DISTRICT HEATING

JANUARY-FEBRUARY-MARCH 1978 VOLUME 63 - NUMBER 3

SIXTY-NINTH ANNUAL CONFERENCE

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AN OFFICIAL PUBLICATION OF THE INTERNATIONAL DISTRICT HEATING ASSOCIATION
PUBLISHED QUARTERLY SINCE 1915

Development of District Heating in Finland

by **Unto Kilpinen**
Chief Engineer, District Heating Department
Helsinki Electricity Works

The first five district heating (D.H.) plants in Finland, and the first power stations with CHP (combined heat and power) production, were built in the 1950's. In the 1960's the number of communities with hot water district heating grew 400%; and in the 1970's it has increased 200%. At the end of 1975, 17% of 1,700,000 residences in the country were connected to actual district heating; about 16% to central heating for small residential groups; 40% had individual central heating; 19% of the dwellings still used wood as fuel in stove heating; and 8% had electric heating.

In 1970, 64% of the whole population in the country lived in densely populated areas, and 49% in communities with at least 3000 people. In 1975 the corresponding figures were about 68% and 53%.

Today, new buildings are equipped, almost without exception, with central heating equipment and common service water heating, because a concentrated heating system is the most advantageous one under Finnish circumstances. Concentrating heat production in large plants saves about 20% annually, compared with fuel supplied to single consumers.

Still greater savings are achieved by combining heat production with back-pressure electricity generation. [Centralized heat production is also more flexible in the use of primary energy than, for example, individual oil or gas heating that is limited to only one fuel.] This has been a growing practice in Finland. The development of district heating and back-pressure electricity generated from 1972 to 1976 demonstrates this fact (Table I). In addition to new buildings, a great number of old buildings with central heating are annually connected to district heating.

Fig. 1 shows the development of heat delivery and connected heat loads of consumers in the decade 1967-1976. The influence of energy-price-crisis and exceptionally warm weather on district heating consumption in 1974 and 1975 is clearly evident. Also, in 1976 specific heat consumptions were about 10% below the pre-crisis level. In the future, because new buildings will be better insulated and equipped with triple-glazed windows, it can be expected that specific heat consumption will remain lower than it was before the crisis.

Fig. 2 shows the locations of Finland's district heating undertakings in 1977. The southwestern corner of the country, marked with a dash-line, is the area where 50% of the population lived in 1970.

The CHP production of district heating undertakings is based on the long experience of Finnish industry in the combined production of electricity and industrial process heat. Back-pressure power is important in the supply of electricity to Finland, as illustrated by Table II.

The market share of district heating in the energy supply of buildings will probably still grow considerably. Every Finnish locality with at least 30,000 inhabitants has district heating service; and many with as few as 15,000 inhabitants. Some smaller localities also have it.

By the end of 1976 district heating growth in some towns, measured as the share of occupants in district heating houses, was as follows:

Location	Percentage
Lahti, Helsinki	60 - 70
Kuopio, Jyvaskyla, Espoo, Vantaa	50 - 60
Vaasa, Tampere, Hameenlinna, Lappeenranta, Oulu	40 - 50

This growth has been about the same in all towns, averaging three per cent of the population per year.

District heating has had a beneficial effect on air purity in Finnish towns. A study made of the development of sulphur dioxide concentrations from 1960 to 1990 in Helsinki showed that: although net energy consumption in the city, and particularly in its neighbouring towns, is rapidly increasing because of house-building activity, the actual sulphur dioxide content of the air is decreasing. The reason for this is that with combined heat and power production, the fuel consumption increases slowly. ["Sulphur in the Air of Helsinki," a study published by the Helsinki Electricity Works in 1977.]

Combined Heat-Power Stations

At the end of 1971, Finland had eight CHP plants. Their steam turbines produced 680 MW of back-pressure heat and 270 MW of back-pressure electricity. In addition, there was one gas turbine providing district heat (17 MW D.H. output and 15 MW electric output).

By the end of 1976, members of the Finnish Heating Plants Association had 11 CHP plants using steam turbines. Their back-pressure district heating output was 1121 MW, and back-pressure electric output 500 MW. Also, there was the gas turbine plant mentioned above. The increase in five years was three new CHP plants (Kuopio, Jyvaskyla and Vantaa) with 441 MW district heating output capacity, and 230 MW back-pressure electric output capacity. In addition, during the period from 1972 to 1976 three other CHP plants were completed; these are mutually owned by power companies and district heating undertakings.

TABLE I

Development of District Heating in Finland
Finnish Heating Plants Association Statistics

	Year-End Figures		Ratio
	1971	1976	
Number of D.H. undertakings	20	39	1.95
Number of communities with D.H. systems	16	40	2.50
Number of consumers	4720	11 832	2.51
Contracted heat loads of consumers, MW	2056	4 250	2.07
Consumers' total building volume, million m^3	81	163	2.01
Occupants of D.H. buildings, 1000 persons	490	840	1.71
Total length of D.H. pipelines, km	544	1 276	2.35
Heat delivered to consumers, GWh*	5200	9 850	1.89
Back-pressure heat in ratio to all heat produced, per cent	57	60	
Back-pressure electricity joining to heat production, GWh	1160	2 340	2.02
Heat sales income, million Fmk**	84	492	5.86
Average selling price of heat, Fmk/MWh	16.2	50.0	3.09

* 1 GWh (gigawatthour) = 10^6 kWh
** 1 Fmk = 23 U.S. cents (September 1977)

In 1972, the second steam-turbine unit began operation at the Vaskiluoto power station in Vaasa. Its electric output in condensing operation is 165 MW. In district heating operation the total electric output is 160 MW, and the plant provides 116 MW district heat and 63 MW back-pressure electricity. Oil is the fuel.

Mertaniemi CHP plant was completed in Lappeenranta during 1975 and 1976. It is mutually owned by the State Power Company, Imatran Voima Oy, and by the Town. In this station there is one 35 MW gas turbine with a district heating output of 50 MW; and a combined power plant with two 37 MW gas turbines and one 76 MW extraction condensing turbine. These turbines produce 140 MW heat and 130 MW electricity, and when not producing heat the electric output is 145 MW. Natural gas coming from the Soviet Union is used as fuel. ["An Example of a Combined Gas Turbine-Steam Turbine Power Plant with District Heat Production," P. Ahvenainen, Third International District Heating Conference, Warsaw, Poland, 1976.]

The Kymijarvi CHP plant, completed in Lahti in 1976, is mutually owned by the State and the Town. In this plant, fueled by oil, there is a steam turbine that generates 150 MW electricity in the condensing operation. The district heating operation output is 210 MW heat, and 119 MW electricity.

The three power stations noted, generate a total of 516 MW district heating output and 347 MW electric output combined with heat production. In addition to their normal activities, five industrial plants have produced and distributed district heat since the 1950's. Their district heating output is a total of 79 MW. Back-pressure electric output, combined with district heating, is 18 MW. In addition to these, four industrial plants and one refuse incineration plant have produced district heat since the 1970's; the heat is sold to municipal electricity works for distribution. District heating output generated by these plants is 138 MW, and corresponding back-pressure electric output 23 MW. The industrial plants generate a part (about 35%) of the district heating energy from waste heat, their processes, or refuse fuels.

New CHP plants are being built continually. In the spring of 1977, the fourth turbine unit (back-pressure turbine) of the Hanasaari power station was completed in Helsinki. This unit has a district heating output of 203 MW, and an electric output of 113 MW. Turbine No. 3 is the same type as No. 4, while Nos. 1 and 2 are the extraction condensing type with district heating output 193 MW, and corresponding back-pressure electric output 79 MW; maximum electric output in the condensing operation is 182 MW. Power stations in Helsinki burn coal.

The second district heating turbine at the Naistenlahti power station was completed in Tampere during 1977. Its district heating output is 115 MW, and corresponding electric output is 60 MW. This unit burns peat, while the first unit (district heating output 113 MW, electric output 57 MW) burns oil.

The district heating turbine at the Toppila power station in Oulu was also completed during 1977. Its district heating output is 145 MW, and corresponding electric output 75 MW. This station burns mainly peat; 80% of the boiler output is from peat, and 20% from oil or alternatively 100% from oil.

TABLE II
Finland Electricity Supply

	1971	1976
Electricity Supply, TWh*	23.4	31.8
Division Percentage		
Water power	45	30
D.H. back-pressure power	5	7
Industrial back-pressure power	20	17
Condensing and gas turbine power	19	34
Net import	11	12

*One TWh (terawatthour) = 10^9 kwh

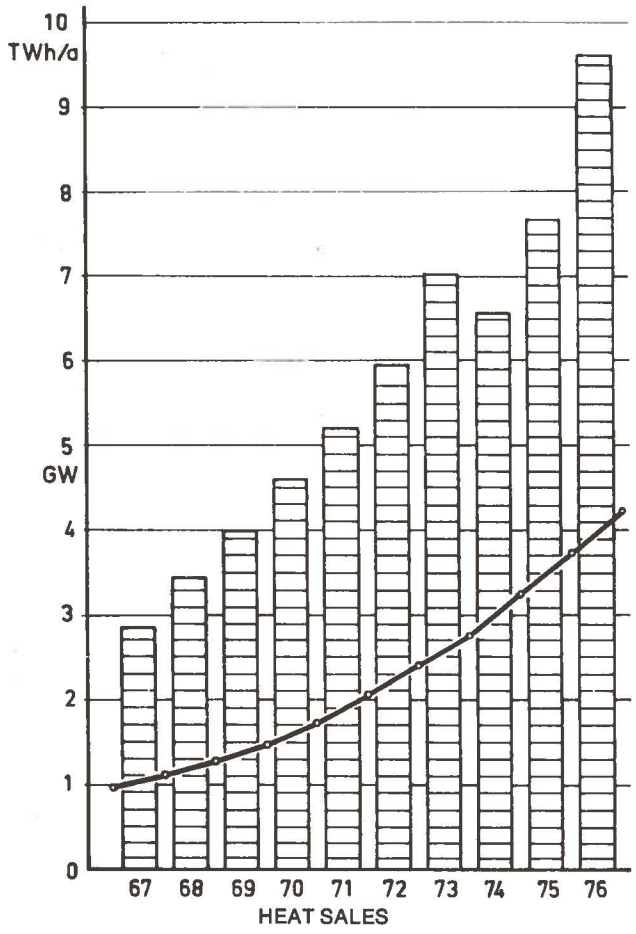

Fig. 1—Development of district heating in Finland 1967-76. Curve shows connected heat loads.

The Suomenoja CHP plant is being built in the town of Espoo. It will be completed by the end of 1977. The district heating output of the turbine is 160 MW, and the corresponding electric output 80 MW. This plant burns coal.

The four stations just described (Hanasaari, Naistenlahti, Toppila, Suomenoja) increased the district heating output of CHP plants in 1977 by a total of 623 MW, and back-pressure electric output by 328 MW.

All of the preceding electric output capacities are the output measured at the generator poles, i.e., the gross output capacity.

All CHP plants which operate with back-pressure turbines are equipped with auxiliary coolers for district heating water. By means of these coolers, the full electric output capacity is assured if it is needed when the district heating load is small.

So far, there is no diesel CHP plant in operation in Finland, but the first one of this kind has been ordered. It will be put into operation at Kiuruvesi, a town with 12,000 inhabitants. District heating was started in 1975 by means of a transportable heat supply station. In the CHP plant, there will be two diesel water generators, both built in Finland. Each generator will produce 2 MW of electricity, and 6 MW of district heat. The first unit will go into operation in 1978, and the second one three years later.

Plants Producing Only District Heat

District heating turbines are not sized according to the maximum load. The optimum energy production is achieved when about 60% of the maximum district heating load is taken via turbines; and short contributions at times of the maximum heat load, from single-purpose hot-water boiler plants. These are often located elsewhere than at the CHP plants. More than 90% of the yearly district heating energy is received from CHP turbines.

As long as the heat distribution system is small, the building of a CHP plant is, of course, out of the question, and all district heat is generated directly in a hot-water boiler plant.

Currently, it is general practice in Finland to start district heating activities in new housing areas by means of transportable heat supply stations. This temporary arrangement continues until there is sufficient heat load to warrant the construction of a heat transmission line. Most temporary heating lasts from two to five years.

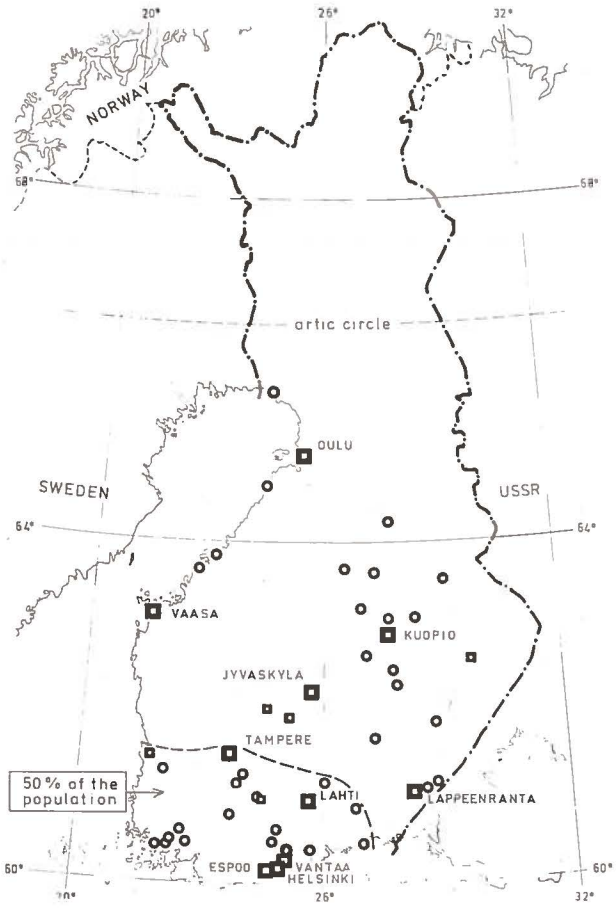

Fig. 2—Communities with district heating in 1977. Municipal CHP stations ■. District heat from industry ◘. Heating plants only O.

At the end of 1971, Finnish district heating undertakings had, in addition to CHP plants, 38 separate stationary heating plants with total heat output of 1230 MW; and 88 transportable heat supply stations, with a total heat output of 270 MW. At the end of 1976, there were 69 stationary heating plants (2290 MW), and 281 transportable ones (790 MW).

The development of district heating output, and that of combined back-pressure electric output production, is shown in Table III. In 1977, district heating activity has been started in ten new communities.

Transportable Heat Supply Stations

Most transportable heat supply stations in Finland comprise a single three-pass flame tube hot water boiler,

TABLE III
D.H. Output and Corresponding Electric Output

	1971	1976
Total D.H. output, MW	2740	5520
From steam and gas turbines	840	1870
Gas turbines, and combined gas turbine-steam turbine plants	17	207
Direct from boilers of power stations	400	570
From stationary heating plants	1230	2290
From transportable heat-supply stations	270	790
Combined electric-heat production output, total MW	283	852
Gas turbine, combined gas turbine-steam turbine plant output	15	180

an oil burner, district heating flow pump, pressurizing pump, regulating equipment and meters—all on a single chassis. The oil tanks, containing 15 or 25 m^3, are separate. The smoke stack is a heat insulated steel pipe assembled from parts. It is supported by guy ropes and rises 15 to 30 metres high.

The capacity of half of the transportable stations varies from 2 to 4 MW, and the biggest are 7.5 MW. Where necessary, two to three transportable stations are connected in parallel and extra oil tanks added. The stations are unmanned. Fault alarms are transmitted by telephone or radio. The fuel is heavy or light oil.

Heat Transmission and Pipeline Construction

In Finland, heat is transmitted from production plants to consumers by means of a closed, two-pipe hot-water system. The flow temperature varies from 75 C to 120 C, depending on the weather; and the return temperature correspondingly, from 45 C to 70 C.

District heating undertakings use almost entirely standardized pipeline construction and prefabricated parts. Standardization is carried out under the direction of the Finnish Heating Plants Association, and in close cooperation with manufacturers of this group. Normally, district heating lines 700-250 mm in diameter consist of

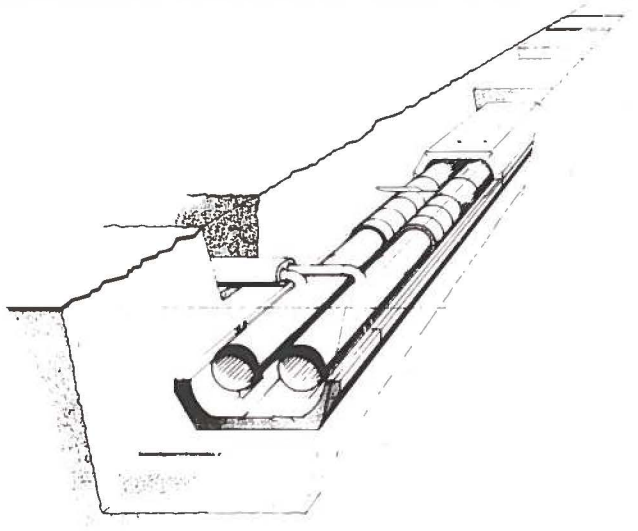

Fig. 3—Prefabricated pipeline construction: concrete duct for 700-250 mm diameter pipe; plastic covered jacket for 200-40 mm diameter.

an outer shell made of 4-m long prefabricated concrete parts; and the steel pipes and heat insulation are made of formed mats of mineral wool. Smaller pipes, 200-40 mm in diameter, are usually laid in a duct made in 12-m long jackets. In the jacket there is an outer shell of HD-polythene and as heat insulation, hard polyurethane foam. Steel pipes are pushed into glass fibre reinforced polyester pipes inside the heat insulation. In addition, there is a drain hole in the lowest part of the jacket. This hole brings water, which could possibly leak in, into the chamber in the lowest part of the line. Also, special parts of a district heating line (e.g., anchor points and small chambers for valves) are brought to the site as prefabricated parts. Fig 3 shows a prefabricated concrete duct (main pipeline), and a jacket going out from it (branch pipeline).

Joining Consumers to Network

Heat consumers are joined to the heat network indirectly, i.e., by means of heat exchangers. Tap water is also heated with district heat. Space heating and tap water heating are connected mainly in series, so that district heating water flow, which is needed for space

Fig. 4—Hanasaari CHP stations, Helsinki. Hanasaari B, left, two back-pressure units: electric output 2 x 113 MW; district heat output 2 x 203 MW (+ 56 MW auxiliary boiler). Hanasaari A, right, two extraction-condensing units: electric output 182 MW maximum (79 MW back-pressure); district heat output 193 MW.

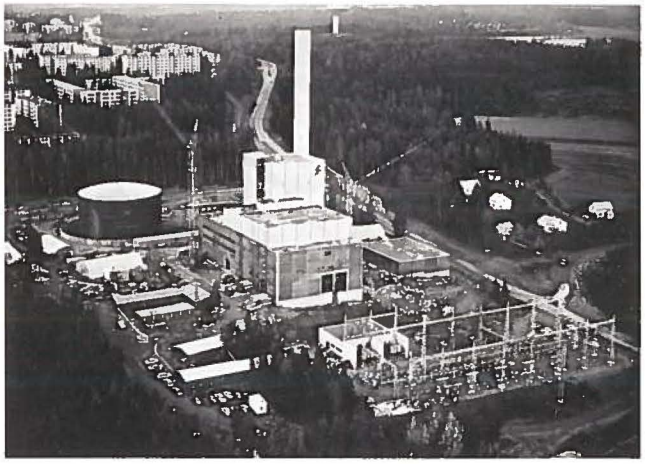

Fig. 5—Martinlaakso CHP station, Vantaa: electric output 60 MW; district heat output 117 MW.

heating, is sufficient also for tap water heating. In some cases, tap water consumption peaks are taken from a hot water accumulator belonging to the consumer's installation.

Measuring and Invoicing Heat

Every new heat consumer pays a lump sum joining fee. In addition, he pays an annual fixed charge for the heat, depending on the contracted maximum water flow and a running charge depending on the amount of energy used.

Fig. 6—Two typical transportable heating plants in operation on a newly built area: heat output 2 x 4 MW.

The heat consumed is measured with a heat consumption meter which consists of a hot-water meter, two resistance thermometers (one for flow and one for district heating return water) and an electronic integrator. In some district heating undertakings, consumers themselves read the meters and mail the readings every second month to the company for invoicing. The invoicing is then done by a computer.

One consumer consists, in most cases, of one apartment house. Sometimes, several apartment houses owned by the same person are considered as one consumer. District heat in Finland is neither measured nor invoiced per one apartment. Usually district heating charges for an apartment house are included in the rent of apartments, together with other corresponding costs, without any specification.

Summary

District heating is now carried out in Finland in all towns with more than 30,000 inhabitants, and even in several smaller ones. It is the aim to join new buildings from the very beginning to district heating, as old buildings are continually connected. Centralized heat production in densely populated areas, and combined heat and power production, are objectives wherever an adequate heat consumption concentration exists. Several new CHP plants have been completed during the last few years. In 1977 the output of back-pressure electricity from CHP plants grew about 330 MW, and that of district heat 620 MW. ✹