<CTCN Pro Bono Technical Assistance Project>

Incorporating Innovative Renewable and Waste Heat Technologies in Belgrade's District Heating System

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KOREA DISTRICT HEATING CORP.

Yujin Energy Consulting Co.
Efficiency, Cost, Optimization and Saving

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Part Ⅰ

Potential Study of Renewables Connected to District Heating

1. General introduction of renewable technologies in District Heating system

1.1 Overview of renewable heat sources for district heating

District heating have been primarily based on fossil fuels up until now, with coal and natural gas meeting the bulk of demand. Combined heat and power (CHP) plant and Heat only boiler (HOB) was a conventional heat source of district heating. District heating system enables the use of a variety of heat sources such as heat from waste incineration, biomass, geothermal, solar thermal, biogas, etc. District heating systems are one of the most effective means for integrating renewable heat sources into heating sectors.

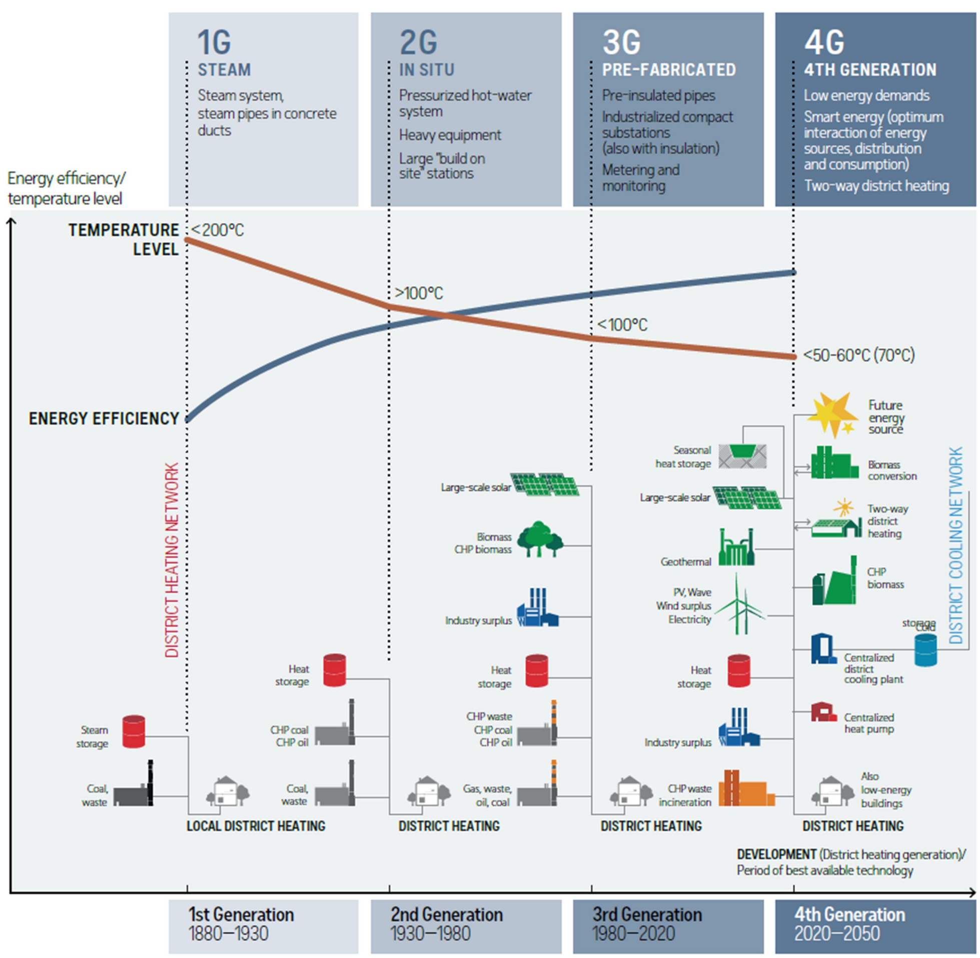
Some of conventional and renewable technologies used in district heating are described in table 1 as followed. Conventional technologies means that do not considered use of renewable heat sourece.

Table 1. Conventional and renewable technologies for district heating

Category	Technology	Fuel Source	Benefits	Impact on Climate change
Conventional (Non-Renewable)	Combined Heat and Power (CHP)	Fossil Fuel(Coal, Petroleum, Natural gas)	◆ Increase of primary enery efficiency. ◆ Cost effective by large and centralized heat supply	◆ Partially CO_2 emission reduction ◆ Recycled Heat
	District Heating Boiler	Fossil Fuel(Coal, Petroleum, Natural gas)	◆ Reduce overall system cost. ◆ Suitable for peak load	CO_2 emission
	Waste-To-Energy, Incineration plant	Municipal solid waste (MSW) and other combustible waste	◆ Low cost heat	◆ Partially CO_2 emission reduction ◆ Recycled heat
Renewables	Combined Heat and Power (CHP)	Biomass, Biogas	◆ Production of electricity and heat by low CO_2 emission	CO_2 neutral
	District Heating Boiler	Biomass, Biogas	◆ Renewable and low CO_2 emission	CO_2 neutral
	Geothermal	Heat from Underground Reservoir	◆ Cheap running costs and 'fuel' for free	CO_2 free
	Waste Heat Recovery	Waste heat from Industrial process, data centers, low-grade heat from sewage, etc.	◆ Recycling waste energy increase the energy efficiency of city	CO_2 free
	Heat Pump	Electricity from renewable and low-grade heat source	◆ Renewable heat in case of heat pump connect with renewable electricity	CO_2 free,
	Solar Thermal	Solar radiation	◆ Cheap running costs and 'fuel' for free ◆ Renewable and CO2 free energy	CO_2 free

In the historical development of district heating system, the present is defined as the 3rd generation network. The future standard of district heating is referred to as 4th generation district heating system and is the natural progression from a developed 3rd generation network. 4th generation systems operate at lower temperature, resulting in reduced heat loss compared to previous generation, and they make it feasible to connect to areas with low energy density. The system can use diverse sources of heat, including low-grade waste heat, and can allow consumers to supply heat as well. Heat storage, smart energy systems and 2-way district heating systems in 4th generation DH provide the flexibility required to integrate a variety of renewable energy into the heat grid. Figure 1 shows the historical development of district heating systems, including their increased efficiency and diversification of heat sources.

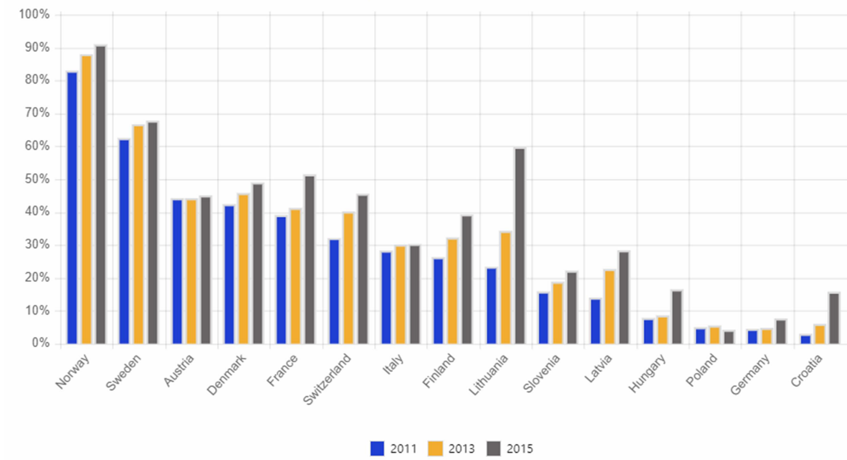
Figure 1 historical development of district energy networks



Source: UNEP, District Energy in cities, 2017

According to a recent report by Euro heat&power, district heating has been constantly providing its potential to integrate more renewable energy sources and the trend is going upwards in almost European countries. On average, the share of renewable energy in district heating increased by 10% since 2011 in the 15 European countries. Norway, Sweden, Lithuania and France accounted for over 50% of renewable energy in district heating in 2015. Denmark also had a share of renewable energy close to 50%.

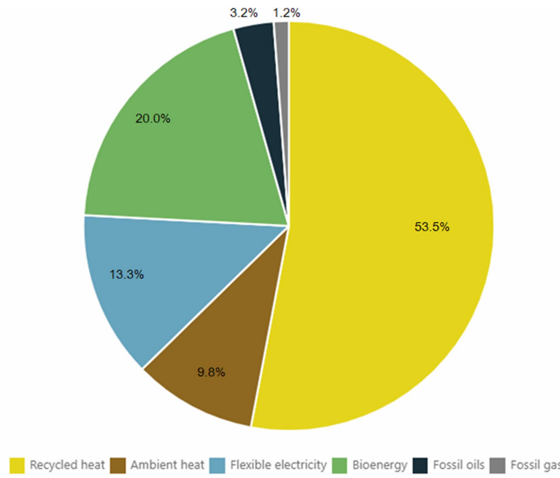
Figure 2 the share of renewable energy in DHC



Source: Euroheat & power, Country by Country, 2017

However, the renewable energy statistics for district heating in this reports include recycled heat, including waste incineration heat. For example, the share of renewable energy in Norway's district heating exceeded 90% in 2015. Recycled heat, which accounts for 53.3%, is industrial heat and waste heat. Recycled heat is regarded as CO_2 neutral, as household waste is recycled. The plastic fractions are mostly recycled, so the fossil fractions of household waste are low. But recycled heat is not a CO_2 free. 9.8% of ambient heat is consist of heat pumps, solar heat, heat from cooling processes. Renewable electricity from hydro power is used in heat pumps. Therefore, strictly this ambient heat ratio is only truly CO_2 free renewable heat. Flexible electricity (13.3%) is means use of electricity in electric boilers, in period of surplus electricity. Flexible electricity can also be regarded as CO_2 free heat as the perecentage of hydro power in the Norway energy mix is 44%. Bioenergy (20.0%) consist of wood chips, briquette, wood waste, bio-oil and biogas. Bioenergy is also regarded CO_2 neutral.

Figure 3 Energy sources in Norway 2015



Source: Euroheat & power, Country by Country, 2017

In Sweden, the proportion of combustible renewable CHP was 27.9% and waste CHP was 18.5% in district heating source in 2015. In case of direct use, a component of ratio of combustible renewables was 21.1%, renewable waste was 7.7%. Heat pumps were occupied 6.9% of the district heating heat source, industrial surplus heat accounted for 6.7% in 2015.

Even in European countries, CO_2 neutral technologies such as biomass and waste incineration account for a large portion of renewable energy sources in district heating systems. This is because the large-scale heat required for district heating is still difficult to secure from the CO_2 free renewable energy source.

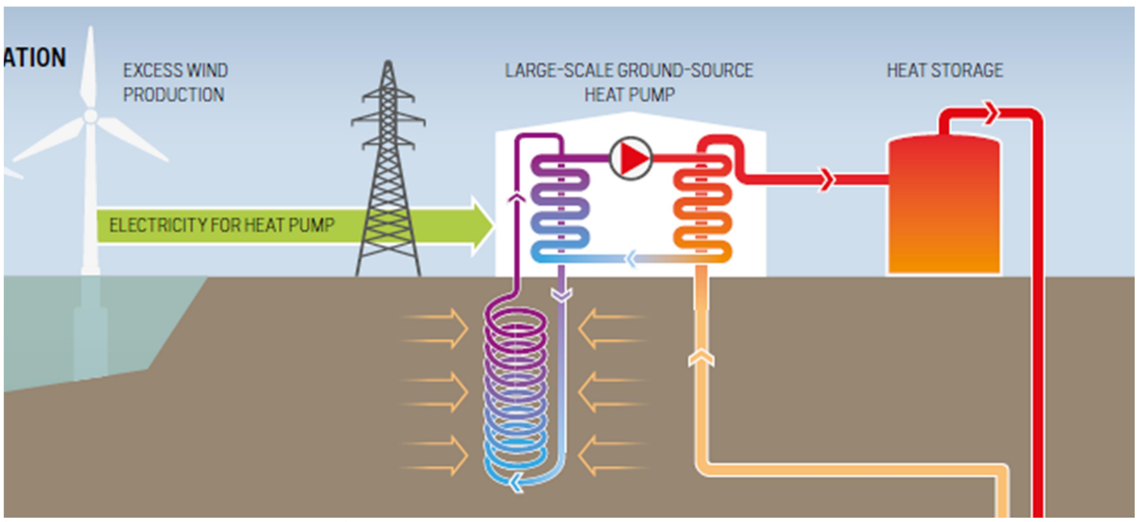
However, even CO_2 neutral technologies, when applied to district heating, can reduce the proportion of fossil fuels in the heating sector and have a positive effect on climate change.

The next sections describe the renewable technologies applied to district heating.

1.2 Heat Pump

Recently, Large-scale heat pumps have emerged as the most appropriate technological alternatives to convert surplus electricity generated from renewable energy into heat sources in district heating. It uses the excess of electricity generated by wind, hydropower and solar power as the power of the heat pump to upgrade low-grade heat (such as underground water, sewage water, condenser cooling water of power plant, river, etc.) technology. This method is combined with heat storage, and it possible to use renewable energy for district heating by power-to-heat method using surplus power generation period.

Figure 4 Connecting Renewable Electricity Generation

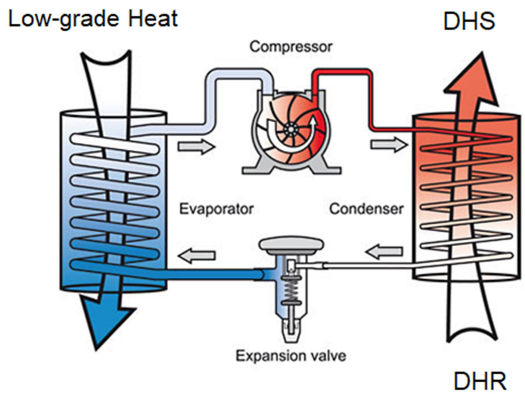


Source: UNEP, District Heating in Cities, 2017

Heat pumps have mechanical heat pumps that use electricity, and also absorption heat pumps that use heat. The mechanical heat pump is a conventional technology in which electricity is used as a compressor power for refrigerant compression, refrigerant absorption heat source for expanding low-grade heat in an evaporator, and refrigerant condensation heat discharged from a condenser as a heat source for heating return water of district heating system.

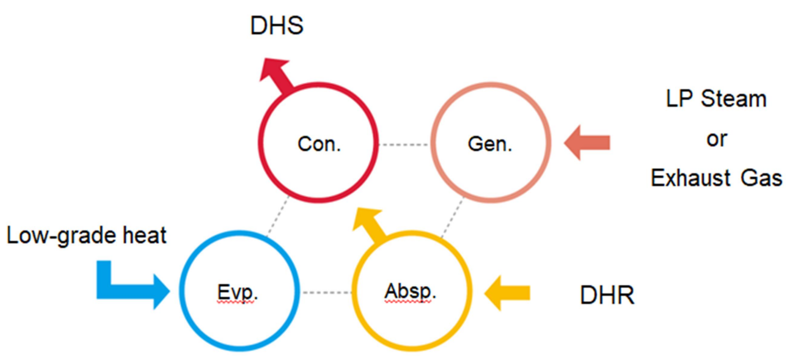
In order for the mechanical heat pump to be positioned as a renewable energy source for district heating, it is considered that the electricity generated from the renewable energy must be directly connected or the renewable energy ratio must be high on the national grid.

Figure 5 Mechanical Heat Pump for District Heating



The absorption heat pump is a system that can supply both cooling and heating using waste heat without using electricity. The absorption heat pump is generally a technology that utilizes lithium-bromide as a absorbent and water as a refrigerant and exploits heat absorption and release in the condensation-evaporation cycle of water and the absorption-evaporation cycle of lithium-bromide with high vacuum pressure.

Figure 6 Absorption Heat Pump for District Heating



DHR: District Heating Retrun water
DHS: District Heating Supply water
LP Steam: Low Pressure Steam from Steam Turbine
Gen. : Regenerator
Con. : Condensor
Absp. : Absorbor
Evp. : Evaporator

The high temperature waste heat (such as LP steam or heat recovered from exhaust gas) is supplied to the regenerator to separate the water from the mixture of lithium-bromide and water. The low-temperature waste heat is supplied to the evaporator and maintains the boiling temperature at low temperature and low pressure, and the district heating return water passes through the absorber and condenser and is heated through absorption heat of lithium-bromide and condensation heat of water to become district heating supply water.

The absorption heat pump is a system that can simultaneously produce hot water for heating and chilled water for cooling by using waste heat, which can be used as a renewable energy source for district heating and cooling.

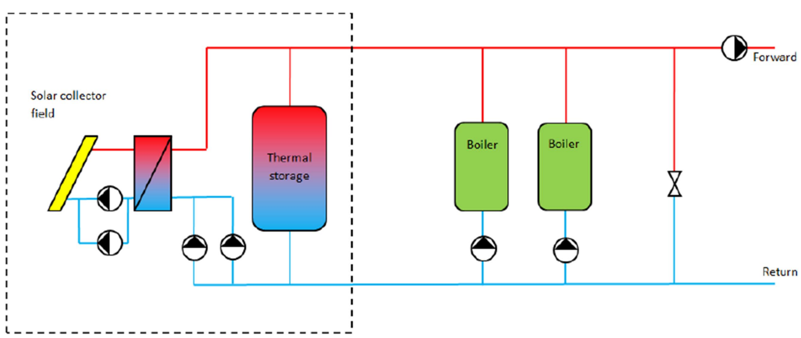
1.3 Solar thermal

Solar thermal systems transform solar radiation into heat. The solar thermal system can be simply configured as a solar collector and a circulation and control system of heat medium. The solar collectors can be located on the field or on roofs. But roof top solar collector types is more useful for prosumers not to district heating provider. The rows of solar collectors are placed in parallel, and the solar panel in each row is connected in series. The heat transfer liquid(ex. Propylene glycol, etc.) is heated in the solar panels, and the temperature is controlled by control of the flows.

For the solar thermal is utilized in the district heating system, then the solar collectors are connected to the district heating pipe network and first option is heat energy storage in all district heating pipe network. This stored heat will be consumed from district heating network by the consumers.

Solar thermal systems are capable of producing heat in the daylight hours, whereas the time required to supply heat is usually outside of daylight hours. Therefore, a minimum daily heat storage system is required for the solar thermal system. Recently, a seasonal heat storage system has been adopted to overcome the low efficiency of the solar thermal system in the winter season.

Figure 7 Principal drawing of solar district heating



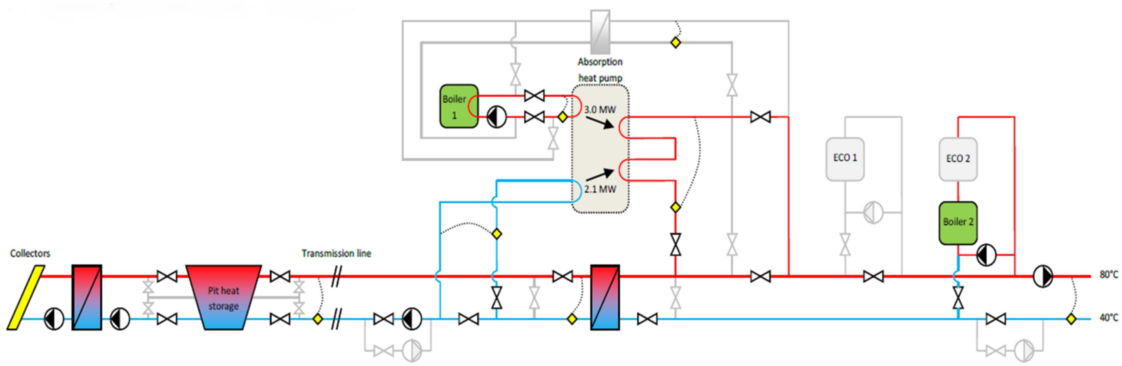
Source: PlanEnergi, Investigation of Solar District Heating in Belgrde,2016

The thermal storage can be of different sizes; designed for diurnal variations or seasonal storage. Larger heat storage will enable a higher solar fraction, and it is common to apply a heat pump to the system because the temperature of stored water is lowered. In case of a low temperature district heating system, heat pump is not required.

Large heat storage would also facilitate a high degree of flexibility in the heat production. An investment in solar district heating, seasonal heat storage and heat pump would therefore imply options for exploiting other heat sources, e.g. surplus heat from industry, which would otherwise not be exploited.

As shown in Fig. 8, the solar thermal system employing PTES can be supplied with high tempaerature water even in winter by absorption heat pump. Absorption heat pumps using boiler heat can be used to increase the temperature of the low temperature water stored in the pit without the need for electricity.

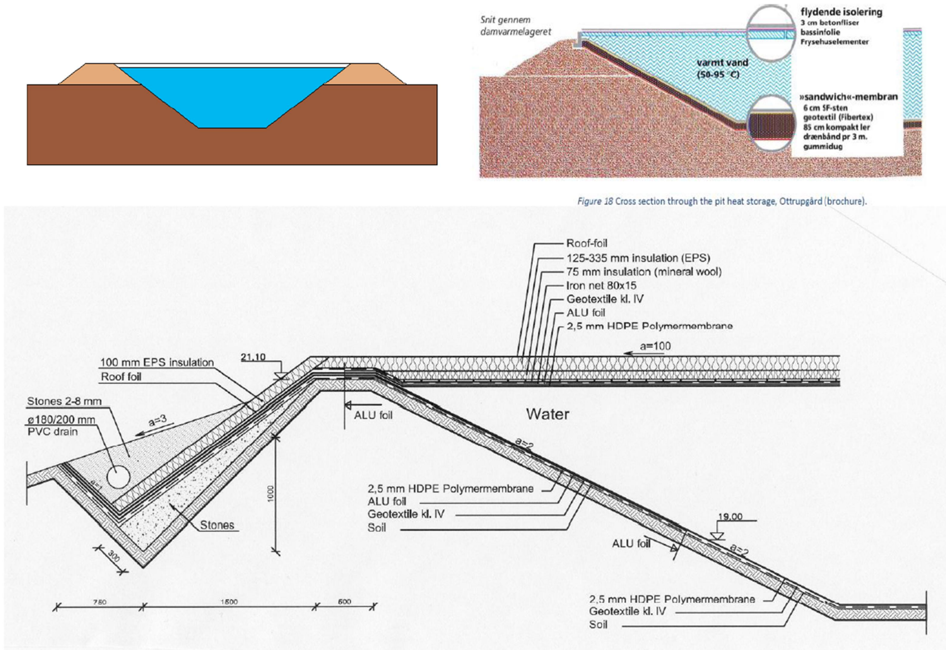
Figure 8 The Dronninglund solar thermal plant and pit thermal energy storage



Source: PlanEnergi, Investigation of Solar District Heating in Belgrde,2016

There are different technical concepts for seasonal heat storage. One of the concept is the pit thermal energy storage (PTES), which has been developed since the 1980's at Danish Technical University. Liners are applied both as part of the lid and in the top of the PTES. The slope of the sides is relatively low, but depends on the local soil conditions.

Figure 9 Principal of pit thermal energy storage(PTES)



Source: PlanEnergi, Investigation of Solar District Heating in Belgrde,2016

The key points for PTES are choice of material and water chemistry. Water treatment – removal of salts and calcium, raise of PH to 9.8- is important to reduce and avoid corrosion. In addition, choice of steel quality of the pipes is crucial to ensure long technical lifetime.

The insulation material in the lid should be resistant to water in case of a leakage, so that the insulation effect is not lost. Leakages can be found and repaired by divers.

A key component of the PTES is the liner. The technical lifetime of the liner depends on the temperature of the water – the higher the temperature the shorter the lifetime.

1.4 Biomass

Most countries possess major volumes of underutilized biomass feedstock potentially available for district heating boilers or CHP plants.

Fuelwood is harvested for energy generation. Its high quality and multiple use options make it the most expensive biomass resource.

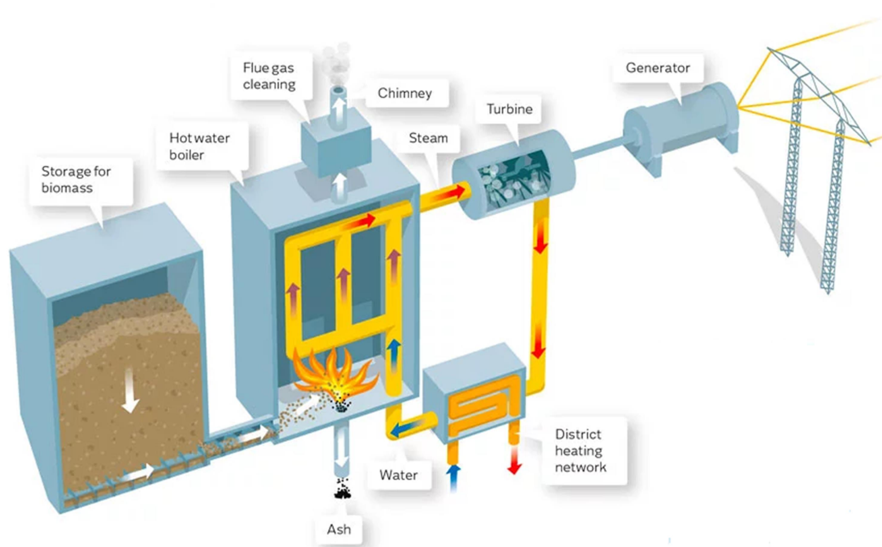
Energy crops include all sorts of woody and grassy crops cultivated specifically for direct combustion or fuel generation.

Agricultural residues are available in large quantities in major farming regions. They include straw from several types of grains as well as stalks and leaves from corn or other locally produced plants.

Forestry residues are residues removed from logging and dead trees. This resource is underutilized because it is not economical to collect and transport the material in the absence of a market for bioenergy feedstock.

Organic waste is defined as the organic component of municipal solid waste. Its availability is determined by the number of urban residents, the per capita generation of waste and the typical composition of household waste. In some countries the resource is mainly used for compositing.

Figure 10 Biomass CHP for District Heating



Many European countries already makes significant use of biomass for district heating, especially to fuel converted coal power plants. However, much of this fuel is imported from neighbor countries because the domestic resources are limited. On the other hand, some countries benefit from large forest resources, and it is likely that these residues will be underutilized. In general, the potential to increase biomass use in direct heat generation is significant.

Generally, the biomass CHP plant consist of a biomass storage fit, furnace, boiler, flue gas cleaning facility, steam turbine generator and district heating heat exchanger.

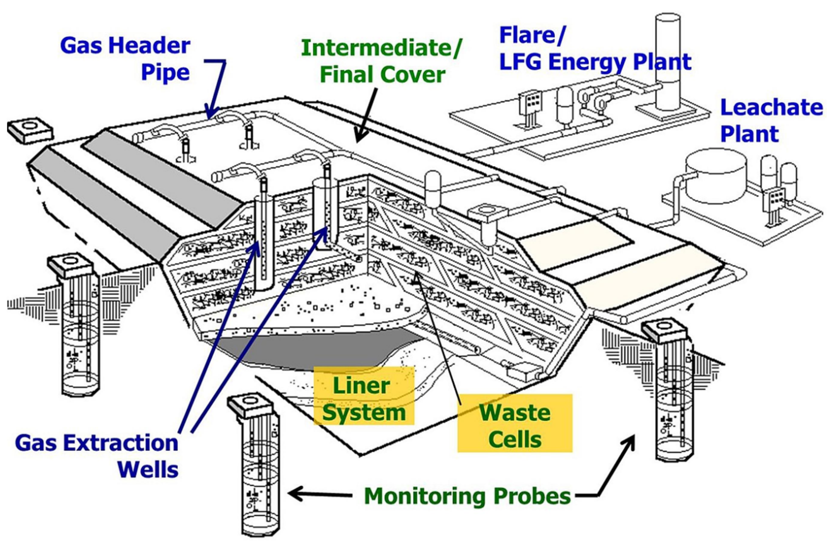
Biomass fuel is stored in a bunker for further transport to the boiler. In the boiler, water is heated to high temperature under pressure and then made high pressure steam. Steam from the boiler powers the turbine, which is connected to the generator. Steam that has passed through the turbine heats district heating water, which is distributed through the district heating network piping.

1.5 Biogas

Biogas includes LFG from waste landfill site and ADG from organic waste anaerobic digesters. LFG is generally a good fuel source with a methane content of 45~55% and a calorific value of 4,500~5,500 kcal/Nm_3. Generally, ADG has higher methane content and higher calorific value.

LFG is collected through a vertical gas extraction wells installed on the landfill body and transported to the energy facility through individual pipe, manifold and header pipes. The collected LFG is supplied as fuel to the gas engine power plant after moisture, H_2S and siloxanes components are removed from the pretreatment facility.

Figure 11 LFG collection and utilization system

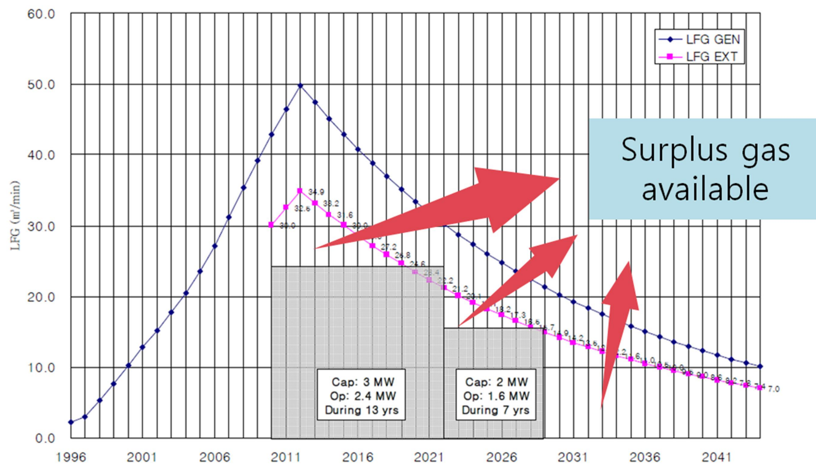


The moisture and H_2S of LFG can cause corrosion in the energy plant, and the siloxanes component can be converted into SiO_2 in the combustion process, causing wear on the engine cylinder and exhaust valve, which can lead to breakage, it must be removed.

LFG power generation facilities usually utilize gas engine generator system, and it can be used as a cogeneration plant by heat recovering of exhaust gas and engine cooling water. In addition, LFG is a medium calorific gas fuel and can be supplied directly to a gas boiler as fuel.

In order to utilize LFG as a renewable energy source for district heating, the landfill site should be a planned landfill equipped with intermediate soil cover, final soil cover and leachate collection and treatment facilities, and LFG collection facilities and pretreatment facilities should be installed.

Figure 12 Availability of surplus LFG



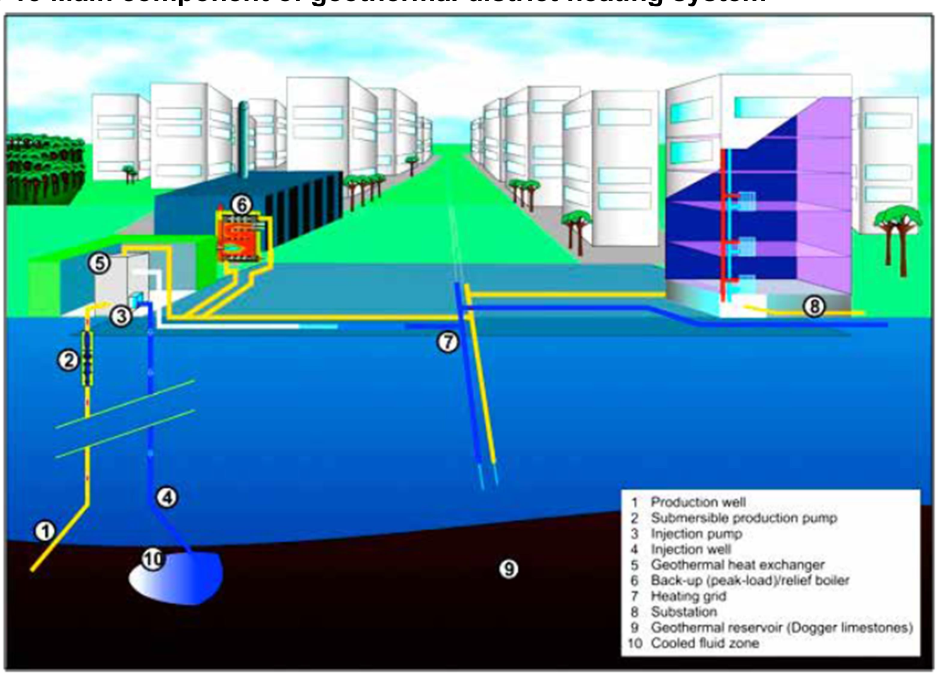
The annual amount of landfill gas is collected over an exponential curve over time, but the use of power generation facilities is constant. Therefore, surplus gas can be generated, which can be used as a separate heating fuel from the LFG CHP plant.

1.6 Geothermal

Geothermal district heating is the use of the Earth's natural thermal energy in order to provide heat resource to a group of buildings and also for one building. There are locations on earth that may make better use of this heat, where they have access to higher underground temperatures.

A geothermal district heating system comprises three major components, as shown bellows. The first part is heat production which includes the geothermal production, conventionally fuelled peaking station, and wellhead heat exchanger. The second part is the transmission/distribution system, which delivers the heated or cooled water to the consumers. The third part includes central pumping station and in-building equipment. Geothermal fluids may be pumped to a central pumping station/heat exchanger or to heat exchangers in each building. Thermal storage tanks may be used to meet variations in demand.

Figure 13 Main component of geothermal district heating system



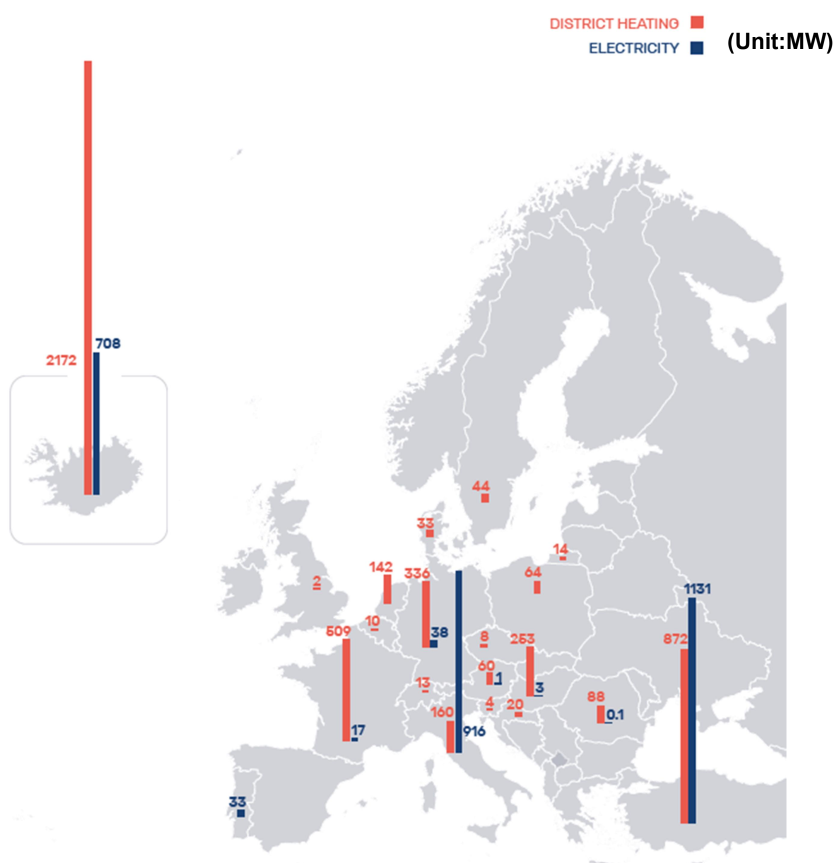
Source: European Geothermal Energy Council, Developing Geothermal District Heating in Europe, 2014

Geothermal district heating has been used since a long time ago but is only available at specific locations, requiring abundant geothermal heat resources within a short distance of the heat demand area. Unlike geothermal power generation, geothermal district heating can be used even at low temperature geothermal resources. Temperatures above 40℃ and less than 150℃ are ideal for geothermal applications, since geothermal temperature above 150℃ are better used for geothermal power generation.

The main geothermal provinces of Europe reflect the geological conditions. High enthalpy resources are associated with active volcanic areas (Iceland, Italy, Turkey), while medium enthalpy sedimentary basins are found in various geological settings.

The use of geothermal for heating is increasing, supported by the construction of new district heating networks and the retrofitting of old ones. In 2017.9 new plants were inaugurated, adding over 75MWth across France, the Netherlands and Italy. Geothermal district heating accounts for over 4.9 GWth of capacity in Europe, with 294 plants currently in operation.

Figure 14 Installed capacity for geothermal electricity and district heating by country in 2017



Source: EGEC, Geothermal Market Report 2017

If the temperature of geothermal resource in the area is more than medium enthalpy, only heat exchanger can be used for district heating. However, if the temperature is low, heat pump can be used for district heating or individual heating.

2. Overview report of Best Practice and Case studies

2.1 Heat Pump

1) Bergheim, Germany

① District Heating System I

- A lignite mine is located in the proximity of the town, where the sump water is extracted from the mine to prevent the ground water to seep into the pit.
- This water was used by the cooling towers of a nearby power plant, and the rest was dumped into a nearby river. As this water has a temperature of 26°C, it is now collected by two heat pumps to cool it down to 10°C, and the heat is used to supply a local district heating system. The two heat pumps use the R134a refrigerant, which is a hydrofluorocarbon with low GWP, and provide supply temperatures of approximately 55 – 60°C, whilst achieving a COP of 4,4. The first unit was commissioned in March 2014, and given it’s success, the second unit was installed at the beginning of 2015. Now, the system is providing heat to the offices of Erftverband, which house approximately 500 employees. Based on an energy demand of 1200 MWh, the local non-profit water supply and distribution association saves 58 000 Euro/year.

Table 2. Technical details

Heating capacity	586 kW
COP	4,4
Refrigerant	R134a
Heating Source	Water
Supplied temperature	Max 73 ℃

Source: ehpa, Large scale heat pumps in Europe

Table 3. Overview of case study

Lessons learned A ground water which is a temperature of 26°C discarded from nearby mines is cooled it down to 10 ° C using a heat pump and the heat is used to supply a local district heating system. Thereby distribution association saves energy costs.
Factors for successful projects A ground water which is a temperature of 26°C discarded from nearby mines

② District Heating System II

- Since these buildings needed a new heating source, the solution took shape in the form of a CHP which supplies 314 kWe and 220 kWth, along with a high-temperature 865 kWth thermeco2 heat pump. The heat pump uses the 26°C sump water from the mining pit as a heat source.

- The electric output of the CHP can supply 100% of the electricity for the heat pump and together they feed almost 1 MW of heat into the network. This solution was chosen as the CHP-heat pump system features a fuel utilization coefficient of 167%, compared to 90% for a boiler. Since the communal district heating network works at a temperature of 80 – 93°C, this scenario proved suitable for a CO_2 heat pump which is designed to work at high, transcritical temperatures. However, since this heat pump requires a low return temperature, the district heat was adjusted to provide a return water temperature of max. 50°C, allowing the heat pump to achieve a COP of 3.

- The system also contains two 12,6 m^3 storage tanks which can be filled up in approximately 2 hours and can supply the heat in the district heating network for several hours. For peak loads, a gas boiler is used, kept from the previous system. Overall, the CHP-heat pump system reduced the fuel demand by 26%, and the CO_2 emissions by 32%.

Table 4. Technical details

Heating capacity	865 kW
COP	3,1
Refrigerant	R744(CO_2)
Heating Source	District Heating Water
Supplied temperature	90 ℃

Source: ehpa, Large scale heat pumps in Europe

Table 5. Overview of case study

Lessons learned The CHP-heat pump system features a fuel utilization coefficient is better than a boiler. Thereby it reduced the fuel demand and the CO_2 emissions.
Factors for successful projects CHP-heat pump system

2) Drammen, Norway

① District Heating

- The municipality of Drammen has over 63 000 inhabitants and is located in the capital area of Norway. The city has a population density of 421/km2, and it is known for receiving environmental and urban development awards, including for their large heat pump and district heating grid. Their system takes advantage of the low prices of electricity in Norway and it has been operational since 2010. The three heat pump units use the 8°C deep sea water from the fjord to deliver heat at a temperature which can reach 90°C, and by doing so, the plant still manages to achieve a COP over 3. The refrigerant used is ammonia, which enables a greater efficiency than other synthetic refrigerants and does not present any global warming potential. The heat pumps manage to cover 85% of the district heating demand, the rest being covered by oil boilers during the peak loads. With the use of this heating system, the plant reduces the CO_2 emissions by approximately 15 000 t/a, as the electricity comes from renewable sources, and saves up to 6,7 million liters of fuel/year.

Table 6. Technical details

Heating capacity	13.2 MW
COP	3,05
Refrigerant	R717
Heating Source	River Water in at 8 ℃, out at 4 ℃
Supplied temperature	90 ℃ flow, return at 60 ℃(Hot water)

Source: ehpa, Large scale heat pumps in Europe

Table 7. Overview of case study

Lessons learned
The heat pumps manage to cover more than 85% of the district heating demand, it has realized the reduction of greenhouse gas emission and fuel reduction by using the heat pump by utilizing the electricity provided through the renewable energy source.
Factors for successful projects
Low electricity price($94.5 per MWh in domestic, $35.3 per MWh in industrial)[1]. It is lower than OECD average.

[1] Energy Price and Taxes 2016(OECD, IEA)

2.2 Solar thermal

1) Smørum, Denmark

① District Heating

- The 11,312 m2 solar field, which is located in the town of Smørum, consists of flat solar-thermal panels capable of producing 5,568 MWh heat annually.
- Altogether 59 rows of flat panels were installed with up to 20 collectors placed in one row. These 13,3m2 optimized panels have shown the highest performance among all known mass-produced large-scale solar collectors on the international market.
- The system has been harvesting the sunrays since Spring 2018. Due to Danish weather records in May, the solar plant was able to produce 40% more energy than anticipated and thereby to cover nearly 100% of the city's hot water and heat demands. This enabled the plant to make a high-performance debut for the official opening, which took place in June 2018. The plant has continued its good results and during the Summer performed above the guaranteed level. Besides offering a cost competitive solution for heat production, the solar plant also avoids the emission of at least 1,100 tons of CO_2 annually.

Table 8. Technical details

Heating capacity	8 MW
Plant layout	59 rows with up to 20 collectors in one row
Area	11,312 m2
CO_2 savings	1,100 t/y

Source: AALBORG CSP, 8MWTH SOLAR DISTRICT HEATING PLANT, Denmark

Table 9. Overview of case study

Lessons learned It is a natural step in development to switch to a renewable energy source that can also compete with the fluctuating gas prices. So it can stabilize the cost of energy production by flat solar-thermal collectors that matched energy needs the most.
Factors for successful projects Receiving an order from the combined heat and power plant(Smørum Kraftvarmeværk A.m.b.A.) to deliver solar heating plant that reduce the facility’s natural gas dependency as well as stabilize energy prices. The flat solar-thermal collectors is matching the client's energy needs.

2.3 Biomass

1) Stockholm, Sweden

① District Heating and electricity

- Fortum Värme supplies on annual basis approximately 8,300 gigawatt-hours (GWh) heat to the Stockholm district heating grid, 400 GWh district cooling and 1,500 GWh electricity. District heating covers well over 80% of overall heating demand in Stockholm. The aim is that district heating in Stockholm will be entirely produced from renewable and recovered energy no later than 2030.

- An important step to reach this goal is the new biomass fired CHP plant (KVV8) at Värtaverket, situated in the harbour of Stockholm, which represents a proof of concept when it comes to large scale production of sustainable district heating. It is a large scale set up in an urban environment with high demands on local environmental performance (in terms of emissions, smell, water treatment, noise, safety, transport movements). The plant has a production capacity of 280 MW heat and 130 MW electricity, making it one of the largest biomass fired CHP plants in the world. The plant will produce 750 GWh of electricity and 1,700 GWh of heat each year – enough to heat nearly 200,000 apartments. The project will reduce CO2 emissions related to heat provision in Stockholm by about 126,000 t/per year. The global CO2 emissions will decrease by 650,000 tons annually, based on an assumption that fossil power production within the north Europe power grid will be replaced. The project represented a total investment of around 500 MEuro.

- The fuel, which is produced from waste and residues from the forestry industry, is transported to Värtahamnen mainly by ships and trains. The plant's biomass demand is 12,000 m^3/day and 3 million m^3/year. About 60% arrives by boat and is imported from the Baltic Sea area; around 40% arrives by train and is mostly domestic. All fuels will be verified according to FSC Controlled Wood.

Table 10. Technical details

Heating capacity	280 MW(Electricity : 130MW, Total : 410MW)
Biomass demand	12,000 m3/day
CO_2 savings	126,000 t/y

Source: IEA Bioenergy, Large biomass CHP plant in Stockholm, Sweden, 2018

Table 11. Overview of case study

Lessons learned
The plant is the largest in the world originally designed for 100% biofuel and combined production of electricity and district heating. It demonstrates that it is possible to build such facilities in large cities that have district heating systems. Alternatively, focus can be on electricity production but then the heat from the turbine must be cooled off as in a thermal power plant.
Factors for successful projects
Using waste products as a fuel CO_2 reduction targets in Stockholm and Sweden. The project delivers a major contribution to decarbonize heat/energy provision in Stockholm. Accessibility (harbor)

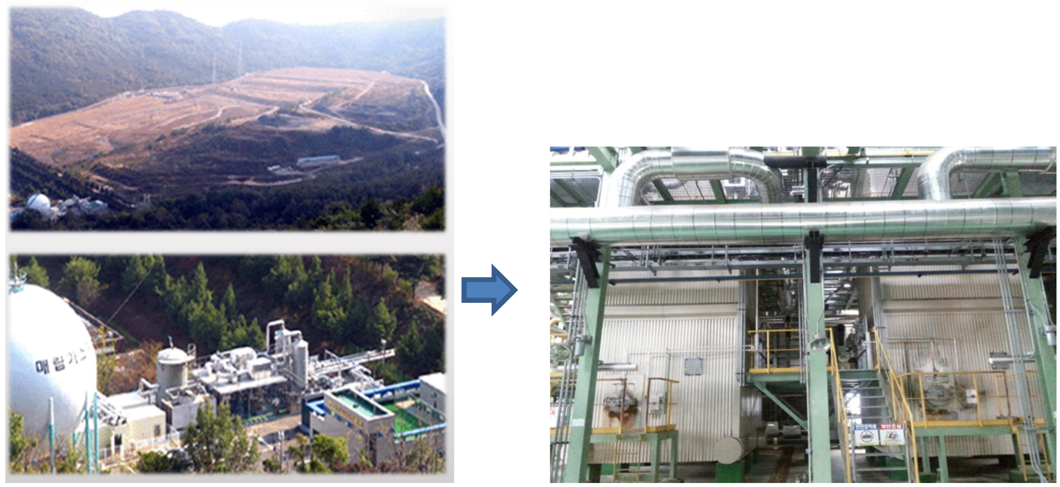
2.4 Biogas

1) Deagu, South Korea

① District Heating(Landfill gas)

- Landfill gas in biogas is generally a good fuel source with a calorific value of 4,500 ~ 5,500 kcal / Nm3 with a methane (CH_4) content of 45 ~ 55%.
- An example of using landfill gas as a district heating source is at KDHC Daegu branch of South Korea.
- The KDHC Daegu branch uses the landfill gas collected for the hot water boiler as fuel at the Bangcheon landfill site in Daegu City which is 8.5 km away. Since 1991, the landfill of MSW has been landfilled in Daegu Bungcheon Landfill, and about 17 million tons of landfill gas has been landfilled. 105 landfill gas vertical capture stations have been installed and average 110 ~ 120 Nm3 / min landfill gas has been collected. The collected landfill gas is transferred to the hot water boiler of Daegu branch after removing water and impurities from the landfill.
- KDHC Daegu branch has B-C oil cogeneration facility, steam boiler, hot water boiler, wood chip CHP facility, and the landfill gas is supplied as fuel of the hot water boiler. Two hot water boilers of 34 Gcal / h are installed and can supply 68 Gcal / h with landfill gas. Heat supply using landfill gas reaches 150,000 ~ 200,000 Gcal per year which is about 20 ~ 25% of heat supply of Daegu branch.

Table 12. Technical details



Heating capacity	150,000~200,000 Gcal/y (34 Gcal/h x 2)
Type	Heat only boiler(Hot water)
LFG Consumption	110~120 Nm3/min
CO_2 savings	t/y

Table 13. Overview of case study

Lessons learned Demonstrated the possibility of using district heating of landfill gas as low calorific fuel gas. Demonstrated the value of landfill gas as a low-cost renewable energy source that can be used as a district heating energy source.
Factors for successful projects There is a landfill equipped with a landfill gas collection facility near the district heating heat source. Lower fuel costs (about 20% of natural gas)

2.5 Geothermal

1) Hengill, Iceland

① District heating and electricity

- Of the six geothermal power plants in Iceland, Hellisheiði (pronounced "het-li-shay-thee") is the newest and largest in Iceland and the third-largest geothermal power station in the world. Hellisheiði Power Plant is situated in the Hengill area in South West Iceland and provides electricity and hot water for space heating in the industrial and domestic sectors in Iceland. The plant has a capacity of 303 MW of electricity and 133 MW of hot water for Reykjavik's district heating.
- The concept of Hellisheiði power plant was to co-generate electricity for power intensive industry and hot water for district heating. The power plant consists of six 45 MWe high pressure and one 33 MWe low pressure turbine generator units and 133 MWt thermal production.
- To access the potential energy under the surface, wells are drilled thousands of metres into the ground, penetrating reservoirs of pressurised water. Heated by the Earth's energy, this water can be more than 300°C in temperature, and when released it boils up from the well, turning partly to steam on its way. At Hellisheiði, the steam is separated from the water to power some of the plant's seven turbines, while the remaining water is further depressurised to create more steam, used to power other turbines. At its maximum output the station can produce 303MW of electricity, making it one of the largest single unit power plants in the world.
- Co-generation of electric and thermal power therefore utilized the resource economically.

Table 14. Technical details

Heating capacity	133 MW(Electricity : 303 MW, Total : 436 MW)
Plant layout	Steam supply system, fresh water supply system, electric power production, thermal production, auxiliary system
CO2 savings	33,000 t/y

Source: GRC Transactions, The Geothermal Power Plant at Hellisheiði, Iceland, 2012

Table 15. Overview of case study

Lessons learned The possibility of varying the condenser pressure and separated water temperature gives flexibility for an optimal utilization of the geothermal field for production of both thermal and electric power with varying demand for electrical and heat.
Factors for successful projects Hengill is a volcano area which is one of the most powerful geothermal areas in the world with several thousand of hot springs at the surface and a giant magma chamber lying underground. The area covers about 112 km2 and constitutes one of the most extensive geothermal areas in Iceland.

3. Study report to incentivize and accelerate RE technology in BE

3.1 Overview of renewable energy policies in Serbia

In the case of Serbia, it is necessary to respond to the global climate change after the signing of the Paris Agreement following the Kyoto Protocol, and it is necessary to gradually reduce GHG emissions from conventional fossil energy use while increasing the ratio of renewable energy, to reduce GHG emissions, energy conservation policies are being implemented or implemented at the government level.

Serbian renewable energy policies can be summarized as shown in the table below.

Table 16. Overview of all renewable energy policies and measures

Name and reference of the measure	Type of measure	Expected results	Start and end dates of the measure
Energy Law ("Official Gazette of the RoS", No. 57/11, 80/11 – correction, 93/12 и 124/12)	regulatory - goals of the energy policy, reliable, quality and secure supply of energy and energy carriers, goals for the use RES, manner, conditions and incentives for the production of energy from RES	increased use of RES	2011
Energy Sector Development Strategy of the Republic of Serbia until 2015. ("Official Gazette of the RoS", No. 44/05)	planned - energy sector development priorities	increased use of RES	2005-2015
Energy Sector Development Strategy Implementation Program of the Republic of Serbia until 2015 for the period 2007-2012. ("Official Gazette of the RoS", No. 99/09)	planned - energy sector development priorities, priorities in the use of RES	increased use of RES	2007-2012
Decree on conditions and procedure for acquiring the status of privileged power producer ("Official Gazette of the RoS", No. 8/13)	regulatory- specifies conditions and procedure for acquiring the status of privileged power producer, content of the request for acquiring the status of privileged power producer, evidence of eligibility for acquiring the status of privileged power producer, minimum primary energy efficiency level in co-generation power plants depending on type of primary fuel and installed power, maximum total installed power for wind and solar power plants which may acquire the status of privileged producer i.e. temporary status of privileged power producer, obligations of privileged power producers and methods of monitoring and control, as well as methods of keeping the Privileged Power Producers Registry	increase production of electricity from RES	2013
Law on Rational Use of Energy ("Official Gayette of the RoS" No. 25/13)	Regulatory – prescribes conditions and manner of efficient use of energy and energy carriers in the energy production, transmission, distribution and consumption sectors; policy of efficient use of energy, energy management	Increased use of RES	2013

	sys5tem; labeling of energy efficiency level of products affecting consumption of energy, minimum requirements of energy efficiency in production, transmission and distribution of heat and electricity and delivery of natural gas; financing, incentives and other measures in this field, as well as other issues of importance for rights and obligations of physical and legal persons regarding efficient use of energy		
Law on Incentives in Agriculture and Rural Development ("Official Gazette of the RoS", No. 10/13)	Financial – defining the kind of incentive, manner of using the incentive, register of incentives in agriculture and rural development, as well as conditions for exercising rights to incentives in agriculture and rural development	Increased use of RES	2013
Decree on incentive measures for privileged power producers ("Official Gazette of the RoS", No. 8/13)	financial - specifies the categories of privileged power producers, prescribes incentive measures, conditions for their obtaining, method of determining of the incentive period, rights and obligations arising from these measures for the privileged power producers and other energy entities and regulates the content of the Power Purchase Agreement and Preliminary Power Purchase Agreement with a privileged power producer	increase production of electricity from RES	2013-2015
Decree on the method of calculation and allocation of funds collected for the purpose of incentive remunerations for privileged power producers ("Official Gazette of the RoS", No. 8/13)	financial - specifies the method of calculation, charging i.e. payment and collecting of funds related to incentive remunerations for Privileged Power Producers as well as the method of allocation of funds collected on that basis	increase production of electricity from RES	2013
Decree on the amount of special feed-in tariff in 2013. ("Official Gazette of the RoS", No. 8/13)	financial – the amount of special feed-in tariff in 2013 is set	increase production of electricity from RES	2013
Law on ratification of the Kyoto Protocol ("Official Gazette of the RoS", No. 88/07 and 38/09)	regulatory – reduction of GHG emission	increased use of RES	2009
National Strategy of Sustainable Development("Official Gazette of the RoS", No. 57/08)	planning - sustainable development, reduction of impacts on environment and natural resources	increased use of RES	2008
Action plan for the implementation of the national strategy of sustainable development for the period from 2011 to 2017 ("Official Gazette of the RoS", No. 62/11)	planning – measures and activities for the implementation of the Strategy of sustainable development	promotion of and increased use of RES	2011-2017
National Program of Environmental Protection ("Official Gazette of the RoS", No. 12/10)	planning – protection of environment and application of the most favorable measures for the sustainable development and management of environmental protection	increased use of RES	2010
Strategy of sustainable use of natural resources and assets ("Official Gazette of the RoS", No. 33/12)	planning - the use of natural resources in a sustainable manner, securing their availability in the future and reduction of impacts of their use on environment	increased use of RES	2012
Strategy of the Science and Technological Development of the Republic of Serbia for the period from 2010 to 2015	planning – raising the level of knowledge in the society and enhancement of the technological development and economy	increased energy efficiency, increased use of RES	2010

("Official Gazette of the RoS", No. 13/10)			
Strategy for Cleaner Production in the Republic of Serbia ("Official Gazette of the RoS", No. 17/09)	planning – definition of measures for pollution prevention	energy efficiency, increased use of RES	2009
Law on Environmental Impact Assessment ("Official Gazette of the RoS", No..135/04 and 88/10)	regulatory – defining of the procedure of environmental impact assessment for the projects which might have significant impacts on environment	Prevention of impacts on environment in the construction of RES-based facilities	2010
Decree on establishing the list of projects for which EIA is mandatory and the list of projects for which the EIA may be requested ("Official Gazette of the RoS", No. 114/08)	regulatory – defining the type of facilities requiring EIA	prevention of impacts on environment in the construction of RES-based facilities	2008
Law on Strategic Environmental Impact Assessment („Official Gazette of the RoS", No.135/04 and 88/10)	regulatory – conditions, manner and procedure of conducting the assessment of impacts of certain plans and programs on environment	Environmental protection, improvement of sustainable development	2010
Law on Waste Management („Official Gazette of the RoS", No. 36/09 and 88/10)	regulatory – waste management planning, waste management – activity of public interest	waste management, the use of waste as fuel	2010
Rulebook on categories, testing and classification of waste ("Official Gazette of the RoS", No. 56/10)	regulatory – classification of waste	Management of special waste streams	2010
Rulebook on conditions and manner of collection, transport, storing and treatment of waste used as secondary raw material or for producing energy("Official Gazette of the RoS", No. 98/10)	regulatory – waste management	the use of waste for energy purposes	2010
Decree on the types of waste for which heat treatment is to be performed, conditions and criteria for determining the location, technical and technological conditions for designing, construction, equipping and operation of installations for heat treatment of waste and handling of residues after combustion ("Official Gazette of the RoS", No. 102/10)	regulatory	the use of waste for energy purposes	2010
Rulebook on conditions, manner and procedure of management of waste oils ("Official Gazette of the RoS", No. 71/10)	regulatory – manner and procedure of management of waste oils	the use of oil for energy purposes	2010
Law on integrated prevention and control of pollution of environment ("Official Gazette of the RoS", No.135/04)	regulatory – conditions and procedure of issuing integrated permit for the plants	construction of RES based facilities	2004

Decree on the kinds of activities and facilities for which the integrated permit is issued("Official Gazette of the RoS", No. 84/05)	regulatory	construction of RES- based facilities	2005
Law on Protection of Nature ("Official Gazette of the RoS", No. 36/09 and 88/10)	regulatory – protection and preservation of nature	the use of RES	2009
Decree on protection regimes ("Official Gazette of the RoS", No. 31/12)	regulatory – protection regimes, procedure and manner of their determination	construction of RES-based facilities in protected areas	2012
Law on Mining and Geological Explorations ("Official Gazette of the RoS", No. 88/11)	regulatory – exploitation and use of geothermal resources	the use of RES	2011
Law on Protection of Air („Official Gazette of the RoS", broj 36/09)	regulatory – management of air quality and measures for implementation of the protection	Fulfilling the requirements on the air protection in construction and exploitation of RES-based facilities	2009
Decree on limit values of emissions of polluting matters into the air ("Official Gazette of the RoS", No. 71/10)	regulatory – defining of allowed limit values of emissions	Fulfilling the requirements on the air protection in construction and exploitation of RES-based facilities	2010
Law on private-public partnership and concessions ("Official Gazette of the RoS", No. 88/11)	regulatory	increased use of RES, the use RES for the production of heat	2011
Action plan for biomass 2010-2012. ("Official Gazette of the RoS", No. 56/10)	planning – defining of activities for overcoming the problems occurring in the use of biomass for energy-related purposes	increased use of biomass and biofuel	2010-2012
Law on Waters ("Official Gazette of the RoS", No. 30/10)	regulatory – surface and underground waters, except the water from which geothermal energy can be obtained	Integral management of waters, water facilities	2010
Rulebook on the content and the template of the application for issuance of water-related acts and the contents of opinions within the procedure of issuance of water conditions ("Official Gazette of the RoS", No. 74/10)	regulatory	Regulation of obtaining of necessary water acts in the procedure of construction of the facility	2010
Law on renewable energy sources	regulatory	increased use of RES-	
Decree on sustainability criteria for	regulatory	increased use of	2013

biofuels		biofuels	
Rulebook on technical and other requirements for liquid fuels of bio- origin ("Official Journal of the Serbia an Montenegro" No. 26/06)	regulatory	increased use of biofuel	2006
Legislation on the system of fuel quality monitoring	regulatory, financial – providing fuel quality monitoring and reduction of GHG emissions	increased use of biofuel	2013
Decree on mandatory placing of a certain percentage of biofuel on the market	regulatory, financial	increased use of biofuel	2013
Rulebook on licenses	regulatory	increased use of biofuel	2013
Rulebook on incentives for growing raw materials and production of biofuel	financial	increased use of biofuel	2013
Rulebook on the Guarantee of Origin for the production of energy from RES	regulatory, financial	increased use of RES	2013
Decree/Recommendation on conditions for obtaining the status of privileged heat producer	regulatory, financial	increased use of RES in the heating and cooling sector	2013
Decree /Recommendation on Incentives for the production of heat from RES	regulatory, financial	increased use of RES in the heating and cooling sector	2013
Strategy of Water Management in the Republic of Serbia	planned	Increased use of RES	2014
Law on Forests ("Official Gayette of the RoS" No. 30/10 and 93/12)	regulatory	Increased use of RES	2012
Forestry Development Strategy of the Republic of Serbia Forests ("Official Gayette of the RoS" No. 59/06	regulatory	Increased use of RES	2006

Source: Ministry of Energy in Serbia, National renewable energy action plan of the Republic of Serbia, 2013

The policies summarized in the table above include various heating and cooling policies. According to the policies, as mentioned above, there are various proven district heating systems that utilize renewable energy, which can reduce GHG emissions and save energy.

3.2 Incentive and acceleration of renewable energy in district heating

Generally, renewable energy output is expressed in electricity, so standards such as incentives are standardized in electricity. However, as much as electricity is needed, and there is heat as energy required to replace with renewable energy, and it is possible to reduce GHG emissions by supplying district heating.

Financial and non-financial incentives to invest in the construction of power plants using renewable energy sources have been introduced.

The most frequently used financial incentive measures are the increase in the purchase price of the generated electricity

In addition to financial measures, countries often adopt additional measures to encourage electricity the production from renewable energy sources, such as exemptions or total tax exemptions, and participation in investment in specific technologies that indicate the direction of strategic development of a given country. Encouragement of the production of heat energy from renewable sources of energy has largely been achieved with the exemption from the more advanced stages of funding and incentive application of the initial capital investments.

The incentive purchase price of electricity produced from renewable energy sources based on the Directive on the Incentive Measures for the Subsidized Manufacturers of Electrical Energy is shown in Table 18 in euro-cents per kilowatt hour (c €/kWh) in Serbia.

Since 2011, the new Public Private Partnership (PPP) law in Serbia has been in compliance with international best practices, and the Treasury has established a PPP department (PPP Commission) and published its Heads of Agreement by issuing practical guides and templates. Therefore, it will be easier to promote the district heating business through PPP. In addition, one of the important parts of the incentive is the approval tariff, and the independent approval process of the regulators will provide a better system and ensure financial survival for sector development.

In particular, the district heating system in Belgrade is managed by the city, and there are some disadvantages such as lack of financial support for large-scale district heating rehabilitation projects in local government-only management. However, if it includes private sector technology and business development experience, it can be found ways to attract funds and investments in energy-efficiency projects without a full privatization scenario where you can choose from a variety of business models. The district heating system improvement option in Belgrade shows that all private sector participation models (Management agreements, Leasing, Concession agreements, Heat entrepreneurship, ESCO) are ready except for privatization.

Table 17. The incentive purchase prices of electricity produced from the renewable energy sources expressed in euro- cents per kilowatt hour (c€/kWh) in Serbia

No.	Type of power plants	Installed power P (MW)	The incentive purchase prices *(c€/kWh)*
1.	Hydropower plants		
1.1		≤ 0.2	12.4
1.2		0.2-0.5	13.727-6.633*P
1.3		0.5-1.0	10.41
1.4		1-10	10.747-0.337*P
1.5		10-30	7.38
1.6.	On the existing infrastructure	≤ 30	5.9
2.	Biomass power plants		
2.1.		≤ 1	13,26
2.2.		1-10	13.82 – 0.56*P
2.3.		> 10	8.22
3.	Biogas power plants		
3.1.		≤ 0.2	15.66
3.2.		0.2-1	16.498 – 4.188*P
3.3.	Animal waste biogas power plants	> 1	12.31
3.4.	Animal waste biogas power plants		12.31
4.	Landfill gas and communal waste water gas power plants		6.91
5.	Wind power plants		9.2
6.	Solar power plants		
6.1.		On the object up to 0.03	20.66
6.2.		On the object 0.03-0.05	20.941-9.383*P
6.3.		Ground-mounted	16.25
7.	Geothermal power plants		
7.1.		≤ 1	9.67
7.2.		1-5	10.358-0.688*P
7.3.		> 5	6.92
8.	Waste power plants		8.57
9.	Combined coal production power plants	≤ 10	8.04
10.	Combined natural gas production power plants	≤ 10	8.89

Source: Official Gazette of the Republic of Serbia, the Directive on the Incentive Measures for Subsidized Manufacturers of Electrical Energy, 2013

4. Analytical report with analyzing geographical areas in BE

4.1 Overview of Belgrade

Belgrade is the capital and largest city of Serbia. The urban area of the City of Belgrade has a population of 1.23 million, while nearly 1.7 million people live within its administrative limits.

Belgrade has special administrative status within Serbia and it is one of the five statistical regions that make up the country. Its metropolitan territory is divided into 17 municipalities, each with its own local council. The city of Belgrade covers 3.6% of Serbia's territory, and around 24% of the country's population lives within its administrative limits.

Belgrade is located at about 116.75m above sea level and is located at the confluence of the Danube and Sava rivers. The geographical coordinate system coordinates are latitude 44 ° 49'14 "and latitude 20 ° 27'44".

The historical center of Belgrade is now called Kalemegdan. This area is on the eastern banks of the river. Since the 19th century, Belgrade has expanded to the south and east. After the end of World War II, in conjunction with the suburban commune, an area called Novi Beograd was constructed on the banks of the western banks of the Sava River. Small residential areas along the banks of the Danube River, including Krnjača, Kotež and Borča, were also merged into Belgrade. Belgrade has an urban area of about 360 km^2. It is an area of 3,223 km^2, which is metropolitan area. Historically, Belgrade has been a crossroads between the West and the East.

Belgrade has Continental climate and Mediterranean climate, according to Köppen climate classification, with four seasons and uniformly spread precipitation. Monthly averages range from 1.4 °C in January to 23.0 °C in July, with an annual mean of 12.5 °C. There are, on average, 31 days a year when the temperature is above 30 °C and 95 days when the temperature is above 25 °C. Belgrade receives about 691 mm of precipitation a year, with late spring being wettest. The average annual number of sunny hours is 2,112. The largest snowfall ever recorded in a single day occurred on February 3, 1962, with a snow cover of 80 cm.

The highest officially recorded temperature in Belgrade was 43.6 °C on 24 July 2007, while on the other end, the lowest temperature was −26.2 °C on 10 January 1893.

Table 18. Climate data for Belgrade (1981-2010)

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Record high °C (°F)	20.7 (69.3)	23.9 (75)	28.8 (83.8)	32.2 (90)	34.9 (94.8)	37.4 (99.3)	43.6 (110.5)	40.0 (104)	37.5 (99.5)	30.7 (87.3)	28.4 (83.1)	22.6 (72.7)	43.6 (110.5)
Average high °C (°F)	4.6 (40.3)	7.0 (44.6)	12.4 (54.3)	18.0 (64.4)	23.5 (74.3)	26.2 (79.2)	28.6 (83.5)	28.7 (83.7)	23.9 (75)	18.4 (65.1)	11.2 (52.2)	5.8 (42.4)	17.4 (63.3)
Daily mean °C (°F)	1.4 (34.5)	3.1 (37.6)	7.6 (45.7)	12.9 (55.2)	18.1 (64.6)	21.0 (69.8)	23.0 (73.4)	22.7 (72.9)	18.0 (64.4)	12.9 (55.2)	7.1 (44.8)	2.7 (36.9)	12.5 (54.5)
Average low °C (°F)	−1.1 (30)	−0.1 (31.8)	3.7 (38.7)	8.3 (46.9)	13.0 (55.4)	15.8 (60.4)	17.5 (63.5)	17.6 (63.7)	13.5 (56.3)	9.0 (48.2)	4.2 (39.6)	0.2 (32.4)	8.5 (47.3)
Record low °C (°F)	−18.2 (−0.8)	−15.4 (4.3)	−12.4 (9.7)	−3.4 (25.9)	2.5 (36.5)	6.5 (43.7)	9.4 (48.9)	6.7 (44.1)	4.7 (40.5)	−4.5 (23.9)	−7.8 (18)	−13.4 (7.9)	−18.2 (−0.8)
Average precipitation mm (inches)	46.9 (1.846)	40.0 (1.575)	49.3 (1.941)	56.1 (2.209)	58.0 (2.283)	101.2 (3.984)	63.0 (2.48)	58.3 (2.295)	55.3 (2.177)	50.2 (1.976)	55.1 (2.169)	57.4 (2.26)	690.9 (27.201)
Average precipitation days (≥ 0.1 mm)	13	12	11	13	13	13	10	9	10	10	12	14	139
Average snowy days	10	7	4	1	0	0	0	0	0	0	3	8	33
Average relative humidity (%)	78	71	63	61	61	63	61	61	67	71	75	79	68
Mean monthly sunshine hours	72.2	101.7	153.2	188.1	242.2	260.9	290.8	274.0	204.3	163.1	97.0	64.5	2,111.9

Source: Hydro meteorological Service of Serbia

The Belgrade district is also known as the Belgrade District and is divided into 17 municipalities. Ten of them have the status of "city municipality" and seven have the status of "local municipality".

Table 19. 17 municipalities of the city of Belgrade

Name	Area (km^2)	Population 1991	Population 2002	Population 2011	Classification
Barajevo	213	20,846	24,641	27,036	Suburban
Čukarica	156	150,257	168,508	179,031	Urban
Grocka	289	65,735	75,466	83,398	Suburban
Lazarevac	384	57,848	58,511	58,224	Suburban
Mladenovac	339	54,517	52,490	53,050	Suburban
Novi Beograd	41	218,633	217,773	212,104	Urban
Obrenovac	411	67,654	70,975	71,419	Suburban
Palilula	451	150,208	155,902	170,593	Urban
Rakovica	31	96,300	99,000	108,413	Urban
Savski venac	14	45,961	42,505	38,660	Urban
Sopot	271	19,977	20,390	20,199	Suburban
Stari grad	5	68,552	55,543	48,061	Urban
Surčin	In the municipality of Zemun until 2004			42,012	Suburban
Voždovac	148	156,373	151,768	157,152	Urban
Vračar	3	67,438	58,386	55,463	Urban
Zemun	438	176,158	152,950	166,292	Urban
Zvezdara	32	135,694	132,621	148,014	urban
Total	3227	1,552,151	1,576,124	1,639,121	

Source: Statistical Institute of the Republic of Serbia, 2014

Figure 15. the Belgrade District and is divided into 17 municipalities

1. Barajevo
2. Voždovac
3. Vračar
4. Grocka
5. Zvezdara
6. Zemun
7. Lazarevac
8. Mladenovac
9. Novi Beograd
10. Obrenovac
11. Palilula
12. Rakovica
13. Savski venac
14. Sopot
15. Stari grad
16. Surčin
17. Čukarica

Source: Statistical Institute of the Republic of Serbia, 2014

Most of these municipalities are located in the south of Danube and in Sava in the Šumadija (Choumadie) region. Zemun, Novi Beograd and Surcin are located in the north of Sava in the Syrmia region and the Palilula municipality is located in the Mamáza and Banat areas of the Danube River.

4.2 Advantages of RE in Belgrade

It will be analyzed the advantages of favorable conditions for utilizing renewable energy due to the geographical characteristics of Belgrade.

1) Heat pump

There are about 20 power plants in Serbia, most of them in the central region. There are 8 power plants that use coal as power source, 1 power plant that uses natural gas as power source (electric and thermal complex production), and 11 hydro power plants.

Among them, Termoelektrana Nikola Tesla is a power plant complex operated by Elektroprivreda Srbije, located on the right side of the Sava River, about 40 km upstream from downtown Belgrade, near Obrovovac. The largest complex in Serbia produces about 16 TWh each year, which accounts for almost half of Serbia's demand for electricity. This power plant uses lignite mined at RB Kolubara as fuel. Coal can be transported from the mine via a 30 km long gauge railway to supply a total of 37 million tons of coal annually.

Table 20. List of power plants in Serbia

Station	Type	Electric Capacity (MW)	Location	Status
TE Kolubara	Coal	225	Lazarevac	Partially operational
TE Kostolac A	Coal	280	Kostolac	Operational
TE Kostolac B	Coal	615	Drmno	Operational
TE Morava	Coal	100	Svilajnac	Operational
TE Nikola Tesla A	Coal	1560	Obrenovac	Operational
TE Nikola Tesla B	Coal	1200	Obrenovac	Operational
TE Kosovo A	Coal	617	Priština	Operational
TE Kosovo B	Coal	618	Priština	Operational
Panonske TE-TO	Natural gas	336	Novi Sad Zrenjanin Sremska Mitrovica	Operational
HE Uvac	Hydro	36	Uvac	Operational
HE Kokin Brod	Hydro	20	Nova Varoš	Operational
HE Bistrica	Hydro	100	Priboj	Operational
HE Potpeć	Hydro	51	Priboj	Operational
HE Bajina Bašta	Hydro	420	Bajina Bašta	Operational
RHE Bajina Bašta (pumped storage)	Hydro	600	Bajina Bašta	Operational
HE Zvornik	Hydro	100	Mali Zvornik	Operational
Đerdap I	Hydro	1080	Kladovo	Operational
Đerdap II	Hydro	270	Kladovo	Operational
HE Vlasina	Hydro	129	Surdulica	Operational
HE Pirot	Hydro	80	Pirot	Operational

Source: “Производни капацитети". *eps.rs* (in Serbian). Retrieved 3 June 2018

Figure 16. Map of power plants in Serbia

Source: “Производни капацитети". *eps.rs* (in Serbian). Retrieved 3 June 2018

Based on the above conditions, TENT A is likely to be a suitable power plant in Belgrade to utilize a mechanical heat pump. In the case of a heat pump, surplus power generation can convert electricity to heat with high efficiency and has the advantage of utilizing low-temperature energy.

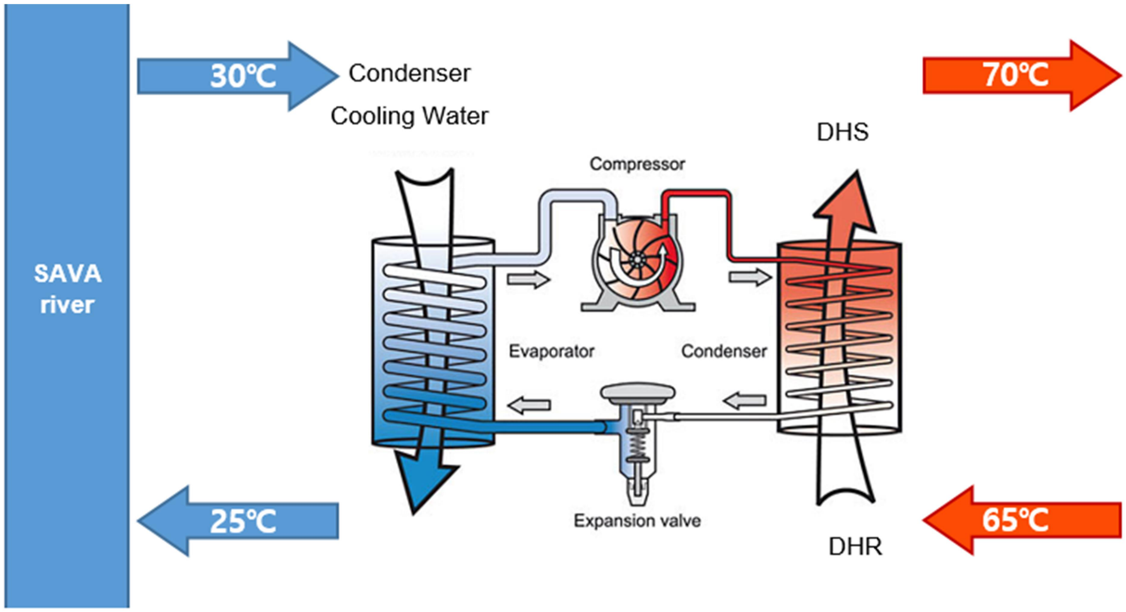
TENT A is Six generation units for electricity with a combined capacity of 1650.5 MW that makes it the largest power facility in the former Yugoslavia. TPP Nikola Tesla A was first synchronized on March 27, 1970. It has two chimneys: one with a height of 220 meters and a second with a height of 150 meters. It produces more than 8 billion kW/h per year.

Table 21. Specifications of TENT A

		A1	A2	A3	A4	A5	A6
Power of the block	MW	210	210	329	308.5	340	347.5
Nominal boiler capacity	t/h	650	650	920	920	920	973.7
The amount of interregional steam	t/h	570	570	810	810	810	881
Water temperature	℃	240	240	248	248	248	251.2
Pressure of the steam at the exit from the boiler	bar	140	140	182	182	182	182
Temperature of steam at the boiler outlet	℃	540±5	540±5	543±5	543±5	543±5	543±5
Pressure in the condenser	Bar	0.05	0.05	0.05	0.05	0.05	0.054
Lower thermal power of coal	kJ/kg	6700	6700	6700	6700	6700	6700
Coal consumption	t/h	350	350	440	440	440	490

Based on the information collected, the expected effect of the mechanical heat pump is shown in the figure below.

Figure 17. Concept of heat pump on TENT A



- Amount of cooling water(warm water) : 190,000 m^3/hr
- Discharge temperature of cooling water(warm water) : 30 ℃
- Available calories(maximum) : 190,000 x 5 ℃ = 950 Gcal/hr

  - Heat pump operating(cooling water inlet/outlet) temperature : 30 ℃ / 25 ℃
- Calories produced : 950 x 1.3 = 1,235 Gcal/hr = 4,322,500 Gcal/yr (3,500 hr/yr)
- Amount of district heating water heating : 247,000 m^3/hr (65 ℃ -> 70 ℃)
- Estimated actual Calories produced : 2,593,500 Gcal/yr (Capacity factor : 0.6)

  = 3,015.7 GWh/year

The total capacity of the district heating system in Belgrade is 4,000 MWh(14,000 GWh/year : 3,500 hr/year), which can cover about 21.5% district heating per year in Belgrade.

However, Above heat pump concept on TENT A have been required to take care of real circumstances such as river flowrate, local heat demand, etc. due to limited information from Elektroprivereda Srbije(Electric power company of Serbia: EPS). Furthermore, TENT A is under jurisdiction of EPS. Therefore, analyzing specific conditions and installing a mechanical heat pump on TENT A requires negotiation and approval procedures with the government and EPS.

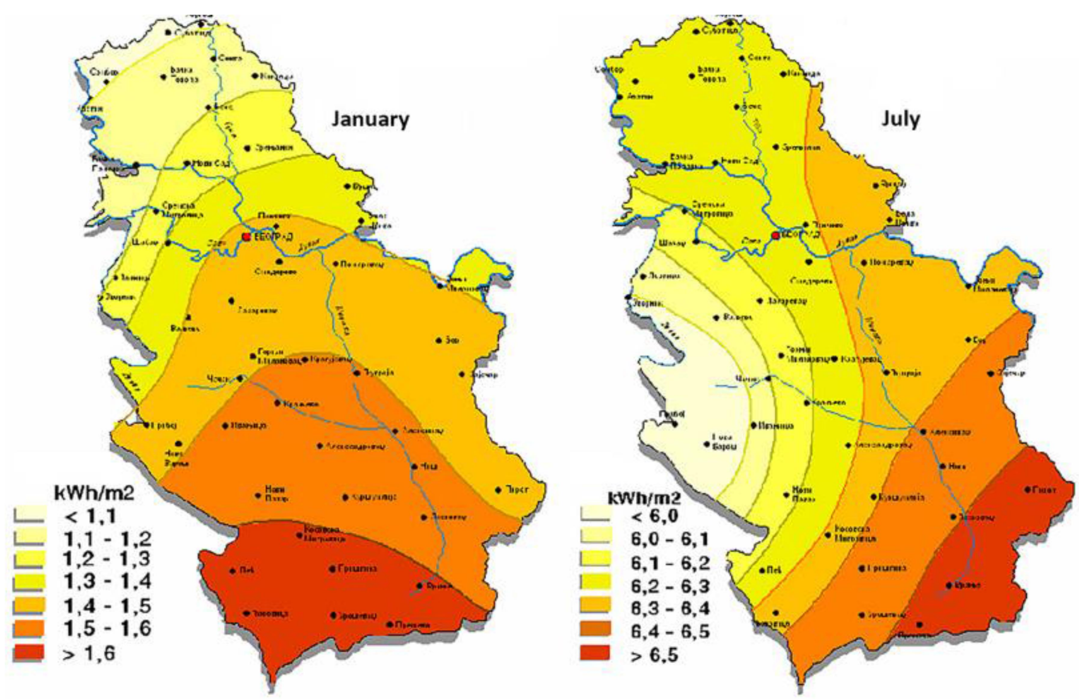
2) Solar thermal

Solar thermal is a renewable, CO_2-free energy source that has the advantage of being able to develop larger solar thermal systems because district heating does not require the building to store heat or consume all the heat produced. In addition, the use of solar energy is one way to reduce GHG emissions wherever possible.

The solar thermal potential on the Central and Eastern Europe and South East Europe countries territory is considerable despite the large differences in the sunlight intensity between the various countries. The average annual sunshine duration is roughly 2,130 hours and the average solar radiation resource is between 1,080 kWh/m^2 and 2,200 kWh/m^2. The average solar radiation in Republic of Serbia is about 30% higher than the European average, but the use of solar energy for electricity generation and heat productions are far behind the EU states.

Average daily solar irradiation on the ranges from 1.1 kWh/m^2 on the north to 1.7 kWh/m^2 on the south during January, and from 5.9 kWh/m^2 to 6.6 kWh/m^2 during July. The average yearly value of the global solar irradiation for the territory of the Republic of Serbia ranges from 1,200 kWh/m^2/year in the northwest to 1,550 kWh/m^2/year in the southeast, while in the middle part it totals to around 1400 kWh/m^2/year. This values shows that Republic of Serbia has favorable conditions for the use of solar energy and its conversion into thermal and electrical energy. In Serbia, solar energy increases steadily from the northwest to the south.

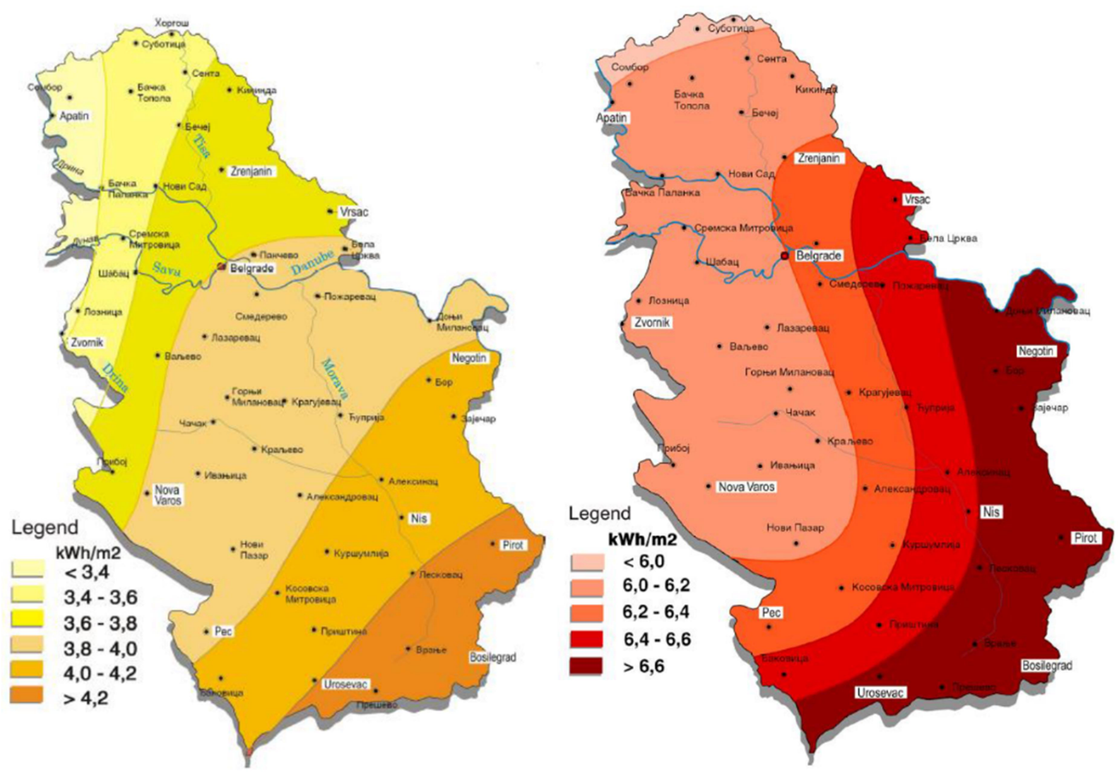
Figure 18. Daily global solar radiation in Serbia on the horizontal surface



Source: Renewable energy sources in Serbia solar and wind energy, 2018

The annual average of the daily global radiation energy on the horizontal plane is presented in Figure 19 left, and the annual average of daily global radiation energy on the plane oriented towards the south and tilted at a 30° angle in relation to the horizontal surface is presented in Figure 19 right. Maps for both plane inclinations are presented to emphasize differences in solar energy values, which are known to be higher as the angle of inclination approaches the site latitude angle (the latitudes in Serbia vary between 42º and 46º - Belgrade). Consequently, the area of maximum global solar irradiation density for the plane inclined 30º S, compared to the one corresponding to the horizontal plane, is characterized not only by more than 50% higher intensity (>6.6 vs. >4.2 kWh/m2) but also by more than twice the size of covered territory. The spatial distribution of solar irradiation density also changes favorably with the angle of inclination increase by extending the prime regions from the southeastern corner to include the whole eastern region of the country.

Figure 19. The annual average of the daily global solar energy on the horizontal plane



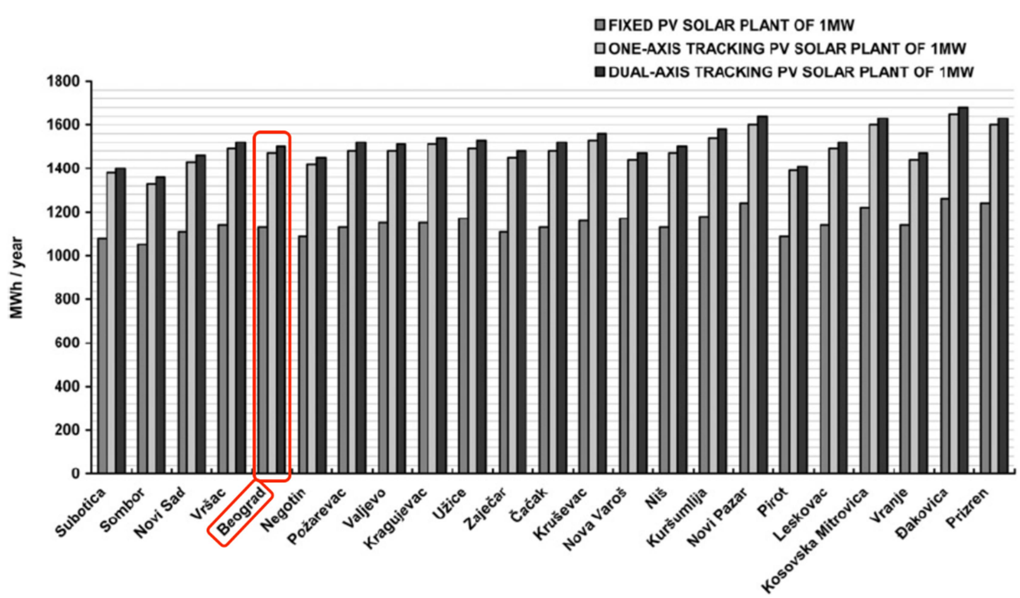
Source: Renewable energy sources in Serbia solar and wind energy, 2018

Figure 20. Geographical position and the results of PVGIS calculation of the yearly average values

Some cities in Serbia	North latitude and east longitude	Optimal panel inclination (°)	Solar irradiation (in Wh/m²/year) Annual irradiation deficit due to shadowing (horizontal): 0–2.0%			Ratio of diffuse to global solar irradiation (–)	Linke turbidity(–)
			On horizontal plane	On vertical plane	On optimally inclined plane		
Subotica	46°4′23″ North, 19°38′36″ East	34	3430	2620	3910	0.49	3.7
Sombor	45°46′30″ North, 19°6′58″ East	34	3370	2530	3810	0.50	3.7
Novi Sad	45°14′38″ North, 19°50′28″ East	34	3550	2690	4040	0.49	3.0
Vršac	45°6′44″ North, 21°18′8″ East	35	3640	2790	4170	0.47	2.7
Beograd	44°47′36″ North, 20°27′23″ East	35	3620	2750	4130	0.47	2.8
Negotin	44°14′14″ North, 22°34′56″ East	32	3560	2600	3990	0.48	2.6
Požarevac	44°36′50″ North, 21°10′14″ East	34	3640	2750	4150	0,47	2.7
Valjevo	44°16′7″ North, 19°53′6″ East	34	3650	2780	4170	0.47	3.1
Kragujevac	44°0′31′ North, 20°55′24″ East	34	3710	2790	4210	0.47	2.7
Užice	43°54′35″ North, 19°44′12″ East	34	3700	2790	4210	0.47	3.0
Zaječar	43°53′52″ North, 22°15′29″ East	32	3640	2640	4070	0.49	2.4
Čačak	43°53′9″ North, 20°21′7′ East	34	3750	2850	4290	0.46	2.8
Kruševac	43°35′3″ North, 21°19′8″ East	33	3770	2790	4260	0.47	2.5
Nova Varoš	43°27′24″ North, 19°48′30″ East	33	3730	2750	4230	0.46	2.9
Niš	43°18′47″ North, 21°53′5″ East	33	3700	2690	4140	0.48	2.5
Kuršumlija	43°8′42″ North, 21°16′39″ East	34	3800	2840	4310	0.47	2.5
Novi Pazar	43°7′59″ North, 20°31′1′ East	35	3890	2990	4470	0.46	2.7
Pirot	43°9′40′ North, 22°35′55″ East	32	3590	2590	4000	0.51	2.5

Source: Renewable energy sources in Serbia solar and wind energy, 2018

Figure 21. Comparison of total for year electricity production of different types of PV solar plants with monocrystal silicon solar modules of 1 MW



Source: Renewable energy sources in Serbia solar and wind energy, 2018

In the above data, solar thermal is available in Belgrade. In Belgrade is already investigating the possibility of solar thermal district heating in 2 locations, Cerak and Batajnica.

Cerak and Batajnica have 2 common grounds: the cheap land and the lack of alternative possibilities to use any other energy resource better than solar thermal except for natural gas.

Assuming that the available area for solar thermal of Cerak and Batajnica is 3.8 ha and 1.0 ha each.

Table 22. Solar thermal locations comparison

Parameter	Unit	Batajnica on-site	Cerak on-site
Total area of heat plant	m^2	18,000	82,000
Area of Main Facilities	m^2	8,000	44,000
Available area for solar thermal	m^2	10,000	38,000

In 2016, Danish company PlanEnergi conducted an investigation on solar district heating in Belgrade. In that investigation estimated annual solar heat production at Batajnica and Cerak heat plants. In the case of Batajnica heat plant, it predicted that 3,618MWh of heat can be produced annually by installing 6,200m^2 solar panels at 4m intervals. In the case of Cerak heat plant, it predicted that 22,245MWh of heat can be produced annually by installing 35,000m^2 solar panels at 4m intervals.

3) Biomass

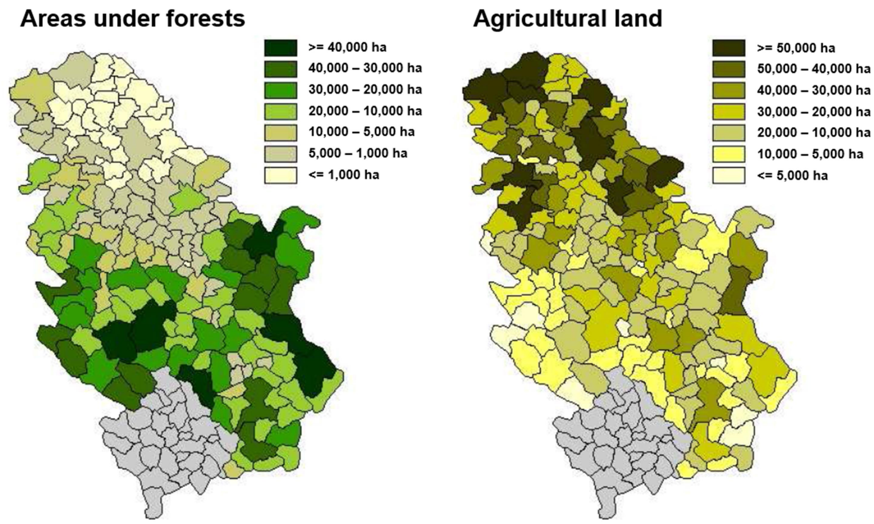
The total biomass energy potential of Serbia is estimated at about 2.7 Mtoe and consists of remnants or waste from the forestry and timber industry, agriculture, livestock breeding, fruit growing, viticulture and primary processing of fruits.

Serbia has a relatively high biomass energy potential and forest biomass accounts for 39.8% of Serbia's total biomass energy potential.

Of all forms of biomass, wood biomass is currently the most developed in Serbia as energy.

Also, a very important source of biomass in Serbia (especially in Vojvodina) is plant biomass in agriculture (crop residue due to plant, fruit and grape production).

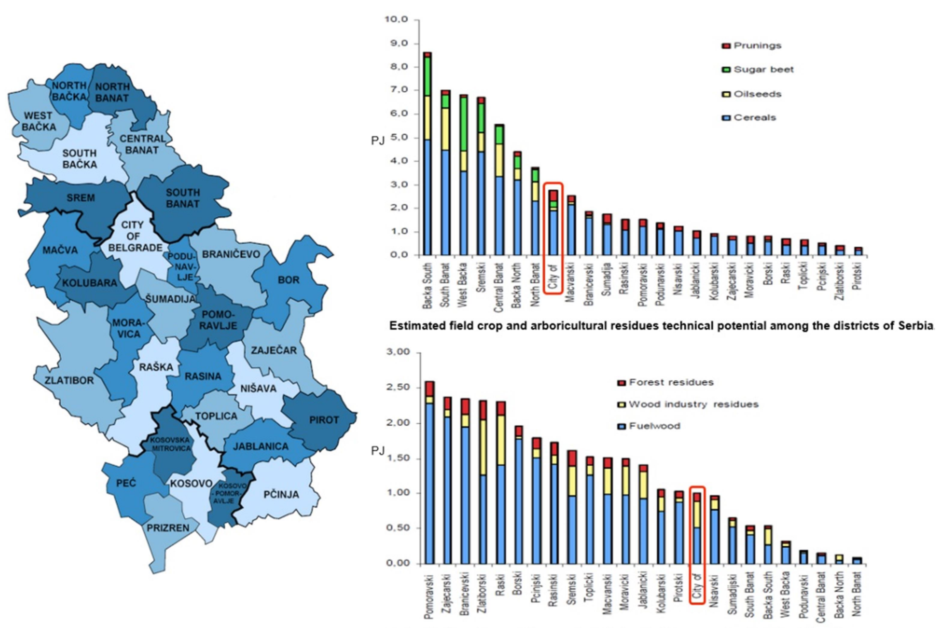
Figure 22. Biomass in Serbia



Source: Status of Bioenergy in Serbia, International cooperation in the field of bioenergy, 2013

There are about 2.0 million hectares of forest area in the entire territory of Serbia, of which ~ 2.5 million m3 / y is used annually. Approximately ~ 5.1 million hectares are used as agricultural land in the whole territory, and about 2/3 is arable land, 2/3 of arable land cultivate crops (straw, corn stalks, cobs, stalks, husks, seeds). The following table shows the energy source structure used for biomass.

Figure 23. Estimated biomass technical potential among the districts of Serbia



Source: Biomass potential for future investments in Serbia, 2011

The district of Backa south shows Serbia's highest potential (8,6 PJ). In addition, the combined potential of the Vojvodina and Belgrade and Máváski areas amounts to 52,8 PJ, which accounts for 75% of the total potential. Outside Vojvodina, residues are derived from grain and pruning, but the pruning of this area is much more important than in Vojvodina.

The total biomass potential for forestry for energy production is the same as Serbia's 31.8 PJ, representing 5.3% of Serbia's total primary energy supply, centered in central and southern Serbia.

Table 23. Biomass Supply potentials

	Potential (PJ)
Total biomass (I + II)	**101.8**
I. Forest biomass	**31.8**
Fuelwood	23.6
Forest residues	2.8
Other wood industry residues	0.5
Sawmill residues	4.4
Bark	0.5
II. Agricultural biomass	**70.5**
Field crop residues	58
Arboricultural residues	5.5
Livestock residues (for biogas)	7

Source: Reducing Barriers to Accelerate the Development of Biomass Markets in Serbia, 2019

However, it is of particular interest to have pictures of where residual biomass that can be used for high density wood fuel or industrial heat production. In the western Zlatiborski and Raski areas, a large amount of wood industry residues are produced. As shown in the table below, residual biomass contributes significantly to the total potential. The residual biomass potential in these areas is over 800 TJ in each one of them. Also it can be found significant amount of residue in the neighboring areas of Sremski, Moravicki, Macvanski and Belgrade.

Table 24. The potential contribution of domestic biomass to energy production in Serbia

Biomass source		Potential	
		Mtoe	PJ
Wood biomass		1.53	64
Fuel wood		1.15	48
Forest residue		0.16	7
Wood processing residue		0.18	8
Wood from trees outside the forest		0.03	1
Agricultural biomass		1.67	70
Crop residue		1.02	43
Residues from fruit growing, viniculture and fruit processing		0.61	25
Liquid manure (for biogas production)		0.02	2
Biofuels for transport		0.19	8
Total Biomass	Without transportation fuel	2.70	113
	with transportation fuel	3.39	142

Source: LEGAL FRAMEWORK FOR SUSTAINABLE USE OF BIOMASS IN SERBIA AND DENMARK, 2012

Biomass has a great energy potential and one of the largest renewable energies in Serbia. It can be used in almost all over Serbia. In particular, the use of biomass in forestry and agriculture can be utilized in the case of Belgrade. However, due to the biomass nature, it is inconvenient to collect / store and transport, and excessive use can destroy the environment. In addition, there is a problem that a variety of resources and consequently large-scale facility investment of a unit process are required.

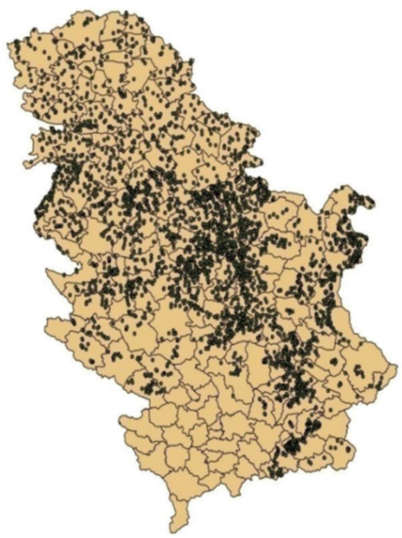
4) Biogas (LFG : Landfill Gas)

Even few years ago waste management in Serbia was based only on collection and waste disposal at not strictly sanitary landfills, but often on small open dumps. However, recently the main goals of waste management in Serbia have been changing to increase in selection and separation of recyclables, especially of packaging waste, and disposal of remaining waste at sanitary (regional) landfills.

At the moment, most of the landfills in Serbia are public owned. There is no way to utilize energy facilities through combustion facilities (incinerators) or other waste, and waste selection and separation is very low level.

There are 3,582 identified landfills in Serbia, 165 of them are municipality landfills, 5 are sanitary landfills and rest are wild dump sites where majority are small open dumps. There are 5 more local sanitary landfills and some municipal landfills are closed, sanation and/or recultivation.

Figure 24. Landfills in Serbia



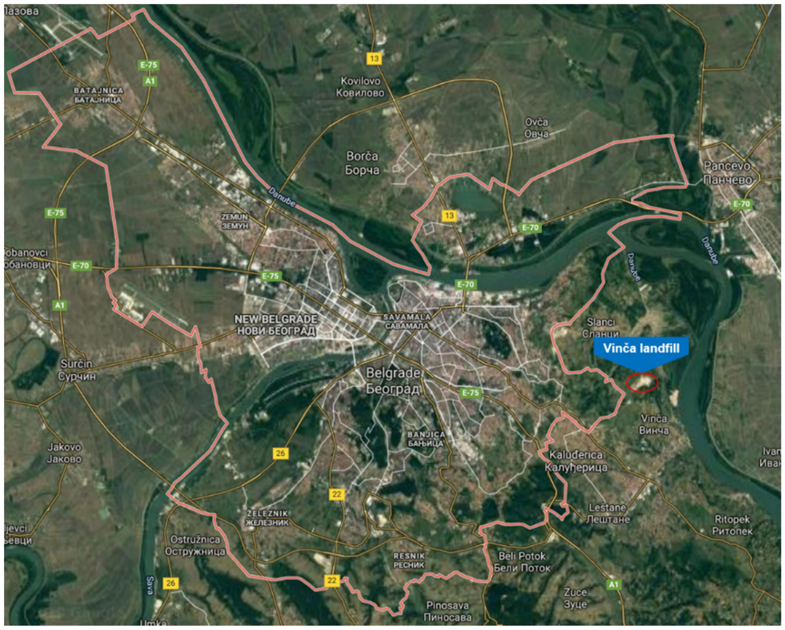
Criteria (m^3)	Number of landfills	Total area (ha)	Total volume (m^3)
to 1.000	2,702	154.50	604,628.93
from 1.001 to 10.000	698	480.04	2,251,995.18
from 10.001 to 100.000	131	313.11	4,087,590.55
from 100.001 to 500.000	37	199.24	8,693,492.43
from 500.001 to 1.000.000	7	62.59	5,296,214.07
Over 1.000.000	7	131.98	23,123,124.56
Total	3,582	1,341.46	44,057,045.71

Criteria height h (m)	Number of landfills	Total area (ha)	Total volume (m^3)
To 1 m	3,322	819.69	3,643,830.68
From 1,1 to 5 m	227	274.36	7,340,340.56
Over 5 m	53	246.92	33,601,845.34
Total	3,602	1,340.97	44,586,016.58

Source: Landfill gas production modeling on landfills in Serbia, 2011

Among the landfill sites in the country, Vinča landfill is a landfill that is close to the city and is available. GC manages and operates the only official landfill in Belgrade known as "Vinča". The landfill is located in the Belgrade municipality of Grocka on the right bank of the Danube, about 15 km from the downtown of Belgrade, as shown in red in Figure 25. The landfill occupies an area of 70 hectares and it was opened in 1977, and until 2014 approximately 14,500,000 tons of municipal solid waste(MSW) have been collected from the city and disposed off at this site. The body of the landfill has an area of 45 hectares and a depth / height of 5 to 50 meters.

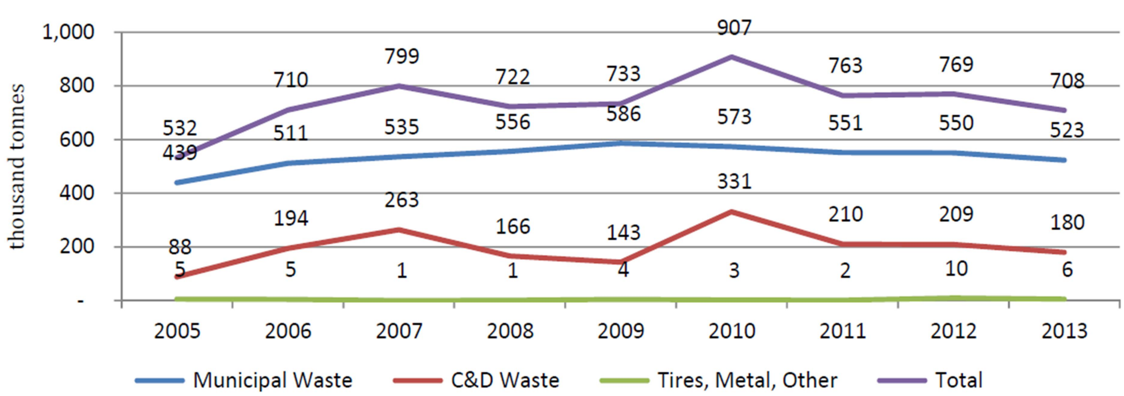
Figure 25. Vinča landfill location



In view of the above conditions, Vinča landfill is the best place to use LFG as a RES in Belgrade City among the landfills.

The landfill is used for the disposal of waste collected on the territory of 13 municipalities (11 municipalities served by GC, plus Barajevo and Grocka), together representing 90% of the waste generated in Belgrade. Presently, all non-hazardous waste, including bulky waste, a portion of industrial waste, construction and demolition (C&D) waste and treated medical waste are all disposed of at Vinča. The following figure shows amounts of the main types of waste disposed of at the Vinča landfill in the period 2005 - 2013, as recorded and measured by the weighbridge installed at the landfill entrance.

Figure 26. Vinča landfill historical waste amounts



Source: Belgrade Waste Treatment and Disposal PPP Project, 2015

The composition of MSW generated in the city of Belgrade is given in Table 25 as percentage wet waste (%wt).

Table 25. The physical composition of solid waste in Belgrade (%wt)

Components	Percentage (%)
Garden waste	6.68
Other biodegradable waste	30.93
Paper	10.78
Glass	6.84
Cardboard	8.97
Cardboard-wax	1.74
Aseptic packages	1.20
Metals - packaging and other	1.98
Metals - Al cans	0.40
Plastics - packaging	4.58
Plastic bags	5.61
Hard plastics	4.73
Textile	5.31
Leather	0.61
Diapers	3.67
Fraction less than 20 mm	5.98

Source: BELGRADE SOLID WASTE MANAGEMENT OPTIMIZATION - POTENTIAL OF LANDFILL GAS RECOVERY, 2015

Data regarding the amounts of waste landfilled at Vinča in the period 2004 - 2013 are given in Table 26.

Table 26. Quantities of solid waste landfilled at Vinča landfill site - period 2004–2013

Year	Quantity of landfilled MSW, (t)	Quantity of total landfilled waste (t)
2004	277,126	423,121
2005	399,571	532,345
2006	463,573	710,155
2007	484,792	799,226
2008	457,627	722,083
2009	528,590	733,284
2010	512,738	907,008
2011	491,171	763,095
2012	487,875	769,127
2013	465,589	708,276

Source: BELGRADE SOLID WASTE MANAGEMENT OPTIMIZATION - POTENTIAL OF LANDFILL GAS RECOVERY, 2015

According to calculations, the Vinča site can accept maximum of 21,000,000 tons of waste and disposal rates it is predicted. therefor the site has been scheduled to close in 2016, but the plan changed to develop the landfill.

Waste is disposed off using the method of surface disposal in successive 0.3 – 0.5 m thick layers. These layers are leveled and compacted to the density 750 kg/m^3. The landfill body showed no signs of disturbance over the years, although it is estimated that in some parts the thickness of waste layer is about 60 m. The landfill has no system for landfill gas extraction, and this gas is released from the landfill surface directly to the atmosphere. The precise amount of landfill gas in the landfill body is still unknown.

First decay model is used to predict of LFG generation, and the US EPA LandGem v.3.02 is generally applied to LFG feasibility study. Data on annual landfill quantities and physical composition of solid waste in Vinča landfill site were applied to LandGem model to predict LFG generation.

LandGem model is to input methane potential value Lo and kinetic factor k together with annual landfill amounts. Methane potential Lo value were calculated by the DOC calculation based on the physical composition and the Lo calculation formula based on this, as recommended in the IPCC 2006 guideline. The Lo value based on the physical composition of waste in Belgrde was calculated as 83.01Nm^3_{CH4}/ton, and the kinetic factor k value was 0.04yr^{-1}, which is the recommended value of US EPA for the region with an average annual precipitation exceed 635mm.

Figure 27. US EPA LandGem v3.02 model

$$Q_{CH_4} = \sum_{i=1}^{n} \sum_{j=0.1}^{1} k L_o \left(\frac{M_i}{10} \right) e^{-k t_{ij}}$$

Q_{CH_4} = Annual amount of CH_4 generation in the relevant year (m^3/year)
i = One year of time interval
n = (Relevant year Initial year of landfill)
j = One year of time interval
k = Rate constant of CH_4 generation ($year^{-1}$)
L_o = Potential amount of CH_4 generation (m^3/Mg)
M_i = Amount of waste buried in the ith year (Mg)
t_{ij} = jth hour of M_i (decimal year, i.e. 3.5 years)

Source: US EPA

Figure 28. Methane Potential calculation formula

$$L_0 = DOC \times DOC_f \times MCF \times F \times 16/12$$

DOC = Decomposable organic carbon

DOC_f = Actual decomposition rate of DOC

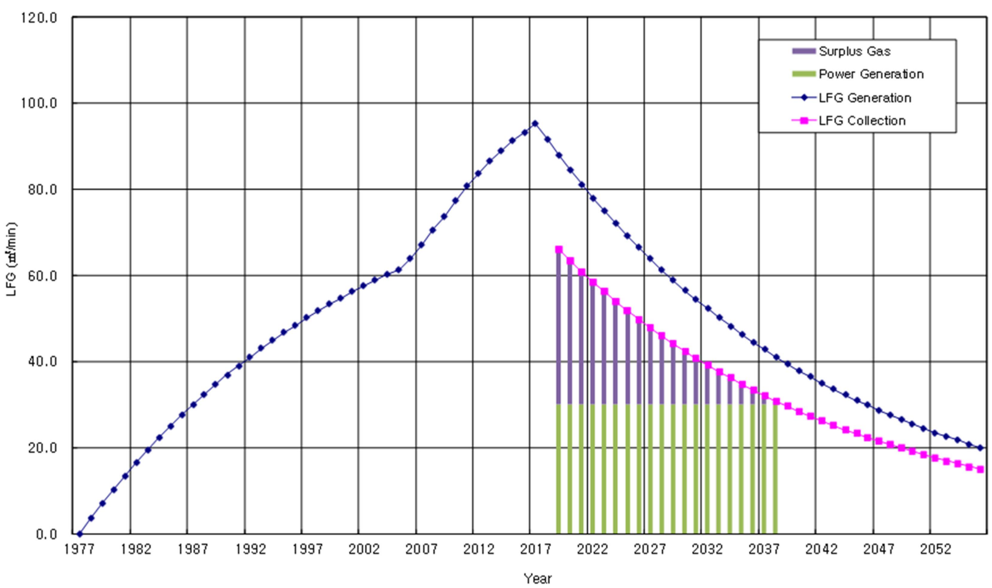
MCF = CH_4 correction factor

F = CH_4 concentration in LFG

16/12 = Molecular ratio of CH_4/carbon

Source: IPCC 2006 Guideline

Figure 29. Prediction of LFG Generation in Vinča landfill



Estimation of LFG generation for Vinča landfill site is estimated as 88 N㎥/min as of 2019 and collection flow is 66 N㎥/min when 75% collection rate is applied. The LFG collection flow is expected to decrease gradually from 2019 to 30.9 N㎥/min in 2038, 20years later.

If a 3MW gas engine power plant is installed and operated, 30 N㎥/min LFG will be required and it will be possible to operate for 20 years. The surplus LFG remaining in the gas engine power plant will reach 36 N㎥/min in 2019 and there will be no surplus in after 20 years. The average surplus LFG for the decade after 2019 reaches 25.5 N㎥/min, which can be used as fuel for district heating. Assuming that the average calorific value of LFG is 5.8Kw/N㎥, it will be able to secure an average of 8.9 MW of fuel over the next 10 years with surplus LFG.

5) Geothermal

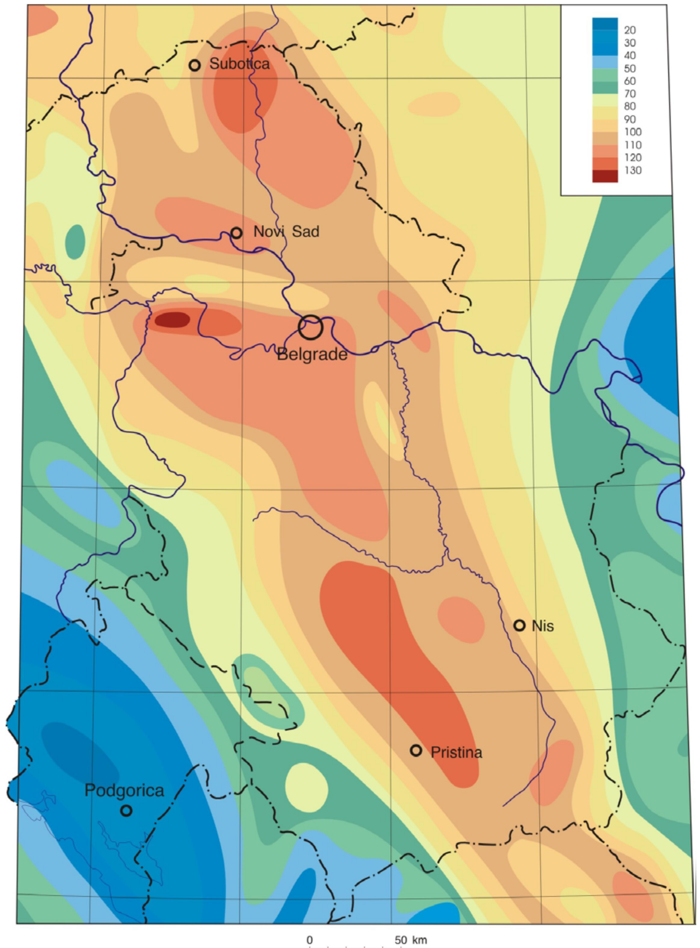
Serbia is centrally situated in the Balkan Peninsula and its territory covers the surface of 88,361 km^2. The territory of Serbia has favorable geothermal characteristics. In particular, the southern edge of the Pannonian Basin is beneficial to geothermal.. Serbia has 159 natural hot springs with a temperature of 15 ℃ or higher, excluding the Pannonian basin, with a total flow of 4,000 l/s. The Pannonian watershed has 81 water drill holes with a total average flow of approximately 700 l/s and a water temperature of 21 ℃ to 82 ℃.

Figure 30. Tectonic map of Balkan Peninsula

Source: Martinovic and Milivojevic, 2010

The geothermal energy of Serbia is used for space heating using hot water exchange drill and heat exchanger and heat pump, and has greater geothermal potential than currently used.

Figure 31. Heat flow density map of Serbia(mW/m2)



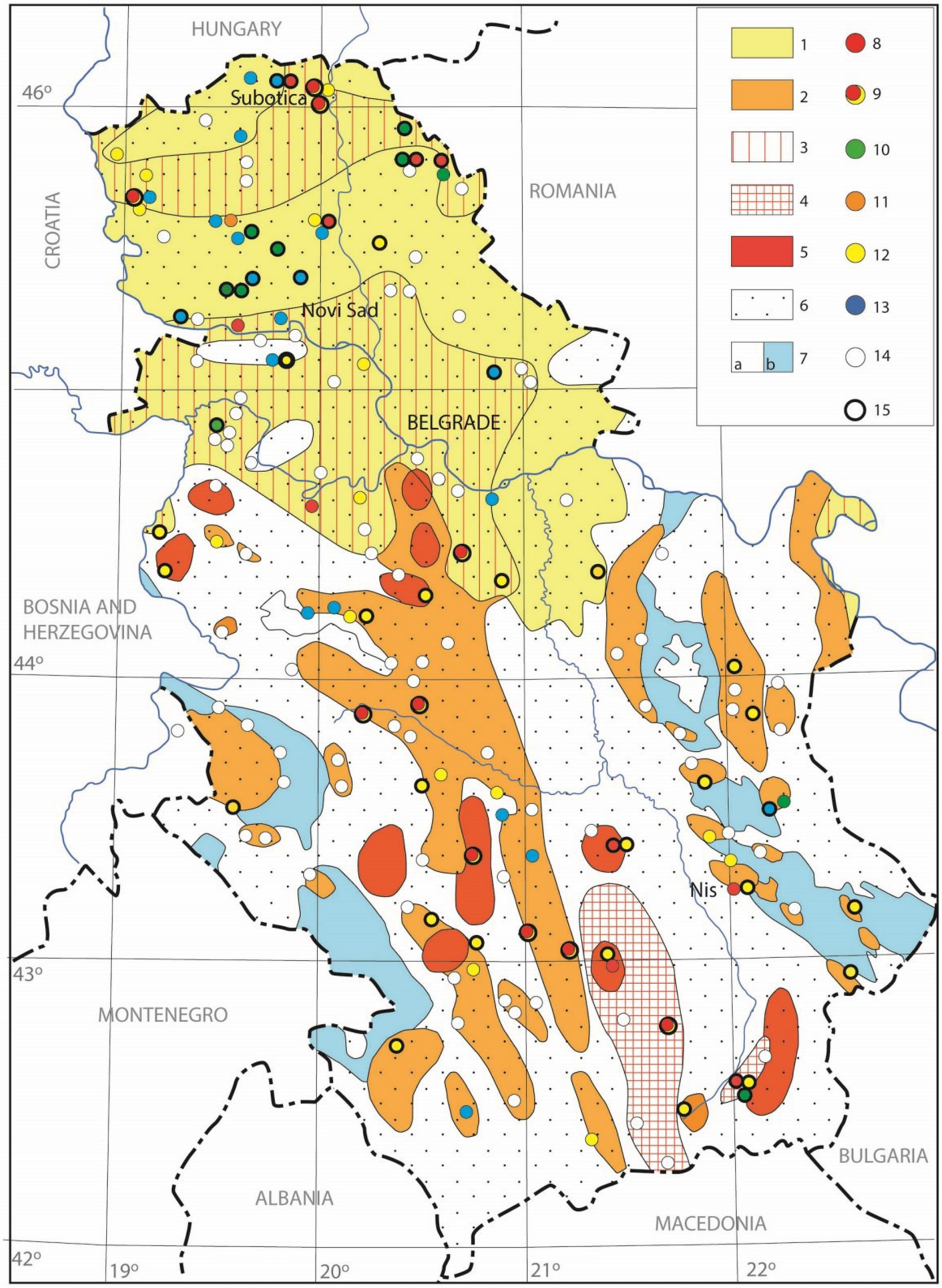
Source: Geothermal resources map, Milivojevic, 2001

According to M. Milivojevic, (1989) there are four geothermal units in four large geological units. The terrestrial heat flow density values in most Serbia are higher than the continental average in Europe. The highest values are in the boundary of the Pannonian Basin,> 100 mW/m^2, the Serbian-Macedonian Massif and the Dinarides and the Serbian-Macedonian Massif, or the terrain of Neogene magmatic activation. The value of land heat flow density is lowest on the Mesh platform.

These values of high heat flow density certainly indicate the presence of geothermal variation that represents an extension of the Pannonian Basin geothermal variant.

There are 60 convective hydrogeothermal systems in Serbia. Of this number, 25 are in the Dinarides, 20 in the Carpatho-Balkanides, 5 in the Serbian-Macedonian Massif, and 5 in the Pannonian Basin under Tertiary sediments.

Figure 32. Map of geothermal resources of Serbia



Legend: 1-Hydrogeothermal aquifer in Cenosoic rocks; 2-Hydrogeothermal aquifer in Mesosoic rocks; 3-Hydrogeothermal aquifer in Mesosoic rocks bellow Cenosoic rocks; 4-Hydrogeothermal aquifer in Paleosoic rocks; 5-Petrogeothermal resources in Tertiary granitoide rocks; 6-Hydro-petrogeothermal resources to 200 m deep for exploitation of geothermal energy with heat pumps; 7-Areas without significant geothermal resources: a) terrains with rocks of Paleosoic and Proterosoic age, b) karstic terrains;
UTILIZATION OF RESOURCES: 8-heating; 9-heating, balneotherapy and recreation, 10-Food production; 11-industry; 12-Balneotherapy; 13-Recreation and sport; 14-Occurences not used; 15-In operation in 2014.

Source: Geothermal resources map, Milivojevic, 2001

Conductive hydrogeothermal systems are developed in basins filled with Paleogene and Neogene sedimentary and as such they mainly occur in the Pannonian Basin in Vojvodina, northern Serbia.

At present, Serbia's geothermal energy is only 104.5 MWt and shallow system is only 11 MWt.

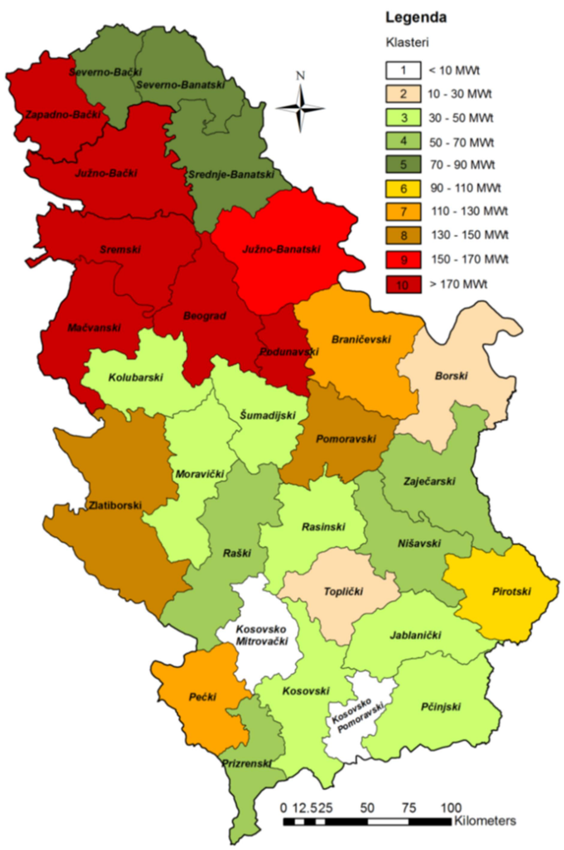
This can be considered quite low because Serbia on geothermal potential is one of the "rich" countries. Its exploitation and use must be intensified by many factors. The most important uses of geothermal energy for Serbia are settlement and agricultural development district heating, more precisely, ecological standards and food production for electricity production in the near future.

Interest in using geothermal energy is growing in Serbia, as fossil fuel prices and the government subsidize investment in renewable energy projects.

Belgrade's greatest interest is that exciting reservoirs use heat pumps to heat large residential buildings, hotels and shopping centers in the alluvial deposits of Sava, Danube and Shinigen sediments. It is also very good to use heat pumps for pumped groundwater in alluvial sediments of all major rivers. The development of geothermal energy using heat pumps is considered to be very effective.

As you can see in the table, Belgrade has a potential of 1,200 MW in the urban city area and 1,100 MW in the city area. The amount of energy needed in the Urban area in Belgrade is expected to be approximately 4,000 MW and 57.5% of the energy will be covered through the development of the geothermal potential.

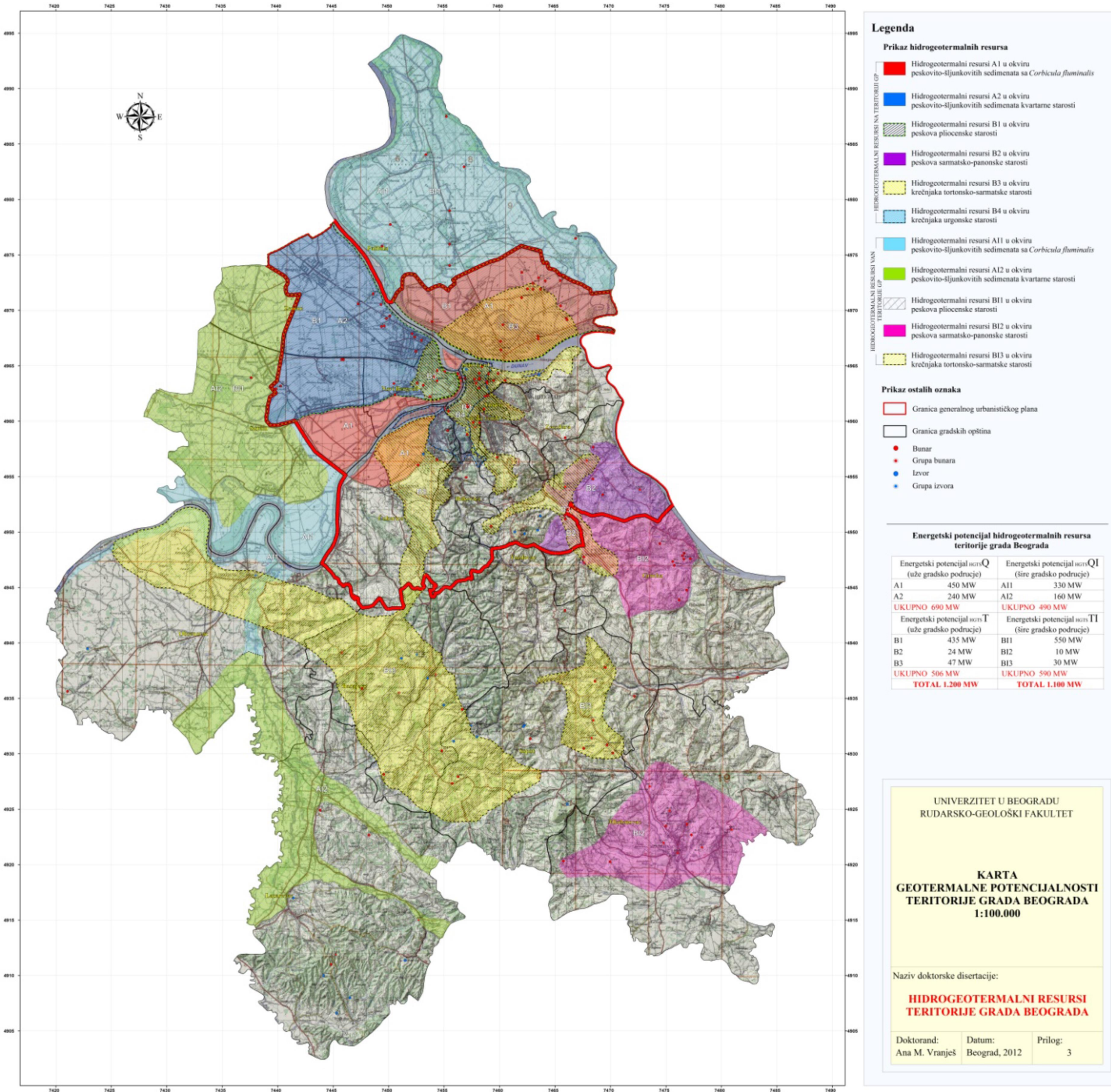
Figure 33. Subgeothermal potential in Serbia



Region	Districts	Potential thermal power	Effective thermal power	Total thermal power
		1	2	3=1+2
		MW.	MW.	MW.
Beograd	Urban city area	1.200		1.200
	City area	1.100		1.100
Vojvodina	Severno bački	37.4	45.9	83.3
	Zapadno bački	28.5	157.1	185.6
	Južno bački	65.6	139.0	204.6
	Severno banatski	36.3	46.2	82.5
	Srednje banatski	29.9	57.3	87.2
	Južno banatski	41.8	126.4	168.2
	Sremski	37.3	250.6	287.9
Šumadija i Zapadna Srbija	Mačvanski	37.1	233.7	270.8
	Kolubarski	9.2	32.8	42.0
	Zlatiborski	15.7	120.9	136.6
	Moravički	11.2	21.7	32.9
	Šumadijski	12.2	28.9	41.1
	Rasinski	11.1	20.7	31.8
	Raški	10.5	57.4	67.9
	Pomoravski	29.7	106.7	136.4
Južna i Istočna Srbija	Podunavski	21.5	160.1	181.6
	Braničevski	20.1	98.0	118.1
	Borski	7.2	18.7	25.9
	Zaječarski	28.0	32.6	60.6
	Nišavski	24.4	45.3	69.7
	Pirotski	27.2	76.3	103.5
	Toplički	3.7	10.1	13.8
	Jablanički	17.8	28.6	46.4
	Pčinjski	14.7	22.9	37.6
Kosovo	Kosovsko-Mitrovački	3.6	4.2	7.8
	Kosovski	8.9	26.0	34.9
	Pećki	28.2	92.7	120.9
	Kosovsko-pomoravski	1.8	1.8	3.6
	Prizrenski	10.5	43.4	53.9
TOTAL		631.1	4.414	5.045

Source: GEOTHERMAL DEVELOPMENTS IN SERBIA, 2012

Figure 34. Subgeothermal potential in Belgrade



Source: GEOTHERMAL DEVELOPMENTS IN SERBIA, 2012

According to geothermal exploration results, intensive use of hot water in agriculture, aquariums and district heating is the best view in western Belgrade. The most versatile use of geothermal energy is in the western part of Belgrade, west of the Macba area, a reservoir of karstified limestone beneath the Shinju river sediments.

Geothermal energy potential is expected to be sufficient throughout Serbia. In particular, Belgrade is expected to have a high energy demand, so it will be beneficial to switch to renewable energy through geothermal energy development. However, in the case of geothermal energy, there is a problem that the initial investment cost is high.

6) Conclusion

In Serbia, renewable energy has good conditions and high potential to develop and utilize, it estimated at more than 4 million tons of oil per year (estimated), which is half of the annual energy demand.

Technically useful renewable energy potential in Serbia is estimated to be over 4.3 Mtoe per year. Of these, about 2.7 Mtoe (63%) are produced in biomass development. The untapped hydroelectric power capacity is 0.6 Mtoe (14%) per year, 0.2 Mtoe (4.5%) per year from existing geothermal springs, 0.2 Mtoe (4.5%) per year for wind energy and 0.6 Mtoe (14%) per year for solar thermal.

In particular, solar thermal, biogas (LFG), and geothermal can be used in almost all areas of Serbia, but they can be developed and utilized mainly in energy-consuming Belgrade.

The potential for renewable energy is highest for biomass and solar is the second highest, excluding hydro.

Table 27. Structure (%) of renewable energy potential in Serbia

Type of RES	Potential
Biomass	63%
Solar	14%
Wind	4.5%
Geothermal	4.5%
Hydro	14%

Source: A roadmap for deploying renewable energy sources in Serbia and the regional perspective, 2015

Comparing five major renewable energy sources that are currently determined to be available for development and utilization in Belgrade, the table below shows.

Table 28. Comparing 5 major RES in Belgrade

	Heat pump	Solar thermal	Biomass	Biogas(LFG)	Geothermal
Available location	TENT A	Cerak, Batajnica	Suburb of Belgrade	Vinča landfill site	Western Belgrade
Amount of potential (GWh/year)	3,015.7	27.4 4.5	3,247.5	77.9	20,148
Heat plant	Novi Beograd	Cerak Batajnica	Novi Beograd	Vozdovac	Novi Beograd
Accessibility : To heat plant (km)	28	< 1 < 1	> 50	9	10
Thermal energy yearly produced on the heat plant (GWh/year)	1,048.3	293.4 33.4	1.048.3	225.3	1,048.3
Heat resources	Limited	Infinity	Limited	Limited	Infinity
Reduce CO2 emissions (tCO_2/year) (Emission factor: 0.792 tCO_2/MWh)	2,388.4	21,701 3,564	2,572.0	61,697	15,957.2
Associations	- MEP - MEM - Belgrade city - EPS - BE	- Belgrade city - BE	- MEP - MEM - Belgrade city - EPS - BE	- SUEZ - Belgrade city - BE	- MEP - MEM - Belgrade city - EPS - BE

Evaluation based on Belgrade, geothermal has the largest energy potential, but there are some adverse conditions such as the distance from the heat plant, and consultation with associations. On the other hand, in the case of solar thermal, the energy potential is small, but the distance from the heat plant is the closest, the energy resources are infinite, and there is no GHG emissions. In the case of CO2 reduction of solar thermal, CO2 does not occur at the time of heat production, and CO2 is not produced in the heat source even itself, so it can be seen more effectively in CO2 reduction than heat pump, biomass, and biogas (LFG). In addition, the Council for the Development of RES also has the simplest procedure because it can proceed with consultation between BE and Belgrade City.

In the among 2 locations of solar thermal, Cerak and Batajnica have free areas where solar thermal development is possible.

In both locations, similar conditions are favorable for solar thermal development, but Cerak is considered to be more advantageous when comparing the amount of potential and the area that can be developed.

In summary, the optimal renewable energy technology in Belgrade City is solar thermal technology at Cerak.

Part Ⅱ.

Feasibility Study and Analytical Assessment Report of Cerak Heat Plant

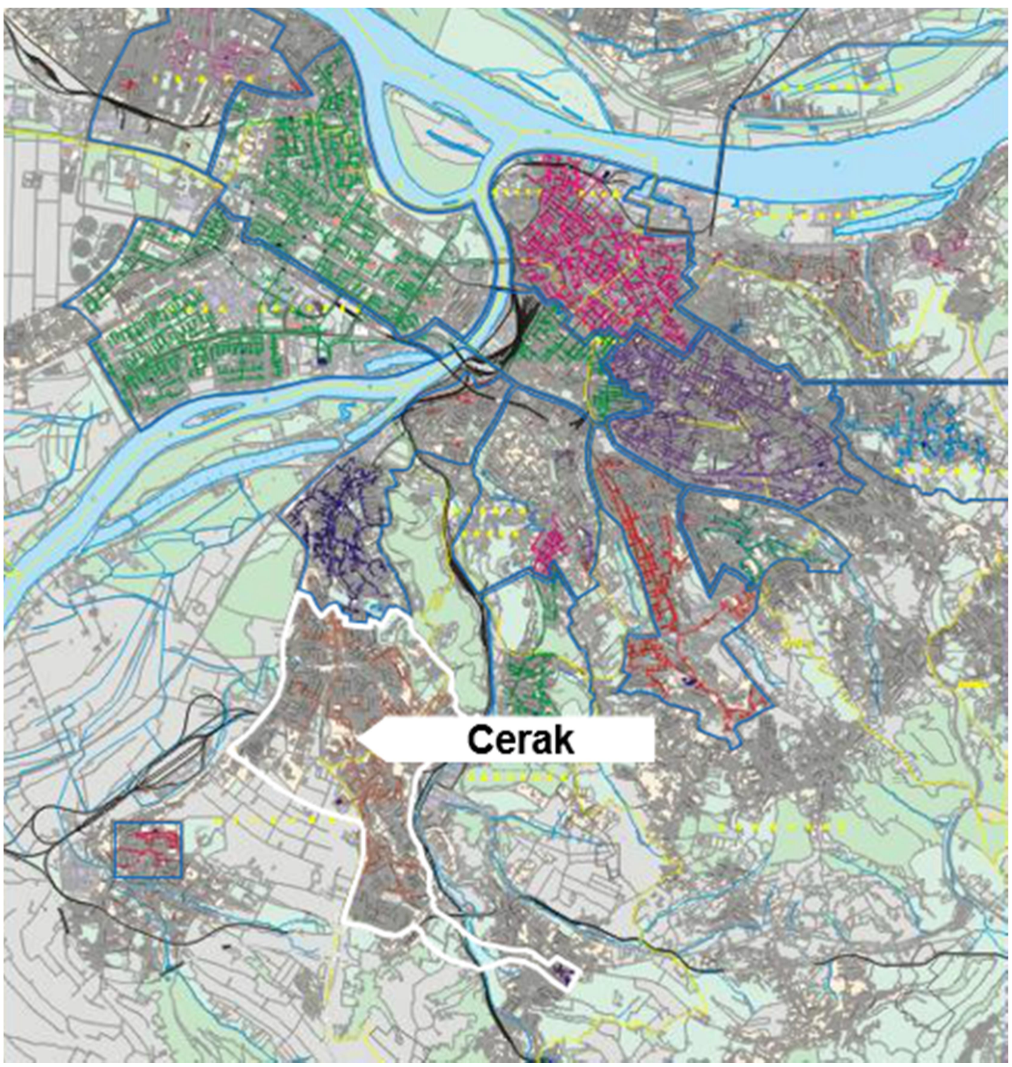
5. Technical report of one chosen site

5.1 General Information - Cerak

Cerak is an urban neighborhood of Belgrade, the capital of Serbia. It is located in Belgrade's municipality of Čukarica. By the census of 2011 all three local communities were united in one named Cerak with the population of 43,993.(local communities of Cerak 12,591, Vinogradi 13,091 and Sportski Centar 17,528)

The geographical coordinate system coordinates are latitude 44°44′N and latitude 20°25′E. Cerak is located by a 100m difference in height compared to the neighboring part of Belgrade. This characteristic makes the limit for the DH-zone of Cerak.

Figure 35. Location of Cerak site



Cerak, like the city of Belgrade, has a continental and Mediterranean climate with four seasons and uniform rainfall according to the Köppen climate classification.

Cerak belongs to Central Serbia, like Belgrade, with the same overall climate but with slightly different average temperatures and precipitation. Compared to Belgrade, the average temperature is lower and precipitation is less. The average sunshine hours per day is about 5.8 hours, which is much different from summer to winter. Comparing daily average daytime, On average, the sunshine hours compared to the daytime was about 22% which is short in winter, and it is up to 64% which is long in summer.

Table 29. Climate data for Cerak

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Max Temperture(℃)	4.2	8.5	14.1	19.1	23.6	**28.0**	**31.1**	**31.0**	26.9	19.6	10.4	5.1	18.5
Average Temperture(℃)	0.4	3.7	8.2	12.5	16.9	20.8	23.4	23.0	19.4	13.4	6.0	1.7	12.4
Min Temperture(℃)	-3.4	-1.1	2.4	5.8	10.1	13.5	15.7	14.9	12.0	7.1	1.6	-1.7	6.4
Average Precipitation(mm)	46.9	40.0	49.3	56.1	58.0	101.2	63.0	58.3	55.3	50.2	55.1	57.4	690.9
Daily Average Sunshine Hours	2	4	5	6	8	**9**	**9**	**9**	7	5	3	2	5.8
Daily Average Sun Hours	9:15	10:31	11:57	13:33	14:54	**15:38**	**15:18**	14:07	12:35	11:03	9:38	8:52	12:32

Source: https://www.accuweather.com/en/rs/cerak/, https://www.climatestotravel.com/climate/serbia, http://ashrae-meteo.info/

5.2 Condition of Cerak Heat Plant

Cerak heat plant has been in operation since 1985 and has 100% ownership in the city of Belgrade. Cerak heat plant has a site of about 75,900 m^2 and has two tank storages for medium fuel oil. The Cerak heat plant, with a nominal heat of 232MW, is currently providing heat energy to consumers. However, the total capacity of the actual supply is 245 MW in the hot water boiler (two 58MW boilers and one 116MW boiler) and a steam boiler (two 6.5MW steam boilers).

Table 30. Boilers capacities

Boiler type	Unit	Capacity(MW)	Fuel type
Hot water	1	116	Natural gas
Hot water	2	58	Natural gas
Steam	2	6.5	Medium oil

Cerak heat plant produced about 275 GW of heat energy per year by 2018 and has increased by about 29% compared to 2017. It is analyzed that the average temperature difference in 2018 compared to 2017 was not large, but the heat demand of consumers was increased.

Table 31. Total heat demand in Cerak

Date	Total heat demand in Cerak (MWh) - 2017	Total heat demand in Cerak (MWh) - 2018	Average heat demand in Cerak in 2017-2018 (MWh)	Share from total heat demand in Cerak In 2017-2018 (%)
Jan	41,265.0	51,327.2	46,296.1	19.0
Feb	32,281.0	53,845.8	43,063.4	17.6
Mar	24,380.0	45,078.9	34,729.5	14.2
Apr	13,865.0	10,213.6	12,039.3	4.9
May	3,188.0	3,116.6	3,152.3	1.3
Jun	2,369.0	2,630.8	2,499.9	1.0
Jul	1,992.0	2,659.0	2,325.5	1.0
Aug	2,042.0	2,147.5	2,094.7	0.9
Sep	2,488.0	2,337.6	2,412.8	1.0
Oct	13,663.0	11,470.1	12,566.5	5.1
Nov	29,620.0	36,018.6	32,819.3	13.4
Dec	45,724.0	54,437.5	50,080.8	20.5
Total	212,877.0	275,283.1	244,080.1	100.0

Table 32. Average temperature in Cerak

℃	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
2017	-0.5	1.6	6.3	11.7	16.6	19.4	21.2	21.1	17.2	12.1	6.3	1.4	11.2
2018	0.4	3.7	8.2	12.5	16.9	20.8	23.4	23.0	19.4	13.4	6.0	1.7	12.4

Source: https://www.accuweather.com/en/rs/cerak/

As such, the heat demand in Cerak region is expected to increase steadily, and according to data from another report, the maximum demand increase over the long term is estimated to be about 160 MW, which is about 385 MW in the consumer's side. This means that the existing capacity of the plant meets the need for increased planned consumption in the long run.

The heat supply and return pipeline of Cerak has a total length of 110.2 km and diameter of main pipes consists of two DN 700 and DN 600. The number of households that supply district heating in the Cerak heat plant is about 26,684 households, which is about 1,534,382 m^2 in area.

Figure 36. Transmission pipelines and Cerak heat plant site

5.3 Heat demand status

Cerak heat plant consists of two supply lines, M1 and M2. Looking at the hourly supply and return temperatures of the two supply lines, it shows patterns that are generally high in the winter and low in the summer.

Figure 37. M1 temperature data of the supply and return flow

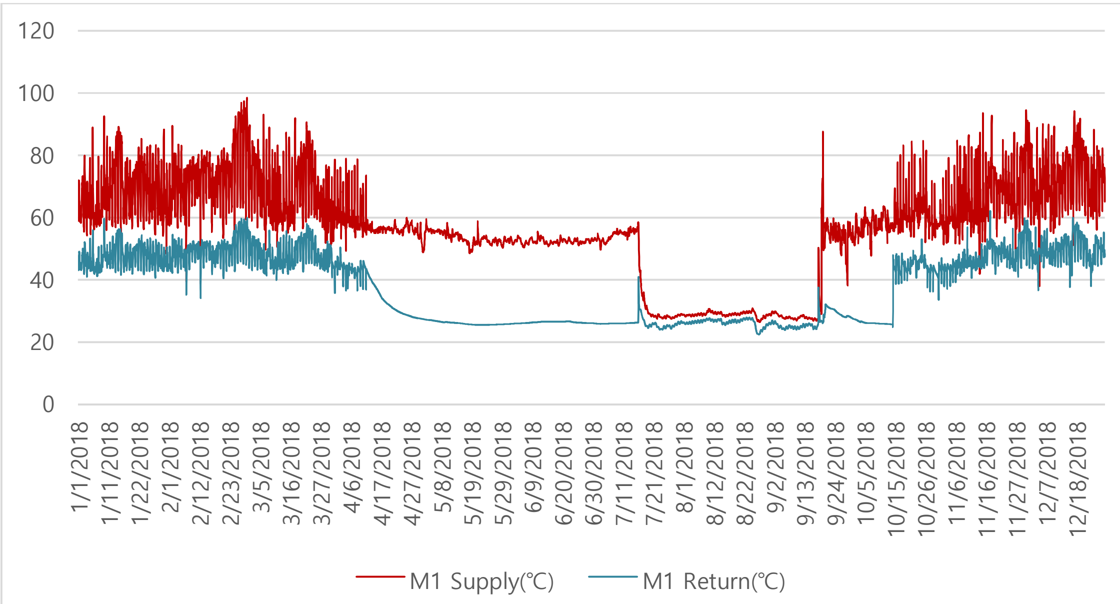
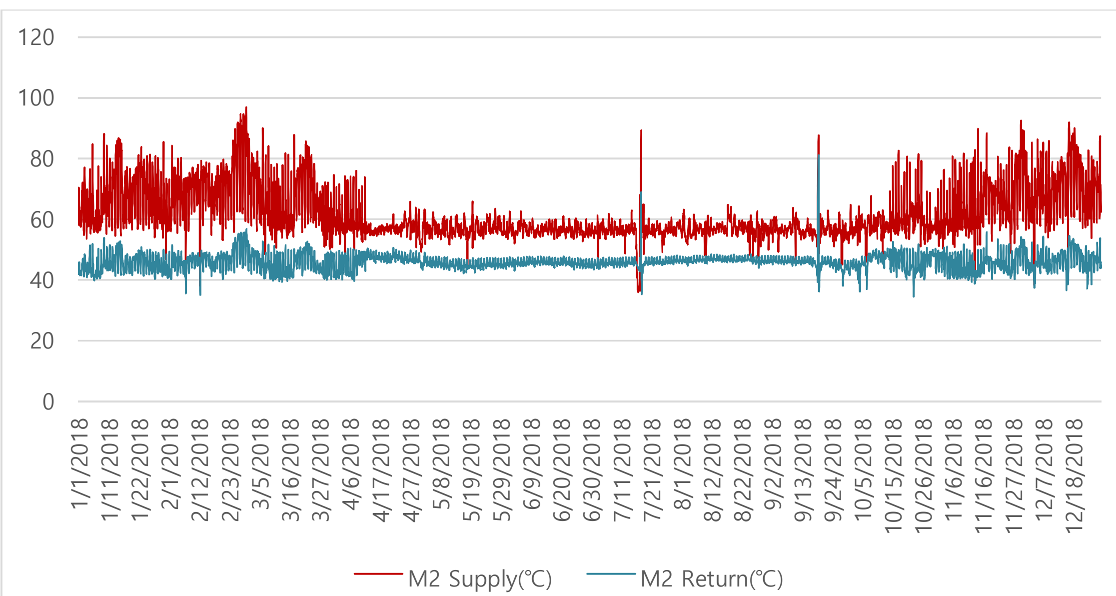


Figure 38. M2 temperature data of the supply and return flow



As shown in Figure 37, in the case of M1, the supply temperature drops sharply from mid-July to mid-September. This phenomenon is caused by discontinuing the operation in the regular summer repair period. In addition, intermittently sudden temperature changes from mid-September to mid-October were found to be due to the progress of pipeline flushing and water replenishment during the period. The sudden change in temperature during July and September in Figure 38 was identified as a data error due to power supply problems.

Although there are some issues when we divide M1 and M2 in this way, overall temperature pattern is low in summer and high in winter. If the average value by combining the temperature data, the following graph will appear.

Figure 39. Average temperature data of the supply and return flow

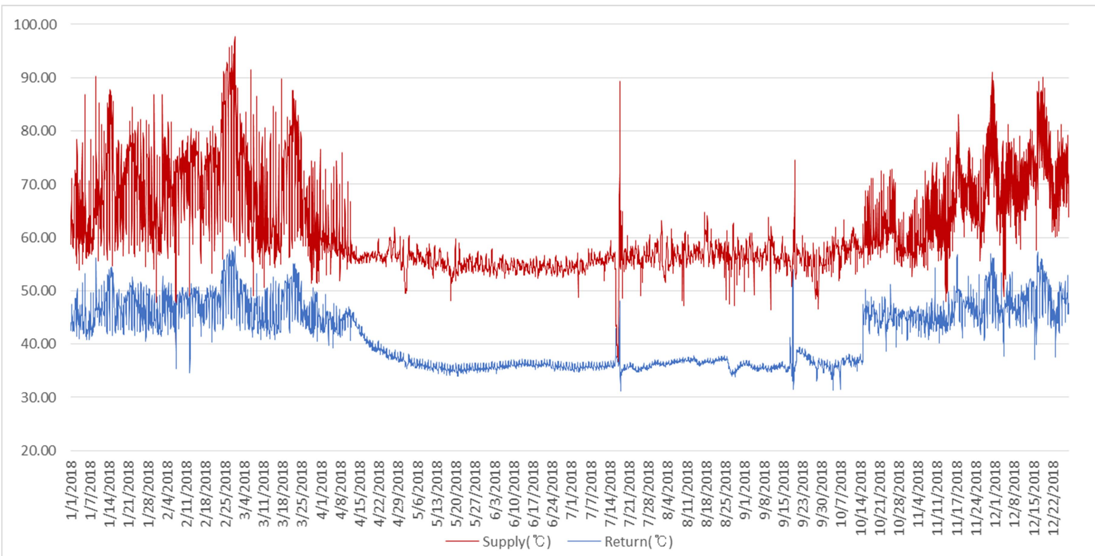


Table 33. Monthly supply and return temperature

Date	Max Supply(℃)	Max Return(℃)	Min Supply(℃)	Min Return(℃)	Average Supply(℃)	Average Return(℃)
Jan	90.34	56.17	53.88	40.42	67.79	46.36
Feb	95.98	57.73	38.29	34.57	72.24	48.15
Mar	97.72	58.42	49.08	40.51	67.50	46.97
Apr	76.60	49.30	51.87	36.61	57.73	41.55
May	60.34	38.26	48.13	33.99	55.16	35.69
Jun	57.86	37.21	52.27	34.49	54.49	36.00
Jul	61.46	48.16	35.91	31.20	49.37	35.87
Aug	46.76	37.79	37.12	33.84	42.92	36.50
Sep	74.51	53.98	36.88	31.45	47.47	36.34
Oct	72.82	51.28	51.84	31.33	59.11	41.07
Nov	90.99	56.93	47.99	40.23	65.02	46.22
Dec	90.18	57.26	48.90	37.10	71.77	48.30

However, in terms of the amount of heat load supplied per unit of time, unlike the change of the supply / return temperature, the winter and summer seasons are observed in a certain pattern. It can be seen that Cerak heat plant is operating well balanced with M1 and M2 supplied.

The hourly heat load supply varies from a maximum of 145.4 MWh to a minimum of 0 MWh. Generally, it can see patterns that have a large supply in winter and a small supply in summer.

Figure 40. Hourly heat load

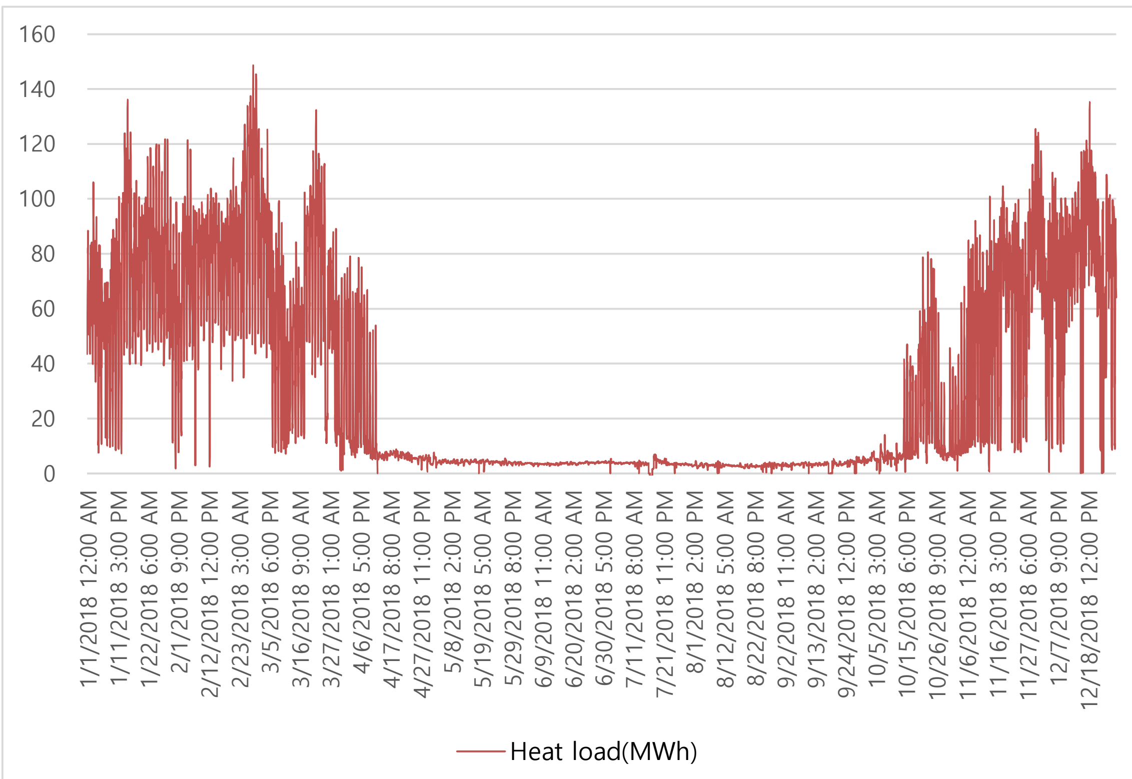
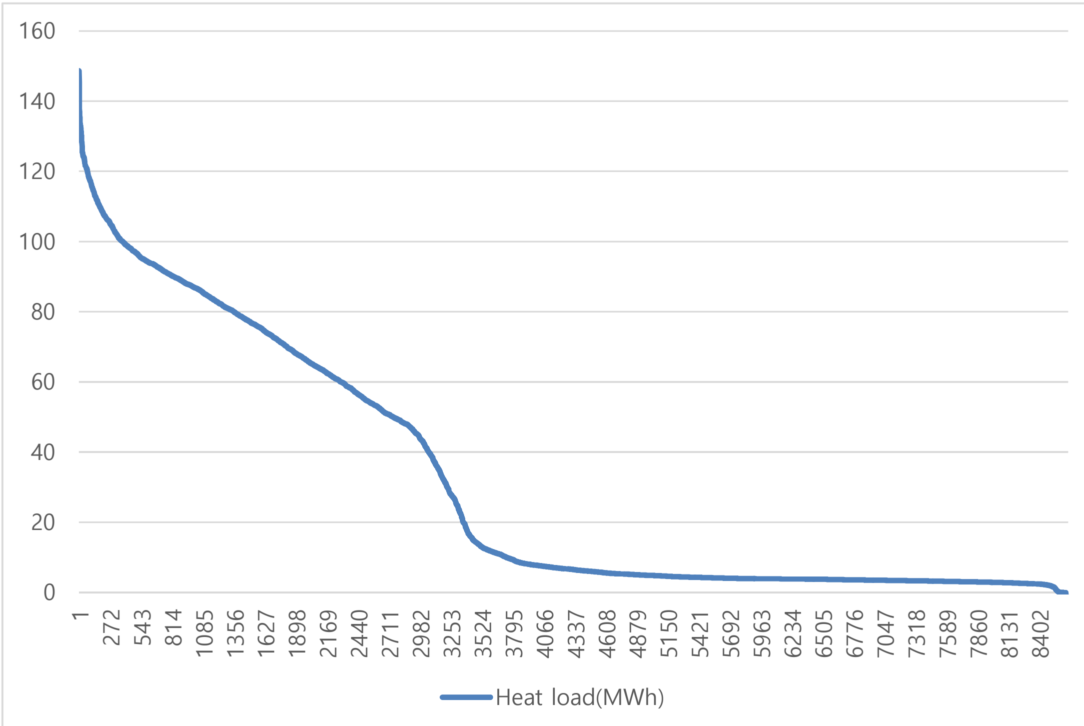


Figure 41. Heat load duration curve



By time, day and night can be distinguished. At night time, it shows a similar level of heat load for a year, while it seems that seasonal effects are more likely to be affected during the day time. (Except for one hour before and after the sunrise / sunset time to analysis typical daytime and nighttime demand patterns)

Table 34. Monthly average sunrise/sunset time

Type		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Day	Sunrise	08	07	06	06	06	05	06	06	07	07	07	08
	Sunset	16	17	17	19	20	20	20	19	18	18	16	16
Night	Sunset	17	18	18	20	21	21	21	20	19	19	17	17
	Sunrise	7	6	5	5	5	4	5	5	6	6	6	7

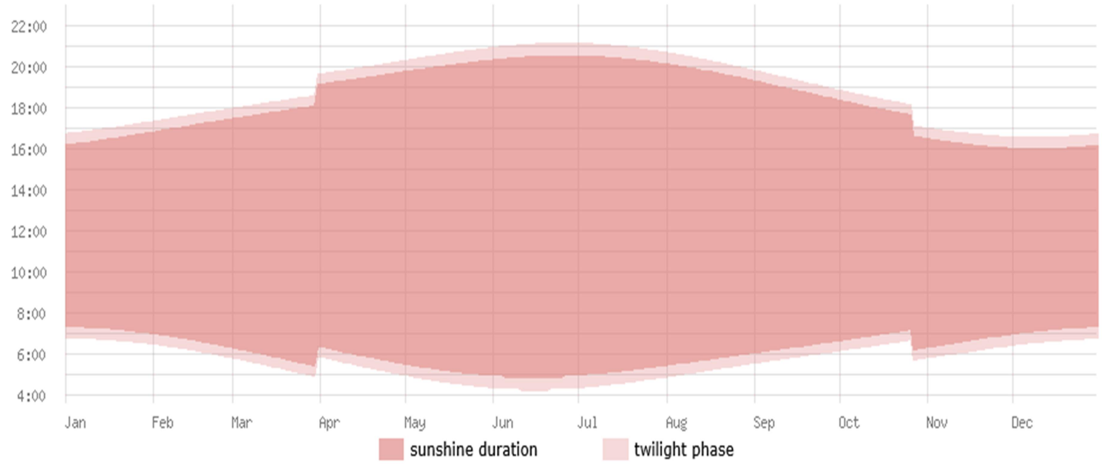
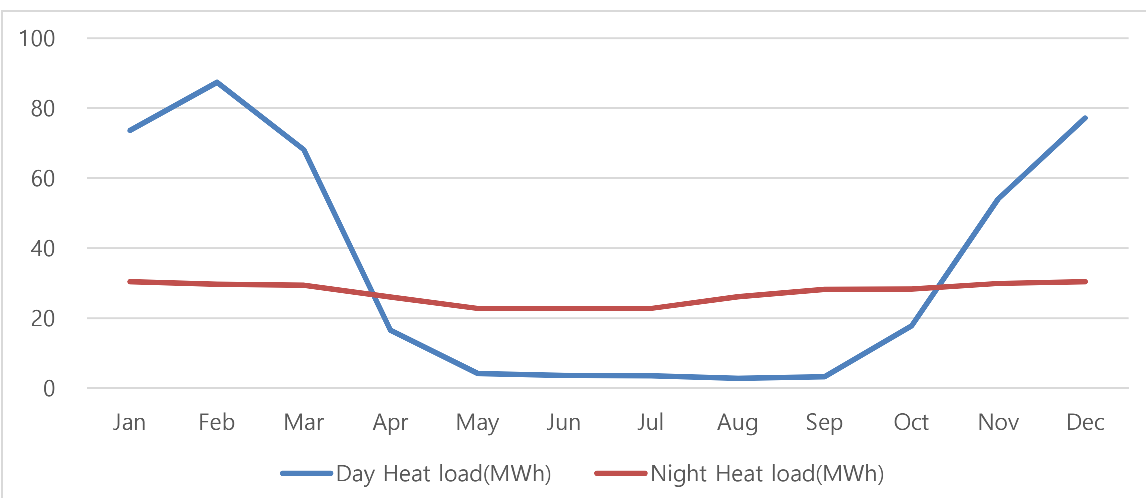


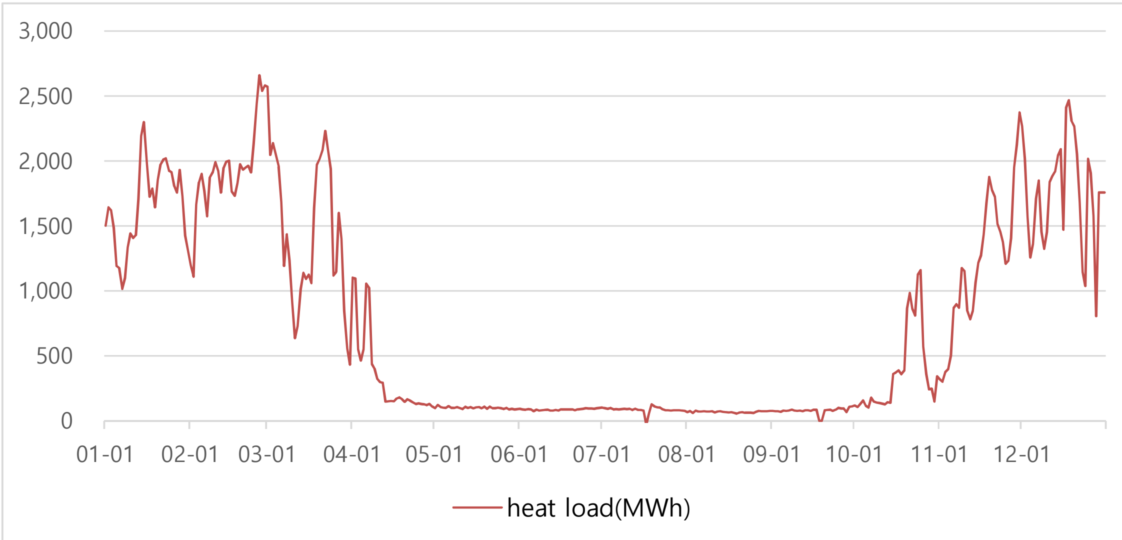
Table 35. Monthly day and night heat load

Type	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Day Heat load (MWh)	73.7	87.4	68.1	16.5	4.2	3.6	3.6	2.9	3.3	17.8	54.1	77.2
Night Heat load (MWh)	30.5	29.7	29.4	26.1	22.8	22.8	22.8	26.2	28.2	28.3	30.0	30.4



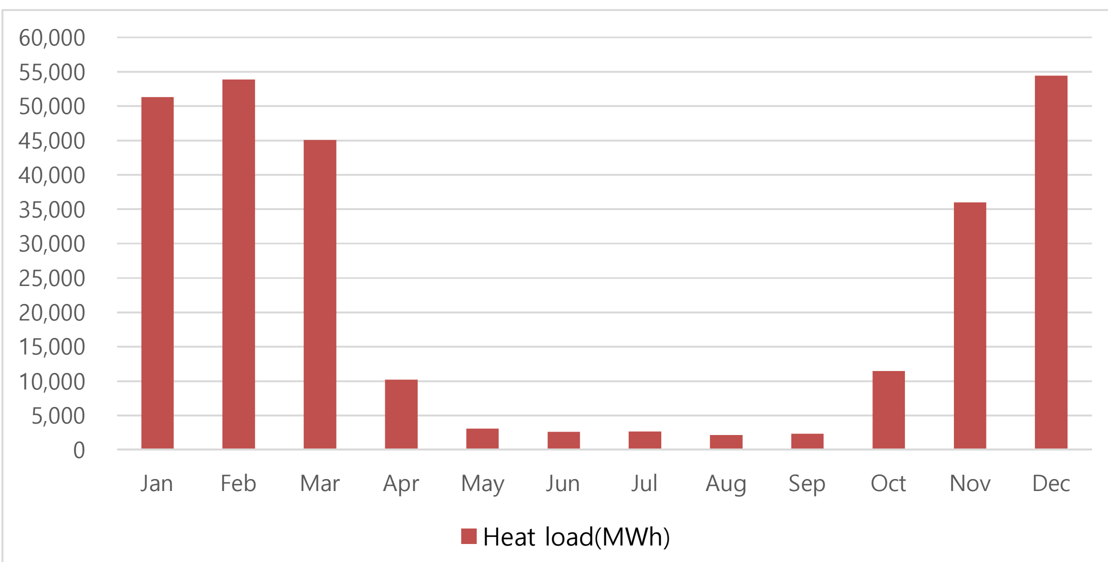
Daily heat load supply can see the difference ranges from a maximum of 2,659.6 MWh to a minimum of 0.8 MWh.

Figure 42. Daily heat load



Monthly heat load capacity differs from maximum 54,437.5 MWh in December to minimum 2,147.5 MWh in August. Average supply of 22,940.3 MWh of heat load per month, and supply tends to surge from November to March.

Figure 43. Monthly heat load



As it can be seen from data that there is a big difference in the heat load supply by dividing into the summer season and the winter season, and the summer heat supply is approximately 4.7% compared with the winter season.

5.4 Analysis of heat supply status

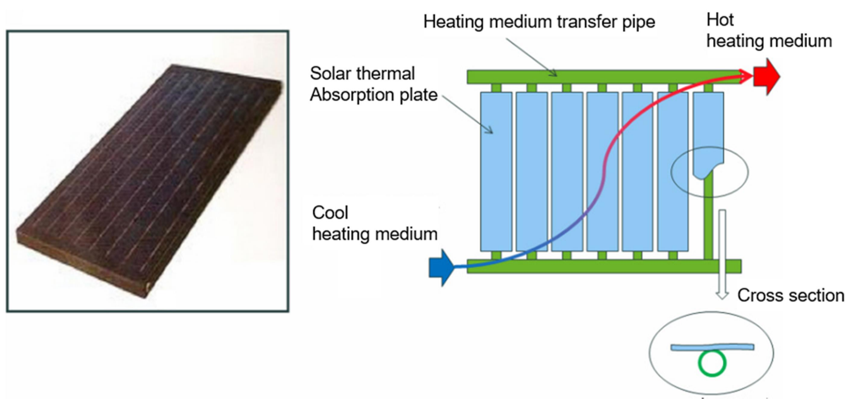
1) Renewable Energy Resource : Solar thermal

Solar thermal, a renewable energy resource, needs to predict solar thermal production per unit area before it can be used for district heating In Cerak. Solar thermal production will determine the size and utilization of facilities.

There are two main types of solar collectors, which are the most important equipment for calculating solar thermal production and solar thermal systems.

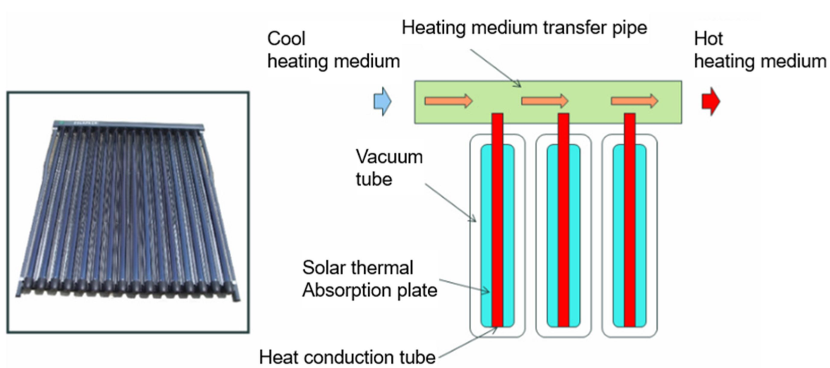
Flat plate type collectors are the most widely used collectors in the world. They are flat plate type and consist of permeable body, absorption plate, heat medium tube insulation.

Figure 44. Flat plate solar collector



Vacuum tube type collector is a collector that makes the inside of the permeable body vacuum and the absorber is located inside. There are one vacuum tube and two vacuum tubes depending on the type of vacuum tube.

Figure 45. Vacuum tube solar collector



Comparing the flat plate type solar collector with the vacuum tube type solar collector, it is analyzed that the flat plate solar collector is preferable for the district heating which uses the low cost in terms of cost and utilizing the low temperature.

Table 36. Comparing the types of solar collector

Type	Usage	Acquisition temperature	Advantages
Flat plate	Low temperature field (heating, hot water supply)	100 ℃ (mainly 60 ℃ or less)	- High efficiency at low temperature - Price cheaper - Both direct and dispersed solar radiation can be used
Vacuum tube	Medium-high temperature field (Cooling and heating, Industrial process heat)	80 ~ 200 ℃	- High efficiency in middle temperature utilization - Block heat loss through vacuum - 30% reduction in installation area - Lightweight and easy to install

Among the flat plate type solar collector products that are favorable for district heating, the products used for calculation are HTHEATstore 35/10 from Arcon-Sunmark (http://arcon-sunmark.com/), a Danish supplier. The product is installed in more than 80% of large power plants in Europe and applied to the solar district heating plants in Denmark.

Details of the panel performance can be found in the certificate below.

http://www.estif.org/solarkeymark/Links/Internal_links/SP/SC0843-14-2015-11-11-issue-2.pdf

The solar collector efficiency of the panel is about 35%. As a result, the following table summarizes solar thermal production based on central Serbia.

Table 37. Monthly solar heat product

Type	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Average daily beam irradiance (Wh/m2)	751	796	823	803	828	832	824	799	781	758	727.0	713	786.25
Average monthly beam irradiance hours	62	112	155	180	248	270	279	279	210	155	90	62	2102
Average daily heat product (Wh/m^2)	262.9	278.6	288.1	281.1	289.8	291.2	288.4	279.7	273.4	265.3	254.5	249.6	275.2
Average monthly heat product (KWh/m^2)	16.3	31.2	44.6	50.6	71.9	78.6	80.5	78.0	57.4	41.1	22.9	15.5	588.6

Source: http://ashrae-meteo.info/

2) Solar thermal collector size

A case analysis of a solar district heating plant installed in Europe was performed to estimate the proper size of the solar thermal system to be installed in the Cerak heat plant. According to data from www.solar-district-heating.eu, the solar thermal district heating system in Europe has been found to have 194 installations in 17 countries by 2017. Among them, 108 cases are small cases with solar panel area less than 5,000m^2. There are 58 cases with solar panel area over 5,000m^2 and less than 15,000m^2. In addition, there are 21 cases with solar panel area of more than 15000m^2 and less than 30000m^2. There are only 7 cases of large-scale solar thermal district heating systems with a solar panel area of over 30000m^2.

The largest solar district heating system currently installed is 156,694m^2 in Silkeborg, Denmark. The next ranking is 70,000m^2 in the city of Vojens, Denmark. Of the 50 installation cases with solar panel area over 10,000m^2, 48 cases were installed in Denmark. Of the 36 installation cases of more than 5,000m^2 and less than 10,000m^2, 30 installation cases were also installed in Denmark.

Most countries except Denmark have small installations with a solar panel area of less than 3,000 m^2.

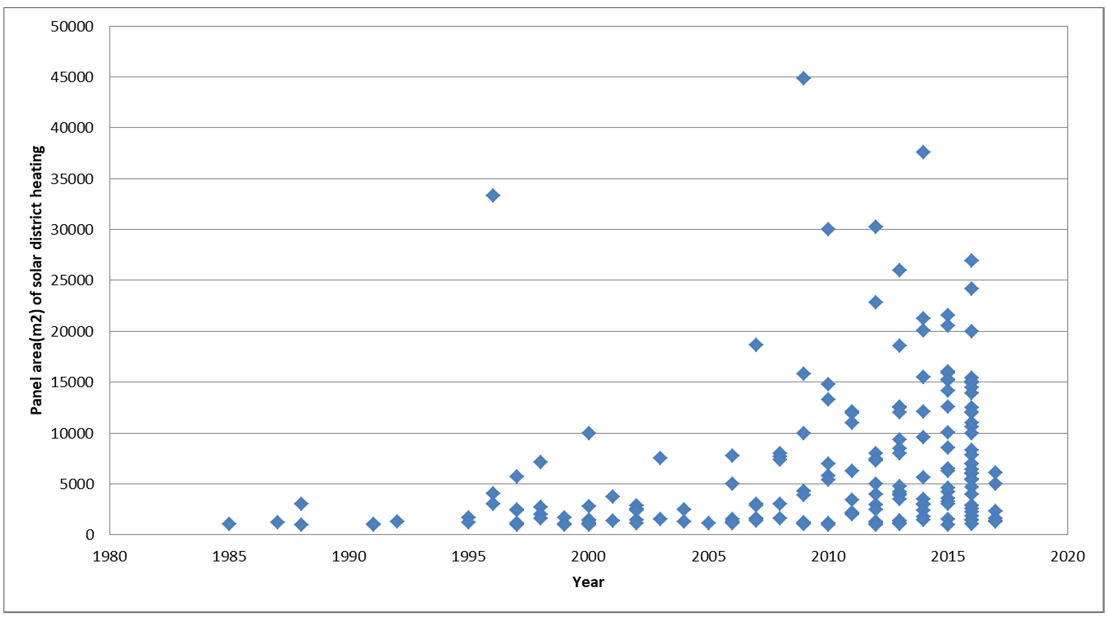
Table 38 Case of solar district heating system in Europe (until 2017)

Solar collector area(m^2)	No. of case	Country(No. of case)
≥35,000m^2	4	Denmark(4)
≥30,000m^2	3	Denmark(3)
≥25,000m^2	2	Denmark(2)
≥20,000m^2	7	Denmark(7)
≥15,000m^2	12	Denmark(12)
≥10,000m^2	22	Denmark(20), Norway(1), Sweden(1)
≥5,000m^2	36	Denmark(30), Germany(3), Netherlands(1), Poland(1)

≥3,000m²	25	Austria(2), Denmark(19), France(1), Germany(2), Italy(1)
≥2,000m²	23	Austria(3), Denmark(8), France(1), Germany(3), Greece(3) Netherlands(2), Poland(2), Sweden(1)
<2,000m²	60	Austria(12), Bosnia and Herzegovina(1), Denmark(4), Finland(1), France(4), Germany(10), Greece(2), Italy(1), Montenegro(1), Netherlands(1), Poland(3), Spain(3), Sweden(11), Switzerland(4), Turkey(1)

In addition, the annual installation of the solar district heating system shows that installation has increased more than 10,000m² since 2010. Prior to 2010, small facilities, usually less than 5,000m², were usually installed, and there were not many cases. In recent years, however, the number of installations has increased, and the scale of installation has also become larger.

Figure 46 Trend of solar district heating system in Europe



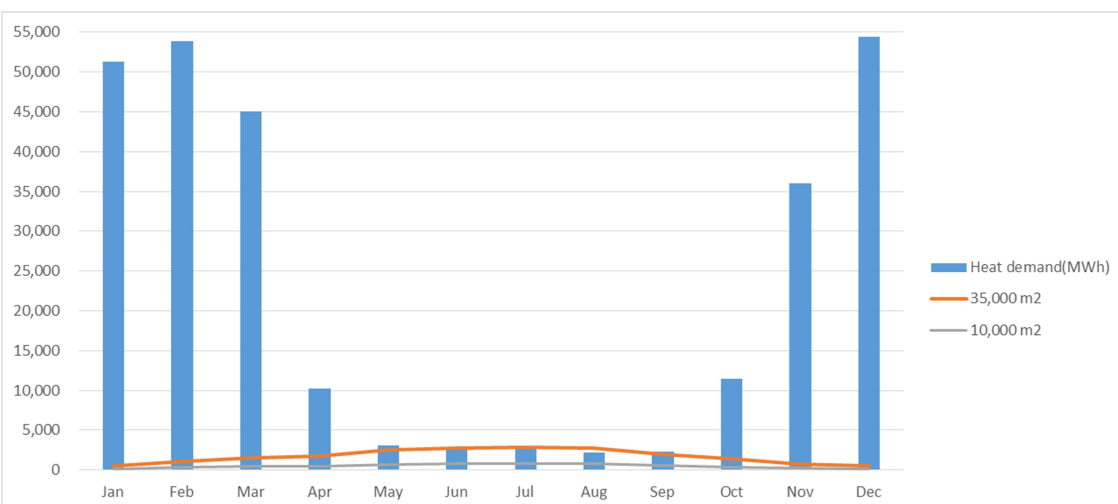
Considering the installation of solar thermal systems in Cerak heat plants, it is necessary to reflect these recent trends along with the heat demand in capacity estimation. Considering the recent tendency of solar thermal system installation scale in Europe and the site condition of Cerak heat plant, it is appropriate that the solar panel area of 10,000m² is suitable. The solar thermal collector panel area of 10,000m² is not small scale in Europe. However, considering the heat demand of the summer season of Cerak heat plant, a solar thermal collector panel area of more than 30,000m^2 is required.

The table 39 below shows the comparison of solar thermal products in four areas compared to existing heat demand. The four comparison areas are based only on the collector size of the HTHEATstore 35/10 used for calculation of solar thermal products.

Table 39. Heat demand and solar heat production per solar thermal collecting area

Date	Heat demand (MWh)	Monthly heat product (KWh/m^2)	Monthly heat product (MWh/m^2)			
			10,000 m^2	31,800 m^2	35,000 m^2	39,700 m^2
Jan	51,327.2	16.3	163.0	518.2	570.4	647.0
Feb	53,845.8	31.2	312.0	992.3	1,092.1	1,238.8
Mar	45,078.9	44.6	446.5	1,419.8	1,562.7	1,772.5
Apr	10,213.6	50.6	505.9	1,608.7	1,770.6	2,008.4
May	3,116.6	71.9	718.7	2,285.5	2,515.5	2,853.3
Jun	2,630.8	78.6	786.2	2,500.2	2,751.8	3,121.4
Jul	2,659.0	80.5	804.6	2,558.7	2,816.2	3,194.4
Aug	2,147.5	78.0	780.2	2,481.1	2,730.8	3,097.5
Sep	2,337.6	57.4	574.0	1,825.4	2,009.1	2,278.9
Oct	11,470.1	41.1	411.2	1,307.7	1,439.3	1,632.5
Nov	36,018.6	22.9	229.0	728.2	801.5	909.1
Dec	54,437.5	15.5	154.7	492.0	541.5	614.2
Total	275,283.1	588.6	5,886.1	18,717.9	20,601.5	23,368.0

Figure 47 Heat demand and Solar heat production



Considering the installation of solar thermal systems in Cerak heat plants, it is necessary to reflect these recent trends along with the heat demand in capacity estimation. Considering the recent tendency of solar thermal system installation scale in Europe and the site condition of Cerak heat plant, it is appropriate that the solar panel area of 10,000m^2 is suitable. The solar thermal collector panel area of 10,000m^2 is not small scale in Europe. However, considering the heat demand of the summer season of Cerak heat plant, a solar thermal collector panel area of more than 30,000m^2 is required.

If the solar thermal collector panel area is installed at 10,000m^2 in the Cerak heat plant, it is expected to produce 804.6MWh of heat output in July, which will supply 30.3% of the heat demand of 2,659.0MWh in the same month. In December, 154.7MWh of heat production is expected to supply 0.28% of 54,437.5MWh of heat demand.

The area of solar thermal collector panel capable of maximize providing the heat demand in the summer season of the Cerak heat plant was compared in three cases. As the comparative data, except for August, 31,800 m^2 does not exceed the demand, but the production is insufficient compared with the overall demand. In the case of 39,700m^2, 27% more production is produced than the amount demanded from June to August, so more heat is produced than the base load and wasted heat energy are increased.

The heat demand is increasing in 2018 compared to 2017. In particular, the average heat demand increased by 16% in 2018 compared to 2017 between June and August. Looking at the trend, 35,000 m^2 increased an average of 12% during the three months in summer compared to the heat demand in 2018. Therefore, 35,000 m^2 seems to be most appropriate considering the future growth.

10,000 m^2 and 35,000 m^2, it is necessary to select the required land area and location for panel installation. The site area is calculated by calculating the row distance to 4 m considering the installation area and panel interference of HTHEATstore 35/10 used in the calculation.

The required site area for installation of 10,000 m^2 of solar thermal collector panels is about 18,000 m^2, and the solar thermal collector area of 35,000 m^2 requires about 62,000 m^2. The unit area of solar panel and spacing of installation were applied equally in both cases.

The location was chosen as the nearest site in Cerak heat plant to minimize the transfer loss when utilizing the heat production.

Table 40. Area calculation

Type	Basic	Maximum
Single solar collector area(panel)	13.55 m^2	13.55 m^2
Total solar collector area(panel)	10,000 m^2	35,000 m^2
Solar collector length	5.97 m	5.97 m
Row distance	4 m	4 m
Ground area	23.88 m^2	23.88 m^2
Required land area	17,624 m^2	62,000 m^2

Source: http://www.estif.org/solarkeymark/Links/Internal_links/SP/SC0843-14-2015-11-11-issue-2.pdf, Investigation of solar district heating in Belgrade, 2016

3) Land availability of Cerak heat plant

The site area of the Cerak heat plant is about 82,000m^2 and the area of the main facilities including boilers, oil tanks and management/control building is about 44,000m^2, so the surplus site area can be estimated to be about 38,000m^2.

Figure 48 Land area of Cerak heat plant

Figure 49 allowance area 18,000m^2 in Cerak heat plant

If the solar thermal collector penal area of 10,000m^2 is applied to the Cerak heat plant, the necessary are of 18,000m^2 will be able to be installed enough in the current site. In the current site layout, it may be possible to use an empty area in the north or an empty area in the west and south.

Installing a solar thermal collector panel of 35,000m^2 requires about 62,000m^2 of installation area. In this case, there is not enough surplus area on the current site, and it is necessary to secure additional area externally.

Figure 50 extended area 62,000m2 of Cerak heat plant

As shown in figure 16, if an additional 30,000m^2 of west or north external area of the Cerak heat plant is available, it will be possible to install a solar thermal district heating system with 35,000m^2 solar panel. In this case, it can be provide heat supply to cover summer season heat demand.

However, this case should be reviewed for the possibility of securing the surrounding site. Even if it is possible to secure the surrounding area, the purchase cost or use cost of the land should be included in the investment cost and reflected in the economic analysis, unless it is available free of charge.

The selected Cerak heat plant adjacent sites are almost open ground and even if only simple foundation work such as piping and cement work is carried out, it could be utilized in the construction of solar thermal facilities. In addition, it is advantageous because there are no factors that can interfere with the production of solar thermal, such as high buildings or hills.

Figure 51. Site view of potential area for solar sollectors

5.5 Solar Thermal District Heating System Integration

1) System Configuration

The application of solar thermal in district heating generally consists of a panel that absorbs solar radiation, a heat exchanger that recovers the heat, and a thermal storage facility that is linked to the district heating heat supply system. In general, water is used as a heating medium applied to a solar panel, but propylene glycol is used to prevent freezing at a subzero temperature and prevent boiling at a high temperature. The application of Propylene Glycol should also be considered for the convenience of operation since the lowest temperature in the cold season from Dec. to Feb. in Cerak area is below 0℃.

Table 41 Physical property of propylene glycol

Physical Property	Unit	Value
Boiling Point	℃	187
Freezing Point	℃	-60
Density (25℃)	g/cm3	1.032
Vapor Pressure (25℃)	mmHg	0.13
Viscosity (60℃)	mPas	8.42
pH		6~8

The specific heat of Propylene Glycol varies depending on the concentration and temperature, but generally shows a specific heat similar to that of water. The specific heat of Propylene Glycol is higher at lower weight percentage of glycol and at higher temperature.

Table 42 Specific Heat of Propylene Glycol

Temp.℃	Propylene Glycol % by Weight					
	10	20	40	60	80	100
15.6	0.985	0.970	0.900	0.795	0.687	0.587
37.8	0.988	0.975	0.913	0.821	0.717	0.619
60.0	0.991	0.980	0.925	0.846	0.748	0.651
82.2	0.994	0.984	0.936	0.871	0.778	0.683
104.4	0.996	0.990	0.949	0.895	0.809	0.715

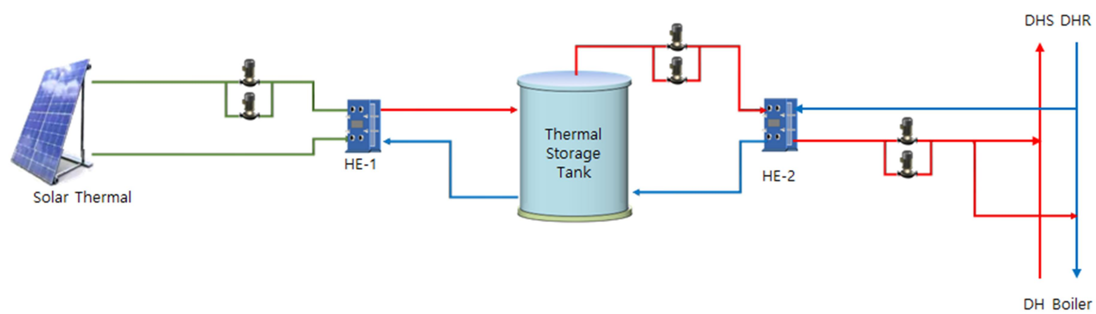
Propylene Glycol heated in the solar panel transfers heat to the heating circulation water through the heat exchanger and returns to the solar panel with the temperature lowered.

The heat exchanger can be generally a plate heat exchanger, which can be equipped with circulation pumps, valves, various measuring instruments and control equipment in each side piping circuit.

Solar heating systems require thermal storage facilities because solar thermal systems produce heat in the daytime, but heat demands are higher at night than in the daytime. The solar thermal heating system in the individual house also has a facility for storing heat in the form of hot water, and a larger capacity thermal storage tank is required for district heating.

Therefore, the solar thermal system applied to the district heating system should be composed of solar panel, thermal storage tank, primary and secondary heat exchanger, circulation piping system, circulation pump per each cycle, valves and instruments. The solar system configuration diagram for the district heating plant is shown in Figure 15 as below.

Figure 52 System configurations for solar thermal district heating



In the primary heat exchanger (HE-1), heat exchange occurs between the propylene glycol which circulates the solar panel and the water sent from the thermal storage tank and heat exchange occurs between the hot water of the thermal storage tank and the return water of the district heating through the secondary heat exchanger (HE-2), and the heat generated by the solar thermal system is supplied to the district heating pipe network.

In the summer season, heat demand is low and solar thermal heat production is high, so most of the heat demand of Cerak can be covered by solar heat. In this case, the HE-2 heated district return water is directly connected to the supply line to supply heat. In the winter season with high heat demand, hot water heated in HE-2 is supplied to the district heating boiler, and the solar system warms the boiler feed water to save fuel.

2) Capacity of basic solar thermal system

As described in the previous chapter, 10,000m^2 solar panels are capable of producing 804.6MWh of heat in July, which can cover about 31~37% of the heat demand from June to August. In May and September, solar thermal system will be can covered 22.8~23.8% of the heat demand.

In table 15 above, Cerak's monthly heat demand is the average for 2017-2018 and heat production is the monthly heat production availability of 10,000 m^2 solar thermal panels. Based on the 279 hours of sunshine in July, the solar thermal capacity of 10,000m^2 will be 2,885kW.

Table 43 Heat demand of Cerak and heat production of 10,000m^2 solar thermal panel

Month	Heat Demand(MWh)	Heat Production by Solar thermal(MWh)
May	3,152.3	718.7
Jun	2,499.9	786.2
Jul	2,325.5	804.6
Aug	2,094.7	780.2
Sep	2,412.8	574.0

In table 15 above, Cerak's monthly heat demand is the average for 2017-2018 and heat production is the monthly heat production availability of 10,000 m^2 solar thermal panels. Based on the 279 hours of sunshine in July, the solar thermal capacity of 10,000m^2 will be 2,885kW.

When the monthly supply mean temperature and return mean temperature of Cerak heat plant are seasonally averaged, the winter season supply mean temperature is 65.27℃ and the return mean temperature is 45.98℃. And the summer season supply mean temperature is 56.64℃ and the return mean temperature is 45.84℃. Based on this, the standard temperature for supplying heat from the solar thermal system to the district heating network is based on the supply mean temperature of the winter season, the supply temperature is 65 ℃ and the return temperature is 45 ℃. The heat balance of the solar thermal system was calculated based on this temperature.

Table 44 Monthly average supply and return temperature of winter and summer season

Winter Season			Summer Season		
Month	Supply Temp. (℃)	Return Temp. (℃)	Mont h	Supply Temp. (℃)	Return Temp. (℃)
Jan.	67.17	45.29			
Feb.	71.20	46.80	May	56.88	45.24
Mar.	66.47	45.49	Jun.	56.58	45.67
Apr.	57.77	46.43	Jul.	56.22	45.81
Oc.t	58.97	46.10	Aug.	56.92	46.64
Nov.	64.58	45.17	Sep	56.58	45.86
Dec.	70.74	46.58			
Ave.	65.27	45.98	Ave.	56.64	45.84

If propylene glycol is used as the heating medium of the solar panel and the inlet temperature of the primary side of the primary heat exchanger HE-1 is set to 100 ℃ and the outlet temperature is set to 60℃, the circulation flow rate is 68t/h. The secondary side has an inlet temperature of 55℃ and an outlet temperature of 75℃, and the circulating water flow rate is 115t/h. When hot water at 75℃ is supplied from the storage tank to the primary side of the secondary heat exchanger (HE-2) and the outlet temperature is 55℃, then a district heating return water of temperature 45℃ and a flow rate of 115 t/h can be input to the secondary side of the secondary heat exchanger (HE-2) and heated to 65℃ to supply it to the supply line.

From the solar thermal panel to the primary heat exchanger, from the primary heat exchanger to the thermal storage tank, from the thermal storage tank to the secondary heat exchanger, from the secondary heat exchanger to the district heating pipe, the circulation cycle and the heat exchange amount were simulated by THERMOFLEX v28.2. The system heat balance of winter season and summer season is calculated and expressed in Fig. 20 and Fig.21.

Figure 53 Heat balance of 10,000m^2 solar thermal system (Summer season)

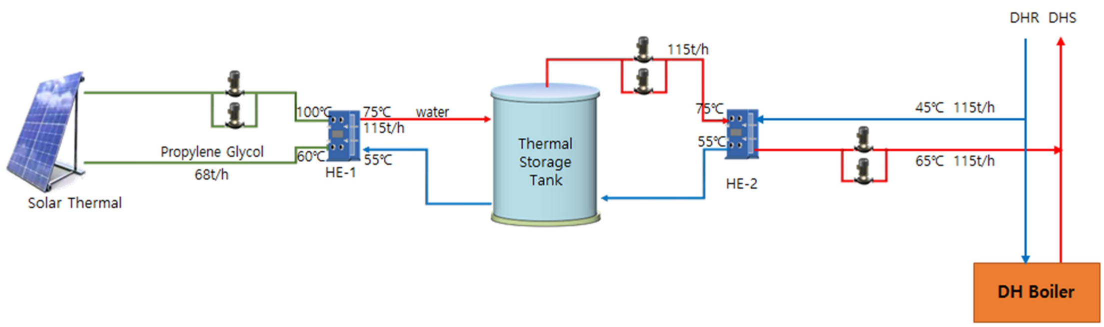
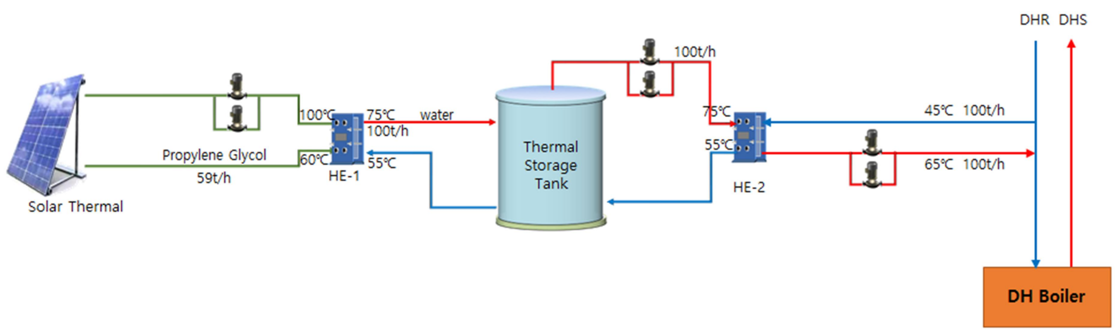


Figure 54 Heat balance of 10,000m^2 solar thermal system (Winter season)



In the winter season, when the heat demand is high, the amount of heat generated by the solar thermal system is small, so the ratio of the total heat load is low and the district heating supply temperature is higher than the temperature produced by the solar thermal system. Therefore, rather than directly connecting the heat generated from the solar thermal facility to the district heating supply line, the temperature of the return water of the district heating is increased to feed to the DH boiler to obtain the fuel saving effect.

When 100 t/h of DH return water at 45℃ is heated to 65℃ through solar thermal facility, the increase in calories is 2.33 MWh. Which is equivalent to 1.57% of the maximum peak load(148.68MWh), and this amount of fuel savings can be expected.

3) Capacity of maximum solar thermal system

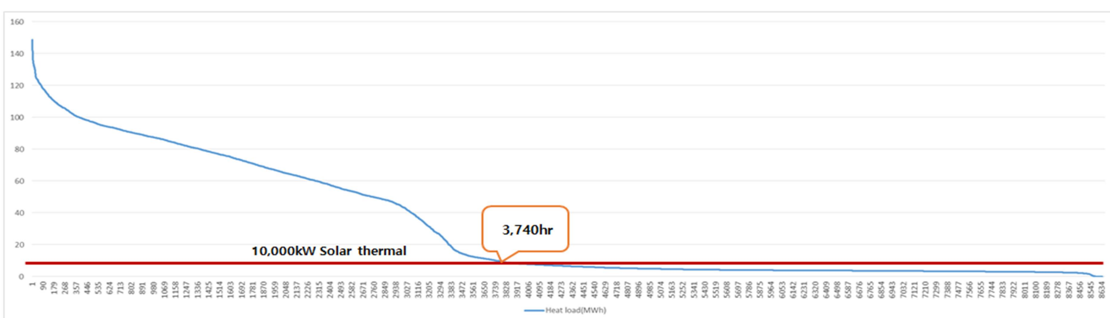
As described in the previous chapter, 35,000m^2 solar panels are capable of producing 2816.2mWh of heat in July, which can cover the heat demand from June to August and partially cover the heat demand in May and September. Therefore, 35,000m^2 of solar panels is expected to be suitable as solar thermal system capacity for Cerak heat plant.

Table 17 Heat demand of Cerak and heat production of 35,000m^2 solar thermal panel

Month	Heat Demand(MWh)	Heat Production by Solar thermal(MWh)
May	3,152.3	2,515.5
Jun	2,499.9	2,751.8
Jul	2,325.5	2,816.2
Aug	2,094.7	2,730.8
Sep	2,412.8	2,009.1

In table 14 above, Cerak's monthly heat demand is the average for 2017-2018 and heat production is the monthly heat production availability of 35,000 m^2 solar thermal panels. Based on the 279 hours of sunshine in July, the solar thermal capacity of 35,000m^2 will be 10,000kW. By substituting this into Cerak's heat duration curve, it is calculated that the heat demand can be supplied to the solar thermal 5,020 hours, excluding 3,740 hours, which is higher than 10,000 Kw. The total heat demand for 5,020 hours with a heat demand of less than 10,000 Kw is 20,931.8 MWh, which can supply 7.6% of Cerak's annual heat demand of 275,283.1 MWh to the solar plant.

Figure 55 Solar thermal capacity on heat duration curve



When the monthly supply mean temperature and return mean temperature of Cerak heat plant are seasonally averaged, the winter season supply mean temperature is 65.27℃ and the return mean temperature is 45.98℃. And the summer season supply mean temperature is 56.64℃ and the return mean temperature is 45.84℃. Based on this, the standard temperature for supplying heat from the solar thermal system to the district heating network is based on the supply mean temperature of the winter season, the supply temperature is 65 ℃ and the return temperature is 45 ℃. The heat balance of the solar thermal system was calculated based on this temperature.

If propylene glycol is used as the heating medium of the solar panel and the inlet temperature of the primary side of the primary heat exchanger HE-1 is set to 100 ℃ and the outlet temperature is set to 60℃, the circulation flow rate is 238t / h. The secondary side has an inlet temperature of 55℃ and an outlet temperature of 75℃, and the circulating water flow rate is 400t/h. When hot water at 75℃ is supplied from the storage tank to the primary side of the secondary heat exchanger (HE-2) and the outlet temperature is 55℃, then a district heating return water of temperature 45℃ and a flow rate of 400 t/h can be input to the secondary side of the secondary heat exchanger (HE-2) and heated to 65℃ to supply it to the supply line.

From the solar thermal panel to the primary heat exchanger, from the primary heat exchanger to the thermal storage tank, from the thermal storage tank to the secondary heat exchanger, from the secondary heat exchanger to the district heating pipe, the circulation cycle and the heat exchange amount were simulated by THERMOFLEX v28.2. The system heat balance of winter season and summer season is calculated and expressed in Fig. 17 and Fig.18.

Figure 56 Heat balance of solar thermal system (Summer season)

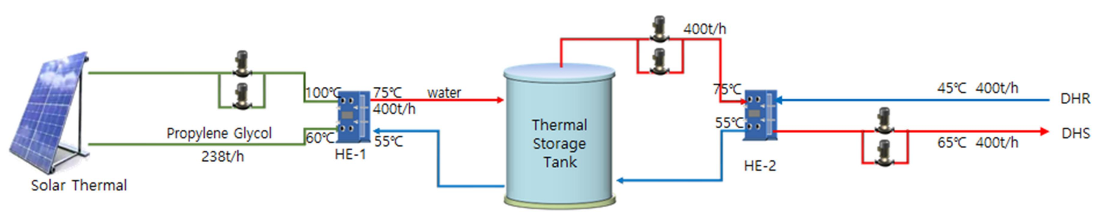
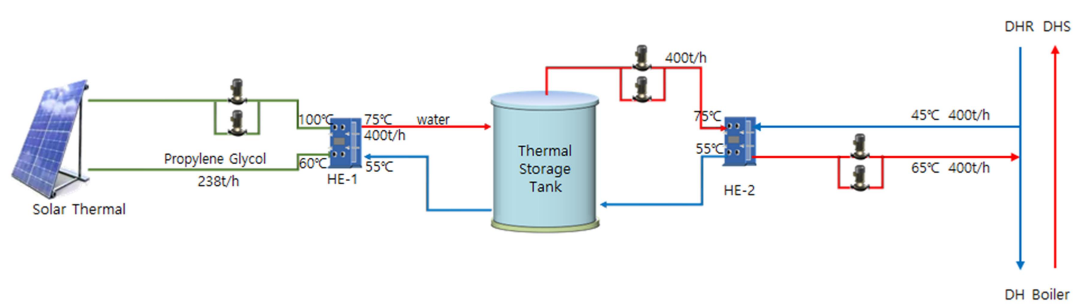


Figure 57 Heat balance of solar thermal system (Winter season)



In the winter season, when the heat demand is high, the amount of heat generated by the solar thermal system is small, so the ratio of the total heat load is low and the district heating supply temperature is higher than the temperature produced by the solar thermal system. Therefore, rather than directly connecting the heat generated from the solar thermal facility to the district heating supply line, the temperature of the return water of the district heating is increased to feed to the DH boiler to obtain the fuel saving effect.

When 400 t/h of DH return water at 45℃ is heated to 65℃ through solar thermal facility, the increase in calories is 9.3 MWh. Which is equivalent to 6.3% of the maximum peak load, and this amount of fuel savings can be expected.

4) Thermal Energy Storage of solar system

The heat demand of Cerak is divided into daytime and nighttime, and the heat load at night is about 10 times that of daytime heat load. Heat production through the solar thermal system occurs during the day but heat demand occurs at night, so a thermal storage tank is needed to overcome this difference. In other words, some of the heat generated during the daytime sunshine hour covers the heat demand of the daytime, and most of the remaining heat is stored in the thermal storage tank, and a system for supplying heat to the nighttime heat demand is needed.

Recent thermal storage in the solar thermal system has a common way of daily base thermal storage and an extended technical concept of seasonal thermal storage. Daily thermal storage is a concept that produces and stores heat in daytime on a daily basis, and supplies heat stored at night, where heat production is impossible and heat demand occurs. Seasonal thermal storage is a concept that produces and stores heat in the summer season on an annual basis and uses it for the winter season. There are several technical methods for seasonal thermal storage, most typically the pit thermal energy storage (PTES) concept, which is predominantly installed in Denmark. There are advantages and disadvantages to daily storage and seasonal storage, which are summarized in the following table.

Table 45 Comparison of advantages and disadvantages of daily and seasonal storage

	Daily thermal storage	Seasonal thermal storage
Advantages	■ The area required for the site is relatively small. ■ Low investment cost	■ High availability of solar thermal system in winter season ■ Advantages of applying renewable energy to district heating
Disadvantages	■ Low availability of solar thermal system in winter season	■ The area required for the site is relatively large. ■ High investment cost ■ Additional heat equipment(Heat pump, Absorption heat pump, etc.) is required

Because the temperature of the water stored in the seasonal storage gradually decreases, heat pump or adsorption heat pump is required for district heating. Therefore, in order to utilize seasonal storage in winter season, electricity or heat is required to operate heat pump or absorption heat pump. If renewable energy is rich in electricity or heat, it can be used, but if not, additional electricity or heat is needed. Since the renewable energy resources are not abundant near the Cerak heat plant, application of seasonal storage is not considered appropriate.

On a daily basis, the capacity of the thermal storage tank is calculated from the following formula considering the capacity of the solar thermal system, the time of day, the temperature difference of the thermal storage tank, and specific heat.

$$V(ton) = \frac{q\left({}^{kcal}/_{hr}\right) \times H\ (hr)}{\Delta T(°C)\ \times Cp\ ({}^{kcal}/_{kg.°C})} \div 1000({}^{kg}/_{ton})$$

$V(ton)$: Capacity of Thermal Storage Tank

$q\left({}^{kcal}/_{hr}\right)$: Heat capacity of solar thermal

$H\ (hr)$: Daylight hour

$\Delta T(°C)$: Temperature difference of thermal storage tank

$Cp\ ({}^{kcal}/_{kg.°C})$: Specific heat

Based on 2,885 KW solar thermal system(solar panel 10,000m^2), 9 hours of daily sunshine hours of Cerak 's summer season and the temperature difference of 20 ℃ in the thermal storage tank were applied and the required storage tank capacity was calculated as 1,117 tons. When 30% of the dead space of the thermal storage tank was considered, a thermal storage tank with a capacity of 1,500 m^3 was calculated. In case of 10,000 KW solar thermal system(solar panel 35,000m^2), a thermal storage tank with a capacity of 5,000 m^3 was calculated to be necessary for the summer heat load.

For the installation of 1,500m^3 capacity thermal storage tank, a circular ground area with a diameter of 14m is required when the height of the storage tank is 10m. In case of 5,000m^3 capacity thermal storage tank, a circular ground area with a diameter of 25m is required when the height of the storage tank is 10m. It is estimated that about 1,600m^2 of area is needed for the separation distance and circulation pump.

Considering the seasonal storage in the solar thermal system of Cerak heat plant, additional solar panel installation is required as well as space for pit installation. Since solar thermal provides most of the summer heat demand, it is necessary to install additional panel for 10,000Kw for hot water production for seasonal storage. Additional 10,000 kW solar thermal systems for seasonal storage requires an additional 62,000m^2 in addition to the existing 62,000 m^2 of solar thermal panel installation site, with a pit for 400,000m^3 of seasonal storage of approximately 60,000 square meters additional sites are needed.

Therefore, if a solar thermal system of 10,000 kW is installed only for the storage tank of the concept of daily storage, it needs about 62,000 square meters of land. However, considering the seasonal storage of PTES method, about 122,000 square meters of land is needed for a total of 184,000 square meters are required.

In addition, when seasonal storage is applied, it is necessary to use a heat pump or an absorption heat pump to raise the temperature because the stored hot water can not be used directly in the winter season. This requires consideration of the investment cost of the heat pump and the need for electricity or heat to operate the heat pump and the operating costs.

Therefore, it is reasonable to apply seasonal storage to Cerak as a substitute for summer heat based on daily storage and as a feedwater preheater in winter season. In order to consider season storage, additional costs need to be assessed as additional land is acquired. In addition, it is necessary to confirm the trend of increasing technological completeness such as seasonal storage methods such as PTES in other European countries, and reduction of investment cost.

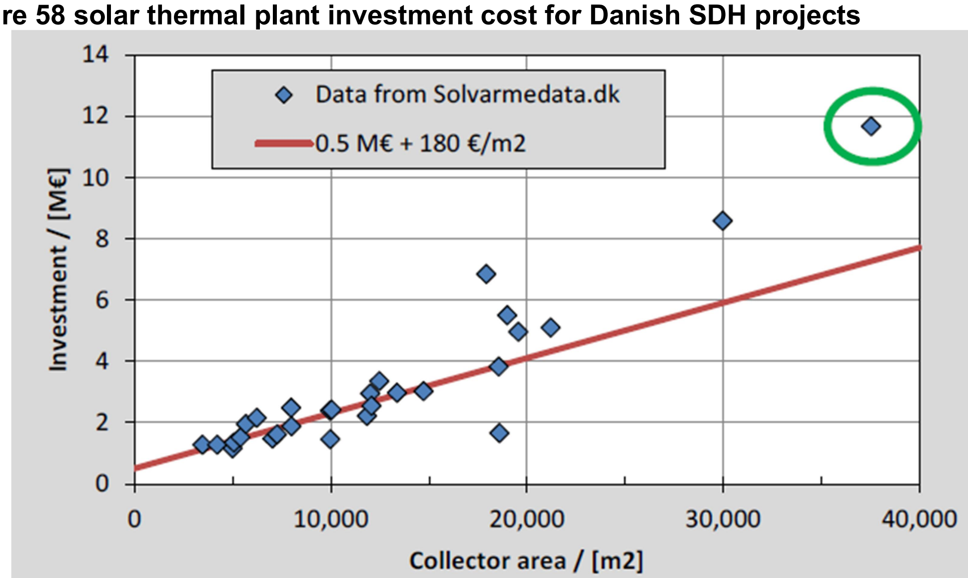
6. Economic analysis

6.1 Analysis of Investment Cost

An economic analysis was conducted to apply solar thermal system as a renewable heat source in Cerak heat plant. The capacity of the solar thermal district heating system to be applied to the Cerak heat plant was determined to be suitable for the solar collector panel of 10,000m^2. Therefore, this economic analysis was performed based on the scale of 10,000m^2 solar thermal collector panel.

The investment cost of the solar thermal district heating system applied to the Cerak heat plant was analyzed by applying the reference cost of Denmark, which has the largest number of installation cases. Using the formula based on the reference cost of solar thermal district heating facilities in Denmark, the investment cost of the system with an area of 10,000m^2 solar thermal collector panel was calculated 2,300,000 EURO.

Figure 58 solar thermal plant investment cost for Danish SDH projects



Source: Plan Energi, Investigation of solar district heating in Belgrde, 2016

The applied investment costs in the calculations are followed formula.

Investment cost by solar collector area : 500,000 EUR + 180 EUR/m^2

- Cerak : 500,000 EUR + 180 EUR/m^2 * 10,000m^2 = 2,300,000 EUR

The element cost of the solar thermal district heating plant was also calculated based on the reference cost according to the installation case in Denmark.

Figure 59 Cost elements of a solar thermal plant

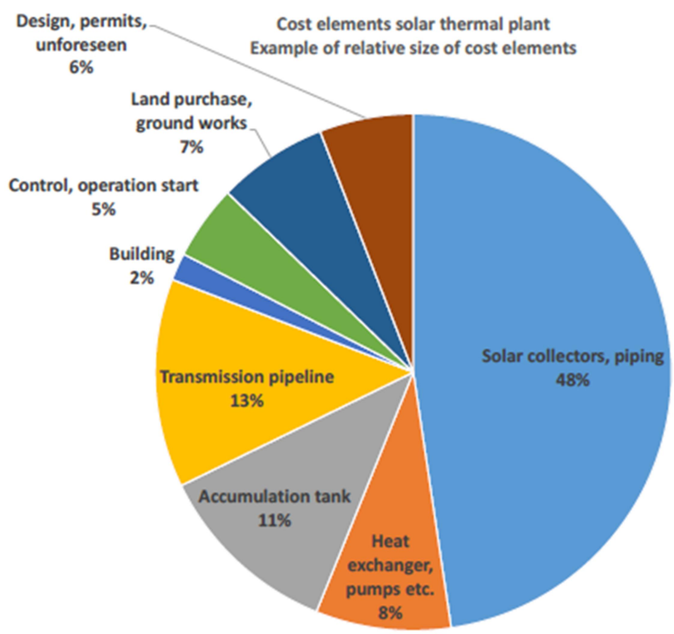


Table 46 Investment cost of 10,000m^2 solar district heating plant in Cerak

Cost Element			Cost
Direct cost	Material cost	Solar Collector Panel	1,104,000
		Storage Tank	253,000
		Transmission pipeline	299,000
		Heat exchanger, pumps, etc.	184,000
		Control, operation start	115,000
		Sub Total	**1,955,000**
	Construction cost	Ground works	161,000
		Building	46,000
		Sub Total	**207,000**
	Direct cost sub total		**2,162,000**
Indirect cost	Engineering Cost	Design, permits	138,000
Total			**2,300,000**

The investment cost calculated by the reference cost of Denmark's case of solar district heating plant can have several saving factor in the actual construction of Cerak heat plant. Approximately 18,000m^2, including 10,000m^2 of solar thermal collector panels and additional facilities can be installed at the surplus area of existing heat plant site. Therefore, it is possible to reduce land purchase and construction costs, and building and pipe costs may also be reduced.

However, investment costs by the Denmark reference cost were applied to make conservative judgments of economic analysis. In addition, the sensitivity analysis will be analyzing the impact of the increase and decrease of investment costs, so it is reasonable to apply the investment cost based on reference cost of Denmark.

6.2 Financial Assessment

Based on the investment cost of 2,300,000 Euro for the solar thermal district heating system in the Cerak heat plant, the financial analysis was conducted with 20 years of operation and a 3% fixed interest rate.

The income for the solar thermal system investment was calculated by applying the fuel cost savings of the Cerak heat plant as much as the heat produced by the solar thermal collector. The fuel gas unit price used to calculate fuel cost savings was 0.3753 Euro/m^3, and the caloric value of fuel gas was 34.5 MJ/m^3. The boiler efficiency of the Cerak heat plant was applied at 80% and the production cost per unit thermal was calculated. And this value was multiplied by the annual heat production of the solar thermal system to calculate the annual fuel savings and applied to financial analysis.

Table 47 Criteria for financial analysis

Classification	Contents	Remarks
Project Period	20 years	
Interest rate	3% fixed	
Depreciation	Equivalence partitioning of 20 years	
Income	Fuel cost saving	Gas calorific value: 34.5MJ/m^3 Gas unit price: 0.3753Euro/m^3 Boiler efficiency: assuming 80%
O&M Cost	0.5% of Material Cost	
Income Tax	0%	
Discount rate	5%	

In the expenses for cash flow analysis, only O&M cost was calculated as 0.5% of material cost. Labor cost, administrative expense and other costs required for the operation of the facility are not included in the expenses of cash flow analysis, assuming that the solar thermal plant operates as an additional facility to the existing Cerak heat plant. Income tax was not considered in this financial analysis because saved fuel cost is regarded as the revenue. The discount rate for net present value analysis was applied to 5%.

As a result of cash flow analysis, IRR was 10.46%, Pay-back period is 8.26 year, NPV 1,010,542 Euro when the project to install and operate of 10,000m^2 class solar thermal district heating system in Cerak heat plant.

Table 48 Cash flow of 10,000m^2 solar thermal in Cerak

Items		2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	Total
Income	Fuel Cost Saving	288,203	288,203	288,203	288,203	288,203	288,203	288,203	288,203	288,203	288,203	288,203	288,203	288,203	288,203	288,203	288,203	288,203	288,203	288,203	288,203	5,764,060
	Sum.	288,203	288,203	288,203	288,203	288,203	288,203	288,203	288,203	288,203	288,203	288,203	288,203	288,203	288,203	288,203	288,203	288,203	288,203	288,203	288,203	5,764,060
Expenditure	O&M Cost	9,775	9,775	9,775	9,775	9,775	9,775	9,775	9,775	9,775	9,775	9,775	9,775	9,775	9,775	9,775	9,775	9,775	9,775	9,775	9,775	195,500
	Deprecication	115,000	115,000	115,000	115,000	115,000	115,000	115,000	115,000	115,000	115,000	115,000	115,000	115,000	115,000	115,000	115,000	115,000	115,000	115,000	115,000	2,300,000
	Sum	124,775	124,775	124,775	124,775	124,775	124,775	124,775	124,775	124,775	124,775	124,775	124,775	124,775	124,775	124,775	124,775	124,775	124,775	124,775	124,775	2,495,500
Business profit		163,428	163,428	163,428	163,428	163,428	163,428	163,428	163,428	163,428	163,428	163,428	163,428	163,428	163,428	163,428	163,428	163,428	163,428	163,428	163,428	3,268,560
Interest Debt		55,200	55,200	55,200	55,200	55,200	55,200	55,200	53,968	47,314	39,429	31,543	23,657	15,771	7,886	1,232	0	0				607,200
Ordinary profit		108,228	108,228	108,228	108,228	108,228	108,228	108,228	109,460	116,114	123,999	131,885	139,771	147,657	155,542	162,196	163,428	163,428	163,428	163,428	163,428	2,661,360
Income Tax																						
Profit (after Tax)		108,228	108,228	108,228	108,228	108,228	108,228	108,228	109,460	116,114	123,999	131,885	139,771	147,657	155,542	162,196	163,428	163,428	163,428	163,428	163,428	2,661,360
EBITDA		278,428	278,428	278,428	278,428	278,428	278,428	278,428	278,428	278,428	278,428	278,428	278,428	278,428	278,428	278,428	278,428	278,428	278,428	278,428	278,428	5,568,560
Accumulated EBITDA		278,428	556,856	835,284	1,113,712	1,392,140	1,670,568	1,948,996	2,227,424	2,505,852	2,784,280	3,062,708	3,341,136	3,619,564	3,897,992	4,176,420	4,454,848	4,733,276	5,011,704	5,290,132	5,568,560	58,469,885
IRR		10.45%			Payback Period			8.26				NPV			1,010,542							

6.3 Sensitivity Analysis

Based on the financing analysis of the 10,000m^2 class solar thermal systems installed in the Cerak heat plant, sensitivity analysis was performed for the variation of the unit price of fuel gas and the variation of the investment cost.

The reason the unit price of fuel gas is selected for the sensitivity analysis is that the profit of the solar thermal system come from the fuel savings of the thermal production facility. In addition, gas price were selected for sensitivity analysis because of the high price variability.

In this economic analysis, since the investment cost of the solar thermal system was calculated by reference cost rather than by the actual design, the effect of its variation was analyzed as sensitivity analysis.

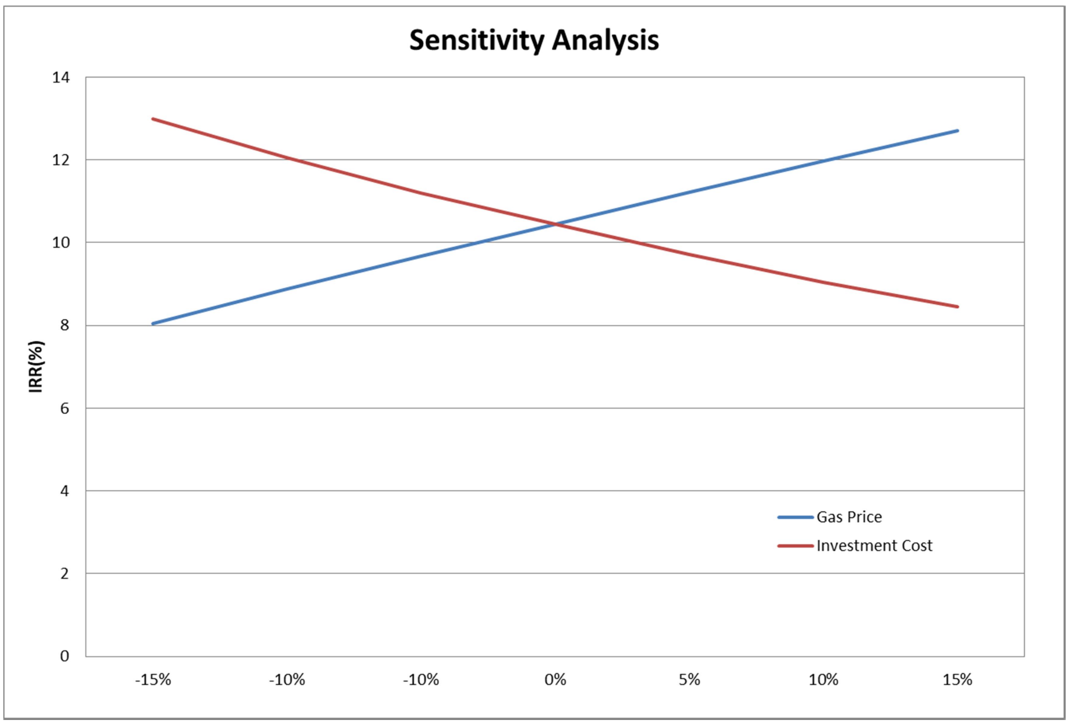
Table 49 Result of sensitivity analysis of Cerak solar thermal district heating plant

Classification	Rate of variation	IRR (%)	NPV (Euro)	Pay-back Period(yrs)	Remarks
Unit price of fuel gas	-15%	8.05	545,152	9.78	Based on 0.3753Euro/m^3
	-10%	8.87	700,282	9.21	
	-5%	9.67	855,412	8.71	
	0%	10.45	1,010,542	8.26	
	+5%	11.21	1,165,672	7.85	
	+10%	11.97	1,320,802	7.49	
	+15%	12.71	1,475,932	7.15	
Investment cost	-15%	12.99	1,300,585	7.02	Based on 2,300,000 Euro
	-10%	12.06	1,201,243	7.43	
	-5%	11.20	1,101,902	7.85	
	0%	10.45	1,010,542	8.26	
	+5%	9.71	903,219	8.67	
	+10%	9.04	803,878	9.09	
	+15%	8.45	712,518	9.50	

As a result of sensitivity analysis, if the unit price of fuel gas is increased by more than 15% or the CAPEX is reduced by more than 10% at IRR 8.46% under the reference conditions, the IRR is increased to more than 10%. Conversely, if the unit price of fuel gas drops by 10% or the CAPEX is rises by more than 10%, the IRR will drop below 7%.

The sensitivity analysis of the IRR showed that the sensitivity of the CAPEX and the unit price of fuel gas were almost similar. However, there is a slight difference in slop, which shows that the sensitivity of CAPEX is slightly higher than the unit price of fuel gas.

Figure 60 Result of sensitivity analysis



6.4 Final Investment Decision

In this study, the application of renewable energy technology to district heating in Belgrde was decided to use solar thermal system. Of the several renewable technologies that can be applied to the district heating system in Belgrade, the solar thermal was chosen because it is the quickest and easiest to implement because there are not many stakeholders. Feasibility study was conducted to install Solar thermal system for Cerak heat plant among heat plants operated by Beogradske elektrane.

In the feasibility study, considering the heat load and land availability of the Cerak Heat Plant, it was selected as the optimal installation of a solar thermal system with a solar panel area of 10,000m^2. It is estimated that the solar panel installation area considering the installation interval is about 18,000m^2, and 20,000m^2 site is required considering daily thermal storage and other auxiliary facilities.

If the 10,000m^2 solar thermal panel is installed, the heat production capacity is 2.8MW and the annual heat production is expected to be 5,886MWh. In this case, the solar thermal system is expected to be fulfilled for about 29% of the heat load in the summer from May to September of the Cerak Heat Plant.

Table 50 Project description

Items	Contents	Remarks
Solar Panel Area	10,000m^2	
Panel Installation Area	18,000m^2	4m distance of panel row
Project Location	Cerak Heat Plant	
Land Availability	Surplus Area in Heat Plant	Surplus area: 38,000m^2
Total Required Area	20,000m^2	Include Thermal Storage
Heat Capacity	2.8 MW	
Yearly Heat Production	5,886 MWh	

The investment cost for installing solar thermal system with solar panel area of 10,000m^2 was calculated using Denmark's reference cost formula based on panel area. As a result, the investment cost was calculated as € 2,300,000, and economic analysis was performed based on this. Annual incomes for economic analysis were based on fuel costs saved through the solar thermal system. The fuel cost savings of Cerak heat plants by the installation of a solar thermal system was estimated at €288,203 per year. This was calculated based on the gas price of Serbia, the standard calorific value and the boiler efficiency.

In operating cost analysis, 0.5% of facility cost was assumed as operation and maintenance cost of solar thermal system, and no additional labor cost was considered. This is because the economic analysis was performed assuming that the solar thermal system was an auxiliary heat source of the existing Cerak Heat Plant, and no additional employment was considered. In this sense, income tax was also not taken into account for operating costs.

As a result of the financial analysis, in case of the 2.8MW solar thermal system with 10,000m^2 solar panel area was installed in the Cerak heat plant with an investment cost of € 2,300,000, the internal rate of return(IRR) was 10.45%, and the net present value(NPV) was € 1,010,542 in 8.26 payback period.

Table 51 Financial Analysis

Classification	Values	Remarks
Capital Investment	€ 2,300,000	Solar Panel 10,000m^2 basis
Annual Incomes	€ 288,203 (Fuel Cost Saving)	Gas calorific value: 34.5MJ/m^3 Gas unit price: €0.3753/m^3 Boiler efficiency: assuming 80%
Project Period	20 years	
Interest rate	3%	
Depreciation	Equivalance partitioning of 20 years	
O&M Cost	€ 9,775/yr	0.05% of Material Cost
Income Tax	0 %	
NPV	€ 1,010,542	
IRR	10.45 %	
EBITDA	278,428 Euro/yr	
Payback Year	8.26 Years	

7. Policy/Regulatory Framework

7.1 Support policy and restrictions: Serbia,Belgrade

7.1.1 Incentives for solar thermal district heating

1) Where do incentives come from? Broader framework.

Serbia transposes EU acquis in the energy sector in a very dynamic fashion since signing and ratifying the Energy Community Treaty in 2005 and 2006 and since concluding Stabilisation and Association Agreement with the EU in 2008. By now Serbia has transposed numerous EU legal acts governing 11 different energy related areas[2].

Renewable energy directive has become part of Serbian legal system since 2012 and has been transposed into national legislation through numerous laws and bylaws[3].

In 2013, Serbia has adopted National Renewable Energy Action Plan (NREAP). NREAP envisages increased share of RES in the heating sector. According to NREAP, the share of RES in the heating and cooling sector is planned to rise from 1 059 ktoe in 2009 to 1 167ktoe in 2020, which amounts to increase of 10.2%. Solar power is foreseen to contribute only with the 5 ktoe in 2020 representing merely 3% of the planned increase. According to the latest report of Serbia to the Energy Community Treaty, Serbia is not on the trajectory to achieve its overall goal set forth by the Renewable Energy Directive.

The transposition wave has also positively influenced the legal status of renewable heat production. Energy law defines privileged producers of heat energy as producers using renewable energy sources in the process of thermal energy production and fulfilling the conditions in terms of energy efficiency.

Energy Law stipulates that local self-government (LSG) unit shall prescribe incentive measures and conditions for acquiring the status of a privileged thermal energy producer and the criteria for the fulfilment of those conditions and shall determine the manner and procedure for acquiring such status.

In addition, LSG is obliged by the law to keep a register of privileged heat producers, which contains, in particular, the data on heating plants, the location where they are located,

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2 https://www.energy-community.org/legal/acquis.html

3 Directive 2009/28/EC of 23 April 2009 on the promotion of the use of energy from renewable sources

the installed power of the plant, the time period required for exploitation, the conditions of construction and exploitation of the plant, the type of primary energy resource that it uses and the entities that perform the energy activity of heat energy production in these facilities. Then, LSG is obliged to inform the Ministry of the data contained in the register of privileged heat producers[4].

2) Are incentives operational? Does this work?

The incentives for privileged heat producers and the governing framework are not in place in Serbia. City of Belgrade is no exception to the rule.

During 2017, the Ministry of Mining and Energy officially requested information from the LSGs about the implementation of this legal obligation, and at the same time offered expert support to the LSGs for the implementation of this legal obligation.

In 2017, the Government adopted “The program for implementation of Energy Sector Development Strategy of the Republic of Serbia until 2025 for the period from 2017 to 2023”. This voluminous document elaborates in detail planned activities across numerous subsectors but has no specific references to the solar thermal production for the district heating, or to the improvement of the situation with the privileged producers of heat energy.

Developers of projects aiming to utilise renewable energy for the heat production may count on some other support mechanisms that are not governed solely by the national or local governments. These mechanisms are presented in more details in Annex to this document.

3) The Case of the City of Pančevo

In 2011, the City of Pančevo applied for the funds of the EUIPA Cross-Border Cooperation Program with the application of the Project for the construction of a pilot solar heating plant for the preparation of DHW, and the promotion of solar energy.

After a long period of approval, the project was approved in October of 2015, and the total project costs amounted up to 580.000 €. 430.000 € out of the total project costs sum represented the costs of the construction and installation of the solar plant. The rest of the amount (150.000 €) covered other costs related to the project such as the costs of the promotion activities, travel costs of the staff involved in the project, costs of the maintenance

[4] LAW ON ENERGY ("Official Gazette of the Republic of Serbia", No. 145/2014 and 95/2018 - other law), Article 366

equipment and other.

The City of Pančevo was obliged to provide the land area for the construction of the solar plant and to cover 22% of the total project costs. The land designated for the construction was in the property of the municipality, i.e. The City of Pančevo. The rest of the costs – 78% were covered from the IPA Program funds. The City of Pančevo, together with its District Heating Company “Grejanje” also provided the engagement of the administration and engineering staff involved in the activities of the project team.

After the project activities ended, the solar plant remained in the property of the City of Pančevo, while the operation and maintenance of the plant is entrusted to the City’ District Heating Company “Grejanje”. This is also the case with all of the heating plants and distribution system of the District Heating System of the City of Pančevo.

During the project activities, The City administration was involved through the provision of the necessary working permits and other project related procedures.

Focusing on the construction component of the project, it should be noted that, in addition to other activities, the project in Pančevo envisaged the construction of a pilot solar plant consisting of 360 solar panels of 906 m^2 and accompanying equipment to distribute heat to the system for the preparation of domestic hot water.

The system produces more than 600 MWh of heat energy annually representing 10% of the annual energy required for the preparation of domestic hot water. The solar collectors are mounted on a steel structure so that the space below the collectors can be used for other purposes.

The plant in Pančevo is the only system in Serbia that is connected to the district heating system. During the winter period, the energy obtained from solar collectors is used to heat the water that is added to the system or to heat the air entering the combustion process, thereby increasing the efficiency coefficient of heating boilers.

Figure 61 Solar DH plant in Pančevo

The results of the work so far have shown that the maximum stable power is about 700 kW. The maximum amount of thermal energy is about 5 MWh/day, the flow in the primary glycol portion is about 25 m^3/h, and in the secondary circle it varies from 7 to 38 m^3/h. The maximum amount of heat for heating the air is 1,2 MWh / day.

Pančevo PUC plans to further expand the capacity of the solar system. With the support of programs of Renewable District Energy and Western Balkans - ReDEWeB and USAID Serbia Energy Efficiency Activity they have started new developments.

7.1.2 Restrictions on building solar DH

There has identified several possible constraints related to the development of solar district heating facility that are not strictly related to the legislation. Other restrictions of a more regulatory of constituting legal pre-conditions are explained in the next chapter.

1) Institutional Restrictions

Local self-governments, as previously explained, had not legal opportunity to support heat production from renewable energy so far. Therefore, project developers in this area could not consider on additional institutional support when developing renewable heat energy projects. It is yet to be seen if and how will be the support programmes listed in the Annex I to this document affect the level and quality of institutional support.

2) Availability and suitability of the land

Land availability in urban settlements where district heating systems are located may be an issue. As district heating systems, and in particular systems which provide domestic hot water preparation, favour high density of population and energy consumption, they tend to be located in the areas where land availability may pose constraint. Perhaps, the most significant constraint in the implementation of solar thermal projects is to determine the optimum location and to provide funds to cover the cost of purchasing.

Therefore, project developer may wish to look for marginal land such as old sanitary landfills, abandoned construction sites, or similar. Finding such locations sufficiently close to an urban settlement can be a challenge.

3) High investment costs

Costs of exploiting solar plants in the district heating system are extremely low, which is a great advantage. However, the limitation in this case are relatively high investment costs, which besides the construction of solar collector fields should cover the costs of building daily and seasonal thermal storages, as well as all accompanying equipment.

4) Technical feasibility of large thermal storage construction

Several limiting factors can be identified when it comes to building large thermal storages. In addition to the necessary available space, appropriate materials that should ensure the long-term preservation of the working fluid temperature have to be used. The costs of building thermal storage can vary significantly depending on the technical solution and the method of installation, or whether the storage is above the surface of the land, partially buried or completely buried. In accordance with the chosen method of installation, the additional limiting factor can be the soil structure, which is especially reflected in the case of fully or partially buried thermal storages.

Relatively new technology in Serbia

As already mentioned, this technology represents a novelty in the Republic of Serbia. This can produce an additional limiting factor since a small number of quality designers and contractors in this field can be found on the market. At the same time, due to the small market offer, potential contractors can offer higher prices for the execution of works, and even it can be expected that foreign contractors will be present at calls causing the prices to rise to the EU levels.

Limited knowledge and capacity in preparing of investment projects

Insufficient number of successfully implemented projects, as well as insufficiently developed awareness of all the benefits of such projects, limits both the level of knowledge and the capacities for the development of projects. In addition, all of the above mentioned also results in insufficient interest of investors to implement such projects.

7.2 Administrative Polices and Laws: Serbia, Belgrade

Project developer who wants to successfully become a heat producer feeding the heat into the heat distribution system of the City of Belgrade has to a) **become legally entitled to produce heat and enter into contractual arrangement with the heat supplier** (or become one) b) **become licenced to perform heat production fulfilling requirements set forth by the Energy Law** and subsequent bylaws and c) **construct heat production facility in line with applicable legislation.** LSGs are fully entitled to further regulate the framework that governs the area of production of heat energy. National level has extremely limited competencies in regulating district heating.

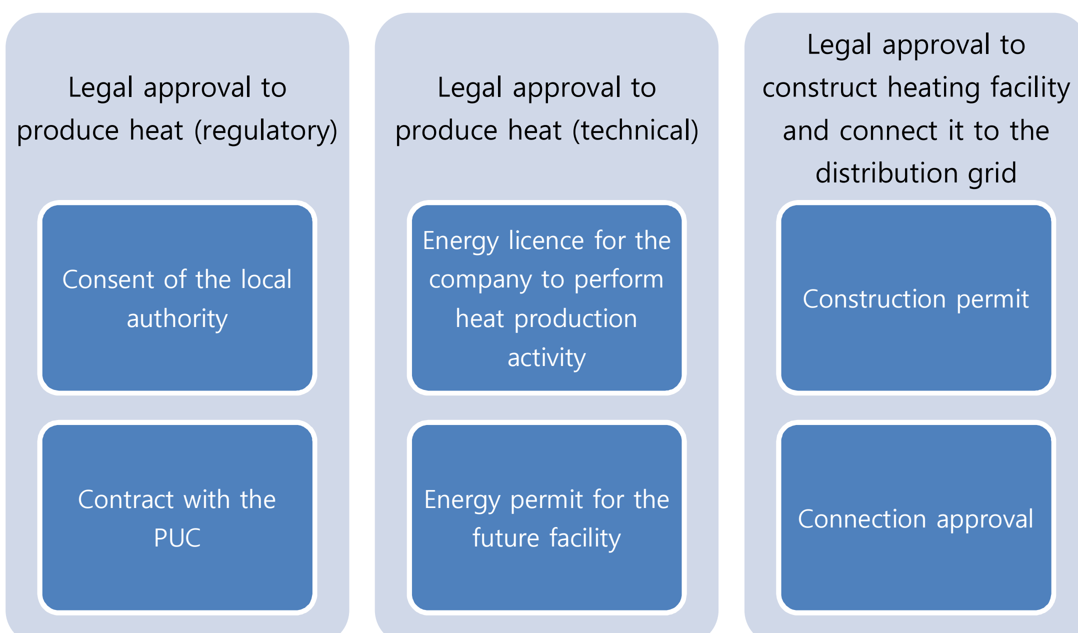

Figure 62 Becoming heat producer in district heating in Belgrade: basic elements

District heating service in the city of Belgrade is governed by different institutions including the Government of the Republic of Serbia, different structures of the city of Belgrade and the BE.

The Government of the Republic of Serbia is in charge for the definition of the Methodology for calculation of the end user price of the district heating.

The city of Belgrade is the major stakeholder in the provision of the district heating service in the city of Belgrade (and non-central municipalities who have competencies similar to the competencies of the City for the district heating service on their territory).

City of Belgrade established and is sole owner of the BE that performs the activities of production, distribution and supply of heat.

Processes and relations relevant for the provision of the district heating in the City of Belgrade are further defined, within the framework set by different laws and bylaws, primarily by: a) the Decision of the City of Belgrade on heat supply, b) Statute of the City of Belgrade and c) acts adopted by the Utility.

7.2.1 National legal framework

The domain of District Heating in Serbia is covered by a very broad legal framework. Herewith, the consultant will present only limited number of information about the general framework focusing on legislation that might be relevant for the construction and operation of solar thermal facility within the framework of the district heating system.

Starting with the Constitution[5], as the overhead legal act of the Republic of Serbia, through laws LSGs[6], communal services[7], energy[8], energy efficiency[9], planning and construction[10],

5 The Constitution of the Republic of Serbia („Official Gazette of Republic of Serbia“, N° 98/2006)

6 Law on Local Self-Government („Official Gazette of Republic of Serbia“ N° 129/07)

7 Law on Communal Services („Official Gazette of Republic of Serbia“, N° 88/2011 and 104/2016)

8 Law on Energy („Official Gazette of Republic of Serbia“, N° 145/2014)

9 Law on Energy Efficiency („Official Gazette of Republic of Serbia“, N° 25/2013)

10 Law on Planning and Construction („Official Gazette of Republic of Serbia“, N° 72/2009, 81/2009 - correction, 64/2010 – decision of Constitutional Court, 24/2011, 121/2012, 42/2013 - decision of Constitutional Court, 50/2013 - decision of Constitutional Court, 98/2013 - decision of Constitutional Court, 132/2014 i 145/2014)

consumer protection[11], obligatory relations[12], housing and maintenance of buildings[13], basis of property-legal relations[14], the legal framework is rounded up with a number of by-laws, the most important of which is the Methodology for Determining the Price for Heat Supplying of End-Customers and a large number of local legal acts.

1) The constitution of the Republic of Serbia

The Constitution determines the competencies of the LSGs, and the first of them is that LSG regulates and ensures the performance and development of communal services[15], including the production and distribution of heat energy[16].

2) LSG has is obliged:

to build an infrastructure (distribution system of District Heating) that would allow to accommodate all demand requests,

to ensure stable operation of such infrastructure,

to regulate legal regulations defining conditions, mode, rights and obligations of energy entities and customers.

3) Law on LSG

Law on LSG elaborated in details competencies outlined in the Constitution. LSG, through its bodies, regulates and provides the operation and development of communal services, including the production and supply of steam and hot water, as well as organizational, material and other conditions for their performance[17].

4) Law on communal services

Even more precisely, the Law on Communal Services determines that LSGs are obliged to

[11] Law on Consumer Protection („Official Gazette of Republic of Serbia“, N° 62/2014)

[12] Law on Obligations („Official Gazette of SFRY“, N° 29/78, 39/85, 45/89 - decision of Constitutional Court of Yugoslavia and 57/89, „Official Gazette of SFRY“, N° 31/93 and „Official Gazette of Serbian and Montenegro“, N° 1/2003 – Constitutional Charter)

[13] Law on Housing and Maintenance of Buildings („Official Gazette of Republic of Serbia“, N° 104/2016)

[14] Law on the basics of ownership relations („Official Gazette of SFRY“, N° 6/80 i 36/90, „Official Gazette of SRY“, N° 29/96 and „Official Gazette of Republic of Serbia“, N°115/2005)

[15] The Constitution of the Republic of Serbia, Article 190

[16] Law on Communal Services, Article 2

[17] Law on Local Self-Government, Article 20 Paragraph 1 Number 5

create conditions for ensuring adequate provision of communal services in terms of quality, volume, availability and continuity. LSGs are also obliged to supervise the performance including performance of the service of production, distribution and supply of heat energy[18].

Article 9 of the Law on Communal Services broadly regulates manner in which performance of communal service may be entrusted to different entities. It clearly says that communal service is entrusted based on the Decision of local self-government assembly and the contract, unless PUC performs communal service when contract is not required. The same article stipulates that when performance of the communal service is entrusted to a third-party, legislation regulating public private partnerships and concessions needs to be observed.

As there are still very little experience when inclusion of third parties in district heating service provision is concerned, it is difficult to judge whether only production of heat and its delivery to the distribution system would be seen as performing the communal service by the competent local authority. When part of the communal service of public transport in the city of Belgrade has been entrusted to private operator this has been the case, and legislation regulating public private partnerships and concessions was observed.

5) Law on energy

Energy Law prescribes the jurisdiction of local self-government unit, i.e. the City of Belgrade in the field of heat. Pursuant to the Articles 345-366 of the Energy Law, local self-government units, i.e. the City of Belgrade are competent for:

- issuance and withdrawal of licenses for heat production, distribution and supply, keeping registry of issued licenses (for the heat production in facilities larger than 1 MW) and registry of heat producers with power from 0.1 MW to 1 MW,
- setting conditions for heat delivery and supply in this area, rights and obligations of heat producers, distributers, suppliers and final customers,
- more detailed definition of the procedure for the allocation of costs of joint metering point in the heat transfer station and conditions for maintenance of a part of the system, including the heating equipment of a customer, rights and obligations of heat customers in case of termination of the contract or suspension of delivery,

[18] Law on Communal Services, Article 2

- approval of the price of heat
- provision of reliable and secure heat supply in line with the law,
- issuance of energy permit for the construction of facilities for heat production of 1MW and higher capacity,
- deciding upon applications for the award of a privileged heat producer status, criteria for the award of the status and manner and procedure for the award of privileged heat producer status,
- more detailed definition of conditions for the award of a vulnerable heat customer status under the conditions prescribed by the Law,
- approval of heat distribution network code
- This law defines the Government jurisdiction in:
- adoption of a legal document which regulates the conditions for issuance, amendment and withdrawal of energy licenses in the field of heat and
- adoption of a methodology for setting price of heat supply to a final customer (Article 362 of the Energy Law)

6) Law on planning and construction

Law on planning and construction identifies two different options when construction permits for solar facilities are concerned:

- Execution of works on the installation of solar collectors, as simple objects – for which it is not required to obtain the act of the competent body for construction (location permits and construction permits). The list of such objects is defined in the Rulebook issued by the Minister in charge for construction[19]. Simple objects are objects that are built on the same cadastral parcel on which the main building was built, so as not to interfere with the regular use of adjacent objects. The Rulebook specifically lists solar collectors not connected **to electricity distribution grid** as such objects not referring to heat at all. **As both the Law and the Rulebook are issued recently this ambiguity will need to be clarified in the future.**

[19] https://www.mgsi.gov.rs/lat/dokumenti/pravilnik-o-posebnoj-vrsti-objekata-i-posebnoj-vrsti-radova-za-koje-nije-potrebno

- The Law envisages that construction permit is issued by the Ministry for the facilities for renewable energy production when its capacity is larger than 10 MW, while local self-governments are competent for issuance of construction permits for smaller capacities.

A construction permit is issued to the investor who a) along with the **request for issuing a construction permit**, submits a **project for a construction permit** and an **extract from the project** for a construction permit prepared in accordance with a regulation that closely regulates the content of the technical documentation; b) has the appropriate right on the land or facility and c) provided the evidence on the payment of the appropriate taxes and fees and other evidence prescribed by the regulation that regulates more closely the procedure for the implementation of the consolidated procedure[20].

For the construction of energy facilities, prior to issuing a construction permit, the investor acquires an energy permit, in accordance with Energy Law.

For the installation of solar collectors and solar cells on objects of **cultural and historical significance** and facilities for which conservation conditions have to be issued in accordance with the provisions of a special law prior to restoration (restoration, conservation, revitalization) or adaptation, the **consent of the body or organization responsible for the protection of cultural goods** on the conceptual or main project is required.

7) Law on public private partnerships and concessions

The Law on Public-Private Partnership and Concessions (hereinafter: the “PPP Law”) was adopted in 2011, introducing the concept of public-private partnerships into the Serbian legal system for the first time. Since then, several public-private partnerships (“PPP”) projects have been initiated and implemented in Serbia, mostly on a small to medium scale, with the sectors involved varying from public transport, public lighting, energy and water, to the maintenance of roads and other infrastructure[21].

The Serbian market, however, is yet to see a large-scale, complex PPP project and its full implementation. PPPs are required to be economically efficient and socially responsible. The economic rationale of this concept is that the return on investment should be greater than the value that would have been obtained by using the traditional public investment model (i e funding from the budget). Another clear advantage of PPP is the fact that the public sector

[20] LAW ON PLANNING AND CONSTRUCTION ("Official Gazette of the Republic of Serbia", No. 72/2009, 81/2009 - Ex., 64/2010 - decision US, 24/2011, 121/2012, 42/2013 - decision US, 50 / 2013 - decision US, 98/2013 - decision US, 132/2014, 145/2014, 83/2018, 31/2019 and 37/2019 - other law), Article 135

[21] Chapter based on the “White Book” of the Foreign Investors Council.

(including municipalities throughout Serbia) typically lacks the appropriate level of expertise, knowledge, and know-how to tackle, implement and manage complex infrastructure projects on its own, so involving a private partner is usually a more practical solution than engaging external consultants on a long-term basis.

To tackle the challenges and foster further development of PPP projects on the Serbian market, the PPP Law has recently been subject to amendments. In addition, the By-Law on Granting Concession in Phases was adopted by the Government in January 2017 to further regulate in sufficient detail the procedure of granting a concession

As far as existing practices are concerned, the preparation of a number of large-scale PPP projects can be reported as a positive development from the investor's perspective.

8) Law on general administrative procedures

Law on general administrative procedures in Article 22-26 defines administrative contract as contract between the competent authority and the third party. As this Law has also been recently changed it is yet to be seen whether this provision will also be used to interpret relations between the LSG and the party to which provision of communal service is entrusted. Provisions in this Law make it difficult for the third party to leave the contract.

7.2.2 Local legal framework

Local self-governments established Public Utility Companies (hereinafter PUC) and entrusted them to perform activities of heat production, supply and distribution. In their acts they have also envisaged the possibility that PUC may purchase heat from other sources based on contractual arrangement providing that all legal framework requirements are met. City of Belgrade has done the same.

The City of Belgrade has legal competencies (based on articles 25 and 31 of the Statute of the City of Belgrade), among others, for the following:

- to define the conditions for provision and development of the communal services and arrange other issues related to the communal service performance;
- to appoint and dismiss supervisory boards members and directors of the public utility companies founded by the City of Belgrade, and to provide consent on its statutes, annual operational plans, financial reports, the borrowing decisions of the public utility companies, the decisions on capital investments of the public utility companies, the decisions on statutory changes and establishment of other legal subjects and other

decisions.

1) Decision on heat supply of the city of Belgrade

The Decision on heat supply for the City of Belgrade regulates numerous topics including the following:

- prescribes conditions and procedures for performing the operations of production and distribution of heat, management of the distribution system
- entrust jurisdiction for the communal services to the Utility
- prescribes the adoption of the Energy development plan for the city of Belgrade
- empowers organizational unit of the administration of the City of Belgrade in charge for communal services to supervise the implementation of the decision

It is important to underline that Energy development plan for the city of Belgrade has never been adopted. This document may be instrumental in facilitating development of solar thermal projects as it represents umbrella document for the development of district heating service in the city of Belgrade.

Decision on heat supply of the city of Belgrade (Article 4) stipulates that PUC may entitle third party to perform some of the activities from its range of competencies. This Order says that such entitlement has to be in line with the manner and procedure prescribed by the Assembly of the City of Belgrade. It is not confirmed whether there is a rule or regulation stipulated above. Heat is currently supplied to the district heating system of the city of Belgrade also by the three entities external to the PUC. These heat supply arrangements are older than the legislation that governs the district heating.

2) Rulebook for the operation of the heat distribution system of the Belgrade city.

Possible existence of third-party heat producer is also recognized in this Rulebook. The Rulebook also stipulates the need for the establishment of contractual relationship with the third-party heat producer recalling the condition that such contract has to be in line with the legal requirements and the Order. The Rulebook also stipulates that such producers have to possess energy licence for the activity of heat production in line with the Order. Order merely reiterates requirements set forth by the Energy Law: licence is required for the companies who operate heat production facilities with thermal capacities larger than 1 MW. Once issued, licence is valid for the period of 10 years and may be extended.

7.3 Regulatory/risk assessment report of solar thermal at Cerak

In addition to the limitations set out in the previous chapters, which can be attributed to organizational, technical and procedural constraints with which investors, at this moment, almost with certainty, may be tempted to meet we list here regulatory and other additional risks that project developer may face when trying to develop solar energy project at Cerak.

7.3.1 Regulatory risks

1) Risk of obtaining the right to perform communal service in district heating

Project developer is facing uncertainty whether and under which conditions it would be possible obtain the right to perform part of the district heating service (heat production activity). As there are no previous cases it is difficult to assess level of this risk and to propose mitigation measures. Public private partnership procedures in some other communal services are becoming more numerous and may in the future provide for a better basis for the assessment of this particular risk.

2) Energy permitting risk

Both energy license for heat production activity and energy permit for solar thermal plant are issued by the city of Belgrade. However, the existence of energy permits or energy licenses issued in the city of Belgrade is not confirmed. Therefore, it is not possible to estimate the time required to obtain the permit or the license.

3) Construction permitting risk

Serbia has significantly improved its position on the Doing Business list of the World Bank primarily due to the fact that construction permitting in the City of Belgrade is assessed as significantly improved when time required is concerned. As these improvements are recent, its sustainability is still difficult to judge.

The other source of risk in this particular case stems from the fact that construction of solar thermal facilities has never been performed after the recent legal changes and has been performed only once before legal changes, but not in Belgrade. Therefore, it is difficult to predict behaviour of the administration in the procedure that would be new to all involved institutions.

Table 52 Doing Business list and Serbia rank

Year	Serbia rank in area: Starting a business	Serbia rank in area: Dealing with construction permits
2016	65	139
2017	90	139
2018	32	10
2019	40	11

4) Risk of land use

Solar plant and associated infrastructure (thermal storage) can only be built on construction land, all in accordance with Article 82 of the Law on Planning and Construction (Official Gazette RS No. 83/2018): "Construction land is a land that is designated by the law or planning document for the construction and use of facilities, as well as the land on which the facilities were built in accordance with the law."

In that sense, as a first step, it is necessary to check the current purpose of the land intended for the construction of the plant. If the land is not land reserved for construction, there is a risk of a formal nature as project developer would need to enter into the land conversion procedure, provided that the law allows it in the particular case.

The Law on Agricultural Land (Official Gazette of RS, No. 95/2018) in the part of agricultural land protection requires that agricultural land will be used as a priority for agricultural production (Article 15): "Agricultural land is used for agricultural production and cannot be used in other agricultural areas purpose, except in cases and under conditions determined by this law." Article 22 of the same law prohibits the use of arable agricultural land for non-agricultural purposes: "It is prohibited to use arable agricultural land of the first, second, third, fourth and fifth cadastral classes for non-agricultural purposes." Exceptionally, the consent to change the purpose of arable agricultural land is provided by the Ministry in charge of agriculture.

It should be kept in mind that by changing the purpose of the land from the agricultural to the constructional, one can enter the additional risk of not meeting the agreed deadlines, since Article 88 of the Law on Planning and Construction allows the agricultural land to which the planning document has changed its purpose in the construction, (Article 28): "It is forbidden to destroy and damage crops, seedlings, trees and agricultural machinery on the holdings, damages that lead to a decrease in productivity, structure and layers of agricultural land, as well as any other damage on agricultural land."

5) Risk of archaeological sites

Bearing in mind that the construction of the solar field and the construction of seasonal buried thermal storages is foreseen on land that is not earmarked for construction, in order to avoid the risk of stopping construction on the basis of the protection of cultural goods in the form of archaeological sites, it is recommended that the land is checked by the competent institutions protection of cultural goods of the Republic of Serbia, that is, the City of Belgrade, and strict adherence to the provisions of the Law on Cultural Property (Official Gazette of RS, No. 99/2011).

6) The risk of challenging of detailed regulation plan

For the construction of solar DH with a field of solar thermal collectors and a seasonal thermal energy storage in heating plant Cerak, a detailed regulation plan for the selected location is required. As it is about the use of relatively new technologies in this area and the legal obligation to organize a public hearing on the detailed regulation plan, there is a real risk of challenging the project by the associations for nature and wildlife protection, as well as by the advocates of the use of fossil fuels for DH, which could impair the dynamic plan of project realization.

7.3.2 Other risks

1) Risk of non-existence of meteorological data

In order to properly assess the capacity of the solar thermal field and the optimal capacity of the seasonal thermal storage, it is desirable to carry out detailed dynamic simulations, for which reliable metrological data is needed on a timely basis. The absence / unavailability of adequate weather data represents the risk of inadequate capacity assessment, which is reflected in the level of investment, but also on the exploitation parameters.

2) The risk of airborne reflection

Bearing in mind that the landing runway at Nikola Tesla Airport, Belgrade spreads on the direction/orientation northwest-southeast, as well as the fact that the heating plant Cerak location is only 8 km (airline) from the Nikola Tesla airport in the southeast access road towards the runway, there is a risk of the inherent impact of the solar field reflection on aircraft while approaching and in the preparation phase for landing at the Belgrade airport. In that sense, it is necessary to assess the impact of the potential solar field on air traffic safety at Nikola Tesla Airport.

3) Climate related risks

The apparent climate change in recent years on the territory of the Republic of Serbia and the city of Belgrade is generally manifested through extremely low temperatures (ice days below -10 °C), extremely high temperatures (tropical days, over 36 °C) or in the form of natural disasters (heavy snow / storms, earthquakes, floods). In order to protect people and property, in times of extremely low / high temperatures, as well as in times of natural disasters, businesses and institutions reduce the working hours of employees, especially open-air workers. Taking into account the specificity of the construction works on the solar field and the large buried thermal storage, as well as the expected length of the same (min. One year), there is a risk of not meeting the agreed deadlines, based on the force majeure.

4) Risk of unexploded mines and explosives

In the period of March-June 1999, the area of the city of Belgrade, and especially the Straževica region, which was more than 1000 m away from the heating plant Cerak, was exposed to air strikes. As the use of land that is not earmarked for construction is foreseen for the needs of the construction of solar fields and seasonal buried thermal storages, there is a risk of residual unexploded mines and explosives, and in order to eliminate the mentioned risk, it is proposed to make the inspection of the land by professional teams of the Serbian Armed Forces.

5) The risk of solar fluid leakages

Due to the operation in the whole year regime, the solar field of thermal collectors must inevitably be filled with a large amount of anti-freeze liquid. The most commonly contained glycol is 30-50%, which ensures that the solar liquid remains in liquid state and at temperatures below -10°C. Potential leakages of solar fluid that does not belong to ecological fluids poses a risk to the negative impact on the environment, and it is necessary to perform all stages of construction and all the positions within them in a high quality and responsible supervision.

8. Long-term Investment Plan

In this study, a long-term plan was established to improve the efficiency of district heating in Belgrade and to increase the utilization of renewable energy. Based on the investigation on the status of district heating and the applicability of renewable energy in Belgrade, the plan was established based on the overall improvement plan.

The characteristic of district heating in Belgrade is that it is operated independently without an interconnection of heat plants and is operated by a thermal boiler instead of CHP. Even if a low-cost heat source is obtained by waste heat or renewable energy from a specific heat plant, it may not be extended to other heat plant supply zones, which may limit operating efficiency.

It is also reported that from in terms of users, the heat charge based on area accounts for a large proportion, rather than the heat charge based on the amount consumed. The charge of heat according to the heating area of households is a system that is distributed in a batch without considering the difference in actual usage between households. Therefore, the user side is passive in reducing heat consumption and there is no incentive to reduce the heat consumption of each household. Therefore, it is difficult to reduce the fuel consumption by increasing the heat used in the district heating system as a whole.

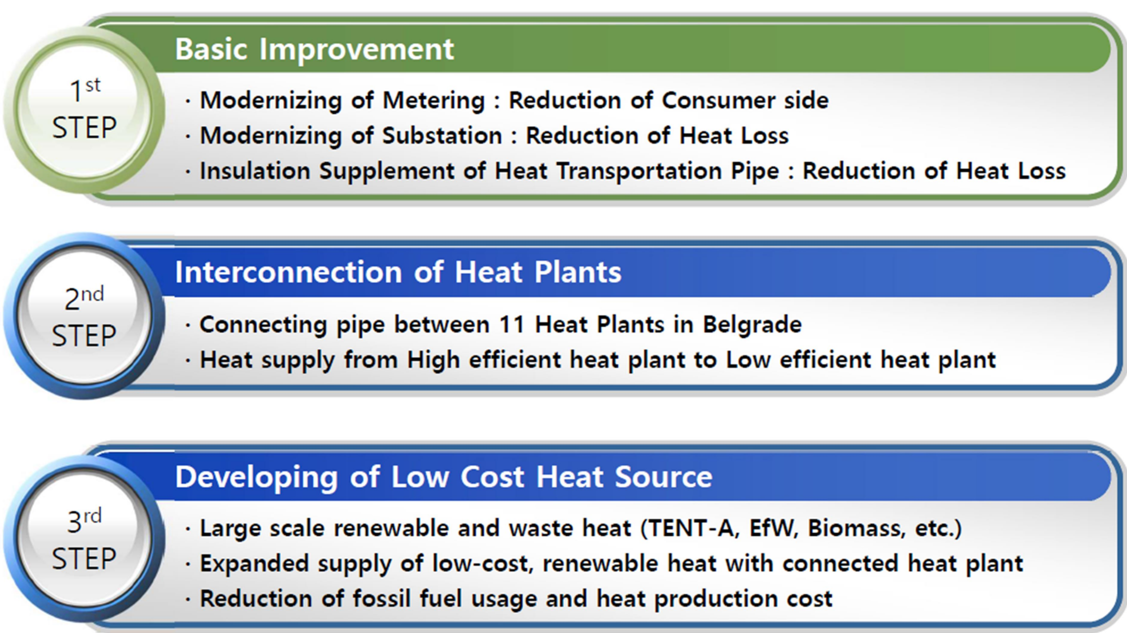

Figure 63 Long-Term Plan for District Heating System of Belgrade City

This report proposes a step-by-step plan to reduce fossil fuel use due to the efficient operation of district heating in Belgrade and the use of renewable energy.

1) 1st step: Basic Improvement

As a basic improvement plan for district heating in Belgrade, investment to reduce consumption and heat loss of consumers needs to be preceded. The metering system for heat use should be improved to be based on the billing according to the amount of usage, and should be gradually changed. If it is not saved on the heat user side and excessive use factor is maintained, it is difficult to expect the reduction of the heat consumption and fossil fuel usage.

In addition, heat loss in the process of transferring heat from the heat plant to the user should be minimized. An investment to minimize heat loss by supplementing the insulation in the substation and the insulation of the heat transport pipe should be preceded.

Low-cost, small-scale renewable or waste heat recovery systems must be developed that can only partially cover the heat load of individual heat plants. It is necessary to reduce the use of fossil fuel even in part by utilizing a small solar thermal system or geothermal system according to the site conditions at each unit heat plant.

2) 2nd Step : Interconnection of Heat Plants

Currently, 11 heat plants are installed in Belgrade, and each of them independently supplies heat to the corresponding supply zone through a Heat only boiler, and there are no heat interconnection pipes between the heat plants. It seems that there was not much need of interconnection pipe until now because it adjusts the output of the heat-only boiler according to the heat load of each heat supply zone. In addition, since the heat is not supplied by cogeneration, it is considered that the reason for the difference in heat production cost according to the output efficiency of each heat source is not large.

However, if large-capacity, low-cost heat sources are developed in the future, being able to supply them to a number of nearby heat sources rather than using them from just one heat source would be beneficial to lower the unit cost of heat production for the entire district heating system. For this reason, it is necessary to consider the installation of interconnection pipes between heat plants.

In Korea's Korea District Heating Corporation, 17 heat plants in the metropolitan area are linked to each other, and each heat plant has a priority of supplying heat with low heat production cost to consumers. In addition, since most heat plants are cogeneration plants, low-cost heat produced by high-heat-efficient, high-capacity cogeneration plants is supplied to the nearby heat plant, so few heat-only boilers are in operation. This system lowers the overall cost of heat production and reduces the use of fossil fuels for heating.

Through the large-scale heat transfer pipe(170km in 2 rows) connected to the heat source of the metropolitan area, This is raising the efficiency of heating supply and improving stability as well as bring down heating prices by expanding distribution of low price surplus heat.

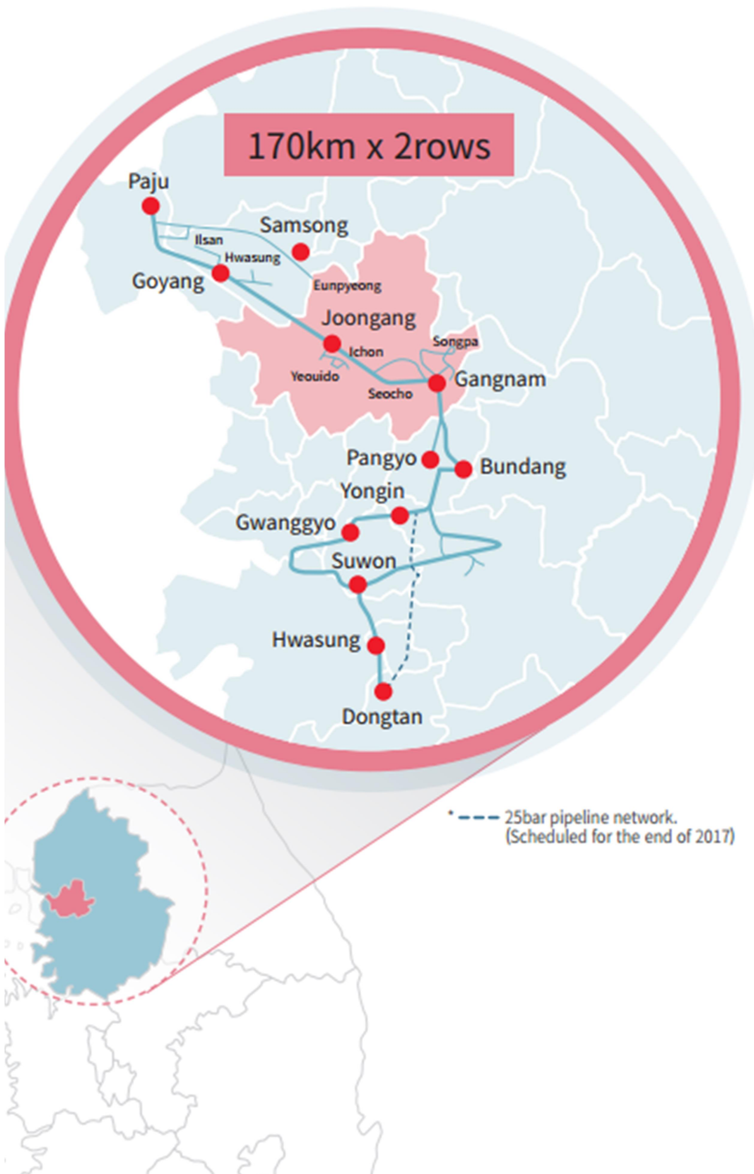

Figure 64 Example of heat plants interconnection of KDHC in metropolitan in Korea

3) 3rd step : Developing of Low Cost Heat Source.

Beogradske Elektrane, a district heating company in Belgrade, is considering producing heat from a heat pump that uses condenser coolant from coal-fired power plant TENT-A as a low-temperature heat source to supply heat to the Novi Beograd heat plant. The distance between TENT-A and Novi Beograd heat plant is about 27 km. While preparing this report, there has been a big progress related with TENT-A power plant. The 200 million EURO amount investment for heat connecting project between TENT A and BE plant was finalized. This project is to extract heat from steam turbine and connect into the heat network of Belgrade city through 1000A pipe line, 27km long. The planned heat capacity is about 600MWth. Due to spare capacity of 1000A pipe, The pumping heat from heat pump could be utilized through same pipeline. Considering maximum capacity of 1000A(800MWth), We can have 200MWth more from the heat pump. The brief technical introduction is described in 4.2 section of Part 1.

In addition, negotiations are underway to receive heat from waste incineration facilities that will be installed in the Vinca region. The EfW system using Vinca's incineration waste heat could be linked to Mirijevo, the nearest heat plant.

Figure 65 the location of TENT-A and Vinca

In the case of supplying heat sources not using fossil fuels only to the corresponding heat plants Novi Beograd and Mirijevo, the effect of reducing the use of fossil fuels in the district heating of Belgrade is limited. Supplying to other heat plants near Novi Beograd and Mirijevo will further maximize the effect of reducing fossil fuel use in district heating in Belgrade. With the interconnection system between these heat plants ready, it will be the basis for developing large-scale renewable energy heat sources such as wood chips.

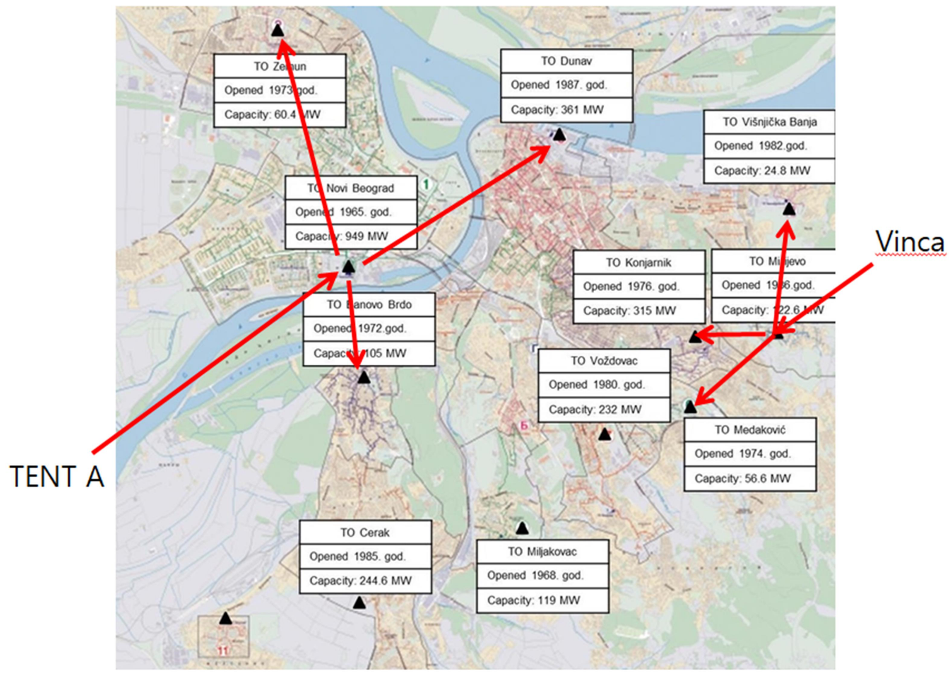

Figure 66 example of interconnection between heat plants

Annex Ⅰ: Other possible supporting schemes for development of renewable heat projects

1) Renewable District Energy in Western Balkans – ReDEWeB

Renewable District Energy in Western Balkans - ReDEWeB aims to contribute to enabling investments in the renewable energy sector in the west Balkans. The ReDEWeB program aims to support the establishment of a market for district energy from RES through a number of measures, including enabling the integration of RES into energy and urban plans of LSGs, the preparation of appropriate design projects and feasibility studies, and the establishment of policy frameworks that foster private sector to initiate these processes.

The ReDEWeB Program Fund provides support within the four main areas of technical assistance:

- work on the framework policy;
- work on city politics;
- technical assistance and support in the preparation of investments (heating plants, LSGs and those implementing development);
- capacity building and cooperation.

In addition, the ReDEWeB Program Fund can provide capital grants to eligible investments if resources are allowed. The use of these resources for investment grants will be agreed on a case-by-case basis in cooperation with the Government of Austria, as a donor to the ReDEWeB Program Fund.

DH systems from RES produce hot or cold water from RES such as:

- solar-thermal;
- geo-thermal;
- pumping pumps;
- biomass;
- biogas;
- waste heat (installations for municipal waste incineration, industrial waste heat,

sewage and wastewater);

- Heat of the sea, lakes and rivers, which is distributed through municipal DH systems.

The Goals of ReDEWeB Program Fund

ReDEWeB aims at facilitating the development of projects in this area, as well as providing the political and technical assistance needed to create and support investment. In particular, the ReDEWeB program aims at:

- assisting West Balkans countries in achieving their contractual obligations in the field of RES arising from the EnC Treaty and progress in readiness to negotiate Chapter 27 to join the EU;
- contributing to the establishment of a market for RES that could in the future reach a 50 million € of investment in the production of energy from RES, storage of heat and Energy Efficiency measures by 2025 to contribute to the achievement of sustainable municipalities in the West Balkans region;
- supporting work with public and private actors for the realization of sustainable investments in RES;
- Providing support to private companies in the preparation of projects for heating/cooling from RES for their own needs (industrial parks, shopping centres, parks for sale, airports, railway and bus stations, etc.).

Field of operation of ReDEWeB

The ReDEWeB program can consist of investment grants and technical assistance to support the development of the market and enable investment in the RES sector in DH systems. The technical assistance component includes providing support through four main areas of action:

Activities on framework policies developed in close cooperation with the EnC Secretariat:

- supporting the development of country action plans regarding RES derived from commitments from the EnC Treaty,
- support to countries to respond to Chapter 27, Environment and Climate Change,
- supporting countries in meeting their RES targets and their EE targets deriving

from commitments from the EnC Treaty,

- Work on incentive mechanisms by the government pushing municipalities to improve the national RES program.

LSG policy actions:

- work with the EnC Secretariat, relevant ministries and LSGs to introduce RES production and its storage, as well as the appropriate EE measures for selected cities,
- emphasizing the importance of consumption based billing and the incorporation of infrastructure (supervisory control systems, large scale application of heat meters and heat cost allocators), needed to switch to the billing system where part of the payment is based on real consumption;
- Integration of energy from RES, production and storage into urban planning of municipalities.

Technical assistance and support for investment preparation for cities and investors:

- mapping of heating and cooling consumption needs in selected municipalities, real current consumption and in line with planned future urban development,
- mapping all potentially economically feasible RESs,
- Incorporating measures to improve DH operations, specifying the necessary additional EE measures, including the side of the demand and the need for network retrofitting/expansion, intelligent operational monitoring, variable flow, large heat pumps and demand side measures,
- providing a support to the DHCs and municipalities in the preparation of design projects and feasibility studies for the application of RES,
- providing a support to the DHCs and municipalities in deciding whether to go for public funding or PPP,
- in the case of PPP, advising municipalities on the preparation of public calls and publishing the expression of interest,
- cooperation with ministries, DHCs and municipalities in cooperation with the EC to provide EU assistance to CAPEX for best projects,

- Support to private investors in preparing feasibility studies for identified projects.

Capacity building and cooperation (networking):

- organizing conferences to exchange knowledge and cooperation among stakeholders,
- Special emphasis would be placed on capacity building and the development of a network of professionals in the field of the application of RES in DH.

For selected DHCs and LSGs, the ReDEWeBB program would support the mapping of demand for heat/cooling energy (to include customer-related programs), followed by mapping of available and most favourable RES for energy production and storage, including EE measures and improving DH performance. These findings would then be integrated into the energy strategy of DHCs and municipalities and urban planning of municipalities.

2) USAID Serbia Energy Efficiency Activity

USAID, through its Serbia Energy Efficiency Activity (SEEA), seeks to improve the efficiency of Serbian DH sector, focusing on decreasing the amount of fuel needed to meet the needs of consumers. It intends to do so by supporting reforms, promoting awareness and building the capacity of DHCs to identify and implement both supply and demand-side EE projects, and implementing pilot projects in selected DHCs. USAID will support such activities mutually agreed between USAID and DHCs, including but not limited to equipment procurement and installation to support implementation and monitoring of selected pilot projects, subject to the availability of funds.

The main purpose of Program is to support EE investments in Serbia’s DH sector through making of the improvements to DHC’s facilities and its supporting infrastructure to reduce consumption from current energy sources.

Among the selected projects one can find the installation of the next 200 solar collectors on the roof of the City of Pančevo DHC. In that way, the already operating solar thermal DH installation will be expanded.

3) EE Budget Fund

The Law on Efficient Use of Energy[22] foresaw the establishment of the EE Budget Fund as an efficient way of collecting and placing funds for the purpose of financing or co-

[22] LAW ON EFFICIENT ENERGY USE ("Official Gazette of the Republic of Serbia", No. 25/2013)

financing projects, programs and activities aimed at more efficient use of energy.

The Fund allocates funds in accordance with the procedures and conditions determined by the Rules and based on the annual funding programs adopted by the Government of the Republic of Serbia. Funds can be given to legal entities and individuals through the implementation of public tenders.

At the end of February, a public call was launched for the allocation of funds from the Budget Fund for the improvement of EE to finance projects in the field of efficient use of energy in 2019 in the LSGs. The total funds available under this call amount to about € 2.7 million.

The subject of the Public Call also envisages, among other things, the financing of projects of EE improvement that implements the measure of installation of solar collectors in the installation for the central preparation of DHW.

Bearing in mind that the public call is intended exclusively for LSGs, it is expected that the realization of this measure would be based on the installation of solar collectors in public sector buildings, and that connection of the installation into the DH system is possible only if the LSG represents the DHC.

4) EU Programs

European programs and funds can also represent a good incentive for the implementation of solar DH systems projects. The only solar thermal DH project that has been successfully implemented in Serbia has been implemented through one of the EU programs.

Through **Banat Sun 4 All** EU-funded project under the IPA Cross-Border Cooperation program between Romania and Serbia, with the co-financing of the city of Pančevo, and in partnership with the Romanian municipality of Lugoj, the construction of a pilot solar plant for the preparation of DHW was implemented.

Annex Ⅱ. Construction permitting using warehouse example: procedures, time and costs

Table 53 Details – Dealing with Construction Permits in Serbia – Procedure, Time and Costs. Source: Doing Business 2019, Economy Profile Serbia

No.	Procedure	Time to complete	Associated Costs
1	**Request and obtain location conditions from the Secretariat of Urban Planning and Construction of the City of Belgrade** *Agency: Secretariat for Urban Planning and Construction of the City of Belgrade* BuildCo applies for the Location conditions through the ePermit system to the City of Belgrade Secretariat for Urban Planning and Construction. The concept design/plan and proof of payment of administrative fees must also be attached. The Municipal One Stop Shop is required to obtain copies of the plan of the parcel and its installations from the Republic Geodetic Authority, check the size of the parcel on the web site of the Republic Geodetic Authority, check the zoning requirements for the parcel and obtain all system operators' (waterworks, sewerage, power company) technical conditions for the project. After checking the zoning requirements and based on the documentation obtained from the Republic Geodetic Authority and system operators' technical conditions, the permitting authority issues the Location Conditions as an eDocument and makes it publicly available at the City of Belgrade website.	33 days	RSD 58,914
2[23]	**Obtain results of geotechnical study / soil test** *Agency: Licensed geodetic agency* BuildCo will request a soil test for the structural calculations for the foundation. Contractors ask for a soil test to ensure that the foundation of the building is solid. The engineer must understand the suitability of the soil for the proposed construction work. It allows to build a solid foundation and avoid structures to be damaged or collapsed or leaned. According to the "Rulebook on content, mode and procedure-making and of the technical documentation according to the class and purpose of the objects," the soil test is part of the	21 days	RSD 21,000

[23] takes place simultaneously with previous procedure

	technical documentation and is consistently done in practice.		
3[24]	**Obtain a topographical survey of the land** *Agency: Private Geodetic agency* According to Art. 47 of the Rulebook on mandatory content of the project design, a topographical survey is needed for the development of the concept design - Idejni projekat - and must be done by a certified surveying agency (Art. 56 of the Rulebook). This topographical survey can be done while obtaining the location conditions from the secretariat of Urban Planning and construction.	13 days	RSD 108,129
4	**Request and obtain technical design of the construction permit** *Agency: Licensed Company* A duly licensed company other than the one that designed the main building plans must verify whether the main construction project is in accordance with the law and with the technical standards, and whether it has all necessary clearances described in the previous procedures. The main construction project must be certified and stamped to that effect	6 days	RSD 92,071
5	**Request and obtain building permit** *Agency: Secretariat for Urban Planning and Construction of the City of Belgrade* The new Rulebook on Electronic One Stop Shops, implemented in December 2015 made it mandatory to request a building permit online through the epermitting system. The following documents must be provided: • building permit plan (project design), • technical control of the building permit plan by a licenses engineer • proofs of payment of administrative fees for the eSystem • Payment for the City of Belgrade for filling and processing a request The permitting authority checks the building permit plan with the zoning requirements and previously issued Location Conditions. There is are no issues, the building plan will request the proof of ownership via the ePermits system	11 days	RSD 5,500
6	**Obtain approval for commencement of works from the Secretariat for Urbanism and Construction Affairs and notify**	2 days	RSD 1,100

[24] ibid

	Ministry of Labor *Agency: Secretariat for Urbanism and Construction Affairs / Ministry of Labor* This procedure is completed through an electronic application system. The applicant submits: a) the notification of the commencement of works to the Secretariat for Urbanism and Construction Affairs and b) the notification for the commencement of works to the Ministry of Labor. The approval from the Secretariat of Urbanism is received one day after submission		
7	**Notify about the completion of foundation works and request inspection** *Agency: Secretariat for Urban Planning and Construction of the City of Belgrade* According to Article 152 of the Law on Construction and Planning, BuildCo must notify the Secretariat for Urbanism and Construction Affairs of the City of Belgrade (competent authority) about the completion of foundation works. The Secretariat shall, within three days of the receipt of the notification, notify the Inspection Authority, which has to conduct the inspection within 3 business days.	7 days	RSD 800
8	**Receive inspection of foundation works** *Agency: The Secretariat for Inspection of the City of Belgrade - Department for Construction and Urban Planning Inspection*	1 day	No charge
9	**Request and obtain water and sewerage connection** *Agency: JP Vodovod-Kanalizacija d.o.o*	18 days	RSD 111,929
10	**Hire an external engineer to conduct the final inspection** *Agency: Certified Independent firm* Prior to the new law from 2015, this inspection was conducted by the Municipality. Now it is conducted by an independent expert. After the inspection, the expert writes the recommendations to the Municipality and based on those recommendations, the Municipality will issue the usage permit.	1 day	RSD 40,000
11	**Obtain usage permit and register the building with the Geodetic Authority** *Agency: Secretariat for Urban Planning and Construction of the City*	27 days	RSD 36,100

	of Belgrade BuildCo must submit a formal request along with the building and the usage permit to register the building at the Republic Geodesy Institute. Article 125 of the Law on Planning and Construction provides for a time limit of 7 days for this permit to be issued following the issuance of technical examination. However, there is no time-limit for the Commission to perform the technical examination. In practice, it may take up to 6 months for the Commission to convene and issue its decision.		