LAPIN AMK
Lapland University of Applied Sciences

DESIGN OF A DISTRICT HEATING SYSTEM IN A MEDIUM-SIZED COMMUNITY IN SEITENSTETTEN IN LOWER AUSTRIA

Seitenstettner Fernwärme GmbH

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Technology, Communication and Transport
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Opinnäytetyön tarkoituksena oli suunnitella kaukolämpölaitos Seitenstettenissa Ala-Itävallassa ja laskea biomassalaitoksen tärkeimmät mittaustiedot prosessien tehokkuuden ymmärtämiseksi. Osa näistä mittaustiedoista koski kuluttajien lämpövoimaa, verkon lämpöhäviöitä, biomassakattilan kuormitusta ja myös polttoaineen kulutusta.

Tutkimuksen aikana kuvailtiin biomassalaitoksen erilaisia työmenetelmiä ja erityisesti laajennusosaa Seitenstettenissa. Erilaisia olemassa olevia kaavoja käsiteltiin opinnäytetyössä ja niissä painotetaan erityisesti Sochinskyn vuotuista kuormituskäyrää.

Olemassa olevaa Excel-pohjaista "VeriNa" -ohjelmaa laajennettiin opinnäytetyön tutkimuksia varten, myös kääntämällä koko ohjelma englanniksi.

Tutkimuksen tulokseksi saatiin yhtiölle ajankohtaista informaatiota liittyen putkien erilaisiin materiaaleihin ja teknologioihin, joilla parantaa tehokkuutta ja alentaa kustannuksia. Lisäksi ohjelmiston laajentaminen auttaa muita yhtiöitä hyödyntämään sitä omiin tarkoituksiinsa.

Avainsanat VeriNa, simulaatio-ohjelma, biomassa, kaukolämpö
Muita tietoja VeriNa Excel pohjainen simulaatio-ohjelma.

Abstract of Thesis

Technology, Communication and Transport
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Author	Niko Valvimo	Year	2018
Supervisor	DI Peter Franz DI Ari Pikkarainen		
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Title of Thesis	Design of a district heating system in a medium-sized community in Seitenstetten in Lower Austria		
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The aim of the thesis was to design a district heating plant in Seitenstetten in lower Austria and to calculate important metrics to understand the efficiency of the processes of a biomass heating plant. Some of these include thermal power of consumers, total heat losses of the grid, the biomass boiler load and fuel consumption.

Throughout the investigation the layout, working methods and expansion plan of a biomass heating plant in Seitenstetten are described. Different existing formulae for the desired calculations are reviewed with a special emphasis on the annual load curve of Sochinsky.

Existing excel-based program “VeriNa” is extended and adapted to this case of study with its translation into English as part of the work for the thesis.

The investigation provided the company with relevant information in terms of the convenience of using different materials and technologies of the pipes for improving efficiency and reducing costs. Additionally, the extension of the software makes it more adaptable for other companies to take the advantage.

Key words VeriNa, simulation program, biomass, district heating
Other information VeriNa Excel based simulation program.

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FOREWORD

I would like to thank my supervisors Mr. Peter Franz and Mr. Ari Pikkarainen for their help and supervision. I would also like to thank Technikum Wien University of Applied Sciences and Lapland University of Applied Sciences. I also want to thank the district heating company Seitenstettner Fernwärme GmbH for the help and provided operational data.

SYMBOLS AND ABBREVIATIONS

UAS	University of Applied Sciences
MCP	Medium Combustion Plant
MWth	Megawatts thermal
EP	Electrostatic Precipitator
SFT	Supply Flow Temperature
RFT	Return Flow Temperature
BMB1	Biomass Boiler One
BMB2	Biomass Boiler Two
OiB	Oil Boiler
GaB	Gas Boiler
VeriNa	Verification program for district heating
CF	Coincidence Factor
Q_j	Annual heat consumption
τ_b	Operating period
P_{min}	Minimum heating power
P_{max}	Maximum heating power
τ	Time in hours
T	Non-dimension time
β	Load curve dimension
d_a,R	Outside diameter of pipe
sR	Pipe thickness of pipe
d_i,R	Inside diameter of pipe
s_{WD}	Insulation thickness
d_a	Outside diameter of insulation
d_i	Inside diameter of insulation
λ_{WD}/λ_g	Thermal conductivity of insulation
a	Distance between single pipes
h	Laying depth
λ_E/λ_i	Thermal conductivity of ground
t_{VL}	Supply flow temperature
t_{RL}	Return flow temperature
t_{EO}	Ground surface temperature

l	Pipe length
S	Construction coefficient single pipes
Q_{losses}	Specific pipe losses for single pipes
b	Clear pipe distance IsoPlus
r_o	Outside radius of insulation
r_i	Inside radius of insulation
D	Half the distance between center of pipes
H	Laying depth
T_1	Supply flow temperature Pipe 1
T_2	Return flow temperature Pipe 2
T_o	Ground surface temperature
T_s	Temperature in the pipes symmetrical problem
T_a	Temperature in the pipes anti-symmetrical problem
h_s^{-1}	Heat loss factor symmetrical
h_s	Heat loss factor symmetrical
h_a^{-1}	Heat loss factor anti-symmetrical
h_a	Heat loss factor anti-symmetrical
γ	Factor
σ	Thermal conductivity factor
q_s	Heat loss in the symmetrical problem
q_a	Heat loss in the anti-symmetrical problem
q_1	Heat losses
q_2	Heat losses
Q_{losses}	Total heat losses
HV	Heating Value

1 INTRODUCTION

The customer of this Bachelor thesis is Seitenstettner Fernwärme GmbH. The main idea of the thesis is to concentrate on simulation of an existing biomass heating plant and verify current operations. Seitenstettner Fernwärme GmbH is responsibly for the official data and information. This thesis is controlled by two supervisors, Professor Peter Franz from Technikum Wien UAS and Professor Ari Pikkarainen from Lapland UAS.

1.1 Goal of the thesis

The first goal of the thesis is the calculation of the total energy balance of the district heating system and the energy balance and simulation of the north extension, such as the calculation of the additional thermal power of consumers, total heat losses of the grid, the biomass boiler load and fuel consumption. The second goal is the added extension simulated by the excel based calculation program. The program will be translated into English and will be available for later use in international projects.

The main purpose is to compare the main data from the biomass heating plant and the simulation results. The new major extension and this thesis focuses on its results, user data and grid design. The grid includes two different kinds of pipes such as plastic and steel pipes. Some of them are single pipes and the new generation is made of twin-pipes.

1.2 Restrictions

The background of the project is the design of a district heating system in a medium-sized community in Seitenstetten in lower Austria. The existing plant will be redesigned for the connection of further consumers. In accordance with the redesign of the plant, an open source, static calculation programme will be used to calculate the energy balances and the consumer load calculation of the extension of the heating plant. The company will use the following data from this thesis in their future purposes. The results are available and the compared results between consumers will be provided in this thesis without any restrictions.

2 BIOMASS DISTRICT HEATING PLANT

The thesis elaborates in this chapter biomass heating plants. It concentrates on biomass heating plants' working methods, history, pollution and efficiency. It also focuses on different biomass heating plants and their design. The medium size-combustion plants and their restrictions will be explained in the following chapters. The biomass fuels will be under comparison and their energy densities will be demonstrated.

2.1 General information

Biomass heating system is a proven technology and it has been used for many years in Austria, Finland and all over the world. There are two important elements of a biomass heating solution such as the fuels and the heating system. There are some most commonly used fuels, which are certain energy crops, industrial wood residues and agricultural residues. These are normally delivered as wood pellets or chips, but they can also be provided in other forms as logs. The system consists of some important items such as a boiler plant, control systems flues and pipe work and system to receive, store and transfer the fuel to the main boiler. (CarbonTrust 2008, 3.)

Therefore, the biomass heating plant works with biomass, which is organic matter of contemporary biological origin. This energy from biomass heating plant is produced by burning or fermentation or distillation. The materials, which are used as fuel sources can provide different energy such as heat, electrical and motive power. (CarbonTrust 2008, 8.)

To produce heat or hot water from biomass fuels is currently being one of the most cost-effective ways of using biomass for energy producing purposes. Cost-effective means cost per tonne of carbon emissions will be avoided. Small heating systems mostly refer to wood-based fuels such as wood pellets, but for instance it can also include other materials such as conventional wood logs or others. (CarbonTrust 2008, 8.)

Fulfilling a working biomass heating solution is normally a potentially complex procedure, although the systems consist of a distribution network and a boiler. When designing a biomass heating plant and its system, there are many choices of fuels and boilers, and many of these could be integrated in an existing system. Therefore, many of the additional components are required for the existing system to perform itself perfectly and optimally. This kind of a biomass heating plant includes an additional boiler, option for thermal storage, ash extraction and fuel storage and this is the reason why it is more likely to refer to it as a biomass system instead of calling it a biomass boiler isolation. (FOREST 2009, 2.)

There are two different kinds of biomass heating plants with different filtering systems. The “wet” heating system is a complex filtering solution where the toxic gases are transferred through the wet filter system. This is a common biomass heating plant system, for example in Finland, due to new regulations from the European Commission. Another solution is EP filtering system, which is similar to Seitenstettner Fernwärme GmbH and this thesis concentrates on this biomass heating plant. This kind of biomass heating system works on EP system, where toxics gases go from the boiler through the cyclone filter and afterwards will be followed by an electrostatic precipitator filter. This is not the so-called “wet” heating system. Many of the medium sized biomass heating plants are provided with EP system, whereas large biomass heating systems use another solution. In figure 1 from company Kohlbach Group GmbH can be seen a good example of this kind of biomass heating system.

Figure 1. Biomass heating system with EP system (Kohlbach Group GmbH)

2.2 Biomass heating system fuels

There are many different fuels and choosing the right one may be difficult. Low quality fuels demonstrate high moisture, variable particle size and bad ash-melting behavior. Higher quality fuels are used more e.g. in medium and small sized heating systems, while so called low quality fuels in large scale systems. Many biomass heating systems burn wood pellets and wood chips, therefore agricultural residues and energy crops. The sustainability of using biomass heating fuels are more regional, than using coal for example. In Austria and Finland biomass fuels are provided and harvested locally and not distributed from other countries, such as the coal is mainly imported. (FOREST 2009, 9.)

The low-quality chips are mostly damp, and their moisture content can be 50% or more, also they have a low energy density 630-860 kWh/m3, while the high-quality chips should have 30% moisture content or even less. Although, high quality pellets are expected to have less than 10% water and the energy density is around 3,100 kWh/m3. (FOREST 2009, 9)

Table 1. Energy values for biomass heating fuels (FOREST 2009, 21)

Fuel	Net Calorific Value kWh/kg	Bulk density kg/m³	Volumetric energy density kWh/m³
Wood (solid, oven dry, 0% mc)	5.3	400-600	2,100 - 3,200
Wood pellets (~8% mc)	4.8	650	3,100
Log wood (stacked, 20% mc)	4.1	350-500	1,400 - 2,000
Wood chips (30% mc)	3.5	250	870
Miscanthus (bale, 25% mc)	3.6	140-180	500 - 650
Heating oil	11.8	845	10,000
Anthracite	9.2	1,100	10,100
House coal	7.5-8.6	850	6,400 - 7,300
Natural gas (NTP)	10.6	0.9	9.8
LPG	12.9	510	6,600

Figures from Biomass Energy Centre

2.3 Size of district heating plants

There are major differences between district heating plants and their sizes. The European Commission has set the MCP directive (EU) 2015/2193 of the European Parliament and the Council on 25th November 2015 that separates small-sized, medium-sized and large-sized plants. The directive describes the limitation of emission of certain pollutants into the air, which is set for medium combustion plants. In medium combustion plants the pollutant emissions from the combustions of fuels are equal or greater than 1 MWth with a rated input and less than 50 MWth (Directive European Commission 2015/2193). They are used for a wide variety of applications such as residential heating and cooling, providing heat for industrial processes. The important sources of emissions are dust, sulphur dioxide (SO2) and nitrogen oxides (NOx). In the European Union there is around 143,000 medium combustion plants. (European Commission 2016.)

2.4 European commission emission directive

The following directive was transposed by Member states by 19th December 2017. This regulates the emission of NOx, SO2 and dust into the air, because these may be risky to human health and the environment. It also regulates and rules to follow the emissions of carbon monoxide. The district heating plants will make sure that their synergies are maximised and air quality policies are right. (European Commission 2016.)

2.5 District heating and procedure

Biomass heating working method is simple and effective. Therefore, the heating will be provided for the district heating. The large-sized biomass heating plants use the steam for providing the heat, but the medium-sized plant in Seitenstetten does not work like this. There are two different kinds of biomass heating plants, such as a steam boiler system and a hot water system. This thesis focuses on the hot water system that is described below in figure 2. This hot water system consists of the biomass fuel storage, stairs grate, the heating boiler, the cyclone filter and the electro filter and the hot water boiler.

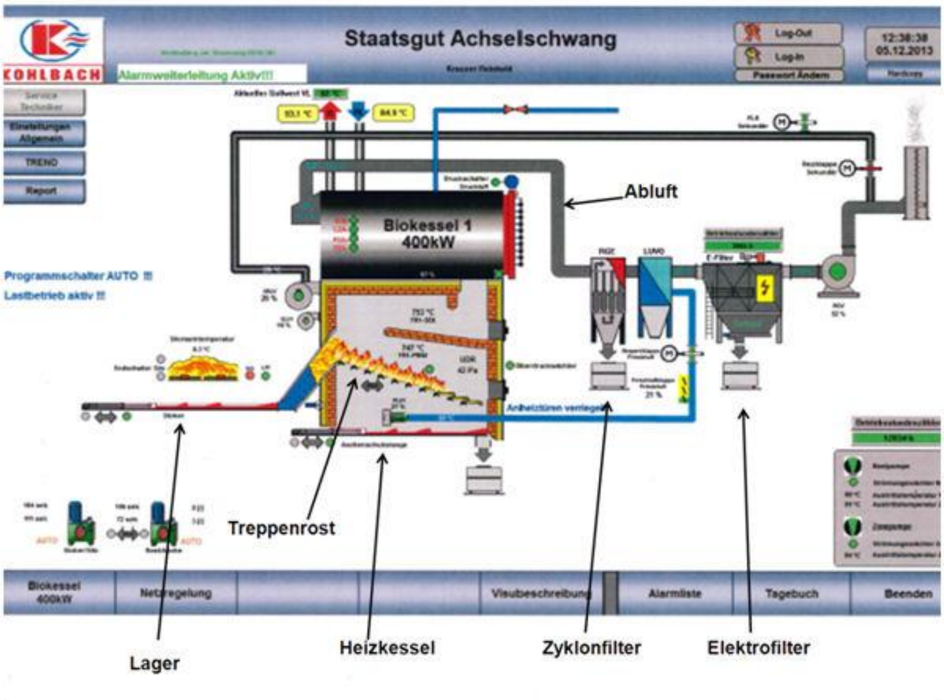


Figure 2. Medium-sized biomass heating plant (Lehr-, Versuchs- und Fachzentrum Achselschwang 2018)

District heating is often connected with biomass in different reasons. This is a huge advantage when considering how many properties can be more economic and at the same time attractive. There are many heat networks that are in different scales for different-sized cities and villages. District heating systems consists of the line load and the areal energy density, which is the ratio of the total energy demand normally in GWh or MWh and the geographical area. For example, in Sweden, if the annual areal density is 5 kWh/km2 and same time line loads are between 200-300 kWh/m, then this would be considered as a good ratio. The pipe load has a different meaning, which is the ratio between the total energy demand and therefore the total length of the pipes in kilometres. This solution can be described such as 1 MWh/km. (FOREST 2009, 19.)

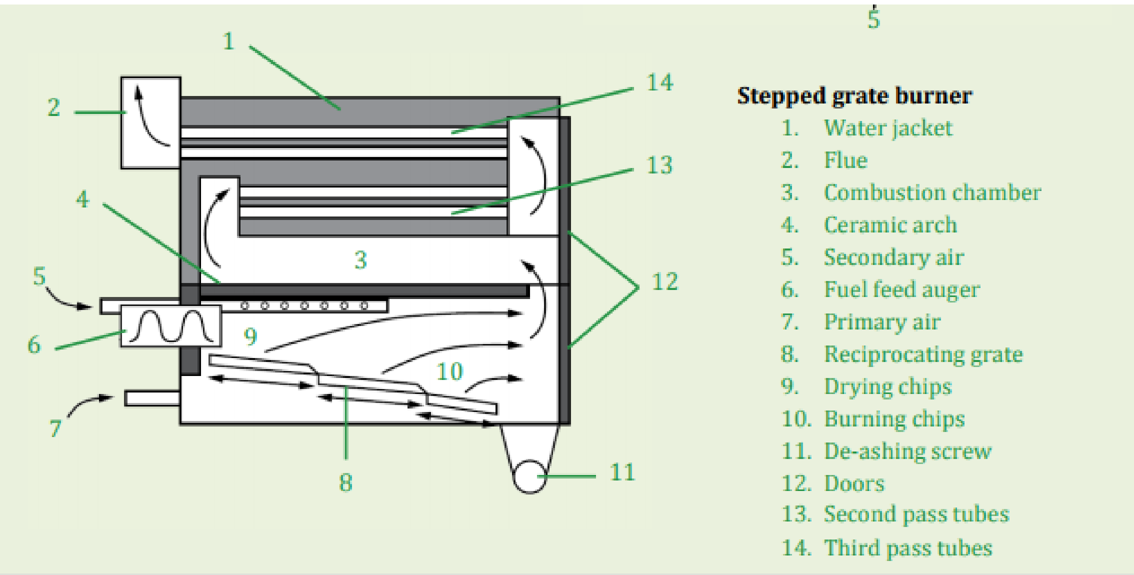


Figure 3. Biomass grate burner (FOREST 2009)

2.6 Emissions of biomass heating plants

Biomass heating system is one of the most cost-effective and best way to provide hot water and process heating and steam with low carbon emissions. Using these sources for heating provide a lot more carbon savings for electricity etc. This method usually offers the highest carbon savings per unit mass of biomass and these can be obtained by using a unit of land to grow biomass fuels. There are many important reasons to choose a biomass heating system such as significant carbon saving, operational cost savings, reduced fuel price volatility, reduced exposure to climate-change related legislation and improved energy performance ratings for buildings. A biomass heating system help to meet CCAs (Climate Change Agreements), because of reducing emission of greenhouse gases and therefore consumption of fossil fuels. (CarbonTrust 2008, 9-10.)

So unlikely using a biomass heating, many coal plants contain air pollution matters and toxics such as sulphur, fluorine, lead, mercury, arsenic and silica. When combusting these matters are not destroyed, but they will be released into the air in different forms. Measuring for coal and biomass total combustions, the emissions of nitrogen dioxide (NO2) were higher when burning coal than biomass materials and fuels, because generally coal burns at a higher temperature than biomass fuel. (Zhang, Smith, Ma, Ye, Weng & Jiang 2000, 4537–4549.)

Table 2. Emission regulations medium-sized combustion plants 1 MW up to 5 MW (European Union law 2015)

Pollutant	Solid biomass	Other solid fuels	Gas oil	Liquid fuels other than gas oil	Natural gas	Gaseous fuels other than natural gas
SO_2	200 (1) (2)	1 100	—	350	—	200 (3)
NO_x	650	650	200	650	250	250
Dust	50	50	—	50	—	—

Table 2 presents the emission regulations limit values (mg/Nm3) for already existing medium combustion plants, when a rated thermal input is at least equal or greater than 1MW and at the same time less than or equal to 5 MW. (European Union law 2015).

Table 3. Emission regulations medium-sized combustion plants greater than 5 MW (European Union law 2015)

Pollutant	Solid biomass	Other solid fuels	Gas oil	Liquid fuels other than gas oil	Natural gas	Gaseous fuels other than natural gas
SO_2	200 (4) (5)	400 (6)	—	350 (7)	—	35 (8) (9)
NO_x	650	650	200	650	200	250
Dust	30 (10)	30 (10)	—	30	—	—

Table 3 presents the emission regulations limit values for the MCPs greater than 5 MW. (European Union law 2015).

Table 4. Emission limit values for new medium combustion plants regulations for MCPs 1 MW up to 50 MW. (European Union law 2015)

Pollutant	Solid biomass	Other solid fuels	Gas oil	Liquid fuels other than gas oil	Natural gas	Gaseous fuels other than natural gas
SO_2	200 (19)	400	—	350 (20)	—	35 (21) (22)
NO_x	300 (23)	300 (23)	200	300 (24)	100	200
Dust	20 (25)	20 (25)	—	20 (26)	—	—

Table 4 presents the emission regulations limit values for the MCPs equal to 1 MW up to 50 MW. (European Union law 2015).

3 ANNUAL LOAD CURVE OF SOCHINSKY

The annual load curve of Sochinsky is a way to calculate district heating energy losses. In these chapters the following tables, figures and formulas are included and their meanings explained. The Sochinsky's load curve for the existing plant will be discussed in this chapter.

3.1 Theory

The annual load curve of Sochinsky is often used to measure a district heating network heat loss and it can be drawn as an annual duration line. With Sochinsky's load curve one can see the losses of the network results from the heating load curve of the district heating plant. The losses can be calculated, when the consumer load curve and the boiler load curve are compared to each other. Looking for the coincidence factor, the annual duration line of the consumer results is concentrating on the grid losses, then the heating load curve of the heating plant results may be seen. The duration line shows the annual duration of the frequency distribution of the heat load approx. 8,760 hours. (Kossak 2016.)

There are some benefits using the formula from Sochinsky that could be seen in figure 4 and figure 5. These figures show the errors when calculating the annual load curve. The error rate increases the estimation of the reduction of energy loss, which is seen in figure 5 and compared to the estimation energy loss for the network, which is seen in figure 4. The estimation of the reduction uses therefore two different energy loss appraisals for the network. The results for the appraisals are wide width and they vary between 15.0% and 19.3% in figure 5 and between 6.0% and 7.9% in figure 4. (Dickert, Hable & Schegner 2009, 6.)

Figure 4 shows the errors of the energy loss estimation for the networks for the planned reconfiguration and as well as in the actual state. Although, figure 5 shows the possible reduction of energy loss after the network has had reconfigurations. The oldest formula "Buller" has in both cases the largest error for energy loss, which can be seen in figure 4 and 5. (Dickert, Hable & Schegner 2009, 5.)

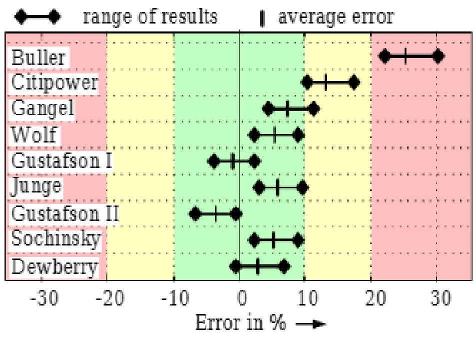


Figure 4. Errors of the energy loss estimation for the examined approximation (Dickert, Hable & Schegner 2009, 6)

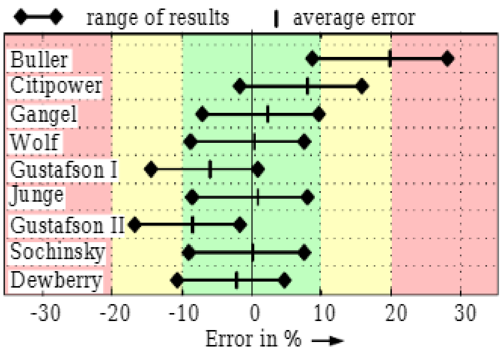


Figure 5. Error of the estimated reduction of energy loss for the networks for the examined approximation (Dickert, Hable & Schegner 2009, 6)

Although, most of the results for the reduction are placed between the range of ±10 %. The best formulas are those from Sochinsky, Wolf, Junge, and Dewberry. In these the performance is good, when concentrating on the method for the timesaving energy loss estimations. This thesis focuses on the annual load curve of Sochinsky. (Dickert, Hable & Schegner 2009, 6).

3.2 Formula of the annual load curve of Sochinsky

In figure 6 can been seen a good example for annual load curve of Sochinsky. It shows load curve in percentages for the district heating plant. Therefore, the declining line can be seen with produced heat power and the plants operating hours annually.

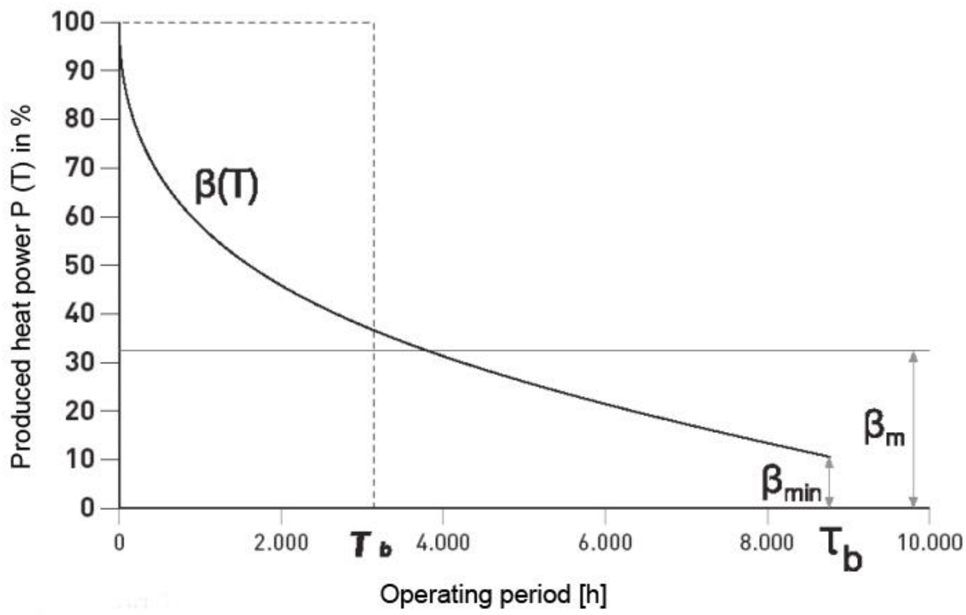


Figure 6. Annual load curve of Sochinsky (Obernberger 1997)

Equations (1) – (5) describe the annual load curve of Sochinsky

$$\beta(T) = 1 - (1 - \beta_{min}) * T^{\frac{\beta_m - \beta_{min}}{1 - \beta_m}} \quad (1)$$

$\beta(T) = \frac{P(T)}{P_{max}}$… The load in the system (2)

$T = \frac{\tau}{\tau_b}$ … Non-dimension time is equal hour per hour (3)

$\beta_{min} = \frac{P_{min}}{P_{max}}$ … The minimum load (4)

$\beta_m = \frac{Q_j}{P_{max} * \tau_b}$ …The average load (5) where

Q_j	is	annual heat consumption [kWh/a]
τ_b	is	operating period [h]
P_{min}	is	minimum heating power [kW]
P_{max}	is	maximum heating power [kW]
τ	is	time in hours [h]
T	is	non-dimension time [h/h]
β	is	load curve dimension [%]

The load curve dimension beta (β) can be calculated by power (time) divided by the maximum power. Non-dimension time could be calculated time in hours divided by operating period in hours annually. The minimum heating power is the minimum power divided by the maximum power and therefore the average load is the annual heat consumption divided by maximum power times the operating period in hours.

3.3 Heating load curve of district heating plants

Sochinsky's heating load curve shows the heat losses in annual declining line. In figure 10 can be seen the heat losses by the consumer and by the boiler. On the y-axis is marked the heat load in kW and on the x-axis are the operating hours referred to the heating season. With this figure one may see the heat losses between the consumer and boiler load. The consumer load line describes heat load by consumer and the boiler load line heat load by boiler. The area between these two lines are the heat losses and the gap between them should be as small as possible or otherwise the plant's efficiency is not the best as possible.

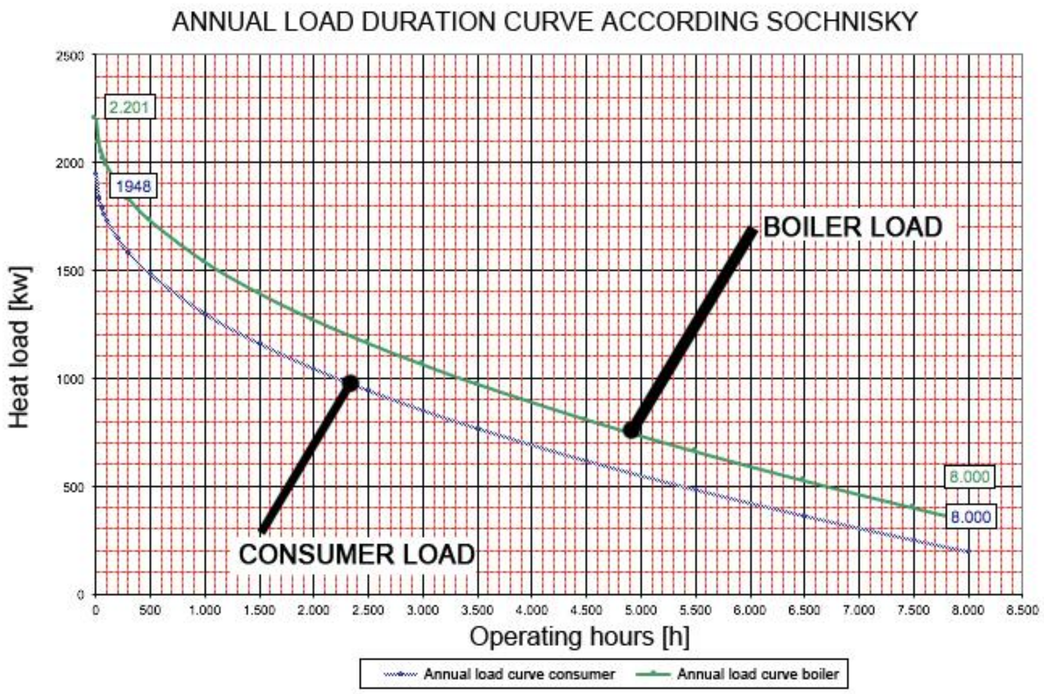


Figure 7. Example for an annual load duration curve according Sochinsky (Kossak 2016)

In figure 7 is an example of an annual load curve of Sochinsky. This figure shows the consumer load and the boiler load difference and the gap between them. The gap shows annual heat losses in this example and the Seitenstetten biomass heating plant has a similar load curve of Sochninsky described later in this thesis.

3.3.1 Annual load curve in Seitenstetten

The research group of Brustmann, Catic, Dörsch, Hofko, Lengheim and Wegscheider calculated the annual load curve by Sochnisky for the existing biomass heating plant. The following results may be seen in figure 8. This figure shows the annual load curve of Sochinsky for the existing biomass heating plant in Seitenstetten.

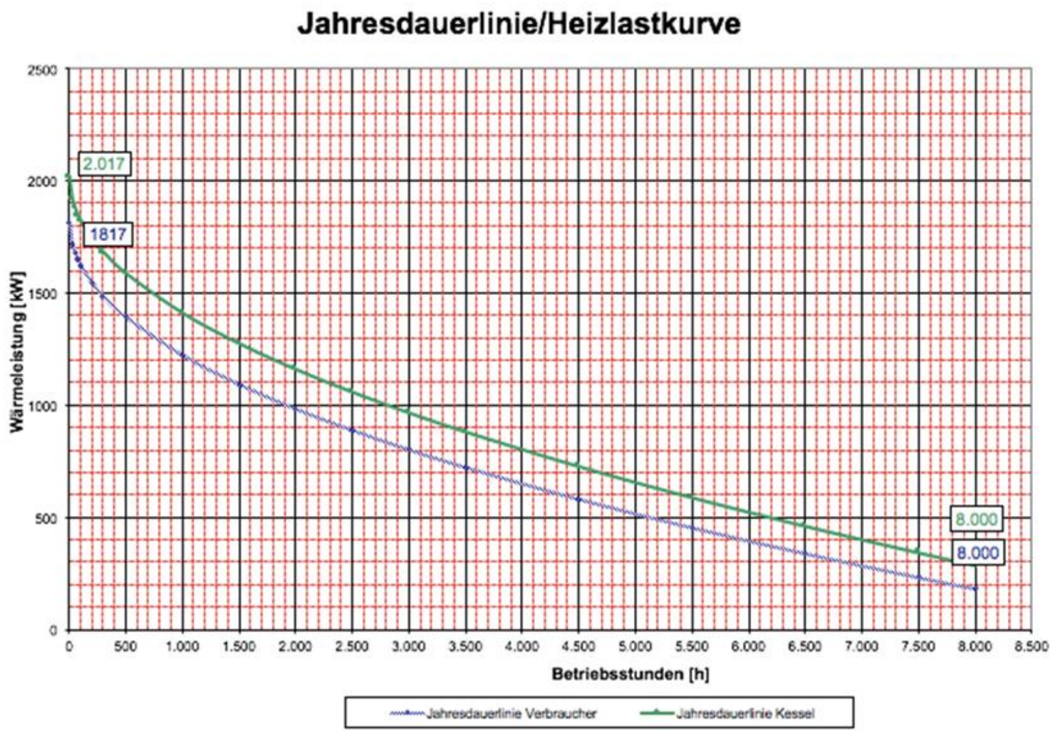


Figure 8. Existing annual load curve of Sochinsky (Brustmann, Catic, Dörsch, Hofko, Lengheim & Wegscheider 2018)

In figure 8 may be seen the annual load curve of existing plant in Seitenstetten. The maximum boiler load is 2,201 kw and the maximum consumer load is 1,948 kw. The area between these two lines illustrates the heat losses and this figure shows the annual load curve in operating hours up to 8,000 hours.

4 DESCRIPTION OF SEITENSTETTEN DISTRICT HEATING PLANT

This chapter concentrates on the existing biomass heating plant in Seitenstettnen. It consists of general information and technical data from the system. The first plant was built around 30 years ago, and the history of the plant will be also under the investigation in following chapters.

4.1 Design and development of the plant

The original district heating plant in Seitenstetten in lower Austria was built in 1986. After 30 years, a new district heating plant was rebuilt in 2015 and 2016 due to the age of the old plant. The pipeline network consists of two branches, which were built in two different years. The first was built in 1986 and the second in 2005. The planned northern extension will be connected to the pipeline network in the future. (Latschenberger 2016, 7.)

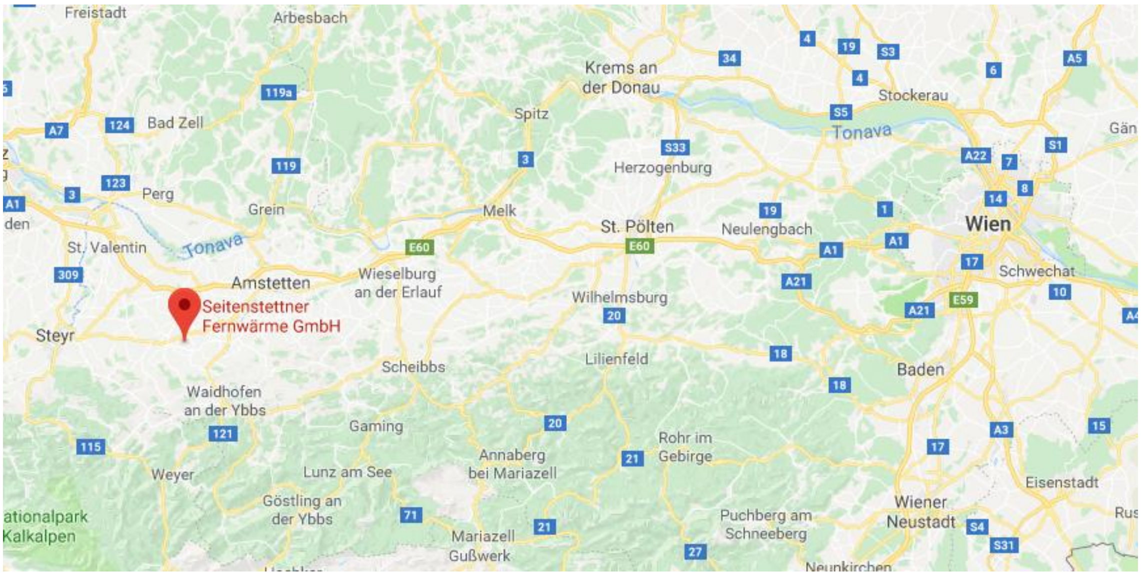


Figure 9. The location of the biomass heating plant (Google Maps 2018)

The pipeline network of the district heating plant is designed in the form of a radial layout and it is designed and dimensioned with reserves. This kind of network system is different from the so-called ring network. These different network systems can be seen below in figure 10.

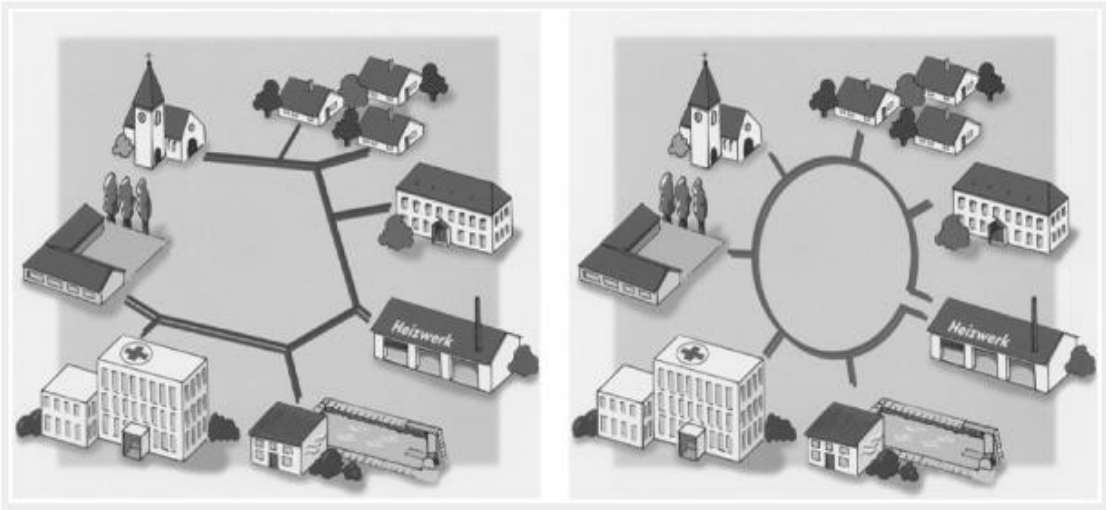


Figure 10. On the left side is network with radial layout and on the right side the network with the ring layout (Energy-Mag 2015)

The length of the existing network is approximately 5,000 meters. Hence, this network has 65 different-sized households, from detached houses to large customers. They have a total connected load of approx. 3,800 kW. There is one of the customers, who is called Stift Seitenstetten and has connected a load of approx. 1,500 kW. The other customers are, for instance supermarkets, a shopping center, a pizzeria, a kindergarten, an elementary school, an upper secondary school, etc. (Latschenberger 2016, 10.)

Figure 11. 3D design for the new heating plant (Latschenberger 2016)

4.2 Heating network

The original heating network was built in 1986 and it was only designed for the biggest customer “Stift Seitenstetten”, being the only one, which was supplied with heat and therefore the biomass boiler was designed only for this customer. The first extension, built in 2005, was a major improvement for the existing network. However, there was a problem with the extension since the output of the boilers was not increased. Due to this, the biomass heating boiler did not meet the requirements of the extended network. To supply the heat for the new customers an additional oil boiler had to be put into operation. Because of the next severe winters, the oil consumption raised up to 40,000 liters. This was leading to business inefficiency. (Latschenberger 2016.)

The new heating plant was designed in 2015/16 and it used different kinds of pipes than in 1986. Back then, single pipes made from steel were used and the pipelines for flow and return were buried separately. The single pipes were used also in the extension in 2005, but these were made particularly from steel and plastic. Later in the extension in 2015 and 2016 single pipes made from steel were used by Logstor. (Latschenberger 2016.)

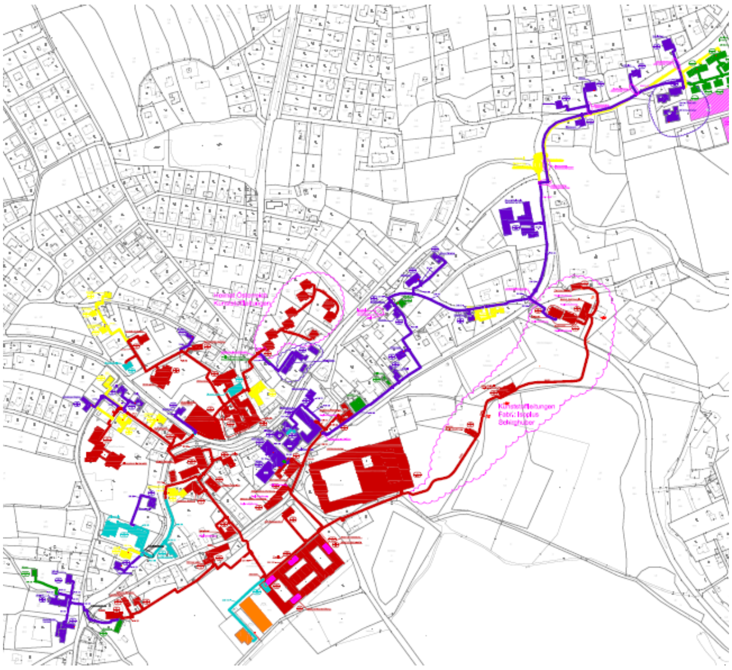


Figure 12. The existing layout of the network of Seitenstetten (Latschenberger 2016)

In figure 13 can be seen the extension area for the new district heating.

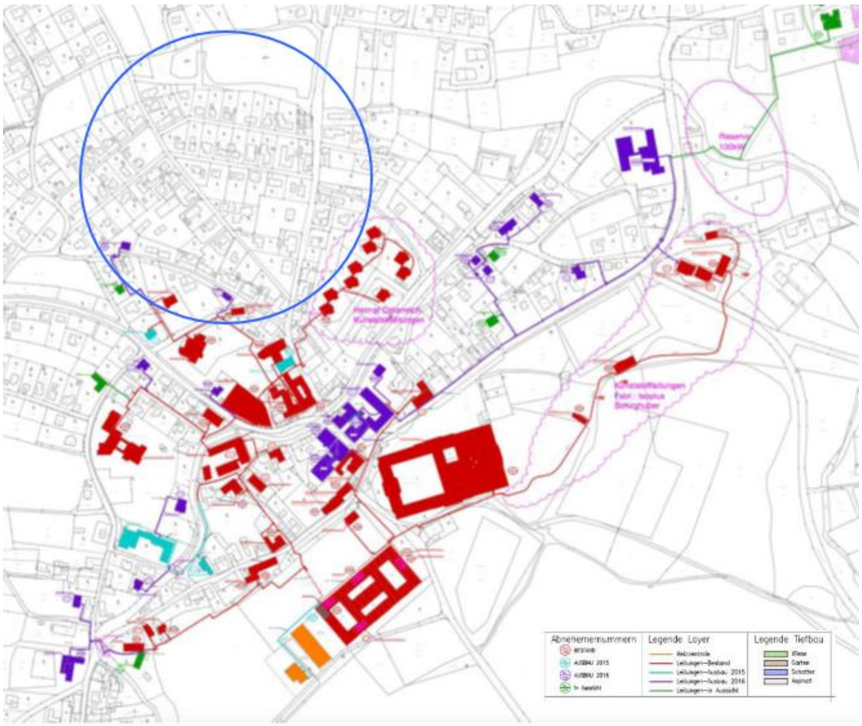


Figure 13. The extension layout of the network of Seitenstetten (Brustmann, Catic, Dörsch, Hofko, Lengheim & Wegscheider 2018)

4.3 Excursion of Seitenstetten

The first excursion to Seitenstettner Fernwärme GmbH was made in the middle of December. The main purpose of the excursion was to collect some technical data, take pictures and meet the owner of the company. The excursion was also the first step into the thesis.

The visit to the biomass mass district heating plant in Seitenstetten was on Thursday 14th of December. The first excursion was eight hours long and there were also the owner of the heating plant Mr. Paul Latschenberger and other researchers. The excursion was completed in a cooperation with UAS Technikum Wien and Seitenstettner Fernwärme GmbH heating plant.

The main purpose of the excursion was to investigate the land field and get a better idea of the existing district heating plant. The district heating plant is in lower Austria in a small town called Seitenstetten that has around 3,000 inhabitants.

4.4 Plant description

The excursion and how the district heating plant works in real life opened the main idea of the thesis. The specific information was collected about it and many pictures were taken for later usage. The plant was renovated around two years ago by the owner and it was easy to see. The biomass boilers and the furnaces were manufactured around two years ago in 2015/16. The biomass fuel so as the wood chips and other biomass fuel materials were stored outside. It was pushed under a shelter and it was mostly wet up to 50% moisture. As it is known that the biomass fuel should be dry, but some of it was totally outside without any safety and completely wet also. It proved the owner does not buy or use always the best biomass fuel for the furnaces. They use mainly cheap and wet biomass fuels.

Figure 14. Biomass fuel stored outside

Figure 15. Twin pipes in Seitenstetten

The visit to the plant gave a huge advantage and the owner gave the important statistics about the furnaces and the working methods. The plant comprises a smaller vessel, which has a nominal heat output of 500kW and the bigger one has a nominal heat output of 2,000kW.

Figure 16. AVR 2000 vessel fully operating

The district heating plant was running at full capacity and the machines were working. There was a specific machine for the biomass fuel, which was pushing automatically the right amount of fuel into the furnace. This was located inside of the heating plant. The first excursion and the research in the heating plant gave considerable insights into the thesis.

Figure 17. On the right side is the bigger vessel “AVR 2000” and on the left side the smaller vessel “AVR 500”

5 OPERATION RESULTS OF THE EXISTING PLANT

This chapter concentrates on the results of the existing biomass heating plant in Seitenstetten. In following chapter consumers information, coincidence factor current operation and the operational data will be provided. At the end of the chapter five the results and summary can be seen.

5.1 Current operation and technical design data

Seitenstetten biomass heating plant has currently 72 consumers and the expected number of consumers will be 107 after the planned extension. The collected and following data is provided by the current consumers. The current operation data and design has been collected for example, from the boiler load, the fuel load, heat losses by annual load curve of Sochinsky, fuels and the emissions of the plant. Technical design data includes the main excel data, which is provided by the simulation program VeriNa. (Brustmann, Catic, Dörsch, Hofko, Lengheim & Wegscheider 2018.)

5.1.1 Coincidence factor

The coincidence factor is a value that depends on the heat consumers and it describes the maximum demand of the consumers in a specific period and to add up the maximum demands within the same period. The factor takes in concern that all consumers are not operating at same time in the district heating network and not the same time at fully load. The coincidence factor is dependent on the number of customers and this can be seen below in figure 18. (Brustmann, Catic, Dörsch, Hofko, Lengheim & Wegscheider 2018, 15; Energy.eu 2018.)

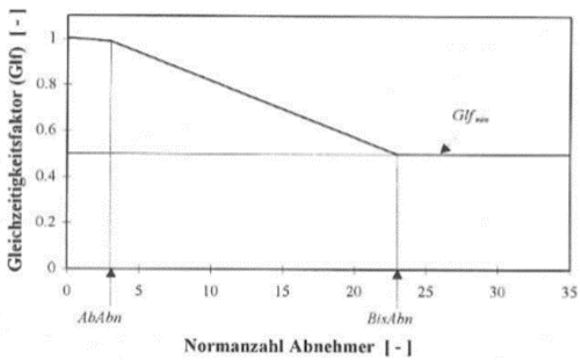


Figure 18. The coincidence factor by consumers (Bios-bioenergy 1997)

The coincidence factor declines from value 1 slowly until three consumers and then declines linear line until 23 consumers. After 23 consumers the coincidence factor will stay no matter of the value of 0.5. Therefore, this is the ratio of the maximum installed heat output and the coincidence factor is always under 1 and between 0.5 for the whole district heating plant. The connected load of all the loads is then multiplied by this coincidence factor. (Brustmann, Catic, Dörsch, Hofko, Lengheim & Wegscheider 2018, 15.)

5.1.2 Heat load of current operation

The consumer load of the current existing operation in Seitenstetten by 72 consumers is 3,633 kW and the mean value of the single consumer full load hour is 1,577 hours per year. The maximum connected consumer load of 1,817 kW considers the coincidence factor of 0.5 which is constant after more than 23 consumers (see figure 18). This corresponds with the amount of the annual consumer heat of 5,730,200 kWh/a. (Brustmann, Catic, Dörsch, Hofko, Lengheim & Wegscheider 2018, 32.)

Equation (6) describes the coincidence factor with 72 consumers.

$$\dot{Q}_{max} = \dot{Q}_N \cdot F_{Glz} = 3{,}633 \cdot 0.5 = 1816.5\ kW \approx 1{,}817\ kW \quad (6)$$

where

Q_{max} is maximum connected load [kW]
Q_N is consumer load [kW]
F_{Glz} is coincidence factor

The table in appendix 3 shows all consumers from one to seventy-two and their data for the simulation program VeriNa, such as the type, the heated surface, the connected load, the user full load time and the consumers heat annually in kWh/a.

5.1.3 Boiler load

The existing biomass heating plant consist of two different biomass boilers, which can be seen in figure 23. These boiler loads include the boiler 1 (BMB1), the boiler 2 (BMB2) and the oil boiler (OiB). The operation is working with two different possibilities and with three different boilers. The operation depends on the flow temperature of the network (90/60°C; 85/55°C) and the outside air temperature. (Brustmann, Catic, Dörsch, Hofko, Lengheim & Wegscheider 2018, 43-44.)

The total heat losses of the network with SFT/RFT 90/60°C and minimum outside air temperature of -13°C are 1 467 880 kWh, which corresponds to 20% of the energy provided by the heating plant in Seitenstetten. The other network temperature of SFT/RFT 85/55°C causes heat losses of 1 227 771 kWh, which is around 18% of the provided energy. (Brustmann, Catic, Dörsch, Hofko, Lengheim & Wegscheider 2018, 39-40.)

This does not really affect the boiler operation mode of the plant. The bigger heat losses of the network with 90/60°C increases the maximum boiler load from 2017 kW to 2052 kW. This could be done by a parallel operation of BO1 and BO2 or even by the OiB. The performance of the three boilers is described in table 5.

Table 5. Maximum boiler load by SFT/RTF 85/55°C or SFT/RFT 90/60°C (Brustmann, Catic, Dörsch, Hofko, Lengheim & Wegscheider 2018)

Boiler	**Maximum boiler load**	**Partial load (30%)**
BO1	2000 kW	600 kW
BO2	500 kW	150 kW
OiB	2000 kW	--

Below in figure 19 can be seen the annual load curve of Sochinsky at 85/55°C. Between the two lines can been seen the heat losses. The amount of heat losses grows a little bit compared to 90/60°C and this annual load curve can be seen in figure 20.

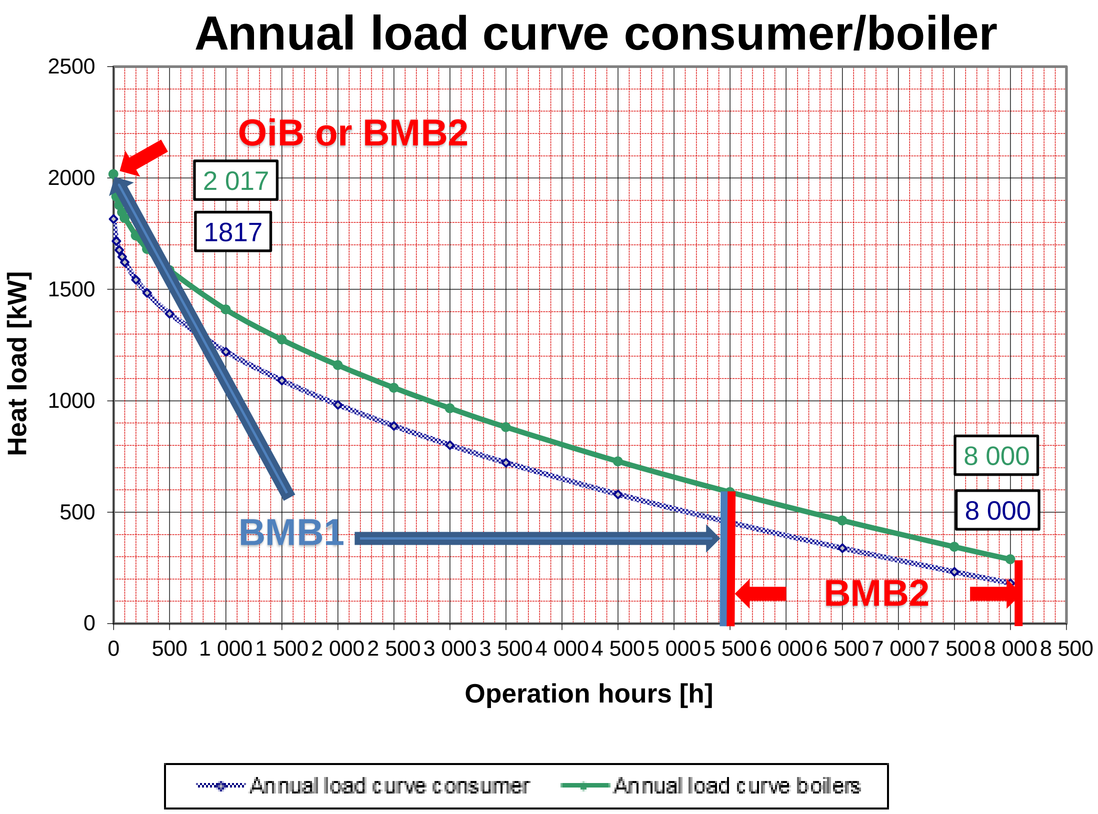


Figure 19. Annual load curve of Sochinsky for the existing plant (Brustmann, Catic, Dörsch, Hofko, Lengheim & Wegscheider 2018)

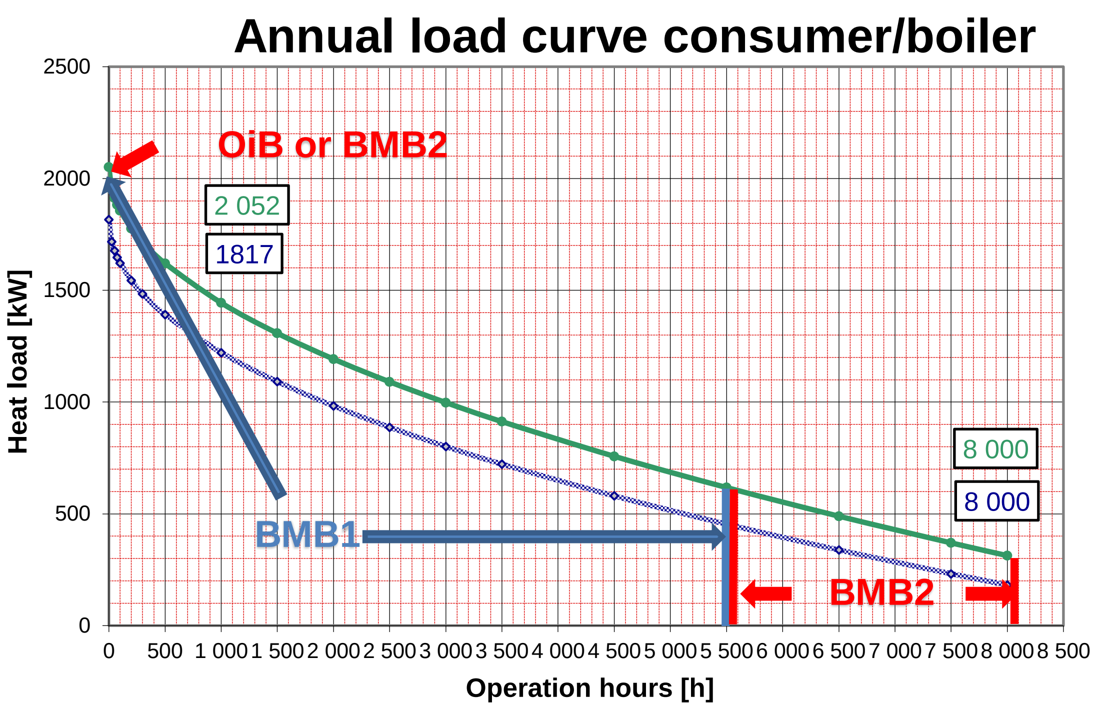


Figure 20. Annual load curve of Sochinsky for the existing plant (Brustmann, Catic, Dörsch, Hofko, Lengheim & Wegscheider 2018)

5.1.4 Fuels

The heating plant uses two different kind of wood chips, such as W30 (water content of 30% of weight) and W50. They have different specification, for example the heat value in kWh/kg and density in kgFS/m³ (kilogram fresh substance per cubic meter). W30 values are 3.43 kWh/kg and 250 kgFS/m³ and W50 specifications are 2.25 kWh/kg and 340 kgFS/m³.

Table 6. Fuels for the existing plant in Seitenstetten.

Type	Heat value kWh/kg	Density kgFS/m3	Water content %
W30	3.43	250	30
W50	2.25	340	50

5.1.5 Pipelines for the network

The pipelines are named and drawn for the existing network below in figure 21. These lines will be used in the data, which is provided in the following chapters.

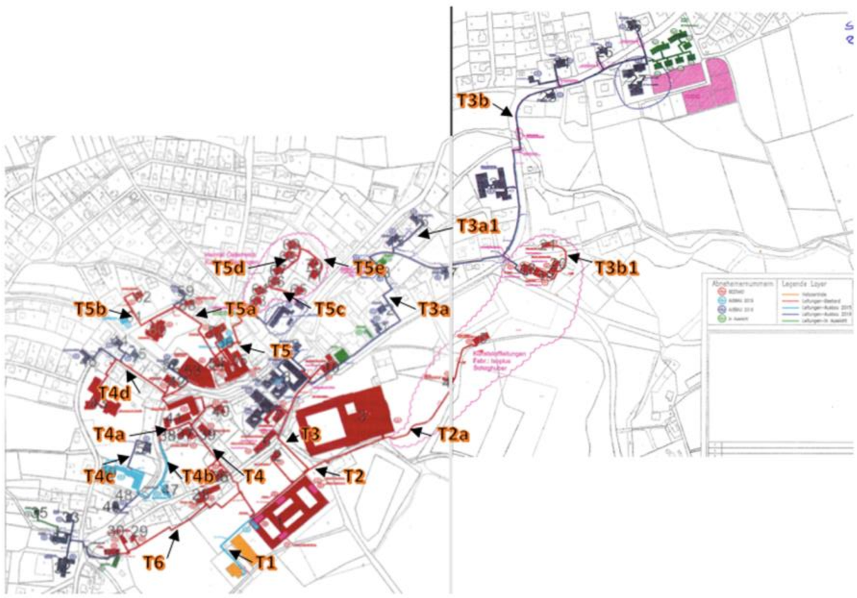


Figure 21. Pipe lines network for the existing plant in Seitenstetten (Brustmann, Catic, Dörsch, Hofko, Lengheim & Wegscheider 2018)

5.2 Results and summary

Following results are collected from the existing plant in Seitenstetten. These results will be compared with the results with the extension later. The main difference will be in the number of consumers, heat amounts, the network length and mainly in heat losses. This summary is carried out for the further analysis about the extension and the plant. These results are listed below in the table 7 and they are collected in 2017 by Brustmann, Catic, Dörsch, Hofko, Lengheim & Wegscheider. All data are verified by the operator of Seitenstettner Fernwärme GmbH.

Table 7. Results from the existing plant (own illustration including data from (Brustmann, Catic, Dörsch, Hofko, Lengheim & Wegscheider 2018)

Number of consumers	72
Connected heat load consumers	3,633 kW
Coincidence factor	0.5
Connected heat load with CF	1,817 kW
Consumer full load hours	1,577 h/a
Annual consumer heat	5,730,200 kWh/a
Network length	5,652.5 m
Maximum power of the plant (90/60)	2,052 kW
Maximum power of the plant (85/55)	2,017 kW
Heat losses (SFT/RFT:90/60)	1,467,880 kWh/a
Heat losses (SFT/RFT:85/55)	1,227,771 kWh/a
Annual heat by the plant (90/60)	7,208,804 kWh/a
Annual heat by the plant (85/55)	6,957,971 kWh/a
Plant full load hours (90/60)	3,513 h/a
Plant full load hours (85/55)	3,450 h/a

So far, the main information and data from the existing plant is provided fully in chapter 5.

6 HEAT DISTRICT NORTH EXTENSION

This chapter concentrates the northern extension part of the heating plant in Seitenstetten. It will include the general information, data for the simulation, the gird design and introduce the steel twin pipes. Following chapter is important for the result, when the data will be compared to the operational data in chapter 7.

6.1 General information about the extension

There will be a big extension in the future for the district heating plant in Seitenstetten, which will increase the number of the consumers from 72 up to 107 consumers. These future consumers will be connected more likely to the new district heating network as soon as possible. The preparation for the extension is done carefully and by investigating the best possibilities to build the most efficient network for its consumers and the company. (Brustmann, Catic, Dörsch, Hofko, Lengheim & Wegscheider 2018, 47.)

The consumers full load hours are set in the program by the same way, as the old 72 consumers were in page in figure. New consumers data will be set on the excel based program that calculates the potential amount of heat for the described extension. For this reason, it can use earlier equation (6) from chapter 5.1.2 to calculate the maximum connected load, which can be seen below in the equation. (Brustmann, Catic, Dörsch, Hofko, Lengheim & Wegscheider 2018, 48.)

Equation (7)

$$\dot{Q}_{max} = \dot{Q}_N \cdot F_{Glz} = 4{,}147\ kW \cdot 0.5 = 2{,}073.5\ kW \approx 2{,}074\ kW \qquad (6)$$

The following approx. 2,074 kW is the maximum connected load after the extension and calculated by the equation (6) with the coincidence factor of 0.5. The maximum connected load is equal to connected load times the coincidence factor after 23 consumers.

In the table below can be seen the basic summed-up data from the district heating plant extension and existing part. The results include basic information, such as heat losses with different flow temperatures, the number of consumers and maximum power of the plant.

Table 8. Results from the extension plant (own illustration including data from Brustmann, Catic, Dörsch, Hofko, Lengheim & Wegscheider 2018)

Number of consumers	107
Connected heat load consumers	4,147 kW
Coincidence factor	0.5
Connected heat load with CF	2,074 kW
Consumer full load hours	1,553 h/a
Annual consumer heat	6,441,400 kWh/a
Network length	6,877.5 m
Maximum power of the plant (90/60)	2,115 kW
Heat losses (SFT/RFT:90/60)	1,980,720 kWh/a
Annual heat by the plant (90/60)	8,203,569 kWh/a
Plant full load hours (90/60)	2935 h/a

6.2 Consumers of the extension

The number of consumers for the extension is 35 in the north of district Seitenstetten. The total connected load is 4,147 kW and the total consumer heat is 6,441,400 kWh/a. The figure x shows all consumers from one to 107 and their data for the simulation program VeriNa, such as the type, the heated surface, the connected load, the user full load time and the consumers heat annually in kWh/a. This table includes the existing consumers the consumers from the extension part and it can be seen in appendix 4 1-3(3).

6.3 Network design

The network design is tentatively premeditated for the northern extension in Seitenstetten. This design is simply drawn by yellow lines 7, 7a, 7b, 7c and 7d. Hence, this is the excepted pipeline network and the following suggestion is described below in figure 22.

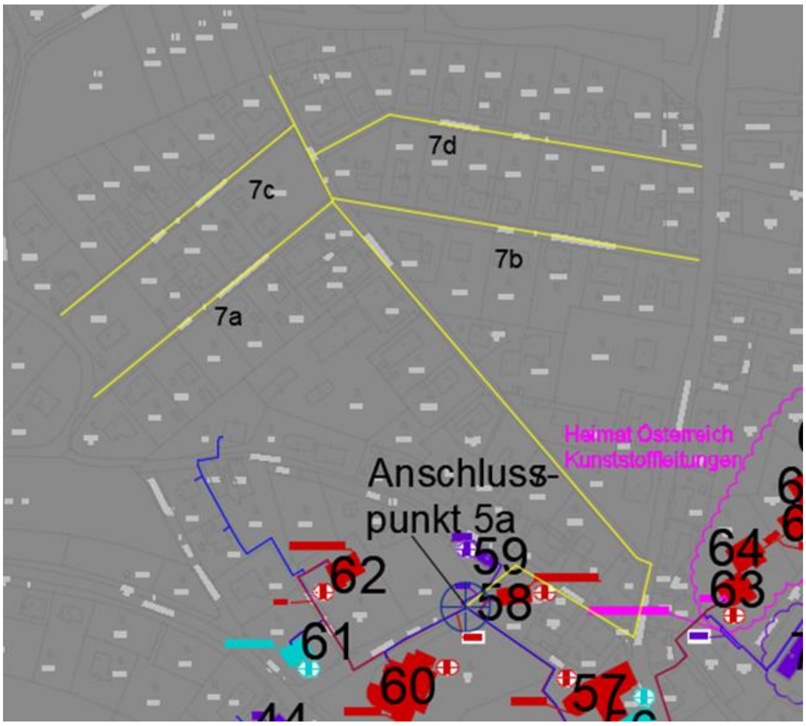
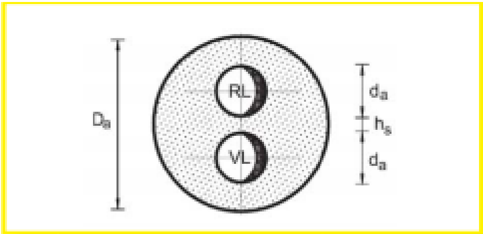


Figure 22. Pipeline network design for the extension (Brustmann, Catic, Dörsch, Hofko, Lengheim & Wegscheider 2018, 55)

6.4 Steel twin-pipes

The extension will be done with new kind of steel twin pipes, which are better insulated than the old ones in the existing network. The existing network includes steel and plastic pipes. By the time pipe markets has changed a lot and these twin pipes are more efficient by every specification for the consumers and the district heating system. These steel pipes are made from company called by IsoPlus. In figure 23 can be seen all relevant data for building a new network with these twin pipes.



Dimensions respectively Types

Dimensions Steel Pipe P235						Dimensions Jacket Pipe PEHD: PEHD-Jacket Pipe Outside-Ø • Wall Thickness D_a • s in mm — Insulation Class / Delivery Length L in m												Clear Pipe-distance h_a in mm	Weight G without water in kg/m (s according to isoplus) — Insulation Class		
Type	Nominal Diameter / Dimension in: DN	Inch	Outside-Ø d_a in mm	Wall-thick-ness acc. to isoplus s in mm	Wall-thick-ness acc. to EN 253 s in mm	Standard	6	12	16	1x reinf.	6	12	16	2x reinf.	6	12	16		Stand.	1x rf.	2x rf.
DRD-20	20	3/4"	2 • 26,9	2,6	2,0	125 • 3,0	√	-	-	140 • 3,0	√	-	-	160 • 3,0	√	-	-	19	5,32	5,70	6,24
DRD-25	25	1"	2 • 33,7	3,2	2,3	140 • 3,0	√	√	-	160 • 3,0	√	√	-	180 • 3,0	√	√	-	19	7,03	7,57	8,16
DRD-32	32	1¼"	2 • 42,4	3,2	2,6	160 • 3,0	√	√	-	180 • 3,0	√	√	-	200 • 3,2	√	√	-	19	8,86	9,45	10,20
DRD-40	40	1½"	2 • 48,3	3,2	2,6	160 • 3,0	√	√	-	180 • 3,0	√	√	-	200 • 3,2	√	√	-	19	9,72	10,31	11,06
DRD-50	50	2"	2 • 60,3	3,2	2,9	200 • 3,2	√	√	-	225 • 3,4	√	√	-	250 • 3,6	√	√	-	20	12,79	13,80	14,91
DRD-65	65	2½"	2 • 76,1	3,2	2,9	225 • 3,4	√	√	-	250 • 3,6	√	√	-	280 • 3,9	√	√	-	20	16,02	17,13	18,65
DRD-80	80	3"	2 • 88,9	3,2	3,2	250 • 3,6	√	√	-	280 • 3,9	√	√	-	315 • 4,1	√	√	-	25	18,88	20,40	22,25
DRD-100	100	4"	2 • 114,3	3,6	3,6	315 • 4,1	√	√	√	355 • 4,5	√	√	√	400 • 4,8	√	√	√	25	27,73	30,24	33,25
DRD-125	125	5"	2 • 139,7	3,6	3,6	400 • 4,8	√	√	√	450 • 5,2	√	√	√	500 • 5,6	√	√	√	30	36,95	40,76	44,99
DRD-150	150	6"	2 • 168,3	4,0	4,0	450 • 5,2	√	√	√	500 • 5,6	√	√	√	560 • 6,0	√	√	√	40	47,90	52,13	58,54
DRD-200	200	8"	2 • 219,1	4,5	4,5	560 • 6,0	√	√	√	630 • 6,6	√	√	√	-	-	-	-	45	70,39	77,78	-

Figure 23. IsoPlus steel twin pipe P235 (IsoPlus 2018)

6.5 Preparation of design data for the simulation

The data, which is collected earlier and introduced in chapters 6.1-6.5 will be used in chapter 7. The main purpose is to compare the data with existing information provided by the simulation program and afterwards in this thesis the information will be shown by the program. The excel data is shown precisely in chapter 6.3 and appendices. The following chapter includes the important data, information and specifications that the simulation could be done properly.

The problem is to simulate the data with the excel based calculation program while there is the difference between the steel and plastic pipes, therefore also difference between twin and single pipes. In three decades the heating plant has been using different kinds of pipes with different specifications, such as the twin pipes in the extension part. This will be discussed later in chapter 7, but otherwise the preparation of design data is ready for the simulation.

7 SIMULATION OF THE DISTRICT HEATING PLANT- NORTHERN EXTENSENSION

The simulation of the existing district heating plant for single and twin pipes is made by an excel based program called “VeriNa”. This program will help to verify the operation data of the district heating plant and focusses especially on the heat losses of the new twin-pipe section of the plant. The simulation program consists of several different calculation sheets and this chapter will describe how the program works and how the calculation sheets correspond to each other. The main task was to find a solution for calculating heat losses for insulated twin-pipes and the theoretical equations. These equations can be seen in the following chapters.

7.1 Simulation of the district heating plant

The main purpose of the thesis was to integrate a new feature to calculate the heat losses of twin-pipe installations for optimised district heating networks. Therefore, the program includes now one new sheet “Twin-pipe losses calculation” for calculating the heat losses for buried insulated twin-pipes. This theory is taken from Wallentén’s model. The corresponding sheet “Twin-pipe formulas” consists of the instructions to understand these equations. The exact equation of Wallentén can be seen in chapter 7.3.1.

The existing and extension part includes different kinds of pipe lines, some of them are constructed with traditional kind of single pipes. Anyhow, the research of the thesis mainly concentrates on the extension part in the northern district, which will have a new kind of steel twin pipes. The program is developed with the new solution and therefore it can calculate the heat losses for twin-pipes too.

These new kind of twin pipes have a lower conductivity of the insulation than single pipes and this should already decrease the heat losses by itself. The existing single pipes are from 1986 and some of them are even from 2015 and 2016. Their conductivity of the insulation differs from 0,038 to 0,024 W/mK and the twin-pipe at 0,027 W/mK. The new model for twin pipes integrates not only the conductivity but the whole heat losses of pipe system in W/m.

7.1.1 Data-Annual Load Curve-Consumer

The Data-ALC-Consumer sheet is redesigned for this thesis implementing the number of consumers including the extension part. In fact, the total number of consumers is “107”, including the extension part. The maximum number of consumers, which can be simulated with the program is extended up to 150 customers. See the actual screenshot in table 9.

Table 9. The screenshot of the sheet “Data-Annual Load Curve-Consumer”

Nr.	**Consumer name**	**Type**	**Heated area**	**Connected consumer load**	**Consumer full load hours**	**Consumer heat**
			[m²]	[kW]	[h/a]	[kWh/a]
107	TOTAL heat consumers			**4229**	**1 468**	**6 206 885**
1	Landgashof Patzalt + Meierhof	Restaurant	2 500,00	300	33	10 000
2	EFH Altbau (Stift Rosengarten)	EFH	120,00	15	1 002	15 033
3	Stift	Church	2 500,00	1 200	6	7 794

The following information about the consumer have to be given in the table such as, “Consumer name”, “Type”, “Heated area”, “Connected consumer load” and “Consumer heat”. The results of the total values are shown in the first horizontal line of the table.

The coincidence factor “CF” is automatically calculated depending on the total number of heat consumers.

Define the maximum operating hours “τ_b” of each consumer from zero to a maximum of 8,760 h/a.

The minimum power of the consumer heating load has to be given in the vertical line of each consumer (Pmin in kW).

7.1.2 Annual Load Curve of Sochinsky

The sheet shows a diagram of two characteristically time dependent load curves

- Annual load curve of consumers
- Annual load curve of boilers

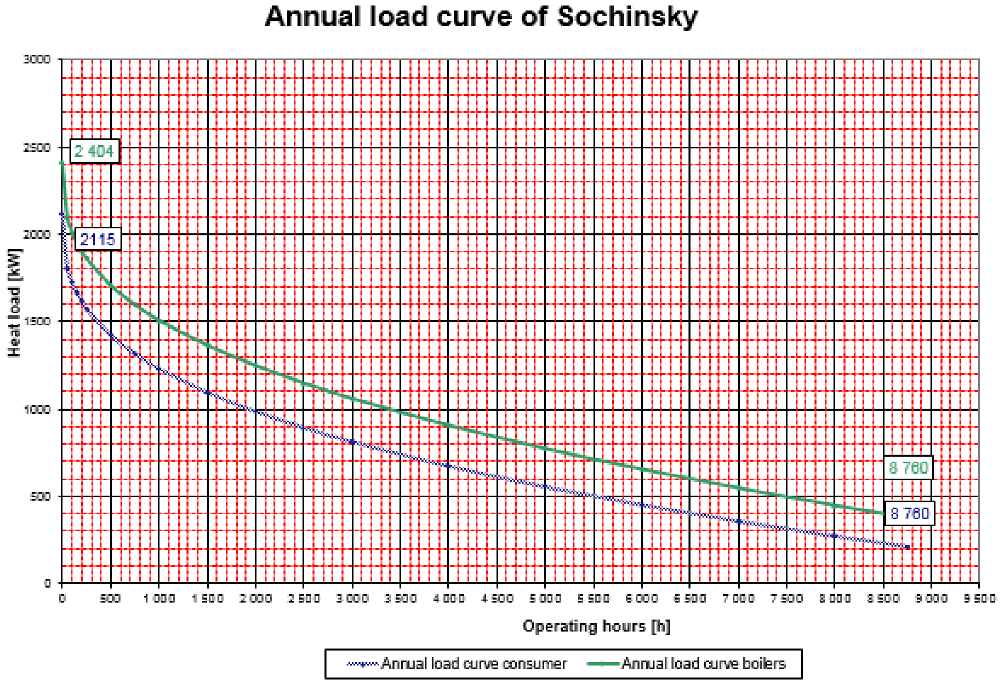


Figure 24. The example of the annual load curve of Sochinsky

The following information is given:

- The maximum heat load of consumers and boilers
- The maximum of operating hours

The data correspond with the sheet “Data-Annual Load Curve-Boilers”.

7.1.3 Data-Annual Load Curve-Boilers

First fill in the basic design data of the location “Seitenstetten”.

Table 10. The basic design data of “Data-Annual Load Curve-Boilers

Seitenstetten Dorf	Day	Temperature	Unit
Min. Temperature			°C
Max. Temperature			°C
Heating limit (Austria +12 C Germany +15 C)		12	°C
Standard outside temperature DIN EN 12831; OIB-Richtlinie 6		-14,1	°C

The standard outside temperature according to DIN EN 12831(Germany) and OIB-Richtlinie 6 (Austria) defines the minimum calculation temperature which affects the design of the max. pipe heat losses and pipe dimensions.

The heating limit temperature is the maximum outside temperature, which defines the end of the heating season. The value of Austria is given 12°C and it is a little bit different compared to the value of Germany, which is 15°C.

Predesign of biomass boiler (BMB) according to a manufacturer has to be given by the certain values. See table 11.

Table 11. Predesing of the boiler (BMB)

Predesign of biomass boiler BMB:			**Standard values**
Consumer heat:	6 206 885	[kWh/a]	
Network losses presumed :	30	[%]	20-30 %
Boiler heat:	8 866 979	[kWh/a]	
Share of biomass boiler heat BMB:	90	[%]	>80 %
Full load hours BMB presumed:	4000	[h/a]	>4000 h/a
Pmax, BMB presumed:	1995,1	[kW]	
Pmax, BMB selected:	2000	[kW]	acc. manufacturer
Pmin, BMB selected:	500	[kW]	acc. manufacturer
Fuel type BMB	Wood chips		
Water content	50	[%]	
Lower heating value	9,50	[MJ/kg]	
Fuel type OiB/GaB	Fuel oil		
Lower heating value	10,00	[kWh/l]	
Lower heating value	36,00	[MJ/l]	
Lower heating value	42,60	[MJ/kg]	
Density	0,845	[kg/l]	

The user has to decide the net heat power of the boiler (BMB) corresponding with the total net heat power of the boiler house. These data have to fulfill the manufacturer proposal of the maximum load (Pmax, BMB) and minimum load (Pmin, BMB). To complete the energy balance of the fuel heat of the boiler and oil and gas boiler (OiB/GaB) the user has to implement the data for the boiler efficiency according to manufacturer data. The load is dependent on the efficiency.

7.1.4 Network pipe data

The Network pipe data sheet is designed to calculate the annual heat losses. The user has to define the dimensions of the pipes, line length, supply flow temp.-SFT and return flow temp.-RFT and has to define/calculate the heat load of the pipe entrance. The following example can be seen in table 12.

Table 12. Network pipe data

		Total column	Pipes 1 Single New 2015	Pipes 2 Single Old 1986	Pipes 2a Single Old 1986	Pipes 3 Single Old 1986
Dimension	[mm]	DN	DN 150	DN 150	DN 50	DN 65
Inside diameter Pipe	[mm]		159,3	159,3	41	67,1
Outside diameter Pipe	[mm]		168,3	168,3	50	76,1
Outside diameter Insulation	[mm]		250	250	110	140
Material Pipe			Steel	Steel	Plastic	Steel
Line length	[m]	**5652,5**	151,5	280	260	231
Flow temperature	[°C]	**90**				
Return Flow Temperature	[°C]	**60**				
Heat load Pipe entrance	[kW]		2133,45	1339,25	33	480,48
Velocity	[m/s]		0,64			

After filling the data, the user may calculate the heat losses for every pipe line in the sheets “Single pipe heat loss calculation” and/or “Twin-pipe heat loss calculation”. After calculating each pipe section separately, the user has to copy the result to the sheet “Network pipe data”.

7.2 Single pipe losses calculation

The single pipe equation calculates the total heat losses for buried single pipes. These equations have been verified to be correct and they can be found on the sheet “Single pipe heat loss calculation”.

The user has to give the basic data of the single pipes such as, basic dimensions, laying depth, ground and insulation conductivities and temperatures. After filling up the right information the program calculates the heat loss for the pipe section. See the example below in table 13.

Table 13. The example of the sheet “Single pipe losses calculation”

Nominal pipe size:	150	DN [mm]		Network len	63	m		
Outside temperature	Outside temperature	SFT Temp.	SFT Temp.	RFT Temp.	RFT Temp.	Center distance RL	Laying depth	WLK Ground
[°C]	[K]	[°C]	[K]	[°C]	[K]	[m]	[m]	[W/m*K]
-30	243,15	90	363,15	60	333,15	0,26	1	1,6
-29	244,15	90	363,15	60,00	333,15	0,26	1	1,6

WLK Insulation	Inside diameter of insulation	Outside diameter of insulation	Ground surface temperature	S	Qloss	Network losses
[W/m*K]	[m]	[m]	[K]	[-]	[W/m]	[kW]
0,024	0,0483	0,11	243,15	0,106	35,449	2,23
0,024	0,0483	0,11	244,15	0,106	35,111	2,21

The sheet “Singe pipe formula” includes the explanations and theory for calculating heat losses. In this sheet the user may change the to calculate the total heat losses. This sheet is made for verifying the equation that is used in the verification program. It is meant to educate the user that the program would be easy to use.

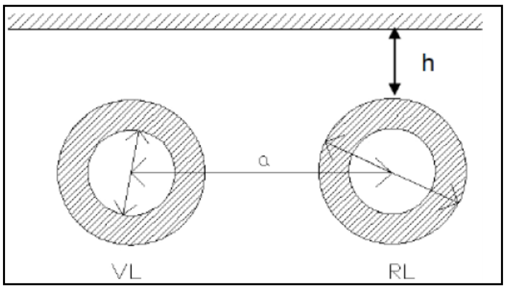


Figure 25. Single pipes example of the sheet “Singe pipe formula”

7.3 Twin-pipe losses calculation

The twin pipe heat loss calculation comes from Wallentén's theory and it calculates the heat losses from buried insulated twin pipes. This thesis refers to two equations from Wallentén's theory, the so called "Zero order formulas" and the "First order formulas". These equations calculate the heat losses from buried insulated twin pipes and the equations can be found in the sheet "Twin-pipe formulas". This sheet consists of both equations and includes the explanations and theory for calculating the heat losses. In the program the user can calculate the total heat losses by changing the dimensions and the values. These green cells in the sheet are meant to help the user to identify the necessary values for the equation.

The sheet called "Twin-pipe heat loss calculations" is designed as a main part of the thesis. The sheet refers to the "First order formula of Wallentén", which was proved to be the most exact equation with an error less than 1%. In the sheet the user may change the values such as, the basic pipe dimensions, network length, temperatures, laying depth, thermal conductivity of the ground and of the insulation. When the user changes these values then the program calculates the total heat losses in W/m and the total network losses in kW.

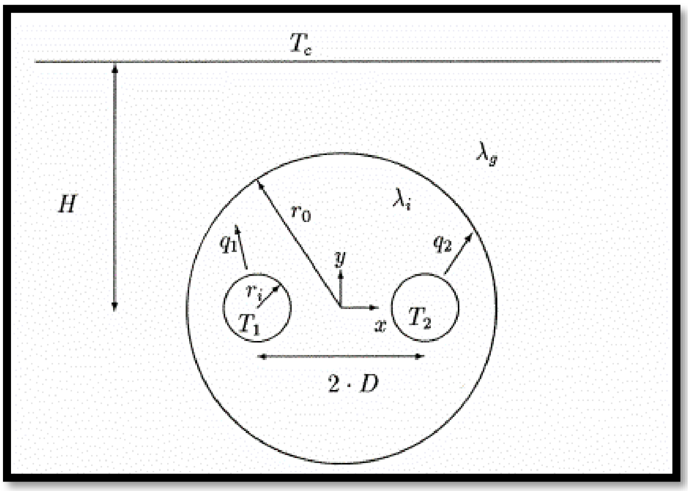


Figure 26. Twin-pipe with symbols and abbreviations (Wallentén 1991)

7.3.1 First order formula by Wallentén for twin-pipe losses

This chapter consists of the equations by Wallentén to calculate the heat losses from insulated twin pipes. The equations and the symbols are explained below. Total heat losses depend on only the symmetrical part from the calculation and these equations are relevant for calculating the losses.

Equations (8) – (12) describe the first order formula to calculate heat losses from buried insulated twin pipes

$$\mathrm{h}_s^{-1} = \frac{2\lambda_i}{\lambda_g}\ln\left(\frac{2H}{r_o}\right) + \ln\left(\frac{r_o^2}{2Dr_i}\right) + \sigma * \ln\left(\frac{r_o^4}{r_o^4 - D^4}\right) - \frac{\left(\frac{r_i}{2D} - \frac{\sigma 2 r_i D^3}{r_o^4 - D^4}\right)^2}{1 + \left(\frac{r_i}{2D}\right)^2 + \sigma\left(\frac{2 r_i r_o^2 D}{r_o^4 - D^4}\right)^2}$$

… heat loss factor in symmetrical problem (8)

$T_s = \frac{T_1 + T_2}{2}$… The temperature in symmetrical problem (9)

$q_s = (T_s - T_c) * 2\pi\lambda_i * h_s$ … heat losses in symmetrical problem (10)

$Q_{losses} = 2 * q_s$ **…** Total heat losses for twin pipes (11)

$\sigma = \frac{\lambda_i - \lambda_g}{\lambda_i + \lambda_g}$ …Thermal conductivity factor (12)

where

h_s^{-1}	is	heat loss factor symmetrical [-]
D	is	half distance between center of pipes [m]
H	is	distance from the center of the large pipe to the ground surface [m]
r_o	is	radius of circumscribing large pipe [m]
r_i	is	radius of imbedded pipes [m]
q_s	is	heat losses in symmetrical problem [W/m]
T_s	is	temperature at the ground surface [°C]
T_1	is	temperature in pipe 1 [°C]
T_2	is	temperature in pipe 2 [°C]
λ_i	is	thermal conductivity of the insulation [W/mK]
λ_g	is	thermal conductivity of the ground [W/mK]
σ	is	thermal conductivity factor [-]

With the heat loss factor (h_s^{-1}), the factor for following equations could be calculated, which helps to calculate the total heat losses (Q_{losses}). By calculating the heat loss factor for symmetrical problem and after that one can calculate the heat losses for symmetrical problem (q_s). Then calculating the right values for ground surface (T_c) and the temperatures for the pipes, therefore the symmetrical problems' heat losses in (W/m) can be calculated to the total heat losses (Q_{losses}). This is a simple equation while total heat losses are twice the heat losses in the symmetrical problems.

7.4 Main simulation results of Seitenstetten district heating plant

The results consist of the following data from the research of Seitenstetten district heating plant. The main results can be seen in the sheet "Results" in the program. These results are described and presented in the tables later in this chapter. All results are collected from the sheets "Network pipe data", "Data-Annual Load Curve-Consumer", "Data-Annual Load Curve-Boilers" and "Annual Load Curve of Sochinsky". The main purpose was to re-calculate the heat losses for existing single pipes and the heat losses for new insulated twin-pipes, therefore also to calculate the boiler loads, full load hours and produced heat. This analysis and report of results include following topics about the extension part verification:

- Data from customers from existing and extension part
- Connected load
- Full load hours
- Coincidence factor
- Annual load curve of Sochinsky
- Heat losses for single pipes
- Heat losses for twin pipes
- Annual boiler data

The purpose of the thesis was to calculate the heat losses for twin-pipes and the right equation from Wallentén was implicated to the program. The program has now also whole new sheets such as, “Twin-pipe losses calculation”, “Twin-pipe formulas”, “Single pipe losses calculation” and “Single pipe formula”.

The results of the district heating plant of Seitenstetten are described in this chapter. The main data can be seen on the sheet “Results”, which includes information such as, “Fuel”, “Heating Plant”, “Consumers”, “Network occupancy” and “Efficiency”.

Table 14. Fuel results of Seitenstetten

Parameter		**Unit**	**Values**	**Optimal**
Fuel description:	Wood chips	-	-	-
Water content		[%]	50	
Lower heating value (Hu)		[MJ/kg]	9,500	
Bulk density		[kg/srm]	300	250-350
Amount of fuel		[t/a]	3 412	
		[srm/a]	11 375	

Above table 14 presents the amount of fuel and specified type of fuel. The district heating plant Seitenstetten uses lower quality of wood chips with a water content approx. 50% and the annual amount of fuel is up to 3,412 t/a.

The results show that the annual produced heat is around 8,203,569 kWh/a and. The heating plant results can be seen in table 15.

Table 15. The results of the heating plant Seitenstetten

Parameter	**Unit**	**Values**	**Optimal**
Biomass boiler	**-**	**-**	**-**
Nominal load of the boiler	[kW]	2000	
Produced heat from the biomass boiler		7 654 204	
Full load hours biomass boiler	[h/a]	3827	4000
Annual efficiency biomass boiler	[%]	85,00	85
Oil boiler (OiB) or gas boiler (GaB)	-	-	-
Nominal load OiB/GaB	[kW]	2404	
Produced heat from OiB/GaB	[kWh/a]	549 365	
Full load hours oil boiler		229	
Annual efficiency OiB/GaB		88,00	
Total	-	-	-
Produced heat from boilers	[kWh/a]	8 203 569	
Emitted peak load heating plant	[kW]	2 404	
Technology heat recovery	[-]	no	
Heat recovery (referred to heat production boilers)	[%]	0	

The table of “Consumers” shows the basic information about the consumers such as, “Line length”, “Consumer Heat”, “Total consumers connected load” and “Specific network losses”. These results of Seitenstetten can be seen below in table 16.

Table 16. Consumer operational results of Seitenstetten

Parameter	Unit	Values	Optimal
Network occupancy (Consumers power)	[kW/m]	0,61	1,25
Network length	[m]	6877,5	
Specific network losses	[kWh/m*a]	288	250
Coincidence factor consumers load (Private consumer)	[1]	0,5	
Total consumers connected load	[kW]	4229	
Consumers full load hours	[h/a]	1468	1500
Average consumers connected load	[kW]	39,52	
Consumer heat	[kWh/a]	6 206 885	

8 DISCUSSION

Everything of this thesis started in January 2018, by the visit to the district heating plant. This was an important part of the research on the early stage, while the owner of Seitenstettner Fernwärme GmbH gave a lot of crucial operational data.

This thesis will help the owner in Seitenstetten to understand the operational data of the extension part. The program and the thesis will help many users and companies to verify and calculate the heat losses for other biomass district heating plants. The new version of the program solved the problem of calculating the heat losses for twin-pipes, while in the future more twin-pipes will be installed all over the world.

The other part of the thesis was to design the North extension of the district heating plant in Seitenstetten. The design includes both parts such as, existing and the extension part. This step was important beside finding the right solution for the existing program.

The solution for the program was found after long time of researching the right equations and collecting some information about the program and biomass heating plants. The hard part of the thesis was to integrate and find a correct solution for buried insulated twin-pipes to calculate the heat losses, but still the main goal of the thesis was obtained, because the right equation was found, and the program can calculate the total heat losses of the grid, the biomass boiler load and fuel consumption. The research also proved that twin-pipes are better than single pipes and their heat losses are less than single pipes. In the conclusion of this thesis, the results were satisfactory and hopefully it could help other researchers hereafter and give them understanding of biomass heating plants and the simulation program “VeriNa”.

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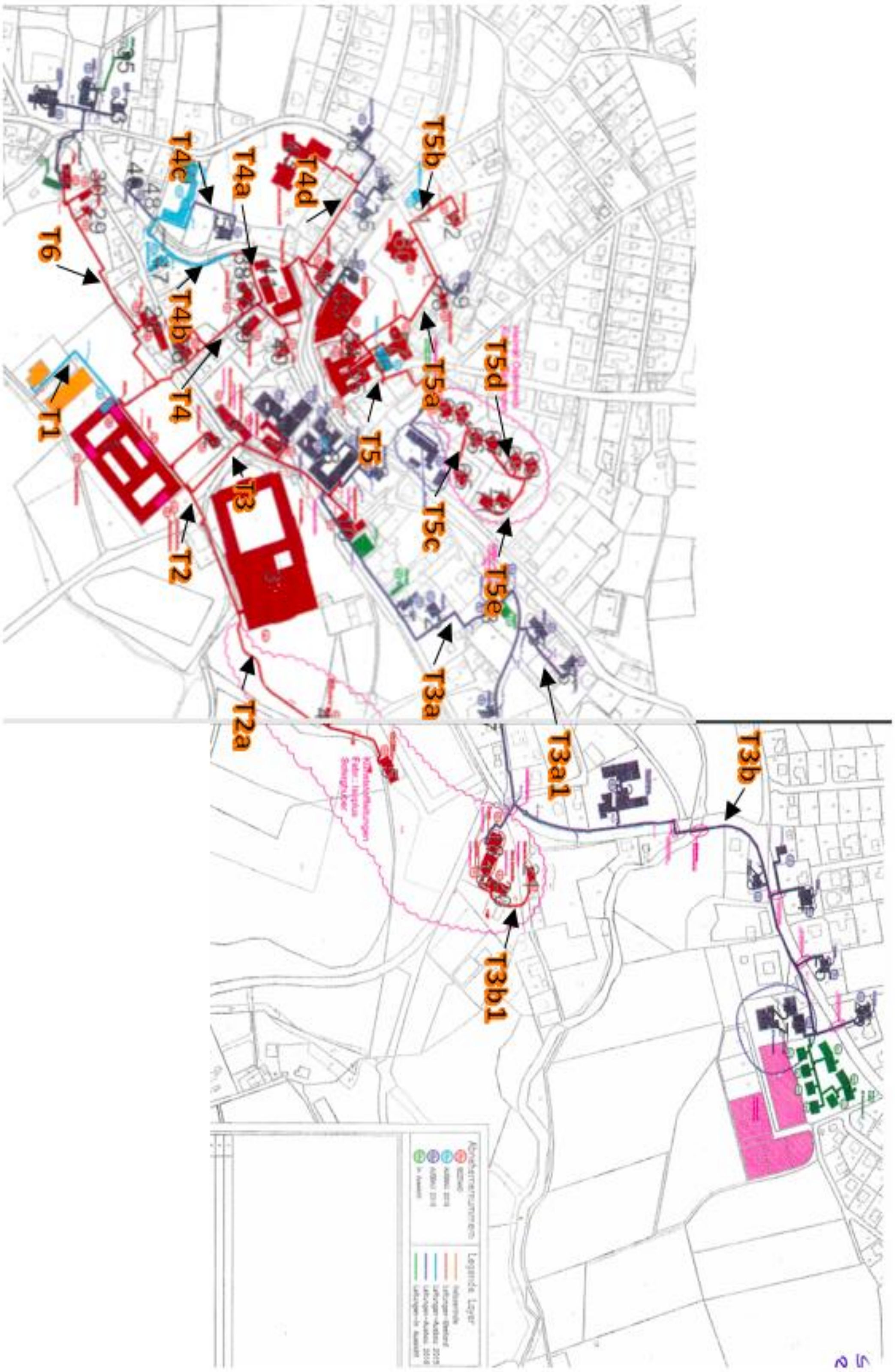
APPENDICES

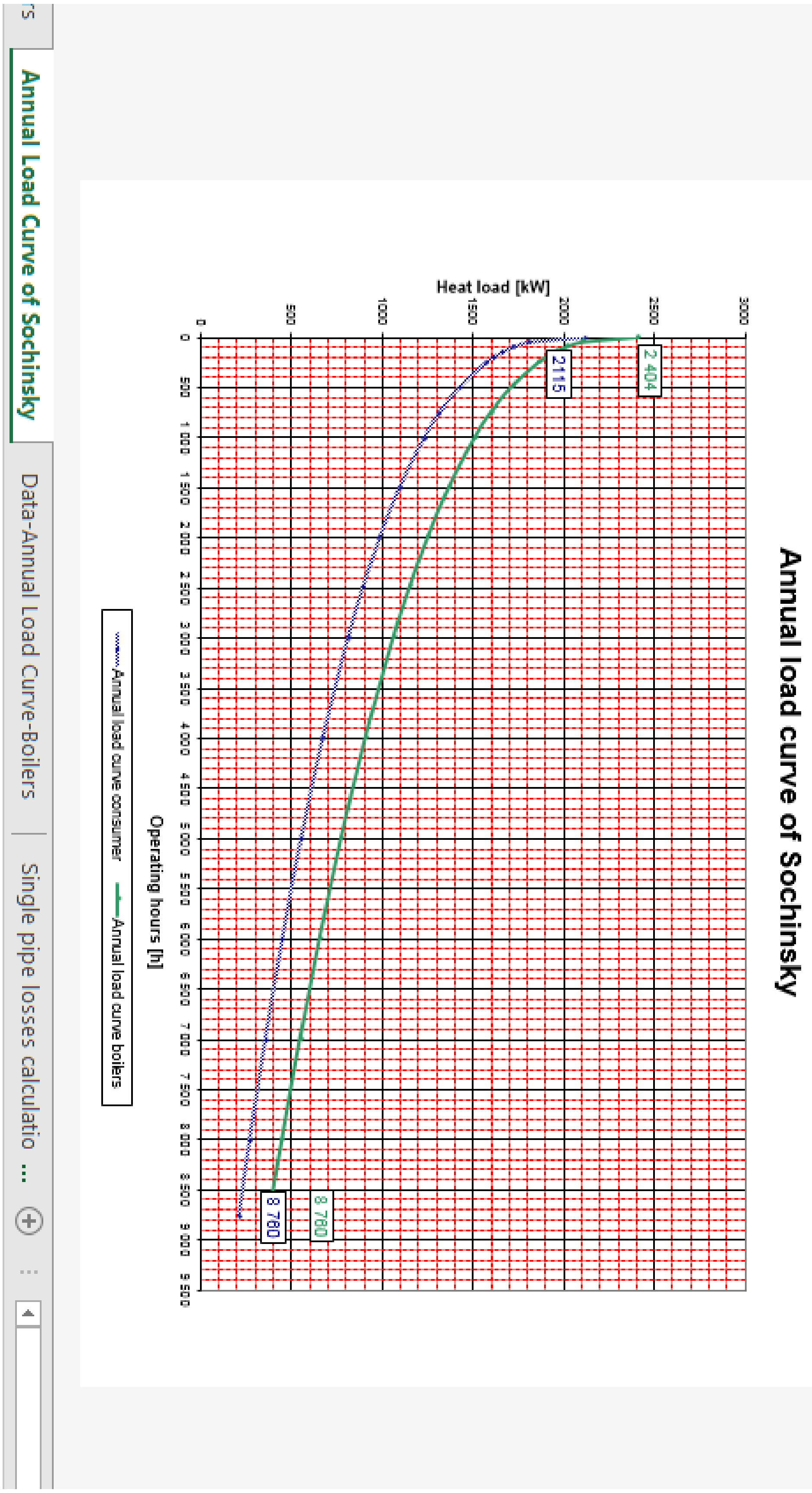
Appendix 1.	Seitenstetten district heating plant network
Appendix 2.	VeriNa- simulation program
Appendix 3.	The consumer data of the existing plant
Appendix 4.	The consumer data of the extension and existing plant

Appendix 1


T1
T2
T2a
T3
T3a
T3a1
T3b
T3b1
T4
T4a
T4b
T4c
T4d
T5
T5a
T5b
T5c
T5d
T5e
T6

Nr.	Consumer name	Type	Heated area	Connected consumer load	Consumer full load hours	Consumer heat
			[m²]	[kW]	[h/a]	[kWh/a]
107	TOTAL heat consumers			**4229**	**1 468**	**6 206 885**
1	lgashof Patzalt + Mei	Restaurant	2 500,00	300	33	10 000
2	Altbau (Stift Rosenga	EFH	120,00	15	1 002	15 033
3	Stift	Church	2 500,00	1 200	6	7 794
4	Stift Ritt	EFH	90,00	10	1 363	13 625
5	Union Fußball	EFH	400,00	20	727	14 541
6	FH, Altbau,Cafe Mitter	EFH	300,00	15	40	602
7	EFH, Altbau ? Lehner	EFH	300,00	15	405	6 076
8	eria Palermo / Fleiscl	Restaurant	1 500,00	75	217	16 259
9	geplant (noch nicht in	EFH		50	355	17 758
10	Postfiliale / Ärztehaus	EFH	800,00	30	473	14 197
11	EFH / Krend	EFH		15	40 000	600 000

β_{min}	β_m	τ	τ_b	T_b	T	Q_j	Pmin	Pmax	β(T)	P(T)
[1]	[1]	[h]	[h]	[h]	[h/h]	[kWh]	[kW]	[kW]	[1]	[kW]
0,10	**0,34**	**0**	**8760**	**2935**	**0**	**6 206 885**	**211**	**2 115**	**1**	**2 115**
0,1	0,00	0	8760	33	0	10 000	30	300		
0,1	0,11	0	8760	1002	0	15 033	1,5	15		
0,1	0,00	0	8760	6	0	7 794	120	1 200		
0,1	0,16	0	8760	1363	0	13 625	1	10		
0,1	0,08	0	8760	727	0	14 541	2	20		
0,1	0,00	0	8760	40	0	602	1,5	15		
0,1	0,05	0	8760	405	0	6 076	1,5	15		
0,1	0,02	0	8760	217	0	16 259	7,5	75		
0,1	0,04	0	8760	355	0	17 758	5	50		
0,1	0,05	0	8760	473	0	14 197	3	30		
0,1	4,57	0	8760	40000	0	600 000	1,5	15		


Annual load curve of Sochinsky
Heat load [kW]
0
500
1000
1500
2000
2500
3000
0
500
1 000
1 500
2 000
2 500
3 000
3 500
4 000
4 500
5 000
5 500
6 000
6 500
7 000
7 500
8 000
8 500
9 000
9 500
Operating hours [h]
2115
2 404
8 760
8 760
Annual load curve consumer
Annual load curve boilers
Annual Load Curve of Sochinsky
Data-Annual Load Curve-Boilers
Single pipe losses calculatio ...

T	τ	P(T) Consumer load	Network losses	Total losses	Net heat power boiler house	Net heat power BMB	Net heat power OiB/GaB	Fuel power BMB	Fuel mass flow BMB	Fuel power OiB/GaB
[1]	[h/a]	[kW]	[kW]	[%]	[kW]	[kW]	[kW]	[kW]	[kg/s]	[kW]
0,00	0	**2115**	289,72	**12**	**2 404**	**2000**	404	2353	0,02461	459
0,01	50	**1808**	288,99	**14**	**2 097**	**2000**	97	2353	0,02255	110
0,01	100	**1723**	288,27	**14**	**2 011**	**2000**	11	2353	0,02175	13
0,02	150	**1663**	287,54	**15**	**1 950**	**1950**	0	2294	0,02125	0
0,02	200	**1614**	286,82	**15**	**1 901**	**1901**	0	2237	0,02074	0
0,03	250	**1573**	286,09	**15**	**1 859**	**1859**	0	2188	0,02034	0
0,06	500	**1423**	282,46	**17**	**1 705**	**1705**	0	2006	0,01880	0
0,09	750	**1316**	278,83	**17**	**1 595**	**1595**	0	1877	0,01765	0
0,11	1 000	**1231**	275,20	**18**	**1 506**	**1506**	0	1772	0,01507	0
0,17	1 500	**1095**	267,94	**20**	**1 363**	**1363**	0	1603	0,01463	0
0,23	2 000	**986**	260,69	**21**	**1 246**	**1246**	0	1466	0,01306	0
0,29	2 500	**893**	253,43	**22**	**1 146**	**1146**	0	1349	0,01136	0
0,34	3 000	**812**	246,17	**23**	**1 058**	**1058**	0	1244	0,01054	0
0,46	4 000	**672**	231,65	**26**	**904**	**904**	0	1063	0,00984	0
0,57	5 000	**554**	217,14	**28**	**771**	**771**	0	907	0,00842	0
0,68	6 000	**450**	202,62	**31**	**652**	**652**	0	768	0,00709	0
0,80	7 000	**357**	188,10	**35**	**545**	**545**	0	641	0,00586	0
0,91	8 000	**272**	173,58	**39**	**445**	**0**	445	0	0,00561	506
1,00	8 760	**211**	162,55	**43**	**374**	**0**	374	0	0,00536	425

Fuel mass flow OiB/GaB	Efficiency BMB (low HV)	Efficiency OiB/GaB (low HV)	Consumer heat	Net heat boiler house	Net heat BMB	Net heat OiB/GaB	Fuel heat BMB	Fuel heat OiB/GaB
[kg/s]	[%]	[%]	[kWh]	[kWh]	[kWh]	[kWh]	[kWh]	[kWh]
0	85	88,0						
0	85	88,0	98 066	112 534	100 000	12 534	117 647	14 243
0	85	88,0	88 281	102 712	100 000	2 712	117 647	3 082
0	85	88,0	84 646	99 041	98 757	284	116 185	322
0	85	88,0	81 928	96 287	96 287	-	113 279	-
0	85	88,0	79 692	94 015	94 015	-	110 606	-
0	85	88,0	374 543	445 612	445 612	-	524 249	-
0	85	88,0	342 433	412 594	412 594	-	485 405	-
0	85	88,0	318 428	387 683	387 683	-	456 097	-
0	85	88,0	581 448	717 235	717 235	-	843 806	-
0	85	88,0	520 107	652 264	652 264	-	767 370	-
0	85	88,0	469 645	598 173	598 173	-	703 733	-
0	85	88,0	426 142	551 041	551 041	-	648 284	-
0	85	88,0	741 867	980 777	980 777	-	1 153 855	-
0	85	88,0	612 914	837 308	837 308	-	985 068	-
0	85	88,0	501 746	711 623	711 623	-	837 204	-
0	85	88,0	403 158	598 518	598 518	-	704 139	-
0	85	88,0	314 039	494 882	272 317	222 565	320 373	252 914
0	85	88,0	183 538	311 270	-	311 270	-	353 716
			6 222 621	**8 203 569**	**7 654 204**	**549 365**	**9 004 946**	**624 278**

Predesign of biomass boiler BMB:			Standard values
Consumer heat:	6 206 885	[kWh/a]	
Network losses presumed :	30	[%]	20-30 %
Boiler heat:	8 866 979	[kWh/a]	
Share of biomass boiler heat BMB:	90	[%]	>80 %
Full load hours BMB presumed:	4000	[h/a]	>4000 h/a
Pmax, BMB presumed:	1995,1	[kW]	
Pmax, BMB selected:	2000	[kW]	acc. manufacturer
Pmin, BMB selected:	500	[kW]	acc. manufacturer
Fuel type BMB	Wood chips		
Water content	50	[%]	
Lower heating value	9,50	[MJ/kg]	
Fuel type OiB/GaB	Fuel oil		
Lower heating value	10,00	[kWh/l]	
Lower heating value	36,00	[MJ/l]	
Lower heating value	42,60	[MJ/kg]	
Density	0,845	[kg/l]	

Nominal pipe size:	150	DN [mm]		Network len(	63	m		
Outside temperature	**Outside temperature**	**SFT Temp.**	**SFT Temp.**	**RFT Temp.**	**RFT Temp.**	**Center distance RL**	**Laying depth**	**WLK Ground**
[°C]	[K]	[°C]	[K]	[°C]	[K]	[m]	[m]	[W/m*K]
-30	243,15	90	363,15	60	333,15	0,26	1	1,6
-29	244,15	90	363,15	60,00	333,15	0,26	1	1,6
-28	245,15	90	363,15	60,00	333,15	0,26	1	1,6
-27	246,15	90	363,15	60,00	333,15	0,26	1	1,6
-26	247,15	90	363,15	60,00	333,15	0,26	1	1,6
-25	248,15	90	363,15	60,00	333,15	0,26	1	1,6
-24	249,15	90	363,15	60,00	333,15	0,26	1	1,6
-23	250,15	90	363,15	60,00	333,15	0,26	1	1,6
-22	251,15	90	363,15	60,00	333,15	0,26	1	1,6
-21	252,15	90	363,15	60,00	333,15	0,26	1	1,6
-20	253,15	90	363,15	60,00	333,15	0,26	1	1,6
-19	254,15	90	363,15	60,00	333,15	0,26	1	1,6

WLK Insulation	Inside diameter of insulation	Outside diameter of insulation	Ground surface temperature	S	Qloss	Network losses
[W/m*K]	[m]	[m]	[K]	[-]	[W/m]	[kW]
0,024	0,0483	0,11	243,15	0,106	35,449	2,23
0,024	0,0483	0,11	244,15	0,106	35,111	2,21
0,024	0,0483	0,11	245,15	0,106	34,773	2,19
0,024	0,0483	0,11	246,15	0,106	34,436	2,17
0,024	0,0483	0,11	247,15	0,106	34,098	2,15
0,024	0,0483	0,11	248,15	0,106	33,761	2,13
0,024	0,0483	0,11	249,15	0,106	33,423	2,11
0,024	0,0483	0,11	250,15	0,106	33,085	2,08
0,024	0,0483	0,11	251,15	0,106	32,748	2,06
0,024	0,0483	0,11	252,15	0,106	32,410	2,04
0,024	0,0483	0,11	253,15	0,106	32,073	2,02

Heat loss calculations for single pipes according to theory:

Obernberger, "Nutzung fester Biomasse in Verbrennungsanlagen", dbv-Verlag, 1998
Kapitel 5.2 Allgemeine Grundlagen für die richtige Dimensionierung von dezentralen Fernwärmenetzen, Seite 206 ff

Nominal pipe diameter	DN	**40**	[mm]	Nennweite Rohr
Outside diameter	$d_{a,R}$	48,3	[mm]	Aussendurchmesser Rohr
Pipe thickness	s_R	3,2	[mm]	Wandstärke Rohr
Inside diameter	$d_{i,R}$	41,9	[mm]	Innendurchmesser Rohr
Insulation				
Insulation thickness	s_{WD}	0,0459	[m]	Wandstärke Wärmedämmung
Outside diameter insulation	d_a	0,140	[m]	Außendurchmesser WD
Inside diameter insulation	d_i	0,0483	[m]	Innendurchmesser WD
Thermal conductivity insulation	λ_{WD}	0,027	[W/mK]	Wärmeleitfähigkeit Wärmedämmung
Construction details				
Distance between single pipes (>d_a!)	a	0,29	[m]	Mittelpunktsabstand RL
Laying depth	h	0,93	[m]	Überdeckung
Thermal conductivity ground	λ_E	1,600	[W/mK]	Wärmeleitfähigkeit Erde
Temperatures				
Supply flow temperature	t_{VL}	90	[°C]	Temp. VL
	t_{VL}	363	[K]	
Return flow temperature	t_{RL}	60	[K]	Temp. RL
	t_{RL}	333	[K]	
Ground surface temperature	t_{EO}	-30	[°C]	Temp. Erdoberfläche, Umgebung
	t_{EO}	243	[K]	Temp. Erdoberfläche, Umgebung
Pipe network heat losses				
Pipe lenght	l	50	[m]	
Construction coefficient single pipes	S	0,093	[1]	Formkoeffizient
Specific pipe heat losses	$Q_{Verlust}$	**31,274**	[W/m]	spec. Rohrverlust
Pipe heat losses		**1,6**	[kW]	Rohrverlust

Nominal pipe size:	40	DN [mm]		Network length:	206	m				
Outside Temperature	**Outside Temperature**	**SFT Temp.**	**SFT Temp.**	**RFT Temperature**	**RFT Temp.**	**T_s (Temperature in symmetrical problem)**	**d_i (inside diameter of insulation)**	**r_i (inner radius of the pipe)**	**d_a (outside diameter of insulation)**	**r_o (outer radius of large circumscribing pipe)**
[°C]	[K]	[°C]	[K]	[°C]	[K]	[K]	[mm]	[m]	[mm]	[m]
-30	243,15	90	363,15	60	333,15	348,15	48,30	0,02415	200	0,10
-29	244,15	90	363,15	60,00	333,15	348,15	48,30	0,02	200,00	0,10
-28	245,15	90	363,15	60,00	333,15	348,15	48,30	0,02	200,00	0,10
-27	246,15	90	363,15	60,00	333,15	348,15	48,30	0,02	200,00	0,10
-26	247,15	90	363,15	60,00	333,15	348,15	48,30	0,02	200,00	0,10
-25	248,15	90	363,15	60,00	333,15	348,15	48,30	0,02	200,00	0,10
-24	249,15	90	363,15	60,00	333,15	348,15	48,30	0,02	200,00	0,10
-23	250,15	90	363,15	60,00	333,15	348,15	48,30	0,02	200,00	0,10
-22	251,15	90	363,15	60,00	333,15	348,15	48,30	0,02	200,00	0,10
-21	252,15	90	363,15	60,00	333,15	348,15	48,30	0,02	200,00	0,10
-20	253,15	90	363,15	60,00	333,15	348,15	48,30	0,02	200,00	0,10
-19	254,15	90	363,15	60,00	333,15	348,15	48,30	0,02	200,00	0,10
-18	255,15	90	363,15	60,00	333,15	348,15	48,30	0,02	200,00	0,10
-17	256,15	90	363,15	60,00	333,15	348,15	48,30	0,02	200,00	0,10
-16	257,15	90	363,15	60,00	333,15	348,15	48,30	0,02	200,00	0,10
-15	258,15	90	363,15	60,00	333,15	348,15	48,30	0,02	200,00	0,10
-14	259,15	90	363,15	60,00	333,15	348,15	48,30	0,02	200,00	0,10

b Clear Pipe Distance	D (half the distance between center of pipes)	H Laying depth	λ_g Thermal conductivity Ground	λ_i Thermal conductivity Insulation	σ Thermal conductivity factor	T_c Ground surface temperature	h_s	h_s^{-1}	Q_{losses}	Network losses
[mm]	[m]	[m]	[W/m*K]	[W/m*K]	[-]	[K]	[-]	[-]	[W/m]	[kW]
20,000	0,03415	1,1	1	0,027	-0,947419669	243,15	1,8	0,546	19,467	4,01
20,00	0,03	1,1	1	0,027	-0,947419669	246,15	1,8	0,546	18,911	3,90
20,00	0,03	1,1	1	0,027	-0,947419669	247,15	1,8	0,546	18,725	3,86
20,00	0,03	1,1	1	0,027	-0,947419669	248,15	1,8	0,546	18,540	3,82
20,00	0,03	1,1	1	0,027	-0,947419669	249,15	1,8	0,546	18,354	3,78
20,00	0,03	1,1	1	0,027	-0,947419669	250,15	1,8	0,546	18,169	3,74
20,00	0,03	1,1	1	0,027	-0,947419669	251,15	1,8	0,546	17,984	3,70
20,00	0,03	1,1	1	0,027	-0,947419669	252,15	1,8	0,546	17,798	3,67
20,00	0,03	1,1	1	0,027	-0,947419669	253,15	1,8	0,546	17,613	3,63
20,00	0,03	1,1	1	0,027	-0,947419669	254,15	1,8	0,546	17,427	3,59
20,00	0,03	1,1	1	0,027	-0,947419669	255,15	1,8	0,546	17,242	3,55
20,00	0,03	1,1	1	0,027	-0,947419669	256,15	1,8	0,546	17,057	3,51
20,00	0,03	1,1	1	0,027	-0,947419669	257,15	1,8	0,546	16,871	3,48
20,00	0,03	1,1	1	0,027	-0,947419669	258,15	1,8	0,546	16,686	3,44
20,00	0,03	1,1	1	0,027	-0,947419669	259,15	1,8	0,546	16,500	3,40
20,00	0,03	1,1	1	0,027	-0,947419669	260,15	1,8	0,546	16,315	3,36
20,00	0,03	1,1	1	0,027	-0,947419669	261,15	1,8	0,546	16,130	3,32
20,00	0,03	1,1	1	0,027	-0,947419669	262,15	1,8	0,546	15,944	3,28

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
1			Total column	Pipes 1 Single New 2015	Pipes 2 Single Old 1986	Pipes 2a Single Old 1986	Pipes 3 Single Old 1986	Pipes 3.1 Single Old 1986	Pipes 3.2 Single Old 1986	Pipes 3.3 Single Old 1986	Pipes 3a Single New 2016	Pipes 3a1 Single New 2016	Pipes 3b Single New 2016	Pipes 3b1 Single New 2016	Pipes 4 Single Old 1986	Pipes 4a Single Old 1986	Pipes 4b Single New 2015
2	Dimension	[mm]	DN	DN 150	DN 150	DN 50	DN 65	DN 40	DN 32	DN 40	DN 65	DN 20	DN 50	DN 40	DN 100	DN 80	DN 50
3	Inside diameter Pipe	[mm]		159,3	159,3	41	67,1	39,3	33,4	39,3	67,1	17,9	51,3	31	105,3	79,9	51,3
4	Outside diameter Pipe	[mm]		168,3	168,3	50	76,1	48,3	42,4	48,3	76,1	26,9	60,3	40	114,3	88,9	60,3
5	Outside diameter Insulation	[mm]		250	250	110	140	110	110	110	140	90	125	90	200	160	125
6	Material Pipe			Steel	Steel	Plastic	Steel	Steel	Steel	Steel	Steel	Steel	Plastic	Steel	Steel	Steel	Steel
7	Line length	[m]	5652,5	151,5	280	260	231	21	105	42	609	84	546	147	357	84	147
8	Flow temperature	[°C]	90														
9	Return Flow Temperature	[°C]	60														
10	Heat load Pipe entrance	[kW]		2133,45	1339,25	33	480,48	16,5	137,5	33	479,16	49,5	430,76	110	794,2	174,24	176
11	Velocity	[m/s]		0,64													
12	Losses by outside temperature of		kW														
13	-30	°C	342,39	10,84	29,85	14,49	16,37	1,13	4,92	2,25	28,75	2,06	21,76	5,26	27,77	6,19	5,86
14	-29	°C	338,64	10,74	29,56	14,35	16,21	1,11	4,87	2,23	28,47	2,04	21,55	5,21	27,51	6,13	5,80
15	-28	°C	335,37	10,63	29,28	14,21	16,06	1,10	4,83	2,21	28,20	2,02	21,34	5,16	27,25	6,07	5,75
16	-27	°C	332,11	10,53	29,00	14,07	15,90	1,09	4,78	2,19	27,92	2,00	21,13	5,11	26,98	6,01	5,69
17	-26	°C	328,85	10,43	28,71	13,93	15,75	1,08	4,73	2,17	27,65	1,98	20,93	5,06	26,72	5,95	5,63
18	-25	°C	325,59	10,33	28,43	13,80	15,59	1,07	4,69	2,14	27,38	1,96	20,72	5,01	26,45	5,89	5,58
19	-24	°C	322,33	10,22	28,14	13,66	15,43	1,06	4,64	2,12	27,10	1,94	20,51	4,96	26,19	5,83	5,52
20	-23	°C	319,07	10,12	27,86	13,52	15,28	1,05	4,59	2,10	26,83	1,92	20,31	4,91	25,92	5,78	5,47
21	-22	°C	315,81	10,02	27,57	13,38	15,12	1,04	4,55	2,08	26,56	1,90	20,10	4,86	25,66	5,72	5,41
22	-21	°C	312,55	9,91	27,29	13,25	14,97	1,03	4,50	2,06	26,28	1,88	19,89	4,81	25,39	5,66	5,36
23	-20	°C	309,29	9,81	27,01	13,11	14,81	1,02	4,45	2,04	26,01	1,87	19,68	4,76	25,13	5,60	5,30
24	-19	°C	306,03	9,71	26,72	12,97	14,65	1,01	4,41	2,02	25,73	1,85	19,48	4,71	24,86	5,54	5,24
25	-18	°C	302,77	9,60	26,44	12,83	14,50	1,00	4,36	1,99	25,46	1,83	19,27	4,66	24,60	5,48	5,19
26	-17	°C	299,51	9,50	26,15	12,69	14,34	0,99	4,31	1,97	25,19	1,81	19,06	4,61	24,34	5,42	5,13
27	-16	°C	296,24	9,40	25,87	12,56	14,19	0,98	4,27	1,95	24,91	1,79	18,86	4,56	24,07	5,36	5,08
28	-15	°C	292,98	9,29	25,58	12,42	14,03	0,96	4,22	1,93	24,64	1,77	18,65	4,51	23,81	5,30	5,02
29	-14	°C	289,72	9,19	25,30	12,28	13,87	0,95	4,17	1,91	24,37	1,75	18,44	4,46	23,54	5,25	4,96

... Single pipe Formula | Twin-pipe losses calculations | Twin-pipe formulas | **Network pipe data** | Results | Coincidenc ...

R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD	AE	AF
Pipes 4c Single New 2016	Pipes 4d Single Old 1986	Pipes 5 Single Old 1986 1986	Pipes 5a Single Old 1986	Pipes 5b Single Old 1986	Pipes 5c Single Old 1986	Pipes 5d Single Old 1986	Pipes 5e Single Old 1986	Pipes 6 Single Old 1986	Feeding pipes Single Old 1986	Pipes 7 Twin-Pipe New	Pipes 7a Twin-Pipe New	Pipes 7b Twin-Pipes New	Pipes 7c Twin-Pipe New	Pipes 7d Twin-Pipe New
DN 40	DN 65	DN 65	DN 65	DN 40	DN 40	DN 50	DN 40	DN 40	DN 25	DN 65	DN40	DN40	DN40	DN40
39,3	67,1	67,1	67,1	39,3	39,3	41	31	39,3	24,7	67,1	39,3	39,3	39,3	39,3
48,3	76,1	76,1	76,1	48,3	48,3	50	40	48,3	33,7	76,1	48,3	48,3	48,3	48,3
110	140	140	140	110	110	110	90	110	90	280	200	200	200	200
Steel	Steel	Steel	Steel	Steel	Steel	Plastic	Plastic	Steel	Steel	Steel	Steel	Steel	Steel	Steel
63	189	315	136,5	105	63	94,5	42	420	1160	493	161	200	165	206
126,5	335,5	273,9	77,55	93,5	1,1	42,592	44	181,104	42,66197183					
kW														
2,23	13,39	22,32	9,67	5,63	3,38	5,27	2,26	22,51	52,53	10,95	3,25	4,03	3,33	4,15
2,21	13,27	22,11	9,58	5,57	3,34	5,22	2,24	22,30	52,03	10,63	3,15	3,92	3,23	4,03
2,19	13,14	21,90	9,49	5,52	3,31	5,17	2,22	22,08	51,53	10,53	3,12	3,88	3,20	4,00
2,17	13,01	21,68	9,40	5,47	3,28	5,11	2,20	21,87	51,03	10,43	3,09	3,84	3,17	3,96
2,15	12,88	21,47	9,30	5,41	3,25	5,06	2,18	21,65	50,53	10,32	3,06	3,80	3,14	3,92
2,13	12,75	21,26	9,21	5,36	3,22	5,01	2,16	21,44	50,03	10,22	3,03	3,76	3,11	3,88
2,11	12,63	21,05	9,12	5,31	3,18	4,96	2,13	21,22	49,53	10,11	3,00	3,73	3,07	3,84
2,08	12,50	20,83	9,03	5,25	3,15	4,91	2,11	21,01	49,03	10,01	2,97	3,69	3,04	3,80
2,06	12,37	20,62	8,94	5,20	3,12	4,86	2,09	20,80	48,53	9,90	2,94	3,65	3,01	3,76
2,04	12,24	20,41	8,84	5,15	3,09	4,81	2,07	20,58	48,03	9,80	2,91	3,61	2,98	3,72
2,02	12,12	20,20	8,75	5,09	3,06	4,76	2,05	20,37	47,53	9,70	2,88	3,57	2,95	3,68
2,00	11,99	19,98	8,66	5,04	3,02	4,71	2,03	20,15	47,03	9,59	2,84	3,53	2,91	3,64
1,98	11,86	19,77	8,57	4,98	2,99	4,66	2,01	19,94	46,53	9,49	2,81	3,49	2,88	3,60
1,96	11,73	19,56	8,47	4,93	2,96	4,61	1,98	19,72	46,03	9,38	2,78	3,46	2,85	3,56
1,94	11,61	19,34	8,38	4,88	2,93	4,56	1,96	19,51	45,53	9,28	2,75	3,42	2,82	3,52
1,91	11,48	19,13	8,29	4,82	2,89	4,51	1,94	19,29	45,03	9,18	2,72	3,38	2,79	3,48
1,89	11,35	18,92	8,20	4,77	2,86	4,46	1,92	19,08	44,53	9,07	2,69	3,34	2,76	3,44

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Consumer Nr.	Type	Heated area	Connected consumer load	Consumer full load hours	Consumer heat
		[m²]	[kW]	[h/a]	[kWh/a]
			3,633	**1,577**	**5,730,200**
1	Landgashof Patzalt + Meierhof	2,500	300	2,000	600,000
2	EFH Altbau (Stift Rosengarten)	120	15	1,400	21,000
3	Stift	2,500	1,200	1,500	1,800,000
4	Stift Ritt	90	10	1,400	14,000
5	Union Fußball	400	20	2,000	40,000
6	EFH, Altbau,Cafe Mitterer	300	15	1,400	21,000
7	EFH, Altbau ? Lehner	300	15	1,400	21,000
8	Pizzeria Palermo / Fleischerei	1,500	75	2,000	150,000
9	EFH / Geplant (noch nicht in Betrieb)		50	1,400	70,000
10	Postfiliale / Ärtztehaus	800	30	1,300	39,000
11	EFH / Krend		15	1,400	21,000
12	EFH / Pizzamann (noch nicht in Betrieb)		50	1,400	70,000
13	EFH / Schoder	100	10	1,400	14,000
14	EFH	100	20	1,400	28,000
15	EFH / Habsburg	250	30	1,400	42,000
16	EFH / Mayr	250	15	1,400	21,000
17	EFH/ Kerschner	200	20	1,400	28,000
18	Feuerwehr	450	50	1,300	65,000
19	Musikverein	450	15	2,000	30,000
20	Bauhof Schützengilde	1,500	20	1,500	30,000
21	Pfarrhaus	150	15	1,500	22,500
22	Neue Mittelschule	3,000	250	1,300	325,000
23	EFH / Edermayer (ab 2018)	100	15	1,400	21,000
24	EFH / Wieser (ab 2018)	100	15	1,400	21,000
25	EFH / Hörndler (ab 2018)	100	15	1,400	21,000
26	EFH / Sonnleitner (noch nicht in Betrieb)	100	50	1,400	70,000
27	Heimat Österreich	100	100	1,400	140,000
28	MFH / Kern+Wimmer Josef	300	30	1,400	42,000
29	EFH / Schoder Barbara	100	15	1,400	21,000
30	EFH / Kammerhofer Andreas	100	11	1,400	15,400
31	Autohaus Fritsch	400	40	1,500	60,000
32	MFH / Kammerhofer Heinrich	300	30	1,400	42,000
33	EFH / Wieser Rupert		15	1,400	21,000
34	Angerer		40	1,400	56,000

Consumer Nr.	Type	Heated area	Connected consumer load	Consumer full load hours	Consumer heat
35	Wieser (noch nicht in Betrieb)		15	1,500	22,500
36	MFH / Schadauer	450	30	1,400	42,000
37	Dorfmayr		15	1,500	22,500
38	Dorfmayr Geschäft		20	1,400	28,000
39	HÖ / Heimat Österrech		55	2,200	121,000
40	Höfler		40	1,500	60,000
41	HÖ2 / Heimat Österreich		125	2,200	275,000
42	Gemeindeamt		20	1,300	26,000
43	Bildungshaus St. Benedikt		211	2,000	422,000
44	EFH / Holl		30	1,400	42,000
45	EFH / Fiala (noch nicht in Betrieb)		24	1,400	33,600
46	EFH / Stockinger Regina	200	20	1,400	28,000
47	EFH / Schwarenthorer	300	15	1,400	21,000
48	EFH / Humpl	100	15	1,400	21,000
49	EFH / Matzenberger	100	15	1,400	21,000
50	Volksschule		100	1,300	130,000
51	EFH / Maurer Niel	100	15	1,400	21,000
52	EFH / Gerstmayr		15	1,400	21,000
53	Grossabnehmer /SCS		70	1,400	98,000
54	Grossabnehmer / Gasthaus Ott Hubert		98	1,500	147,000
55	Grossabnehmer / Ott Aton		50	1,500	75,000
56	Betrieb/EFH /Wunsch Erich		20	1,400	28,000
57	Betrieb Schirghuber		30	1,400	42,000
58	EFH / Kammerhofer Andreas		11	1,400	15,400
59	EFH / Gruber		15	1,400	49,000
60	Grossabnehmer / Kindergarten		35	1,300	45,500
61	EFH / Stockinger Klaus		20	1,400	28,000
62	EFH /Schreiner		30	1,400	42,000
63	MFH		1	1,400	1,400
64	MFH		1	1,400	1,400
65	MFH		1	1,400	1,400
66	MFH		1	1,400	1,400
67	MFH		10	1,400	14,000
68	MFH		10	1,400	14,000
69	MFH		10	1,400	14,000
70	MFH		10	1,400	14,000
71	MFH		10	1,400	14,000
72	Mag Wieser		50	1,400	70,000

Consumer Nr.	Type	Heated area	Connected consumer load	Consumer full load hours	Consumer heat
		[m²]	[kW]	[h/a]	[kWh/a]
			4147	**1.553**	**6.441.400**
1	Landgashof Patzalt + Meierhof	2.500	300	2.000	600.000
2	EFH Altbau (Stift Rosengarten)	120	15	1.400	21.000
3	Stift	2.500	1200	1.500	1.800.000
4	Stift Ritt	90	10	1.400	14.000
5	Union Fußball	400	20	2.000	40.000
6	EFH, Altbau,Cafe Mitterer	300	15	1.400	21.000
7	EFH, Altbau ? Lehner	300	15	1.400	21.000
8	Pizzeria Palermo / Fleischerei	1.500	75	2.000	150.000
9	EFH / Geplant		15	1.400	21.000
10	Postfiliale / Ärtztehaus	800	30	1.300	39.000
11	EFH / Krend		15	1.400	21.000
12	EFH / Pizzamann		10	1.400	14.000
13	EFH / Schoder	100	10	1.400	14.000
14	EFH	100	20	1.400	28.000
15	EFH / Habsburg	250	30	1.400	42.000
16	EFH / Mayr	250	15	1.400	21.000
17	EFH/ Kerschner	200	20	1.400	28.000
18	Feuerwehr	450	50	1.300	65.000
19	Musikverein	450	15	2.000	30.000
20	Bauhof Schützengilde	1.500	20	1.500	30.000
21	Pfarrhaus	150	15	1.500	22.500
22	Neue Mittelschule	3.000	250	1.300	325.000
23	EFH / Edermayer	100	15	1.400	21.000
24	EFH / Wieser	100	15	1.400	21.000
25	EFH / Hörndler	100	15	1.400	21.000
26	EFH / Sonnleitner	100	15	1.400	21.000
27	Heimat Österreich	100	100	1.400	140.000
28	MFH / Kern+Wimmer Josef	300	30	1.400	42.000
29	EFH / Schoder Barbara	100	15	1.400	21.000
30	EFH / Kammerhofer Andreas	100	11	1.400	15.400
31	Autohaus Fritsch	400	40	1.500	60.000
32	MFH / Kammerhofer Heinrich	300	30	1.400	42.000
33	EFH / Wieser Rupert		15	1.400	21.000
34	Angerer		40	1.400	56.000
35	Wieser		15	1.500	22.500
36	MFH / Schadauer	450	30	1.400	42.000
37	Dorfmayr		15	1.500	22.500
38	Dorfmayr Geschäft		20	1.400	28.000
39	HÖ / Heimat Österrech		55	2.200	121.000
40	Höfler		40	1.500	60.000
41	HÖ2 / Heimat Österreich		125	2.200	275.000
42	Gemeindeamt		20	1.300	26.000
43	Bildungshaus St. Benedikt		211	2.000	422.000
44	EFH / Holl		30	1.400	42.000

Consumer Nr.	Type	Heated area	Connected consumer load	Consumer full load hours	Consumer heat
46	EFH / Stockinger Regina	200	20	1.400	28.000
47	EFH / Schwarenthorer	300	15	1.400	21.000
48	EFH / Humpl	100	15	1.400	21.000
49	EFH / Matzenberger	100	15	1.400	21.000
50	Volksschule		100	1.300	130.000
51	EFH / Maurer Niel	100	15	1.400	21.000
52	EFH / Gerstmayr		15	1.400	21.000
53	Grossabnehmer /SCS		70	1.400	98.000
54	Grossabnehmer / Gasthaus Ott Hubert			1.500	0
55	Grossabnehmer / Ott Aton		50	1.500	75.000
56	Betrieb/EFH /Wunsch Erich		20	1.400	28.000
57	Betrieb Schirghuber		30	1.400	42.000
58	EFH / Kammerhofer Andreas		11	1.400	15.400
59	EFH / Gruber		15	1.400	49.000
60	Grossabnehmer / Kindergarten		35	1.300	45.500
61	EFH / Stockinger Klaus		20	1.400	28.000
62	EFH /Schreiner		30	1.400	42.000
63	MFH		20	1.400	28.000
64	MFH		20	1.400	28.000
65	MFH		20	1.400	28.000
66	MFH		20	1.400	28.000
67	MFH		20	1.400	28.000
68	MFH		20	1.400	28.000
69	MFH		20	1.400	28.000
70	MFH		20	1.400	28.000
71	MFH		20	1.400	28.000
72	Mag Wieser		50	1.400	70.000
73	EFH		10	1.400	14.000
74	EFH		10	1.400	14.000
75	EFH		10	1.400	14.000
76	EFH		10	1.400	14.000
77	EFH		10	1.400	14.000
78	EFH		10	1.400	14.000
79	EFH		10	1.400	14.000
80	EFH		10	1.400	14.000
81	EFH		10	1.400	14.000
82	EFH		10	1.400	14.000
83	EFH		10	1.400	14.000
84	EFH		10	1.400	14.000
85	EFH		10	1.400	14.000
86	EFH		10	1.400	14.000
87	EFH		10	1.400	14.000
88	EFH		10	1.400	14.000
89	EFH		10	1.400	14.000
90	EFH		10	1.400	14.000
91	EFH		10	1.400	14.000
92	EFH		10	1.400	14.000
93	EFH		10	1.400	14.000
94	EFH		10	1.400	14.000

Consumer Nr.	Type	Heated area	Connected consumer load	Consumer full load hours	Consumer heat
95	EFH		10	1.400	14.000
96	EFH		10	1.400	14.000
97	EFH		10	1.400	14.000
98	EFH		10	1.400	14.000
99	EFH		10	1.400	14.000
100	EFH		10	1.400	14.000
101	EFH		10	1.400	14.000
102	EFH		10	1.400	14.000
103	EFH		10	1.400	14.000
104	EFH		10	1.400	14.000
105	EFH		10	1.400	14.000
106	EFH		10	1.400	14.000
107	EFH		10	1.400	14.000