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COST CALCULATIONS FOR DISTRICT HEATING NETWORKS WITH DIFFERENT HEAT DENSITIES AND UTILIZATION FACTORS

Jorg Lilljeqvist, *Engineer, District Heating Department*
Stockholms Energiverk, Stockholm, Sweden

0) General

A heating plan was established in Stockholm from which can be seen how buildings can best be heated in future. With few exceptions, one of the following methods was chosen - district heating, electric heating, gas heating and local oil heating.

The present report is statistically valid for 1976 prices. The assumption has also been made that the heating energy is produced in thermal power stations or heating stations of the Stockholm power supply authority. Districts with existing buildings and with varying heat densities and varying utilization factors were likewise studied with a view to the cost of connection to the district heating network of the Stockholm power supply authority, in order in this way to obtain costs which are as realistic as possible.

The figures are not, however, consequently limited to Stockholm but apply generally.
The rating output component for the ex-works subscriber was calculated from known power consumption and utilization times, which were mainly taken from the district heating statistics. Allowance was made for the possibility of

lowering the temperature and ventilation during the night for certain categories of heat consumer by reducing the utilization time to below 3,000 hours p.a.

The following rating values were applied:-

Type of subscriber	Power requirement	Utilization time ex-works x)	Rated output requirement ex-works
	$\frac{KWh}{m^2 \; a}$	$\frac{h}{a}$	$\frac{W}{m^2}$
Office	180	3,000	60
Industry	250	3,000	83
Schools	180	2,200	82
Hospital	210	3,000	70
Small subscriber house	200	2,400	83
Tenement house,old	240	3,000	80
Tenement house, new	200	3,000	67

x) Overlapping of output included.

The load for the different town sectors and the distribution of load were taken from the statistics of the Town Planning Office and should be sufficiently accurate for the present purposes. All values are therefore given here at mid-1976 prices and at a rate of exchange of 1 $ = 5 Skr.

1) Method of calculating heating expenses.

In Stockholm, the cost of heating buildings by district heating is made up of the following component items:-
(You find the same method in other towns)

1.1) Production costs

These costs are considered here as dependent only on the power consumed annually, but independent of which production point in the combined network this is supplied from.

District heating production costs are assumed, as in the heating plan, as $ 30/KW in the case of a purely heating station. A rate of return of 10% was applied. The production costs allow for 25% reserve effect and a combustion efficiency factor of 90%.

Various energy supply alternatives in various combinations and also at various price levels were examined in the heating plan.

An energy price ex-works of $ 6/MWh and a production variant combining an oil-fired thermal station and an oil-fired thermal power station are assumed.

The calculation gave production costs for the

oil-fired thermal station of	$ 9.6/MWh
and for the	
oil-fired thermal power station of	8.6/ "

An average of $ 9/MWh is used here.

A utilization time of 3,000 hours p.a. (or $\frac{\text{KWh}}{\text{KW p.a.}}$) is also adopted.

A production price ex-works of

$$9 \times \frac{3{,}000}{1{,}000} = \$ \ 27/\text{KW p.a.}$$

1.2) Transfer line costs

All the costs are combined here which mainly arise from the capital costs of the major transfer lines from the production point to the distribution lines. These costs depend partly on the distance between the thermal station and the main distribution point and partly on the final output rating.

In Stockholm, 50% of the transfer lines are included in walk-through tunnels, and this method is also being used in newly developed areas. A number of studies has been carried out to compare the comparative economics of laying the lines in culverts or tunnels under the conditions prevailing in Stockholm, and it has by and large been found that laying the lines in tunnels involves initially higher investment costs than the normal method of laying them in culverts, but in the final stage the difference is only small (probably not more than 5%), apart from the fact that laying the transfer lines in culverts makes it more likely that the work of construction can be completed on time.

Under Stockholm conditions it has been found that the costs of transfer lines amount to $ 20,000 MW.

This figure includes a reserve supply facility. With a distance from the production point to the main take-off point of 4 km (Värtan- city centre) and an ultimate capacity of 1300 MW, the cost comes to $ 14,800/MW.

For a capacity of 540 MW (Södermalm) and a distance from the production point to the user area of 3 km, the cost of the transfer lines is approx $ 2,400/MW.

For a capacity of 115 MW (Hässelby and Vällingby) and a distance from the production point to the main consumer point of 3 km, the cost is around $ 32,000/MW.

Appendix 1 shows the costs for transfer lines as a function of distance from the production point to the main consumer point. Other parameters used are the total ultimate capacity of the relevant system. Reserve supply facilities are included in the figures (25%).

1.3) Distribution line costs

These combine all the heat distribution costs from the transfer lines to the connection valve in the subscriber's transfer station. They are generally the costs which arise for pipes from 40 to 150 in diameter.

The distribution costs depend partly on the heat density of the area and partly on the average capacity component of the house stations in the area under consideration.

To obtain a good insight into distribution costs under the various preconditions, the network was plotted and calculated for each area considered. It was assumed in this that all existing heating plants are connected to district heating. In areas with many small users it was also assumed that each villa would be connected separately, as it has proved administratively difficult to connect villas group-wise. The distribution network was always based on a central supply system.

The calculations provide the following approximate total distribution line costs in the various areas:-

Town sector	Heat density	Total connected load	Allocated connected load	Costs	Costs per KW
	$\frac{MW}{km^2}$	MW	No.x KW	Millj. $	$ / KW
Hässelby & Vällingby					
Johannelund	40	115	133 x 864	1,84	16
Blackeberg	12	23	6 x 3833	0,90	40
Årsta	16	49	140 x 350	3,00	78
Traneberg	13	12	60 x 200	1,40	116
Södra Ängby	8	7	500 x 14	1,80	320
Norra Ängby	12	14	1550 x 9	5,00	360
Centrala distriktet	70	1300	5900 x 220	15,60	212
Södermalm	96	540	1930 x 280	6,20	11.6

In Appendix 2 the distribution line costs are shown as a function of heat density with the average capacity component of the house stations as parameters.

1.4) House station installation costs

The house station installation costs consist of the costs of the transfer plant, the costs of which are borne by the thermal station, and the heat distribution system, the costs of which are borne by the house-owner.

Only the portion borne by the thermal station, that is to say the transfer plant, is included here in the calculation.

Appendix 3 shows the installation costs used here per KW of capacity component in the thermal station as a function of the capacity component of the house stations.

1.5) Operating and administrative costs

Are taken here as 15% of the energy costs.

$ 1.40/MWh; 3 x 1.40 = $ 4.20/KW (capacity component in thermal station) p.a.

1.6) Losses

This covers the costs of heat loss in the district heating network, pumping costs and other operational energy loss costs.

The following loss figures are included:-

a) Small subscribers with capacity component of

0 to 50 KW and 2600 hours p.a. utilization

$ 1.40/MWh; $1.4 \times \frac{2600}{1000}$ = $ 3.64/KW (capacity component in station) p.a.

b) Tenement houses and industrial users with capacity component of

50 to 200 KW and 3000 hours p.a. utilization

$ 0.60/MWh; 0.6 x 3 = $ 1.80/KW p.a.

c) Tenement houses and industrial users with capacity component of

200 to 1000 KW and 3000 hours p.a. utilization

$ 0.40/MWh; 0.4 x 3 = $ 1.20/KW p.a.

d) Tenement houses and industrial users with capacity component of

1000 KW or more and 3000 hours p.a. utilization

$ 0.30/MWh; 0.3 x 3 = 0.90/KW p.a.

1.7) Taxes

This covers all costs arising from taxes, storage and clearing charges. The following taxes are included:-

a) Small consumers with a capacity of 0 to 200 KW:-

$ 1.20/MWh and 2,600 hours p.a. utilization

$ 1.20 x $\frac{2600}{1000}$ = $ 3.20/KW (capacity component in station) p.a.

b) Building with a capacity of 200 or more:-

$ 1.00/MWh and 2600 hours p.a. utilization

$ 1.00 x 3 = $ 3.00/KW p.a.

2.0. Income

The costs shown in 1.1 to 1.6 must be covered by connection charges and tariffs.

2.1) Connection charges

The following applies in principle in Stockholm:-

In buildings where there are existing oil-fired furnaces, no connection charge is paid by the customer. Certain exceptions can be made if the reheating equipment is comparatively new and the thermal station would like to connect up as quickly as possible.
In new buildings, the customer pays about $ 5/m^2 to the thermal station as an advance loan which is repaid at 7% interest over 30 years. The connection charge is not taken into account in this report. In this form, the connection charge is only a lending of spontaneous capital requirements on the part of the thermal station, from which the customer is thereby released. The connection charge thus has no economic effect according to the purpose of this report.

2.2) Tariff income

The costs according to 1.1 to 1.6 must therefore be covered in principle by the tariff income if the district heating is to be economically rewarding. In Stockholm the tariff consists of various component items such as the energy consumption charge and the subscription, distribution and index charges. Here the tariff is reproduced in simple form by breaking it down into only 2 items, an energy-dependent component and a component which depends on the size and nature of the building.

The following rates are thus calculated as <u>an average</u> for the tariff income:-

Energy price	= $ 9.20/MWh
Subscription, distribution and index charges	= $ 4.80/ "
Total	= $ 14.00/"

According to the district heating statistics, this corresponds to the tariff income for an average subscription in Stockholm with a capacity component ex-works of approx. 330 KW and an energy consumption of 1000 MWh p.a., that is to say with a utilization time of 3000 hours p.a. in the station.

The following variants are assumed:-

a) Small customers with a capacity component ex-works of 20 KW on average

Energy price	= $ 9.20/MWh
Subscription, distribution and index charges	= $ 8.40 "
Total	= $ 17.60/"
This gives	$ 53/KW capacity component p.a.

b) Tenement houses and industrial buildings with a capacity component of <u>100 KW</u> on average

Energy price	= $ 9.20/MWh
Subscription, distribution and index charges	= $ 6.80/ "
Total	= $ 16.00/"
This corresponds to	$ 48/KW p.a.

c) Tenement houses and industrial buildings with a capacity component of <u>500 KW</u> on average.

Energy price	= $ 9.20/MWh
Subscription, distribution and index charges	= $ 4.80/ "
Total	= $ 14.00/ "
This corresponds to	$ 45/KW p.a.

d) Tenement houses and industrial buildings with a capacity component of <u>1000 KW</u> on average

Energy price	= $ 9.20/KWh
Subscription, distribution and index charges	= $ 2.20/ "
Total	= $ 11.40/ "
This corresponds to	$ 36.60/KW p.a.

3) <u>District heating expenses as a function of heat density</u>

The diagram in Appendix 4 provides a summary of the listed component costs for areas with different reheating characteristics.

For house stations of equal average size, the district heating price per capacity component and year (\$ /KW p.a.) increases with reduction in heat density (MW/Km^2). The price increases moderately within the heat density range of 100 to 40 MW/Km^2, but very quickly in the area below 40 MW/Km^2. The diagram also shows the parameters of average house station size. The economic limit for transmission line costs of \$ 1.80/KW p.a. is shown as a line of dots and dashes. This corresponds to a station with an ultimate capacity of 1500 MW and approx. 5 km distant from the main customer centre. (See Appendix 1).

Shorter distances from the main customer centre improve heating costs insignificantly and impair them somewhat for smaller ultimate capacities at the station.

4) <u>Costs of district heating for different utilization factors</u>

With the aid of the figures so far given, the costs of district heating as a function of utilization are treated here with parameters of heat density and average output components of the transfer stations.

Appendix 5 summarises the total costs for the different preconditions.

The component costs for different preconditions can for several exempels also be obtained from Appendices 6 and 7.

5) SUMMARY

The following calculations are generally applicable and have been documented by means of figures obtained from the district heating network in Stockholm and Västeras, Sweden.

Here has been done calculations of the costs for connecting areas with different heat densities to the district heating network. By way of summary these costs were set up in a diagram of district heating expenses as a function of heat density (Appendix 4). In addition, the average house station magnitude was used as a parameter. The standard rates for equivalent conditions were indicated in the same diagram. This also reveals the economic limits of district heating for different heat densities ($\frac{MW}{km^2}$) and house station magnitudes.

In a new area (a suburb such as Hässelby) the heat density ranges between 30 and 40 $\frac{MW}{km^2}$. Accordingly, the economic limit can be reached even with very small house stations. On the other hand, in a private home area with a heat density of only $< 10 \frac{MW}{km^2}$ the economic limit is reached at a house station magnitude of about 1,000 kW.

Thus collective collections are necessary if the costs are not to be exceeded. In this connection it should also be noted that Stockholm, unlike other cities, does not yet have a special rate for single-family houses and small users.

As was to be expected, it can be seen from Appendix 5 that the district heating costs decrease as the <u>utilization factor</u> increases.

Generally speaking, it can also be stated that the utilization factor dependence is smaller for large heat densities than for smaller ones. The magnitude of the average percentage output of the transfer station appears to affect district heating costs to a lesser extent, but in the same direction.

Thus for a given heat density it is advantageous to increase the utilization factor as quickly as possible by means of different measures and see that the transfer stations are not too small.