# DISTRICT HEATING

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District Heating in Finland

Solid Waste Recycle Energy System in Akron, Ohio

District Heating in Sweden

Energy Conservation in Eugene Oregon

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# The Economic and Environmental Aspects of District Heating in Sweden

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**AB ENERGIKONSULT is a consulting firm with a staff of 700 engineers. It covers a broad range of activities in thermal and power fields, and its major activity is designing and planing plant systems and equipment: thermal power stations, hot water systems, district heating systems, and industrial power systems. The Company and Mr. Kohler are members of IDHA.**

The increasingly strict anti-pollution measures now being introduced in Sweden will have a decisive effect on the energy supplies to the towns. The pollution deriving from the combustion of oil or coal, the discharge of heated cooling water and the destruction of household waste constitutes the important issues that will have to be dealt with. A large number of small plants spread over a large area create serious local pollution problems. The transport of fuel to such plants also creates air pollution, as well as noise and traffic trouble. A large district heating plant can be provided with a tall stack and the combustion gases given a high discharge velocity at acceptable cost. In unfavourable weather, it is always possible to switch over to non-sulphurous fuels. In this way, the air pollutants will be distributed over much wider areas and controlled much better. For these reasons, district heating can be regarded as preferable from an environmental point of view.

The large space heating loads prevailing in Sweden offer the municipal authorities excellent opportunities to produce power at high rates of efficiency in dual-purpose generating plants. A town with a fully developed municipal space heating service is capable of producing a great deal more power than can be consumed locally. From a national point of view it is of the utmost importance to take advantage of the possibilities offered, since they result in substantial savings in energy and reduce the discharges of heated cooling water from the large condensing turbine plants that would otherwise be required.

Discharges of heated cooling water may in some cases cause damage. Cooling towers will create environmental problems of their own and increase the cost. The advantage of dual-purpose district heating plants is that they operate with small volumes of cooling water.

In Sweden, collaboration between municipal works and the major power producers is well developed, resulting in substantial savings in fuel and capital. The benefits are primarily that the cities and towns have been able to develop large-capacity production units and operate them in a manner best suited to the national energy balance. The need for local stand-by capacity has also been reduced.

The handling of the household waste generated by the population centres will become an increasingly difficult problem with population growth and the rising standard of life. A complete disintegration of the waste by incineration or composting must be achieved. Economies of scale can also be attained with incineration, and thereby compensate for longer transport. Heat recovery becomes economical in large plants when the heat can be utilized. The best solution is to use the heat to produce steam with such data that it can be applied for power generation. Waste incineration offers great potentials for integration with a dual-purpose energy generation plant.

## DETERMINING THE SCALE OF DISTRICT HEATING SYSTEMS

### Distribution Networks

In a district heating system, the cost of the distribution network represents a major part of the system cost. It varies from 45 to 60 per cent depending on the size of the network and whether it also includes the supply of electric power. The major factors that determine the cost of the system are the following:

Choice of delivery and return temperature, and water velocity

Choice of conduits

Soil conditions

Topographical conditions

Facilities for laying conduits

Heat density of the distribution area

Geographical shape of the distribution area

Location of the production plant in relation to the concentration of the load.

The last three factors have been subject to special studies, from which some general cost patterns have been developed.

The specific cost of networks with the same capacity and geographical shape consists of one constant part, and one that is reciprocal to the square root of the heat density. In Fig. 1 is shown the relation between heat density and specific cost for areas with a heat requirement of 100 MW, and a rectangular shape with the length and width in the relation 1:3.

The effect of the geographical shape of the distribution area with different length-width relations is given in Fig. 2. In the example, the relations apply to a heat requirement of 300 MW.

The distance of the production plant from the centre of the load concentration also affects the cost of the network. Cost comparisons have been made between centrally sited plants, and plants placed on the short side of rectangular areas. The off-centre plant increases the cost by two per cent in a square area and 4.5 per cent in a rectangular one, with length and width in the relation 1:5.

The choice of site should be considered from the point of view of air pollution, the prevailing winds, and other pertinent meteorological conditions. A central site which necessitates increasing the height of the stack will often reduce the cost of the network. Calculations must be made on the basis of accurate meteorological investigations, so that different siting alternatives can be directly comparable. Aesthetic, noise and transport questions should also be considered.

**Heat Production Plants**

The specific cost of a district heating plant drops rapidly with increasing net capacity. A cost study of a hot water plant with four boilers of the same capacity — one of which is in reserve — is shown in Fig. 3. The specific cost of boilers is lower for large units, and the same applies to the building space required for them, resulting in a total reduction of the cost of the boiler house. Some auxiliary equipment costs are same regardless of the size of the plant.

The relative change in the distribution cost, with increasing load due to the expansion of the distribution area, is shown in Fig. 4. The heat density is assumed to remain constant.

Adding the specific cost of a heating plant to that of the network, gives the relations shown in Fig. 5 for different heat densities. The minima of the curves suggest that it may be more economical to distribute the load over two or more plants, when the distribution area is extended beyond certain limits and when no power generation is involved.

## COMBINED HEAT AND POWER PRODUCTION

**Optimizing Problems**

The most important and difficult problem when designing a plant for combined power and heat production is to decide on the optimal size for the plant and the optimal steam data.

**Choice of Unit Size**

The plant can be planned along two lines, either as a condensing power plant using bleed-off steam for heat generation, or as a straight back-pressure turbine plant. The first alternative requires large sets, in the range of 125 to 250 MW electrical capacity, and a relatively large heat load of 300 — 600 MW when the distribution net is complete. Owing to major investments required, such projects are usually undertaken in collaboration with a supplier of bulk power. The need for large volumes of cooling water may be of decisive importance, because the

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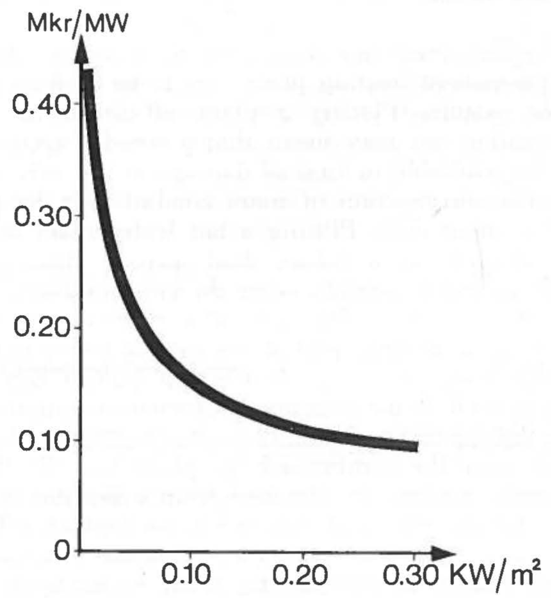


**Fig. 1 — Specific cost of the distribution net as a function of the heat density of the distribution area.**

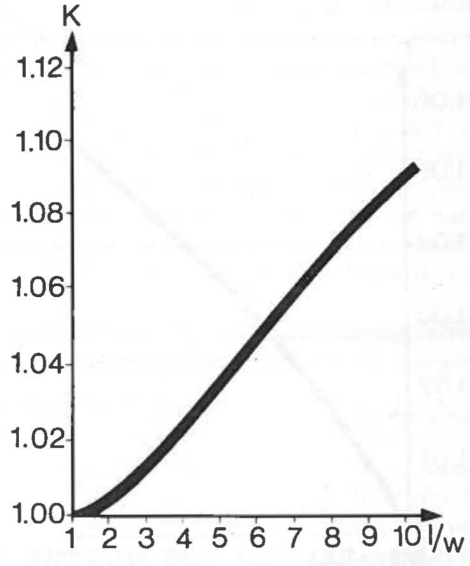


**Fig. 2 — Cost of a distribution network with a varying relation of length and width for the area.**

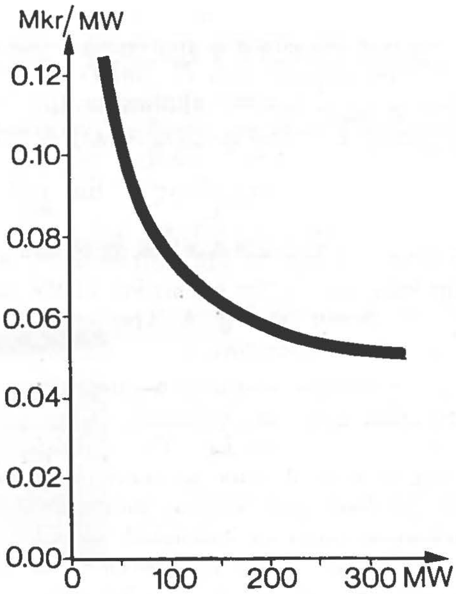


Fig. 3 — Specific cost of a hot water plant as a function of the net output.

necessary cooling towers or air coolers will increase the overall costs.

The size of a straight back-pressure plant is determined by the ultimate heat load, and the expansion rate of the network. In Sweden, it is common practice to make the heat generating capacity equal to the maximum heat load, even when the largest heat producing unit is out of service. This means that a large dual-purpose unit (producing both heat and power) is operated at its most economical load when the stand-by heat generation unit is a large hot water boiler. The result is, of course, that the economies gained from the lower specific costs of a large dual-purpose plant cannot be fully utilized.

Since a district heating system is constantly growing, a dual-purpose plant retains its optimal size for only a certain period. If the rate of extension is low, units with smaller capacity tend to become more economical.

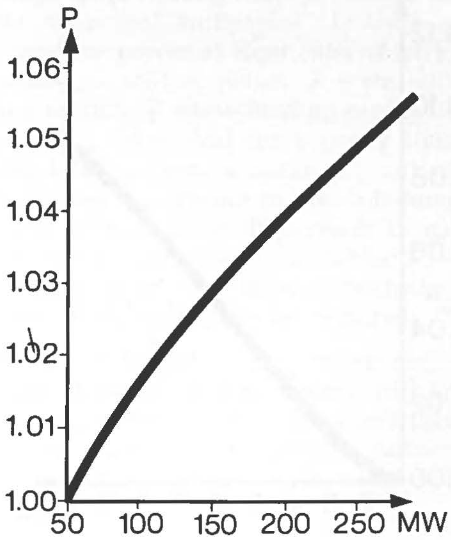


Fig. 4 — Relative specific cost of the distribution network as a function of the output.

In Sweden, the dual-purpose unit is usually scaled to a capacity equivalent to 50 — 60 per cent of the maximum heat load. This limit is chosen due to the peak characteristics of the duration curve of the heat demand. Hot water boilers are used to satisfy the remaining space heating requirements, and to serve as a maximum standby unit.

During the early stage in the development of a district heating system, it is frequently more economical to use portable hot water plants to satisfy the heating needs of limited distribution areas. This is particularly the case when building development is proceeding in different localities in a community, and interconnecting conduits would be poorly utilized and increase the cost of the project. These mobile plants are moved to new building areas, when the time is ripe for joining up the small networks to a hot water plant with a large capacity.

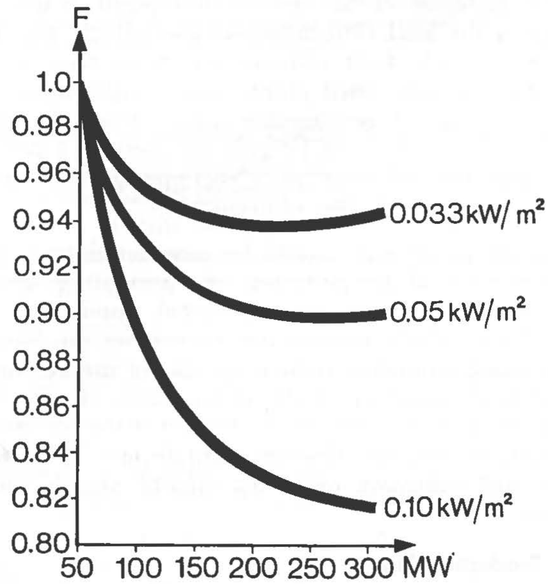


Fig. 5 — Relative specific cost of a hot water plant and a distribution network as a function of the output at different heat densities.

The important question, then, is to decide where the permanent heating plants are to be sited in the whole system. Placing a plant off-centre in the distribution net may mean that a standby capacity will be available in case of damage to the net, and that the construction of main conduits can be put off for some time. Placing a hot water plant on a site selected for a future dual-purpose plant will result in major savings, since the two buildings can be linked together. The hot water plant is then designed as an integral part of the electric power plant. In this way, the same distribution pumps can be used, as well as the pressure maintenance equipment with the expansion vessel, the water treatment plant, oil storage, the compressed air plant, etc. Further economic savings are obtained from using the same control room, electrical equipment, smokestack, office and shop premises. Since this practice obviously means that some investments must be made at an earlier stage, an accurate plan of the whole plant is required with the subsequent stages carefully scheduled in time. Linking the hot water plant with the dual-purpose plant also offers advantages from an environmental and manning point of view.

During the initial stages in the extension of the distribution net, when a heat load is being collected for future power generation, the system frequently runs at a loss, particularly when the extension rate is low.

An earlier scheduling of the power plant, although on a smaller scale, may therefore be preferable in some cases. This is particularly the case when the plan calls for a large-capacity power unit such as a bleed-off condensing plant serving also as a supplier to a district heating network. But such a minor dual-purpose unit should not be scaled to a heat capacity higher than the hot water capacity that would otherwise have to be installed. The investment required for the early scheduling of the power production, then becomes equal to the difference in cost between the small dual-purpose block and a hot water plant of the same heat capacity. The small-scale dual-purpose block should be simply designed with moderate steam data, since it has to be depreciated over a relatively short period. Certain minor economic benefits are obtained from this early power schedule, such as availability of steam for maintaining pressure in the distribution net, for the preheating of oil, for atomizing the oil in the burners, and for other heating purposes for which steam is more suitable. Availability of service steam for the future large-capacity power block is another advantage.

#### Choice of Steam Data

For bleed-off condensing plants, the steam supply should have a pressure of 160 — 180 bar and a temperature of 530 — 535 C (986 — 995 F) obtained by intermediate superheating. The bleed-off is arranged so as to obtain a temperature of 85 — 95 C (185 — 203 F) at the turbine, and 50 C (122 F) when delivered to the heating plant. The service water is heated in two stages to increase the power output. For straight back-pressure plants with an electric capacity in the 25 — 125 MW range, the admitted steam has a pressure of 105 bar and a temperature of 530 C (986 F). At the higher limit, 125 MW, intermediate superheating may be used, but it has not proved economical in Swedish projects. Heating the service water in two stages, on the other hand, has proved economically advantageous. The temperature of the water before and after the hot water condensers is usually the same as for bleed-off condensing turbines.

#### On Combined Operations

In most cases, the municipal power authority is responsible for the construction and operation of a local district heating system, with or without power generation. In some instances, an independent utility is formed to run the system. Generally speaking, the manner in which the supplier of crude power collaborates with the municipal works has a direct bearing on the planning of the dual-purpose plant. When a close collaboration is at hand and both parties are interested in attaining the best overall economic operation, it is possible to plan for a bleed-off condensing turbine. Then the joint venture takes the form of a corporation that is made responsible for the construction and operation of the dual-purpose plant. There are also recent examples of collaboration between municipal authorities and adjacent heat consuming industries for joint production of power and heat.

The power and space heating requirements of a city usually vary at the same rate throughout the year, whereby the generation of back pressure power can be scaled to the prevailing power load. However, this close agreement does not hold true at certain times of the year, such as spring and autumn; nor is there close agreement between the heat load and power load over the 24 hours of the day. Therefore, in order to minimize the purchase of crude power the back-pressure plants are usually provided with return water coolers and hot water storage facilities.

The cooler consists of a heat exchanger, where the temperature of the service water is reduced by the use of natural cooling water — when available — or air. In this way the heat load and hence the output of back-pressure power can be increased. The heat consumption with "cooler operation" becomes somewhat higher than in a modern condensing turbine plant. Since the idling losses of the turbine are always balanced by the heat load, the heat consumption is only marginal. With steam admitted at 105 bar and 530 C, the heat consumption of the turbine is about 2240 kcal/kWh when operated with return water coolers.

The hot water storage tanks consist of vertical stratified units having a volume of 1500 — 3000 $m^3$. They are switched on when the power load exceeds the back pressure power output — with the prevailing hot water load — and become charged with the delivered hot water. When the power load drops, the accumulated hot water is discharged into the network. In this way, it is possible to balance the heat production and hence the back-pressure power generation with the power load. The charging and discharging cycles, therefore, have to be balanced over 24 hours. The method does not lead to any waste of energy, and hot water storage should therefore be used in preference to cooling. In order to be able to optimize coolers and hot water storage tanks, the variations in the heat and power requirements must be determined over the 24 hours of the day and for a number of years. Since such calculations are exceedingly laborious and time-consuming, a computer programme has been developed for the purpose.

If the heat load should vary during the days when it reaches maximum, the hot water is used to boost the heat capacity. The storage is then charged at night, when the load is lower and discharged during the day in parallel with the full capacity back-pressure output. In this way, the production capacity of a dual-purpose plant has in some cases been raised by 20 per cent during the coldest day of the year. Δ