CHALMERS

Pricing models in district heating

Master's Thesis within the Sustainable Energy Systems programme

OLOF LARSSON

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Division of Energy Technology
CHALMERS UNIVERSITY OF TECHNOLOGY
Göteborg, Sweden 2011
Report No: T2011-351

MASTER'S THESIS

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Technical report no. T2011-351
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Chalmers Reproservice
Göteborg, Sweden 2011
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ABSTRACT

The pricing models, i.e. how the customer price is determined, in the Swedish district heating (DH) sector are constructed in numerous ways. The price components that constitute the pricing models are defined and applied differently due to the absence of standards or a common business area terminology. This makes it complex to overview the actual price a customer has to pay for the delivered heat. Transparent pricing models can be used to govern customers DH consumption pattern, affecting the production mix when more expensive peak load production needs to be utilized. Different pricing models give the customer more or less incentive to change his or her consumption pattern, for example by performing energy conservation measures. This study contains an analysis of the pricing models applied in the residential sector and an analysis of how the pricing models affect the outcome of two typical energy conservation measures.

The analyzed pricing models are those of the companies certified in the *Reko Fjärrvärme* business agreement, which corresponds more than 90 % of the district heat deliveries in Sweden. In the analysis two different artifact buildings, a one/ two family house and an apartment building, are evaluated.

The results from the analysis indicate a tendency among the DH companies to focus on the total *annual* energy use, even though an important part of the cost for the DH production is more related to the *capacity requirement*. Only a few pricing models are designed to address this. One of the assessed measures implies reduced peak load during the winter months. The other measure is instead assumed to reduce the load evenly throughout the year and does therefore not specifically reduce the peak load. The two energy conservation measures yield close to twice as high savings in percentage in the DH networks with pricing models encouraging such measures, compared to those which do not. This result can be attributed to the absence of a fixed cost. There are generally no clear incentives to perform energy conservations measures aimed specifically at reducing peak load demand, although exceptions exist. The results indicate possibilities of positive synergies with respect to potential cost reductions in the production system by avoiding high cost peak load generation as well as increased incentives for energy conservation measures on the customer side if a suitable pricing model is applied.

Price components currently in use in the business that can be utilized for promoting peak load reductions include seasonal differentiation of the energy price, capacity cost based on winter consumption, actual measurement of capacity and the absence of a fixed cost.

Key words: district heating, pricing models

Prismodeller i fjärrvärme

Examensarbete inom masterprogrammet Sustainable Energy Systems

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Avdelningen för Energiteknik
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SAMMANFATTNING

De prismodeller som tillämpas på den svenska fjärrvärmemarknaden är idag konstruerade på ett stort antal olika vis. Definitionerna av de olika priskomponenter som utgör prismodellen varierar dessutom. Sammantaget ger detta en komplex och svårgreppbar bild av vilket pris kunden behöver betala för fjärrvärmeleveranserna. En tydlig och transparent prissättning medför möjligheten att styra kundens förbrukningsmönster och på så sätt påverka produktionsmixen genom minskad efterfrågan på dyrare spetslastproduktion. Olika prismodeller ger olika incitament att förändra förbrukningsmönstret, exempelvis genom energibesparingsåtgärder. Denna studie innehåller en analys av de prismodeller som tillämpas för bostadshus på den svenska fjärrvärmemarknaden och hur prismodellen påverkar utfallet av två typiska energibesparingsåtgärder.

De företag som har kartlagts och ingår i studien är de som är *Reko Fjärrvärme*-certifierade, en branschöverenskommelse som omfattar mer än 90 % av de totala fjärrvärmeleveranserna. I analysen placeras två fiktiva typhus, ett en-/ tvåfamiljshus och ett flerbostadshus, i de olika fjärrvärmenätverken och prismodeller såväl som priser jämförs.

Resultaten från analysen visar en generell tendens bland fjärrvärmeföretagen att fokusera på årlig energiförbrukning även om en stor del av produktionskostnaden är relaterad till effektbehovet. Bara ett fåtal prismodeller är utformade på ett sådant sätt att de tar hänsyn till detta. Den ena undersökta åtgärden medför minskad topplast under vintermånaderna. Den andra åtgärden leder däremot till en jämn energibesparing över året, och bidrar således inte specifikt till minskad topplast. De prismodeller som uppmanar till respektive besparingsåtgärder ger nästan dubbelt så stora procentuella besparingar jämfört med de som inte gör det. Resultaten kan förklaras med avsaknaden av en fast priskomponent. Generellt sett ges få incitament till energibesparingsåtgärder som specifikt syftar till att begränsa topplasten, men det finns undantag. Därmed indikerar resultaten möjlighet till positiva synergieffekter mellan kostnadsminskningar i producentled (genom att behovet av dyra topplastbränslen minskas) och konsumentled då incitament till energibesparingsåtgärder ges av en väl vald prismodell.

Bland de priskomponenter som kan ge incitament till topplastreduktion finns säsongsdifferentierat energipris, effektkostnad baserad på vinterförbrukning, uppmätt effekt och avsaknad av en fast priskomponent.

Nyckelord: fjärrvärme, prismodeller

Contents

Preface

This master thesis work was initiated by Profu (Projektinriktad forskning och Utveckling i Göteborg AB) and performed at the Department of Energy and Environment at Chalmers University of Technology from January to June of 2011 as a part of the Masters programme in Sustainable Energy Systems.

I would like to express my gratitude to Mikael Odenberger, my supervisor at Chalmers University of Technology and Mårten Haraldsson at Profu for their help and guidance during the project. Thanks also to Håkan Sköldberg, Daniel Stridsman and Per Werton at Profu for taking interest in my work and providing me with suggestions, information and encouragement.

Thanks also to my examiner Filip Johnsson and his colleagues at the Department of Energy and Environment.

Göteborg July 2011

Olof Larsson

1 Introduction

1.1 Background

The pricing model is the way the district heating (DH) company charges its customers for the heat they deliver. It can vary in terms of which components it is constructed from, the actual rates of the components and how they are defined. A transparent pricing model is desirable from the customer point of view in order to facilitate comparisons between various methods of providing heat as well as between the prices of the different companies.

The pricing model can also be an important competitive tool and provide incentive for performing energy conservation measures. Such measures can be desirable from the district heating company point of view since the production units used during peak load operation often are expensive. Due to the different designs of the pricing models used in the DH sector, the incentives for energy conservation measures in general and peak load demand reductions in particular differ. However, there is a multitude of factors which are to be taken into account. No two district heating networks are identical, and combined with the fact that some companies use as much as seven different price components (EKAN, 2010) makes it a complex business in terms of pricing.

Furthermore, the individual DH networks are operated as natural monopolies which motivates comparisons and monitoring of pricing models and price levels.

Previous work

An annual survey of the costs for energy and other societal services such as waste management is performed and published by EKAN. The survey is called *Nils Holgersson* and it maps the total cost for a specified artifact apartment building which is assumed to be "moved" from one of the 290 Swedish municipalities to another. The survey covers all Swedish municipalities and also includes other services than district heating, but only for one type of artifact house which from a DH market perspective and price model point of view does not provide full insights. Yet, it provides a comparative tool for assessment of the living costs in the Swedish municipalities which is especially important since many of the services are performed by municipal companies or monopolies (EKAN, 2010). The Nils Holgersson survey is based on numbers reported by the DH companies themselves. Insufficient instructions on how to specify and report the costs might therefore lead to unbalanced comparisons between the companies.

A report on incentives from ten Swedish DH companies targeting implementation of energy conserving measures was published in 2009 by *Fastighetsägarna*, the Swedish Property Federation. The report, "Incitament för energieffektivisering" ("*Incentives for energy efficiency improvements*"), does not only cover district heating but also electricity and other services. It analyses five different energy conserving measures. The aim is to investigate the potential savings from energy conservation measures, especially since energy prices are rising (Fastighetsägarna, 2009). It does however not cover the incentives provided by the pricing models for measures aimed at reducing the peak load demand in particular.

1.2 Aim and methodological approach

The aim of this study is to perform an analysis of the pricing models in practice in the Swedish district heating sector and whether these provide incentive for energy conservation measures in general and peak load demand reduction in particular. To provide a realistic picture of the DH sector the aim is to cover a major part of the market as well as to include two different customer categories.

The following research questions are investigated:

- What pricing models are applied to residential customers in the Swedish district heating sector today?
- What characterizes the pricing models used in the business today?
- What are the economical results of energy conservation measures when different pricing models are used? More specifically, do the pricing models encourage peak load demand reductions? If so, what pricing models are best suited for such encouragement?

The effect on yearly costs for the customer from changes in the heat demand is analyzed with respect to two energy conservation measures. These measures intend to provide the same *annual* energy reduction but have different impact on the heat capacity requirement in order to highlight the differences between different pricing models. The analysis put emphasis on advantages and disadvantages of the different pricing models when it comes to reducing peak load capacity requirement.

In order to analyze how the pricing models used in the present day DH sector are constructed and whether they do provide incentives for implementing energy conservation measures a survey is required, including a description and decomposition of the price into different components, how they are defined and what they are based upon.

1.3 Scope and limitations

This study is limited to only include companies certified by the district heating business agreement *Reko Fjärrvärme*. This agreement aims at providing transparency in the pricing of the district heating by presenting price figures for a standardized artifact house from all certified utilities. The companies included in *Reko Fjärrvärme* make up for about 90 % of the Swedish district heating deliveries (Svensk Fjärrvärme, 2010), and the companies included in this study are listed in Appendix A.

The pricing models are examined with respect to two different types of buildings, namely an artifact one/ two family house and an artifact apartment building. The choice of using artifact buildings is an effort to promote comparability between the companies. Whether these buildings types actually exist within each of the DH networks included in the study is not verified.

In the pricing-model survey only the *operational costs* for the customer are investigated. Connection and deposition fees are excluded, but are known to vary quite substantially. The maintenance and service demand are difficult to evaluate and are therefore excluded. The results should therefore not be regarded primarily as an absolute comparison of DH prices.

2 Introduction to district heating

District heating is a method of supplying heat to a heat load by centralized production and distribution of water heated to 70-120 °C in a network of insulated pipes. The DH water is heat exchanged with a local system where the heat load exists. Thus, the water is kept into separate loops and an in-door leakage will only drain the local heating system. After being heat exchanged the water is returned to the production facility where it is reheated. The Swedish district heating business provided 56 % of the space heating for residences and commercial premises in 2008 (Energimyndigheten, 2009).

2.1 District heating systems

The main use of DH is to provide space heating and hot tap water in the residential and service building sectors. There are however examples of other uses such as pool heating and heating of parking lots and sidewalks. Dish washers and washing machines using DH are also under development (Svensk Fjärrvärme, 2011). A large temperature drop in the heat exchanger is desirable from the DH company point of view since a lowered return water temperature reduce the heat losses. DH is often a cost-efficient method of heating, but it is associated with high investment costs. Both the production facilities and the distribution networks require large investments. Plants designed to handle "difficult" fuels such as unrefined biofuels and municipal waste are costly since the fuels often have a high content of moist and other compounds leading to corrosion problems (Avfall Sverige, 2008). The operational costs of such plants are however low, since the fuels are inexpensive. Peak load reductions in the DH networks are generally beneficial since it decreases the need for more expensive fuels such as fuel oil which are only used in peak load periods.

Both the outdoor distribution systems and the indoor water based systems are costly and the pay-back period for the customer can be long, e.g. when switching from direct electric heating to a hydronic heating system. The outdoor or primary distribution system normally consists of foam insulated steel pipes placed underground. The pipe diameter varies depending on the design water flow.

From a customer point of view DH needs little management compared to pellet and oil burners, since no fuel handling is performed by the customer. For the DH utility it is flexible in terms of energy supply since all fuel handling is managed centrally by a variety of different production units. Thus, the system as a whole has the advantage of fuel flexibility whereas the distribution systems remain unchanged. The relative independence of any specific fuel could also act as a safeguard against drastic price increases.

Sweden has a large district heating system which makes efficient use of the waste heat from pulp and paper mills, steel plants, refineries and waste incineration plants. In addition, plants configured for combined heat and power (CHP) provide a highly efficient energy supply. District heating distribution is subject to natural monopoly due to the fact that it would be economically difficult for competing companies to establish and operate parallel networks in the same city. The situation can be compared to that of electric power transmission, a field of business that is still not fully deregulated. The national grid is run by a public company called *Svenska Kraftnät (Swedish National Grid)*, although management of the regional and local grids is deregulated. Yet, competition in the DH sector is not totally absent, since consumers always have the possibility to substitute to other heating methods. The foremost alternatives are heat pumps and wood pellet burners, which often are more cost efficient options than DH in one/ two family houses (Boverket, 2008). The possibility of third-party connection in

Swedish DH networks is currently not statutory, yet, investigated by the government (further described in Section 2.2).

District heating benefits from large scale production and consumption, preferably geographically close to one another. It is also beneficial if the consumers (heat loads) are situated close to each other since it reduces the heat losses that occur from the distribution network. The ideal situation is that of large urban areas, with high heat load density. The Swedish urban areas generally have developed DH networks with sufficient heat load density for efficient DH use. The networks are as previously stated costly and this is a barrier to further expansion of existing DH networks as well as the establishment of new ones (Svensk Fjärrvärme, 2010). Local conditions in terms of waste heat availability, density of population, soil conditions among other factors have a large impact on the costs of establishing a DH network.

Apartment buildings in Sweden heated by DH account for 84 % of the total heated area of such buildings. The corresponding value for the one/ two family house is 12 %. In 2009, an average of 10.9 MWh was used in each apartment for heating and hot water (Energimyndigheten, 2011). In 2008, about 42.5 TWh of district heating was used for space heating and hot water in residential buildings, of which 22.3 TWh was used in apartment buildings and 5.4 TWh in one/ two family houses (Energimyndigheten, 2009).

2.2 District heating markets

The Swedish District Heating Association, *Svensk Fjärrvärme*, claims that there are two basic pricing methods in the industry. The first one, *cost based pricing*, is intended to match the DH price with the costs involved. The second method, *alternative pricing*, is focused on the customers' alternative options with the objective to set the price lower than the competitors but still yielding profit (Svensk Fjärrvärme, 2010). Third-party connection to DH is something that is currently being discussed. Presently, only one utility supply the DH in each network and the same company manages distribution and sales. With third-party connection, one or more of these services can be subject to competition. The possibilities of deregulating the market and allowing competition within each DH network are being investigated. Fear has been raised that third-party connection might lead to increased prices for the customers, since it adds costs related to the splitting of the present day companies into producers and distributors. Furthermore, operation management and the balancing of supply and demand might become costlier when performed by more than one actor (Lindholm & Ångström, 2010).

In order to provide a cost-related method of pricing, the companies might have to adopt complicated pricing models based on the factors that influence the cost of the DH utilities, e.g. energy consumption, peak load, seasonal differentiation, availability and price of the fuel. This could lead to consumers receiving complex energy bills, which due to lack in transparency gives little incentives to perform efficiency measures. For instance, a reduced heat load is something that would be seen as positive from a societal point of view during the parts of the year when waste heat is insufficient to fulfill the demand for DH. It is obviously doubtful if the companies can be expected to promote decreased consumption of their product, yet costly peak load productions reduced by changes in demand (as would be seen in transparent pricing models) during peak load situations could offer positive synergies for consumers as well as producers.

Price components

The pricing models currently in use in the DH sector are constructed by a number of price components. The categorization of price components described here has a number of limitations but has become practice in the DH sector, and is therefore applied in this study. The most common price component is the *energy price* which is charged per unit of energy delivered. It can be differentiated during the year with higher prices in winter time and lower prices in the summer.

A fully *fixed cost* is another frequently used component. There are however numerous examples of companies describing a price component as fixed, even when it is not. A frequently used price component is a *fixed cost based on one or several previous years' consumption.* Although it is fixed for the present year, it is in the long run directly proportional to the energy use and can therefore be considered variable.

Capacity cost (i.e. subscribed capacity) is another commonly used price component, especially in the pricing models of larger consumers such as apartment buildings. It is designed and described as a way of limiting the peak load of DH, something that is associated with high costs for the DH production. In most cases the capacity price is however directly linked to the energy use rather than the real-time capacity use. The subscribed capacity is calculated using the so called category number method (*kategoritalsmetoden*) by Svensk Fjärrvärme (Svensk Fjärrvärme, 2007). The most frequently used method is to divide the mean consumption in previous years (the number of years vary and the consumption should be normal corrected with respect to the outdoor temperature) by a *category number*, a theoretical number of hours of the year during which the full capacity of the district heating systems has to be employed in order to fulfill the entire energy demand.

$$Capacity\ [kW] = \frac{Consumption\ over\ a\ certain\ time\ period\ [kWh]}{Category\ number\ [h]}$$

Different values for the category number are employed for different building categories. Residential buildings, where demand is assumed to be more evenly distributed, have a higher category number and subsequently a lower subscribed capacity. Other premises, with little or no use during weekends and holidays have a lower number. For further explanation see Appendix B. The values differ between companies, to some extent due to different climate in different parts of Sweden. The subscribed capacity is normally adjusted when the deviation is more than 5 % between the new calculated capacity and the previously calculated one. There are cases where the subscribed capacity is determined by dividing only the winter consumption by a category number. It can therefore be used as a way of providing incentive for reduced energy consumption during the peak load periods.

In this study, energy use measurements on a daily or hourly basis are regarded as sufficient for the capacity to be considered *measured*. The general trend is that more companies are adopting actual measurement of the capacity (Fastighetsägarna, 2009). This is due to recent developments in remote reading apparatus. The methods of calculating the *subscribed capacity* in the case of actual measurement, i.e. the capacity with which the capacity cost is multiplied, varies and is explained in Appendix C.

Flow cost is a less common price component. It is generally only based on the volumetric flow of the DH water through the customer heat exchanger, but occasionally also include the temperature of the return water. It is used in order to promote more efficient heat transfer with low return temperatures. Some companies only apply the *Flow cost* when the flow per delivered unit of energy is above a certain threshold value, e.g. 20 m^3/MWh (Bodens Energi, 2010). It therefore gives consumers an indication of when it is time to replace or perform maintenance to the heat exchanger.

In addition, some DH companies offer different tariffs depending on the chosen size of the deposition fee (a one-time payment when connecting to the DH network). The basic idea is that customers are offered to choose a high “investment cost” followed by lower annual costs or vice versa. In reality, the difference between the deposition fee and the installation cost can be unclear and is not covered in this report. In addition, there are companies who use another pricing model or another price level for customers who only use DH to fulfill a part of their heating demand. If another energy source is used for the base load, the energy use over the year will decrease drastically, but the peak load only marginally.

Table 2.1   Price components and abbreviations used in figures and graphs.

Price component	Description
Fix	A fully fixed cost, independent of energy use, SEK/year
Fix (prev)	A cost which is fixed for the current year but is based on previous years' consumption and therefore ultimately variable, SEK/MWh
Energy	The energy cost in SEK/MWh
Category	Capacity cost based on category number, a number of hours determining the subscribed capacity of a certain type of customer. In most cases the total annual consumption is used, but there are also cases where the winter consumption determines the subscribed capacity, SEK/kW
Measured	Capacity cost based on measurement, SEK/kW
Flow	Flow cost, SEK/m3

3 Method

This study consists of a survey of the pricing models used in the DH sector and an analysis of the economic effect for the DH consumer if implementing two different energy conservation measures. The focus of the analysis is put on the impact from the pricing model. The same energy conservation measure can therefore yield different results due to the different compositions of the pricing models. The survey is performed mainly by gathering pricing data from the investigated DH companies.

3.1 Data collection

The pricing models of the DH companies were mapped between February and April of 2011, mainly by gathering data from company web pages, which they are obliged to publish if a member of the *Reko fjärrvärme* agreement. The price components that constitute the pricing model as well as the actual tariffs were collected. In cases when information about the pricing model or the tariffs was not published online direct contact was taken with the companies. Statistics of the heat deliveries within the respective networks were mainly provided by *Energimarknadsinspektionen*, the Swedish Energy Markets Inspectorate. In some cases such data had to be attained directly from the companies.

In addition, information from the *Nils Holgersson* survey has been used to specify the two artifact buildings (EKAN, 2010). The apartment building is identical to that of the Nils Holgersson survey in terms of heating. The one/ two family house is assumed to use the same DH water flow per unit of energy. This study compares the energy costs of the artifact buildings assumed to be situated in each one of DH networks, in a similar manner as in the Nils Holgersson survey but here limited to companies member of the *Reko fjärrvärme* agreement. Among the companies included in this study there are cases of larger companies being responsible for publishing the pricing models of smaller companies on their homepages, usually due to split ownership.

3.2 Building parameters

In this study the surveyed and analyzed pricing models are limited to two artifact houses, namely; a one/ two family house and an apartment building. The first category, the one/ two family house is assumed to have an annual heat demand of 20 MWh of DH. Recent figures indicate that in 2009, the average one/ two family house used a little less, 18.7 MWh, for space heating and hot tap water (Energimyndigheten, 2011). The value of 20 MWh is considered to be sufficiently close to this value and is used for simplicity, since the DH companies publish calculated yearly costs for buildings with that consumption on an annual basis.

The second category, the apartment building, corresponds to the artifact building applied in the *Nils Holgersson* survey. This building has 15 apartments and a heat demand for 193 MWh of DH per year (EKAN, 2010). Specifications of the two building types included in this study are presented in Table 3.1.

Table 3.1 Specifications of the two selected building types

	Energy consumption [MWh/yr.]	DH water flow [m^3/yr.]	Hot water share of DH [%]
One/ two family house	20	400	25
Apartment building	193	3860	25

For the networks where the category number method is used, the stated category number of hours is used. The category number is applied to calculate the DH capacity for the two building types and does thereby sometimes determine the price interval to use in the survey, in cases when capacity instead of annual energy use determines the price interval. In the networks where actual capacity is measured, the subscribed capacities are calculated differently. This is because some companies base the capacity on hourly values while others use daily values. The values used, and methods used for deciding them, are presented in Appendix C. Measured capacity is not used for the one/ two family house in any of the DH networks included in the survey. It is therefore only relevant for the apartment building. In the *Nils Holgersson* survey building, the calculated DH water flow is 20 m^3/MWh. For comparability the same reference value is assumed in this study for both building types.

3.3 Cost calculations

The DH consumers are generally divided in numerous consumer categories (here the two assumed artifact houses), depending either on annual energy use or subscribed capacity. The costs of DH are calculated using company specific tariffs from 2011, in the relevant price interval. When the energy price is differentiated over the year, the monthly distribution of DH demand presented in Figure 3.1 has been applied. The load curve is assumed to be equal for all DH companies and networks. The specific method of calculating the subscribed capacity stated by each company is used, leading to different subscribed capacities within different DH networks. Only averaged monthly values are used, due to lack of information on weekly or more frequent values for energy use. The fluctuations within each month are thus excluded. Prices include all taxes.

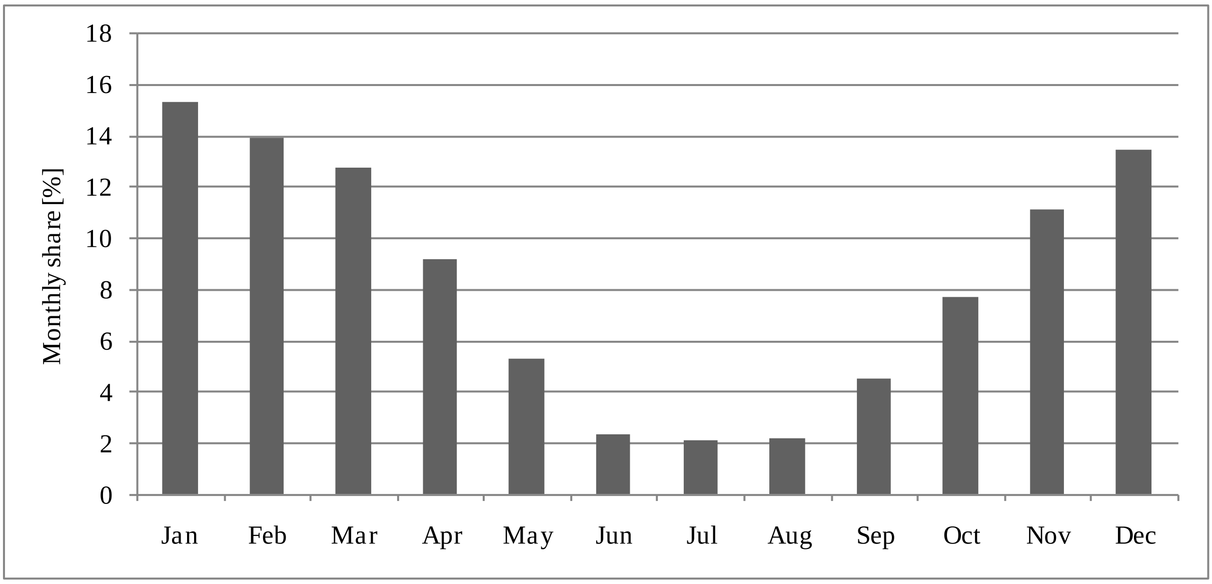

Figure 3.1 Assumed monthly distribution of district heating energy use for the average building in both analyzed building categories. The distribution is an average based on values obtained from Varberg Energi AB, Götene Vatten & Värme AB and Luleå Energi AB.

3.4 Assumptions

Energy conservation measures

To study how the different pricing models provide incentives for implementing energy conservation measures, the effect of two such measures have been analyzed. Both measures decrease the energy use and the capacity requirement of the district heating unit in the building. The first measure, a switch to low flush water taps, leads to a proportionally *larger reduction in annual energy use* than in installed capacity, using the January average capacity as installed capacity (see Table 3.2). This can also be seen in Figure 3.2 below. However, the second measure, changing the windows and doors to better insulated ones, instead leads to a proportionally *larger reduction in installed capacity* than in annual energy use.

The two measures are chosen due to the different nature of the energy use reductions they lead to. The switch to low flush taps further increases the peaks of the load curve, while the improved insulation measure reduces the peaks. Other measures resulting in similar results could therefore just as well have been analyzed. The important distinction is whether the peak capacity is reduced more or less than the energy use. The same energy reduction is chosen for comparability. This analysis should not be regarded to be an economic feasibility study of the measures themselves nor compared to each other, since the cost of implementing them is excluded from this study and might differ significantly.

There are companies have pricing models in which a fixed cost is based on the consumption of previous years. In such cases an energy conservation measure would not have its full impact until a point in time when the measures have been in place during a full backcasting period. This time factor is not included in this study. Instead, all measures are assumed to have full economic impact regardless of when the measure was taken. The reductions are in turn used to calculate the annual cost reductions within the respective DH networks, see Chapter 4.

Table 3.2 Reductions in annual energy use, ΔE, and needed capacity, ΔP, for the two energy reduction measures analyzed.

Measure	ΔE	ΔP
Low flush water taps	-10 %	-5.45 %
Improved insulation	-10 %	-11.5 %

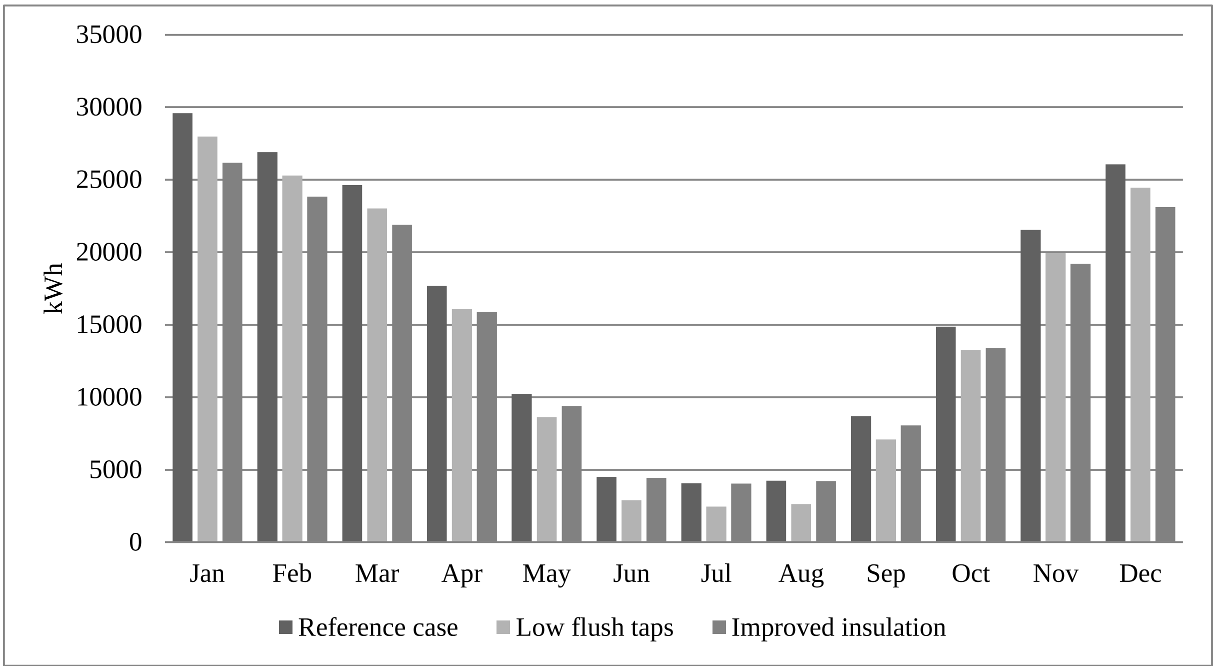

Figure 3.2 Estimated monthly shares of the DH energy use. The leftmost bars of each month show the reference building before any energy conservation measure. The middle bars show the remaining share of the energy use after a switch to low flush taps. The rightmost bars show the corresponding values for the improved insulation measure. The remaining energy use after each measure adds up to 90 % of the reference case on an annual basis.

Switch to low flush water taps

The switch to low flush water taps measure is, as previously mentioned, chosen in this study because it reduces the energy use evenly throughout the year. It is therefore a measure not specifically targeting the peak load periods.

The Swedish Energy Agency states that a switch to low flush water taps has the potential of reducing the hot water consumption by up to 40 % (Energimyndigheten, 2006). The hot water consumption can be assumed to correspond to 25 % of the district heating energy use in a residential building (Aronsson, 1996) and is assumed to be evenly distributed over the year, this would lead to a 10 % reduction of the energy consumption over the year as seen in Figure 3.3 below.

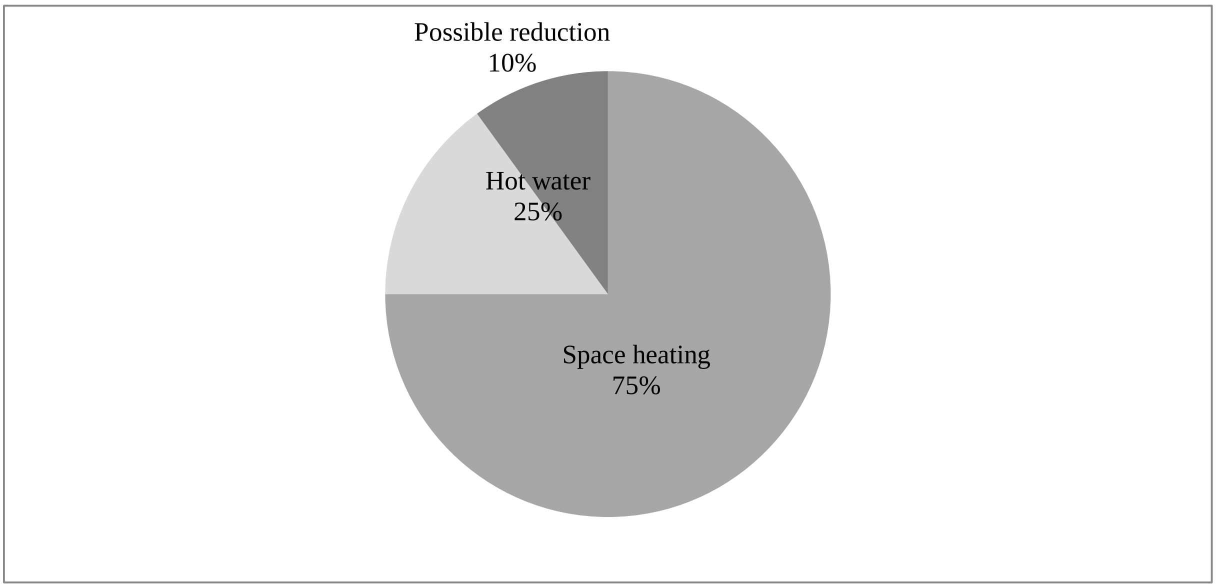

Figure 3.3 Annual hot water use and possible reduction by switch to low flush water taps.

<u>Calculations of the reductions in energy use and required capacity:</u>

The annual energy demand of the one/ two family house specified in section 3.2 is used. The same percentage decrease would, however, be obtained if using the apartment building for calculations.

<u>Annual DH energy use:</u> 20000 kWh

<u>Annual hot water energy use:</u> 5000 kWh or 25 % of the DH energy use

<u>Monthly hot water use:</u> 5000/12 = 416.7 kWh

<u>DH energy use in January:</u> 0.153 * 20000 = 3060 kWh

<u>Annual DH energy use after 40 % reduction in hot water energy use:</u>

20000 - 0.4*5000 = 18000 kWh

<u>Annual reduction in energy use:</u> $\Delta E = 1 - 18000/20000 = 10\ \%$

<u>Reduction in capacity requirement use in January (here assumed to correspond to the reduction in energy use):</u>

$\Delta P = 1-(3060 - 0.4*416.7)/3060 = 5.45\ \%$

Improved insulation of windows and doors

The second measure is more aimed at reducing the capacity demand at peak load periods.

The Swedish Energy Agency states that "the average 144 m^2 one/ two family house use about 15000 kWh annually for heating. Regular double glass windows and poorly insulated doors release about a third of the heat."(The Swedish Energy Agency, 2011)

Assuming, as with the previous measure, a 25 % share of the district heating energy being used for hot water implies that 15 MWh are used for the space heating of the building (the same value as stated by the Swedish Energy Agency).

Hence, the double glass windows and poorly insulated doors correspond to 5 MWh of heat lost annually. Here a possible 40 % reduction in the heat loss by means of better insulated windows and doors is assumed (The Swedish Energy Agency states 33 - 50 %) (Energimyndigheten, 2008).

<u>Calculations of the reductions in energy use and required capacity:</u>

<u>Annual energy use:</u> 20000 kWh

<u>Annual heat loss:</u> 5000 kWh

<u>Annual DH energy use after 40 % reduction in heat losses through windows and doors:</u>

20000 - 0.4 * 5000 = 18000 kWh

<u>Annual reduction in energy use:</u> $\Delta E = 1 - 18000/20000 = 10\ \%$

<u>Monthly hot water use:</u> 5000/12 = 416.7 kWh

<u>DH energy use in January for heating:</u> 0.153 * 20000 - (5000/12) = 2649.3 kWh

<u>Heat loss in January:</u> 2649.3/3 = 883.1 kWh

<u>Heat loss in January after 40% reduction:</u> 529.9 kWh

<u>Heat loss reduction:</u> 883.1 - 529.9 = 353.2 kWh

<u>Reduction in capacity requirement use in January (here assumed to correspond to the reduction in energy use):</u>

$\Delta P = 1 - (3060 - 353.2) / 3060 = 11.5\ \%$

4 Results

The survey and analysis of the pricing models and the potential savings from the two energy conservation measures are described below. The results for the two analyzed artifact buildings are presented separately in an effort to reduce confusion. In the graphs and figures, the abbreviations described in Chapter 2 and Table 2.1 are used.

4.1 One/ two family house

Survey

For the one/ two family house consuming 20 MWh annually, the vastly dominating pricing model is made up of a fixed price and a uniform energy price. The number of DH networks in which the different price components and pricing models are applied can be seen in Figures 4.1 and 4.2. There is a distinction between a uniform energy price throughout the year and energy prices with seasonal differentiation in two or three levels. The Figures 4.1 and 4.2 show that there is a multitude of combinations of the price components in use. However, for the one/ two family house category the dominating pricing model consists of a fixed price in combination with an energy price.

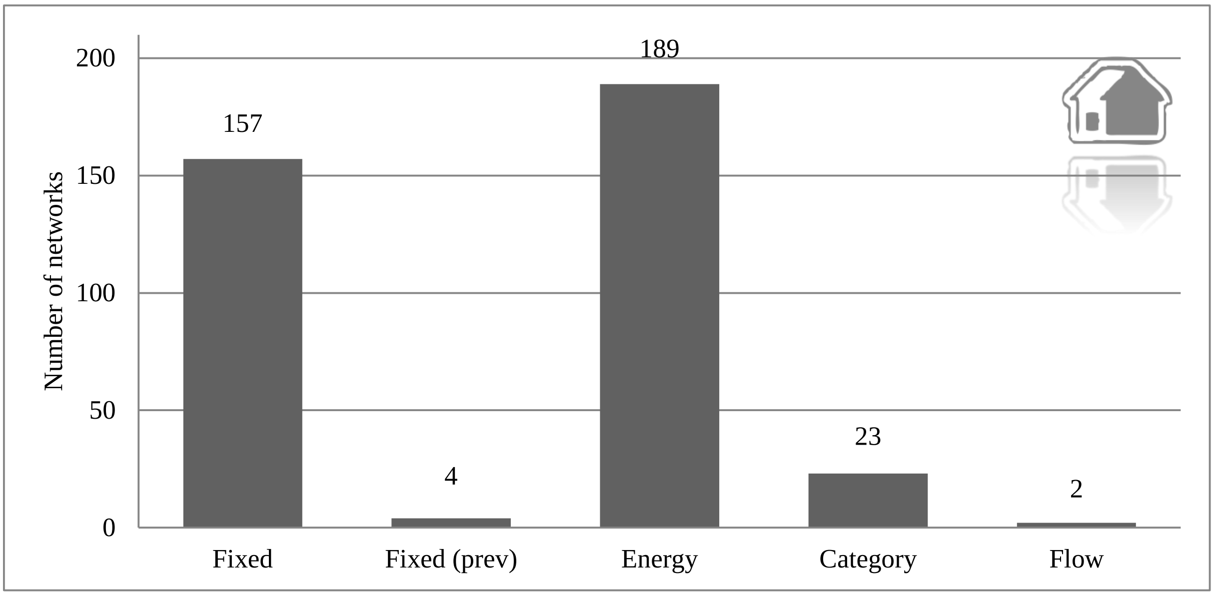

Figure 4.1 Number of networks in which the different price components are applied for the one/ two family house.

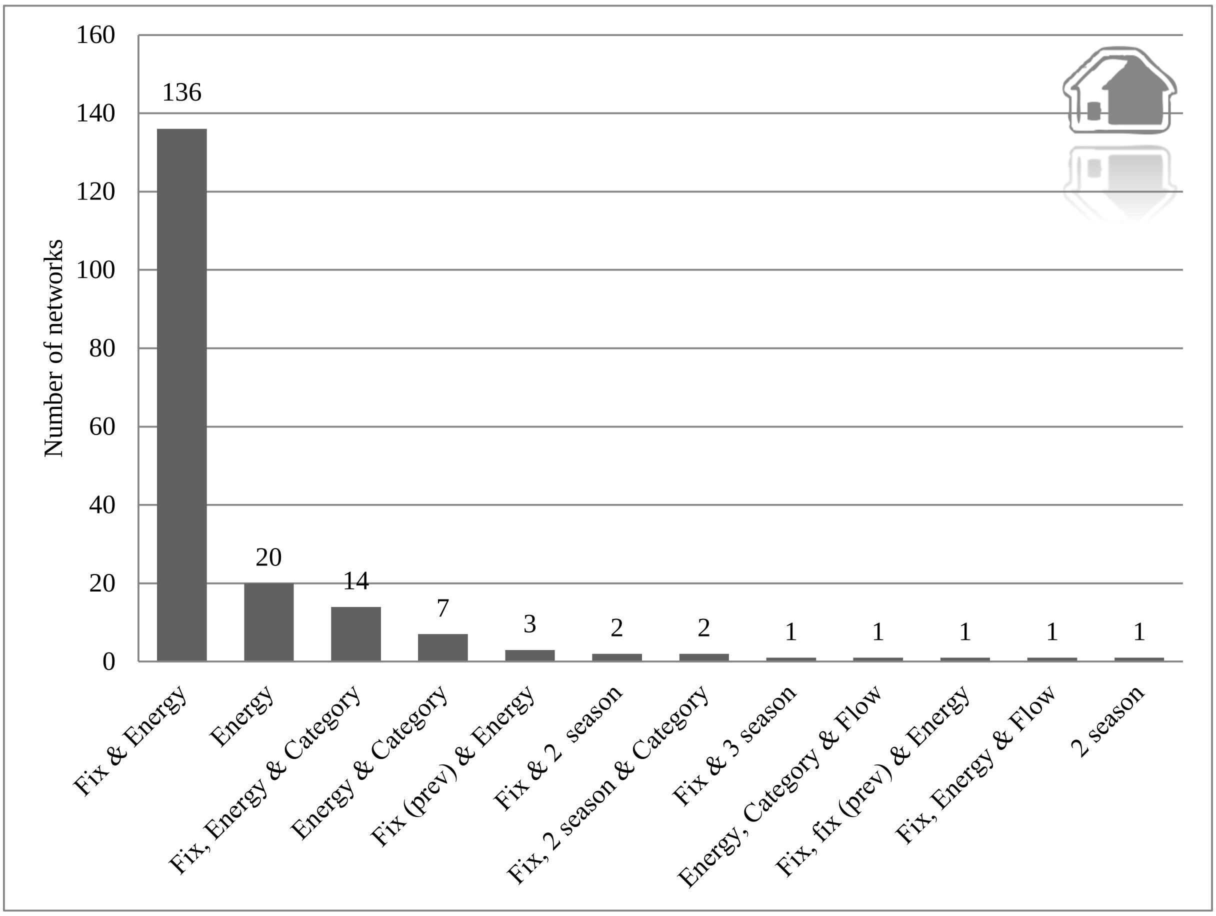

Figure 4.2 Number of networks in which the different pricing models for one/ two family house are applied. "2 season" is a summer/winter divided energy price. "3 season" represents an additional spring/autumn differentiation of the energy price.

Table 4.1 below shows the presence and average values for the price components used in the one/ two family house category. The average values can be compared to the prices of individual companies as well as other technologies used for space and hot water heating. It also shows the different prices of the energy consumed, since several price components are based on the annual energy use. In 31 of the 189 networks (or 16 %), the price differs for customers that only use the DH for part load in the case of the one/ two family house.

Only one company, Skellefteå Kraft AB, uses a part of the annual consumption to determine the subscribed capacity with the category number method (the consumption from December to February divided by 940 hours). Therefore the category number based capacity costs can be seen as proportional to annual energy use.

Table 4.1 Average values for the price components applied to the one/ two family house customers. Measurement of capacity on a daily or hourly basis is not utilized in any of the pricing models in the 189 networks of the survey.

Price component	Networks	Percentage	Average value	Unit
Fixed cost	157	83 %	3557	SEK
Fixed cost (based on previous consumption)	4	2 %	0.29	SEK/kWh
Energy cost	189	100 %	0.65	SEK/kWh
Summer price	6	3 %	0.48	SEK/kWh
Spring/autumn price	1	1 %	0.44	SEK/kWh
Winter price	6	3 %	0.71	SEK/kWh
Capacity cost (based on category number)	23	13 %	492	SEK/kW
Capacity cost (based on measurement)	-	-	-	SEK/kW
Flow price	2	1 %	2.5	SEK/m^3

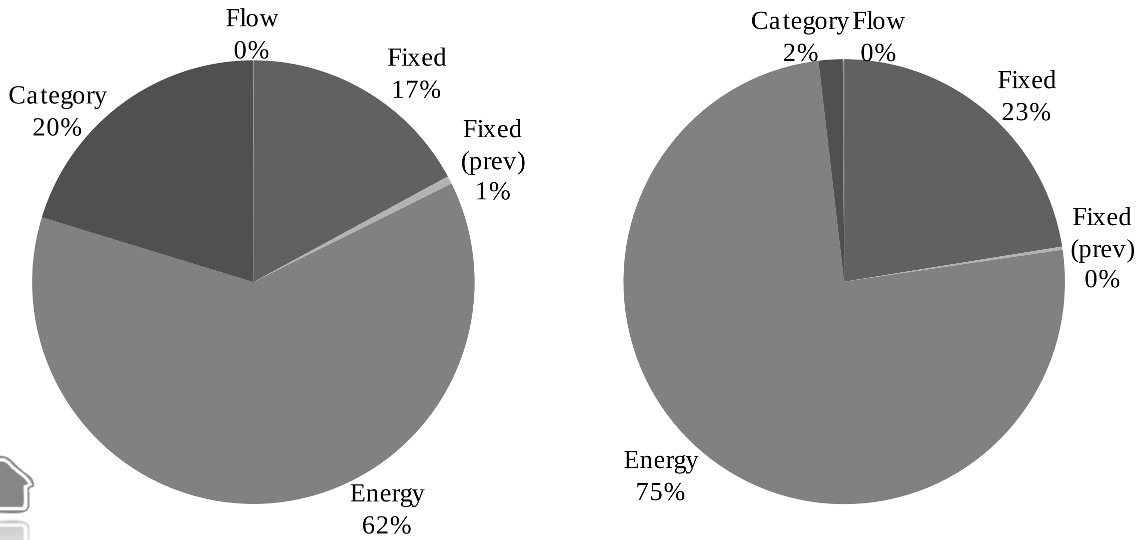

Figure 4.3 Average share of the total cost of each price component for the one / two family house, rounded to integers without regard to the size of the networks (left) and weighted against size of DH deliveries within the respective networks (right).

The annual cost is to a large extent based on the energy use. The shares of the total cost by each price component can be seen in Figure 4.3 above. In both cases roughly 80 % the price is directly proportional to the energy use (since the capacity is calculated using the category number method).

When weighting the price components against the size of the DH deliveries, the capacity cost based on category number is smaller. Still about 80 % of the total costs are directly proportional to energy use. The fixed cost share is somewhat larger in the larger networks. If the shares of the price components instead is weighted against the total costs of the networks, calculated in a similar fashion, the shares are similar to that of the unweighted (seen to the left in Figure 4.3 above). No clear trend regarding the shares of the price components related to the total price can be seen.

Seasonal differentiation can be a way of promoting reduced energy use in periods of peak load. It is therefore of interest to include the different levels in the survey and the monthly average prices of the six companies with seasonal differentiation can be seen in Figure 4.4. The companies are listed in Appendix D. The total annual cost (excluding installation and deposition fees) itself varies quite drastically, as seen in Figure 4.5 below. No clear trend can be seen about the correlation between individual pricing models and total costs. The different pricing models are therefore not presented explicitly in the figure.

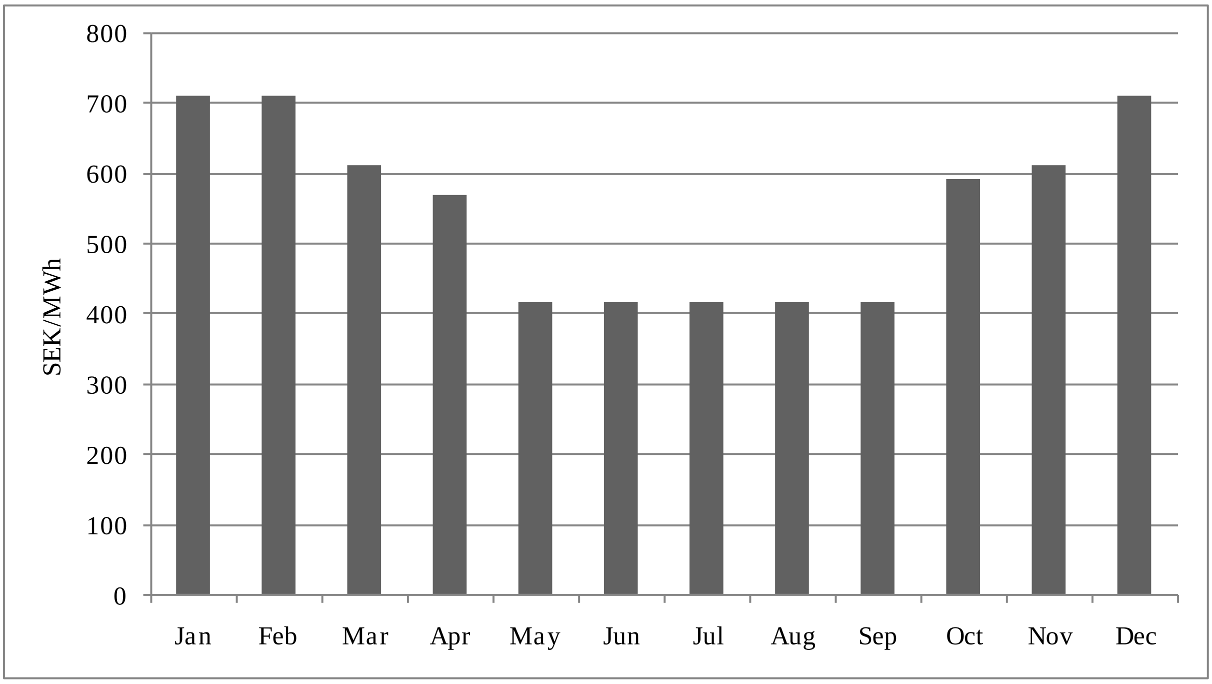

Figure 4.4 Average monthly energy prices for the six DH networks applying seasonal differentiation for the one/ two family house category.

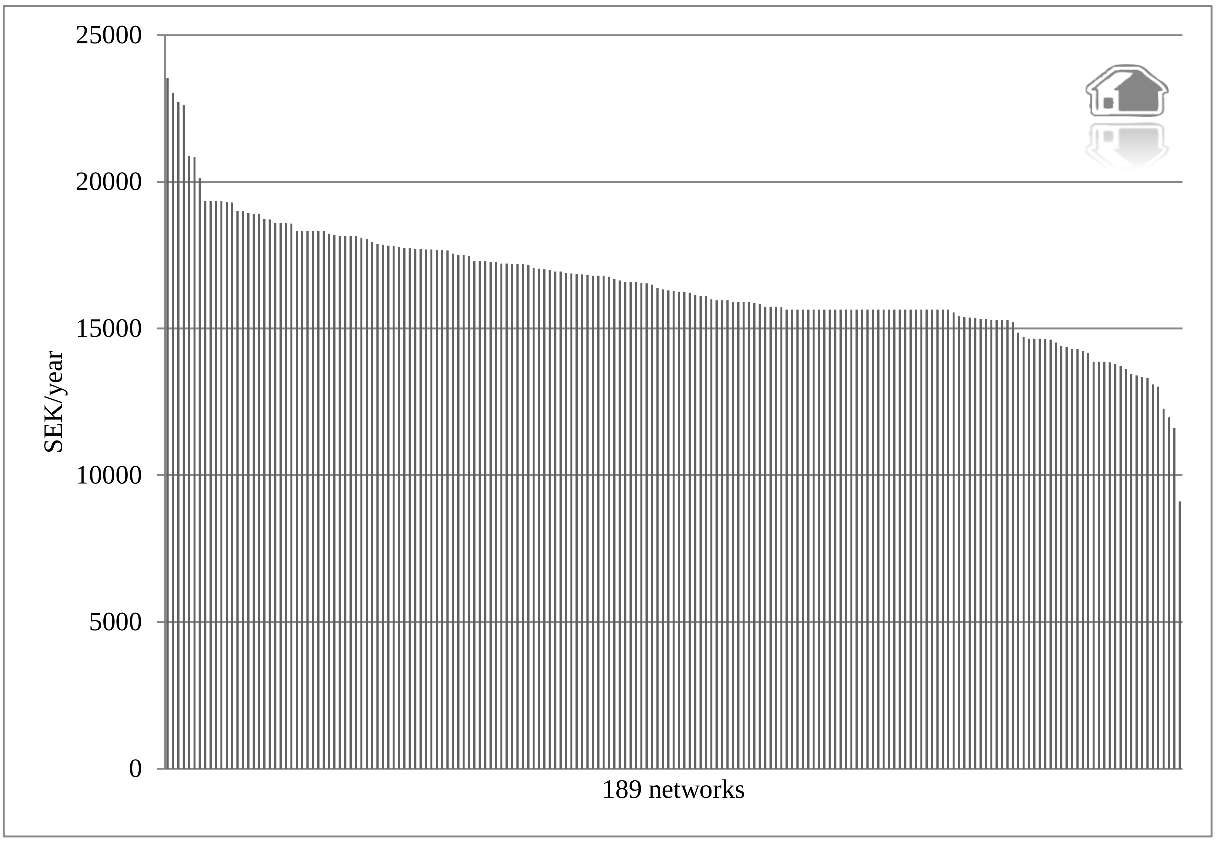

Figure 4.5 Annual DH costs faced by the typical Swedish one/ two family house consuming 20 MWh of heat annually in the 189 networks investigated. The costs range from 9110 to 23552 SEK with an average of 16574 SEK (2011 prices). The average price per kilowatt hour is 0.83 SEK.

Energy conservation measures

Figures 4.6 and 4.7 below show the calculated cost reduction for the one/ two family house after implementing the energy conservation measures in the DH networks with the highest and lowest cost reductions to visualize the range of the cost reductions respectively. The average cost reduction is often proportionally smaller than the annual energy savings since a fixed price component is frequently applied in the pricing models. In no cases are the cost reductions larger than the energy use reductions for the low flush water taps measure. Seasonal pricing also reduce the cost reduction for this measure, since a proportionally smaller part of the energy use is reduced during the peak load periods. A common factor among the companies in which the energy conservation measures lead to low annual cost reductions are high fixed price components. The ten networks with the lowest total cost reduction from the low flush taps and improved insulation measures have average fixed costs of around 6300 and 6500 SEK/year respectively, corresponding to about 40 % of the total cost. The overall average fixed price is around 3500 SEK/year.

Only in four cases does the 10 % energy reduction lead to a cost reduction larger than 10 %. Three of these DH networks are operated by Skellefteå Kraft AB which uses a pricing model with a subscribed capacity based on the consumption from December to February. Since the winter consumption determines the subscribed capacity, the improved insulation measure will have a larger impact on the cost reduction. Sala-Heby Energi AB uses a pricing model consisting of an energy price with a summer and winter differentiation. In the case of Sala-Heby Energi AB, the relatively larger energy use reduction in the colder months combined with a higher winter price leads to such cost reduction (10.1 %), which in terms of promoting implementation of energy conservation measures aiming at capacity reduction can be regarded as advantageous. In the case of Skellefteå Kraft AB there is no seasonal differentiation of the energy price. Instead, a capacity cost determined only by the January and February energy use leads to the improved insulation measure yielding a 10.3 % annual cost reduction.

Generally the annual cost will not be reduced as much as the energy demand, since a fixed price component is applied in most cases. Whether the energy conservation is economically feasible depends on the local DH prices, which vary substantially, as well as the costs of the actual measure. This in turn depends on the current status of the building as well as the cost of capital. For further reading, see Fastighetsägarna (2009).

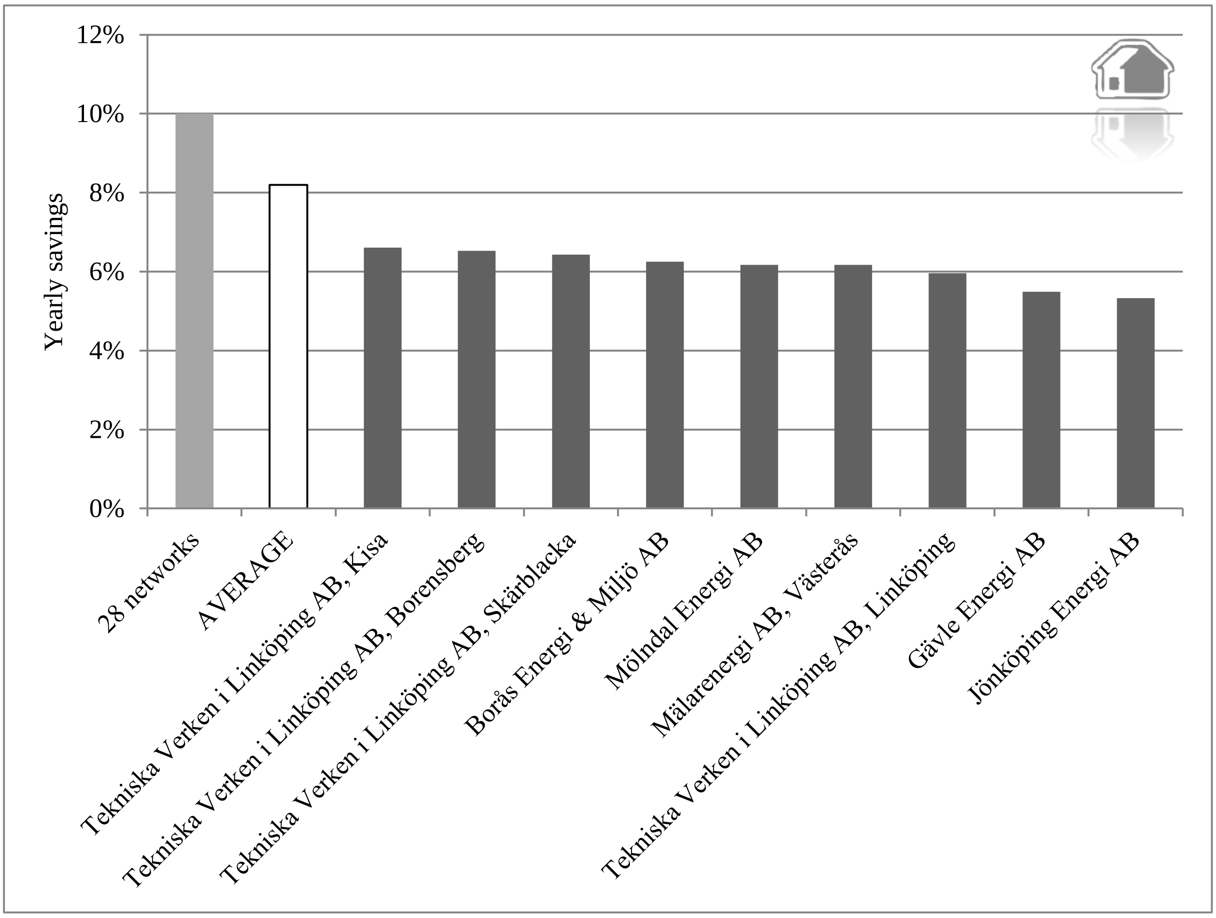

Figure 4.6 Annual savings for the one / two family house after a switch to low flush water taps. In 28 of the 189 networks, the cost reduction is equal to the energy reduction. The average cost reduction is 8.2 % as indicated by the white bar. The nine networks with the smallest cost decreases all have a cost reduction of less than 7 % and show the range of the cost reductions.

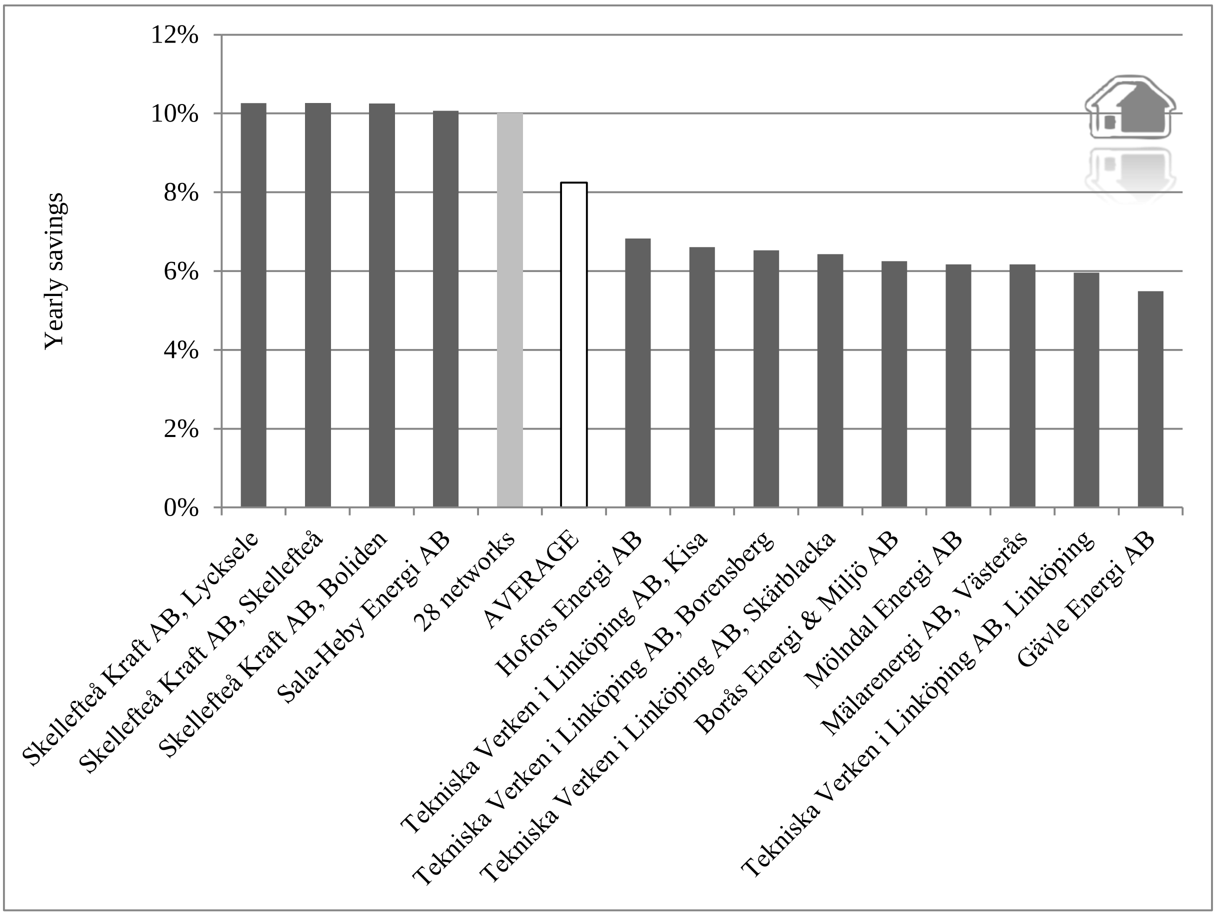

Figure 4.7 Annual savings after the implementation of improved insulation of windows and doors measure. Only four networks have pricing models which give cost reductions larger than 10 %. The average reduction is 8.2 %. In 28 networks, the savings are exactly 10 %.

4.2 Apartment building

Survey

In the apartment building category, the number of different pricing models currently in use is higher than in the one/ two family house category. The subscribed capacity is in some cases determined by measurement on a daily or hourly basis. The number of DH networks in which the different price components are applied are shown in Figure 4.8. However, the combinations of the price component which constitute the pricing model cannot be distinguished in this figure; only the presence of the components. The most frequently used pricing model consists of a fixed cost, a uniform energy price (no seasonal distinction) and a capacity cost based on a category number. The distribution of the use of other pricing models is displayed in Figure 4.9 below. As many as 27 different combinations of the price components are used. In a majority of the networks, 111 of the 189 networks, the pricing models differ for customers that only use the DH for part load in the case of the apartment building. Table 4.2 shows the presence and average values for the price components used in the apartment building category. In the apartment building category an environmentally friendly price is offered in 9 of the 189 networks, or about 5 %.

The total annual energy consumption determines the subscribed capacity in 77 of 123 cases (corresponding to 63 %) in which the capacity is based on a category number, When including the size of DH deliveries 68 % of the category number based capacity is determined by annual energy consumption. Overall, between 60 and 70 % of the category number-based capacity price can be seen as directly proportional to annual energy use.

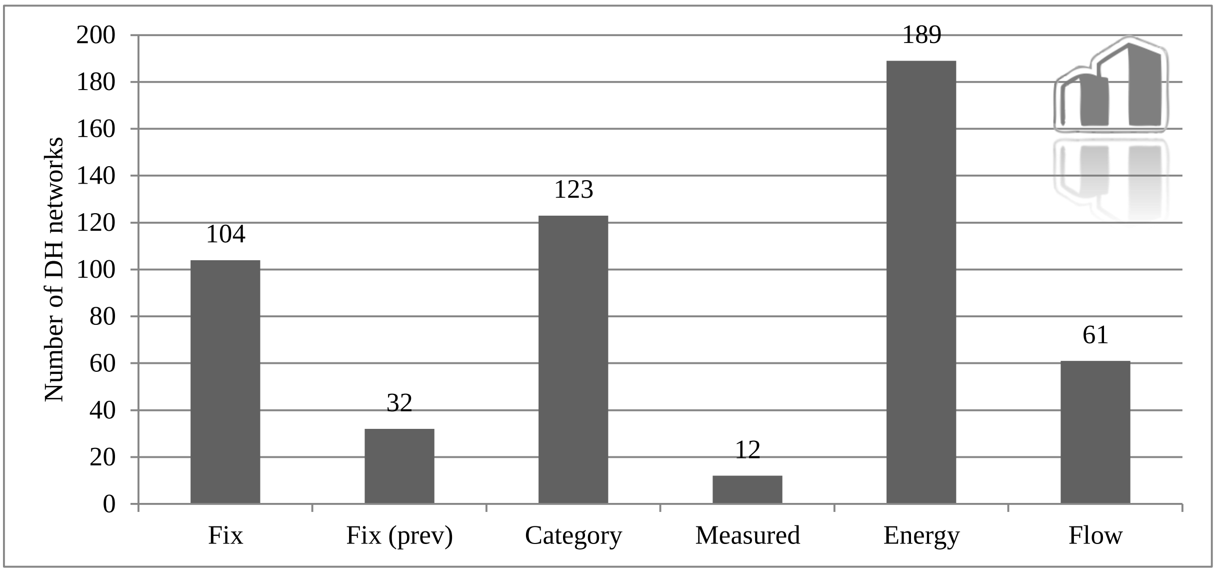

Figure 4.8 Number of DH networks in which the different price components are applied for the apartment building.

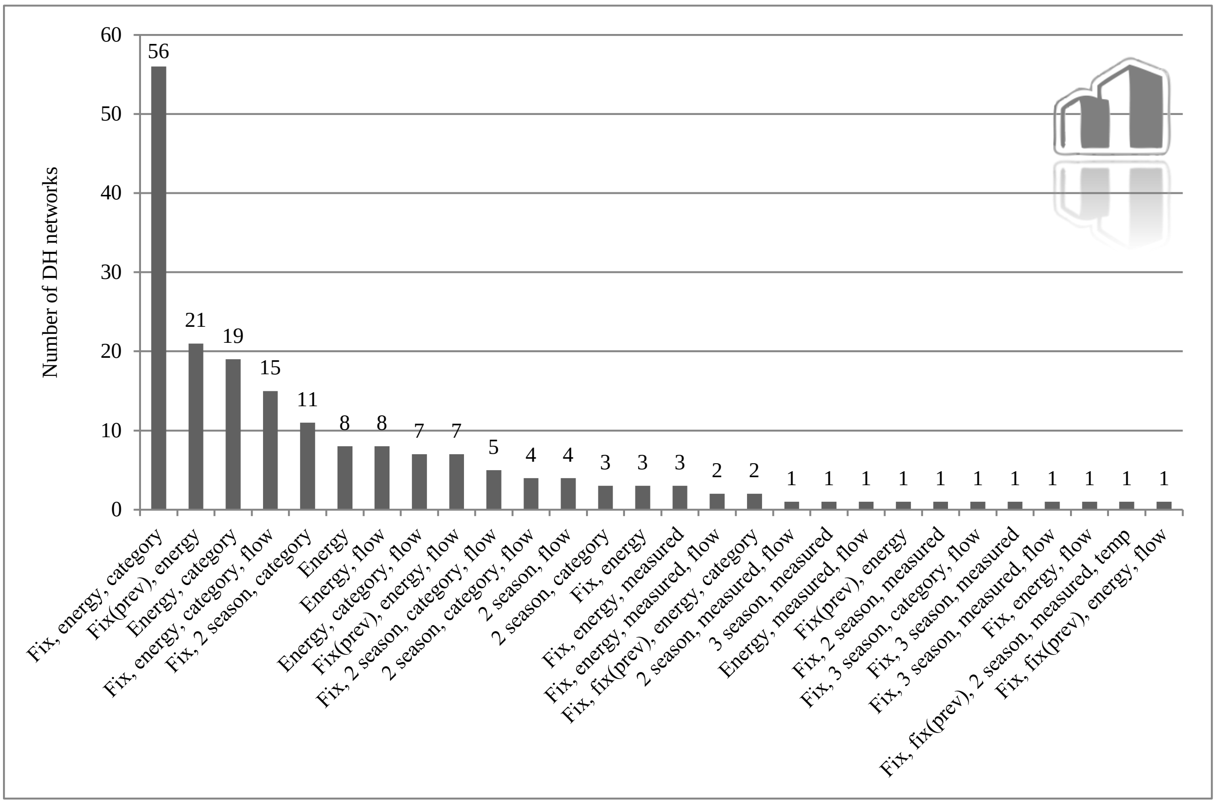

Figure 4.9 Distribution of the different pricing models for the apartment building category in the 189 examined DH networks.

Table 4.2 Average values for the price components in the apartment building category. The presented average seasonal prices only include the companies that apply a seasonal distinction.

Price component	Networks	Percentage	Average value	Unit
Fixed cost	104	55 %	4307	SEK
Fixed cost (based on previous consumption)	32	15 %	0.31	SEK/kWh
Energy cost	189	100 %	0.54	SEK/kWh
Summer price	34	18 %	0.33	SEK/kWh
Spring/autumn price	4	2 %	0.38	SEK/kWh
Winter price	34	18 %	0.60	SEK/kWh
Capacity cost (based on category number)	123	66 %	731	SEK/kW
Capacity cost (based on measurement)	12	6 %	740	SEK/kW
Flow price	61	30 %	2.1	SEK/m^3

Analysis

The calculated energy reductions from the two types of energy conservation measures can be seen in Figure 4.10. As the graphs indicate, the monthly distribution of the energy reductions differs even though the total annual energy use is the same. This leads to a variation in the cost reduction depending on the pricing models of the surveyed companies.

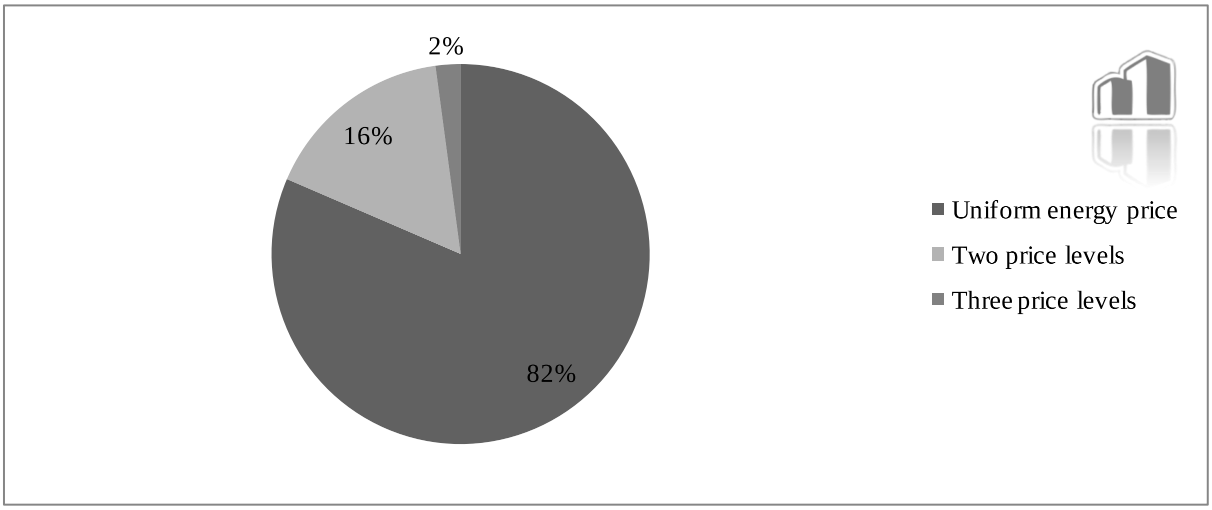

Figure 4.10 Seasonal variation of the energy price based on the number of DH networks in which it is used for the apartment building.

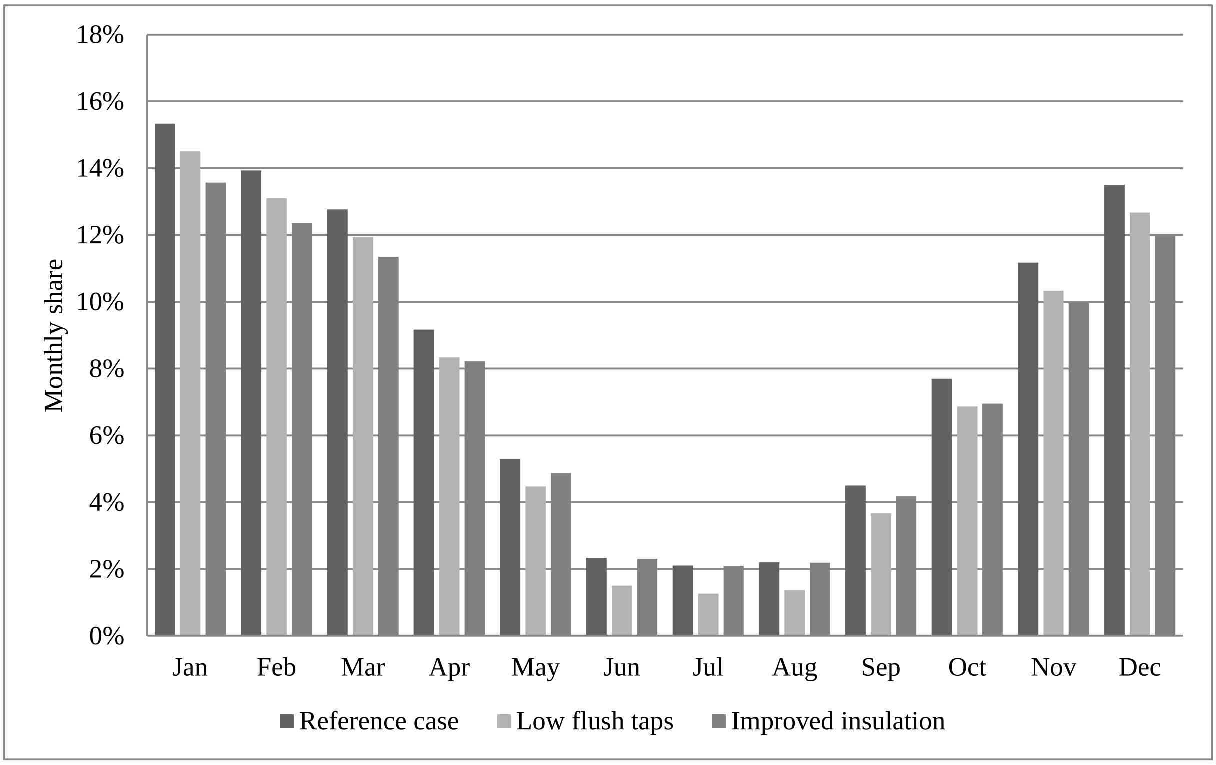

Figure 4.11 Calculated monthly DH use for the apartment building in the reference case and after the two energy conservation measures. The improved insulation measure provides the lowest monthly values in the peak load periods, while the low flush taps measure has the lowest values in the summer.

All surveyed DH networks apply pricing models in which the energy use is charged. A uniform price per heat unit (SEK/MWh) throughout the year is most common, but the use of two or three price levels also exist. Seasonal differentiation of the energy price can be a simple method of promoting energy conservation in peak load periods, as the highest priced part of the energy use is reduced. This is turn reduces the costs for the DH utility if it limits the need for expensive peak load production. There is clearly potential for expanded use of differentiation of the energy cost. On the other hand, it might increase the complexity of the pricing model. For the apartment building category, the distribution of the number of energy price levels can be seen in Figure 4.10 above.

The part of the year during which the different seasonal prices apply varies significantly. Karlstads Energi AB charges the winter price from September to April which leads to about 90 % of the delivered heat being charged with the higher price using the assumed consumption pattern described in Figure 4.11. Sala-Heby Energi AB only charge the winter price from December to February, which gives about a 40 % share of the total energy sold to the winter price. This implies that seemingly equal seasonal energy prices must be assessed in combination with the share of the year during which they are charged. The shares can be seen in Figure 4.12 below. On average, close to 80 % of the energy is charged with the winter price by the companies using a summer/ winter price differentiation. The share of the energy charged at the winter price for the companies that utilize a summer/ winter energy price is about 75 %.

When it comes to the capacity price, the situation is the opposite. There is generally little difference in price for the category number based capacity costs and those based on measurement. There is again a large difference between the companies, with price ranges from 125 to 2190 SEK/kW for the category number based prices, and 279 to 1138 SEK/kW for the capacity costs based on actual measurement, which can be seen in Figure 4.13 below.

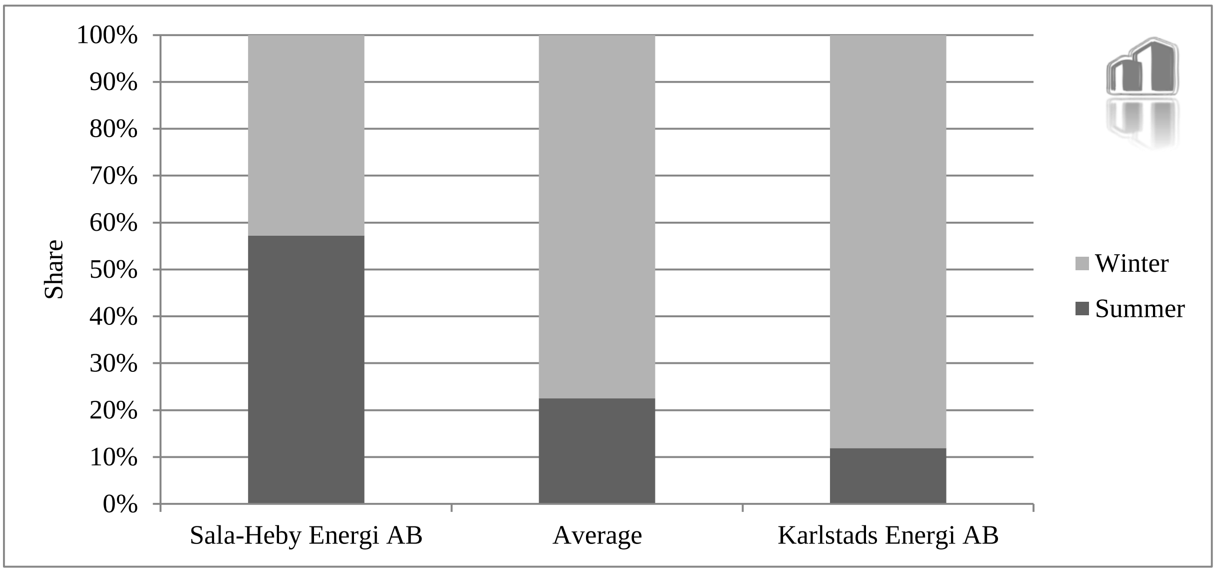

Figure 4.12 The summer and winter shares of the energy costs, based on the months during which they are applied. Sala-Heby Energi AB charges close to 60 % of the sold energy throughout the year according to the winter price table. It should be pointed out that the relative difference in the summer and winter prices can be very different and is only 3.4 % in the case of Sala-Heby Energi AB.

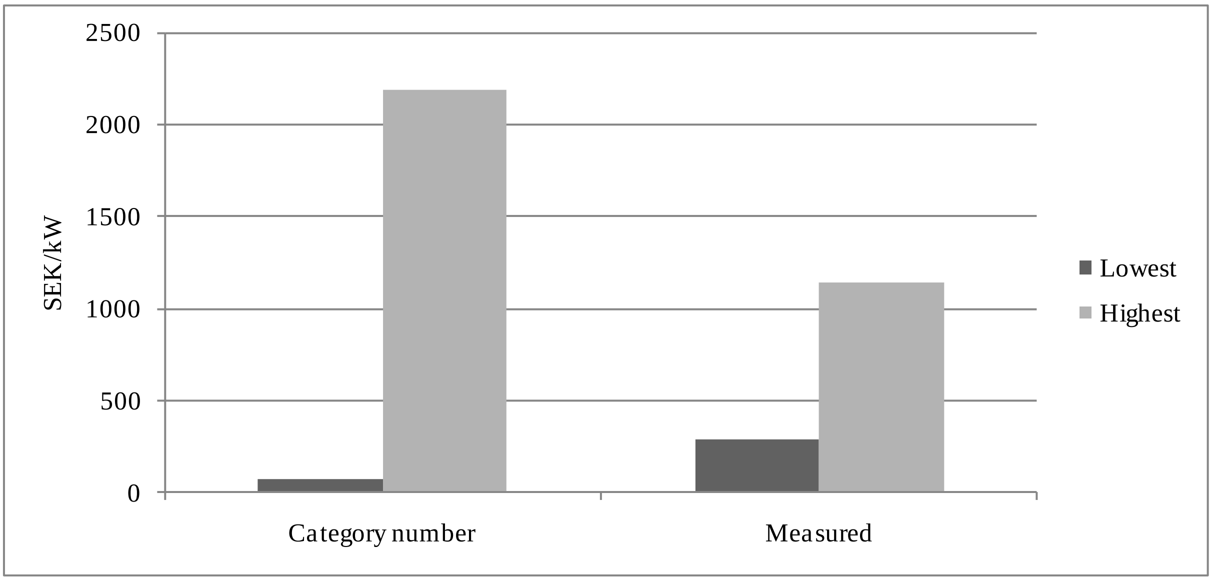

Figure 4.13 Price ranges for the applied capacity cost. The left bars show the lowest and highest prices of the category based capacity and the bars to the right when it is based on actual measurement. As the bars indicate, the capacity prices of certain companies are several times higher than others. Different methods of calculating the subscribed capacity does however counter this.

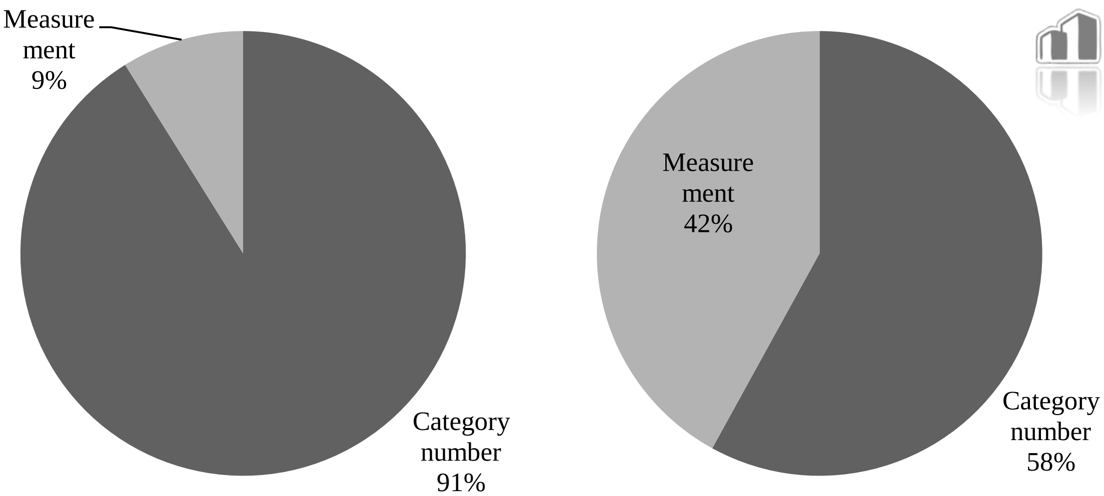

Figure 4.14 Distribution of the use of the two methods of determining the subscribed capacity for apartment buildings based on number of networks (left) and weighted against delivered heat (right). As indicated, the use of actual measurement is more frequent in larger networks.

The distribution of the methods for determining the subscribed capacity can be seen in Figure 4.14 above. The category number method is applied in the majority of the DH networks, but as the weighed figure shows, actual measurement is more common in larger DH networks.

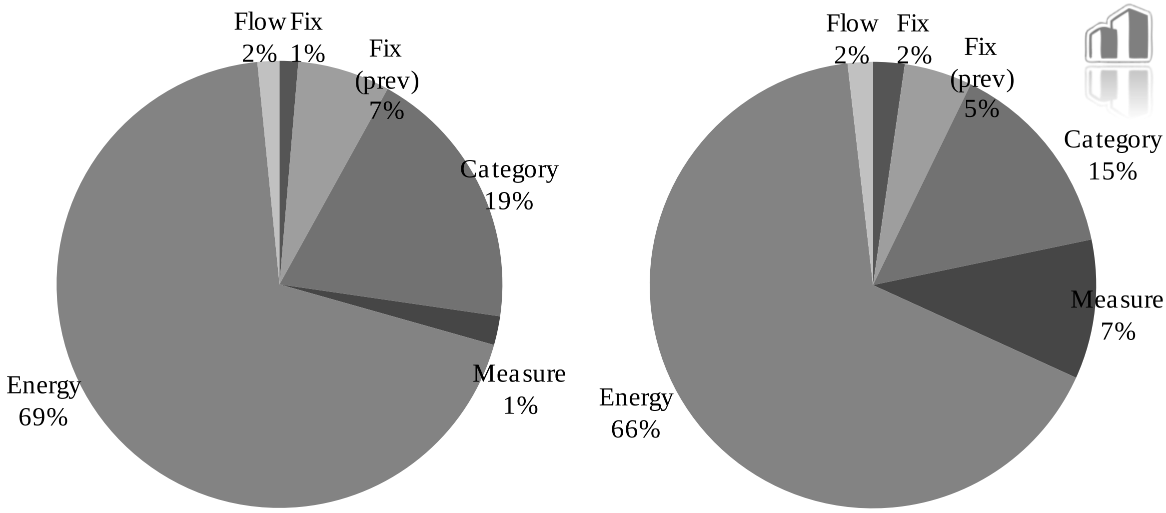

Figure 4.15 Average shares of the price components applied to set a DH price for the apartment building category with all networks weighted equally (left) and weighted against the size of the total DH deliveries of each network (right). The "Energy", "Fix (prev)" and "Flow" components are all directly proportional to the annual energy use. The capacity calculated using the category number method, called "Category" in the figure, is sometimes based on the consumption of an entire year and in other cases not.

Figure 4.15 above indicates that more than 90 % of the cost is directly proportional to energy use in the average network, assuming that 65 % of the "Category" share is based on annual energy consumption. The fixed cost and the capacity cost based on measurement are to some extent independent of energy use. The category number based capacity and fixed cost based on previous years consumption are proportional to the energy use, but with a "lag" of one or more years. The figure also shows the share of the price components weighted against the total heat deliveries in the DH networks. Large networks therefore have a higher impact. As seen in Figure 4.15, the use of measured capacity is more common in the larger DH networks. The average fixed cost component tends to be larger in larger DH networks, making about 85 % of the total costs directly proportional to annual energy use. Thus, there might be a tendency that energy conservation measures in general are less favored in the larger networks. The difference should, however, not be overstated, since a strong correlation between total cost and annual energy consumption remains.

Energy conservation measures

When analyzing the results from the estimated implementation of the two energy conservation measures it is obvious that the savings are strongly correlated to the absolute reduction in energy use. This can be explained by the fact that the total cost is dominated by variable energy costs, especially for the apartment building category. The calculated cost reductions are presented in Figures 4.16 and 4.17 below. Of the 30 networks with the *least* relative cost savings from the low flush taps measure, 25 have seasonal differentiation of the prices. The relative energy savings per month are highest during the summer, since hot water is then the dominating use of DH.

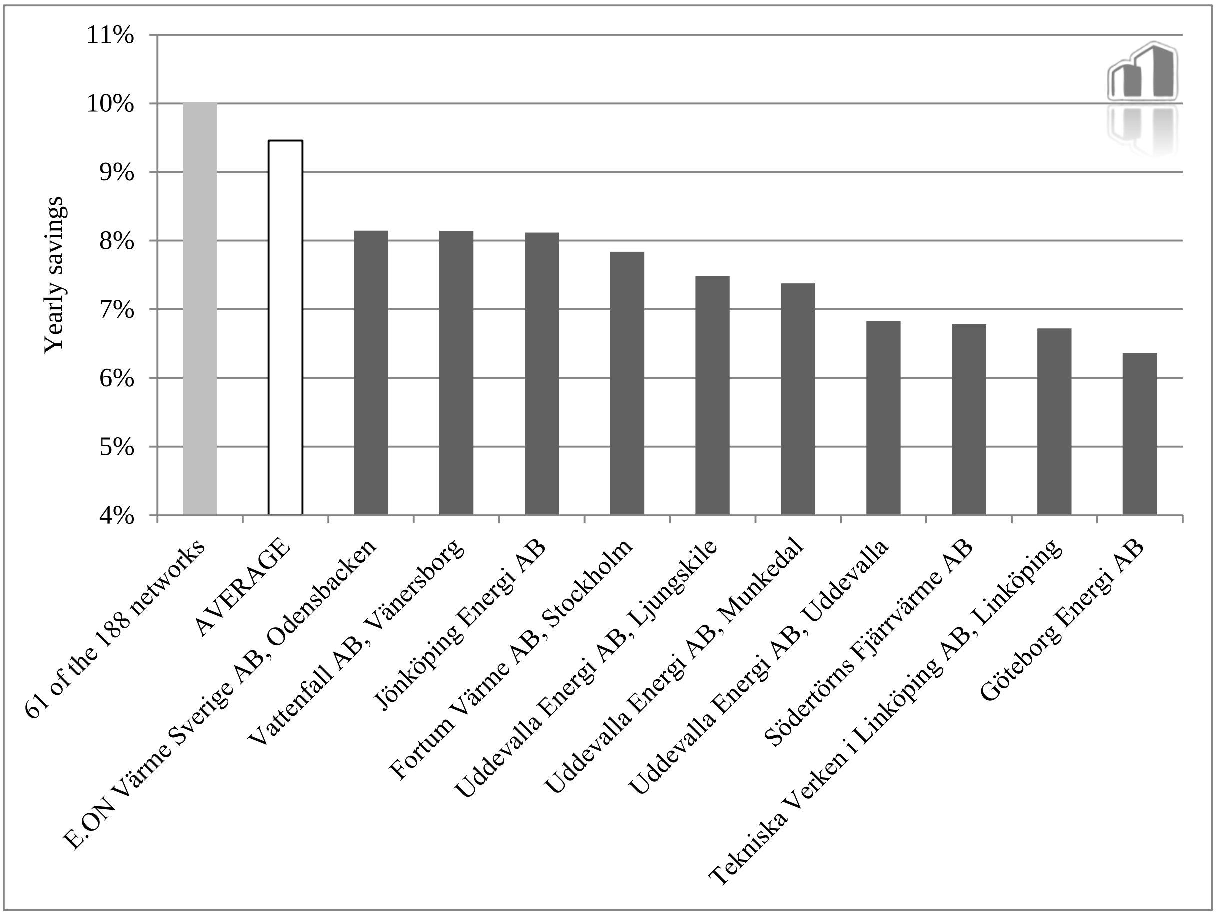

Figure 4.16 Annual estimated savings after implementation of a switch to low flush water taps for the apartment building category. In 61 of the 189 DH networks, the cost reduction is equal to the annual energy reduction. The average estimated cost reduction is 9.5 % as indicated by the white bar. In the seven companies where the percentual savings are smallest, capacity is based on measurement. Seasonal energy prices are also common in the pricing models of these companies.

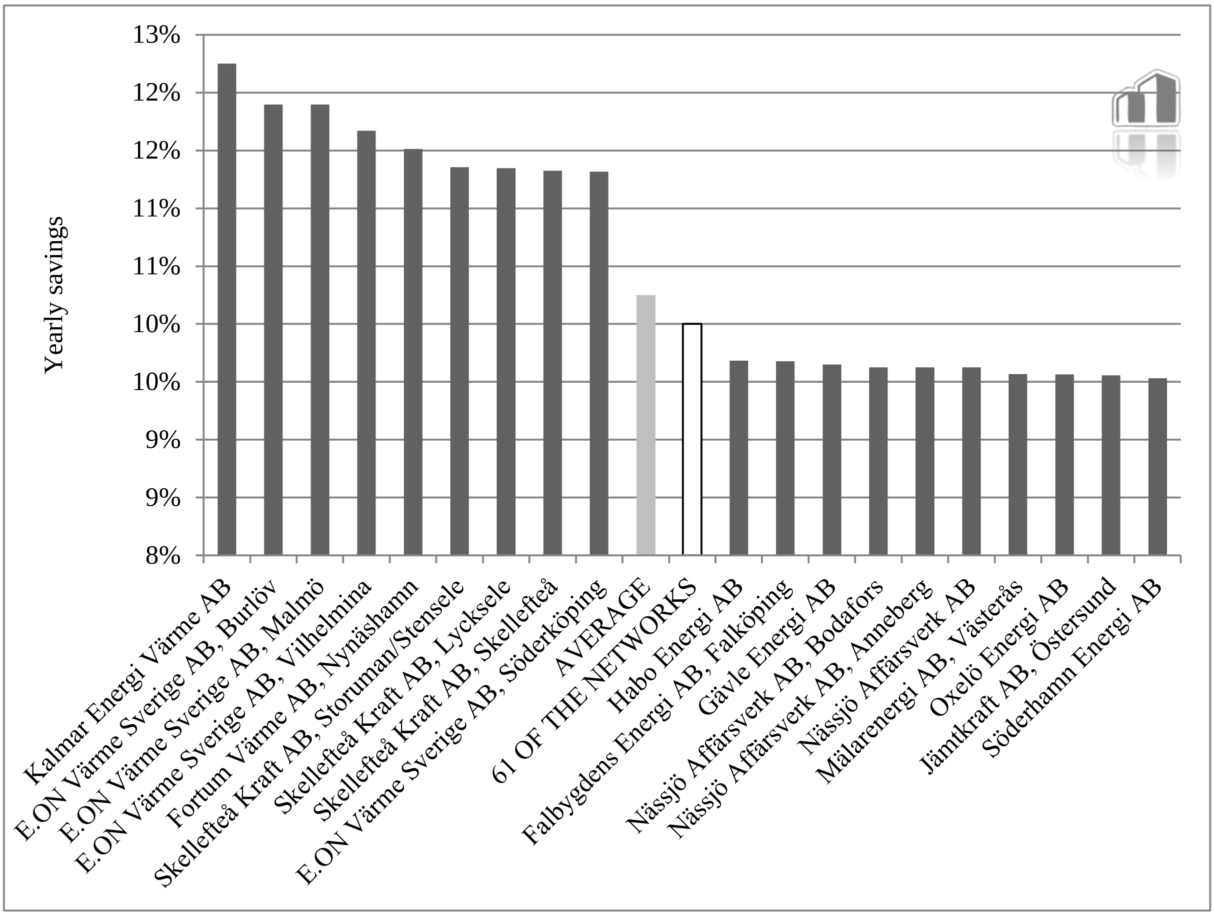

Figure 4.17 Annual estimated relative cost savings after the improved insulation of windows and doors measure. The average estimated cost reduction based on all 189 DH networks is 10.3 %.

Table 4.3 Share of the cost reduction in the 189 networks for the improved insulation measure.

Annual cost reduction	Number of networks	Share of the networks
More than 10 %	67	35 %
Exactly 10 %	61	32 %
Less than 10 %	61	32 %

For the second analyzed energy conservation measure, improved insulation of windows and doors, the average cost reduction is 10.3 % for the apartment building category. This is somewhat higher than the energy use reduction despite the fact that a fixed price component generally is applied. In 67 DH networks the cost reduction is larger than the corresponding reduction in energy use. The distribution of the cost reduction can be seen in Table 4.3 above. This may suggest that in almost two thirds of the networks, energy conservation measures aimed specifically at reducing peak load demand cannot be seen as encouraged.

All of the 40 networks where the relative cost reduction per year is highest have a capacity cost based on category number *and a few winter months* (the most common being January and February) or, in one case, measured capacity. Capacity costs are therefore clearly an efficient way of promoting peak load demand reductions.

Seasonal differentiation of the energy price is applied in six of the 40 networks with the highest relative cost reductions, corresponding to 15 %. Of the DH networks in the survey, seasonal differentiation of the energy price is applied in 18 %. This indicates little correlation between seasonal differentiation and pricing models that provide incentive for peak load reduction.

The total cost of DH for the apartment building in the 189 DH networks are seen in Figure 4.18 below. Since the correlation between annual cost and annual energy consumption is strong, the high-cost companies give much stronger incentive for energy conservation in absolute terms (SEK). Thus, not only the pricing model but also total annual cost of DH determines whether an energy conservation measure is cost-efficient or not. It does however also depend on factors such as the cost of the measure, the price of alternative heating methods and the cost of capital and is not examined in this study.

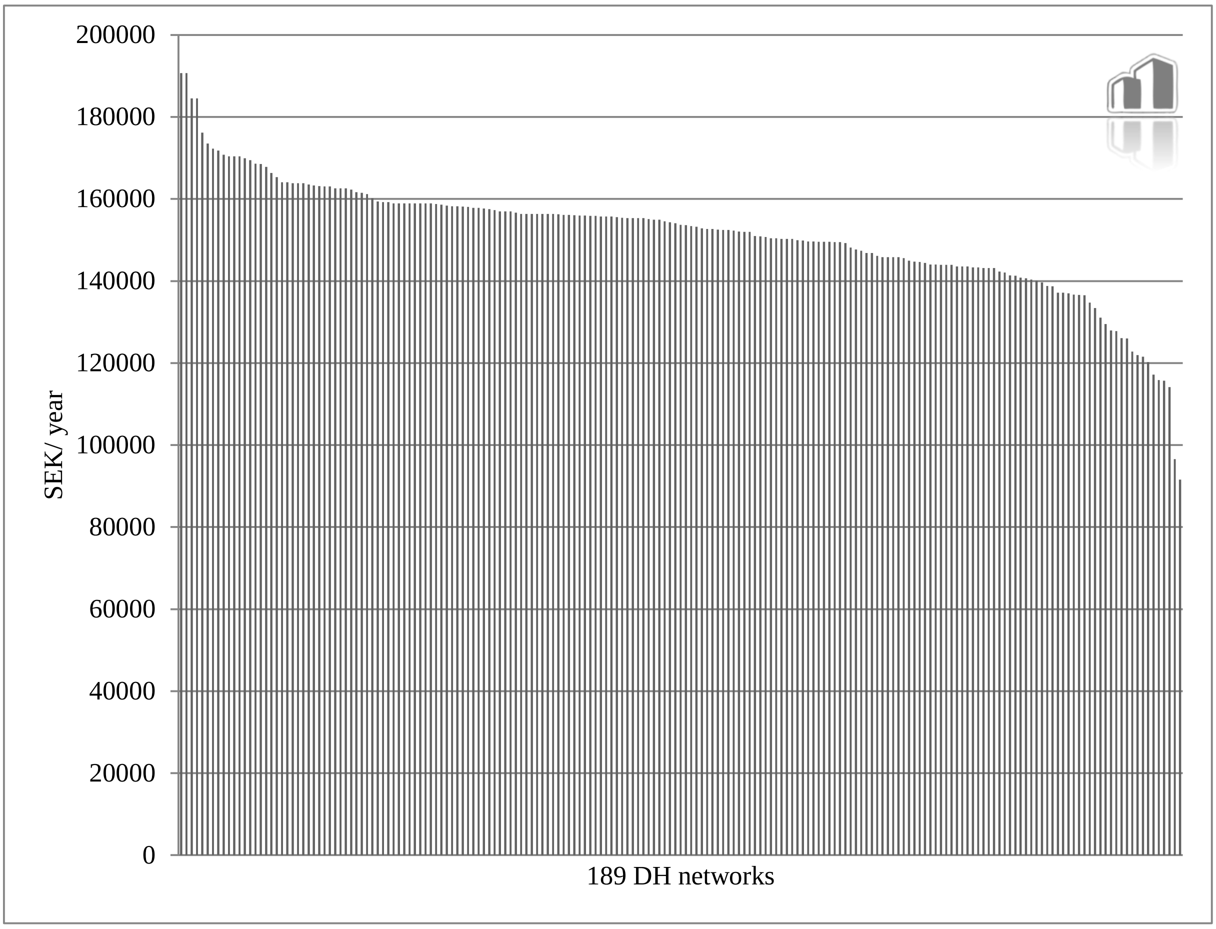

Figure 4.18 Calculated total annual costs for the reference apartment building in the 189 surveyed DH networks.

4.3 Comparison of building categories and pricing models

A comparison of the rates of each price component for the two analyzed building types shows that the average energy cost is somewhat higher for the one/ two family building while the apartment building has a higher capacity cost, as indicated by Figures 4.3 and 4.15. The fully fixed cost for the apartment building is higher in absolute terms, but much lower compared to the size of the building (on average 18 SEK/MWh for the apartment building and 175 SEK/MWh for the one/ two family house) . The average prices can be seen in Figure 4.19 below.

The results of the two energy conservation measures differ between the two building types, as seen in tables 4.4 and 4.5 below. The higher share of fixed costs for the one/ two family house implies a decreased incentive for energy conservation measures. For both building types the improved insulation measure reduces the average annual cost more than the switch to low flush taps, which implies that a certain encouragement for peak load reduction does exist. As previously mentioned, the actual costs of performing the measures are not considered and lie outside the scope of this study. Therefore, no conclusions are drawn about the pay back periods for the measures.

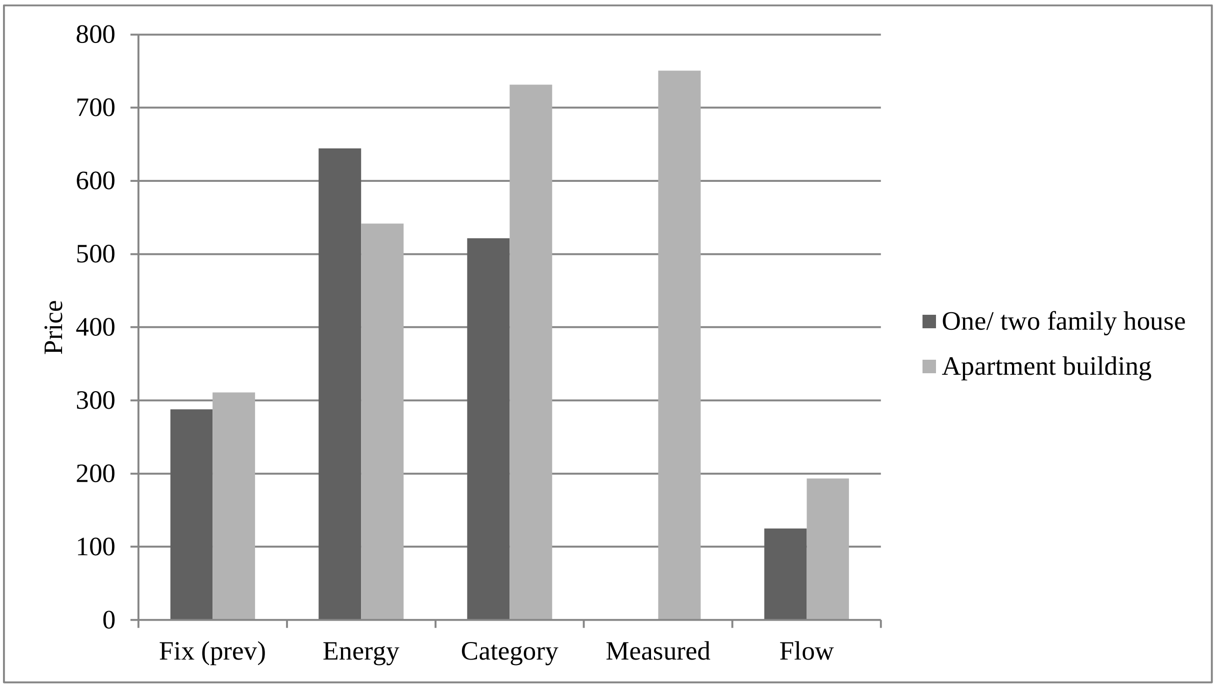

*Figure 4.19 Comparison of the price components for the two building types. The "Fix (prev)" and the "Energy" cost is in SEK/MWh, "Category" and "Measured" capacity in SEK/kW and the "Flow" is in 100 * SEK/m^3.*

Table 4.4 Calculated/estimated reductions in annual cost for the two building types after a switch to low flush water taps. The extreme values in terms of SEK and percentage change among the companies are presented, thus the cost reduction in percentage does not necessarily correspond to the same company as the reduction in SEK. Instead, the extreme values both in terms of SEK/MWh and percentage are presented.

Building category	Cost reduction [SEK/MWh]	%
Apartment building, average	**74**	**9.5**
Highest	99	10
Lowest	47	6.4
One/ two family house, average	**68**	**8.2**
Highest	107	10
Lowest	40	5.3

Table 4.5 Reductions in annual cost for the two building types after improved window and door insulation. The extreme values in terms of SEK and percentage change among the companies are presented as in Table 4.5.

Building category	Cost reduction [SEK/MWh]	%
Apartment building, average	**80**	**10.3**
Highest	101	12.3
Lowest	47	9.5
One/ two family house, average	**68**	**8.2**
Highest	107	10.3
Lowest	40	5.5

The average cost reductions in the DH networks where seasonal pricing and measurement of capacity is used can be seen in Table 4.6 below. The cost reduction for the improved insulation measure is on average greater in the DH networks where a seasonal price with three levels is used, but the difference is marginal. For the one/ two family house, the savings are larger in the DH networks where a summer/ winter price differentiation is used. There is however only one DH network where three price levels are used for this building category. In general, the companies using seasonal prices provide stronger incentive for the peak demand reducing measure.

Table 4.6 Calculated average annual cost reductions in the DH networks with seasonal prices and capacity price.

	Improved insulation		Low flush taps	
	Apartment	One/ two family	Apartment	One/ two family
Seasonal	10.4 %	9.0 %	8.5 %	8.0 %
• **2 season**	10.3 %	9.2 %	8.7 %	8.5 %
• **3 season**	10.6 %	8.1 %	7.1 %	5.3 %
Category number	10.4 %	9.3 %	9.4 %	9.2 %
Category number, part of year	11.1 %	10.3 %	9.1 %	9.2 %
Measurement	10.3 %	-	7.7 %	-

Table 4.7 Calculated average annual cost reductions in the five DH networks with the highest fixed costs.

	Improved insulation		Low flush taps	
	Apartment	One/ two family	Apartment	One/ two family
Average	10.1 %	6.2 %	7.6 %	6.2 %

For the one/ two family house the five DH networks with the highest fixed cost the annual cost reduction is only little more than 6 % for any of the measures, although energy consumption is reduced by 10 %, as seen in Table 4.7 above. For the apartment building, the annual savings are higher as seen in the table. This can to some extent be explained by the lower fixed share of the costs. The average annual cost reductions for the different pricing models can be seen in Tables 4.9 and 4.10 below. High fixed costs can be assumed to provide little incentive for any energy conservation measure.

Table 4.8 Average annual cost reductions for the different pricing models used in the one/ two family house category.

Pricing model, One/ two family house	Number of DH networks	Low flush taps [%]	Improved insulation [%]
Fix & energy	136	7.7	7.7
Energy	20	10	10
Fix, energy & category	14	8.9	8.9
Energy & category	7	9.7	10.1
Fix (prev) & energy	3	10	10
Fix & 2 season	2	7.4	8.5
Fix, 2 season & category	2	9.0	9.5
Fix & 3 season	1	5.3	8.1
Energy, category & flow	1	10	10
Fix, fix (prev) & energy	1	9.6	9.6
Fix, energy & flow	1	9.2	9.2
2 season	1	9.8	10.1

As seen in Tables 4.8 and 4.9, many of the pricing models give no extra incentive for energy conservation measures focusing on reductions of peak load. Instead, they provide the same cost reductions regardless of when the energy need is reduced. Both the second and third most commonly used pricing models are in most cases entirely dependent on energy use. The exception is when the category number method is used for a few winter months (used by Skellefteå Kraft AB).

A few pricing models do, however, provide clear incentives for peak load reduction. An obvious one is the “3 season & measured” (that is, an energy price with three levels and measurement of capacity) used by Södertörns Fjärrvärme for the apartment building customers. The annual cost reduction from the improved insulation measure is nearly twice that of the switch to low flush water taps, as seen in Table 4.10 below. The absence of a fixed price component combined with a higher energy price at periods of peak loads as well as actual measurement of maximal capacity need are the reasons for this. For a company which wishes to lower the peak load capacity demand a pricing model like this might be suitable. The largest cost reduction, 12.3 %, is achieved with Kalmar Energi Värme AB for the apartment building customer. The pricing model consists of a category number based capacity cost, using the energy consumption of January and February, as well as a uniform energy price. The capacity price is however high and the energy price low, which means that a large reduction of energy use in January and February leads to a drastic decrease in the total cost. The example clearly shows that not only the pricing model, but also the actual price rates applied are important for deciding whether a certain consumer behavior is encouraged or not.

With the assumptions and calculation methods used in this study, many of the price components are interchangeable and yield the exact same result. This is to some extent due to simplifications such as the energy use being assumed to be constant from one year to the next. It must however be stressed that for example the fixed cost based on previous years' consumption ("Fixed (prev)") might provide some stability in terms of income for the DH utility, since it is already decided for the present year. The same argument is valid for the capacity based on category number, since it is also based on the consumption of one or more previous years. A pricing model based solely on the energy use of the present year might be fair and easily understood but somewhat risky from the DH utility point of view.

The category number based capacity (when based on the consumption of an entire year) and the fixed cost based on previous years' consumption generally have the same result, even though they are described as two different components. A business agreement to decide on using one of them but not the other could be a way of reducing the complexity of the pricing models used in the business.

Finally, the total cost per unit of energy is somewhat higher for the one/ two family house. The differences between individual DH networks is however much larger than the differences between different categories of customers.

Table 4.9 Average cost reductions for the pricing models used for the apartment building.

Pricing model, Apartment building	Number of DH networks	Low flush taps [%]	Improved insulation [%]
Fix, energy & category	56	9.5	10.4
Fix (prev) & energy	21	10	10
Energy & category	19	10.5	9.7
Fix, energy, category & flow	15	9.7	10.0
Fix, 2 season & category	11	8.8	10.0
Energy	8	10	10
Energy & flow	8	10	10
Energy, category & flow	7	9.7	10.7
Fix (prev), energy & flow	7	10	10
Fix, 2 season, category & flow	5	8.6	10.5
2 season, category & flow	4	9.0	10.9
2 season & flow	4	8.8	10.4
2 season & category	3	8.9	10.4
Fix & energy	3	9.8	9.8
Fix, energy & measured	3	7.9	9.9
Fix, energy, measured & flow	2	8.7	9.9
Fix, fix (prev), energy & category	2	9.8	9.8
2 season, measured & flow	1	8.1	10.6
3 season & measured	1	6.7	11.1
Energy, measured & flow	1	9.0	10.4
Fix (prev) & energy	1	10	10
Fix, 2 season & measured	1	6.8	10.1
Fix, 3 season, category & flow	1	8.7	10.1
Fix, 3 season & measured	1	6.4	10.3
Fix, 3 season, measured & flow	1	6.7	11.0
Fix, energy & flow	1	9.9	9.9
Fix, fix (prev), 2 season, measured & temp	1	7.8	10.4
Fix, fix (prev), energy & flow	1	10.0	10.0

5 Discussion

The customer's district heating costs are to a high degree depending on the *annual* energy consumption of the customer. The short term marginal production costs for the DH utilities however are related to the total capacity demand at a specific point in time. Obviously, with a fully functioning and deregulated market the price paid by consumers should be kept in balance with the supply, and thus, reflect the marginal production cost for all instants within the chargeable time period weighted by consumption. For example, at peak loads more expensive production units are utilized, but the energy cost for the customers is generally unaffected by this in the present DH market. This in turn implies a mismatch between the price the customers pay and the actual costs of the district heating companies due to the inherent inertia of some of the price components (common in the current pricing models such as fixed cost based on the consumption of previous years) that are energy dependent but with a certain "lag" (usually one to three years). This can provide the DH utilities with a certain level of security in terms of payment, yet in the long run it is possible that a large reduction in energy use could lead to a difficult situation for the district heating companies if the peak load is not reduced to the same extent.

Many of the production facilities have large investment costs which need to be paid regardless of the energy production. There are large differences in how the pricing models are able to maintain revenues when such changes in energy use occur. The general trend is a shift towards actual measurement of capacity (Fastighetsägarna, 2009). This is something that could assist a transition to a less energy demanding housing sector. There is however limited understanding among customers that the costs of the district heating companies is not directly related to the annual energy use. Information campaigns of some sort might be necessary. Increased costs for CO_2 emissions might further increase the peak load costs, since a proportionally larger part of the fossil fuels are used to match the peaks in demand.

The large difference in actual savings from performing the energy conservation measures described in chapter 3 can be viewed from two perspectives. On one hand, the lower prices of certain companies, in particular many in northern Sweden are beneficial for the customers. On the other hand, assuming the same cost for the energy conservation measures, the payback time is up to three times longer in some DH networks. This might be a limiting factor in the switch to a less energy demanding society since heating of buildings is a large part of the energy use, about 75 TWh in 2008 (Energimyndigheten, 2009). The total final energy use was 376 TWh is 2009 (Energimyndigheten, 2010). When it comes to the cost reduction, there is a strong connection to the decrease in annual energy use, as previously stated. The main priority of the district heating companies might however be to decrease the peak load. In order to achieve that pricing models based on actual capacity is likely to continue to gain ground. There are also examples of other applications being developed that might utilize district heating in order to "even out" the demand by increasing the load over the year or even specifically during the summer. Pool heating, dish washers and washing machines are such examples. The ideal situation for the district heating companies would of course be an even load distribution throughout the year. Better insulation of houses combined with a more varied use of district heat might lead towards that situation, and could theoretically be promoted by the pricing models. It is obviously impossible to achieve a totally even distribution over the year, but the peak load can be reduced and the summer load can be increased.

There might be a conflict between what the DH companies consider to be the optimal pricing model and what the customers prefer. If peak load reduction is desired by the DH utility, a complex pricing model with many components can be effective. The customers can however be assumed to prefer a more simple pricing model, more readily understood. There are examples of companies offering several different pricing options to meet varying customer preferences. In this study a single pricing model per DH network has been analyzed in each DH network in order to limit the complexity of the survey.

If the DH market is deregulated, one or more price components representing the transmission costs might be added. This could provide additional incentive to the companies to limit the number of components in the pricing models to limit the complexity.

The chosen apartment building, the *Nils Holgersson* building, might be another factor affecting the pricing models. It is used for price comparisons on an annual basis and has been so since 1996. Being the sole building type in the comparison it could be tempting for DH companies to choose a price which favors this particular building. The costs for the one / two family house customers in the DH networks where the apartment building prices are the lowest does however not confirm this. The companies with the highest prices in the apartment building category are generally more expensive in the one / two family house category as well, and vice versa. Awareness should however be raised if the *Nils Holgersson* survey continues to be the only relative price comparison performed on a regular basis. In general, the price per unit of energy is somewhat lower for the apartment building. This can to some extent be explained by the fact that the apartment building is larger and thereby offer large-scale benefits. For example, a single heat exchanger usually serves a larger number of customers. Conversion to wood-pellet burner or heat pump might however be easier for the one/ two family house customer who in most cases is the sole decider of the heating system, providing an incentive to the DH utility to keep prices reasonably low. Alternative pricing is frequently mentioned by the DH utilities when describing their pricing models in order to prevent such conversions and the subsequent loss of customers. Partial conversion of the heating system is also a threat to the utilities, since it could lead to customers only requiring DH during the peak load periods and thereby further increasing peak capacity demand.

The actual measurements of capacity can provide incentive for efficient district heating use, but the large variations in methods of deciding the subscribed capacity makes it difficult for any customer to get a clear view on the relative prices of the DH companies. There are examples of companies using the highest measured values, which could be the result of disturbances in the distribution network. Should a failure occur with a consequent temperature drop in the DH water, many customers will be forced to run their DH units on full load to compensate for the heat loss. If this leads to a peak in the measured capacity it could lead to the customers being “punished” for a failure of which the DH utility is to blame. If too many extreme values are disregarded the peak load hours might be missed instead. It is of course impossible to predict the optimal method, since it depends on the technical status of the DH network. In addition, extreme load peaks which are not explained by exceptionally low outdoor temperatures could force an automatic system to alert the DH system operators, and perhaps be used as a way of pinpointing leakages and other failures. This is clearly an area which should be investigated further in order to allow fair and reasonable pricing systems without too much need of human monitoring. Regular measurements of capacity do naturally generate large amounts of data which could be a problem if not properly managed. The benefits of increased possibilities of detecting disturbances of various kinds could however counter-balance this.

Using the same argument, seasonal differentiation of the energy prices can be a cheaper and more easily implemented way of providing incentive for reduced consumption in peak load periods, perhaps as efficient as actual measurement of capacity. The possible benefits in terms of monitoring are however lost. The same is valid for a category number based capacity price, when the consumption of a few peak load months is used. Generally, the energy use in two or three winter months decide the subscribed capacity.

The category numbers used in the DH sector vary quite a lot. The actual capacity cost is however a combination of the category number and the price per kilowatt of subscribed capacity. A company using a high category number (which leads to a low subscribed capacity) can counter this by charging a high capacity price. A low capacity price can in the same way still lead to a high capacity cost, if a low category number is used.

There are also examples of the subscribed capacity being based on the energy use at a certain outdoor temperature. This reference temperature does however vary quite substantially (from -2 °C to -17.6 °C) which naturally results in large differences in the subscribed capacity. Two companies use the highest average values from more than one previous year, which gives a long payback time for energy reduction measures (it only starts to affect the capacity cost after more than one year). Generally, an averaged value is used in order to even out peak values in capacity demand.

The large price differences are highlighted in the *Nils Holgersson* survey. Although somewhat outside of the scope of this study, it is still something that should be noted. The prices in the most expensive DH networks are more than twice as high as in the least expensive ones.

To what extent a reduction in DH use is desirable from an environmental point of view must be seen with the system boundaries in mind. Sweden has a relatively CO_2 free DH production, which can give the impression that there are no environmental benefits associated with a reduced DH consumption. The energy market is however international and therefore both waste and biomass of Swedish origin can be utilized in other countries in order to reduce fossil fuel use. The same argument is of course valid for electricity which is also produced with little CO_2 emissions in Sweden. Another benefit of DH use reduction is the required learning, both technological and in consumer habits. Energy conservation knowledge has the potential of becoming an export industry in which Sweden can take a strong global position. Looking only at Sweden a domestic reduction in electricity use could lead to increased CO_2 emissions if the heat generated by domestic electricity use is replaced by district heating using an average fuel mix of Sweden. This perspective is somewhat narrow since the saved electricity could readily be sold and thus replace fossil fuelled electricity in other countries.

6 Conclusions

The pricing models in the Swedish district heating sector are surveyed and analyzed. Two specified buildings are used for comparisons. In addition, the economic impact of two energy conservation measures is analyzed for the two buildings. The measures analyzed lead to an identical reduction in *annual* energy use, but a different reduction in peak load demand.

There is *a clearly dominating pricing model for each building category*. For the one/ two family house it consists of a fixed cost and a uniform energy cost (that is, no seasonal differentiation). For the apartment building a fixed cost, a uniform energy cost and a capacity cost based on a category number represents the most common pricing model.

There is a large variation in how the pricing models in district heating are constructed. Some companies have simple models consisting of a single price component. Other companies have adopted more complex models in order to reflect the actual costs that are associated with the production and distribution of the district heating water following seasonal variations.

The overall price of district heating is dominated by a variable energy cost, especially for the apartment building customers. For the one/ two family house about 80 % of the cost is directly linked to the energy use. For the apartment building the share is around 85 %.

The *large variation in how the price components are defined* can lead to large differences in actual costs for two companies with seemingly equal prices. The higher winter price is sometimes charged for nearly 90 % of the delivered energy, while in other cases it can be as low as around 40 %. The use of category number as a way of deciding the subscribed capacity has the same drawback. The lowest category numbers leads to subscribed capacities nearly 40 % higher than the highest category number. Obviously, one cannot decide the annual cost by simply looking at the different seasonal prices or the capacity fee. Naturally, the actual price of the capacity can counter this.

For the one/ two family house customer, the problem of complex definitions of the capacity price component is in most cases limited, simply because the most common pricing model consists of a fully fixed part and an energy price without seasonal differentiation. A pricing model of such simplicity does however have drawbacks, too. The costs of the district heating companies are not fully dependent on the energy consumption, but also on the actual capacity demand at peak load hours. *Little incentive is given to the customers to reduce the peak load* in particular. The growing practice of measuring the capacity is a way of countering this.

Pricing models including seasonal pricing, measured capacity or capacity based on winter consumption provide increased incentive for peak load reduction. The analysis in this study suggests that the capacity cost generally has the largest impact as the pricing models are constructed. For the one/ two family house capacity measurement on an hourly or daily basis is not being utilized presently in the pricing models. This makes seasonal pricing and a capacity cost based on winter consumption the only effective ways of promoting peak load capacity reductions for this customer category. The pricing model alone cannot however decide whether strong incentive for a certain consumer behavior is encouraged or not. The price rates of the price components can be equally important.

The larger share of fixed costs for the one/ two family house leads to lower incentives for energy conservation measures in general compared to the apartment building.

Finally, the survey shows that *a large difference in the total price of district heating remains,* due to large differences in the production costs of various fuels, including waste heat as well as the pricing strategies of the DH utilities. This is the case for both the one/ two family house and the apartment building customers.

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Appendix

A. DH Companies and networks

A total of 84 companies are included in the survey (of around 200 in the entire Swedish DH sector). The number of individual DH networks operated by these companies is 189 (of around 400 in Sweden), where some companies run a single network and others up to nearly 40. The following 84 companies and 189 networks are included in the survey:

COMPANIES
AB Borlänge Energi
AB Piteenergi
Affärsverken i Karlskrona AB
Alingsås Energi Nät AB
Arvika Fjärrvärme AB
Bollnäs Energi AB
Borås Energi & Miljö AB
Bromölla Fjärrvärme AB
C4 Energi AB
E.ON Värme Sverige AB
Eskilstuna Energi och Miljö AB
Falbygdens Energi AB
Falu Energi & Vatten AB
Farmarenergi i Ed AB
Filipstad Värme AB
Fortum Värme AB
Gotlands Energi AB
Gävle Energi AB
Göteborg Energi AB
Götene Vatten och Värme AB
Habo Energi AB
Halmstad Energi och Miljö AB
Haparanda Värmeverk AB
Hofors Energi AB
Hällefors Värme AB
Härnösand Energi och Miljö AB
Jämtkraft AB
Jönköping Energi AB

Kalix Fjärrvärme AB
Kalmar Energi Värme AB
Karlshamn Energi AB
Karlstads Energi AB
Katrineholm Energi AB
Kreab Energi AB
Kristinehamns Fjärrvärme AB
Landskrona Energi AB
Lantmännen Agrovärme AB
Laxå Värme AB
Lerum Fjärrvärme AB
LEVA i Lysekil AB
Lilla Edet Fjärrvärme AB
Luleå Energi AB
Lunds Energi AB
Mariestad-Töreboda Energi AB
Mark Kraftvärme AB
Mjölby-Svartådalen Energi AB
Mälarenergi AB
Mölndal Energi AB
Neova AB
Norrenergi AB
Nässjö Affärsverk AB
Oskarshamn Energi AB
Oxelö Energi AB
Rindi Energi AB
Ringsjö Energi AB
Sala-Heby Energi AB
Sandviken Energi AB

Skellefteå Kraft AB
Smedjebacken Energi AB
Sollentuna Energi AB
Sundsvall Energi AB
Säffle Fjärrvärme AB
Sävsjö Energi AB
Söderhamn NÄRA
Södertörns Fjärrvärme AB
Tekniska Verken i Kiruna AB
Tekniska Verken i Linköping AB
Telge Nät AB
Tierps Fjärrvärme AB
Tranås Energi AB
Trelleborgs Fjärrvärme
Trollhättan Energi AB
Uddevalla Energi AB
Ulricehamn Energi AB
Umeå Energi AB
Varberg Energi AB
Vattenfall AB
VB Energi
Värnamo Energi AB
Växjö Energi AB
Öresundskraft AB
Öresundskraft AB
Överkalix Värmeverk AB
Övertorneå Värmeverk AB

NETWORKS
AB Borlänge Energi
AB Piteenergi
Affärsverken i Karlskrona AB
Alingsås Energi Nät AB
Arvika Fjärrvärme AB
Bollnäs Energi AB, Arbrå
Bollnäs Energi AB, Bollnäs
Bollnäs Energi AB, Kilafors
Borås Energi & Miljö AB
Bromölla Fjärrvärme AB
C4 Energi AB
E.ON Värme Sverige AB, Bara
E.ON Värme Sverige AB, Bollstabruk
E.ON Värme Sverige AB, Boxholm
E.ON Värme Sverige AB, Bro
E.ON Värme Sverige AB, Broby
E.ON Värme Sverige AB, Burlöv
E.ON Värme Sverige AB, Bålsta
E.ON Värme Sverige AB, Dorotea
E.ON Värme Sverige AB, Hede
E.ON Värme Sverige AB, HÖK
E.ON Värme Sverige AB, Järfälla
E.ON Värme Sverige AB, Kungsängen
E.ON Värme Sverige AB, Lagan
E.ON Värme Sverige AB, Lammhult
E.ON Värme Sverige AB, Långsele
E.ON Värme Sverige AB, Malmö
E.ON Värme Sverige AB, Mora
E.ON Värme Sverige AB, Mönsterås
E.ON Värme Sverige AB, Nora
E.ON Värme Sverige AB, Nordmaling
E.ON Värme Sverige AB, Norrköping
E.ON Värme Sverige AB, Näsåker
E.ON Värme Sverige AB, Odensbacken
E.ON Värme Sverige AB, Orsa
E.ON Värme Sverige AB, Ramsele
E.ON Värme Sverige AB, Ryd
E.ON Värme Sverige AB, Sollefteå
E.ON Värme Sverige AB, Staffanstorp
E.ON Värme Sverige AB, Svalöv
E.ON Värme Sverige AB, Sveg

E.ON Värme Sverige AB, Söderköping
E.ON Värme Sverige AB, Timrå
E.ON Värme Sverige AB, Vallentuna
E.ON Värme Sverige AB, Vaxholm
E.ON Värme Sverige AB, Vilhelmina
E.ON Värme Sverige AB, Vännäs
E.ON Värme Sverige AB, Åkersberga
E.ON Värme Sverige AB, Åseda
E.ON Värme Sverige AB, Älmhult
Eskilstuna Energi och Miljö AB
Falbygdens Energi AB, Falköping
Falbygdens Energi AB, Stenstorp
Falu Energi & Vatten AB, Bjursås
Falu Energi & Vatten AB, Falun
Falu Energi & Vatten AB, Grycksbo
Falu Energi & Vatten AB, Svärdsjö
Farmarenergi i Ed AB
Filipstad Värme AB, Filipstad
Filipstad Värme AB, Storfors
Fortum Värme AB, Avesta
Fortum Värme AB, Grums
Fortum Värme AB, Hudiksvall
Fortum Värme AB, Kopparberg
Fortum Värme AB, Nynäshamn
Fortum Värme AB, Stockholm
Fortum Värme AB, Torsby
Gotlands Energi AB, Fast
Gävle Energi AB
Göteborg Energi AB
Götene Vatten och Värme AB
Habo Energi AB
Halmstad Energi och Miljö AB
Haparanda Värmeverk AB, Fast
Hofors Energi AB
Hällefors Värme AB
Härnösand Energi och Miljö AB
Jämtkraft AB, Åre
Jämtkraft AB, Östersund
Jönköping Energi AB
Kalix Fjärrvärme AB
Kalmar Energi Värme AB
Karlshamn Energi AB

Karlstads Energi AB
Katrineholm Energi AB
Kreab Energi AB
Kristinehamns Fjärrvärme AB
Landskrona Energi
Lantmännen Agrovärme AB, Bjärnum
Lantmännen Agrovärme AB, Grästorp
Lantmännen Agrovärme AB, Horred
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Lantmännen Agrovärme AB, Ödeshög
Laxå Värme AB
Lerum Fjärrvärme AB
LEVA i Lysekil AB
Lilla Edet Fjärrvärme AB
Luleå Energi AB, Luleå
Luleå Energi AB, Råneå
Lunds Energi AB
Mariestad-Töreboda Energi AB, Lyrestad
Mariestad-Töreboda Energi AB, Mariestad
Mariestad-Töreboda Energi AB, Töreboda
Mark Kraftvärme AB
Mjölby-Svartådalen Energi AB
Mälarenergi AB, Hallstahammar
Mälarenergi AB, Kungsör
Mälarenergi AB, Västerås
Mölndal Energi AB
Neova AB, Hultsfred
Neova AB, Bjuv
Neova AB, Kramfors
Neova AB, Tanumshede
Neova AB, Tibro
Neova AB, Valdemarsvik
Neova AB, Årjäng
Neova AB, Österbybruk
Norrenergi AB
Nässjö Affärsverk AB
Nässjö Affärsverk AB, Anneberg
Nässjö Affärsverk AB, Bodafors
Oskarshamn Energi AB

Oxelö Energi AB
Rindi Energi AB, Flen
Rindi Energi AB, Gnesta
Rindi Energi AB, Hörby
Rindi Energi AB, Höör
Rindi Energi AB, Sjöbo
Rindi Energi AB, Sunne
Rindi Energi AB, Tomelilla
Rindi Energi AB, Vadstena
Rindi Energi AB, Vingåker
Rindi Energi AB, Vårgårda
Rindi Energi AB, Älvdalen
Ringsjö Energi AB
Sala-Heby Energi AB
Sandviken Energi AB, Sandviken
Sandviken Energi AB, Storvik/Järbo
Skellefteå Kraft AB, Boliden
Skellefteå Kraft AB, Lycksele
Skellefteå Kraft AB, Skellefteå
Skellefteå Kraft AB, Storuman/Stensele
Smedjebacken Energi AB
Sollentuna Energi AB
Sundsvall Energi AB, Indal
Sundsvall Energi AB, Sundsvall
Säffle Fjärrvärme AB
Sävsjö Energi AB
Söderhamn Energi AB
Södertörns Fjärrvärme AB
Tekniska Verken i Kiruna AB
Tekniska Verken i Linköping AB, Borensberg
Tekniska Verken i Linköping AB, Kisa
Tekniska Verken i Linköping AB, Linköping
Tekniska Verken i Linköping AB, Skärblacka
Tekniska Verken i Linköping AB, Åtvidaberg
Telge Nät AB
Tierps Fjärrvärme AB
Tranås Energi AB
Trelleborgs Fjärrvärme
Trollhättan Energi AB
Uddevalla Energi AB, Ljungskile

Uddevalla Energi AB, Munkedal	Vattenfall AB, Uppsala
Uddevalla Energi AB, Uddevalla	Vattenfall AB, Vänersborg
Ulricehamn Energi AB	Vattenfall AB, Värmdö
Umeå Energi AB, Bjurholm	VB Energi, Fagersta
Umeå Energi AB, Umeå	VB Energi, Grängesberg
Varberg Energi AB	VB Energi, Ludvika
Vattenfall AB, Askersund	VB Energi, Norberg
Vattenfall AB, Haninge	Värnamo Energi AB
Vattenfall AB, Knivsta	Växjö Energi AB
Vattenfall AB, Motala	Öresundskraft AB, Helsingborg
Vattenfall AB, Nacka/ Älta	Öresundskraft AB, Ängelhom
Vattenfall AB, Nyköping	Överkalix Värmeverk AB
Vattenfall AB, Storvreta	Övertorneå Värmeverk AB

Ale Fjärrvärme AB and Partille Energi AB are excluded since they use the pricing model of Göteborg Energi (via their homepage) and the networks are connected. The Fliseryd, Lidhult and Timmernabben networks of E.ON Värme Sverige AB (3 out of 44 networks) have all been excluded due to difficulties in finding values for the heat production. None of them have unique prices or pricing models.

During 2010 Fortum sold the district heating operation outside of Stockholm to the Australian fund manager Macquarie Funds Group. The prices are however still presented on the Fortum Värme AB home page.

The Kopparberg and Bångbro networks are run by Värmevärden AB but the pricing model was presented at the Fortum Värme AB webpage when the survey was initiated.

Kalix Fjärrvärme AB has their DH prices presented via the Vattenfall web page.

B. Glossary

Category number

The *category number* method is used to calculate a capacity based on energy use and building type. It is done by dividing the energy use of a certain time period with a category number of hours. Since residential buildings require heating at all times, the category number is higher, and consequently the calculated capacity will be lower for a given energy consumption. When the entire energy demand during the year is used in the calculation, the category number is normally around 2100 hours. The reason for choosing a particular category number is seldom accounted for, but it is most likely based on experience. Other category numbers use a specified part of the annual energy consumption, for instance during the three coldest months. In those cases, it can be an effective way of promoting reduced consumption during peak load periods.

Capacity

The capacity is the energy use over a certain period of time.

- **Subscribed capacity**
  The subscribed capacity is the determined capacity for which the customer pays to the DH utility. There are many ways of determining the subscribed capacity, but the most commonly used is the category number method. Other companies use measured capacity instead, which is then equal to the subscribed capacity (see Appendix C below).

- **Measured capacity**
  The capacity is always a measurement of energy use over a time period. In this study the required measurement frequency is on a daily basis or more often in order for the capacity to be considered as measured.

C. Measured capacity

The nine companies in the survey that measure the actual capacity of their customers have large variations in how the subscribed capacity is defined. The individual methods are described by the companies are described below. For calculations, companies using *hourly* values, a subscribed capacity of 69 kW is assumed (which is the reported value of Växjö Energi AB). For companies using *daily* values, 60 kW is used (as reported by Tekniska Verken i Linköping AB).

Södertörns Energi AB

The DH price is made up of a variable part and a fixed part. The fixed part is based on a subscribed capacity, which is supposed to correspond to the *maximal hourly mean capacity at an outdoor temperature of -5 °C* and is given in kW. The subscribed capacity will reflect the customers' share of the total load on the DH production and distribution facilities. The reason for choosing -5 °C is to get a sufficiently long and reliable period with heat load, since the mean winter temperature is -4.6 °C. The subscribed capacity is measured using remote reading and the measurements are done during the winter half of the year. The measurement time should be at least two weeks, during which at least 20 % of the daily average temperatures should be between 0 °C and -10 °C.

In this study, the subscribed capacity of Södertörns Energi AB is assumed to be 69 kW.

Uddevalla Energi AB

The subscribed capacity is the *average value of the two highest monthly values from different months for used hourly capacity*. When determining the monthly value the third highest value of the month is used. The two highest values are neglected since there can be a risk of measurements taking place at moments of disruption in the DH network.

In this study, the subscribed capacity of Uddevalla Energi AB is assumed to be 69 kW.

Tekniska Verken i Linköping AB

The capacity price is based on a capacity signature. When determining the capacity signature measured daily values for capacity and temperature from November 1 to March 31 of the previous winter are used. Each daily value becomes a dot in the diagram and forms a straight line. The line describes the capacity value depending on outdoor temperature. Read capacity from the line at -17.6 °C is the value that determines the customers' capacity signature and forms the subscribed capacity. The capacity signature is updated January 1 each year.

In this study, the the subscribed capacity of Tekniska Verken i Linköping AB is assumed to be 60 kW, since that is the subscribed capacity reported to the Nils Holgersson survey (Tekniska Verken i Linköping AB, 2011).

Vattenfall AB, Vänersborg

The subscribed capacity is measured as the *highest daily average capacity during the last three January months*. During 2011 it consists of the average daily maximum capacity from January 2009, January 2010 and January 2011. The capacity cost is fixed during the year but varies from one year to the other.

In this study, the subscribed capacity of Vattenfall AB is assumed to be 60 kW.

Göteborg Energi AB

The capacity component is calculated as the average value of the three highest daily values. This is done without correction with respect to an average year in terms of outdoor temperatures and means that the capacity component will vary more between warm and cold years than before. The capacity component is based on the average value of the actual measured capacity. *The average of the three highest daily average values from the last twelve-month period* constitute the subscribed capacity.

In this study, the subscribed capacity of Göteborg Energi AB is assumed to be 60 kW.

Fortum Värme AB, Stockholm

The annual subscribed capacity is revised annually by the DH company and is valid from January 1 each year. The subscribed capacity, in kW, is based on measured hourly values (kWh/h) during the period from October 2009 to April 2010. When calculating the capacity the five highest measured values are removed and the capacity is calculated as the the average of the five subsequent values. The calculated capacity is rounded down to the nearest integer (Fortum Värme AB 2011, "*Fjärrvärmepris 2011 A - Normalpris Stockholm*").

In this study, the subscribed capacity of Fortum Värme AB is assumed to be 69 kW.

VB Energi

Actual measured capacity. The average of the 5 highest hourly average values is used. No correction with respect to an average year in terms of outdoor temperatures.

In this study, the subscribed capacity of VB Energi is assumed to be 69 kW.

Växjö Energi AB

The capacity is determined by averaging the highest hourly average capacity during the 10 days when the average temperature has been closest to -2 °C, during the period January to March. This value will be applied from April1 to March 31.

In this study, the the subscribed capacity of Växjö Energi AB is assumed to be 69 kW, which is the value that is reported annually to the *Nils Holgersson* survey (Nilsson, 2011).

Ulricehamns Energi AB

For customers with an annual consumption of more than 100 000 kWh a capacity fee is applied. The first year an estimation of the required capacity is made together with the customer. During the year the hourly consumption is measured. The highest value of each year is used and the highest values for the three last years divided by three is used for the coming year. This value constitutes the subscribed capacity.

In this study, the subscribed capacity of Ulricehamns Energi AB is assumed to be 69 kW.

D. Companies using seasonal differentiation of the energy price in the one/ two family house customer category

Company
Jönköping Energi AB
Lantmännen Agrovärme AB
Sala-Heby Energi AB
Uddevalla Energi AB
Varberg Energi AB
Värnamo Energi AB