.1952; *Karjala*, 7.11.1952.
371. *HS*, 6.3.1951; *US*, 2.9.1951, 4.11.1951 and 11.11.1951; *Maakansa*, 19.9.1951; *Kansan Työ*, 3.10.1951 and 21.10.1951.
372. *Kauppalehti*, 13.11.1951; *US*, 15–17.11.1951; *HS*, 13–17.11.1951.
373. *Kauppalehti*, 14.11.1951.
374. *Kauppalehti*, 28.11.1951; *Eteenpäin*, 9.12.1951; *US*, 20.12.1951; *Savo-Karjala*, 27.1.1952; *Karjala*, 5.3.1952.
375. *Savo-Karjala*, 29.4.1952; *US*, 27.3.1954, 23.6.1954.
376. Aarno Kekoni, 'Oulujoen koskivoimahankkeen toteuttaminen', *Talouselämä* (1940) no. 47–48, pp. 577–80; E. A. Autio, *Merikosken vesivoimalaitos* (Oulu, 1951) pp. 40–118; Lasse Nevanlinna and Gunnar E. Lax, 'Development of Hydro Power', in *Waterpower in Finland* (Tampere, 1969) p. 25.
377. Nevanlinna and Lax, 'Development', p. 27; Uwe Siemen, 'Die Stellung der Binnengewässer im Strukturwandel Finnlands nach dem Zweiten Weltkriege', *Zeitschrift für Ostforschung*, 8 (1959) pp. 554–5.
378. Kustaa Vilkuna, *Lohi* (Keuruu, 1974) pp. 384–6.
379. Erkki Aalto (1904–84) was a son of a Lutheran priest from Finnish-speaking central Finland. After taking a civil engineer's degree at the Helsinki University of Technology, he worked as a planner of hydro-electric power plants and made several business trips to Germany, Switzerland, Sweden, England, the USA and many other countries. During his career, he took part in the planning and building of fifteen power plants. Like Fritz Wilén, Aalto was also politically active and keen to use the press for bringing his view to public attention. He

frequently gave interviews to journalists and wrote dozens of newspaper articles himself. In the mid-1950s, he became one of the first prominent proponents of nuclear power plants in Finland. As the director general of the State Railways (1956–66), he strongly supported the modernisation of steam-driven rolling stock, i.e. dieselisation and electrification, but he was forced to resign because of his peculiar ways of doing business. After retiring, he became conservative chairman of the town council of Espoo for the years 1977–80. *Who's Who in Finland 1950 and 1982* (Helsinki, 1949 and 1982); Pentti Oka, *Sähköinen asia, Valtionrautateiden sähköistäminen* (Helsinki, 1983) pp. 28–63.

380. P. Hintikka and J. Salmela, 'Isohaaran voimalaitos', *VV*, (1952) no. 7–8, pp. 134–9; Nevanlinna and Lax, 'Development', p. 27.

381. In the tributaries of the river Kemi, local power companies also built two small hydroplants in the late 1950s. Nevanlinna and Lax, 'Development'. p. 27.

382. The most vocal opponents of Kemijoki Oy were Erkki Aalto, who put forward the views of private power companies in press, and the conservative MP Tuure Junnila and an MP of the centrist Agrarian League, Veikko Vennamo, who campaigned in Parliament, *Kauppalehti*, 1.3.1950; *US*, 29.6.1951, 1.11.1952, 22.11.1952, 6.12.1952; *HS*, 1.11.1952, 29.11.1952, 3.12.1952; *Suomen Sosiaalidemokraatti*, 6.12.1952.

383. In January 1953, Urho Kekkonen was elected as the chairman of Kemijoki Oy's supervisory board and Penna Tervo its vice-chairman. Heikki Lehtonen, the professional engineer and the managing director of Imatran Voima Oy, was nominated as the managing director of Kemijoki Oy. *US*, 29.1.1953, 6.2.1953; *Kemijoki Oy:n vuosikertomus 1954*, p. 1.

384. *Valtiopäivät 1952, Pöytäkirjat*, pp. 1705–6, 2125–6, 2159–60.

385. To promote the national development scheme, Kekkonen wrote a popularised book with the appealing title 'Does our country have composure to become prosperous?'. Urho Kekkonen, *Onko maallamme malttia vaurastua?* (Helsinki, 1952); *HS*, 1.11.1952; *Kansan Työ*, 1.11.1952; *US*, 1.11.1952.

386. Lenin pronounced the slogan in the Eighth All-Russian Congress of Soviets in December 1920. V. I. Lenin, *On the Development of Heavy Industry and Electrification*, 4th edn (Moscow, 1979) pp. 84–9.

387. *HS*, 3.12.1952; *Maakansa*, 3.12.1951.

388. Nevanlinna and Lax, 'Development', p. 26.

389. *Sähkölaitostilasto 1945–1965* (Helsinki, 1947–66).

390. Hintikka and Salmela, 'Isohaaran voimalaitos', pp. 134–9; *Muistelmia sähkön vuosisadalta I* (Helsinki, 1985) p. 22.

391. *Suomen sosiaalidemokraatti*, 18.11.1948, 12.6.1952; *US*, 22.11.1949; *HS*, 6.4.1952; *Karjala*, 23.8.1952.

392. *US*, 1.10.1950; *Suomen Kuvalehti*, 14.10.1951; *Karjala*, 26.9.1951; *Savo-Karjala*, 17.11.1 951.

393. Mechanisation was, nevertheless, insufficient. Labour was used extensively. Because the northern provinces were plagued by persistent unemployment, a number of power plants were partly financed with the government's loans and subsidies for hiring unemployed. Due to the profuse use of unqualified labour and poor occupational safety, over fifteen labourers might die in accidents at work during the construction of one single hydroplant, such as was the case in Petäjäskoski in Lapland. *HS*, 15.4.1949, 29.7.1951, 15.4.1953; *Uusi Suomi*, 15.4.1953; *Voiman miehet*, compiled by Antti Tuuri (Oulu, 1986) p. 108.

394. Auer and Teerimäki, *Puoli vuosisataa*, p. 293.

395. See, for example, the correspondence between Enso-Gutzeit Oy and the representatives of Metropolitan Vickers Ltd on the delays of deliveries. The generators for the Tainionkoski power plant were delayed by 6–18 months. Probably they constituted a too-demanding delivery for Metropolitan Vickers, because it had never before made such large units. In some other cases, the deliveries were delayed even longer. *The Archives of Enso-Gutzeit Oy*, CBAF; *HBL*, 20.2.1949; *Savo-Karjala*, 22.7.1949; *Etelä-Saimaa*, 22.7.1949.

396. Nordqvist, 'Onko Suomen voimatalous turvattu?', pp. 147–50.

397. It was claimed that the 'filibustering and bureaucracy of the Licence Board' delayed the completion of the plant by a year. *Turun Sanomat*, 6.11.1948; *US*, 30.12.1949.

398. *Etelä-Saimaa*, 27.7.1946; Nordqvist, 'The Power Economy', p. 23; *HS*, 26.2.1952.

399. Paavo Siltamaa, 'Generators', in *Waterpower in Finland*, p. 80.

400. Satu Tuuva, *Vesivoimalaitosinvestointien rahoitus vuosina 1945–1965* (mimeographed report for the research project 'Energy Economy of Finland', Helsinki University, 1984); Satu Tuuva, 'Rahoitusvaikeudet vesivoiman rakentamisen esteenä toisen maailmansodan jälkeen', *Sähkö* (1985) no. 3B, pp. 6–7.

401. Matti A. Paavonsalo, 'Vesivoimatalouden rahoittaminen Suomessa toisen maailmansodan jälkeen' (unpublished master's thesis in economics, Helsinki University, 1957) pp. 53–5.

402. J. E. Kilpeläinen, 'Voimalaitosten rakennustoiminnasta maassamme ja sen rahoituksesta', *Kela pyörii* (1958) no. 3. p. 20; Heikki Lehtonen, 'Voimatalouden kasvun rahoittaminen', *VV*, 29 (1929) pp. 235–56; Siemen, 'Die Stellung der Binnengewässer', pp. 556–7.

403. *VV*, 13 (1940) no. 7–8, p. 30; *Sähkölaitostilasto v. 1940 and 1946* (Helsinki, 1941, 1947); G. M. Nordensvan, *Länsi-Suomen Voima* (Helsinki, 1946) pp. 73–96.

404. Auer and Teerimäki, *Puoli vuosisataa*, pp. 61–2.

405. Timo Järvikoski and Arto Kankaanpää, *Suomen voimatalouden yhteiskunnallista tarkastelua*, Vaasan kauppakorkeakoulun julkaisuja, Tutkimuksia no. 38 (Vaasa, 1976) pp. 31–2.

406. *Power on the Oulu River*, Oulujoki Oy (Helsinki, 1953) pp. 3–5; Markku Nurmi, *Energiatalous* (Jyväskylä, 1980) p. 203.

407. Nurmi, *Energiatalous*, p. 204.

408. Ibid, p. 202; Järvikoski and Kankaanpää, *Suomen voimatalouden yhteiskunnallista tarkastelua*, p. 50.

409. Auer and Teerimäki, *Puoli vuosisataa*, pp. 135–6.

410. Nurmi, *Energiatalous*, p. 198.
411. Järvikoski and Kankaanpää, *Suomen voimatalouden yhteiskunnallista tarkastelua*, appendices 2, 13, 14.
412. Linkama, 'Katsaus', p. 104.
413. *Sähkölaitostilasto v. 1960* (Helsinki, 1960) p. 5; Väinö Pulkkinen, 'Tilastollinen yleiskatsaus Suomen sähkölaitoksiin vuonna 1965', *Sähkö*, 39 (1966) no. 10, p. 343.
414. Bror Nordqvist, 'Suomen energiavaroista', *VV*, 26 (1953) no. 5–6, p. 95; Nevanlinna, 'Present Day', p. 35.
415. *Sähkölaitostilasto v. 1946*, (Helsinki, 1947); Nordqvist, 'Onko Suomen voimatalous turvattu?', p. 149; Nevanlinna, 'Present Day', p. 34.
416. Nordqvist, 'Suomen energiavaroista', p. 95; Linkama, 'Katsaus', p. 106; Nevanlinna, 'Present Day', p. 35.
417. Smeds, 'District Heating', p. 10.
418. Heikki Lehtonen, 'Suomen kaukovoimansiirrosta', *TAik* (1951) no. 9, p. 380.
419. Ibid.
420. The exception was the line of 287 kV built in 1935 between Boulder Dam and Los Angeles in the USA. L. Haro, 'Suomen ensimmäinen 400 kV johto', *VV*, 30 (1957) p. 238.
421. Lasse Nevanlinna, '400 kV voimansiirtojärjestelmämme', *VV*, (1957) pp. 243–4; Linkama, 'Katsaus', pp. 104–5.
422. Haro, 'Suomen ensimmäinen 400 kV johto', p. 238.
423. In Finland, overhead lines have been preferred to underground transmission lines. Obtaining wayleaves was not a great difficulty in the sparsely populated country. Above all, overhead lines were more economical in Finnish conditions. In 1965 only 6 per cent of all the transmission lines over 0.5 kV consisted of underground cables. *Sähkölaitostilasto v. 1965*, p. 7; Auer and Teerimäki, *Puoli vuosisataa*, pp. 140–1.
424. A. Hiekko, 'Maamme kaukovoimansiirtoverkon käyttövarmuus', *VV*, 31 (1958) no. 12, p. 249.
425. Rauno Linkama, 'Ruotsin ja Suomen voimataloudellisesta yhteiskäytöstä', *VV*, (1960) no. 11. p. 238.
426. Ibid.
427. Lasse Nevanlinna, 'Pohjoismaiden voimayhteistyö ja NORDEL', *Sähkö*, 42 (1969) no. 7–8, pp. 199–204; Auer and Teerimäki, *Puoli vuosisataa*, pp.4146–8.
428. The frequency of alternating current is synchronised between the Nordic power systems (except the Danish Jylland which is synchronously interconnected with the power pool of West-Central Europe), but a high voltage direct current back-to-back link was constructed between the Finnish and Soviet power systems. Antero Jahkola, 'Co-operation between Power Systems in Western Europe', *Sähkö*, 40 (1967) no. 5–6, pp. 144–9; Lasse Nevanlina, 'Nordel and Nordic Co-operation in the Field of Power', *Sähkö*, 46 (1973) no. 11, pp. 492–8; Yrjö Laiho, 'Power and Frequency Control in the Nordic Synchronous Power Pool', *Sähkö*, 46 (1973) no 11, pp. 499–501; Viktor P. Stepanov and Heikki J. Heikkilä 'Electric Energy Imports from the USSR to Finland', *Sähkö*, 56 (1983) no. 10, pp. 54–7.

429. Pekka Rekola, 'Suomen energiapolitiikka', *Sähkö*, 43 (1970) no. 7–8, p. 170.
430. Erkki Laurila, *Atomienergian tekniikka ja politiikka* (Helsinki, 1967) pp. 242–4.
431. Väinö Pulkkinen, 'Tilastollinen yleiskatsaus Suomen sähkölaitoksiin v. 1962', *VV*, 36 (1963) no. 9, p. 214; *OSF Energy Statistics 1987* (Helsinki, 1988) p. 65.
432. *Hallituksen energiapoliittinen selonteko eduskunnalle 21.3 .1978 sekä ryhmäpuheenvuorot*, Ministry of Trade and Industry, Energy Department, Series C:5 (Helsinki, 1978) p. 25.
433. Jaakko Auer and Niilo Teerimäki, *Puoli vuosisataa Imatran Voimaa* (Helsinki, 1982) p. 220.
434. Sven-Olof Hultin, 'Suomen vesivoima käännekohdassa', *Sähkö*, 40 (1969) no. 9, p. 213.
435. *OSF 42:6 Energy Statistics 1986* (Helsinki, 1987) p. 65.
436. Risto Mäntynen, 'Using a Chain of Hydroelectric Plants for Diurnal Regulation', *Sähkö*, 39 (1966) no. 9, pp. 256–8.
437. Hultin, 'Suomen vesivoima', p. 213.
438. Matti O. Koskinen, 'Sähköenergian tarve ja sen tyydyttäminen Suomessa tällä vuosikymmenellä', *Sähkö*, 38 (1965) no. 7–8, p. 206.
439. The nominal capacity of producing engines in district heating rose from 212 MW to 1085 MW between the beginning of the years 1965 and 1977. *OSF 42:6 Energy Statistics 1986*, p. 72.
440. *Hallituksen energiapoliittinen selonteko*, p. 69.
441. L. Nevanlinna, 'Joining the Finnish and Swedish 400 kV Supergrids', *Sähkö*, 41 (1968) no. 2, pp. 33–6; L. Nevanlinna, 'Nordel and Nordic Co-operation in the Field of Power', *Sähkö*, 46 (1973) no. 11, pp. 492–8; *HS*, 7.3.1979.
442. Imatran Voima Oy and V/O Energomashexport completed two parallel lines of 400/330 kV between Lappeenranta in Finland and Leningrad in 1981 and 1982 respectively. Viktor P. Stepanov and Heikki J. Heikkilä, 'Electric Energy Import from the USSR to Finland', *Sähkö*, 56 (1983) no. 10, pp. 54–6.
443. Seppo Ruohonen, 'Voimalaitosten yhteiskäyttö', *Sähkö*, 57 (1984) no. 12, pp. 20–1.
444. Ibid, pp. 20–5.
445. Erkki Laurila, 'Atomienergia ja Suomi 1945–62' in *Atomienergia ja Suomi – Atomenergin i Finland 1945–1962*, ed. by Ilkka Mäkipentti and Osmo Ranta (Helsinki, 1962) pp. 4–11.
446. The Finnish delegation was headed by professor Erkki Laurila (born in 1913) who was the government's aide and the country's topmost expert in nuclear physics from the 1950s to the 1970s.

Laurila's life story from a poor country boy to a man of distinction fits well with the adored Finnish pattern of the successful rise of a nationally prominent figure. After renunciations and intensive studies, he took his doctor's degree in physics at the University of Helsinki at the age of 28. Except for one brief visit to Germany in

1939, he did not make any study tours abroad before becoming professor of technical physics at the Helsinki University of Technology in 1945. Thereafter, he travelled a great deal in the West and East representing Finland in many scientific congresses, international organisations and negotiations. He greatly influenced the transfer of know-how on nuclear power technology into Finland and the creation of the education programme in nuclear physics. In 1963 the government granted him the title of academician. Erkki Laurila, *Muistinvaraisia tarinoita* (Helsinki, 1982); *Muistelmia sähkön vuosisadalta II*, ed. by Sakari Maaniemi (Helsinki, 1985) pp. 841–3.

447. Ibid: Laurila, *Atomienergian tekniikka*, pp. 73–81, 155–64; Osmo Ranta, 'Nuclear Energy Comes into its Own', *Sähkö*, 38 (1965) no. 1, p. 2.
448. Laurila, 'Atomienergia', pp. 7–8.
449. Laurila, *Atomienergian tekniikka*, pp. 164–78.
450. (Statute of 25.10.1957), 'Atomienergialaki', *Suomen asetuskokoelma 1957*, no. 356.
451. *Komiteanmietintö 1956:28 Mon. Energiakomitean mietintö* (Committee Report) (Mimeograph, Helsinki, 1956) pp. 3–11, appendix 1; Sven-Olof Hultin, 'The Prospects of Atomic Energy in Finland', *Finnish Trade Review* (1957) no. 100, p. 166.
452. Hultin, 'The Prospects', p. 166.
453. The country needed international consent to obtain highly radioactive materials. The Paris Peace Treaty of 1948 between Finland and the Allies, the Soviet Union and the UK, prohibited Finland from possessing nuclear weapons. Laurila, 'Atomienergia', pp. 13–22; Laurila, *Atomienergian tekniikka*, pp. 191–222; Jaakko Ihamuotila, 'Suomen ydinvoimalaitoshistoriikki', *TAik* (1968) no. 9, pp. 63–6.
454. Laurila, 'Atomienergia', pp. 22–3; L. Nevanlinna, 'Paving the Way for Nuclear Power in Finland', *Sähkö*, 38 (1965) no. 12, pp. 397–99.
455. Nevanlinna, 'Paving the Way', p. 398.
456. IVO's managers who were then not on good terms with the government have a totally different story to tell. They consider their hasty open tender competition was a smart countermove.

    In 1965, the general manager of the company Heikki Lehtonen had received a postcard with only one word and initials: 'Greetings, UK'. With his closest men, Lehtonen supposed the sender was president Urho Kekkonen who was then on holiday on the Black Sea coast. They deduced that Kekkonen had decided something important with the Soviet leaders and surmised: Finland will order a NPP from the Soviet Union. 'We got busy to obtain as much technical and economic know-how from the Western manufacturers as possible, because we thought they would immediately shut their doors on us when it became public knowledge that Finland was purchasing a NPP from the Soviet Union', recalls the former manager Pentti Alajoki. Laurila, *Atomienergian tekniikka*, pp. 5278–82; *Muistelmia sähkön vuosisadalta I*, ed. by Sakari Maaniemi (Helsinki, 1985) p. 31; Tuomas Keskinen, *Idänkauppa 1944–1987* (Porvoo, 1987) p. 315.

457. Laurila, *Atomienergian tekniikka*, pp. 255–77; *Ydinvoiman käyttöönotto Suomessa*, ed. by Antero Jyränki, Tampereen yliopisto, Hallintotieteiden laitos, Raportti B2/1979 (Tampere, 1979) pp. 54–5; Antero Jyränki, 'Ydinvoima tuli kuin itsestään', *HS*, 10.6.1979.
458. *Valtioneuvoston pöytäkirja*, 31.3.1867; *Ydinvoiman käyttöönotto*, pp. 54–6;
459. Ihamuotila, *Suomen ydinvoimalaitoshistoriikki*, pp. 63–6; Erkki Laurila, 'Det ligger alltför mycket politik i ordet "atom"', interviewed by Björn Palmén *Forum* (1969) no. 17, pp. 18–21.
460. *HS*, 26.7.1968.
461. The plan would have meant an almost 60 per cent increase on the existing capacity. However, the construction of the co-generating NPPs in the capital had later to be abandoned and the realisation of the rest of the plan was substantially curtailed. *Energian tarve ja talouskasvu I*, Imatran Voima Oy (Helsinki, 1979) app. 6.5; Jouko Mikola, 'Nuclear Power in the Helsinki City Energy Supply', *Sähkö*, 44 (1971) no. 7–8, pp. 167–75; Kaarlo Kirvelä, 'Nuclear Power Plants for District Heating', *Sähkö*, 45 (1972) no. 2, pp. 87–91.
462. The USSR engaged to supply nuclear fuel elements ready for use and afterwards to receive the highly radioactive fuel wastes of the plant. *Nuclear Energy in Finland*, Finnish Atomic Energy Commission (Helsinki, 1983) p. 8.
463. Later V/O Technopromexport changed its name to V/O Atomenergoexport. Ibid, pp. 179–85; *Ydinvoiman käyttöönotto*, pp. 65–6.
464. Auer and Teerimäki, *Puoli vuosisataa*, pp. 180–90.
465. *HS*, 3.8.1981.
466. These dates refer to commercial operations which began later than originally planned: in the case of the TVO 1 NPP, one year and two months; and in that of the TVO 2 NPP, two years. The start-ups of TVO's plants took place in September 1978 and February 1980 respectively. *HS*, 7.7.1979, 20.7.1979, 11.9.1979; Pekka Lehtinen, *Operation of Finnish Nuclear Power Plants, First Quarter, 1986*, Finnish Centre for Radiation and Nuclear Safety (Helsinki, 1986) p. 5; *Industrial Power Company Ltd, Annual Reports 1975–1982* (Helsinki, 1976–83).
467. Auer and Teerimäki, *Puoli vuosisataa*, pp. 184–5; *TVO, Teollisuuden Voima Oy* (Helsinki, 1981) p. 2.
468. These figures refer to the situation in 1981. By contrast, in 1982 when the Olkiluoto II plant was finally taken over by TVO, the total plant payment expenditure of the company amounted to 4846 million marks. *HS*, 3.8.1981; *Industrial Power Company Ltd, Annual Report 1981 and 1982* (Helsinki, 1982 and 1983).
469. *World Energy Supplies*, UN (New York 1983–7); *Petroleum Economist*, November 1987. G. F. Ray, *The Diffusion of Technology in Finland*, ETLA Discussion papers no. 258 (Helsinki, 1988).
470. Risto Hämäläinen, *Jugoslavian energiatalouden kehitysnäkymät, Sähköntuotanto Jugoslaviassa vuoteen 2000*, Vientikoulutussäätiön julkaisuja no. 5:137 (Belgrade–Helsinki, 1982) pp. 20–2; *Petroleum Economist* (Nov. 1987).

471. 'From Post-war Electrification to Nuclear Plants: An Interview with Kalevi Numminen', *Finnish Trade Review* (1983) no. 2, p. 35.
472. Project leader Kalevi Numminen was one of the young engineers trained in the Finnish education programme in nuclear power technology. In 1982 he was nominated managing director of IVO. Therefore, the programme did not produce only qualified engineers but also prominent business managers. Another example of successful trained postgraduates is Jaakko Ihamuotila who in 1980 became managing director of Neste Oy, the largest oil refining company in the Nordic countries, Keskinen, *Idänkauppa*, pp. 319.
473. It has been said that 'in the construction of hydropower, it is more difficult to solve the issues on riparian rights and gain the permits from the authorities than to master technology'. *Voiman miehet*, compiled by Antti Tuuri (Oulu, 1986) pp. 100, 105–24; Ilmo Massa, *Ihminen ja Lapin luonto* (Helsinki, 1983) pp. 108–25.
474. Juha Kylämäki *et al.*, *'Imatra, vallaton hurjapää'*, Turun yliopisto, Sosiologisia tutkimuksia 99 (Turku, 1980) pp. 18–28.
475. Massa, *Ihminen*, pp. 108–25.
476. Ibid, p. 123; Timo Järvikoski and Juha Kylämäki, *Isohaaran padosta Kemijoen karvalakkilähetystöön*, Turun yliopisto, Sosiologisia tutkimuksia 103 (Turku, 1981).
477. *Suomen Luonto* (1962) no. 2, p. 75; (1964) no. 3, p. 106; (1974) no. 3, p. 121.
478. Martti Mutru *et al.*, *Eri mieltä ydinvoimasta*, Yleisradion julkaisusarja 51 (Lahti, 1976); Ingmar Kommonen and Dennis Rundt, *Finlands kärnkraft* (Helsingfors, 1976).
479. The accident at the American Three Mile Island NPP in Harrisburg in March 1979 and the referendum on nuclear power in Sweden in March 1980 caused substantial changes in public opinion in Finland, *HS*, 4.12.1979; Laurila, *Atomienergian tekniikka*, p. 253; *Sähkö*, 59 (1986) no. 1, p. 34.
480. *Sähköviesti*, 39 (1977) no. 2, p. 3.
481. The strike applied to the activities of proper power companies but not to the electricity production of municipal utilities or to the self-generation of industry. It halted the operation of all thermal power plants of the power companies except the Loviisa NPP. Hydroelectric plants were, by contrast, running. At its worst, the strike caused a shortage amounting to 20–25 per cent of the national power requirement. *Sähköviesti*, 39 (1977) no. 3, p. 3.
482. During the same year, other interruptions also took place in the electricity supply which attracted general attention to the question of the reliability of the electricity supply. In the Province of Mikkeli, an autumn storm brought down trees which damaged the distribution network in more than 2000 places. This exceptionally large power cut left about 90 per cent of consumers in the area without electricity for between a couple of hours and four days (7–11 September). The conclusion drawn from this accident as well as from the New York blackout on 21–22 July 1977 was that there were no economic possibilities for a completely troublefree distribution of electricity. Antti Itkonen, 'Electricity Supply Systems in the United States and the New York Blackout', *Sähkö*, 51 (1978) no. 1, pp. 8–13; Tauno Leppämäki and Unto Mökkönen, 'Major Power Cut in Savo', *Sähkö*, 51 (1978) no. 1, pp. 13–17.
483. *Sähköviesti*, 39 (1977) no. 3, p. 3.
484. *Maaseudun sähköistämistyöryhmän mietintö*, Ministry of Trade and Industry, Energy Department, Series C:1 (Helsinki, 1978) pp. 1–4.

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1. Albert O. Hirschman, *The Strategy of Economic Development* (New Haven, 1959) pp. 98–112.
2. Göran Ahlström, *Engineers and Industrial Growth* (London, 1982) p. 14.
3. The educational establishment grew out of a technical real school, founded in 1849, and transformed into a polytechnic institute in 1879. B. Wuolle, *Suomen teknillinen korkeakouluopetus 1849–1949* (Helsinki, 1949) pp. 41–314; Tauno Pyökäri, 'Sähkömiehet opintiellä', *Sähköinsinööriliitto 1926–1976* (Tampere, 1976) p. 79.
4. This was only one year later than the Imperial College, the first British university of technology, was founded. As early as 1908, the Helsinki University of Technology (HUT) was given the right to confer doctor's degrees. The German *Technischen Hochschulen* had received this right in 1900, being the first in the world, but the Swedish counterparts in Stockholm and Gothenburg, for example, were granted it only in 1927 and 1937, respectively. Finnish engineers in general were not, however, very keen to benefit from this right. At the HUT, the first doctor's degree was taken in chemistry in 1911, but the first doctors in electrical engineering completed their studies only in 1946. Ahlström, *Engineers*, pp. 34–6, 80; Wuolle, *Suomen teknillinen korkeakouluopetus*, pp. 553–61.
5. By estimation, in Finland there was one engineer with a higher technical education from abroad to four engineers with domestic qualifications. In Sweden, the corresponding relationship was one to nine. By contrast, the proportion of foreigners accounted for 13–23 per cent of all students in the German universities of technology between 1895 and 1914. It is likely that most foreign students left Germany after graduation. *Hochschul-Nachrichten* (1897) no. 85, pp. 4–6; (1899) no. 6, pp. 117–18; (1901) no. 8, p. 179; (1903) no. 7, p. 154; *Deutsche Hochschulstatistik*, Band 5, Sommerhalbjahr 1930 (Berlin, 1930) p. 10; Ahlström, *Engineers*, pp. 25–6.
6. Ahlström, *Engineers*, p. 100; *SYF 1929* (Helsinki, 1929).
7. (Oskari Terhi), 'Suomen sähköistäminen ulkomaalaisten käsissä', *TAik* (1921) no. 3, pp. 257–8, see also pp. 454–5, 507–9; 583–4, 675.
8. *Deutsche Hochschulstatistik 1930*, p. 112; *Suomen teknillinen korkeakoulu, Vuosikertomus 1929–1930* (Helsinki, 1930).
9. *TAik* (1912) no. 5, pp. 108–9; (1921) no. 11, pp. 663–4; Wuolle, *Suomen teknillinen korkeakouluopetus*, pp. 573, 583–4.
10. Wuolle, *Suomen teknillinen korkeakouluopetus*, pp. 529–30; Pyökäri,

'Sähkömiehet', pp. 142–3; Martti Tiuri, 'Finnish University-Level Training in Electrotechnology, Progress and Development', *Sähkö*, 39 (1966) no. 7–8, pp. 188–90.

11. In the late 1960s, an 'engineer explosion' also took place in the Swedish education system. Tiuri, 'Finnish University-Level Training', pp. 188–90; Lars Pettersson, *Ingenjörsutbildning och kapitalbildning, 1933–1973* (Lund, 1983) pp. 104, 113–14, 132.
12. The archive of the National Board of Vocational Education; The Annual Reports of the Helsinki and Tampere University of Technology and the University of Oulu 1911–75; Pyökäri, 'Sähkömiehet', p. 140.
13. Matti Peltonen, 'Teknikoiden ja insinöörien koulutus tulevaisuudessa teollisuuden kannalta katsottuna', *Höyrykoneesta tietotekniikkaan* (Helsinki, 1986) p. 140.
14. *Yearbook of Nordic Statistics 1979* (Stockholm, 1980); *Tilastotiedotus KO 1978:9*, CSOF (Helsinki, 1978).
15. *OSF 18 Industrial Statistics 1910–1977* (Helsinki, 1912–79).
16. *Sähkölaitostilasto 1950* (Helsinki, 1951) p. 23; *VV*, 36 (1963) no. 9, p. 218.
17. The Swedish economic historian Lars Pettersson is sceptical about the significance of the multitude of engineers. He pointed out that over-investment in obsolete engineering education might be waste. 'The large number of engineers available in Sweden around 1970 for a relatively low wage was not a growth-creating factor sufficient to break the stagnation.' Thereby, the content of education and the qualifications of engineers are more important than their large number. Pettersson, *Ingenjörsutbildning*, pp. 124–5, 133–4.
18. These watercourses are known by their main streams: the rivers Tornio, Kemi, Ii, Oulu, Kokemäki and Kymi flow into the Baltic Sea, the river Vuoksi empties into lake Ladoga and the river Paats into the Arctic Ocean. In total, their catchment areas in the Finnish territory constitute 231 000 sq. km or 68 per cent of the country's total area excluding the sea. *SYF 1984* (Helsinki, 1985).
19. Heikki Simojoki, 'Hydrology in Finland', *Waterpower in Finland* (Tampere, 1969) p. 40.
20. By comparison, the Danube – the second largest river in Europe – discharges a little over 200 000 Mm^3 into the sea annually. Simojoki, 'Hydrology', p. 41.
21. Between the mid-1960s and the early 1980s, specialists' estimate on the economically utilisable potential of Finland increased about 50 per cent, from 13 TWh to approximately 20 TWh p.a.: see pages 132–3. *KTM:n vesivoimatyöryhmän mietintö*, Ministry of Trade and Industry, Energy Department, Series C:12 (Helsinki, 1981) pp. 3–8.
22. H. Frilund, 'Suomen vesivoimavarat', *VV*, 23 (1953) p. 27; Mikko Raatikainen, 'Niitä on 187 888', *Suomen Kuvalehti* (1987) no. 24B, pp. 20–3.
23. From the twelfth century to 1809, Finland was annexed to Sweden.
24. E. J. Manner, *Yleiskäyttö vesioikeudellisena käsitteenä* (Vammala, 1953) pp. 125–6.

25. The principle of the private ownership of waters is applied to Norwegian and Danish law and, in respect of lakes and rivers only, to English law.
26. Earlier in the seventeenth century, for fiscal reasons the Swedish government tried to limit the number of peasants' flourmills for household use and direct all grinding of grain to the taxable mills controlled by the State. Because the authorities harassed equally hand, wind and watermills for household use, the motivation of their measures had no connection with the law relating to rivers and watercourses. Esko Aaltonen, *Länsi-Suomen yhteismyllyt* (Helsinki, 1944) pp. 25–30.
27. In the first half of the autonomy period, the new legislation favoured the defensive law of water rights at the expense of the lucrative one. This can clearly be noticed e.g. from the Imperial decree of 12.12.1817, the statute of 8.3.1820, the Imperial decree of 15.2.1841, and the statute of 17.9.1860. See also Kyösti Haataja, *Vesioikeus vol. III: Rakentaminen vesialueelle* (Porvoo, 1959) pp. 41–2.
28. (Statute of 23.3.1868), 'Asetus vedenjohdoista ja vesilaitoksista', *Suomen Suuriruhtinaanmaan asetus-kokous* (1868) no. 14.
29. *KM*, 1895:7 (Helsinki, 1895) p. 22
30. (Statute of 16.2.1889), 'Lisäys 23 p:nä maaliskuuta 1868 annetun, vesijohtoja ja vesilaitoksia koskevan asetuksen 33 §:ään', *Suomen Suuriruhtinaanmaan asetus-kokous* (1889) no. 6.
31. (Statute of 23.7.1902): 'Vesioikeuslaki', *Suomen Suuriruhtinaanmaan asetus-kokous* (1902) no. 31, 5 §.
32. Reino O. Hinkka, 'Legal Aspects of Hydropower', in *Waterpower in Finland* (Tampere, 1969) p. 30.
33. Haataja, *Vesioikeus vol. III*, p. 117.
34. (Statute of 23.7.1902), 5 §.
35. Hinkka, 'Legal Aspects', p. 32.
36. Haataja, *Vesioikeus vol. III*, p. 117.
37. (Statute of 13.10.1916): 'Armollinen asetus jakolaitoksesta', *Suomen Suuriruhtinaanmaan Asetuskokoelma* (1916) no. 82.
38. The possibility of splitting a waterfall with its banks into a separate parcel of land from a larger estate was mentioned by legislators for the first time in a decree of 1895. It was made more accurate by the Water Act of 1902. See the Statutes of 12.6.1895 and 23.7.1902.
39. *Imatra Power Plant* (Helsinki, 1933) pp. 6–7; Jaakko Auer and Niilo Teerimäki, *Puoli vuosisataa Imatran Voimaa* (Helsinki, 1982) pp. 54–5.
40. Jalm. Maunola, *Vesivoimat* (Porvoo, 1930) p. 10.
41. Juha Kylämäki *et al.*, '*Imatra, vallaton hurjapää*', Turun yliopisto, Sosiologisia tutkimuksia 99 (Turku, 1980).
42. (Statute no. 61 of 2.2.1934): 'Laki vesioikeuslain I luvun 5 §:n muuttamisesta', *Suomen asetuskokoelma* (1934).
43. (Statute no 62 of 2.2.1934): 'Laki eräiden kiireellisten vesioikeusasiain käsittelemisestä', *Suomen asetuskokoelma* (1934).
44. (Statute of 5.5.1939): 'Laki vesioikeuslain muuttamisesta', *Suomen asetuskokoelma* (1939) no. 134.

45. Jorma Korhonen, 'Koskisodan uudet pyörteet', *HS*, 23.10.1983, p. 27.
46. (Statute of 19.7.1940): 'Laki eräiden vesioikeusasiain poikkeuksellisesta käsittelystä', *Suomen asetuskokoelma* (1940) no. 383.
47. (Statute of 21.3.1941): 'Laki toimenpiteistä vesivoiman käyttöön ottamisen helpottamiseksi', *Suomen asetuskokoelma* (1941) no. 196.
48. Hinkka, 'Legal Aspects', p. 33; *OSF 42:4 Energy Statistics 1984* (Helsinki, 1985) p. 61.
49. Simo Jaatinen, 'Uusi vesilaki ja sen vaikutus vesirakennustoimintaan', *Rakennustaito*, 57 (1962) no. 7 pp. 229–34.
50. Ibid.
51. Hinkka, 'Legal Aspects', p. 34.
52. Viljo Castrén, 'Regulating dams', in *Waterpower in Finland* (Tampere, 1969) p. 66.
53. Vietti Nykänen, *Rautabetoni* (Helsinki, 1911) pp. 1–6. This is the first book on reinforced concrete published in Finnish. It is based mainly on the author's notes on lectures held at the Charlottenburg University of Technology in Berlin.
54. Jaakko Holm and Antti Leskelä, 'Padot', *Vesirakenteiden suunnittelu*, RIL 123 (Helsinki, 1979) p. 56.
55. From 1869 up to the early 1890s, Portland-cement was produced in one minor factory, Savio Ab near Helsinki, *HD*, 30.7.1878; A. K. Kroupski, 'Cement Trade', in *The Industries of Russia vol. I* (St Petersburg, 1893) p. 273; *Kauppalehti*, Kotimaisen teollisuuden numero (1911) p. 50.
56. *Kauppalehti*, Kotimaisen teollisuuden numero (1911) p. 50; *Teknikern* (1914) no. 882, p. 159; *Finansbladet* (1924) no. 25, p. 445.
57. Technologically, these two countries were among the leading producers and in per capita terms also among the big consumers of cement in the world. *Finansbladet* (1924) no. 24, p. 428; Urho Åberg, 'Kotimainen sementtiteollisuus', *Kansanvalistusseuran kalenteri 1932* (Helsinki, 1931) pp. 69–70; Hans Christian Johansen, *The Danish Economy in the Twentieth Century* (London, 1987) pp. 38, 54.
58. It is illustrative of the routes of technology transfer to the Nordic countries at the time that the Swedish term *järnbeton* and Finnish term *rautabetoni* for reinforced concrete are calques, loaned concepts, from German (*Eisenbeton*) – not from the language of inventors, French (*le beton armé*). J. A., 'Järnbeton-konstruktionerna vid Läskelä bruk', *Teknikern* (1906) no. 464, pp. 126–7; (1907) no. 502, p. 39; Pentti Vähäkallio, 'Suomen betoniyhdistys 1925–1975', *Suomen betoniyhdistys 1925–1975* (Jyväskylä, 1985) pp. 30–1.
59. *Suomen kauppa, meriliike ja teollisuus, Helsinki II*, ed. by Julius Hirn (Helsinki, 1906–11) pp. 280–6; Otto Sivonen, *Oy Constructor Ab 1917–1942* (Helsinki, 1942) p. 10.
60. In the exhibition, the French inventor François Hennebique presented his new methods for building massive ferroconcrete structures. Nykänen, *Rautabetoni*, pp. 1–6.
61. Jalmar Castrén, 'Suomalainen rautabetonitekniikka täysikäinen', *TAik*, 18 (1928) no. 4, pp. 189–90; Sivonen, *Constructor*, p. 10.

62. Castrén, 'Suomalainen rautabetonitekniikka', pp. 189–90.
63. Holm and Leskelä, 'Padot', pp. 55–8.
64. Ibid., pp. 56–7.
65. Veli Lehtonen, 'Hydro-plants Types in Finland', in *Waterpower in Finland* (Tampere, 1969) pp. 50–4.
66. Veikko Axelson, 'Suomen voimatalous ja nykyaikainen rakennustekniikka voimatalouden palveluksessa', *Rakennusinsinööri*, 11 (1955) no. 5–6, p. 94.
67. H. P. O. Solitander, 'Puoli vuosisataa vesirakennustöitä', *50 vuotta Suomen teollisuutta ja taloutta* (Helsinki, 1946) pp. 342–7.
68. The Archive of Fiskars Company, Pohja.
69. The perfection of this inward flow engine type is attached to the name of an American, James B. Francis, whose turbine construction of 1849 achieved a vast commercial success in the USA. Of the other well-known types which were at least to some extent manufactured in and imported to Finland, there can be mentioned the Frenchman L. D. Girard's hydroturbine patented in 1847, the German R. Schwamkrug's turbine (1851), and the American Briton L. A. Pelton's turbine (1880). Louis C. Hunter, *A History of Industrial Power in the United States, 1780–1930: Vol I Waterpower in the Century of Steam Engine* (Charlottesville, 1979) pp. 338–42; Risto Keskinen, 'Voimakoneiden valmistus Suomessa', *Tampere University of Technology, Dept. of Mechanical Engineering, Hydraulics, Report 16* (Tampere, 1979) pp. 6–10.
70. B. Pfarr, 'Tyska och amerikanska turbiner', *Teknikern* (1902) no. 281, pp. 167–70, no. 286, pp. 209–13.
71. 'Suomalainen turbiiniteollisuus', *Uusi Suometar*, 1.2.1914; Tauno Liuksiala, 'Vesivoimalaitokset', in *Keksintöjen kirja, Vesirakennus, laiva- ja ilmaliikenne*, ed. by Väinö Airas (Porvoo, 1937) pp. 287–94.
72. *TAik*, 18 (1928) no. 7-8, p. 412.
73. *Brockhaus Enzyklopädie*, 9. Band (Wiesbaden, 1970) p. 736.
74. Ibid; *VV*, 7 (1934) no. 9, p. 172.
75. The earliest Kaplan turbine for industrial operation was put to use abroad in Velm, Austria, in 1919. Hans G. Hanson, 'Development of the Kaplan Turbine', *Daedalus 1977* (Stockholm, 1977) pp. 11–35.
76. *Suomen Sosiaalidemokraatti*, 5.12.1949.
77. Hans Rosenberg, 'Neljä vuotta sotakorvaustöitä Tampellan Konepajalla', *Tampella tänään* (1949) no. 3–4, pp. 9–10.
78. Risto Keskinen, 'Hydraulic Turbines', in *Waterpower in Finland* (Tampere, 1969) p. 74.
79. To produce the machinery required for war reparations within tight schedules, Finnish engineering works stopped at nothing. A number of hydroturbines delivered to the Soviet Union at the time were designed by copying American models without licences. Risto Keskinen, 'Manufacture of Water Turbines in Finland', *Sähkö*, 39 (1966) no. 9, pp. 249–51; Keskinen, *Transfer*, p. 9.
80. *Tampella Water Power Machinery*, Brochure (Tampere, 1978); Keskinen, *Transfer*, pp. 10–11.

81. Viljo Holopainen, *Kivihiilen ja halkojen kilpailu Suomessa vuosina 1927–1938*, Metsätieteellisen tutkimuslaitoksen julkaisuja 38.3 (Helsinki, 1950) pp. 20–4, 44–6.
82. *Sähkölaitostilasto 1930–1965* (Helsinki, 1931–67).
83. *Sähkölaitostilasto 1930–1965* (Helsinki, 1931–67).
84. In the wagon type, water was boiled just in a simple iron tank over the fire. The Cornish boiler had one flue and the Lancashire type had two flues running through a cylindrical shell boiler. The latter two types came into general use in England and the USA during the first half of the nineteenth century. W. E. Dalby, *Steam Power* (London, 1915) pp. 54–7; H. W. Dickinson, *A Short History of Steam Engine* (Cambridge, 1939) pp. 117–34; A Stowers, 'The Stationary Steam-Engine, 1830–1900', in *A History of Technology*, vol. 5, ed. by C. Singer *et al.* (Oxford, 1958) p. 137.
85. Matti Lajunen, *Höyrykattilat* (Tampere, 3rd rev. edn, 1973) pp. 2–3; Eberhard Bitterlich and Franz Thelen, 'Entwicklung zum heutigen Stand der Grossdampferzeuger für die öffentliche Stromversorgung', *Elektrizitätswirtschaft*, 75 (1976) no. 20, pp. 712–14.
86. Dickinson, *Short History*, p. 168; Stowers, 'The Stationary Steam-Engine', pp. 137–8; *Teknikern*, 15.4.1894, no. 84; Georg Janson, *Sähkölaitosten taloudellinen suunnittelu* (Porvoo, 1931) pp. 42–3; Lennart Gripenberg, *Maskin- och Brobyggnads Aktiebolaget 1892–1932* (Helsingfors, 1932) p. 119.
87. By early 1915, over 120 Babcock & Wilcox boilers had been delivered to Finland and of these 65 were made by Kone ja Silta Oy under licence. *Mercator*, 23.4.1915, no. 16, p. 250.
88. Janson, *Sähkölaitosten taloudellinen suunnittelu*, pp. 42–3.
89. Hans Rosenberg, 'Neljä vuotta sotakorvaustöitä Tampellan Konepajalla', *Tampella Tänään* (1949) no. 3–4, pp. 7–8.
90. V. W. Granberg, 'Tuliputki-höyrykattilat', *TAik*, 22 (1932) p. 39; Emil Saraoja, 'Voimakoneet', in *Polttoaineet ja voimakoneet, Keksintöjen kirja*, ed. by E. Saraoja (Porvoo, 1935) p. 208.
91. *OSF 18 Industrial Statistics 1887–1976* (Helsinki, 1889–1970); Pertti Suominen, *Vuosisata kattilantarkastusta, Paineastialainsäädännön kehitys 1888–1988* (Helsinki, 1988) pp. 40–52.
92. Wilhelm Nordström, *Höyrytekniikka* (Helsinki, 1947) pp. 16–21; A. Smith and T. Dixon, 'The Steam Turbine', in *A History of Technology, Vol. III The Twentieth Century*, ed. by Trevor I. Williams (Oxford, 1979) p. 1025; Bertrand Gille, *The History of Techniques, Vol. I Techniques and Civilizations* (Montreux, 1986) pp. 700–5.
93. T. K. Derry and T. I. Williams, *A Short History of Technology* (Oxford, 5th edn, 1982) pp. 335–40.
94. *Manufactur-Directionens i Finland årsberättelser 1842–1876* (Helsingfors, 1842–78); *OSF 18 Industrial Statistics 1884–1960* (Helsinki, 1886–1962).
95. In 1884, Charles Parsons constructed the first turbogenerator in the world. This direct-current unit developed 7.5 kW when running at 18000 rpm. R. H. Parsons, *The Early Days of the Power Station Industry* (Cambridge, 1940) p. 170.

96. Saraoja, 'Voimakoneet', pp. 332ff; Janson, *Sähkölaitosten taloudellinen suunnittelu*, p. 38.
97. *Teknikern* (1891) no. 5, p. 36.
98. I. C. R. Byatt, *The British Electrical Industry, 1875–1914* (Oxford, 1979) p. 192.
99. Per-Holger Sahlberg's lectures in the project meetings on the history of energy technology in Finland in the Research Department of Imatran Voima Oy on 25.11.1983 and 25.6.1984. Some other engineers have also speculated on the same idea: see, for example, Kalevi Ryynänen, 'Raskaan sähköteollisuuden kehitysnäkymiä', *Sähkö*, 45 (1972) no. 9, p. 363.
100. B. Epstein and K. R. U. Mirow, *Impact on Developing Countries of Restrictive Business Practices of Transnational Corporations in the Electrical Equipment Industry: A case study of Brazil*, UNCTAD/ST/MD/9 (New York, 1977) p. 2.
101. See page 43 of this book; *Teknikern* (1892) no. 48, p. 263.
102. Yrjö Raevuori, *Fabian Klingendahl ja Klingendahl O.Y.* (Tampere, 1952) p. 102.
103. By 1919 the AEG had delivered eleven turbogenerators with a capacity of 14500 kVA in Finland. *TAik* (1919) no. 4, AEG's advertisement; V. J. Sukselainen, *Oy Strömberg Ab 1889–1939* (Helsinki, 1940) pp. 89–97.
104. Sukselainen, *Strömberg*, p. 213. Strömberg was de Laval's general agent in Finland from 1898 to 1926 when it began to import only the BBC steam turbines.
105. For example, the municipal electricity utility in Helsinki bought Metro-Vickers turbogenerator with 10 MW in 1929. *TFiFF*, 50 (1930) no. 1.
106. *TAik*, 55 (1965) no. 4, p. 31.
107. *HD*, 6.3.1878, 7.8.1878; R. Rosén, *Helsingin kaupungin kaasulaitos 1860–1950* (Helsinki, 1950) p. 14.
108. Väinö V. Airas, 'Polttomoottorit', in *Keksintöjen kirja, Polttoaineet ja voimakoneet*, ed. by Emil Saraoja (Helsinki, 1935) p. 648; *OSF 18 Industrial Statistics 1903–1975* (Helsinki, 1905–78).
109. J-E J, 'Stordieselmotorer i inhemsk licenstillverkning', *Teknisk Forum* (1960) no. 4, pp. 55–6.
110. *Keksinnöt kautta aikojen* (Helsinki, 1982) p. 295.
111. The first unit of 6 MW was commissioned in a sawmill, Riihimäen Saha Oy. Väinö Pulkkinen, 'Tilastollinen yleiskatsaus Suomen sähkölaitoksiin v. 1962', *VV* (1963) no. 9, p. 214.
112. *OSF 42:1 Energy Statistics 1982* (Helsinki, 1983) p. 66.
113. *VV*, 12 (1939), p. 316.
114. See the notes in the Statistical Appendix.
115. *OSF 1A Foreign Trade 1889–1900* (Helsinki, 1893–1901).
116. V. J. Sukselainen, *Oy Strömberg Ab 1889–1939* (Helsinki, 1940) pp. 73–82; Eino S. Repo, *Siemens 60 vuotta Suomessa 1898–1958* (Helsinki, 1958) pp. 1–10.
117. I. C. R. Byatt, *The British Electrical Industry 1875–1914* (Oxford, 1979) p. 71.

118. *OSF IA Foreign Trade 1900–1913* (Helsinki, 1901–15).
119. *OSF IA Foreign Trade 1913–1920* (Helsinki, 1915–22).
120. A. Larjomaa, 'Sähkökone- ja sähkölaitostarviketeollisuutemme', *Katsaus sähköalaa koskevaan Suomen talouselämään* (Tampere, 1945) p. 20; *VV*, 11 (1938) p. 112.
121. 'Sähköalan teollisuustuotteiden tuontitilasto v. 1929–1939', *VV* (1930–7).
122. Jan Glete, *ASEA under hundra år 1883–1983* (Västerås, 1983) pp. 55, 75, 141–3.
123. Hilkka Kunnas, *Kansakunnan omaisuutta, Suomen Pankki 1811–1986* (Helsinki, 1986) pp. 70–1, 81.
124. See Table 3.9 and Appendix Table A.8.
125. *OSF 1A Foreign Trade 1950–1976* (Helsinki, 1951–77).
126. Glete, *ASEA*, pp. 142–3.
127. In 1987 soon after the fusion of ASEA and BBC, Strömberg Oy was merged to the new ABB concern. Ibid.
128. Appendix Table A.8; *OSF 18 Industrial Statistics 1939–1976* (Helsinki, 1941–77).
129. *VV*, 4 (1931) no. 12, pp. 270–1; *Sähkö*, 55 (1982) no. 3, p. 38.
130. V. Malkki, 'Suomen sähköteollisuuden historiaa', in *Sähkö ja sen käyttö*, ed. by M. Heikinheimo (Porvoo, 2nd edn, 1934) pp. 900–1; Sakari Maaniemi, 'Sähköinsinööri ja yhteiskunta', *Sähköinsinööriliitto 1926–1976* (Helsinki, 1976), p. 280.
131. E. Cronström and H. Ström, 'Toiminimen kehitys', *Puoli vuosisataa kaapeliteollisuutta 1912–1962* (Helsinki, 1965) p. 1.
132. *Tekniskt Forum* (1959) no. 8, pp. 144–5.
133. L. Fast, 'Cable Industry in Finland', *Sähkö*, 38 (1965) no. 4, 131ff.
134. Anders Hedberg, *Sähkölamppukartelli maailmaa valloittamassa*, translation from Swedish (Helsinki, 1933) p. 4; Juho Jännes, *Suomen sähkölamppusota* (Helsinki, 3rd edn, 1936) pp. 9ff.
135. Ibid.
136. Eero Saari, 'Suomen sähkölampputeollisuuden kehityksestä', *VV*, 8 (1935) pp. 202–7; A. Airola, 'Finnish Lamp Industry', *Sähkö*, 38 (1965) no. 10, pp. 321–4.
137. Jaakko Juntunen, 'Suomalainen valaistusalan teollisuus', *Sähkö*, 45 (1972) no. 11, pp. 505–8.
138. T. K. Laakso, 'Radioteollisuutemme', *Katsaus sähköalaa koskevaan Suomen talouselämään* (Tampere, 1945) pp. 25–6.
139. *OSF 18A Industrial statistics 1968–1975*; Paavo Velander, *Radiosta elektroniikkaan* (Helsinki 1979) pp. 88–93.
140. E. Hirvonen, 'Elektroniikkateollisuus Suomessa', *Sähkö*, 45 (1972) no. 10, p. 437.
141. Pentti Vartia and Synnöve Vuori, *Development and Technological Transformation, The Country Study for Finland*, ETLA, Discussion Papers no. 245 (Helsinki, 1987).
142. K. Kala, *Eesti NSV elektrifitseerimise ajalugu* (Tallinn, 1974) pp. 24–9.
143. Attila Tarjanne, 'Valtion teollisuustoiminta', *Kansantaloudellinen aikakauskirja*, 32 (1932) pp. 164–9; Hugo Malmi, *Imatra ja sen kahlehtiminen* (Helsinki, 1949) pp. 28–35.

144. In the 1920s, the shortage of credit affected private hydropower developers much more severely than the government's projects. For example, financial problems caused an interruption of fifteen years in the construction of a private hydroelectric plant (15 MW) on the river Kokemäki. G. M. Nordensvan, 'Imatran voimalaitossuunnitelmasta', *TAik* (1924) p. 135; G. M. Nordensvan, *Länsi-Suomen Voima* (Helsinki, 1946) pp. 66–91.
145. Oy Rouhiala Ab was set up in 1934 by four private industrial companies (Kymin Oy, Yhtyneet Paperitehtaat Oy, Tampella Oy, Karhula Oy), one mixed private-municipal power company (Etelä-Suomen Voima Oy) and one government-owned wood-processing company (Enso-Gutzeit Oy) with rather a small joint capital stock of 21 million FIM. However, the company and its shareholders had quite a satisfactory credit standing on the domestic and international financial markets. Tarjanne, 'Valtion teollisuustoiminta', p. 157; Laur Forsblom, 'Rouhialan voimansiirto Osakeyhtiö', *VV*, 10 (1937) no. 7–8, pp. 143–9.
146. Bror Sjögren, 'Suomen rakennettu vesivoima vuoteen 1936 mennessä', *VV*, 9 (1936) no. 3, p. 89; Br. Pankola, 'Suomen sähkölaitokset v. 1937', *VV*, 11 (1938) p. 122; A. E. Tudeer, 'Suomen teollisuusyhtiöden pääomasuhteet ja kannattavuus sekä suhdanteiden vaikutus niihin', *Kansantaloudellinen aikakauskirja*, 34 (1938) pp. 5–10.
147. Relatively speaking, electricity supply was the most capital-intensive of all industries in Finland. During the period 1946–54, the annual turnover of power companies accounted only for 11–22 per cent of the gross invested capital, whereas the corresponding average for all manufacturing industries fluctuated between 112 and 150 per cent. Yngvar Heikel, 'Suomen teollisuuden kehitys vuosina 1945–1948', *Taloudellisia selvityksiä 1950:II* (Helsinki, 1950), p. 71; Yngvar Heikel, 'Teollisuuden kehitys vuosina 1951–1954', *Taloudellisia selvityksiä 1956* (Helsinki, 1956) p. 57.
148. *VV*, 29 (1956) no. 11, p. 234.
149. J. E. Kilpeläinen, 'Voimalaitosten rakennustoiminnasta maassamme ja sen rahoituksesta', *Kela pyörii* (1958) no. 3, p. 15; Satu Tuuva, 'Rahoitusvaikeudet vesivoiman rakentamisen esteenä toisen maailmansodan jälkeen', *Sähkö* (1985) no. 3B, pp. 3–6.
150. In January 1963, a monetary reform was carried out. A new mark was introduced; the value of 1 new FIM was equal to 100 old FIM. Matti A. Paavonsalo, 'Voimatalouden rahoittaminen Suomessa toisen maailmansodan jälkeen' (unpublished master's thesis in economics, Helsinki University, 1957) pp. 48–51; *Taloudelliset tapahtumat* (1962) no. 8, pp. 35–6.
151. *Industrial Power Company Ltd, Annual Reports 1975–1979* (Turku–Helsinki, 1976–80).
152. Bror Nordqvist, 'Hur Finland löser sin kraftfråga', *Mercator* (1956) p. 606; *VV*, 29 (1956) p. 136; see also Paul J. Joskow and Richard Schmalensee, *Markets for Power, An Analysis of Electric Utility Deregulation* (Cambridge, Mass., 1983) p. 3.

153. *Capital Stock in Finland, 1960–1986*, CSOF, Tilastotiedotus KT 1988:4 (Helsinki, 1988).
154. Appendix Table A.3; Filip Hjulström, *Sveriges elektrifiering* (Uppsala, 1940) pp. 277–81; Fritz Hodne, *An Economic History of Norway, 1815–1970* (Oslo, 1975) p. 311.
155. The period for Norway 1900–22. Hjulström, *Sveriges elektrifiering*, p. 281; Hodne, *An Economic History*, p. 311; *NOS XII 245 Historical statistics* (Oslo, 1969).
156. Finland's performance in electricity output did not match the substantial growth in some industrialised economies, such as the UK and France.
157. The period for Norway is 1922–39. *NOS XII 245; SOS, Industri 1920–1939* (Stockholm, 1921–40); Fritz Hodne, *The Norwegian Economy, 1920–1980* (London, 1983) pp. 48–9.
158. Appendix Table A.4; *SOS Industri 1945–1975*.
159. Appendix Tables A.3–A.4; *SOS, Industri 1945–1975*.
160. Ingvar Svennilson, *Growth and Stagnation in the European Economy* (Geneva, 1954) p. 117.
161. Thomas Hughes, *Network of Power* (Baltimore, 1983) pp. 218–19.
162. Leslie Hannah, *Electricity before Nationalisation* (London, 1979) pp. xi–xii.
163. Regressing the Swedish load factor against CUR, the following equation is obtained:

y = 9.519 + 0.837x		Squared R = 0.958
s.e.	(2.084) (0.051)	
t-stat.	(4.568) (16.563)	

SOS Industri 1921–1934 (Stockholm, 1923–36).
164. Appendix Tables A.3 and A.5.
165. Kulno Kala and Mart Vabar, *Electrification of the Estonian SSR* (Tallinn, 1979) pp. 11–12; V. K., 'Förbrukningen av elektrisk energi inom olika industrigrenar i Sverige', *Kommersiella meddelanden*, vol. 25 (1938) pp. 319–22; Sven-Olof Olsson, 'Elektrifieringen ur avnärmarsynpunkt', *Daedalus* (1984) pp. 62–4.
166. Because of intercountry differences in calculation and compiling methods, the figures of Table 3.13 are not entirely comparable.
167. Table 3.5 and Appendix Table A.6.
168. See Table 3.4.
169. Gregory D. McColl, 'The Electricity Supply Industry in Australia, 1953–54 to 1968–69, A Study of Output, Costs and Prices' (unpublished Ph.D. thesis, London School of Economics, 1974) p. 48.

4 Demand for Electricity

1. In 1960, industry used about 70 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 West European countries, the industry's share of electricity consumption was between these two percentages. *VV*, 35 (1962) no. 12, p. 340.
2. *OSF 42:6 Energy Statistics 1986*.
3. *Sähkölaitostilasto v. 1930; Energy Statistics 1986*.
4. According to not completely comparable sources, the corresponding figures for the period 1890–1975 were 205 per cent and just under 100 per cent. *OSF 6:29 Eléménts demographiques principaux de la Finlande* (Helsinki, 1899); *OSF 6C:104 Population Census 1970*, volume 6 (Helsinki, 1974).
5. *SOS, Industri 1912* (Stockholm, 1914) pp. 47–51; Filip Hjulström, *Sveriges elektrifiering* (Uppsala, 1940) pp. 92–6; Lennart Jörberg, *Growth and Fluctuations of Swedish Industry, 1869–1912* (Lund, 1961) pp. 371–82.
6. The British electricity supply statistics pre- and post-1920 are not comparable with each other. The former are said to be only 'rough estimates of sales', not carefully compiled statistics of the total supply. B. R. Mitchell, *European Historical Statistics 1750–1975* (London, 2nd revised edn, 1981) pp. 501–4.
7. Sigmund Schalin's archive in the Archive of MESUH; see also the sources of Figure 4.5.
8. Compare to Rolf Gradin and Sven Lalander, 'Eltariffer och konsumptionsutveckling', *Vattenfall under 75 år* (Stockholm, 1984) p. 103.
9. *SOS, Industri 1938* (Stockholm, 1940); *OSF 18. Industrial Statistics 1938* (Helsinki, 1940).
10. Kulno Kala and Mart Vabar, *Electrification of the Estonian SSR* (Tallinn, 1979) p. 14.
11. *Elektrotechnische Zeitschrift*, B-Ausg. (1956) no. 5, p. 221; *VV* (1956) p. 170.
12. I. C. R. Byatt, *The British Electrical Industry, 1875–1914* (Oxford, 1979) p. 75.
13. The Archive of the Board of Industry (ABI) 1913, *NAF* and *ACSOF*.
14. Timo Myllyntaus, 'Sahateollisuus', in T. Myllyntaus, K-E. Michelsen and T. Herranen, *Teknologinen muutos Suomen teollisuudessa 1885–1920* (Helsinki, 1986) pp. 75–6.
15. R. B. Du Boff, 'The Introduction of Electric Power in American Manufacturing', *Economic History Review*, 20 (1967) no. 4, p. 516; R. Minami, 'Mechanical Power and Printing Technology in Pre-World War II Japan', *Technology and Culture*, 23 (1982) no. 4, pp. 609–24.
16. The printing industry was thus electrified earlier in Finland than in Japan. Minami, 'Mechanical Power', pp. 609–24; Timo Myllyntaus, 'Tekniset uudisteet graafisessa teollisuudessa 1800-luvun puolivälistä 1920-luvun alkuun', *Sanomalehtien taloudellinen tausta, Suomen sanomalehdistön historia-projektin julkaisuja*, 21 (Helsinki, 1983) p. 65.
17. ABI 1885–1930, *NAF* and *ACSOF*; *OSF 18 Industrial Statistics 1884–1977*.
18. The author's estimate based on ABI 1900, *NAF*; Timo Myllyntaus,

Finnish Industry in Transition, 1885–1920 (Helsinki, 1989) p. 83; W. D. Devine, Jr., 'From Shafts to Wires: Historical Perspective on Electrification', *Journal of Economic History*, 43 (1983) no. 2, p. 351.

19. Cardboard and wallboard mills are here included in the pulp grinding industry. ABI 1900–1913, *NAF* and *ACSOF*; *OSF 18 Industrial Statistics 1925–1975*.
20. *OSF 18:66 Industrial Statistics 1950* (Helsinki, 1953).
21. *Suomen teollisuuslehti*, 10 (1892) no. 7, p. 98.
22. In 1908 there was still an excess capacity of 50 per cent in the world's calcium carbide production. Of the total output (200 000 tons), Norway and Sweden produced together about 25 per cent and the USA 20 per cent. *Suomen teollisuuslehti*, 27 (1909) no. 15–16, p. 100; 28 (1910) no. 3, p. 32.
23. In Finland, the number of electrochemical and electrometallurgical plants increased from 3 to 8 between 1900 and 1917, while in Sweden the number grew from 8 to 75 during the period 1904–17. *Berättelse öfver Finska elektrokemiska aktiebolagets verksamhet under år 1914* (Wiborg, 1915); 'Finska elektrokemiska aktiebolaget', *Suomen kauppa, meriliike ja teollisuus, Viipuri* (Helsinki–Turku, 1915) pp. 84–6; *Teknikern*, 28 (1918) no. 1094, p. 95; Ahti Haapaniemi, 'Kemian teollisuutemme historiaa: Tervanpoltosta teollisuudeksi', *Kemia-Kemi*, 10 (1983) no. 6, pp. 504–6.
24. V. Sihvonen, 'Suomen sähkökemiallinen teollisuus', *TAik* (1926) p. 149.
25. Ibid, pp. 149–55; Arnold Almqvist, 'Suomen sähkökemiallinen teollisuus', *TAik* (1926) p. 427.
26. Sihvonen, 'Suomen sähkökemiallinen teollisuus', pp. 149–55; Bror Sjögren, 'Användbarheten av Finlands vattenkraft för elektrokemisk industri', *TFIFF* (1929) no. 2, pp. 21–2.
27. Small-scale production began by the Siemens-method at the Kuusankoski papermill in 1901. Yrjö Talvitie, *Suomen kemiallisen teollisuuden kehitys* (Helsinki, 1945) p. 85.
28. Ibid; Haapaniemi, 'Kemian teollisuutemme', pp. 510, 527; Karl-Erik Michelsen, *Sähköstä ja Suolasta Syntynyt, Finnish Chemicals Oy, Nokia Chemicals 1937–1987* (Jyväskylä, 1989) pp. 120–27.
29. Haapaniemi, 'Kemian teollisuutemme', pp. 523–5.
30. *OSF 42:5 Energy Statistics 1985*, pp. 80–1.
31. J. C. Carr and W. Taplin, *History of British Steel Industry* (Oxford, 1962) pp. 219–20; K. Hjelt, 'Sähkösulatusuunit raudan ja teräksen valmistuksessa', *VV*, 14 (1941) pp. 184–97.
32. *Elektrometall gjuteritackjärn, Handledning för ingeniörer och gjutmästare* (Åbo, 1917) pp. 3–4.
33. Talvitie, *Suomen kemiallisen teollisuuden kehitys*, pp. 67, 120.
34. Y. Talvitie, 'Suomen kemiallinen teollisuus', *50 vuotta Suomen teollisuutta ja taloutta* (Helsinki, 1946) p. 130; Markku Kuisma, *Kuparikaivoksesta suuryhtiöksi, Outokumpu 1910–1985* (Forssa, 1985) pp. 118–23.
35. Kuisma, *Kuparikaivoksesta*, pp. 124–6.
36. Ibid, pp. 162–71, 380–4.

37. *Imatra Power Plant* (Helsinki, 1933) p. 12.
38. *Sähkölaitostilasto v. 1930–1965* (Helsinki, 1931–67).
39. *VV*, 25 (1952) no. 9, p. 165; 27 (1954) no. 10, p. 226; 28 (1955) no. 10, p. 202.
40. Harold C. Passer, *The Electrical Manufacturers, 1875–1900* (Cambridge, Mass., 1953) pp. 211–16; Göran Rönn, 'Elektrifieringen av svenska järnvägar, Motiv för val av system', *Royal Institute of Technology*, Rapport TRITA-HOT-2001 (Stockholm, 1978) pp. 9–10.
41. G. Idström, 'Spårvägarna i Finland intil år 1930', *TFiFF*, 50 (1930) no. 1, p. 2.
42. H. Mäklin, 'Om elektriska spårvägen', *Teknikern* (1896) no. 123, p. 30.
43. Passer, *Electrical Manufacturers*, pp. 237–55.
44. I. C. R. Byatt, *The British Electrical Industry 1875–1914* (Oxford, 1979) p. 29; *Teknikern* (1892) no. 44, p. 213.
45. The first, experimental electric underground line was completed in Budapest, Hungary, in July 1889. *Teknikern* (1911) no. 736, pp. 184–5; Rönn, *Elektrifieringen*, pp. 14–18; John McKay, *Tramways and Trolleys, The Rise of Urban Mass Transport in Europe* (Princeton, 1976) p. 78.
46. James H. Bates, *St. Petersburg, Industrialization and Change* (London, 1976) p. 393.
47. McKay, *Tramways and Trolleys*, pp. 70–3; Byatt, *The British Electrical Industry*, p. 29.
48. 'Några elektriska banor i Finland utförda af Elektriska Ab AEG', *Teknikern* (1905) no. 405, pp. 79–80; 'Suomen vanhin sähköraitiotie käytössä Forsassa', *Yhdyslanka* (1962) no. 16, pp. 20–1; V. J. Sukselainen, *Oy Strömberg Ab 1889–1939* (Helsinki, 1940) p. 74.
49. From December 1890, a horse-driven tramway preceded electric urban transport in Helsinki. Idström, 'Spårvägarna'; Georg Estlander, *Helsingin raitiotie- ja omnibus osakeyhtiö 1891–1931* (Helsinki, 1931) pp. 23, 37–8.
50. In this respect, Helsinki followed the international pattern; see McKay, *Tramways and Trolleys*, pp. 192–205.
51. Rönn, *Elektrifieringen*, pp. 18–19.
52. Electric trams trafficked in Århus from 1904 and in Odense from 1911. P. A. Flindt, 'Elektriskdrevne Köretöjer, Sporveje, Trolleyvogne', in *Elektricitetens historie*, ed. by C. E. Dahl and V. Faarborg-Andersen (København, 1940) p. 501.
53. Idström, 'Spårvägarna', pp. 3–9.
54. *OSF 36:20 Yearbook of Transport Statistics 1978* (Helsinki, 1979) pp. 43–4.
55. In Europe, only Britain at that time had cities with a population of over 1 million without any public tramway service. 'Scope for the Use of Certain Old-established Urban Transport Techniques', *Report of the Thirty-eighth Round Table on Transport Economics*, European Conference of Ministers of Transport held in Paris, 1977, OECD (Paris, 1978) pp. 13–14.

56. For example, the first trolleybus came in use in Copenhagen in 1902. Flindt, 'Elektriskdrevne Köretöjer', pp. 520–4.
57. Mikko Alameri, *Eisenbahnen in Finnland* (Wien, 1979) pp. 61–3; Ilmari Borg, 'Tampereen kaupungin liikennelinjat', *VV*, 23 (1950) no. 5–6, pp. 155–9.
58. Timo Herranen, *Hevosomnibusseista metroon, Vuosisata Helsingin joukkoliikennettä* (Helsinki, 1988) pp. 206–7, 279–81.
59. The City of Cleveland in the USA was the first to introduce electric traffic lights in 1914. The earliest automatically controlled traffic light system was put in operation in London in 1925. *Keksinnöt kautta aikojen* (Helsinki, 1982) p. 154.
60. After many delays and some rather extraordinary political scandals on bribery, one route of about 11 km from the centre to some eastern suburbs was opened in summer 1982. Then Helsinki became one of the few cities with under 500 000 inhabitants which had an underground. Alameri, *Eisenbahnen*, pp. 59–60; Herranen, *Hevosomnibusseista*, pp. 306–22.
61. In Finland, the earliest electrified railway with the same broad gauge of 1524 mm as applied on the State Railways was completed at the sawmill of Halla Ab in Mikkeli in 1904. The length of its track was, however, only 1.5 km. *Teknikern* (1905) no. 405, p. 80; 'Sveriges första bredspåriga elektriska järnväg', *Teknikern* (1907) no. 498, p. 13; *Teknikern* (1911) no. 736, pp. 184–5.
62. Rönn, *Elektrifieringen*, pp. 144–8.
63. H. W. Fogtmann, 'Elektriciteten til banedrift', in *Elektricitetens historie*, ed. by C. E. H. Dahl and V. Faarborg-Andersen (København, 1940), pp. 547–9.
64. *Elektrotechnische Zeitschrift* (1938) no. 19; *VV*, 11 (1938) p. 246; *International Eisenbahnstatistik 1936*, quoted in A. Kierimo, 'Ratojen sähköistyksestä', *TAik* (1938) p. 396.
65. *VV* (1951) no. 1, p. 21.
66. B. Wuolle, 'Sähkön ottaminen liikevoimaksi Suomen valtion rautateillä', *TAik*, 16 (1926) no. 5–6, pp. 277–8.
67. Tuomo Polvinen, *Die finnischen Eisenbahnen in den militärischen und politischen Plänen Russlands vor dem ersten Weltkrig* (Helsinki, 1962) pp. 113–16, 188–229.
68. K. Snellman, 'Miksi rautatiet meillä nykyään tulevat niin kalliiksi', *TAik* (1912) no. 4, pp. 75–7.
69. With its 11.8 km of railway lines per 10 000 inhabitants, the country was the next to Sweden's 26.1 km. It was followed by Germany (10.3 km), Britain (9.0 km), Austria (8.8 km), Russia (5.5 km), etc. 'Finska Statsjärnvägarne 1862–1912', *Mercator*, 22.3.1912, pp. 254–8; *The Economic History of Finland, Vol. 3* (Helsinki, 1983) pp. 18, 273.
70. Wuolle, 'Sähkön ottaminen liikevoimaksi'.
71. Werner Ryselin, 'Valtion rautateiden sähköistämiskysymys', *TAik*, 16 (1926) pp. 628–30.
72. Alameri, *Eisenbahnen*, pp. 25–6.
73. Wuolle, 'Sähkön ottaminen liikevoimaksi', pp. 322–3, 338–9, 384.

74. Pentti Oka, *Sähköinen asia, Valtionrautateiden sähköistäminen*, Sähköradat Oy (Helsinki, 1983) p. 55.
75. Oka, *Sähköinen asia*, pp. 64–71.
76. Ibid.
77. Ibid; *Yearbook of Transport Statistics 1978*, p. 15.
78. Hugo Malmi, *Imatra ja sen kahlehtiminen* (Helsinki, 1949) pp. 14–15, 25–6; S. Pirinen, '100-vuotias Valtionrautatiet ja sähkö', *VV*, 35 (1962) no. 3, p. 58.
79. In Sweden, rural dwellers at the time accounted for 75 per cent of the total population, while 49 per cent of all Swedes lived on primary occupations. *Statistical Surveys* no. 63, CSOF (Helsinki, 1979) p. 331; Olle Krantz, *Die Skandinavischen Länder: Schweden, Norwegen, Dänemark und Finnland von 1914 bis 1970* (Stuttgart, 1980) p. 28.
80. *SYF 1975* (Helsinki, 1976).
81. One of them was a subsidiary of the Fiskars ironworks at Pohja and the other a subsidiary of Ilja Galkin's sawmill in Raivola. The third, Kostian Sähkövirta Osuuskunta, was a tiny co-operative of ordinary men at Pälkäne with a sole aim of supplying electricity for its members. *OSF 18 Industrial Statistics 1900–1903* (Helsinki, 1901–4); *Teknikern* (1906) no. 455, p. 69.
82. In these respects, there were several similarities between Finland and Sweden. Hans Modig, 'El på landsbygden', *Vattenfall under 75 år* (Stockholm, 1984) pp. 165–76; Sven-Olof Olsson, 'Elektrifieringen ur avnärmarsynpunkt', *Daedalus 1984* (Stockholm, 1984) pp. 66–72.
83. T. Vilanen, 'Piirteitä maaseutusähköistyksemme kehityksestä ja nykyisestä tilasta', *VV*, 9 (1936) pp. 63–5; T. Suo, 'Huomattavimpien maaseutusähkölaitoksiemme synty ja kehitys', *VV*, 9 (1936) no. 12, pp. 273–8.
84. Vilanen, 'Piirteitä', pp. 63–7.
85. Viljo J. Varho, Maaseutusähköistyksestä maassamme viime vuonna', *VV*, 3 (1930) pp. 85–6.
86. Suo, 'Maaseutusähkölaitoksiemme synty', p. 227; see also Modig, 'El på landsbygden', pp. 193–9.
87. S. Björkbom, 'Maaseudun sähköistyksen nykyinen laajuus ja tuleva kehitys', *VV*, 21 (1948) p. 71.
88. Ibid.
89. *KM 1950:9 Maaseudun sähköistämiskomitean mietintö* (Helsinki, 1950).
90. Salve Björkbom, 'Twenty Years of Rural Electrification', *Sähkö*, 38 (1965) no. 5–6, pp. 177–8.
91. Björkbom, 'Maaseudun sähköistyksen laajuus', p. 72.
92. Scattered settlements in the forest areas lagged behind in the rural electrification of Sweden, too. Olsson, 'Elektrifieringen', pp. 66–72.
93. Tauno Bergholm, 'Maaseudun sähköistyksen organisaatio', *Sähköurakoitsija* (1965) no. 3, p. 13.
94. *Maaseudun sähköistämistyöryhmän mietintö*, Kauppa- ja teollisuusministeriö, Energiaosasto C:1 (Helsinki, 1978) p. 3.
95. In the case of rural electrification, international comparisons are very unreliable for various reasons. As an example of different calculating

methods for illustrating rural electrification one can mention that by 1939 some two-thirds of the rural houses in Britain had already been electrified but only about 12 per cent of farms were supplied with electricity. Leslie Hannah, *Electricity before Nationalisation* (London, 1979) p. 192; 'Suomen maaseudun sähköistyksestä', *VV*, 2 (1929) no. 5–6, p. 136.

96. By contrast, the difference between Finnish and British farms at the time seems to have been quite small. In late 1952, about 60 per cent of English farms were wired with electricity. Two years earlier, the corresponding figure for Finnish rural households was 59 per cent. Björkbom, 'Maaseudun sähköistyksen nykyinen laajuus', p. 71; M. Pylkkänen, 'Näkymiä maaseudun sähköistyksestä Englannissa', *VV*, 26 (1953) no. 1, p. 26; *SOU 1951:14 Landsbygdselektrifieringens utredning år 1950* (Stockholm, 1951) pp. 7–13.
97. *Maaseudun sähköistämistyöryhmän mietintö*, p. 7.
98. In 1944, the rural consumption accounted for as little as 2 per cent of the total electricity used in Sweden. Modig, 'El på landsbygden', p. 194.
99. Bergholm, 'Maaseudun sähköistyksen organisaatio', p. 13.
100. Thomas Hughes has described how poorly the consequences of electrification were predicted in the USA, too, in his article 'Visions of Electrification and Social Change', in *1880–1980. Un siècle d'électricité dans le monde*, ed. by F. Cardot (Paris, 1987) pp. 327–40.
101. In Helsinki, the high load for generating capacity lasted 2915 hours p.a. in 1929, whereas it totalled 3163 h in Stockholm, 3650 h in Zürich, 3770 h in Bern, 3816 h in Luzern and as much as 5180 h in Basel. The annual maximum is 8760 hours. *VV*, 3 (1930) no. 2, p. 53.
102. Sigmund Schalin held this post from 1929 to 1955. His archive is stored at *AMESUH*; see also S. Schalin, 'Tarvitaanko meillä sähköpropagandaa?', *VV*, 3 (1930) no. 2, p. 52; A. Marsio, 'Muutama sana sähköpropagandan puolesta', *VV*, 3 (1930) no. 3, p. 67; S. Schalin, 'suomen sähköpropagandan suuntaviivoja', *VV*, 3 (1930) no. 5–6, pp. 156–9; P. Veijola, 'Sähköpropagandasta Suomessa', *VV*, 11 (1938) no. 7–8, pp. 170–1; P. Veijola, 'Sähköpropagandasta Sveitsissä ja Hollannissa', *VV*, 11 (1938) no. 10, pp. 234–7.
103. During its early years, the MESUH lent irons free of charge for a fortnight and later, in the 1930s, chargeable leasing of electrical household appliances was under discussion. *Helsingin kaupungin sähkölaitoksen tiedonantoja no 5* (Helsinki, 1911); Schalin, 'Suomen sähköpropagandan suuntaviivoja', pp. 156–9; Leslie Hannah, *Electrification before Nationalisation* (London, 1979) pp. 197–8.
104. *Sähköviesti*, 19 (1957) no. 2, p. 11; 'Miten ja millä pakastan', *Sähköurakoitsija*, 7 (1964) no. 7, p. 37.
105. A good example is the diffusion of black and white television-sets which actually came on sale in Finland in 1956. Ten years later, half of all households were paying for tv-licences although the northern parts of the country were still outside the tv-coverage area. The refrigerator forms another example: only 11 per cent of all households owned a fridge in 1956, but in 1975 the corresponding percentage was 88. Meiju Gebhard, 'Oma pesukone 18,5%:lla kodeistamme', *Sähköviesti*, 19 (1957) no. 2, p. 20; *Sähkökäyttöisten kotitalouskojeiden myynti Suomessa 1954–1980*, Suomen Sähkölaitosyhdistys r.y. (Mimeograph, n.d.); *SYF 1975* (Helsinki, 1976).

106. Schalin, 'Tilastoa', p. 44.
107. *Suomen teollisuuslehti* (1899) p. 94; the archive of Sigmund Schalin, *AMESUH*; Oiva Turpeinen, *Energiaa pääkaupungille, Sähkölaitostoimintaa Helsingissä 1884–1984* (Espoo, 1984) p. 51.
108. The average hourly wage of craftsmen who were at the time building the power plant for the MESUH was equal to the retail price of one kWh. *Teknikern* (1910) no. 667, p. 112; *Kertomus Helsingin kaupungin sähkölaitoksen toiminnasta* (Helsinki, 1911); Aimo Puromäki, 'Markka muuttuu', *Sähköviesti*, 21 (1959) no. 4, pp. 22–3.
109. We should be cautious in drawing conclusions on international electricity rate comparisons based on official exchange rates. In the interwar period especially, changes in exchange rates greatly affected the inter-country relationships of electricity retail prices. For example, in the Estonian capital, Tallinn (Reval) the electricity rate for lighting remained stable from 1926 to 1937 being 0.25 crowns per kWh. At the same time, its value in Finnish currency, however, increased by a third or from 2.37 FIM to 3.14 FIM. *Estonian Economic Review* (1927) no. 3, p. 11; Tallinna linna elektrijaama tegevuse ülevaade, Eesti Rahvuslik Jôukomitee, *ORKA* F. 1011, Nim. Arh. nr. 88 (s.ü) p. 15; Antti Suvanto, 'Raha- ja luottomarkkinat', *Suomen taloushistoria 2, Teollistuva Suomi* (Helsinki, 1982) pp. 294–301.
110. *Statistical Abstract of Sweden 1937* (Stockholm, 1938); *Revue sociale* (1938).
111. The number of radio licenses rose from 107 000 in 1930 to 294 000 in 1938 and again to 722 000 in 1950. The radio was listened to in 26 per cent of households in 1938; the percentage jumped to 50 by 1945 and to 64 by 1950. *SYF 1951* (Helsinki, 1951).
112. In 1910 women who worked outside the home in non-agricultural jobs accounted for 15 per cent of all 15–65-year-old women. By 1970, the percentage had risen to 41. If we include agricultural occupations, about half of all women within this age group has participated in the labour force since the turn of the century. *SYF 1915–1975* (Helsinki, 1916–76).
113. Irja Ritsilä, 'Automaattipesukone – nykyhetken toivekone?', *Sähköviesti*, 22 (1922) no. 2, pp. 6–7.
114. 'Kesälesken talousaskareet', *Sähköviesti*, 24 (1962) no. 2, pp. 12–13.
115. Iiris Niemi, Salme Kiiski and Mirja Liikkanen, *Use of Time in Finland 1979*, CSOF, Studies no. 65 (Helsinki, 1981) pp. 98–9; Eila Kilpiö, *Förprojekt om hushållets tidsanvändning* (Mimeograph 1987).
116. Joann Vanek, 'Keeping Busy: Time Spent in Housework, United States, 1920–1970' (unpublished Ph.D. thesis, University of Michigan, 1973) pp. 127–8, quoted in Charles A. Thrall's article on 'The Conservative Use of Modern Household Technology', *Technology and Culture*, 23 (1982) no. 2, pp. 180–1.

117. Ibid; Compare to Siegried Giedion, *Mechanization Takes Command* (New York, reprint 1975) pp. 512–27.
118. *Sähkökäyttöisten kotitalouskojeiden myynti Suomessa vuosina 1954–1980*, Suomen sähkölaitosyhdistys r.y. (mimeograph, n.d.).
119. O. S., 'Kotitalouden sähkökojeiden hinnat eri maissa', *Sähköviesti*, 19 (1957) no. 2, p. 11.
120. Osmo Simola, 'Sähkö on halpaa', *Sähköviesti*, 19 (1967) no. 1, p. 5.
121. The average price of electricity for households without electric space heating was then 0.22 FIM/kWh and a recommendation for the minimum wage was 6.30 FIM/h. A male farmworker earned on average 9.19 FIM/h and a male industrial worker 12.87 FIM/h. *OSF 42:5 Energy Statistics 1985* (Helsinki, 1985); *SYF 1975* (Helsinki, 1976).
122. The USA and (West) Germany were chosen as the objects of comparison, because all the electrical appliances mentioned in Table 4.7 were first introduced in one of these two countries and their degrees of appliance saturation were among the highest in the world in the early 1970s.

    Many household appliances, such as the vacuum cleaner, washing machine and dishwasher, were invented as early as the 1850s and 1860s, but these inventions were shelved in order to wait for the coming of a handy mechanical drive: the small electric motor. Giedion, *Mechanization*, pp. 542–606.
123. B. Chateau and B. Lapillonne, *Energy Demand: Facts and Trends, A Comparative Analysis of Industrial Countries* (Wien, 1982) pp. 39–42.
124. An ordinary Finnish household of four persons was estimated to consume 2410 kWh p.a. Ibid; *Sähköviesti*, 35 (1973) no. 4, p. 4; *Sähköviesti*, 36 (1974) no. 2, p. 7.
125. Matti Pylkkänen, 'Sähkön hinnasta', *Sähköviesti*, 37 (1975) no. 1, p. 3.
126. *Die Strompreise in den Ländern der EWG und in Österreich*, Österreichischer Energiekonsumenten-verbands Bericht Nr. 21 (Wien, 1963) pp. 12–20.
127. In 1920, the Swedish industrial worker could buy 10 kWh with less than three hours' work. In 1940, to purchase this amount of electricity he had to work 1 hour 10 minutes, in 1950 about 25 minutes, in 1960 10 minutes and in the 1970s just under 5 minutes. From the interwar period to the late 1970s, electricity was relatively two or three times more expensive for households in Finland than in Sweden. Rolf Gradin and Sven Lalander, 'Eltariffer och konsumtionsutveckling', *Vattenfall under 75 år* (Stockholm, 1984) p. 103.
128. Osmo Simola, 'Rakennusten sähkölämmitys', *VV*, 37 (1964) no. 9, p. 219.
129. *Energy Statistics 1985*, p. 65.
130. In the same year, the corresponding percentage was as high as 53 in Norway, 13 in Britain, 8 in Sweden, 6 in West Germany and 2 in France. Sven Lalander, 'Sähkölämmityksen kehitysmahdollisuudet', *Sähköurakoitsija* (1977) no. 1, pp. 10–11.
131. Between 1938 and 1976, the nominal retail price of electricity for

households multiplied tenfold, while the general index for earnings grew by a factor of 202. Consequently, the relative price of electricity decreased by 95 per cent. *Sähköviesti* (1977) no. 3, p. 27.
132. See also T. R. G. Bingham, 'Structural Change in the Post-war Finnish Economy' (unpublished Ph.D. thesis, Oxford, 1976).
133. See, for example: H. M., 'S.k. elektricitetsmätare samt några ord om nu rådande pris på elektriskt ljus i H:fors', *Teknikern* (1892) no. 28, pp. 40–1, and 'Sähkö-, kaasu- ja petrolivalaistuksen keskimääräinen hinta', *Suomen teollisuuslehti* (1899) p. 94.
134. *Sähköviesti*, 25 (1963) no. 4, p. 9; Osmo Simola, 'Sähkö on halpaa', *Sähköviesti*, 29 (1967) no. 1, p. 5.
135. *Maaseudun sähköistämistyöryhmän mietintö* (Helsinki, 1978) pp. 1–4; *SYF 1965–1982* (Helsinki, 1966–83).

5 The Interaction of Electricity and the Economy

1. Albert O. Hirschman, *The Strategy of Economic Development* (New Haven, 1959) p. 106.
2. Warren D. Devine, Jr., 'From Shafts to Wires: Historical Perspective on Electrification', *Journal of Economic History*, 43 (1983) no. 2, pp. 347–72.
3. Timo Myllyntaus, 'Talous, energia ja teknologia – kolmen toimialan vertailu', in *Teknologinen muutos Suomen teollisuudessa 1885–1920* by Timo Myllyntaus, Karl-Erik Michelsen and Timo Herranen (Helsinki, 1986) pp. 185–9.
4. Ibid.
5. Sam Schurr, 'Energy Efficiency and Economic Efficiency: An Historical Perspective', pp. 203–14, and Nathan Rosenberg, 'The Effect of Energy Supply Characteristics on Technology and Economic Growth', pp. 279–305 in *Energy, Productivity, and Economic Growth*, ed. by S. H. Schurr, S. Sonenblum and D. O. Wood (Cambridge, Mass., 1983).
6. *OSF 42:6 Energy Statistics 1986* (Helsinki, 1987) pp. 29, 69.
7. Schurr, 'Energy Efficiency', p. 205.
8. Gustav Sundbärg, *Aperçus statistiques internationaux* (Stockholm, 1908) p. 21; *SYF 1929* (Helsinki, 1929).
9. Sakari Heikkinen *et al.*, *Industry and Industrial Handicraft in Finland, 1860–1913* (Helsinki, 1986) pp. 120–2.

6 Conclusion

1. See, for example: *Voimantarpeen tyydyttäminen Imatran voimalaitoksen avulla*, Koskivoimatoimiston julkaisuja v. 1924 no. 7 (Helsinki, 1924) pp. 13–15.
2. In the field of low current technology, Finland had one early inventor with international reputation. Eric M. C. Tigerstedt (1886–1925), 'Finland's Edison', was granted over 400 patents which were mostly related to electroacoustic technology, such as electronic tube, electrogramophone, radio, sound film and television. After taking an

engineer's degree in Germany and training in Siemens & Halske, he worked in Denmark, Finland and the USA. A. M. P. Kuusela, *E. M. C. Tigerstedt, 'Suomen Edison'* (Helsinki, 1981).
3. T. K. Derry and T. I. Williams, *A Short History of Technology* (Oxford, 1982) pp. 608–36; Klaus Schulz-Hanssen, *Die Stellung der Elektroindustrie im Industrialisierungsprozess* (Berlin, 1970) pp. 161–73.
4. Ibid.
5. Ibid.
6. Schulz-Hanssen, *Die Stellung*, pp. 161–73; Harold I. Sharlin, 'Electrical Generation and Transmission', *Technology in Western Civilization*, vol. 1, ed. by M. Kranzberg and C. W. Pursell, Jr. (New York, 1967) p. 582.
7. John M. Staudenmaier, *Technology's Storyteller* (Cambridge, Mass., 1985) p. 128.
8. John H. Jensen and Gerhard Rosegger, 'Transferring Technology to a Peripheral Economy: The Case of Lower Danube Transport Development 1856–1928', *Technology and Culture*, 19 (1978) no. 4, pp. 675–702.
9. Alexander Gerschenkron, *Economic Backwardness in Historical Perspective* (Cambridge, Mass., 1966) p. 233.
10. 'Kansallinen tehtävä', *Sähköviesti*, 46 (1984) no. 4, p. 5.
11. At the time, that belief was shared by many other nations as well. The Englishman Hugh Quigley wrote: '[Motive] power constitutes the life-blood of industry in the modern state; it lays the foundation for all developments, financial and technical, and renders it possible for man to derive from nature the utmost wealth nature is capable of yielding. . . . The new source of power has been found to be electricity. . . . Complete electrification carried out on a progressive scale would undoubtedly cause a quickening-up of national activity.' Hugh Quigley, *Electrical Power and National Progress*, Foreword by D. N. Dunlop, BEAMA (London, 1925) pp. 16–20.
12. Eino Leino, 'Sähkön sävel; in his *Halla* collection (Helsinki, 1908).
13. The following examples can be mentioned as other pieces of art published on the same theme, such as Frans Viitanen *Vanhan Suuntalan sähkövalo* (Electric Light at the Old Suuntalas') a play in one act (Helsinki, 1915); Kyösti Virta, *Kun Vanhalaan saatiin sähkövalo* (Installing Electric Lighting at the Vanhalas) a novel (Hämeenlinna, 1916).
14. Karl Remme, *Die Hochschulen Deutschlands* (Berlin, 1926) p. 12.
15. Appendix Table A.1; *Peatlands and Their Utilization in Finland* (Helsinki, 1982) p. 9.
16. Compare Appendix Table A.1 with Table 4.2.
17. See Timo Myllyntaus, 'The Finnish Model of Technology Transfer', *Economic Development and Cultural Change* 38 (1990) no.3, pp. 625–43.
18. 'Teknologian siirto ja kansainvälinen työnjako, Teknologiakomitean mietinnön liite no 5;, *Komiteanmietintö 1980:55* (Helsinki, 1981) pp. 20–2; Edwin Mansfield *et al.*, *Technology Transfer, Productivity and Economic Policy* (New York, 1982) p. 29.
19. Table 4.1.
20. Antonio Murolo, 'The Greek Economy: The Role of the Transnationals and the EEC', *Mezzogiorno D'Europa*, 2 (1982) no. 2, pp. 197–220; see also Remy Montavon, Miguel Wionczek and François Piquerez, *The Role of Multinational Companies in Latin America, A Case Study in Mexico* (Farnborough, 1979) pp. 13–18, 107–11.

21. Roger Seymour, 'A Comment on Arthur W. Lake's Paper', in *The Economic Effects of Multinational Corporations*, editor R. G. Hawkins, Research in International Business and Finance, vol. I, 1979 (Greenwich, Connecticut, 1979) pp. 184, 186.
22. Peter F. Cory, *The Transfer of Technology to Developing Countries and the Role of the Foreign Corporation: A Comparison of Yugoslavia and Mexico* (Microfilmed Ph.D. thesis, University of California, Berkeley, 1979) pp. 150, 283.
23. Arghiri Emmanuel, *Appropriate or Underdeveloped Technology?* (Chichester/New York, 1982) pp. 110–11.

Statistical Appendix and Notes on Sources and Methods

1. See pages 132–3 and 159.
2. *The Hydro-electric Potential of Europe's Water Resources, Vol. I*, ECE, United Nations (New York, 1968) p. 39.
3. Ibid; Joel Darmstadter *et al.*, *Energy in the World Economy* (Baltimore, 1971) table 1.
4. *Sähkölaitostilasto v. 1930–1965*, Publication of the Electrical Inspectorate (Helsinki, 1931–67).
5. L. Konkonen, 'Sähkölaitostilastoa vuodelta 1926', *Tilastokatsauksia* (1929) no. 12 (Helsinki, 1929) pp. 36–42; V. V., 'Maamme ensimmäinen sähkölaitostilasto', *VV*, 3 (1930) pp. 60–2.
6. As an example of anomalies in the industrial statistics, it can be mentioned that electricity supply utilities were classified in the group of chemical industries up to 1908. *OSF 18 Industrial Statistics 1884–1908*, CSOF (Helsinki, 1885–1909).
7. For example, partial double counting of the capacity in the statistics on installed power was eliminated. *OSF 18 Industrial Statistics 1920* (Helsinki, 1923) pp. 3–4.
8. OSF 42:6 Energy Statistics 1986, CSOF (Helsinki, 1987).
9. Selected benchmark years are 1885, 1890, 1895, 1900, 1903, 1905, 1910, 1913 and 1920. The figures for the period 1921–9 are based on compiling data from several data sources such as Konkonen's and Sjögren's works. Estimates for the periods between selected years have been calculated by dividing the aggregate capacity into six sections according to main industrial sectors. The capacity of prime movers and generators has been interpolated by using the compound growth-rate method. Konkonen, 'Sähkölaitostilastoa'; Bror Sjögren, 'Finlands monterade vattenkraft', *TFiFF*, 43 (1923) no. 9, pp. 185–96; Bror Sjögren 'Finlands monterade vattenkraft', *TFiFF*, 47 (1927) no. 5, pp. 96–8; Bror Sjögren, 'Suomen rakennettu vesivoima vuoden vaihteessa 1928–1929', *VV*, 1 (1928) no. 12, pp. 229–66; Bror Sjögren, 'Suomen vesivoimarakennukset', *VV*, 2 (1929) no. 5–6, pp. 131–3;

Bror Sjögren, 'Suomen rakennettu vesivoima vuoteen 1931 mennessä', *VV*, 4 (1931) no. 11, pp. 233–64.

10. The Archive of the Strömberg Company, Helsinki.
11. *TFiFF*, 11 (1891) pp. 99–100; 12 (1892) pp. 44–6.
12. G. M. Nordensvan, 'Suomen voima- ja sähköistysoloista', *TAik* (1923) p. 345; Ilmari Killinen, 'Sähkön käyttö ja sen kehitys Suomessa', *VV*, 2 (1929) no. 5–6, p. 169; H. H. Porkka, 'Teollisuutemme voimakysymys', *TAik* (1937) p. 228.
13. Konkonen, 'Sähkölaitostilastoa'.
14. *Sähkölaitostilasto v. 1930–1965*.
15. OSF 42:6 Energy Statistics 1986.
16. See, for example, *Teknikern* (1906) no. 455, p. 69; no. 458, pp. 90–1; *OSF 18 Industrial Statistics 1920*, pp. 3–4; Oskari Terhi, 'Sähkölaitostilasto', *TAik*, 11 (1921) no. 7–8, pp. 485–6; Vilho Annala, 'Sähkölaitostilasto, oikaisu', *TAik*, 11 (1921) no. 11, pp. 673–4; Killinen, 'Sähkön käyttö', pp. 169–70.
17. If we consider the case for the year 1914, for instance, the output figure of the official industrial statistics is 43 GWh and that of an expert working in the private energy sector was 50 GWh. My estimate, 173 GWh, is by a factor of 3.5–4 higher than theirs. *OSF 18 Industrial Statistics 1914*; G. M. Nordensvan, *Etelä-Suomen Voima Osakeyhtiö 1916–1941* (Helsinki, 1941) p. 12.
18. For example, G. M. Nordensvan estimated that electricity was generated between 300 and 400 GWh in 1922. My figure is 384 GWh. Nordensvan, 'Suomen voima- ja sähköistysoloista', p. 345. See also, V. Veijola, 'Maamme sähköistys ja sähkölaitoksia koskeva lainsäädäntö', *VV*, 3 (1930) no. 11, p. 279.
19. *Sommario di statistiche storiche dell'italia 1861–1975*, Instituto centrale di statistica (Roma, 1976) p. 101; B. R. Mitchell, *European Historical Statistics 1750–1970* (London, 1978) pp. 290–4; See also: *Canadian Statistical Review, Historical Summary 1970*, The Ministry of Industry, Trade and Commerce (Ottawa, 1970); *Historical Statistics of the United States, Part 2* (Washington, D.C., 1975) Leslie Hannah, *Electricity before Nationalisation* (London, 1979) pp. 426–34; Hugo Ott, *Statistik der öffentlichen Electrizitätsversorgung Deutschlands 1890–1913, Historische Energiestatistik von Deutschland – Band 1* (St Katharine, 1986) pp. i–xxxvii; Walter Wyssling, *Die Entwicklung der schweizerischen Elektrizitätswerke und ihrer Bestandteile in den ersten 50 Jahren* (Zürich, 1946) pp. 496–503.
20. *OSF 1A Foreign Trade 1889–1977*, CSOF (Helsinki, 1893–1978); *OSF 18 Industrial Statistics 1890–1977*, CSOF (Helsinki, 1892–1979).
21. For example: 'Sähköalan teollisuustuotteiden tuontitilasto', VV, 3 (1930) p. 130; 10 (1937) p. 134; L. Paavolainen, 'Suomen sähköteknillinen teollisuus', *TAik* (1938) pp. 400–4; V. Veijola, 'Sähköteknillinen teollisuutemme ja sen kehittymismahdollisuudet', *VV*, 11 (1938) no. 12, pp. 275–9; V. Veijola, 'Sähköteknillinen teollisuutemme', *VV*, 24 (1951) no. 2, pp. 23–5; V. Veijola, 'Katsaus sähköteknillisen teollisuutemme kehitykseen', *VV*, 28 (1955) no. 4, pp. 75–9; A. R. Saarmaa, 'Suomen sähköteollisuuden tuotannon kehitys', *VV*, 32 (1959) no. 9, pp. 185–6.

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