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OPERATING POLICIES, PROBLEMS AND EXPERIENCES WITH THE HELSINKI ENERGY SUPPLY SYSTEM

by

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1. On National Energy Production

In Finland the energy production and distribution are taken care of by many separate utilities and companies, and also the types of production processes are very diversified. To illustrate this, the diagram shown in Figure 1 was prepared. It shows how the electricity production in 1978 was divided between different types of companies and different types of production processes. The diagram indicates that 28 per cent of the total electricity produced was generated in advantageous combined heat and power processes (back-pressure and district heat) with a high fuel efficiency. This is an indication of the fact that the institutional atmosphere in Finland with regard to the energy production is relatively liberal, allowing the energy producing, distributing and consuming companies to select a supply mix ensuring minimized total cost. The traditionally high cost of fuels (no indigenous natural gas, oil, or coal) has given a special incentive to developing energy efficient systems. The common interests of the energy suppliers have also motivated good mutual cooperation regarding e.g. reserve production capacity and transmission of energy, as well as bying and selling it. This is naturally best developed in the field of electric energy due to the requirements set by the operation of the national transmission grid. Perhaps other significant aspects are the relatively open exchange of information between the companies on the technical development, and the development of standard practices and technical solutions. This has been beneficial to the technical development and to the energy industry in general.

2. Energy Supply in Helsinki

In Figure 1 the Helsinki energy supply system is included in category "Distribution Utilities", like all municipal energy supply undertakings, by reason of all of them having the distribution of electricity as one of their activites and for many of them it still is the main form of activity in their respective service areas. Many of them have, however, subsequently started their own production of electricity and district heat, and the municipality of Helsinki has been the forerunner in this respect.

In November 1953, the Helsinki City Council decided to establish a district heating system in the city, with combined generation of heat and electricity. Steam distribution for some industrial consumers was started already in 1952, and hot-water district heating in 1957. The cogeneration began in 1960.

In 1978 also the Gas Works, supplying towngas (now generated from butane) in downtown Helsinki, was included in the organization of the Helsinki Electricity Works, and the name thereby was changed into a more appropriate one, the Helsinki Energy Board.

The Energy Board generates and distributes practically all the electricity consumed in the city. Today the district heating production and distribution form also a very important part of the activities of the Energy Board. In fact, this year the revenues from the district heat sold will exceed those from the electricity sold. Another fact illustrating the importance of district heating is that over 70 per cent of the heating of building space and domestic hot water within the city is taken care of by district heating. The system is still growing, and this figure is expected to exceed 85 per cent by 1990.

In Table 1 some development figures of the Helsinki system are shown. As background information, it should be mentioned that the population of Helsinki today is about 485 000. The city has experienced a slight decrease in its population during the past few years.

As can be seen from the figures in Table 1, the growth has been rapid, especially in the area of district heating and cogeneration. In fact, today the Helsinki hot water district heating system is the largest one in Western Europe.

Since the share of cogenerated energy of the total production is now quite high, the average efficiency of fuel utilization is also high. To illustrate this, Table 2 is included. It shows the net production of heat and electricity in cogenerating and separate processes and the amount of fuel consumed in 1979. The average annual efficiency obtained was 78.7 per cent (based on lower heat value of fuel).

If the same net heat to the consumers, 16380 Billion Btu, (4800 GWh) were produced in separate heating furnaces for each building (70 per cent annual efficiency), and the electricity, 2053 GWh, in condensing processes (34 per cent annual efficiency), the total fuel consumption in the city would have been 12740 Billion Btu (3730 GWh) i.e 40,7 per cent higher than it actually was. This saving in fuel consumption is equivalent to 2 150 000 barrels (331 000 metric tons) of heavy fuel oil.

This type of saving figures, together with increasing fuel prices, strengthen the motivation to develop the system further.

3. On Development Policies

The growth as such is not, however, the main aim of the Helsinki Energy Board. Since the Board is a fully municipal undertaking, its main purpose is to serve people within the city.

The operating principles of the Energy Board have been defined as follows:"It is the purpose of the Energy Board to satisfy the needs for electricity, district heat, and towngas mainly within the city limits of Helsinki in such a manner that the energy is as advantageous to the users as possible".

To be able to supply energy which is advantageous to the users, the Energy Board has to produce it with a minimum cost. The efficiency of combined heat and power generation provides a good way to reduce the costs. It is not, however, profitable to build expensive cogenerating plants to satisfy the full maximum demand, because a large portion of this expensive capacity would stand still during the major part of the year, waiting for the coldest days to be taken into operation. To minimize the total cost, the peak load should be covered by means of simple plants which are inexpensive in investment costs.

The higher fuel cost does not matter so much because the plants will only be operated for short periods of time annually. Therefore, in spite of increasing oil prices, it is profitable to take care of peaking of heat load by means of heavy oil fired heat-only hot water plants, while the base load is covered by means of coal fired combined heat and power plants (back-pressure turbines and extraction-condensing turbines).

In the electrical side the same principle applies. The peaking and reserve capacity is taken care of by means of gas turbines which are inexpensive in investment costs but use expensive light oil as fuel. The share of gas-turbine power of the total production has been very low lately, since some of the heat and power plants have extraction-condensing turbines and can produce condensing power, if the heat load does not provide for sufficient back-pressure power output. The back-pressure turbine units have also auxiliary coolers by means of which heat from the district heating network can be dumped into the sea, thus generating a possibility to produce additional electricity in back-pressure turbogenerators. Although this additional power is generated with relatively low efficiency (about 28 per cent), it is still less expensive than gas turbine power.

The optimal share of the back-pressure base-load capacity in the heat side has in recent years been 50...55 per cent of the maximum heat demand. The optimum can, of course, change in the future, depending on the escalation of fuel prices and other costs.

Figure 2 shows why the higher fuel cost of the peaking units does not have a very significant effect on the total cost.

A typical duration curve of annual district heat supply shown in the figure (based on average supply and return water temperatures) indicates that 95 to 97 per cent of the annual energy could be supplied by back-pressure processes, although they cover 50 to 55 per cent of the maximum demand only. In the same way a major portion of the electric load is covered by back-pressure power.

In actual practice, however, the share of back-pressure energy is somewhat lower. There are several reasons for this. First of all, the operational characteristics of the production plants are such that they cannot be shut down and started instantaneously, or run on certain partial loads. Therefore, the load variations cannot always be followed by those generating stations which would produce the theoretical optimum operating results.

Also in the heat transmission network there are presently some bottlenecks which do not allow certain areas to be fully supplied from the combined plants in high load conditions. In addition, there are some new housing developments which are served by means of transportable heat generating units and are not yet connected to the main network.

Also the electric load causes sometimes limitations. That is the case when, due to the heat load, the back-pressure power production possibilities exceed the city's electric load, and the nationwide energy supply situation is such that the excess cannot be profitably sold.

It is the goal of the Energy Board to reduce the effect of limiting factors and to keep the share of cogenerated energy on an optimal level by building the right kind of capacity on the long run and by operating the existing capacity in an optimal way at all times.

The growth of heat load provides increasing possibilities for the advantageous combined heat and power generation. Therefore, it has been the Board's policy since 1970 to take care of the heating of such areas where a centralized heating system is motivated, although the areas cannot immediately be connected to the main network. This type of new areas are temporarely heated by means of transportable heating units. For example, at the end of 1979 there were 23 such areas. The temporary heating lasts usually 2...5 years after which the local network can be connected to the main one.

Although the Energy Board wants to expand its district heating service, there is one limiting principle, and that is profitability. District heat is only offered in areas, in which it is cheaper than any other alternative way of heating the consumers could have. At the same time connecting the consumers and supplying them with district heat must be profitable to the Energy Board. The consequence of this principle is that some, normally older, sparsely built areas cannot be supplied with district heat unless they are very close to heat transmission lines serving more densely built areas. Electric heating, either direct, or one with a reserving system using off-peak electricity only, can normally be offered to this type of housing areas.

The reliability of the energy supply is one of the major concerns when developing an energy supply system. In Helsinki, when planning the production plants and distribution equipment, this is always kept in mind.

In the electric side, there is reserve capacity within the steam power plants, and, in addition, there are gas turbines to take care of peaking and back-up. Also the electric net has strong connections to the national grid which can supply reserve power when needed and through which the Energy Board can also supply power to the grid.

In the heat supply side, at least all important and sensitive consumers, such as hospitals and big hotels, can be fed through two different pipelines.

Even though the heat supply system has proved to be very reliable, the reliability requirement has given incentive to locate the combined and peaking plants in different parts of the city. There are, of course, other reasons, some of which are historical, for the present locations of the plants. One of the most important ones is the convenient transportation of fuel. The large generating plants are so located that they have their own coal harbours. The environmental requirements, now and especially in the future, are also important factors when plant sites are being considered.

4. Structure of Energy Supply System in Helsinki

4.1 Generating Plants

At the end of 1979, the total heat and power generating capacities in the Helsinki system were 7 144 million Btu/hr (2093 MW) heat and 585 MW electricity. 2 184 million Btu/hr (640 MW) of heat production capacity was in back-pressure processes, and the corresponding figure in the electric side was 385 MW. The different generating plants, their construction years and capacities, are shown in Table 3, and the locations of the plants on the map in Figure 3 also showing the location of the Main Network of the heat distribution system.

In addition to the plants listed in Table 3, there is a new large combined heat and power plant under construction. It will be built close to the present Salmisaari power plant and will be called Salmisaari B. Its output capacity will so located that they have their own coal harbours. The environmental requirements, now and especially in the future, are also important factors when plant sites are being considered.

4. Structure of Energy Supply System in Helsinki

4.1 Generating Plants

At the end of 1979, the total heat and power generating capacities in the Helsinki system were 7758 million Btu/hr (2273 MW) heat and 585 MW electricity. 2798 million Btu/hr (820 MW) of heat production capacity was in back-pressure processes, and the corresponding figure in the electric side was 385 MW. The different generating plants, their construction years and capacities, are shown in Table 3, and the locations of the plants on the map in Figure 3 also showing the location of the Main Network of the heat distribution system.

In addition to the plants listed in Table 3, there is a new large combined heat and power plant under construction. It will be built close to the present Salmisaari power plant and will be called Salmisaari B. Its output capacity will be 150 MW electricity and 920 million Btu/hr (270 MW) heat. It will be taken into operation in 1984, and the old unit A will be decommissioned after that in due course.

Also one more heat-only station for peaking is under construction and will be commissioned in 1981 (shown in Figure 3). It will serve mainly the North-East section of the city, where the main network will expand considerably. The new station called Patola will in the beginning have an output rating of 408 million Btu/hr (120 MW), which will be doubled in the future.

The main fuel for cogenerating plants is coal, which although also imported, is considerably cheaper than fuel oil in Finland. The plants Salmisaari and Hanasaari B with back-pressure turbines have auxiliary coolers. Hanasaari A is an extraction-condensing power plant which can change heat and power output rather independently. The power plant Myllypuro has nowadays a full heat load throughout the year; earlier a heat accumulator was used to assure full power production.

The only fuel for peak load stations is heavy fuel oil. Also most of the transportable heating units burn heavy oil.

4.2 Heat Distribution System

For the major part of the heat supplied, the heat carrier is hot water. The supply system is a closed two-pipe system. The supply temperature varies from 248 to 167°F (120...75°C), and the return temperature from the 158 to 113°F (70...45°C), depending on the heat load .

The relationship between the ambient temperature and the total heat load is shown in Figure 4. The vertical scale indicates how many per cents the daily mean heat load has been from the total contracted heat demand of the corresponding day. The diagram is based on actual daily mean loads from July 1, 1974 to June 30, 1978. It includes also the daily heat losses which count for 6...7 per cent of the total annual heat energy supplied. The heat storing capacity of the distribution system and the changing weather conditions are causing deviations from the mean curve. The extent of the deviations are shown on the graph by means of dotted lines.

Consumers are indirectly connected to the network by means of heat exchangers. Also domestic hot water is always heated with district heat. District heat is available for consumers throughout the year. (Ref. Mr. Veikko Hokkanen: "Regulating District Heat for Consumers in Helsinki ", III International District Heating Convention, Warsaw, Poland April 1976)

A major portion of the heat delivered is distributed through the Main Network (shown in Figure 3) which covers the Central-Western part of the city. In this section of the system, the connected heat load at the end of 1979 was 5460 million Btu/hr (1600 MW). In the Eastern suburbs there is another hot-water network originally established to heat some newly built housing areas but now serving also many older areas. This, the Myllypuro Network, has a connected heat load of 696 million Btu/hr (204 MW). The Main and Myllypuro systems are now interconnected with a pipe line. It is not, however, sufficient to transmit heat for the whole Myllypuro area from the main system.

At the end of 1979, the total length of district heating pipelines in the Helsinki system was 315 miles (505 km).

70 per cent of the pipelines is underground in ducts and the rest mainly in the basements of buildings. Only one mile of the piping is in tunnels and about the same length at bridges. The length of the steam supply lines is about one per cent of the total length of the district heating pipelines.

The annual increase in the length of the piping system has averaged 28,5 miles (44,8 km) during the past five years.

The construction of the pipelines has been standardized and they are made of prefabricated components as far as possible. (Ref. Risto Vartia: "Planning and Construction of District Heating Pipelines", IV International District Heating Conference, Sirmione Brescia, Italy, May 1980).

The Main Network is normally operated as one system fed by the power stations and peak load stations in parallel. All the valves in the system are kept normally open, but any section of the system can be quickly isolated, if need arises, by means of remotely operated valves.

To circulate the heat carrying water in the network, all power and peaking plants are equipped with pumps, the flow rate of which can be varied by means of a speed-control system. In addition to the pumping stations at the plants, there are some separate booster pump stations which have also variable speeds and are remotely controlled (startup, shutdown and flow rate) automatically by the pressure conditions in the network beyond the pumps.

The highest pressure in hot-water district heating pipelines in Helsinki is 142 psig (9.8 bar) so that the largest pressure difference between the supply pipe and return pipe is only about 120 psi (8 bar). The static pressure of the district heating network (the mean value of supply and return pressures) corresponds to about 200 ft (60 m) of water pile measured at the sea level.

Steam is today supplied almost without an exception for industrial process purposes only. Maximum steam flow rate to the consumers is about 155 000 lb/hr (70 ton/hr).

As regards the aging of the district heat distribution piping system, it can be stated that no failures due to the aging of the system has been experienced in Helsinki.

This is as expected, since the oldest pipelines have been laid only 20...25 years ago. This is not to claim that there has not been any faults or defects during these years.

To reduce the possibility of damages, it is important to keep the piping system dry. The construction has to be such that in case water leaks into the duct, it must flow with minimum moistening of the insulation into an inspection chamber where it can be pumped away. Also sufficient ventilation in the ducts is necessary. The moisture conditions in the ducts in the Helsinki system are continuously monitored.

The most common reason for damages in the piping is groundwater which can trickle in through untight joints in the pipeline duct (concrete or plastic), or through broken casing. Groundwater then causes corrosion in steel pipes. Axial expansion joints consisting of multilayer stainless steel bellows are the most easily damaged components of the pipeline. Stress corrosion arises easily in chromium-nickel steel bellows through the combined effect of stress, high temperature, moisture and chlorides. Chlorides can originate e.g. from salts used to melt snow on the streets.

Faulty work while building district heating pipelines and especially negligence and inadequate methods in sealing the duct elements have also been common causes for damages in pipelines. Damages caused by this kind of defects are usually revealed within a few years after the installation.

After this initial period, the appearance frequency of damages seems to diminishe. This has been experienced also by other district heating undertakings in Finland. (Ref. Pekka Puustinen and Seppo Partanen: "Schäden und Betriebserfahrungen im finnischen Fernheiznetz - Eine erläuternde Untersuchung in Finnland", Ferwärme International - FWI, 1980, 1, pages 36...39).

The cost of maintenance of district heating pipelines in Helsinki is annually about 3,5 per cent of the capital value of the networks. This cost is rather evenly divided between preventive maintenance and repair work.

5. Optimization of System Operation

The Helsinki energy supply system has to satisfy two independent demands, the demand for electricity, and the demand for district heat. However, the combined generating process ties together the production of these two different types of energy. In addition to this basic complexity the Helsinki system consists of different types of plants which operate parallel by feeding energy to two distribution systems, one for electricity, and the other for heat.

To operate such a system in an optimal way is not an easy task. To obtain this goal as closely as possible, a centralized control system has been established. In Helsinki there is an underground control center which monitors continuously the operation of the system, carries out optimization calculations, takes care of some operating measures itself, and gives operating instructions to the generating plants supplying the system. In case of disturbances of the supply and transmission system, the control center locates the disturbance by means of a remote monitoring system and supervises the clearance of the disturbances. Also the operation of the electric transmission network (110 and 30 kV) and the remote control of the off-peak electric space heating system are responsibilities of the control center.

As an example of different load conditions and of how the supply has been divided in an optimal way to different plants, Figure 5 is included. It shows the heat and electric load variations during three typical working days. Also the corresponding outdoor temperature has been plotted. The low load day is June 7, 1979, with the average outdoor temperature of 66°F (19°C), the medium load day October 26, 1979, with the average temperature of 35°F (2°C) and the high load day January 31, 1980, with the average temperature of -4°F (-20°C). The heat loads shown were the loads of the area served by the Main Network only.

These daily mean loads correspond to 8 per cent, 40 per cent and 77 per cent of the heat load contracted by the consumers in the corresponding days.

The electric loads shown correspond to the total load of the city.

During the typical sample days some electricity was obtained from hydro power plants and a nuclear power plant, in which also the Energy Board is a shareholder. A very minor amount of electricity was also obtained from the national grid. This was, however, due to regulating inaccuracies and was cleared against the same amount of electricity sold. The electricity supplied outside was sold to other power companies, in this case to a state owned and a private one, and transmitted through the national grid.

During the summer day, all the heat was generated in back-pressure processes, but since the heat load was low, a fairly large share of the total electricity was generated in the condensing mode of the turbines. During the fall day, some of the heat was generated also in the peaking heat-only plants. The heat load was high, allowing so high a back-pressure power output that only a small amount of condensing power generation was needed.

In the cold winter day, all the plants were in operation and a large share of the heat was generated in the peaking plants.

The total energy values generated during the typical sample days are given in Table 4.

The optimization of the operation of the system is carried out by means of a computer system which simulates the load conditions and the plant operations. In the optimization process the plant characteristics, the cost

of different types of fuels used, and the cost of power purchased and sold, are taken into account. The system simulates also the hydro power production and the follow-up of electric load variations by means of hydro power to the extent the availability of hydro power allows. From the computer results the control center operators know how large a share of the total load each plant should cover to keep the operating cost in the minimum. This computer system produces weekly operating forecasts based on the hourly load statistics and expected weather conditions.
These results are reviewed daily on the basis of the short term weather forecasts. The actual load and operating data are used for the check runs which are carried out every 15 minutes.

In addition to the daily optimization of the system operation, the medium and long term planning are also carried out by means of similar computer systems.

In the long term they are used e.g. for the optimization of production capacity, and in the medium term for budgeting, planning of purchase of fuels, and maintenance shutdowns. The calculations are performed on hourly bases, taking into account population and consumer growth scenarios, weather conditions, fuel price escalations etc.

Also the operation of the heat distribution piping network is simulated by means of the computer. These simulation runs produce results which tell the operators whether the network will set any limitations to the operation of the total system. This is then taken into account in the operating conditions when planning the load sharing between different plants.

By means of the network simulation system, the overall effect of certain operational measures, e.g. such as closing of a valve, can be checked. By means of this system also the planning and sizing of new pipelines can be carried out.

As a point of interest, it may be worth mentioning that all the transportable heat-only plants are unmanned with remote alarm systems. One of the peaking plants, Lassila, is remotely operated and the operation takes place from the Ruskeasuo plant. Only one maintenance man attends the plant during the daytime. This year also the Alppila peaking plant will be modified for remote operation.

In the future, it seems possible to reduce costs and improve the energy supply by still more intensifying the cooperation

with other energy supplying utilities.
This would make the construction of larger generating units possible which would reduce the investment cost per kilowatt and per Btu/hr of capacity. Also the peaking and back-up capacity cost would be lower. The utilization of the available capacity would be more efficient, when e.g. among the cooperating parties always the most efficient generating plants could provide for the energy needs of the joint system independetly of the ownership. To achieve these kinds of goals, the municipalities and energy companies in the Helsinki Metropolitan area have established a new company, the task of which is to delevop the cooperation further. The original goal was to build a nuclear power plant to supply electricity and heat in the Helsinki Metropolitan area under a joint ownership. This project has been postponed and the commissioning will hardly take place in this decade. The cooperation on a conventional basis is, however, under consideration.

As a small-scale example of cooperation between two municipalities, it can be mentioned that a connecting pipeline between the district heating networks of Helsinki and a neighbouring city Vantaa (population about 130 000) is under construction. The systems will be connected by means of a heat exchanger and a pumping station with the heat transfer capacity of 170 million Btu/hr (50 MW). Because the city of Vantaa has some over-capacity in its cogenerating plant, it can supply back-pressure heat in winter time to Helsinki, thus reducing more expensive heat production in peaking plants. In summer when the Vantaa plant has its maintenance shutdown, the Helsinki system supplies back-pressure heat to the Vantaa network. This cooperation procedure will be profitable to both parties and investments required are paid back within one year.

6. Pricing, Metering and Billing of Heat

In Helsinki there are all kinds and sizes of buildings connected to the district heating system. The Helsinki Energy Board considers a group of buildings, a single apartment house, or an individual home as one consumer, as long as there is only one heat meter and one monthly invoice for the entity concerned. One single apartment has at least not so far been accepted as a separate consumer with individual billing.

The cost of heat from the district heating system must be lower than any other source of heat available to the building owner. Otherwise the building owner will not sign a contract with the heat supplying company. There is no such provision in the Finnish law by means of which the supplier could force the house owner to sign a heat supply contract. The above gives the basic criterion for the cost level of the district heat. As an example of the development of energy costs in Helsinki, Figure 6 has been prepared. It shows the average prices of coal, heavy and light fuel oil, district heat, and electricity. There are two curves for the price of electricity. The higher one shows the price paid by average consumers and the lower one is based on the total sale of electricity, including also the sale to other power companies.

By means of the structure of the heat tariff, the supplier is in a position to attract different types of consumers and to give incentive to use heat in such a way that investments required from the supplier stay on a reasonably low level (low peak demand) and that the operation costs of the supply system are optimal (e.g. low return water temperature gives higher power yield in the back-pressure process). To obtain these goals, a tariff system consisting of three different charges has been developed.

When signing a contract to join the district heating system the consumer has to pay an irrevocable connection charge, the amount of which depends on the contracted maximum water flow, and also on the previous heating system for existing buildings. The level of the connection charge is so set that the charge is slightly lower than the investment required for the installation of another type of heating system in buildings to be built and for the repair and renewal of heating equipment in existing buildings. Thus, the connection charge is adjusted to attract different types of customers.

The connection charges cover a part of the investment required for the network extensions. On the average this share has been 36 per cent during the past five years.

The actual heat tariff consists of two parts, one being a fixed annual fee based on the maximum water flow contracted by the consumer, and the other an energy charge based on the amount of heat consumed. The contracted water flow is automatically limited (excluding very small consumers) to the flow rate contracted. The energy charge follows to the confirmed price of heavy fuel oil, being today 1.25 times the price.

The heat consumption of each consumer is measured by means of integrating meters. Usually, the meters consist of a mechanical water flow meter, thermoelements for the temperature measurements in the supply and return water lines, and an electronic device to calculate and integrate the heat consumed. The meters are read by the consumers themselves. The filled-in forms are mailed bimonthly to the Energy Board.

The invoicing is computerized and the consumers get a monthly bill consisting of one twelfth of the annual fixed fee, the energy charge estimated by the computer, and, bimonthly, a correction based on actual consumption figures.

The billing system functions very well. To give the consumers incentive to read the consumption data, there is a small extra charge, if the filled-in form is not sent to the Board in time. Normally, the bimonthly corrections are minimal, since the computer calculations are based on weather data and past consumption statistics, which make the predictions fairly accurate. (Ref. Mr. Veikko Hokkanen: "Metering and Billing District Heat", IV International District Heating Conference, Sirmione Brescia, Italy, May 1980).

7. Profitability of District Heating and Cogeneration

District heating has been profitable from the municipality's point of view right from the start of the system. At the same time it has offered the building owners a heating alternative, the total cost of which is lower than the cost of any other means of heating. The profitability to the consumer as well as to the supplier is, of course, a prerequisite for the development of such a system.

The good profitability already from the beginning is due to the relatively long heating season in Helsinki, as well as to the relatively high density of buildings in the downtown area where district heating was started. Thus, the annual heat sales were high as compared to the length and capital cost of the distribution piping system.

After the increase of fuel prices in 1973, an extensive energy saving campaign was carried out by the Government, and about 10 per cent decrease in the heat consumption level resulted. The heat consumption level has remained lower after that. Insulation of older buildings have been improved, windows have been equipped with triple glazing, etc. In new buildings strict standards concerning insulation, windows, ventilation, and thermostatic controls have also been applied to reduce the heat consumption.

In spite of these measures, the competitiveness of district heating with other heating systems has increased thanks to its capability of reducing the consumption of expensive fuels. This has been beneficial to both the users of the services of the Energy Board and to the Board itself. In fact the electricity and heat sold by the Board are less expensive than anywhere else in Finland.

To the Energy Board district heating is today profitable even if the benefits of the cogeneration are not taken into account.

From the total revenues of the Energy Board, the annual surplus has been such that the Board has been able to self-finance its investments in the replacement of old equipment and in the extension of the service area, and in new production plants. In addition, the Energy Board has been able to give financial assistance to the municipality for other investments, thus lightening the tax burden to the inhabitants of Helsinki.

TABLE 1

DEVELOPMENT OF DISTRICT HEAT, ELECTRICITY AND TOWN GAS IN HELSINKI

Year	1959	1964	1969	1974	1979
District Heating					
Number of consumers at the end of the year	221	819	1744	2971	4979
of them steam consumers	16	44	58	39	26
Heat demand of consumers					
Million Btu/hr	372	1324	2685	4483	6510
MW	109	388	787	1314	1908
Percentage of DH consumers in the whole heat demand of the city	5	19	36	54	71
Heat sales to consumers					
Billion Btu	652	3306	7817	9939	16593
GWh	191	969	2291	2913	4863
Income from heat sales					
Million US$ x)	0.7	3.0	7.3	26.4	83.8
Million Fmk	2.7	11.3	27.8	100.3	318.4
Percentage of heat sales income in the turnover of the Energy Board	4	13	18	29	42
Average heat price					
US$/Million Btu x)	1.06	0.99	0.93	2.65	5.05
Fmk/MWh	13.7	12.8	12.1	34.4	65.5
Power production and purchase					
Hydro shares	93	145	171	237	213
Nuclear shares	-	-	-	-	95
Thermal production (gross)	192	721	1559	1725	2298
. back-pressure production	-	434 (back-pressure and condensing)	766	935	1820
. condensing production	192		721	646	441
. gas turbine production	-	-	-	57	0
. substituting purchase	-	287	72	87	37
Primary purchase	344	28	45	38	21
Production and purchase in total	629	894	1775	2000	2627
Power production in cogeneration GWh (gross)	-	284	766	935	1820
Percentage of cogeneration of the total production and substituting purchase	-	39	49	54	79
Town gas net production (excluding surplus sold to Electricity Works in 1959...69)					
Million m^3	34.4	35.0	31.1	27.7	23.9
Million cu ft	1215	1236	1100	977	842
GWh	151	153	134	124	106
Billion Btu	514	524	456	422	361

x) 1 Fmk = 26 US cents (March, 1980)

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Million Btu/hr	372	1324	2685	4483	6510
MW	109	388	787	1314	1908
Percentage of DH consumers in the whole heat demand of the city	5	19	36	54	71
Heat sales to consumers					
Billion Btu	652	3306	7817	9939	16593
GWh	191	969	2291	2913	4863
Income from heat sales					
Million US$ x)	0.7	3.0	7.3	26.4	83.8
Million Fmk	2.7	11.3	27.8	100.3	318.4
Percentage of heat sales income in the turnover of the Energy Board	4	13	18	29	42
Average heat price					
US$/Million Btu x)	1.06	0.99	0.93	2.65	5.05
Fmk/MWh	13.7	12.8	12.1	34.4	65.5
Power production and purchase					
Hydro shares	93	145	171	237	213
Nuclear shares	-	-	-	-	95
Thermal production (gross)	192	721	1559	1668	2298
. back-pressure production	-	} 434	766	935	1820
. condensing production	93		721	646	441
. gas turbine production	-	-	-	57	0
. substituting purchase	-	287	72	87	37
Primary purchase	344	28	45	38	21
Production and purchase in total	629	894	1775	2000	2627
Power production in cogeneration GWh (gross)	-	284	766	935	1820
Percentage of cogeneration of the total production and substituting purchase	-	39	49	54	79
Town gas net production (excluding surplus sold to Electricity Works in 1959...69)					
Million m^3	34.4	35.0	31.1	27.7	23.9
Million cu ft	1215	1236	1100	977	842
GWh	151	153	134	124	106
Billion Btu	514	524	456	422	361

x) 1 Fmk = 0.26 US cents (March, 1980)

TABLE 2

DISTRICT HEAT AND ELECTRICITY PRODUCTION
AND FUEL CONSUMPTION 1979 IN HELSINKI

Net production			Fuel consumption		Efficiency
District heat Billion Btu	GWh	Electricity GWh	Billion Btu	GWh	%
co-production					
13843	4057	1672	22721	6659	86.0
separate production					
3740	1096	-	4214	1235	88.8
-	-	405	4327	1268	31.9
total (1)					
17583	5153	2077	31262	9162	78.9
- DH pumping energy		-24			
total (2)					
17583	5153	2053	31262	9162	78.7
- DH transmission losses					
-1203	-353				
total (3)					
16380	4800	2053	31262	9162	74.8

Distribution of fuel energy consumed

- hard coal 83.2 %
- heavy fuel oil 16.3 %
- light fuel oil 0.5 %

10/TABLE 3

ENERGY PRODUCTION CAPACITIES IN 1979

Plant	Start year	Power output capacity MW back pressure	other	District heat output capacity Mill.Btu/hr (MW) back pressure	other
DH Main network					
Power plants					
Salmisaari					
2 back-pressure turbines	1962, 1964	62	-	614 (180)	-
1 auxiliary steam boiler	1977	-	-	-	27 (8) x)
1 peak load hot-water boiler	1978	-	-	-	408 (120)
Hanasaari A					
2 extraction condensing turbines	1960, 1966	80	70	546 (160)	-
Hanasaari B					
2 back-pressure turbines	1974, 1977	220	-	1433 (420) xx)	-
1 auxiliary steam boiler	1974	-	-	-	192 (56) x)
Kellosaari					
2 gas turbines	1973, 1974	-	120	-	-
Suvilahti					
1 gas turbine	1965	-	10	-	-
Peak load stations					
Alppila					
4 hot-water boilers	1964, 1965	-	-	-	560 (164)
Munkkisaari					
4 hot-water boilers	1969	-	-	-	792 (232)
Ruskeasuo					
4 hot-water boilers	1972, 1973	-	-	-	960 (280)
Lassila					
2 hot-water boilers	1977, 1978	-	-	-	816 (240)
together		362	200	2593 (760)	3755 (1100)
DH Myllypuro network					
Power plant Myllypuro					
2 back-pressure turbines	1967, 1969	23	-	205 (60)	-
3 hot-water boilers	1964, 1965, 1979	-	-	-	600 (176)
Peak load station Jakomäki					
2 hot-water boilers	1968	-	-	-	192 (56)
together		23	-	205 (60)	792 (232)
23 networks fed by 35 transportable hot-water boilers	1968...1978	-	-	-	413 (121)
Total		385	200	2798 (820)	4960 (1453)

x) for steam district heating

xx) of which 205 Mill.Btu/hr (60 MW) for steam district heating

TABLE 3

ENERGY PRODUCTION CAPACITIES IN 1979

Plant	Start year	Power output capacity MW back pressure	other	District heat ouput capacity Mill.Btu/hr (MW) back pressure	other
DH Main network					
Power plants Salmisaari					
2 back-pressure turbines	1962, 1964	62	-		
1 auxiliary steam boiler	1977	-	-	-	27 (8)
1 peak load hot-water boiler	1978	-	-	-	408 (120)
Hanasaari A					
2 extraction condensing turbines	1960, 1966	80	70	546 (160)	-
Hanasaari B					
2 back-pressure turbines	1974, 1977	220	-	1433 (420)	-
1 auxiliary steam boiler	1974	-	-	-	192 (56)
Kellosaari					
2 gas turbines	1973, 1974	-	120	-	-
Suvilahti					
1 gas turbine	1965	-	10	-	-
Peak load stations Alppila					
4 hot-water boilers	1964, 1965	-	-	-	560 (164)
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Ruskeasuo					
4 hot-water boilers	1972, 1973	-	-	-	960 (280)
Lassila					
2 hot-water boilers	1977, 1978	-	-	-	816 (240)
together		362	200	1979 (580)	3755 (1100)
DH Myllypuro network					
Power plant Myllypuro					
2 back-pressure turbines	1967, 1969	23	-	205 (60)	-
3 hot-water boilers	1967, 1969, 1979	-	-	-	600 (176)
Peak load station Jakomäki					
2 hot-water boilers	1968	-	-	-	192 (56)
together		23	-	205 (60)	792 (232)
23 networks fed by 35 transportable hot-water boilers	1968...1978	-	-	-	413 (121)
Total		385	200	2184 (640)	4960 (1453)

TABLE 4

HEAT AND ELECTRICITY PRODUCTION IN HELSINKI IN THREE DIFFERENT DAYS

Day	Thursday June 7, 1979		Friday Oct. 26, 1979		Thursday Jan. 31, 1980	
Outdoor temperature	66.0°F (18.9°C)		35.1°F (1.7°C)		-4.1°F (-20.0°C)	
DISTRICT HEATING						
Main network						
.Turbines and peaking boilers in operation	Hanasaari 1, 2, 3 Salmisaari 1 Kyläsaari		Hanasaari 2, 3, 4 Salmisaari 3 Kyläsaari Ruskeasuo		Hanasaari 1, 2, 3, 4 Salmisaari 1, 3 Kyläsaari Alppila Munkkisaari Ruskeasuo Lassila	
.Connected heat load MW	1552		1590		1602	
.Heat production MWh	2957	100 %	15193	100 %	29598	100 %
..back pressure	2957	100 %	12972	85 %	17901	60 %
..pressure reduced steam	-		1222	8 %	-	
..hot water boilers	-		999	7 %	11697	40 %
All networks together						
.Connected heat load MW	1840		1890		1910	
.Heat production MWh	3900		17900		35550	
ELECTRICITY						
Production MWh						
.Power stations above	4824	100 %	6529	100 %	8512	100 %
..back pressure	1948	40 %	6168	94.5 %	7734	91 %
..condensing	2876	60 %	361	5.5 %	778	9 %
.Other sources						
..nuclear shares	-		404		426	
..hydro shares	818		621		689	
..other back pressure than above	201		573		544	
Electricity total	5843	100 %	8127	100 %	10171	100 %
City consumption	5560	95 %	7291	90 %	8852	87 %
Sold outside Helsinki	283	5 %	836	10 %	1319	13 %

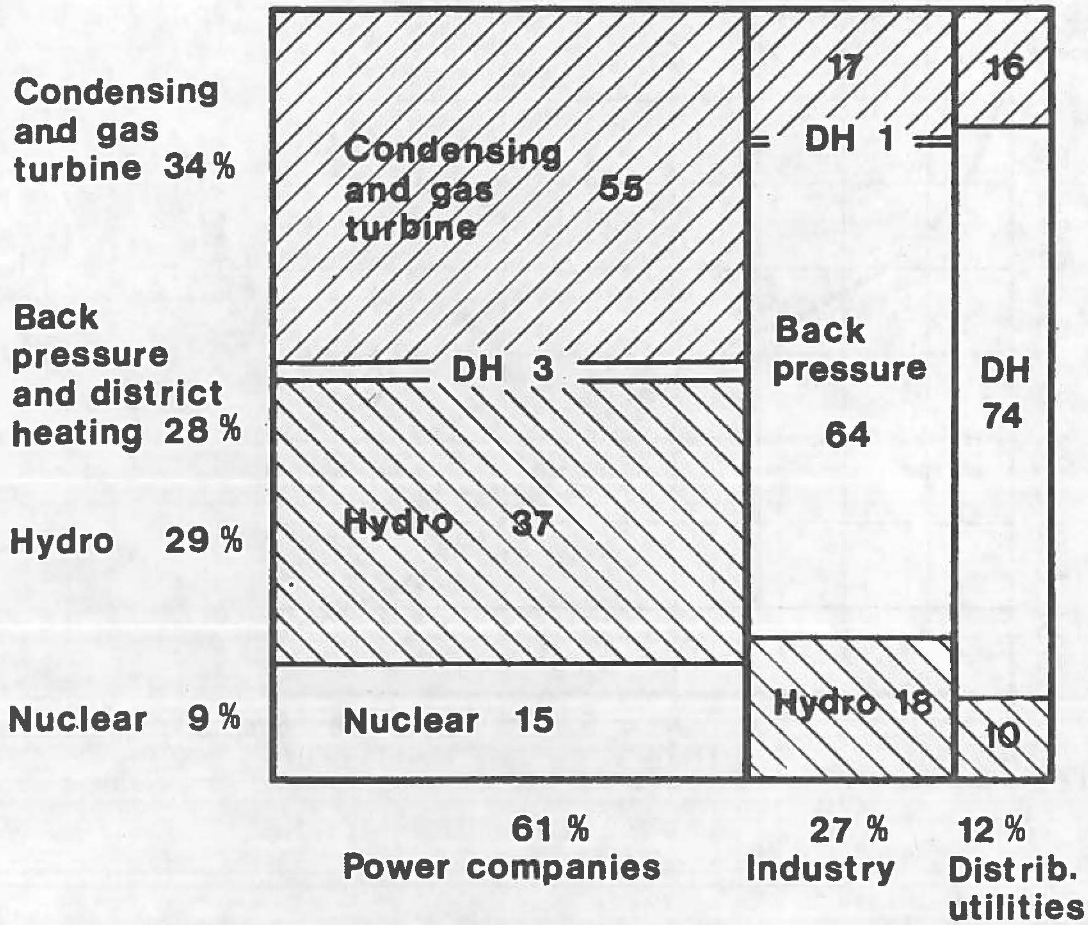

Fig. 1 Structure of electric energy production in Finland, 1978.

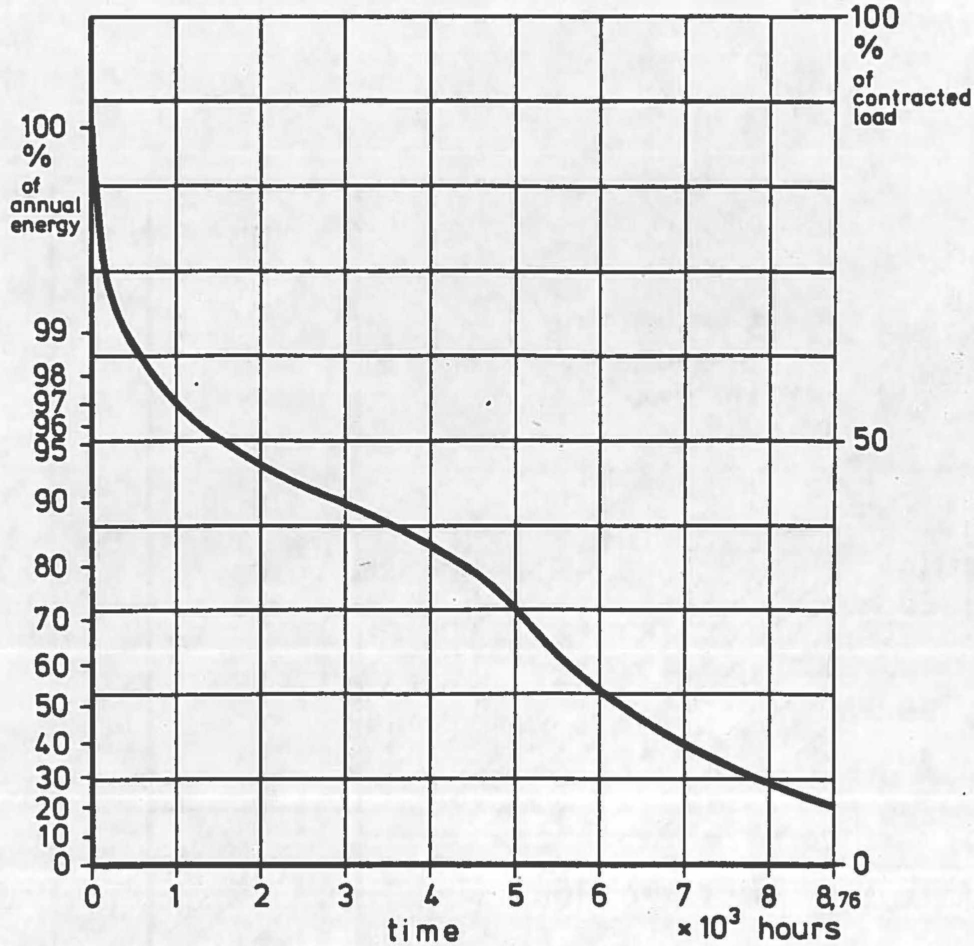

Fig. 2 District heat load duration curve in a normal year in Helsinki based on daily mean loads July 1st 1974 ... June 30th 1978.

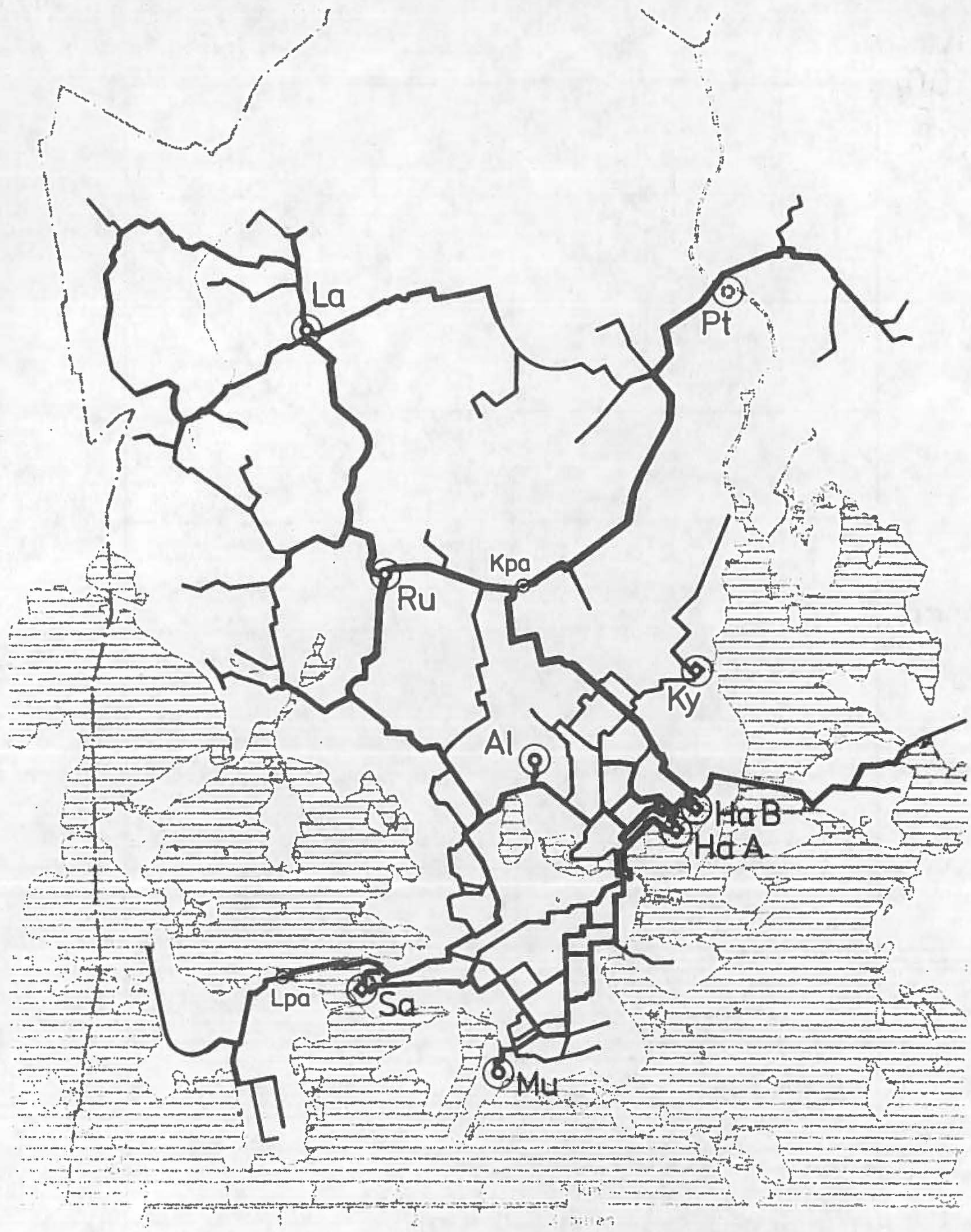

Fig. 3 The main district heating network in Helsinki 1979

Cogeneration plants:

Sa	Salmisaari
Ha A & B	Hanasaari
Ky	Kyläsaari (refuse incineration plant)

Peak load stations:

Al	Alppila
Mu	Munkkisaari
Ru	Ruskeasuo
La	Lassila
Pt	Patola (to be constructed)

Pumping stations:

Lpa	Lauttasaari
Kpa	Koskelantie

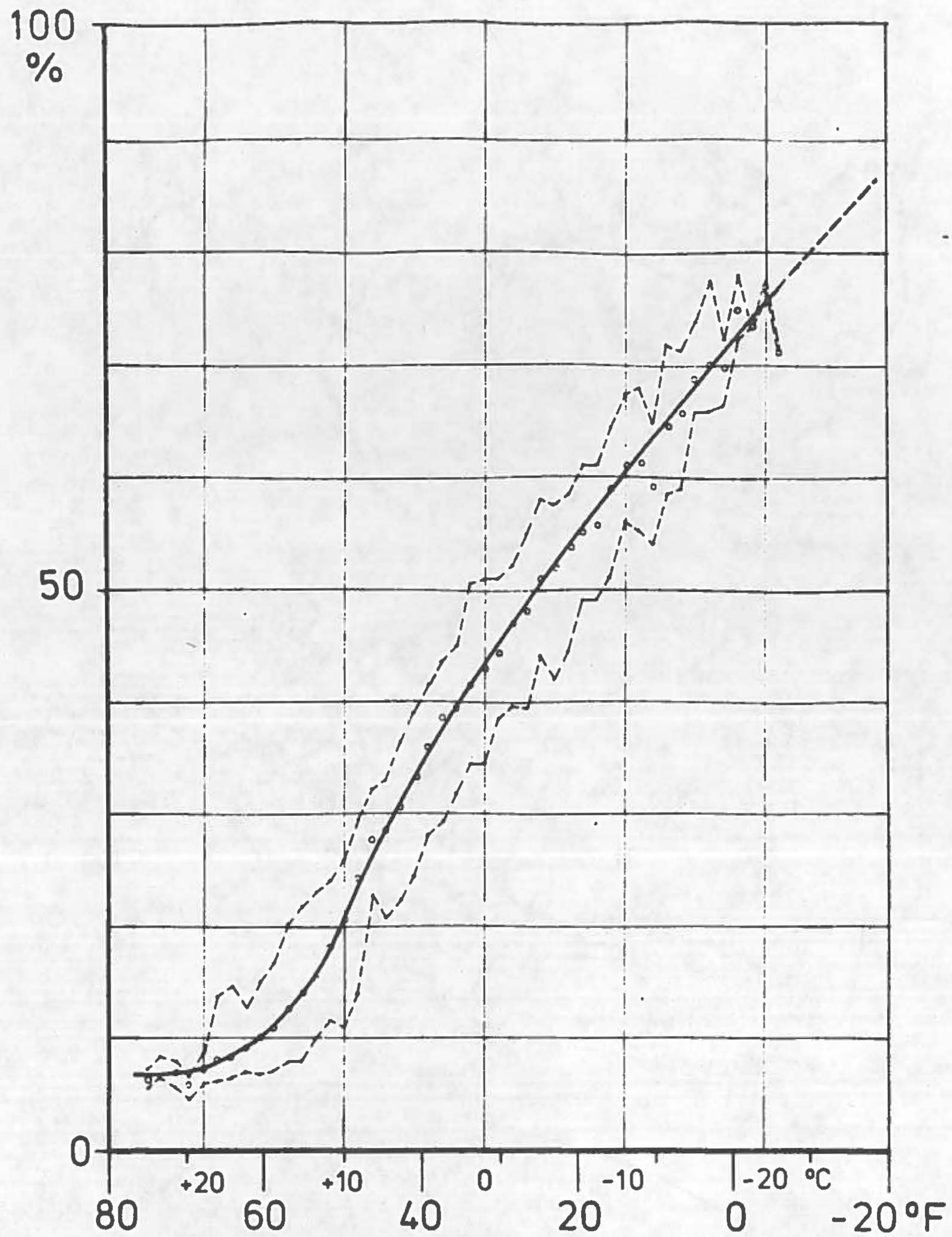

Fig. 4 Daily mean heat load as a function of outdoor temperature in Helsinki

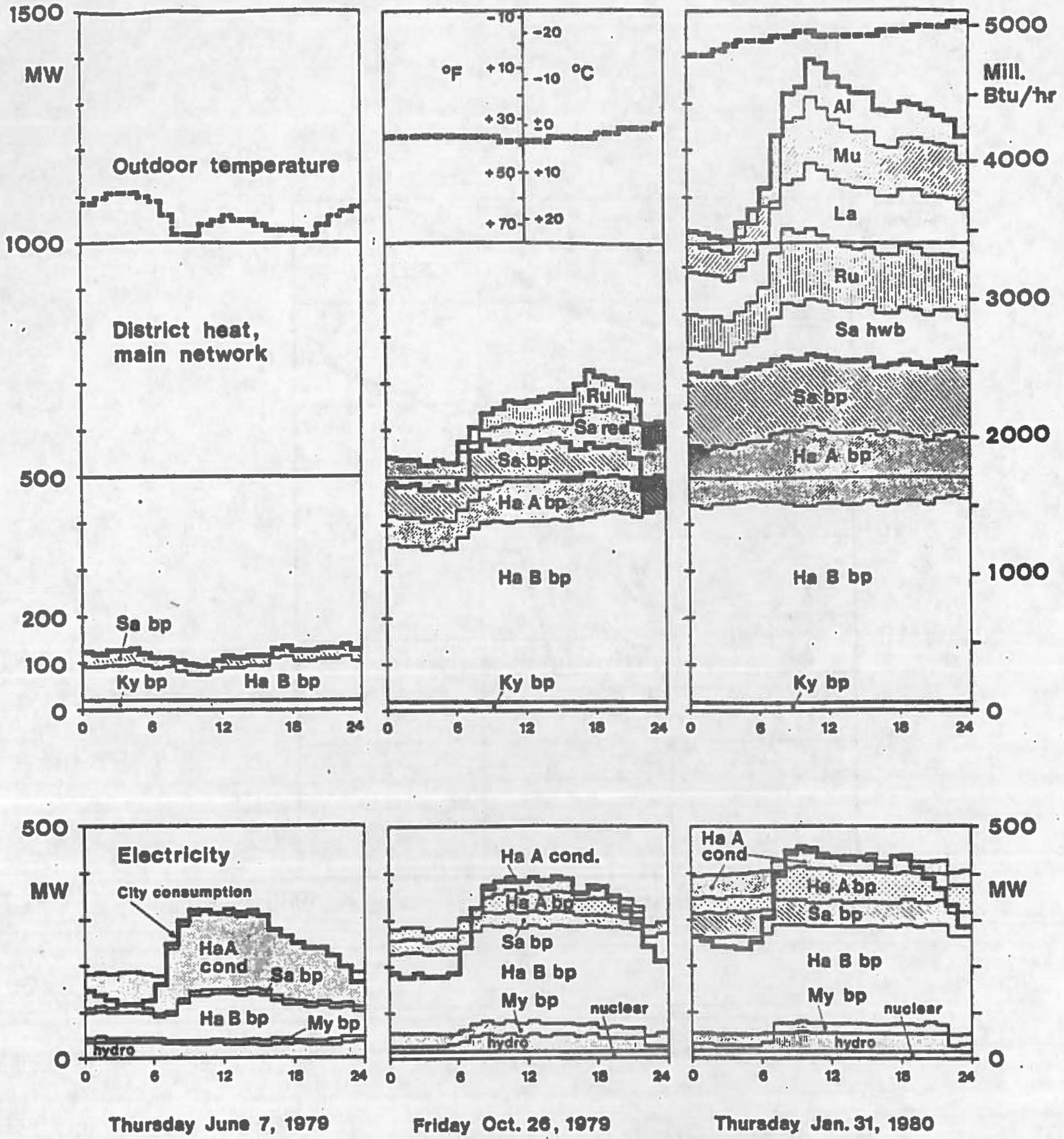

Fig. 5 Electric and heat load variation during three typical working days in Helsinki 1979...80 and division of energy production to different sources.

Ky	Kyläsaari refuse incineration plant
Ha A	Hanasaari cogenerating plant, blocks 1 and 2
Ha B	Hanasaari cogenerating plant, blocks 3 and 4
Sa	Salmisaari cogenerating plant, back-pressure turbines 1 and 3, hot-water boiler
My	Myllypuro cogenerating plant, back-pressure turbines 1 and 2
nuclear, hydro	city's shares from other companies
bp	back-pressure or extraction heat and electricity
cond.	electricity by condensing mode
red.	heat from pressure reduction station
hwb	hot-water boiler
Al	Alppila peak load station (hot-water boilers)
Mu	Munkkisaari " " "
Ru	Ruskeasuo " " "
La	Lassila " " "

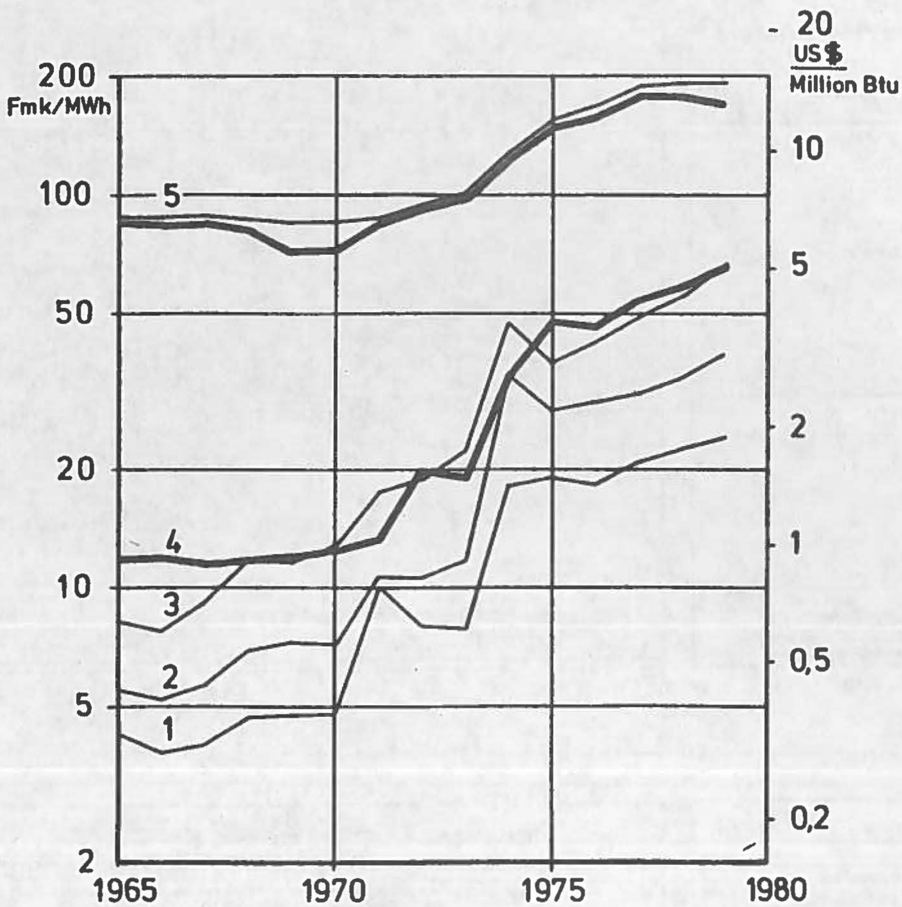

Fig. 6 Energy prices in Helsinki

1. coal
2. heavy fuel oil
3. light fuel oil
4. district heat
5. electricity