

EFFECTIVE WIDTH – THE RELATIVE DEMAND FOR DISTRICT HEATING PIPE LENGTHS IN CITY AREAS

Urban Persson¹, Sven Werner¹

¹ School of Business and Engineering
Halmstad University, PO Box 823, SE-30118 Halmstad, Sweden

ABSTRACT

One key concept when assessing network investment cost levels for district heating systems is the linear heat density. In contrast to a traditional way of expressing this quantity entirely on the basis of empirical data, a recently developed analytical approach has made it possible to estimate linear heat densities on the basis of demographic data categories. A vital complementing quantity in this analytical approach is the concept of effective width.

Effective width describes the relationship between a given land area and the length of the district heating pipe network within this area. When modelling distribution capital cost levels by use of land area values for plot ratio calculations, there is a potential bias of overestimating distribution capital cost levels in low dense park city areas ($e < 0.3$).

Since these areas often include land area sections without any housing, avoiding overestimations of network investment costs demand some kind of corrective mechanism. By use of calculated effective width values, a compensating effect at low plot ratio levels is achieved, and, hence, renders lower anticipated distribution capital cost levels in low dense park city areas.

INTRODUCTION

One key concept when estimating investment cost levels for district heating systems is the linear heat density, i.e. the quota of annually sold heat in a district heating scheme and the trench length of the piping system in this scheme (Q_s/L) [1]. In contrast to a traditional way of expressing this quantity entirely on the basis of empirical data, a recently developed analytical approach has made it possible to estimate linear heat density on the basis of demographic data categories [2]. A vital complementing quantity in this analytical approach is the concept of effective width.

BACKGROUND

Effective width is a stand alone concept within district heating theory, describing the relationship between a given land area, A_L , and the length of the district heating pipe network, L , within this area. Hence, the

effective width becomes the width of an analogous rectangle with the trench length as the length and where the rectangle area is equal to the given land area.

The concept was introduced by Werner [3] and has been further elaborated recently in model estimations of distribution capital cost reactions to decreased heat demands in four north European countries [2]. Essential for calculations of anticipated investment cost levels for future district heating systems, the effective width constitutes an important model parameter indicating levels of network extensions in given land areas.

Since the concept of effective width itself is rather new, with no previous analytical or statistical use, data on effective widths are in principal non attainable within national statistical sources. Effective width might be regarded as an innovative model quantity with no previous representation in the field of district heating research.

AIM

The aim of this paper is to describe the concept of effective width and outline the basic properties of this quantity. On the basis of, although sparse, empirical observations, preliminary statements concerning the properties of effective width are made. The aim is further to enlighten the theoretical environment in which effective width contributes when applying demographic quantities for estimations of district heating network investment costs.

LIMITATIONS

Due to a limited amount of empirical data, in principal less than 100 observations, the specific result values and relationships accounted for in this paper must be considered as preliminary. Although thorough in theory, the concept of effective width needs to be supported further by extended empirical data gathering. In order to be able to produce solid and reliable estimations of effective width values in different kinds of city areas, such information is considered vital for future use of the concept.

EFFECTIVE WIDTH

Effective width is a measure indicating the district heating network extension level within a given land area. The quantity effective width, which is symbolised by use of the letter w , with the unit metres, expresses the ratio between land area and the total trench length of the distribution network within a district heating system [3]

$$w = A_L / L \quad [m] \quad (1)$$

Being in this way the result of explicit area and grid properties, effective width can be used to describe typical district heating properties in different population density areas and hence, give information on prerequisite conditions for future district heat establishments.

THE CONCEPT

In order to introduce the concept of effective width, it is necessary to first understand some basic principals regarding the linear heat density. The concept of linear heat density, being the division of total annually sold heat in a district heating system and the total length of the district heating piping network, indicates the level of district heat distribution system utilisation. Furthermore, linear heat density is a denominator parameter when calculating district heating network capital costs.

$$\text{LinearHeatDensity} = \frac{Q_s}{L} \quad [GJ/m] \quad (2)$$

As has been put out in [2], this traditional presentation of the concept of linear heat density offers “no entrance for estimations of future district heating systems, since none of the two quantities can be known for yet not built systems”, which is the fundamental reason for reformulation of the expression by use of demographic quantities. If combining the two concepts of population density (p) and specific building space (α) into the city planning quantity plot ratio (e), which is suggested in [2], the concept of linear heat density can be alternatively expressed as;

$$\frac{Q_s}{L} = q \cdot e \cdot w \quad [GJ/m] \quad (3)$$

The three new parameters, specific heat demand (q), plot ratio (e) and effective width (w), are defined as:

$$q = Q/A_B \quad [GJ/m^2a] \quad (4)$$

$$e = p \alpha \quad [1] \quad (5)$$

$$w = A_L/L \quad [m] \quad (6)$$

where

$$p = P/A_L \quad [\text{number}/m^2] \quad (7)$$

$$\alpha = A_B/P \quad [m^2/\text{capita}] \quad (8)$$

$$P = \text{Total population} \quad [\text{number}]$$

$$A_L = \text{Total land area} \quad [m^2]$$

$$A_B = \text{Total building space area} \quad [m^2]$$

The concept of effective width hereby plays a key role in the reformulation of the traditional expression for linear heat density, and hence, constitutes a central quantity in model estimations of the feasibility and viability of future district heating network. If linear heat density can be said to indicate the level of district heat distribution system utilisation, the effective width indicates the distribution system coverage of the land area at hand.

THE PROBLEM

From a district heating distribution point of view it is relevant to distinguish between two kinds of land area low plot ratio situations. The land areas can, principally, consist of either a wide dispersion of households spread out over the whole area (A), or households can be closely limited to only a fraction of the land area (B), see figure 1.

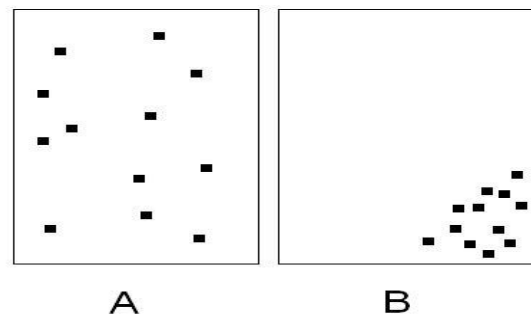


Figure 1. Low plot ratio land areas, scenario A with wide dispersion of buildings and scenario B with high concentration of buildings.

In the first case (A), a district heating distribution grid would have to cover all of the land area at hand in order to deliver heat (at very low linear heat density), while in the latter case (B), the grid could be narrowed down to the limited area fraction. If, when conducting district heating feasibility model analysis, plot ratios are extracted by means of (5), it would be relevant and recommended to somehow adjust the land area magnitude in order not to include non-targeted area fractions. An adjustment to reach this purpose can be achieved in several different ways, of which Effective Width compensation suggested in this paper is one option.

DATA AND VALUES

In the spring of 2009, the authors, both being lecturers at Halmstad University in Sweden, initiated a pre-study to be carried out by two Bsc-students at their department [4]. The study was two-fold in regard of gathered data. Partly it delivered previously assembled and crucial data on plot ratios, land areas and trench lengths in 39 detached house districts heating schemes in Sweden [5], allowing estimations of effective widths in these districts, see Figure 2, and partly own collected data.

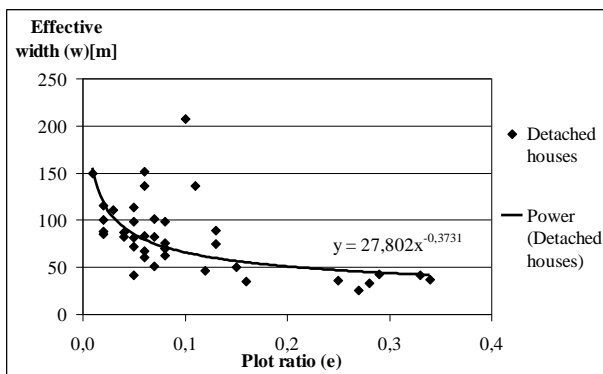


Figure 2. Effective width as a function of plot ratio in 39 district heating schemes in detached house districts in Sweden. Source: [5]

The own collected data of the study refers to data from 34 district heating schemes in multi-family housing districts in the Swedish cities of Halmstad and Gothenburg, see Figure 3.

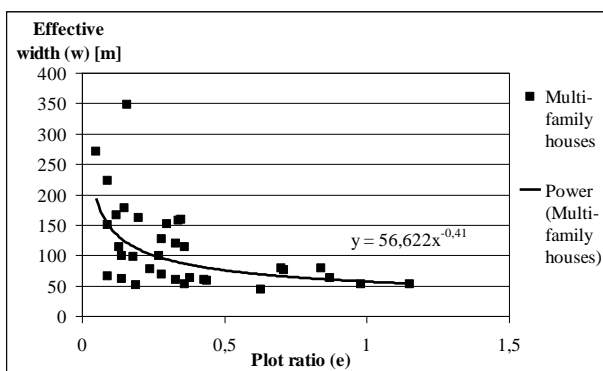


Figure 3. Effective width as a function of plot ratio in 34 district heating schemes in multi family housing districts in Sweden. Source [4]

On the basis of these results, and when combined in one common graph, see Figure 4, a power function were established and presented in [2]. Note that (e) refers to plot ratio values, not to the natural logarithm base (e);

$$w = 61.8 \cdot e^{-0.15} \quad [\text{m}] \quad (9)$$

As can be seen in Figure 4, the graph suggests a convergence at effective width values at 60 meters for

plot ratio values above 1. This would indicate that the relationship between high dense inner city land areas and the length of the required piping grid in such areas is constant.

Still, if plotted explicitly, the function does not converge at any effective width value, no matter how far the plot ratio value is extended, but the rate of divergence decreases with higher plot ratio values. Since plot ratios values above 3 are considered extremely rare, effective width values within high dense inner city areas (plot ratio values above 0.5) can be anticipated to be found in the interval of $50 < w < 60$ meters.

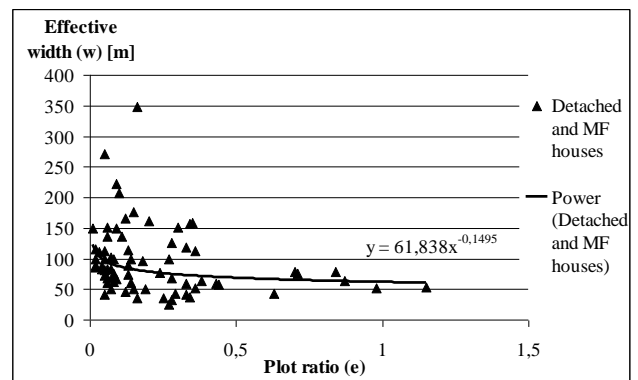


Figure 4. Effective width as a function of plot ratio, combination of 39 district heating schemes in detached house districts and 34 in multi family housing districts in Sweden. Datapoints merged from figure 2 and 3.

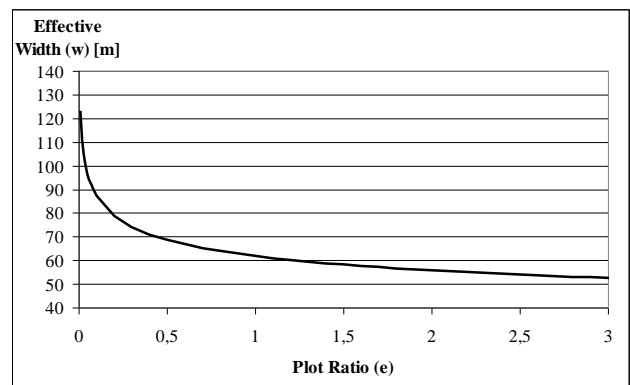


Figure 5. Effective width as a function of plot ratio by use of eq. (9).

For plot ratio values below 0.5, on the other hand (outer city area and park areas), the relationship is by no means constant, but diverges rapidly with increased effective width values as a consequence. At a plot ratio value of 0.04 the effective width reaches a value of 100 meters, and the curve reveals that the increase of effective width values at even lower plot ratio values below 0.04 renders values above 100 meters and beyond.

The graph characteristics of Figure 5 has significance for estimations of district heat distribution capital cost

levels in park areas, since these areas often also include land area fractions without any housing, i.e. not to be targeted by district heating networks. When using crude statistical land area values for plot ratio calculations, there is a potential bias of overestimating distribution capital cost levels in these suburban areas, since actual habitations plausibly only occupy parts of the land area at hand. In these occasions, effective width values arrived at by use of eq. (9). have a compensating effect by rapidly increasing it's value at low plot ratio levels, and, hence, rendering lower anticipated distribution capital cost levels.

CONCLUSION

The main conclusion from this analysis is that the concept of effective width offers a new simple shortcut for quick estimations of capital investments for heat distribution in virgin urban areas.

This conclusion is especially valid if the effective width has almost a constant value over a plot ratio of 0.5 as preliminary stated from Figure 4. Further data collection will show how true this new finding will be.

REFERENCES

- [1] Frederiksen S. and Werner S, Fjärrvärme – teori, teknik och funktion (District Heating – theory, technology and function). Studentlitteratur, Lund 1993.
- [2] Persson U. and Werner S, The Future Competitiveness of District Heating, to be published.
- [3] Werner S, Fjärrvärme till småhus – värmeförluster och distributionskostnader (Sparse district heating – heat losses and distributions costs). Report 1997:11, The Swedish District Heating Association. Stockholm 1997.
- [4] Netterberg H and Isaksson I, District Heating in Slough. BSc thesis from Halmstad University, Halmstad 2009.
- [5] [Andersson S et al, Nuläge Värmegles Fjärrvärme (The current situation for sparse district heating), The Swedish District Heating Association, research report FoU 2002:74. Stockholm 2002.