Analysis of the Energy Efficiency of District Heat Suppliers in Hungary Through Network Losses

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Abstract

Nowadays in Hungary, district heating is provided by 89 companies in 93 settlements, which supply more than 1.6 million people with heat. The sector is considered to be of national economic importance and it is therefore vital that this service is implemented effectively. A measure of efficiency is network loss, which value is on average between 12-13% in the sector. The aim of this study is to investigate whether there is a significant difference between the efficiencies of district heat suppliers. The empirical basis of the study is made up of the individual technical data of district heat suppliers from the years 2012-2017. The analysis was carried out with statistical methods that are suitable for exploring the relationships between qualitative and quantitative indicators.

Keywords: district heat suppliers; energy efficiency; network losses

JEL classification: K132

Introduction

Energy is vital for life and used in many areas in our everyday lives, including heating, lighting, transport or industry. "Human well-being, industrial competitiveness and the functioning of the society as a whole depend on secure, reliable, sustainable and affordable energy" (European Committee, 2011). For this reason, proper management of energy sources is essential. The European Union Energy Strategy, elaborated based on these principles, set different targets for climate and energy policy for 2020, 2030 and 2050 (European Committee, 2012). Renewable energy sources play an important role in the energy strategy. The objective for 2020 is that 20% of the total energy will come from renewable energy sources. By 2030, the rate of renewable energy sources shall reach 32% and by 2050, it shall reach 55% (European Commission, 2018). The energy policy emphasizes sustainable, affordable, competitive and secure energy supply. Because of scarce resources, rational and efficient energy management can make its use sustainable. Achieving the targets will have a significant impact on applied technologies, as the rate of used resources will change fundamentally, and also because of the rising cost of fossil energy sources. These targets and the efforts made to achieve them can also be regarded as catalysts for the spread and development of technologies using renewable energy. Jensen (2019) states that low-temperature heat suppliers based on green and renewable energy sources play a key role in this. Djorup and Hvelplund (2016)

point out their statement more categorically, arguing that a common European Energy System and efficient heat supply are essential to achieve the goals. If the targets are met, the benefits will be multiple: not only can carbon emissions be reduced, but new jobs can also be created and cost saving can be realized (European Committee, 2012). It is worth noting how these principles are present in the law called Act XVIII of 2005on District Heating Services, the most important element of the regulation of district heat suppliers in Hungary. The objectives of the legislation are described as follows: "The Parliament makes the law to ensure objective, transparent and non-discriminatory regulations to ensure the safe, adequate and economical supply of district heating of customers, taking into account the requirements of consumer protection, energy efficiency, energy saving and environmental protection' (Act XVIII of 2005 on District Heating Services).

Although the assessment of district heating varies from country to country[1], experts usually point out the following benefits: There are no heat generators per building which means there are no harmful emission sources. District heating emits harmful substances in a concentrated way which is more preferable from an environmental protective point of view. In the densely populated city centers, where even transportation is a significant burden on the environment (G Fekete and Siposné Nándori, 2013), it is not necessary to install boilers to heat the buildings and the heating plant can be located far away from the city center. District heating has drawbacks as well. It is necessary to establish and operate a large-scale, therefore high-cost system, which is usually a more expensive solution than the establishment of heat generators for each building. The extensive network has significant heat loss and high pumping energy. Compared to gas supply, the installation and operating costs of the energy supply system are also higher. It is more difficult to realize the individual modification of the heating of an apartment, because the system has to be managed jointly. Due to the temperature control of the heating water, 100% power is not always available (Baumann, 2012).

We can see that the creation of the so-called efficient district heating based on the high rate of renewable energy resources has been incorporated into the expectations and objectives of the European Union. Hungary's National Energy and Climate Plan (NEKT) aimed at achieving a renewable share of 21% of the gross final energy consumption, 28.7% in the heating and cooling sector, and more than 60% in the district heating sector by 2030 (Kerekes and Mezőssi, 2020). Improving the efficiency of the existing systems, however, can also contribute to the achievement of the goals of the energy plan.

The aim of the study is to provide a comprehensive view of the efficiency of district heating services in Hungary by examining network losses.

2. Research Methods

2.1. Methodology

The database used for the analysis includes the companies' annual reports from 2013 to 2017. Nowadays in Hungary, 89 companies provide district heating service in 93 settlements. Of these, 72 companies were included in the examined population. It is important to point out that the sampling was representative of the whole population. We choose to examine the

[1] Interestingly, differences in the assessment of district heating services can be found not only among countries, but also within countries, which is due, among other things, to the regional inequalities in energy consumption within countries. (Nagy et al. 2019; Musinszki, 2016)

population along the sold heat, regional distribution and the number of consumers. The deviation among the 89 suppliers is large in terms of sold heat and the number of consumers, so the 72 companies that made up my sample provide 93% of the whole amount of sold heat. Therefore the conclusions drawn are reliable in terms of describing the situation and characteristics of the whole population.

Several databases were used to collect the required information, such as:

Company Information and Electronic Company Registration Service of the Minsitry of Justice (https://e-beszamolo.im.gov.hu),

web pages of the companies in terms of the balance sheets and information on technology and management,

interviews and questionnaires sent directly to the companies in order to gain information on the technology and management.

The technical procedure of the analysis was carried out using the Excel program in Microsoft Office 365 ProPlus and SPSS 24. As for the methodology of the analysis, Excel provided the opportunity to carry out descriptive statistical analysis and the SPSS software package made it possible to carry out more complex analysis.

The purpose of the empirical research of the study is to test the following hypotheses:

H1: There was no significant change in the average energy efficiency of heat suppliers in the examined years.

H2: The average energy efficiency is influenced by the size of sales, the existence of own heat production and the nature of the activities performed

To test the two hypotheses, the applied dependent variable is the network loss, which was defined as follows based on the available data:

1 - ((Heat sold to household consumers + Heat used to heat domestic hot water sold to household consumers + Heat sold to other consumers) / (Total amount of energy used))

The independent variables required for the analysis and the system of the performed analysis are described in the following table.

Table 1: Research questions, applied variables, and statistical methods

Hypothesis	*Applied indicator*	*Method*
H1	*Evolution of network loss over time*	*Methods of descriptive statistics*
H2	*Scales of Sales* *Own heat production* *Activities provided*	*Analysis of variance, Post Hoc test* *Correlation analysis*

2.2. Findings

While testing the first hypothesis, the network losses can provide an overall view of the efficiency of Hungarian district heat suppliers.

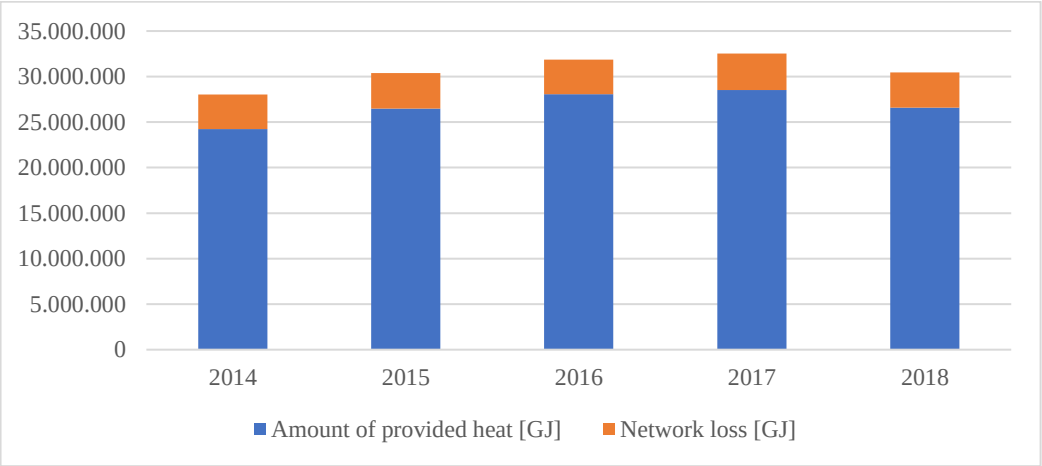

Figure1: Amount of heat output and provided in district heating for the total population

Source: Hungarian energy and public utility regulatory authority (2019)

The data highlight that there was no significant change in the network loss of the district heating sector in the examined period. The average values range between 12.0% and 13.6%. The examined population, however, is heterogeneous in this respect based on the performed statistical analyzes. There are differences among the different enterprises.

We observed the evolution of the network losses of heat suppliers. Between 2012 and 2017, the observed enterprises had an average network loss of 18.77%. The standard deviation was 9.0 percentage points, which corresponds to a relative standard deviation of 48%. In the examined period, half of the observed enterprises had network losses of less than 17.3% and half more than 17.3%. By observing each year, it can be concluded that in the examined period there was no significant change in the network loss data of the enterprises as a function of time. ($F = 0.246$; $p = 0.941$). The box plot of the enterprises' network losses is visualized in Figure 2 which shows that the network losses of the examined companies follow similar distributions in each year.

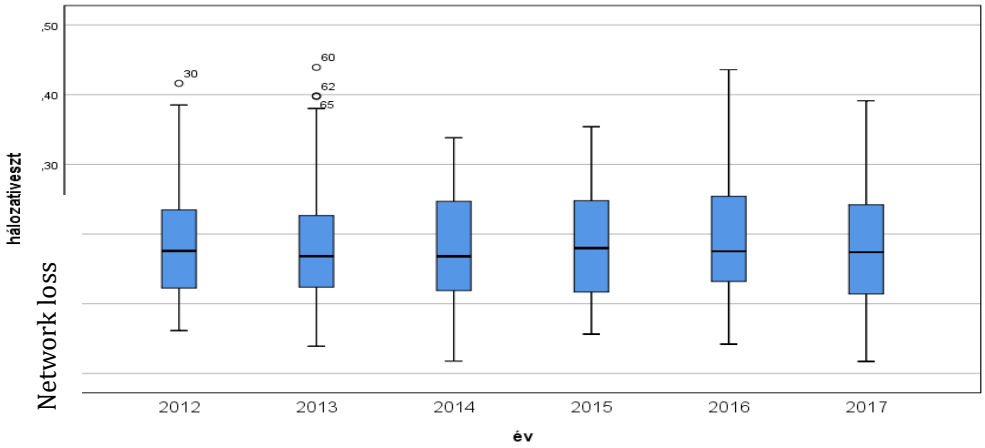

Figure2: Box plot of the network losses in each examined year

Source: Hungarian energy and public utility regulatory authority (2019)

As there was no significant change in the values of the network losses in the examined period, we examined whether there was any difference in the network losses due to some important criteria of the enterprises. Table 1 summarizes the res Years analyses about belonging to the different values of the different discrete variables and the network losses. To test the differences in the expected values of the network losses of the enterprises belonging to the different discrete variables, we used F tests, the values of which are shown in Table 2 with the p values.

Table 2. Analysis of the relationship between network loss and the different discrete variables

discrete variable	*number of categories*	*F value*	*p (critical significance level)*
Scales of Sales	*5*	*2.075*	*0.085*
Own Heat production	*3*	*13.738*	*0.000*
Activity	*3*	*5.371*	*0.005*

Source: own calculations based on the technical data published mandatorily by the enterprises

In this context, our second research question and hypothesis were about to test whether it is possible to create homogeneous groups based on the preselected criteria, and whether there is a significant relationship between the selected quantitative indicators (Domán et al., 2009)

To test H2, it was first necessary to perform analyses of variance and Post-hoc tests, including the following explanatory variables:

Scales of Sales

Own Heat production

Activities performed

The role of the Scales of Sales

The Association of Hungarian District Heat Suppliers (Magyar Távhőszolgáltatók Szakmai Szövetsége) and the Hungarian Energy and Public Utility Regulatory Authority (Magyar

Energetikai és Közmű-szabályozási Hivatal) classify district heating suppliers into four groups according to their size. FŐTÁV is Hungary's biggest district heating company. Therefore, it is justified to treat that company separately and to create a separate size class as a consequence of which groups will be more homogeneous.

Based on the performed analyses, we make the following observations.

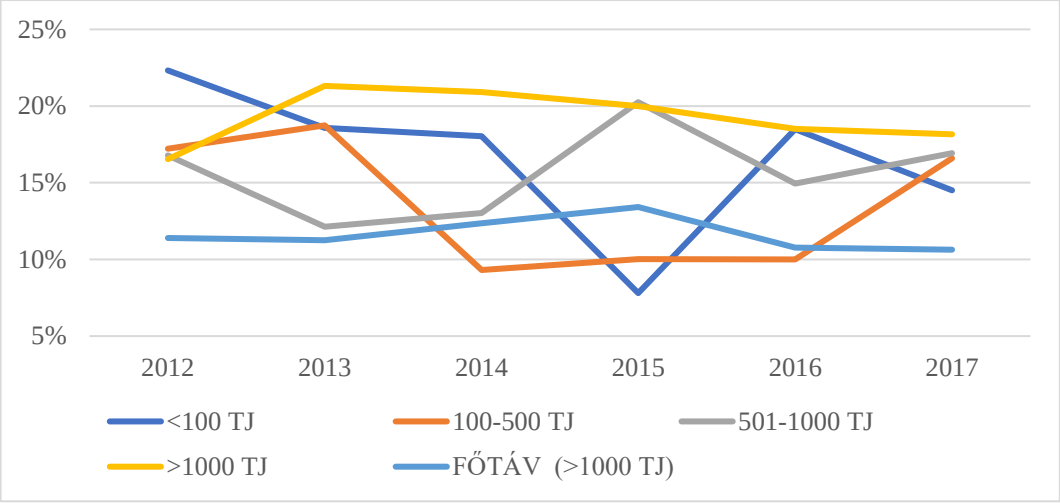

Figure 3: network losses in the function of scales of sales

Source: own calculations based on the technical data published mandatorily by the enterprises

Our initial hypothesis states that the size of the enterprise can significantly reduce network loss. The energy service enterprises included in the analysis were classified into five size categories, which were as follows. The smallest enterprises were those with amount of energy produced less than 100 TJ annually. This was followed by enterprises with sales volumes between 100 TJ and 500 TJ. Medium-capacity companies were those with energy emission between 501 TJ and 1000 TJ. Enterprises with more than 1000 TJ were classified in the fourth size category.

Our previous assumption that scales of sales has an impact on energy efficiency has turned out to be true, as there are differences among the average network losses of heat suppliers of different sizes. It can be concluded that the enterprises with the highest emissions had the worst efficiency in the examined period and the network losses of the enterprises with higher emissions are on average worse than those of smaller enterprises. Interestingly, FŐTÁV, the main heat supplier in the country, is the only exception.

Table 3: Distribution characteristics describing network loss by grouping energy service enterprises according to their size

Size category	*Number of observations*	*Mean network loss (%)*	*Std. Deviation (percentage point)*
<100 TJ	*97*	*18.65*	*9.76*
100-500 TJ	*89*	*19.99*	*8.65*
501-1000TJ	*19*	*15.38*	*7.37*

>1000TJ	*23*	*19.19*	*8.35*
FŐTÁV (>1000TJ)	*6*	*11.64*	*1.06*
Total	***234***	***18.77***	***9.01***

The calculations only partially confirm our preliminary assumption, as it is not clear that with the increase of the sales volume, the network loss tends to decrease. At the same time, however, based on the results, we can conclude that the lowest network loss belongs to Hungary's largest heat supplier. Post Hoc analysis reveals that with the exception of medium-capacity companies (501TJ-1000TJ), its network losses are significantly lower compared to other service providers belonging to the other size categories (p = 0.00) The different size categories are heterogeneous in terms of network losses. The two smallest size categories have the highest standard deviation.

The role of the Own Heat production

Some companies only sell purchased heat, while others also deal with heat production. It was a relevant question to examine whether this factor is a grouping criterion.

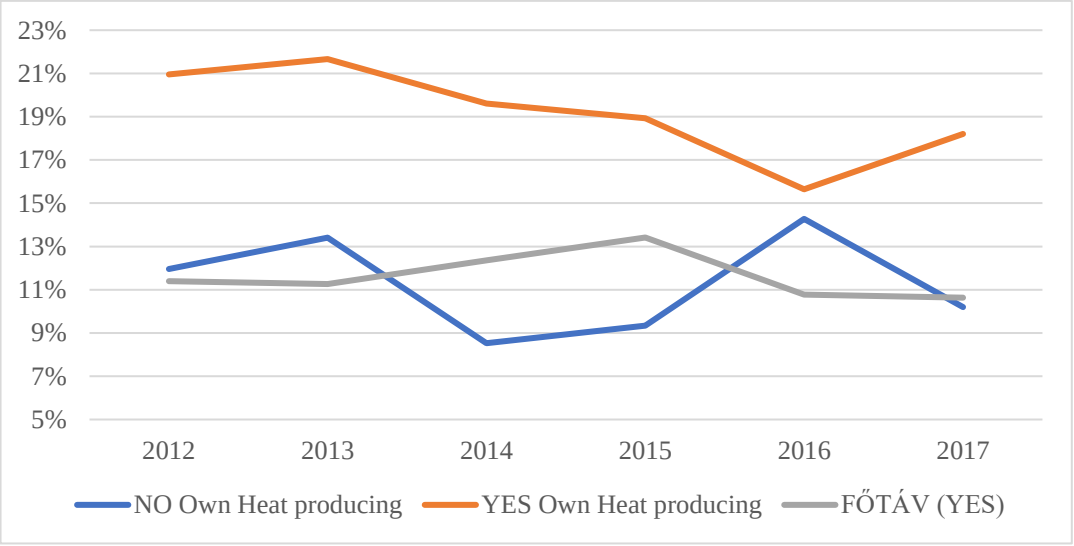

Figure 4: network losses in the function of own heat production

Source: own calculations based on the technical data published mandatorily by the enterprises

The comparison of energy efficiency to the existence of own heat production provides an interesting result. The analyses highlight that enterprises with own heat production operated with significantly lower efficiency in the examined period. Our previous statement that the heat supply of Budapest was the most efficient, proved to be true here as well, despite the fact that this enterprise also has its own heat production.

Based on the results of the hypothesis test, we can conclude that service providers with their own heat production have significantly higher network loss than those who sell only purchased heat. This analysis also shows that the loss data of FŐTÁV are below average.

Table 4: Post Hoc test results about the differences of the group averages of network losses

	without own heat production	*with own heat production*
with own heat production	*0.06222 (p=0.000)*	
Főtáv	*0.02700 (p=0.005)*	*0.08929 ((p=0.000)*

The role of the Activities performed

Act XVIII of 2005 on District Heating Services defines district heating as follows: "A commercial public service provided by the licensee, which supplies consumers with energy intended for heating or other heat utilization. The service is provided from a district heat producing facility through a district heating pipeline network". The Act and the related decrees do not prohibit that companies providing these activities from engaging in other activities as well. Accordingly, besides district heating, the bulk of the 89 Hungarian district heat suppliers carry out other activities, including district heat production, electricity production, waste management, water utility supply and other activities related to urban management.

The next part of our analysis focused on whether the performance of activities other than heating has an explanatory role in the evolution of network losses.

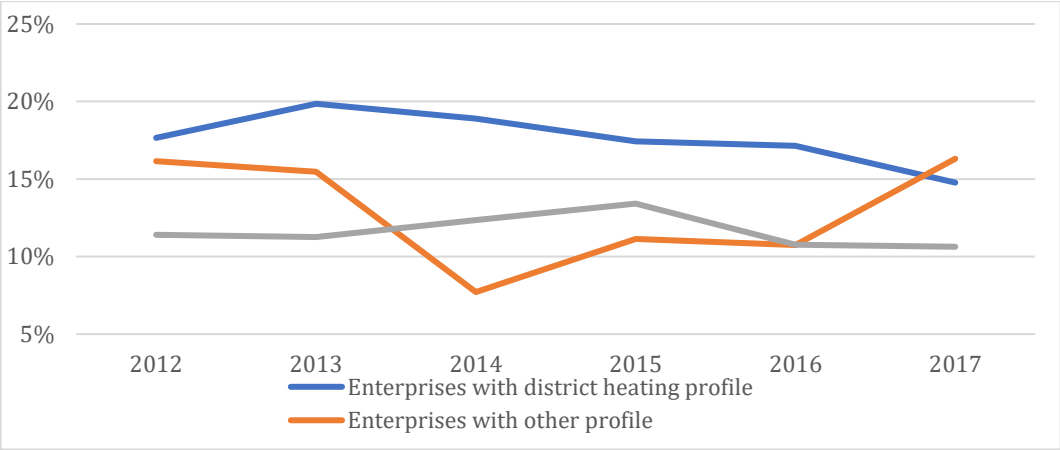

Figure 5: network losses in the function of activities performed

Source: own calculations based on the technical data published mandatorily by the enterprises

As in the previous analysis, significant difference can be found among enterprises with different profiles in this case. District heating enterprises with a lower than average share of non-district heating activity operate on average with lower energy efficiency and higher energy loss.

Our initial assumption is that the activity performed can significantly influence network loss. Three categories were created to test it. One group includes enterprises with district heating services as main activities. Enterprises with other activities belong to another group, and, as before, FŐTÁV is grouped into a separate category. Even in the case of classification according to the type of activity, FŐTÁV operates with the lowest network loss, as it has a significantly lower value than the other two categories. (p = 0.000) The comparison of the data of the

enterprises with district heating profile and the data of the enterprises who perform other activities as well highlight that there is a significant difference in the average and in the median of the network loss values (p = 0.000).

Table 5: Mean values of network losses when the energy service companies are grouped by type of activity

Activity profile	*Number of observations*	*Mean network loss (%)*	*Median network loss (%)*
Enterprises with district heating profile	*123*	*20.36*	*20.14*
Enterprises with other profile	*105*	*17.31*	*14.39*
FŐTÁV	*6*	*11.64*	*11.33*
Total	***234***	***18.77***	***17.29***

Half of the enterprises with a district heating profile have a network loss of less than 20.14%, while half of the enterprises with other profiles have a network loss of less than 14.39%.

3. Results and Discussion

District heating has a key role in enabling Hungary to meet the goals and expectations set out in the Hungarian and European energy strategy. The aim of the study was to review the energy efficiency of heat suppliers through network losses. To do so, we first defined an indicator that makes network losses measurable using the available data (amount of sold and used energy).

Based on the performed analyses, we can state that Hungarian heat suppliers can be characterized by an average network loss between 12.0% and 13.6%, but there are differences between different enterprises. Then we used two groups to examine what factors may cause the differences.

Based on the analyses carried out using qualitative indicators, we conclude that in the examined period, the enterprises with the highest emissions had the worst efficiency, and the network losses of the enterprises with the largest emissions were on average worse than those of the smaller enterprises. Interestingly, the largest heat supplier in the country, FŐTÁV, is an exception, which is the enterprise with the lowest energy loss. Enterprises with own heat production have significantly higher network loss than those who sell only purchased heat. District heating enterprises with a lower than average share of non-district heating activity operate on average with lower energy efficiency and higher energy loss.

In our view, our research results can be useful for the actors of the sector as well as for the regulatory authorities, as a technically efficient district heating service is in our common interests. Our analyses included one-factor calculations. Further research is needed to test whether it is possible to create clusters with different energy efficiencies in the case of heat suppliers and what characterizes the enterprises concerned when they are examined based on further quantitative independent variables.

4. Acknowledgement

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