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Institutional Constraints on District Heating and Cogeneration Feasibility

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Abstract

The causes of the very unequal development of district heating in Western-Europe are investigated. Although particular factors (climate, availability of resources, ...) do explain particular high or low levels of district heating in some nations, it is found that the organisation of the energy sector is most decisive.

We sketch the optimal organisation as being composed of large-scale (private) production firms per energy type on the one hand, and of local, multiproduct (public) distribution companies on the other hand. Based on german statistical information, evidence is given that the presence of local multiproduct energy distribution companies are a necessary but not a sufficient condition for a significant development of district heating.

Introduction

This paper was first presented at the International Association of Energy Economists Conference "Energy Decisions for the Future" in Tokyo, June 1986, and is printed in the proceedings thereof, p. 497-412. Because we think a broader audience may be interested in the subject, this report is published.

District heating or, more generally, heat distribution, is a segment of the energy service sector well-developed in some Westeuropean nations, e.g. Denmark, Sweden, Federal Republic of Germany. In other countries, e.g. United Kingdom, France, the Netherlands, Norway and Belgium, one observes but a wavering building-up or none at all.
In the paper we investigate the causes of this asymmetrical situation in Western Europe. In section I we reconsider highlights of the district heating and cogeneration (DH/CHP*) debate, showing why we focus attention on institutional aspects. These are discussed more in detail in section II. Next, we present and analyse a sample on district heating development in the Federal Republic of Germany. A brief conclusion summarizes our findings.

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* DH = district heating
CHP = combined heat and power (cogeneration)

I. Debate on district heating feasibility

Comparable to all industrial projects, DH/CHP-proposals have to be tested for technical, economic and institutional feasibility. Technically, cogeneration power plants are no more sophisticated than conventional condensing plants. Heat distribution asks for double-pipe conducts, heat exchangers, heating plants, etc...
Although new technologies are forthcoming, any nation in Western Europe can master the technical aspects of DH/CHP projects.

Economically, cogeneration serves a simultaneous demand for power and for heat. The power demand can be integrated in a nation-wide grid. Heat has to be traded on local markets, because transport of heat is very capital intensive. Because of economies of scale, the local heat market should be dense and preferably extended too. Heat density is required to lower distribution costs, while larger systems allow for efficient-scale (cogeneration) plants firing least-cost fuels (coal ; domistic refuse).

In all European nations there are residential and/or industrial concentrations of high heat density and of high total demand. The number of such areas may range from a few (Norway) to several tens (Germany). How to explain that DH/CHP is considered economically feasible in some places, but not in other. We think the main causes of difference are both institutional arrangements and particular circumstances. We first discuss the particular circumstances.

In table 1 we have ranked ten countries according to relative involvement in district heating planning and operation. For measuring this involvement we use a rough and ready scaling, because quantitative figures are often of dubious quality. The symbol +++ means that DH is being developed up to its full potential, i.e. about 50 % of all heating of the country is planned to be served by heat distribution networks. In Denmark about 35 % is attained today; in Sweden and Finland about 25 %. When ++ is noted, DH is a significant option, but will not meet a quarter of the heating requirements in the coming decades. With + we indicate that some development takes place but that a market share of 5 to 10 % for DH will not be exceeded in the years to come. The - sign means no or very little DH is considered.

Table 1 : DH development, climate and energy dependence in ten European nations.

Country	DH-development +++ = full potential ++ = major devel. + = some devel. - = few or none	Climate N = nordic M = moderate S = southern	Net energy import dependence [+] (% of gross inland consumption) (1983)
Denmark	+++	N/M	87,8
Sweden	+++	N	41,3
Finland	+++	N	60,4
F.R. Germany	++	M	50,6
Netherlands	+	M	*
Austria	+	M	50,9
France	-	M/S	58,9
United Kingdom	-	M	*
Belgium	-	M	80,4
Norway	-	N	*

+ nuclear power is considered as an inland energy resource, even if uranium is imported.

a * sign indicates the country is a net exporter.

Sources : 1) International Energy Agency "District Heating and combined Heat and Power Systems", OECD, Paris, 1983

2) United Nations, "Annual Bulletin of General Energy Statistics for Europe 1983", Vol. XVI, Economic Commission for Europe, Geneva, 1985

3) EEC, Energy Statistics Yearbook, Eurostat, 1983, Luxembourg 1985

Two special factors are mentioned : climate and dependence on energy imports. Climate is referred to by three belts : nordic, moderate and southern. Energy dependence is given as a net import percentage, which may obscure important real-live features, e.g. that Norway has since long a large supply of hydropower or e.g. that the Netherlands develop their natural gas resources since about 1960. A main objection against district heating seems to be a gentle climate. People say : "DH should be fostered by nordic countries with long and severe winters. In areas of moderate climate it is no valid option". Climate certainly affects the competitivity of DH, but the argument itself is basically wrong. When in a nordic place residential DH requires a population density of say 10 000 inhabitants/km^2 to be competitive, the same heat density is noticed in a place with half the number of degree days but with a population density of 20 000 inhabitants/km^2. Elsewhere (Verbruggen 1980), we have shown that the load duration curve of heat demand follows the same pattern whether the climate is severe or moderate. In moderate climate areas, DH should be limited to less km^2 and to less communities than in colder areas, but this is not a sufficient reason why it should not be realised at all. That climate is no dominating determinant is illustrated by Norway having no DH at all, while Brescia (Italy) is operating a DH-network succesfully. In the moderate climate belt, the United Kingdom shows no significant DH/CHP realisations whereas the Federal Republic of Germany has the largest heat capacity connected to networks in Western Europe. Climate is an important but not a decisive determinant in explaining the unequal development of DH/CHP in Western Europe.

When in a country a particular energy type is abundant, and therefore cheap, little effort is devoted to the development of other energy sources. Norway is a typical example of an electricity oriented energy economy based on hydropower. The Netherlands have built up an extensive natural gas distribution network. In this country, a program aimed at increasing the share of DH to about 5 % of the heating market is slackening due to fierce competition from natural gas and because of energy conservation reducing heat sales in (overbuilt) systems. In the United Kingdom gas and oil have come to supplement hard coal.

Of the last four countries listed in table 1, only Norway seems to have a reason for omitting the DH/CHP option thusfar. Hydropower does not produce waste heat and industrial waste heat sources are limited. France, United Kingdom and Belgium, however, are expected to be directed more towards DH/CHP. In the following, we concentrate on Belgium, and compare it with Germany. In Belgium no significant DH-development has taken place in the last decades. In most German cities smaller or larger heat distribution networks, many of which started during the sixties, are growing. What are the differences in heat market conditions for the two nations ? The physical differences with respect to heat demand and heat supply are negligible. The only significant differences relate to market organisation and to energy policy. Both nations are blessed with the same (rainy) moderate climate. In both, 1/2 to 3/4 of the population lives in urban areas, often grown in pace with industrial sitings. Heat demand densities are therefore similar in both countries. Availability of waste heat supply is no problem for both countries. In Belgium 98 % of all power is generated in steam cycle plants. Stack industries (steel; metal refineries; chemistry; building materials, ...) represent the backbone of the Belgian economy. Along with the dwindling of domestic coal mining, Belgium has slipped into high energy import dependence. The country moreover is capable of developing DH/CHP all by itself, and imports 80 % of its energy requirements (90 % when nuclear power is referred to as imported uranium). The point, however, is that DH/CHP development not only requires a sound technical and economic basis, but also an adequate energy policy and an adequate organisation of the energy sector.

II. Institutional aspects

Economists are well aware that economic performance, heavily depends on organisation. The optimal type and scale of industrial organisation in turn depend on economic realities, of which economies of scale and economies of scope are crucial ones (Baumol, a.o., 1982)

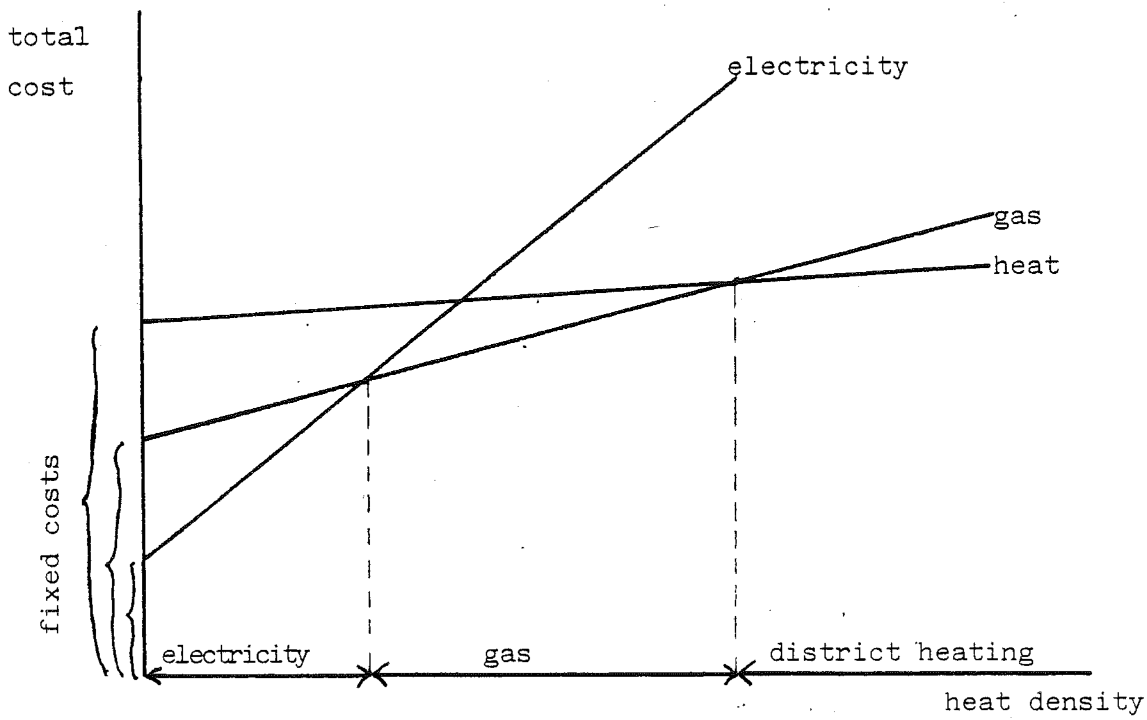
In the provision of energy services, one usually distinguishes between production and distribution. Production encompasses mining, bulk haulage, conversion and/or refining in central plants, and some bulk transport of secondary products. Distribution can be described as the link between bulk transport and delivery to final customers. The predominant part of the energy distribution sector consists of electricity, gas and heat distribution by means of conducts.

The amount of energy traded (kWh, GJ, Btu, etc...) is an evident scale variable for an energy company. Two main reasons account for increases in energy sales : either the company sells more energy to more customers in a given area, or the area covered by the company is enlarged. We denote the former as increase of demand "density" and the latter as increase of demand "extent".

Energy production and energy distribution are differently affected by changes of demand density and changes of demand extent. Production is not very sensitive to density factors. In order to attain levels of minimum efficient scale of energy production units, plants and systems, the demand of several communities need to be pooled.
Significant economies of scale combined with unimportant economies of scope have given rise to large-scale companies specialized in a single energy mode (electricity, gas, oil, coal,...). In most countries, these production companies are investor-owned, but they may also be nationalized firms e.g. France with EDF (Electricité de France), GDF (Gaz de France), CDF (Charbonnages de France).
Nearly the inverse is true for energy distribution. Here economies of scale are very dependent on demand density factors. In addition, a good division of the market area may improve the economics of the various energy types providing low-temperature heat for heating and miscellaneous purposes. In an ordered approach, heat distribution would serve the high density centers, gas would be reserved for lower density built-up areas, while oil and electricity would supply the heat demands of low-density areas.

The ranking follows from the cost structure of the various facilities, as illustrated in figure 1.

Figure 1 : costs of energy distribution facilities



This approach asks for local companies controling most energy supplies, at least the supplies through conducts. It is doubtful whether economies of scale in distribution can result from enlarging the service area if it is already a district of normal size (a community, a city or some other natural urban unity) (see also JOSKOW,a.o. 1983, p. 59)
We summarize the above observations in figure 2. In the remainder of this section we discuss the position of DH/CHP in the scheme of figure 2.

Figure 2 : Link between economies of scale/scope and energy sector organisation.

	ECONOMIES of SCALE/SCOPE due to demand	
in	density	extent
Production	no	YES
Distribution	YES	no
	suggests as ORGANISATION	
for		
Production		regional/national companies per energy type
Distribution	local companies multiproduct (all conducted energy)	

A first point is that DH/CHP has many interdependencies with other parts of the energy sector. The economies of CHP are highly dependent on the terms-of-trade of cogenerated power delivered to the centralized electricity supply industry. Low-grade heat competes directly with fuels converted into this type of energy, or with electricity. Optimizing CHP-facilities requires paradoxically that power output should be maximized under the constraint that heat deliveries have priority. Distribution of low-grade heat by pipeline is very capital intensive. Although lifecycle costs of DH may be lower than lifecycle costs of other solutions, DH cannot in most places stand up to fierce competition from heating systems with a lower pay-back.

To make DH/CHP feasible in energy markets it should be backed by one or both of the following organisations : 1) a mighty energy production company which wants to diversify its activity (e.g. a power company setting up CHP; an oil company selling heat) ; 2) a local company with authority over all energy modes distributed in the area. Because of economies of scope when organising the heating market locally, the second organisation is the most obvious one.

A second point deals with the non-market aspects or externalities related to DH/CHP. The International Energy Agency's experts state that "the main advantages of district heating and combined heat and power production are :

- the very significant potential for oil substitution;
- significant energy conservation potential, particularly for combined heat and power production;
- improved flexibility and security of supply by the use of indigenous solid fuels and low-grade fuels, and by using multi-fuel combustion systems
- environmental improvement;
- positive macroeconomic aspects, such as increased employment, improved balance of payments, etc.".

(I.E.A., 1983,p. 71-72)

It is difficult to make money out of the mentioned advantages if not the money is granted by public authorities. The realisation of the externalities to their full potential requires a public policy which takes all externalities into account and which embodies a long-term global vision. Such a policy opens more perspectives for DH/CHP than any other measure : on the externalities balance DH/CHP scores higher than most other energy systems and hence it assures it of validity as a long-term option; a global approach guarantees that DH/CHP will not be overriden by inferior solutions of shorter pay-back.

Summing up , we conclude that DH/CHP will be stimulated most by multi-product, local and public energy distribution companies. Multi-product means control over all energy deliveries through conducts (electricity, gas, heat), occasionally supplemented by utilities as water supply, TV/FM cable, etc... A centralized control over all conducted energy is necessary because of economies of scope in realizing an optimal market division between distribution systems, each characterized by sub-additive cost functions. The importance of being local refers to the need of a thorough knowledge of local circumstances when forging a policy for the heating market. Choices between energy modes will require difficult trade-offs in many districts, and will ask for detail information on the district. Also, there are many interdependencies between a local energy policy and other local responsibilities (e.g. urban planning, housing, sewerage, street lighting).

A publicly holded company (either directly or through majority shareholder-ship) eases the realisation of DH/CHP because long-term and side-effects of energy systems can be taken into account more fully.

The organisation of the energy sector is often characterized by tensions between on the one hand, large regional or national production companies structured along the various energy modes and, on the other hand, local distribution companies providing utilities to the customers (see figure 2). Depending on the relative strength of the parties involved one has observed local distribution companies climbing into production activities (mostly at higher costs than central producers), or large production companies coming down to distribution of their own energy mode (making an overall equilibrium policy difficult or impossible).

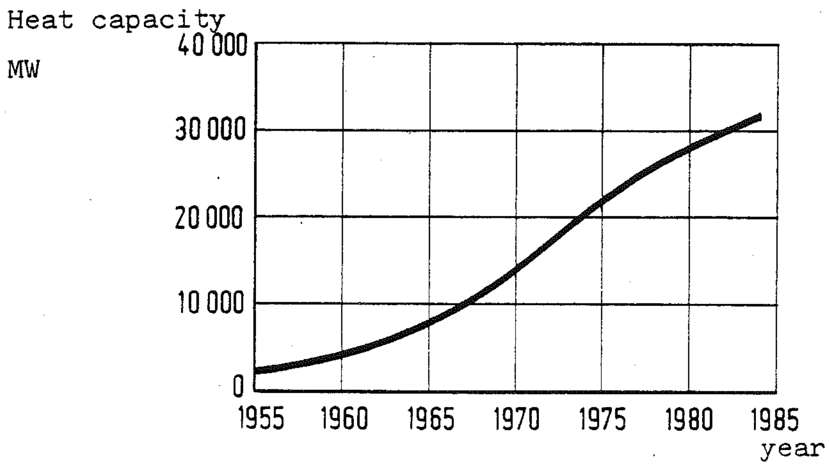
It is our proposition that the single most important explanatory determinant of DH/CHP development is the actual organisation of the energy sector and, more specifically, the relative strength of the two poles in it. Where production firms predominate as in Belgium, DH/CHP is scarcely developed. Where local distribution firms are strong as in many communities of the Federal Republic of Germany, DH/CHP is developed at a significant scale.

In the remainder of the article we substantiate the above proposition with empirical evidence on the German case.

III. District heating development in the Federal Republic of Germany

There are various reasons why we focus attention on the development of DH/CHP in the Federal Republic of Germany. First, there has taken place a steady growth of DH in this country during the last twenty years (figure 3)

Figure 3 : FRG : development of DH since 1955



Source : AGFW

Secondly, the physical and the economic circumstances in Germany were very similar to the ones in Belgium during this period. Thirdly, we could get assistance and information from three different and knowledgeable sources :

1) AGFW (Arbeitsgemeinschaft Fernwärme) is an active association of DH companies publishing its own journal. Yearly, an overview of the main results of affiliated companies is provided (Kröhner, a.o. 1985)
2) ENERGIE & STADTPLANUNG (a consulting firm) has transmitted its files on energy and urban characteristics of all major german municipalities.
3) a questionnaire was send out in January 1986 to 98 municipalities operating a DH system. End of March we have received 54 answers, of which 46 could be used. We obtained 26 perfectly completed formularies.

Because of the late arrival of most of our quantitative information we missed the time to fully integrate the three data sets. For this paper, we therefore have to limit the following analysis to descriptive statistics; we hope to extend our study in the near future.
The present sample consists of 202 German communities with more than 30 000 and less than 1 million inhabitants each (table 2).

Although DH is applied on a large scale in cities as Berlin, Hamburg and Munich these were omitted from the sample because several companies operate seperate DH/CHP-systems in these cities.

Table 2 : FRG : general information on sample communities

Population classes (x 1000)	Number of observations (total=202)	Average population density (inhabit./km^2)	Average * degree of urban density (%)
30 - 50	84	647	12,8
50 - 75	50	857	15,8
75 - 125	30	1 103	18,2
125 - 250	20	1 699	25,5
250 - 500	10	1 764	23,9
500 - 1000	8	2 212	28,6

* this coefficient equals = $\frac{\text{surface covered with buildings}}{\text{total surface of the community}}$

Source : Energie & Stadtplanung (Aachen, Berlin)

One observes in table 2 that, on average, population and building densities increase with larger communities. This makes large cities more adequate for the application of DH/CHP.

Some characteristics of energy use and energy distribution in our sample communities are shown in table 3. The numbers about DH penetration suggest that somewhere a minimum scale of 75 000 inhabitants is necessary to see a major development of DH. Above this limit, scale seems of minor importance.

Table 3 : FRG : general information on energy flows in sample communities (average numbers)

Population classes (x1000)	Deliveries of DH, gas and electricity (1982)				
	As a % of total energy use (1984/85)	in TJ/year	share in distribution through conducts DH	gas	electr.
30 - 50	62	1 003	2,4	72,3	25,2
50 - 75	62	1 802	3,6	73,2	23,2
75 - 125	68	2 185	17,2	62,0	20,8
125 - 250	61	6 022	9,9	59,2	30,9
250 - 500	59	13 259	10,6	66,1	23,3
500 - 1000	55	17 298	19,2	49,5	31,3

Sources : Energie & Stadtplanung, except column (2) which is based on the questionnaire results

On the basis of the sample described, we verify our propositions discussed in the previous sections, summarized briefly as :

1) DH/CHP development will be stimulated most by multi-product, local and public companies.
2) technico-economic variables are of less importance for DH/CHP development than institutional and policy aspects.

At present, we can only provide prima facie evidence on these propositions.

1) The relevance of the multi-product character of the utility to the development of DH/CHP is shown in table 4. Multi-product (in German : "Querverbund") means that the company distributes more than one of the three energy modes : heat (DH), gas and electricity.

Table 4 : Contingency table between the occurence of DH and the multi-product character of energy companies in 202 German communities*

Multi-product (Querverbund) character of community-based utilities	Existence of a DH-system:	No	Yes	Total
	no	52	1	53
	yes	74	75	149
	total	126	76	202

It is obvious from table 4 that "Querverbund" is a necessary but not a sufficient condition for the development of DH. Of the 53 community-based utilities that provide a single energy mode, only 1 is in DH. Of the 76 utilities operating DH, there are 75 utilities that in addition distribute gas and/or electricity.

It follows that the development of DH belongs to the responsibility of existing energy utilities. In countries without DH one cannot expect a growth of DH outside the vested utilities. However, bringing gas and electricity under one scope is not sufficient for DH to develop, as shown by the 74 "Querverbund" utilities without DH (table 4).

The composition of the 75 Querverbund utilities with DH (table 4) is as follows :

60 utilities supply DH + gas + electricity
6 utilities supply DH + electricity
9 utilities supply DH + gas

This learns that DH and gas distribution generally co-exist. It is not true that the availability of gas distribution excludes the realisation of DH. Figure 3 moreover learns that DH has expanded during the last twenty years, i.e. during the same period that natural gas networks have grown considerably.

About the local character of the utilities, the data of table 4 cannot be decisive because the 202 utilities are community-based. Other utilities and communities with several companies providing the same energy mode were omitted from our sample. In addition to community-based firms, there are a few regional heat distibution organisations (e.g. in Ruhr- and Saarland).

The 202 community-based utilities are public. From another AGFW-source, one learns that :

% of DH-companies	ownership
76	more than 95 % public
12	mixed (private and public)
12	more than 75 % private

2) We investigate the impact on DH development of two general indicators measuring urbanization. Population is a measure of the community scale. Building density (table 2) is a measure of concentration of heat loads. Actually, specific urban features may affect DH more than the indicators we use.

For 67 observations in our sample we found the share of DH for non-industrial use in the total demand for heating of non-industrial users. We regressed this share on population and building density :

% DH = constant + C_1 Population (in million inhabitants) + C_2 Building Density (in %; see table 2)

This resulted in :

% DH = 5.075 + 0.133 Population + 0.315 Bldg.Density

s-values (4.737) (9.513) (0.245)

t-values (1.07) (0.01) (1.28)

n = 67; R^2 = 0,8 %

Although we will later extend this investigation, first hand evidence suggests there is no explanatory relationship among the variables.

The minimum efficient scale of about 75 000 inhabitants we derived from table 2, may be less stringent than we assumed. Building density is presumably less important than generally announced.

When we add urban characteristics (population and building density) to the other list of non-decisive factors (climate, technical and economic features) there are no other determinants of DH-development left over than institutional and policy variables.

Conclusion

The development of DH/CHP will be stimulated most when energy in a community is distributed by multi-product, local and public utilities. This means that DH has to be developed in addition to and along with the activities of existing utilities.
DH and gas distribution can expand simultaneously in the same community. Physical differences between communities (climate, population, building density) do not explain differences in DH development.
This suggests that energy sector organisation and energy policy are the major determinants of DH/CHP development.
We hope to investigate the subject further in the near future by ameliorating our sample on German communities, by exploring a few case studies more in detail, and by making use of constructive criticism of our readership.

Bibliography

BAUMOL, W.J.; PANZAR,J.C.; WILLING, R.D. (1982) "Contestable Markets and The Theory of Industry Structure", Harcourt Brace Jovanovich, Inc., 510 p.

DAVIS, J.D. (1985) "Interfuel End Use Competition : Gas/Electricity Competition on Danish and Belgian Space Heating Markets", IAEE-European Conference on "Gas and Electricity Markets in Europe", Luxembourg, September, 23 - 25

I.E.A. (International Energy Agency) (1983) "District Heating and Combined Heat and Power Systems. A Technology Review", Organisation for Economic Co-operation and Development, Paris, 305 p.

JOSKOW, P.L.; SCHMALENSEE, R. (1985) "Markets for Power. An Analysis of Electric Utility Deregulation", The MIT Press, Cambridge, Mass., 269 p.

KROEHNER, P.; REINHARD, K. (1985) "Hauptbericht der Fernwärmeversorgung 1984", Fernwärme International, Jg. 14, Heft 6, p. 297 - 306

VERBRUGGEN, A. (1980) "District Heating : Estimation of a Standard Load Duration Curve", International Journal of Energy Research, Vol. 4, p. 385 - 398.