Market uptake of small modular renewable district heating and cooling grids for communities

Project No: 691679

Heating/cooling demand and technical concept for district heating/cooling in Šabac

Letnjikovac (Suburban Settlement of Šabac)
City of Šabac - Serbia

WP 4 – Task 4.4 and 4.5 / D 4.4

February 2018

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This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691679. The sole responsibility for the content of this report lies with the authors. It does not necessarily reflect the opinion of the European Union nor of the Innovation and Networks Executive Agency (INEA). Neither the INEA nor the European Commission are responsible for any use that may be made of the information contained therein.

CoolHeating website: www.coolheating.eu

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1 Introduction

The heating and cooling demand in Europe accounts for around half of the EU's final energy consumption. Renewable energy policies often mainly focus on the electricity market, whereas policies for renewable heating and cooling are usually much weaker and less discussed in the overall energy debate. Therefore, it is important to support and promote renewable heating and cooling concepts, the core aim of the CoolHeating project.

The objective of the CoolHeating project, funded by the EU's Horizon2020 programme, is to support the implementation of "small modular renewable heating and cooling grids" for communities in South-Eastern Europe. This is achieved through knowledge transfer and mutual activities of partners in countries where renewable district heating and cooling examples exist (Austria, Denmark, Germany) and in countries which have less development (Croatia, Slovenia, Macedonia, Serbia, Bosnia-Herzegovina). Core activities, besides techno-economical assessments, include measures to stimulate the interest of communities and citizens to set-up renewable district heating systems as well as the capacity building on financing and business models. The outcome is the initiation of new small renewable district heating and cooling grids in five target communities up to the investment stage. These lighthouse projects will have a long-term impact on the development of "small modular renewable heating and cooling grids" at the national levels in the target countries.

For each of the CoolHeating target municipalities one or two potential projects are identified in which small modular renewable heating and cooling grids could be implemented. The current report describes the technical concept to meet the heat demand in Letnjikovac, a suburban settlement of Šabac.

2 General description of the current situation and concept

The elementary school "Stojan Novaković" in Letnjikovac, a suburban settlement of Šabac, was built in 2004. For heating purposes of the building, a boiler room with 2 x 400 kW hot water boilers is installed. Fuel oil burners were installed on the boilers and a 20,000 l fuel oil seasonal tank was buried next to the boiler room.

The heat supply is carried-out by pre-insulated pipelines to the building of the school and to the Education center (CSU). Heat demands of these two buildings are: 280 kW (the school building 4,500 m^2) and 20 kW (Education center building 480 m^2).

The average fuel consumption (fuel oil) during the previous period was 24,000 l/year with 103 t/year CO_2 emissions and average fuel costs of 33,000 EUR/year including excise tax (excluding excise tax, the cost was 23,000 EUR/year). Other important data are as following: 2,588 degree-days, 181 heating days, mean temperature in the heating period is 5.7°C. There is no central system for sanitary hot water heating nor central systems for space cooling in both buildings. There is no heat consumption outside the heating season, so the installation of CHP plants at this moment is financially unsustainable.

In the surrounding area there are blocks of single family buildings where individual stoves or central heating systems are used. In those furnaces logwood is burned, but sometimes coal is burned as well. Most of the buildings were built before 2012 when there were no strict regulations on the energy properties of buildings. For this reason, the heat consumption is extremely high. From the aspect of energy efficiency and the energy demand, there are no facilities (except school building and CSU) in class C in this area. Other buildings do not meet the minimum criteria and are found in classes D, E and F (see chapter References: link on Rule book on energy certification of buildings). So far, citizens have not launched an initiative to connect to the district heating system. In 2008, it was planned to build a distribution natural gas network, but in the meantime this project has been canceled.

The concept for Letnjikovac could be a biomass boiler and the existing fuel oil boilers for peak load for phase 1 (public buildings) and a larger biomass boiler plus a new fuel oil boiler for phase 2 (public buildings and households). Thermal storages could help to decrease peak load and to optimize the operation of the biomass boilers.

3 Key results of the survey for heating/cooling demand in the target community

The key results of the survey (Puksec et al. 2016[1]) shows that 74% of the buildings in the city of Sabac are households, 26% apartment buildings, about 28% have outer wall insulation and 26% have insulation on the rooftop. 44% of the buildings have a central heating system and 21% have a district heating system.

About 54% are heating with logwood, 17% with district heating, 16% electricity and 7% with natural gas. Most of the households are producing their domestic hot water with electricity. 79% of the households have no cooling needs.

4 Heating/cooling demand for the concept and initial situation

At the time when the selection of locations was done for the implementation of the project, the assessment of heat demand was done. The results of the assessment were shown during the first presentation of the concept in Šabac on 20 September 2017, at the technical training. At the beginning of October 2017, when the concept has been checked, a short survey was conducted according to the questionnaire submitted by the project partner GET. After that, it was concluded that buildings located at the suburban settlement Letnjikovac could be connected to the DH grid in two phases. The first phase includes the following public buildings: the school, CSU and kindergarten. The second phase encompasses single-family houses, grouped by consumption areas (blocks). Furthermore, there is the intention of the municipality of building a sports hall to fulfil needs of the pupils and inhabitants of the settlement.

The success of the first phase should be measured by the satisfaction of users connected to the district heating network and by expressed interest in connecting of new users. This means the beginning of the second phase, i.e. the connection of users from the second phase, could be expected since the heating season in 2019.

For the purpose of connecting buildings that have been foreseen for the second phase, new boiler units should be installed. Increasing the capacity of the heat source will depend on the adopted coefficient of heating (i.e. simultaneity factor) and the applied energy efficiency measures. In January 2017, the City Council of the City of Šabac adopted the own energy policy according to which one of the goals was the implementation of energy efficiency measures, and on 1 February 2017, a budget fund for co-financing energy efficiency measures has been established. Prior to connection to the district heating network, it is expected that the owners of the buildings will perform energy remediation of own buildings after which the heat consumption would be max. 75 kWh/m^2 per year (energy class "C" according to Rule book[2] of energy certification of buildings). Taking all this into consideration, it is realistic to adopt the simultaneity factor SF = 0.70 in refer to the current heat demand and to calculate the actual capacity of the thermal source for connecting the second phase facilities (counting the reserve for the sports hall).

[1] Pukšec T. et al. (2016) Survey on the energy consumption and attitudes towards renewable heating and cooling in the CoolHeating target communities. – University of Zagreb FSB; CoolHeating Report available at www.coolheating.eu

[2] Ministry of Construction, transport and infrastructure Republic of Serbia - Rule book of energy sertification of buildings (2012) http://www.mgsi.gov.rs/sites/default/files/PRAVILNIK%20O%20USLOVIMA%20SADR%C5%BDINI%20I%20NA%C4%8CINU%20IZDAVANJA%20SERTIFIKATA%20O%20ENERGETSKIM%20SVOJSTVIMA%20ZGRADA.pdf

4.1 Map: Potential buildings to be connected to the DH grid

Figure 1 to Figure 6 show the buildings that could be connected to the district heating network and the basic data about these objects.

Figure 1: Location of suburban settlement "LETNJIKOVAC" (Source: Google maps)

The suburban settlement "Letnjikovac", where the building of district heating network with boilers that use wood chips could be planned, is located in the southern part of the city Šabac. To the center of the settlement leads the local road that is connected to the regional road Šabac - Loznica. In this way, good logistics of supplying biomass is ensured.

Figure 2: Micro location of suburban settlement "LETNJIKOVAC" (Source: Google maps)

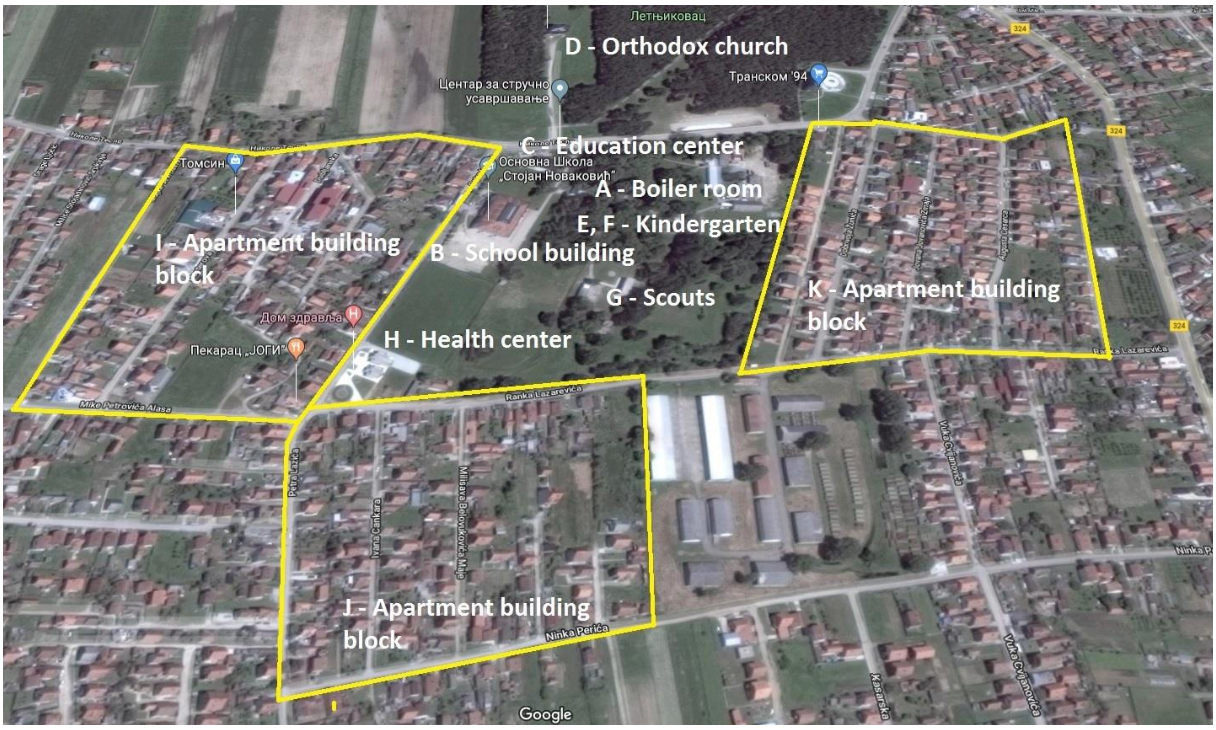

Figure 3: Potential heat consumers at location "LETNJIKOVAC" (Source: Google maps)

Figure 3 to Figure 6 shows individual objects and blocks that can be connected to the district heating network. The existing boiler room (A) belongs to the school and both facilities are on the same plot.

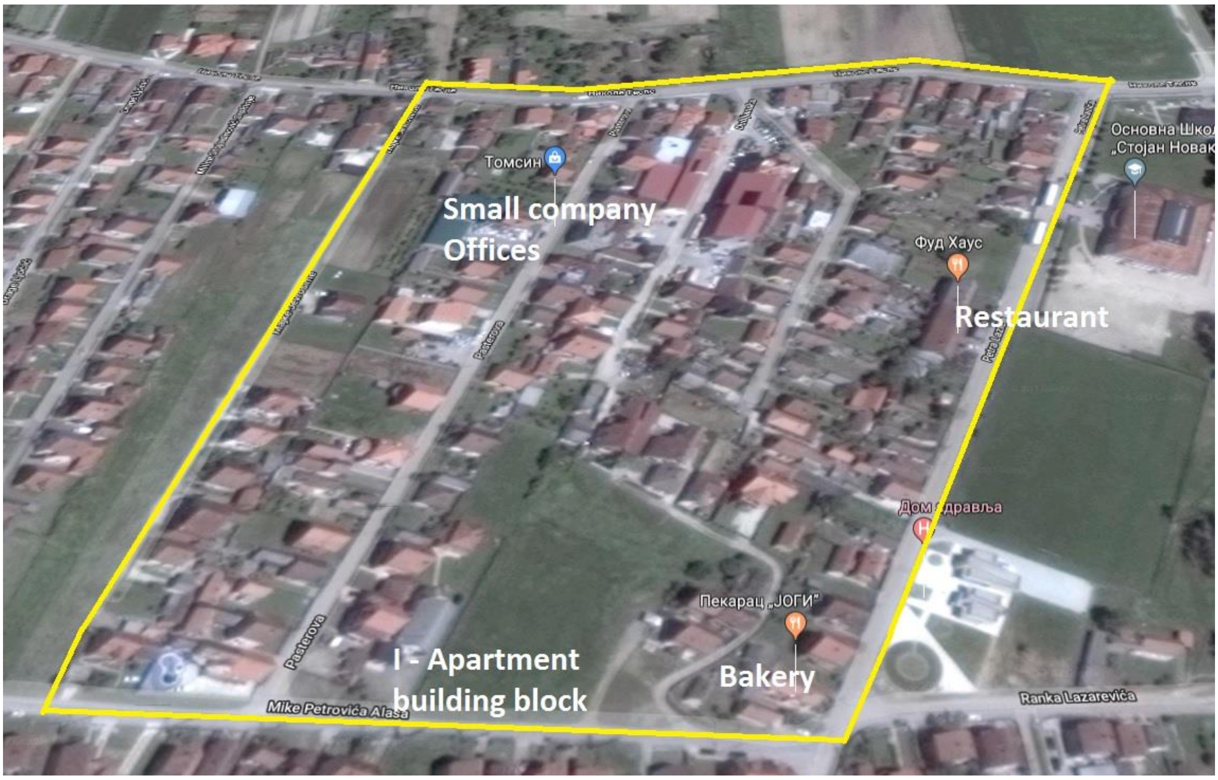

Figure 4: Apartment building block I (Source: Google maps)

Figure 5: Apartment building block J (Source: Google maps)

Figure 6: Apartment building block K (Source: Google maps)

In the apartment building block “I” there are 100 single-family buildings with a total net area of 13,000 m^2. In this block there are also three business facilities: bakery, restaurant and administrative building of company "Tomsin". The bakery and restaurant use electrical devices for preparing food and producing pastries and bread. All three buildings have their own central heating systems in which logwood is used, and for sanitary hot water electric heaters are used.

In apartment building block J there are 80 single-family houses with a total net area of 10,000 m^2. There are no business facilities in this block. Block J on the eastern side is bordered by a military complex that will not be connected to the district heating system.

In apartment building block K there are 130 single-family houses with total net area of 15,000 m^2. There are no business facilities nor facilities for service or production activities.

The common to all single-family buildings in Blocks I, J and K is that individual furnaces are used for space heating, and fewer households use coal. Sanitary hot water heating is done by electrical devices. There is no example of the installation of solar thermal collectors. Very few households use split units for house cooling.

Most of single-family residential buildings were built in the period 1980 to 2012. A small number of buildings were built after 2012. Buildings from this period of construction are without built-in thermal insulation but very few buildings have thermal insulated facade constructions with polystyrene, thickness no more than 5 cm. After 2000, a huge number of household owners decided to replace the windows. Unfortunately, the quality of the built-in windows is very low because during selection the determining factor was price, but not quality. By installing windows, partially the problem of tightness was solved and to some extent the ventilation losses were reduced.

Representatives of citizens who are living in these blocks attended the workshops on the project and expressed their interest in connection their buildings to the heating grid if financial sustainability is proven. After the first discussion, as an important advantage, the comfort that includes district heating is emphasized, there is no need for citizens to provide fuel for months in advance or to occupy space for fuel storage in their households. From the aspect of environmental protection, coal will be removed and the wood will be used more efficiently and the use of electricity for sanitary hot water heating will be reduced, which will contribute to reducing CO_2, soot and fly ash emissions.

Figure 7 shows existing boiler room that is used for heating the school building and CSU. For purpose of the installation of a biomass boiler, the reconstruction of the boiler room should be carried out, including the upgrade of the fuel storage, which can receive up to 70 m^3 of wood chips.

Figure 7: Existing boiler room at location "LETNJIKOVAC" (Source: Slobodan Jerotić)

Inside the existing boiler room there are two boilers with a capacity of 2 x 400 kW, shown in Figure 8. Burners for combustion of fuel oil have been installed onto these boilers.

Figure 9 shows the controller on which the temperature mode of the working medium is set. Working medium is water. The supply water temperature is set to 80°C for a minimum outside air temperature of -20°C. The outdoor air temperature sensor is located on the north facade wall of the boiler room.

Figure 8: Two fuel oil boilers inside of the boiler room (Source: Slobodan Jerotić)

Figure 9: Boiler controller (Source: Slobodan Jerotić)

Figure 10 shows the west facade of the mentioned school building.

Figure 10: West facade of school building (Source: Slobodan Jerotić)

4.2 Assessment of heating/cooling demand

During November 2017 heating and cooling demand was assessed with the owners and users of the buildings in the area of "Letnjikovac" settlement. The general conclusion of the assessment is that there is the interest of citizens and users of facilities to connect to the DH grid. The connection process could be realized in two phases.

The first phase of the project implementation could be carried out in 2018. The following facilities could be connected in phase I, shown in Table 1:

Table 1: Assessed heating demand for phase I

Building number	Heating load (kW)	Useful heat (kWh/a)	Consumer
B	230	184,000	School building
C	17	16,000	Education center building
E	61	60,000	Kindergarten building
F	61	60,000	Kindergarten building
Σ	369	320,000	

During the second phase of project execution, the following users could be connected (Table 2):

Table 2: Assessed heating demand for phase II

Building number	Heating load (kW)	Useful heat (kWh/a)	Consumer
D	12	5,500	Orthodox church
G	20	9,000	Scouts building
H	23	24,000	Health center
I	1,213	1,184,121	Apartment building block
J	938	915,569	Apartment building block
K	1,433	1,398,773	Apartment building block
Σ	3,759	3,536,963	

As already mentioned there are only three commercial buildings in the residential blocks as well as single-family buildings. All of those buildings need heat for space heating only. There are no industrial or process heat consumers and therefore there is no need for steam or sanitary hot water.

Apartment building blocks I, J and K have not been fully developed which means that number of potential end users could be increased. On the other hand, the local Energy Policy promotes energy efficiency measures and the city administration have been considered a proposal to allow connection to the district heating grid only for facilities that meet the requirements of the minimum energy class "C", i.e. that the annual heat consumption is 75 kWh/m^2. Also, the city administration will continue to co-finance the improvement of the energy properties of existing buildings, and for newly constructed buildings the legislation regulates the maximum required annual energy consumption at level of 70 kWh/m^2 of heated space.

5 Technical concepts for heat/cold generation

The management of the DH grid could be done the local heating company PUC "Toplana-Sabac", which could also be obliged to provide the logistics of fuel supply. The City Council of the City of Sabac has the authority to issue the necessary regulatory acts such as: Decree on the operation of the heating system, tariff system and heat prices, model of the contract between PUC and end consumers including the rights and obligations of the contracting parties and the duration of the contract as well as other legally prescribed documents. In accordance with the Law on Efficient Use of Energy, the city administration could decide on subsidizing the costs of equipment procurement or costs of heat production using renewable sources.

Other technologies at this moment are expected to be not financially viable because of the excessive investment costs, such as the construction of seasonal heat storages that is referred to increase use of solar energy. Research on the potential of geothermal energy at this location has not been carried out, but based on the existing data for the city of Sabac it can be expected that individual facilities could use underground water of an average temperature of 13°C for heating. The problem is the obligation to build absorbent wells through them the used water will pushed down into ground. Legislation is not fully clear in relation to the use of groundwater for heating and cooling purposes and the system of control and monitoring of the use of groundwater has not been built yet (under the jurisdiction of the republic authorities).

5.1 District heating / cooling grid

Based on the density of the existing facilities and the existing urban organization, the concept of the district heating network is presented in Figure 11 to Figure 14.

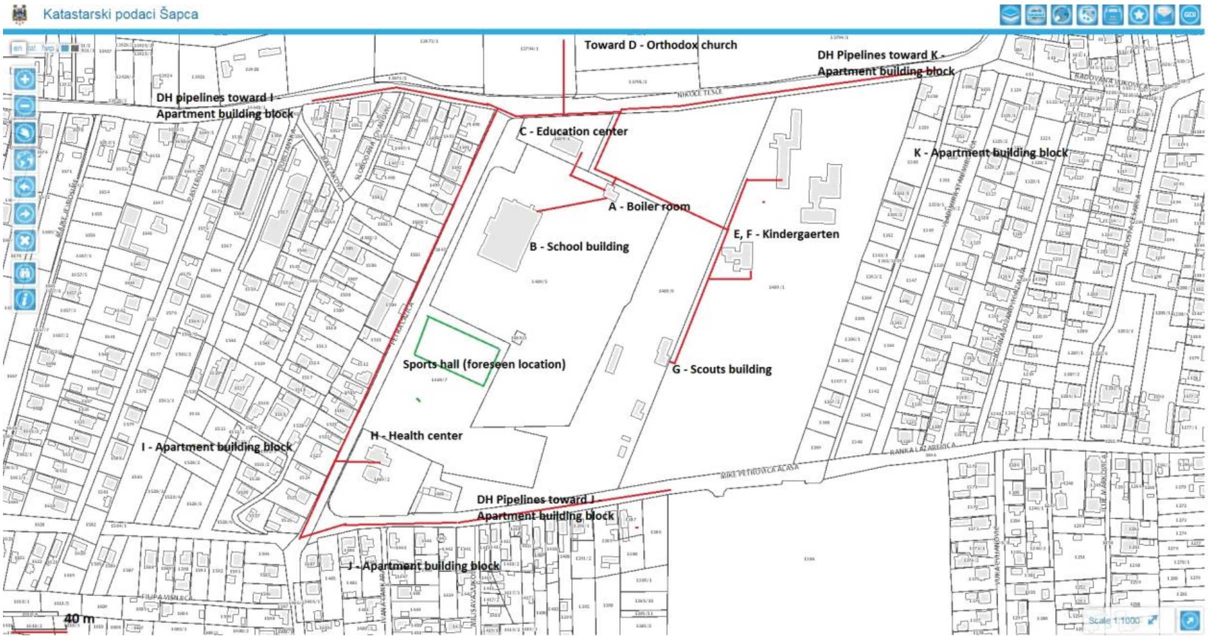

Figure 11: DH network proposal (Source: Geographic information system of City of Šabac)

Figure 12: DH network proposal (Source: Google maps)

Figure 13: DH network proposal (Source: Google maps)

Figure 14: DH network proposal (Source: Google maps)

The DH grid could be designed in 2 phases.

Phase 1:

Phase 1, as shown in Table 1, could be supplied with 100% connection rate. The grid length at this phase could be about 420 m. The grid density of a DH grid is an important indicator for the economy of a system, as well as for the DH grid losses. The grid density is calculated with the annual heat consumption of the consumers, divided by the grid length. The calculated grid density for phase 1 is 762 kWh per meter pipeline and per year. Compared to Austrian regulations the value should be higher than 900 kWh/m/a. So, the economy of the project needs to be checked in detail at the next steps.

The annual heat losses for the DH grid for phase 1 were calculated with 12%, or 46 MWh/a, based on real DH grids data in Austria (calculation based on Malik (2012)[3]), for the grid density shown above.

About 320 MWh per year could be sold to the consumers. In total 366 MWh/a are needed to feed the DH grid, including heat losses. The annual load line is shown in Figure 15.

The temperature level of the DH grid could be designed with 90°C flow and 65°C return flow. An operation of the DH grid in summer time, e.g. for domestic hot water, is not planned yet.

Using night setback (reduction of room temperature at night and heat up in the morning) by the consumers causes higher peak loads in the morning and could also cause very low loads at night. The calculation is based on 50% of the consumers having night setback. That's why the peak load of the grid is higher than without night setback. The thermal peak load of the DH grid was calculated with about 400 kW.

The material of the DH pipes could be steel or plastic (if the flow temperature is lower than 90°C). Simultaneity of the load was calculated with 100%.

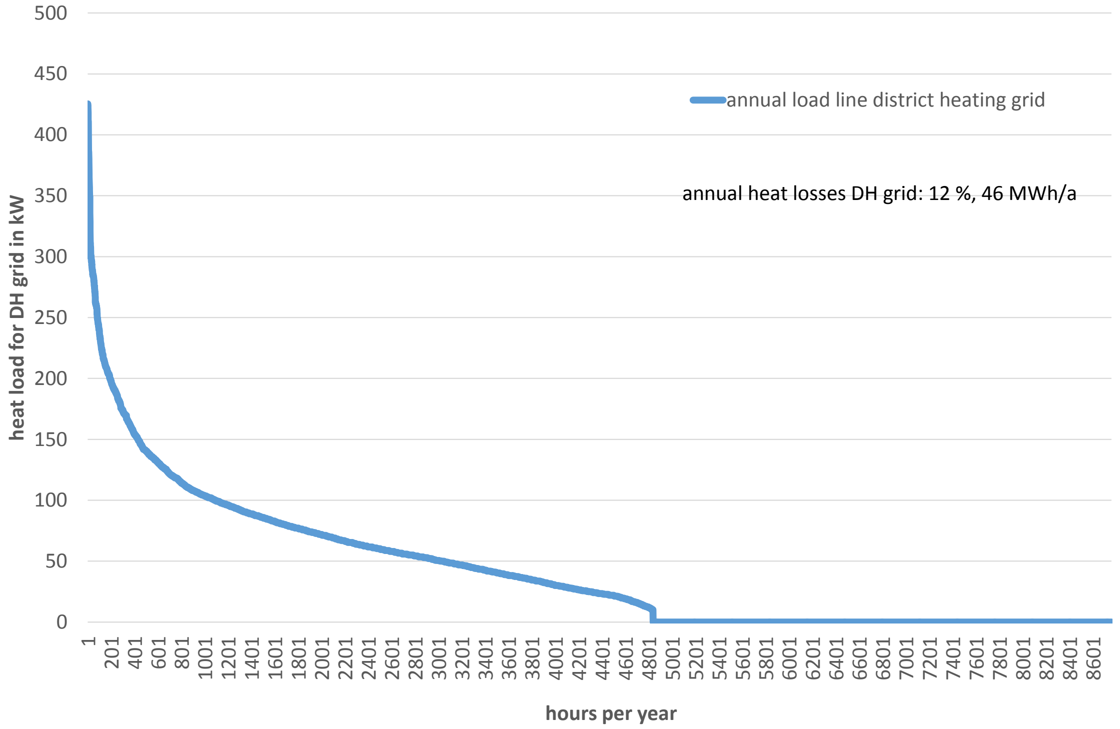

Figure 15: Annual load line for phase 1, including heat losses of the grid

[3] A. Malik et. al. (2012) Was ist ein gutes Heizwerk? - Landesenergieverein Steiermark and qm heizwerke Datenbank; https://www.klimaaktiv.at/dam/jcr:9f6e7fe5-48b0-4cb1-a9d6-8a57dc908713/Was_ist_ein_gutes%20Heizwerk.pdf

Phase 2:

Phase 2, as shown in Table 2, considers all consumers from phase 1, plus 80% of the potential residential consumers. The total grid length could be about 7,656 m, including connections to the consumers (on average 7 m per consumer for 248 households). The calculated grid density for phase 2 is 462 kWh per meter pipeline and per year. So, the economy of the project needs to be checked in detail at the next steps.

The annual heat losses for the DH grid for phase 2 were calculated with 17%, or 738 MWh/a, based on real DH grids data in Austria (calculation based on Malik (2012)[4]).

About 3,537 MWh per year could be sold to the consumers. In **total 4,275 MWh/a** are needed to feed the DH grid, including heat losses. The annual load line is shown in Figure 16. In phase 2 it is also planned not to operate the DH grid in summer time.

Based on 50% of the consumers using night setback, the peak load was calculated with about 4,500 kW. If the consumers don't use night setback at the coldest days, this peak load could be lowered to about 3 MW.

Caused by the only 21% of the households with cooling needs, a cooling grid might not be feasible.

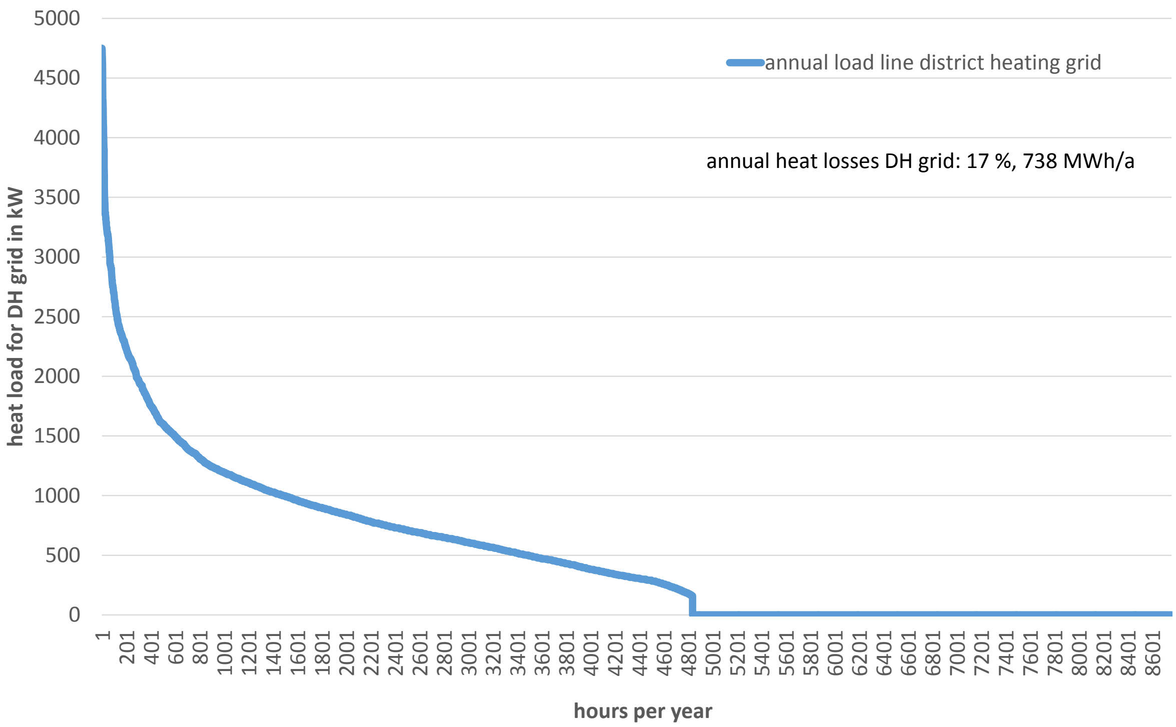

Figure 16: Annual load line for phase 2

5.2 Heating / Cooling generation

The concept for the heating units plans the location of the boiler room at the existing place, close to the education center, shown in Figure 17. The existing building could be expanded and rebuilt for the new boilers.

[4] A. Malik et. al. (2012) Was ist ein gutes Heizwerk? - Landesenergieverein Steiermark and qm heizwerke Datenbank; https://www.klimaaktiv.at/dam/jcr:9f6e7fe5-48b0-4cb1-a9d6-8a57dc908713/Was_ist_ein_gutes%20Heizwerk.pdf

Figure 17: Plot for the boiler room (Source: Google maps)

At phase 1, one biomass boiler with 150 kW nominal capacity could be installed. The existing fuel oil boilers could be used for peak load. About 93% of the annual heat demand could be covered with the biomass boiler and only 7% with the peak fuel oil boilers. The calculated data for the heating units for phase 1 are shown in Table 3, the annual load line in Figure 18.

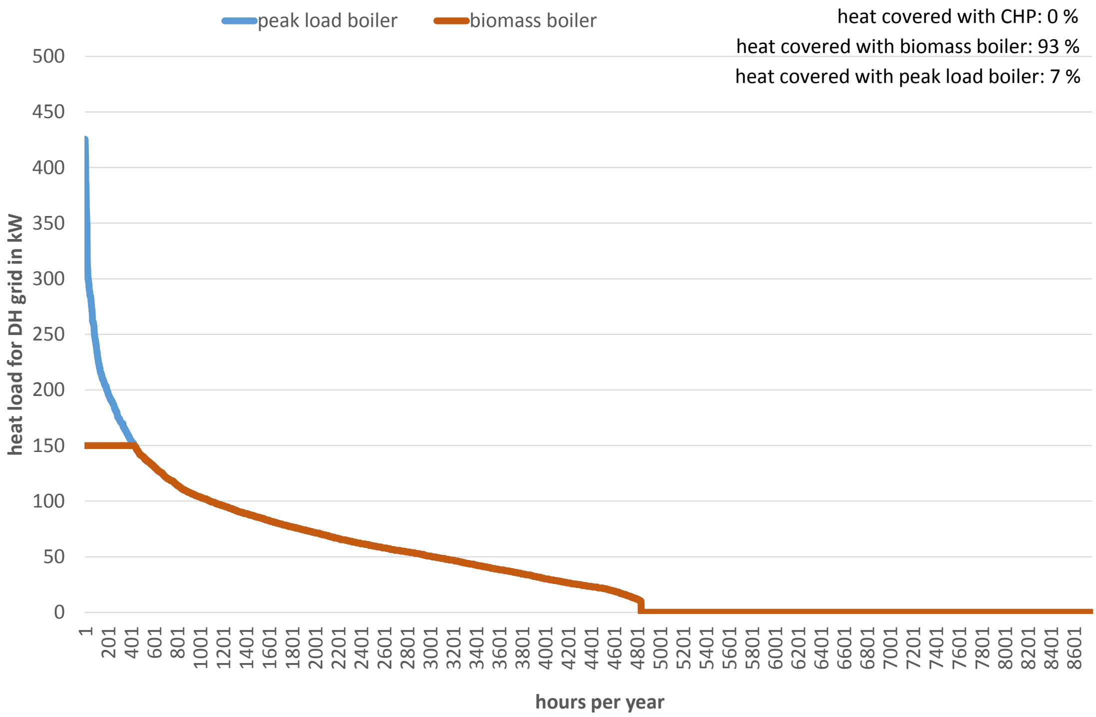

Figure 18: Annual load line of the heat production units for phase 1

Table 3: Calculated data for the heating units for phase 1

	load in kW	produced heat in MWh/a	needed fuel energy in MWh/a	annual efficiency in %	share of total heat for DH in %	full load hours per year
Biomass boiler	150	340	415	82%	93%	2,268
Oil peak load boiler	416	26	32	80%	7%	62

A buffer storage tank with 6 m³ could help to optimize the operation of the biomass boiler, as well as to lower peak loads after night setback in the morning. This thermal storage could be located inside or outside (with better insulation and weather proof coating) of the boiler room. The hydraulic scheme for the heating units is shown in Figure 19.

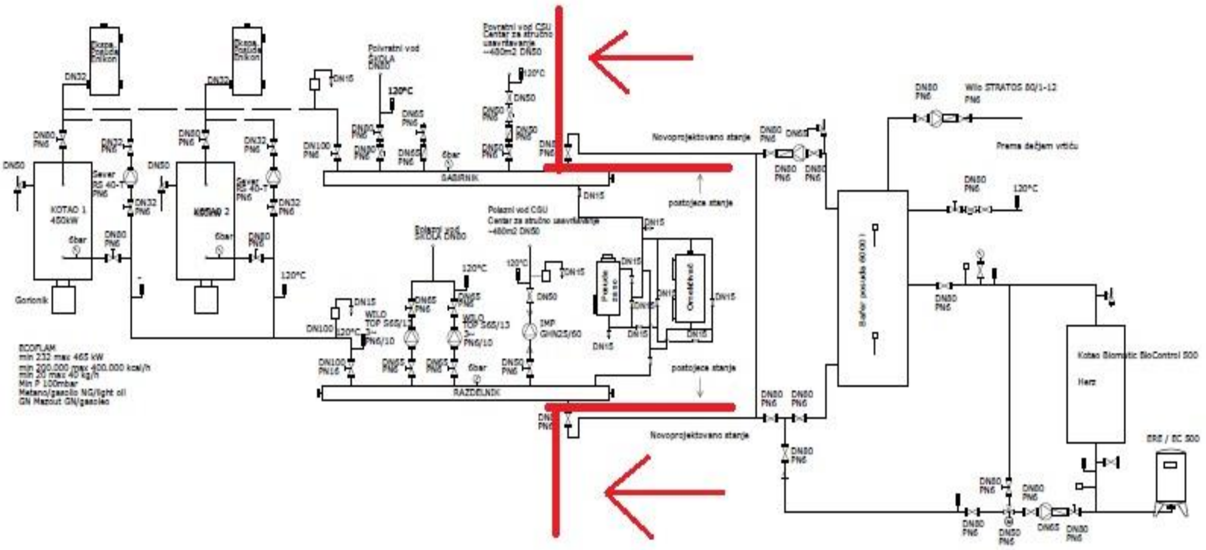

Figure 19: Hydraulic scheme of the heating units for phase 1 (Source: Slobodan Jerotić)

At phase 2, one biomass boiler with 1,500 kW nominal capacity could be installed. The peak load should be covered with an fuel oil boiler with about 3.5 MW. About 91% of the annual heat demand could be covered with the biomass boiler and only 9% with the peak fuel oil boilers. The calculated data for the heating units for phase 2 are shown in Table 4, the annual load line in Figure 20.

If the night setback at the coldest outside temperatures could be reduced to 0% of the consumers, the peak load could be reduced to 2.5 MW.

Table 4: Calculated data for the heating units for phase 2

	load in kW	produced heat in MWh/a	needed fuel energy in MWh/a	annual efficiency in %	share of total heat for DH in %	full load hours per year
Biomass boiler	1,500	3,887	4,741	82%	91%	2,592
Oil peak load boiler	3,500	387	484	80%	9%	84

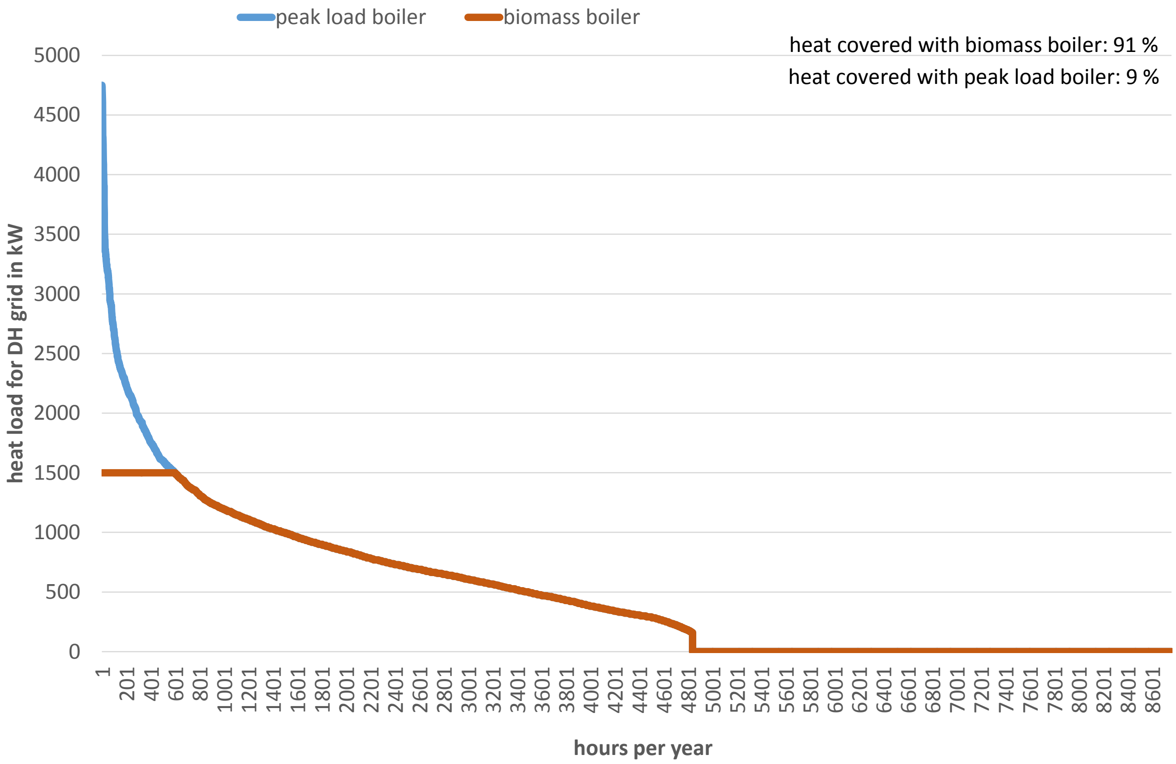

Figure 20: Annual load line of the heat production units for phase 2

A buffer storage tank with 60 m³ could help to optimize the operation of the biomass boiler, as well as to lower peak loads after night setback in the morning. This thermal storage could be located outside (with better insulation and weather proof coating) of the boiler room.

Figure 21 shows a possible heat substation for each consumer.

Figure 21: Heat substation for households (Source: Danfoss, Denmark)

6 Summary of the technical concept

The concept for Letnjikovac could be a biomass boiler with 150 kW and the existing fuel oil boilers for peak load for phase 1 (public buildings) and a 1,500 kW biomass boiler with a 3.5 MW fuel oil boiler for phase 2 (public buildings and about 248 households). Thermal storages with 6 m³ (phase 1) and 60 m³ (phase 2) helps to decrease peak load and to optimize the operation of the biomass boilers.

The DH grid could be 420 m at phase 1 and 7,656 m in phase 2. The grid density is in phase 1 with 762 kWh/m/a higher than in phase 2 with 462 kWh/m/a. The feasibility study could show if this DH grid is economic, due to the low grid density.

In **total 4,275 MWh/a** heat are needed to feed the DH grid, including heat losses.

In the next step, economic calculations will be made for these scenarios in order to facilitate the selection of the best concept in order to develop an individual business model. In the final step, a feasibility check will be made to present the potential project with most feasible technologies and business options to decision makers and investors.