REPUBLIC OF SLOVENIA
MINISTRY OF INFRASTRUCTURE

Reporting by the Republic of Slovenia to the European Commission

Expert basis for a comprehensive assessment of options for cogeneration and district heating

Final report

April 2017

Ministry of Infrastructure

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ABBREVIATIONS USED

AGEN-RS	Energy Agency of the Republic of Slovenia
AP nZEB	Action plan for nearly zero-energy buildings
GDP	Gross domestic product
GAV	Gross added value
CBA	Cost-benefit analysis
CO_2	Emissions of carbon dioxide, a greenhouse gas
VAT	Value added tax
DP EPS	Long-term strategy to promote investments in energy renovation of buildings (Dolgoročna strategija za spodbujanje naložb energetske prenove stavb)
DREN	National energy development plan (Državni razvojni energetski načrt)
EKS	Slovenia's energy concept (Energetski koncept Slovenije)
ENPV	Economic net present value
EU	European Union
EU ETS	The EU Emissions Trading System (a European scheme for trading with CO_2 emission allowances)
EZ-1	Slovenia's Energy Act
GURS	Surveying and Mapping Authority of the Republic of Slovenia (Geodetska uprava Republike Slovenije)
LECs	Local energy concepts
MOP	Ministry of the Environment and Spatial Planning
SMEs	Small and medium-sized enterprises
MZI	Ministry of Infrastructure – commissioned the study; hereinafter referred to as the contracting authority
NACE	Classification of Economic Activities (matches ISIC Rev. 4 at the European level)
RES	Renewable energy sources
CHP	Combined heat and power – cogeneration
SURS	Statistical Office of the Republic of Slovenia (Statistični urad Republike Slovenije)

SUMMARY

In March 2014, the Energy Act (EZ-1) (Uradni List RS (UL RS; Official Gazette of the Republic of Slovenia) Nos 17/14 and 81/15) entered into force, which, among other things, transposes Directive 2012/27/EU of the European Parliament and of the Council of 25 October 2012 on energy efficiency, amending Directives 2009/125/EC and 2010/30/EU and repealing Directives 2004/8/EC and 2006/32/EC (Energy Efficiency Directive (2012/27/EU)) into Slovenian national law.

Article 360 of the EZ-1 (comprehensive assessment of the options for high-efficiency cogeneration and efficient district heating and cooling, and cost-benefit analysis) lays down the obligation of the ministry responsible for energy to make a comprehensive assessment of the potential use of high-efficiency cogeneration and efficient district heating and cooling, including a cost-benefit analysis, together with the content of Article 14 and the relevant Annexes to the Energy Efficiency Directive (2012/27/EU) every five years.

In accordance with Article 364 of the EZ-1 (assessment of the options for efficient district heating and cooling), when planning new buildings and major renovations, the investor must produce a cost-benefit analysis of using high-efficiency cogeneration and efficient district heating and cooling in the process of obtaining a building permit for facilities with a total power input exceeding 20 MW, while also considering the comprehensive assessment of options.

Against this background, the Ministry of Infrastructure has defined a project task that sets out detailed content and scope of a comprehensive assessment of national potentials for efficient heating and cooling, as well as a cost-benefit analysis. It also lays down an obligation to submit a plan for a Regulation by the minister responsible for energy, which will determine the detailed content of the comprehensive cost-benefit analysis, as well as the methodology, assumptions and timing of the economic analysis and principles to be observed in the cost-benefit analysis at plant level.

Chapter 1: Description of heating and cooling demand

This chapter comprises the modelling of the end use of energy for heating and cooling, which involves a number of complex forms of energy-based and other related data, especially for individual sectors – households, services and industry. In the preparatory phase of the project, data sources were identified, and then cooperation with relevant institutions was established in order to structure data into a form needed for this research. For the purpose of making an analysis of heating energy and cooling energy consumption in the industrial sector, the Statistical Office of the Republic of Slovenia prepared detailed information on the use of all forms of energy in individual industries per industrial sector. Unfortunately, due to individual data protection, the Statistical Office of the Republic of Slovenia could not deliver data for individual industries, but only those grouped at the level of statistical regions, which was then included in the analysis.

Chapter 2: Forecast of the changing heating and cooling demand

For the purposes of the second chapter, projections for heat consumption by 2035 have been made based on assumptions of changes in the main macro-economic parameters in this period, i.e. gross domestic product (GDP) and population. Analysis of the projection for changing heating and cooling demand includes households, services and industry. For the analysis, official data was used, in particular from the Statistical Office of the Republic of Slovenia, as well as other institutions and documents relating to the substantive part of the study.

According to the statistical report, in 2014, the total number of housing units for permanent residence in the household sector amounted to 654 000, while the average size of residential units amounted to 97 m². The model estimates that the average size of housing units will gradually increase, and will amount to about 110 m² in 2035. It can be concluded from the analysis that in 2014, the average annual consumption of energy for heating households amounted to around 150 kWh/m² of heated area, while the average consumption of a household member stood at around 720 kWh per year. We obtained these values after making a climatic correction, which had to be done due to the significant differences between degree days for the base year 2014 and the average degree days in a thirty-year period. The total heat potential for cogeneration in the household sector in 2014 is estimated at 31.8 PJ, and it is predicted that by 2035, it will have decreased to 19 PJ. The share of energy consumption for cooling in the total end-use consumption is 0.3%, and because of this, this form of energy consumption is neglected.

Characteristics of energy consumption in the service sector are the least known of all the sectors with end-use energy consumption, because there is no related research performed systematically in Slovenia. Total energy consumption in the service sector is considered as the energy consumption for heating, cooling and non-heating purposes. The basic parameters for calculating energy consumption by sector are floor areas of buildings where certain services are performed, and the energy consumption norm. According to available information, in 2012, the total floor area of buildings in the service sector was about 26 million m^2, which makes for an average of about 12.5 m^2 per capita. In the service sector in 2014, the average heat consumption, after climate correction, amounted to approximately 104 kWh/m^2, which includes heating, cooking and hot water. In addition, energy consumption for non-heating purposes amounted to about 120 kWh/m^2 and includes lighting, operation of electrical equipment and cooling, as well as electricity consumption for cooling, which is approximately 16.6 kWh/m^2 of cooling area. In 2014, the total heat potential for cogeneration stood at approximately 6.66 PJ, while in 2035, it will amount to approximately 5.07 PJ. In 2014, the total cooling potential amounted to 0.6 PJ, and by 2035 it will have dropped to 0.45 PJ. Projections of cooling energy potential in the service sector are related to electricity.

When estimating the proportion of cogeneration in the industrial sector, thermal energy is divided by temperature level, taking into account that the space for efficient heating and cooling is mainly at low- and medium-temperature levels. In the analyses, the industrial sector is also divided into three groups – the first one comprises the four most intensive industries with energy intensity between 11 kWh/EUR and 3 kWh/EUR of product, the second group consists of industries with energy intensity between 2 kWh/EUR and 0.8 kWh/EUR, and the third group is made up of industries with energy intensity of less than 0.8 kWh/EUR. At national level, it is expected that the total usable heat needed will fall from 23 PJ in 2015 to 19 PJ in 2035. At the same time, the market for cogeneration plants, i.e. the need for low and medium heat, will go from 11 PJ in 2015 to 10 PJ in 2035. For this reason, the cogeneration market will see relative growth from 48% of total usable heat in 2015 to 53% of usable heat in 2035. The cooling potential in industry mainly refers to space cooling (to a lesser extent) and to freezing and refrigeration in the food industry. As this part of energy demand is met mainly by electricity, this part is excluded from the analysis.

Chapter 3: Mapping the Republic of Slovenia with spatial and attribute data

In this chapter, heat atlases of selected areas are presented. Using cartographic displays, municipal infrastructure and thermal energy consumption, one can gain a detailed insight into each municipality, town and village, which is the basis for all further analyses of energy consumption and energy system planning. The mapping approach used is based on the use of heat consumption, which is spatially distributed in a rectangular grid. In the first step, the entire territory of Slovenia is divided into areas of 1 km², or square polygons of 1 x 1 km. After mapping the heat potential of the entire Republic of Slovenia, we started determining the heat potential that could be met using high-efficiency cogeneration.

Chapter 4: Identifying the heating and cooling demand that could be met using high-efficiency cogeneration

In this chapter, we analysed the existing situation, the cogeneration plants in the Republic of Slovenia, and the existing district heating systems. It was found that the total gross installed electrical capacity of cogeneration plants is 137 879 kW$_e$, while the total installed heat capacity stands at 152 544 kW$_t$. Cogeneration plants are divided into five categories, depending on the size and installed capacity. It turns out that small cogeneration plants, or plants with less than 1 000 kW$_e$ installed electrical capacity dominate the market. When observing the percentage of cogeneration plants that are part of the district heating system, we found that 38% of the installed heat capacity is emitted into district heating systems. A potential for expansion of existing heating and cooling systems in the amount of 800 518.45 MWh annually was also established. By checking the estimated heat demand in the Republic of Slovenia and by meeting the specific heat consumption equal to or greater than 120 TJ/km^2 (the financial profitability condition), we established the actual potential for high-efficiency cogeneration in Ljubljana with an output of 1 882 189 656.95 MJ (1 332 451 500.99 MJ in Ljubljana and 549 738 155.96 MJ in Maribor). For these two cities, a polygon grid with a resolution of 100 x 100 m was used.

Chapter 5: Defining the potential for additional high-efficiency cogeneration

This chapter elaborates on cogeneration plants that are based on cogeneration with combined gas-steam cycle and cogeneration using biomass, as these technologies represent the only realistic option for production units with power exceeding 20 MW to produce heat and electricity from high-efficiency cogeneration. It was found that the construction of a new thermal plant for electricity production with a total thermal power exceeding 20 MW, which is required by Directive 2012/27/EU (Article 14(5a)), is being planned in the Republic of Slovenia. According to available data, this plant will be located in Ljubljana and is planned to start operating by 1 January 2020. This plant has 140 MW rated power and 110 MW thermal power. The estimated annual production is 700 GWh of electricity and 720 GW of heat.

According to the data available in the Republic of Slovenia that we have seen, there are currently no plans for extensive renovations of existing thermal plants for generating electricity with a total thermal power exceeding the required amount of 20 MW (Directive 2012/27/EU, Article 14(5b)), and there is no intention to substantially renovate existing industrial plants with a total heat capacity exceeding the required amount of 20 MW that produce waste heat at a usable heat level (Directive 2012/27/EU, Article 14(5c)). The potential of waste heat from industrial plants has not been analysed at this time, mainly due to the unavailability of the necessary information.

However, we plan to address this issue in the future through existing, as well as new, projects dealing exclusively or partly with usable waste heat from industrial plants.

The analysis of available LECs has shown that district heating systems exist or are planned in 19 municipalities and that only two municipalities utilise waste heat.

Chapter 6: Identifying options to increase energy efficiency of district heating and cooling infrastructure

The beginning of the chapter presents the current state of the infrastructure for district heating and cooling. According to Directive 2012/27/EU, efficient district heating and cooling refers to district heating or cooling systems using at least 50% renewable energy, 50% waste heat, 75% cogenerated heat, or 50% combination of the above. We have analysed 85 systems for district heating or cooling. Only 56 production plants or 66% of all analysed production plants meet the efficiency condition set out by Directive 2012/27/EU. Below is a list of all analysed plants that did not meet the efficiency condition of district heating and cooling, and where the potential to increase energy efficiency amounting to 138 924 MWh was observed. Indicatively, the linear network density and age are also shown.

Chapter 7: Share of high-efficiency cogeneration, potential established and progress achieved

This chapter addresses technologies suitable for micro-cogeneration, which can be based on an internal combustion engine, a Stirling engine or fuel cells. Regarding the technical requirements of energy efficiency in buildings and the obligation to use renewable energy sources, necessary measures for the building envelope are described, and appropriate micro-cogeneration systems are put together. The analysis has shown that micro-cogeneration systems can meet the requirements for saving primary and end-use energy (under relevant technical regulations), but they are not cost-optimal due to high initial investment costs. The same applies to micro-cogeneration systems in existing buildings without envelope renovation.

Chapter 8: Estimate of primary energy to be saved

Based on a common potential for high-efficiency cogeneration in the amount of 2 144 500 092.95 MJ, the potential total amount of primary energy savings of 794 259 293.68 MJ was established.

Chapter 9: An assessment of public support measures for heating and cooling

This chapter addresses an analysis of public support measures for heating and cooling. Relevant rules of the European Union, such as treaties, directives, regulations, guidelines, etc., relating to the allocation of government grants, were analysed. An overview of the organisational aid structure in the Republic of Slovenia is also provided.

Chapter 10: Cost-benefit analysis

The subject of the cost-benefit analysis is the replacement of existing heat production plants and is based on the results from previous chapters. The plants are connected to district heating in the cities of Maribor and Ljubljana. The analysis took into account only heat production, and it is assumed that there will be no interference in the heat network.

Based on the input assumptions of the model presented in this chapter, the economic analysis shows that investment in high-efficiency cogeneration in the areas addressed is not economically viable. Furthermore, investment in high-efficiency cogeneration is not profitable even according to the sensitivity analysis, which took into account a ± 40% change of input parameters. The input parameters include the cost of investment, the OPEX and the cost of energy products such as electricity, gas, biomass, coal, and fuel oil.

Currently, about 60% of the total heat demand in Maribor is met by natural-gas-powered cogeneration, while in alternative scenarios, approximately 80% of heat demand would be met by high-efficiency cogeneration, CCGT technology and woody biomass technology. The remainder of thermal energy would be generated in natural gas- or woody-biomass-fuelled peak boilers, depending on the scenario. The newly built high-efficiency cogeneration plants for the Maribor case would have a significantly higher installed capacity, particularly in the alternative scenario, which is based on the CCGT. This results in higher maintenance costs and increased fuel consumption. The reason for the extremely negative economic net present value is the fact that currently in Maribor, heat is produced in plants with relatively high efficiency. Investment in new units with a higher degree of efficiency cannot be outweighed by additional savings and benefits resulting from new cogeneration plants.

Currently, about 95% of the total heat demand in Ljubljana is met by coal- and natural-gas-powered cogeneration, while in alternative scenarios, approximately 80% of heat demand would be met by high-efficiency cogeneration. The remainder of thermal energy would be generated in natural-gas- or woody-biomass-fuelled peak boilers, depending on the scenario. The newly built high-efficiency cogeneration plants for the Ljubljana case would have a significantly higher installed capacity, particularly in the alternative scenario, which is based on the CCGT. This results in higher maintenance costs and increased fuel consumption.

The revenue generated in alternative scenarios comes from the sale of additional electricity produced and savings in CO_2 emissions. Revenue generated from the sale of additional electricity produced and reduced CO_2 emissions are not sufficient to justify the initial investment and the new fuel costs and plant maintenance costs. In addition, coal is extremely cost competitive compared to other fuels, resulting in significantly higher fuel costs in the case of an alternative scenario.

The conclusion that high-efficiency cogeneration is not economically justified must be seen in the context of input data and the current situation in Maribor and Ljubljana. The existing production plants in the two observed cities are relatively efficient, therefore, the benefit from using high-efficiency cogeneration is not sufficient to cover the investment costs. It is expected that if individual plants were to be replaced, the conclusion would be different.

The cost-benefit analysis also shows that the installation of micro-cogeneration plants is not economically viable from a social point of view, because benefits for society are much lower than the associated costs. It should be noted here that calculations were made based on data for reference buildings and that this conclusion applies only to reference values in buildings. In some cases, it is possible to come to a different conclusion due to varying technical characteristics of buildings. However, given the lack of detailed information, it cannot be concluded whether or not investment in micro-cogeneration plants will be justified.

1. DESCRIPTION OF HEATING AND COOLING DEMAND

1.1 END-USE ENERGY CONSUMPTION MODEL FOR HEATING AND COOLING IN THE REPUBLIC OF SLOVENIA

The consumption of energy for heating and cooling is based on the modelling of total end-use energy consumption in the baseline year, and selected indicators describing consumer habits and needs, characteristics of facilities, technology to be used for a specific purpose (heating, cooking, cooling), and other parameters. For the purpose of this study, we performed an analysis of energy consumption for heating and cooling in households, services and industry. Due to data availability, 2014 was chosen as the baseline year. One objective of this study was to divide the total energy consumption calculated for the entire territory of the Republic of Slovenia into lower administrative units, namely statistical regions and municipalities. All analyses and models that have been developed and used are based on the principles laid down by the EU (*Regulation (EC) No 1099/2008 on energy statistics*) and other international standards and recommendations relating to energy statistics, energy balances and energy indicators.

The model used has been developed specifically for the Republic of Slovenia and is based on the analysis of usable energy consumption. Usable energy consumption refers to *end-use* consumption, which is the amount of energy that is actually used for a certain purpose (e.g. heating, cooling, cooking, etc.). *End-use* consumption is calculated in such a way that the final consumption of energy delivered to the end user/technology is reduced by the loss incurred in the process of heat production or space cooling, taking into account the energy efficiency of the device. Energy efficiency of devices/technologies used for heating and cooling is taken from the recommendations adopted by international organisations.

The total end-use energy consumption in Slovenia in 2014 came in at 4 604 000 toe, the industry accounting for 26.7%, transport for 39.5%, households for 22.5%, services for 9.47% and agriculture for 1%. According to energy balances in the period from 2000 to 2014, the total end-use energy consumption grew in line with the average growth rate of 0.28%. At the same time, consumption increased most in the transport sector – by 2.8%, while the industrial sector and households together with other consumers recorded a negative growth rate of –1.02% and –0.56%, respectively.

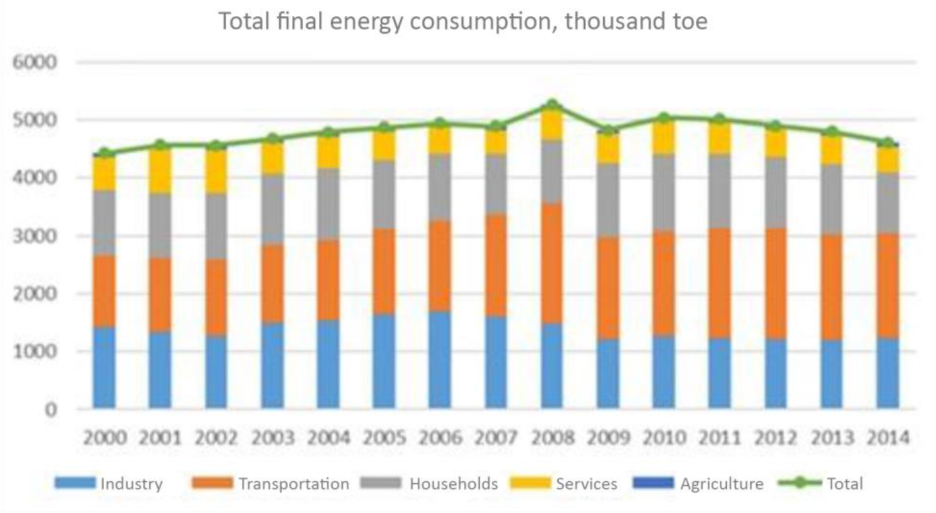

Figure 1: Total end-use energy consumption by sector, 2000–2014

Total consumption of certain forms of energy is depicted in the following diagram, and shows the total consumption in industry, households, services and agriculture. Transport is not included, because it is not the subject of this study. In 2014, total energy consumption in these sectors amounted to 2.8 million toe. Following 2000 it was declining at an average rate of –0.86%. Electricity is the most widely used energy product form and accounts for about 38% of total consumption. It is followed by firewood and other forms of renewable energy at 22.3%, natural gas at 18%, petroleum products at 13.7%, while all other forms of energy combined account for less than 10% of total consumption.

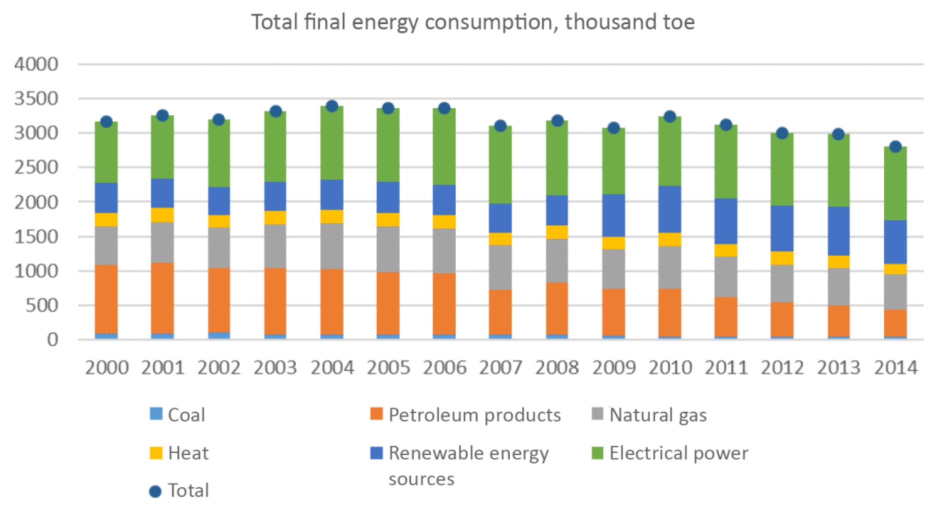

Figure 2: Total end-use energy consumption in industry, households, services and agriculture, 2000–2014

1.2 GROUNDS AND INFORMATION SOURCES

Preparation and implementation of *end-use* heating and cooling energy consumption modelling is a very complex task involving a number of complex forms of energy and other related data, especially for sectors such as households, services and industry.

In the preparatory phase of the project, data sources were identified, and then cooperation with relevant institutions was established in order to structure data into a form suitable for this research. The main sources of data used for this chapter of the study are the following:

- Statistical Office of the Republic of Slovenia (SURS):
  - number of population, households and housing in Slovenia, statistical regions and municipalities, 2011 and 2015;
  - statistical energy balances, 2010–2015;
  - results of the survey on energy consumption in households in 2014 (including *'Microdata'*);
  - detailed statistics on energy consumption in industry by regions and NACE;
  - production of electricity and heat by autoproducers by region and Standard Classification of Activities (Standardna klasifikacija dejavnosti –SKD);
  - economically active population by municipality where they work and by activity (SKD 2008) for 2011 and 2015;
  - time sequences of the gross domestic product structured in accordance with the NACE.
- Ministry of Infrastructure (MZI):
  - long-term strategy to promote investments in energy renovation of buildings, October 2015;
  - Action plan for nearly zero-energy buildings for the period up to 2020 (AP nZEB), April 2015;
  - long-term energy balances for Slovenia until 2030 and an expert basis for setting national energy goals, 2014; and
  - energy performance certificates.
- Ministry of the Environment and Spatial Planning (MOP), Surveying and Mapping Authority of the Republic of Slovenia (GURS):
  - building cadastre.

The data sources listed are extremely important for energy consumption modelling. Some of the above may be specifically highlighted.

Statistical energy balances describe the entire energy flows in the country, including a detailed end-use energy consumption by energy product forms and end-use sectors. This is the basic framework for further energy analysis in Slovenia.

The long-term strategy to promote investments in energy renovation of buildings (DP EPS) was implemented in October 2015. It shows the state of the housing stock in the Republic of Slovenia, and defines the objective of energy renovation of buildings. It is planned that this strategy will reduce energy consumption by 15% by 2020, and by 30% by 2030 compared to consumption in 2005, due to the renovation of approximately 26 million m^2 of residential and non-residential buildings. The projected rate of residential building renovation (dwelling and multi-dwelling) is 2% per year, and 3% per year for publicly owned buildings. In the period 2014–2030, the strategy envisages the renovation of 16.9 million m^2 of buildings in the residential sector, 3.1 million m^2 of buildings in the public sector, and 4.9 million m^2 of buildings in the wider service sector. The total area of buildings in which services are performed amounted to 25.7 million m^2 in 2014. The strategy also describes parameters related to reference buildings in the residential sector, public sector and other non-residential buildings. All guidelines from the strategy are included in the models for planning the energy consumption for heating and cooling in the service sector. The data taken from this study were used to model the heat consumption in the whole territory of the Republic of Slovenia.

The action plan for nearly zero-energy buildings (AP nZEB) was created in April 2015. It covers the period until 2020 and provides the conditions for nearly zero-energy buildings – one-dwelling, multi-dwelling and non-residential buildings. The action plan provides information on planned new constructions, building types and their characteristics for the period from 2016 to 2020. This information was used as input data for the model predicting future energy demand for heating and cooling in Slovenia. According to the AP nZEB, the thermal energy required for heating amounts to 25 kWh/m^2 per year.

Energy performance certificates, which are available for certain buildings in Slovenia, are used to verify energy consumption indicators, particularly in the service sector, and are compared to norms shown in studies related to reference buildings. Since the current MZI does not have organised databases that could be used for data investigation, we randomly selected 100 energy performance certificates from the database available on the official website of the MZI. Information taken from the certificate is as follows: year of construction, usable area, annual consumption of all forms of energy, heating mode, the structure of energy products used for heating, the method of hot water preparation, the structure of energy products used for water heating, cooling mode and annual consumption of electricity for electrical appliances and lighting.

Since the objective of the study is to estimate consumption at municipal level, the models use all the data published by the SURS that refer to the statistics of population, households and industry. When analysing households, it was particularly important to know the floor area of housing units and the heating mode at municipal level.

Survey on energy consumption in households also provides a lot of additional information on types of residential buildings, technologies used for heating, forms of energy used for specific purposes, and more. In addition, the survey contains data on the total floor area of residential buildings, heated and cooled surfaces and other energy consumption indicators. Furthermore, for each household from the sample, data on total end-use consumption of all forms of energy was collected. For the purpose of this study, the SURS allowed the use of *'micro data'*, but owing to data protection it was agreed that only data grouped at the level of statistical regions was to be displayed. In the consumption analysis, the survey was used as the main information source to calculate the norms of energy consumption.

For the purpose of the analysis of thermal energy and cooling energy consumption in the industrial sector, the SURS prepared detailed information on the use of all forms of energy in individual industries within the industrial sector. Unfortunately, due to the protection of individual data, the SURS could not deliver data for individual industries, but rather only those grouped at the level of statistical regions.

Building cadastre is a basic record of buildings. It is connected with the land cadastre and the land registry, and contains detailed information about buildings and parts of buildings used to demonstrate energy consumption. The building cadastre contains information on the function of a building as required by models for projecting future heating and cooling demand.

Local energy concepts (LECs) should be available as a key source of information for describing energy demand at municipal level. By 20 May 2014, 209 municipalities (out of 212) have adopted LECs. This included 99.9% of Slovenia's population (according to AP URE 2020). LECs are considered an important source of information based on which one can get a picture about the energy situation in each municipality and plans for its future energy development. Unfortunately, different time frames when creating LECs, different data sources and methodological approaches to energy consumption modelling by sector, the lack of precision in individual sectors regarding direct energy consumption, and shortcomings of *up-to-date* reports on the implementation of LECs have made the data collected from them insufficient for the requirements of this document. For the purpose of this study, only LECs created after 2011 have been analysed. In total, only 87 of them were collected and analysed, because the other (older) ones are unsuitable – both regarding content and availability of data – to be used as the basis for calculations that are part of the present study.

In addition to the above information sources, other data were also used to prepare the expert basis, e.g. the distribution of thermal energy and natural gas by municipality and region.

2. FORECAST OF THE CHANGING HEATING AND COOLING DEMAND

2.1 PROJECTIONS OF MACROECONOMIC FACTORS

For the purposes of this study, projections for heat consumption by 2035 have been made based on assumptions regarding changes in the main macroeconomic parameters in this period, i.e. gross domestic product (GDP) and population.

It should be noted that the models used in the study required that all indicators and assumptions be displayed at the lower level of administrative units, and not only at the level of the Republic of Slovenia.

Changes in GDP, structured in accordance with the *NACE Rev. 2*[1] in the period from 1995 to 2015, are shown below (Figure 3) and are taken from the SURS database. Values from 2016 to 2035 relate to projections of changes in GDP or economic growth of the Republic of Slovenia, and are calculated based on projected growth rates of Slovenian GDP, which are taken from the European Commission report titled *'The 2015 Ageing Report: Economic and budgetary projections for the 28 EU Member States (2013–2060)'.* It is expected that by 2020, GDP will grow at an average rate of 1.9%, then in the period until 2025, growth will decrease to 1.5%, while in the period from 2025 to 2035, the average GDP growth rate will be 1.4%.

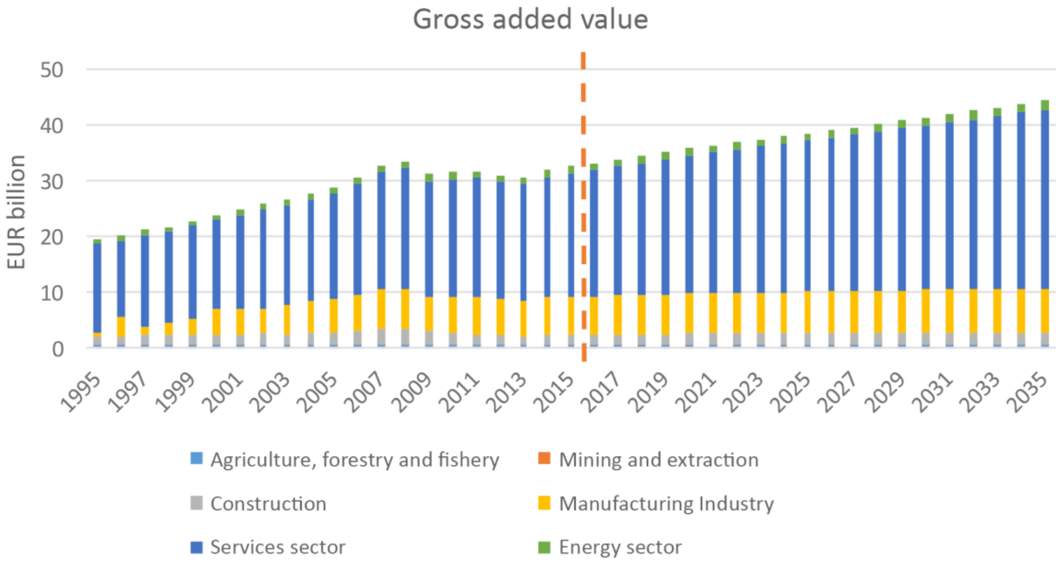

Figure 3: Changes in gross domestic product in the Republic of Slovenia (1995–2035)

The number of inhabitants in a country is one of the main indicators of energy consumption, and with the help of this macroeconomic indicator, a number of indicators and intensities are calculated. The following figure (Figure 4) shows the population in the baseline year (2014) and the following year (2015), and was issued by SORS, whereas the projection for the period up to 2035 is based on the official Eurostat projections, which show changes in the population by gender and age in the period from 2013 to 2080 by statistical region in all EU Member States. In accordance with the above sources, the population of the Republic of Slovenia in 2015 stood at 2.063 million inhabitants, and it is expected that by 2025 the population will grow to 2.088 million, then this number will gradually decrease and by 2035, the Republic Slovenia will have around 2 078 000 inhabitants.

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[1] *NACE Rev. 2 – Statistical classification of economic activities in the European Community*

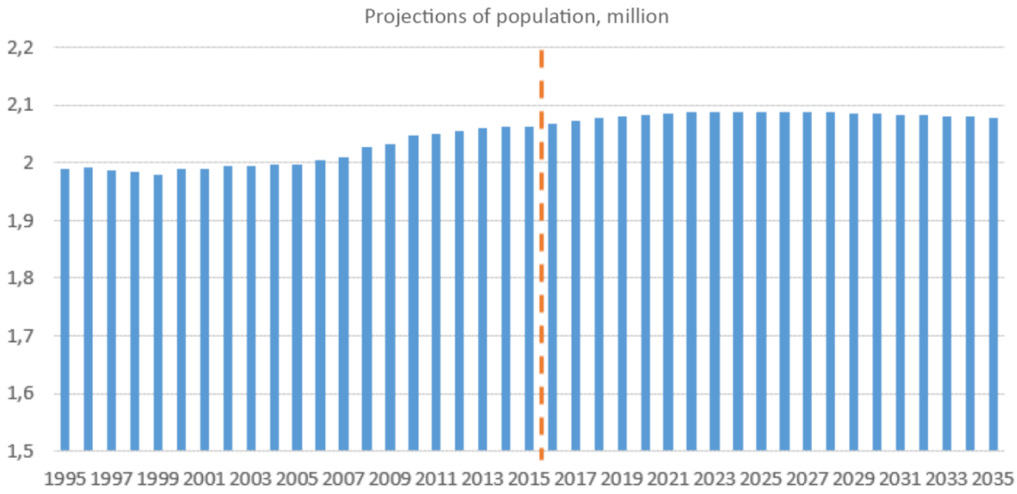

Figure 4: Projection of population by 2035

In addition to the analysis of the total population, we made another analysis of population by statistical region based on population estimates by municipality. Due to the fact that already in 2015, official Eurostat projections differ from the actual situation, according to official data from the SURS, the baseline year is modelled in accordance with the actual data, while we adopted the growth and reduction rates from official projections and applied them to the reference year.

2.2 PROJECTIONS OF ENERGY CONSUMPTION IN HOUSEHOLDS

When analysing future demand for heating (heating, hot water) and cooling, it is essential to anticipate and assess the size of the main factors for future energy consumption in households, i.e. number of households, household size (number of people in a household), floor area of a household, heated floor area, and other. The SURS publishes very detailed statistics of guidelines at national level as well as at the level of administrative units – statistical regions and municipalities. According to the statistical report, in 2014, the total number of housing units for permanent residence amounted to 654 000, while the average size of residential units was 97 m². The model estimates that the average size of housing units will gradually increase, and will amount to about 110 m² in 2035. Furthermore, the model is structured so that one can specifically observe *end-use* energy consumption in housing units that are connected to district heating systems, have their own district heating systems, or room heating.

Given that the results of the latest survey on energy consumption in households in the Republic of Slovenia has shown that the share of energy consumption for cooling accounts for 0.3% of total end-use energy consumption, this form of energy consumption is neglected in further analyses that are part of this study.

The entire display of thermal energy consumption in households is in line with the guidelines defined in the *AP nZEB* for the period up to 2020, and in the *DP EPS*. In accordance with the latter strategy, a renovation of residential buildings at a rate of 2% per year is planned, one-dwelling buildings are to be renovated at a rate of 1.75%, and multi-dwelling buildings at a rate of 2.5%. Expected total area of renovated residential buildings by 2030 is around 17 million m². *AP nZEB* envisages the construction of approximately 2.4 million m² zero-energy residential buildings by 2020, and the same pace of construction is planned in this study by 2035. In 2014, it was estimated that approximately 71% of residential buildings were built before 1985, and that about 65% of the buildings have not been renovated, which makes for a huge potential for renovation. It is assumed that by 2035, not all buildings built before 1985 will have been renovated. The model identifies six additional categories of residential buildings grouped according to the following classification:

- residential buildings built before 1985 – renovated after 2015
- residential buildings built before 1985 – renovated before 2015
- residential buildings built before 1985 – not renovated
- residential buildings built between 1985 and 2015
- residential buildings built after 2015, new construction – zero-energy buildings
- one-dwelling buildings built after 2015, new construction – other.

The figure below (Figure 5) shows the projected growth of residential areas in the household sector by 2035. It is expected that in 2035, the total area of residential buildings in the Republic of Slovenia will stand at around 73.8 million m^2.

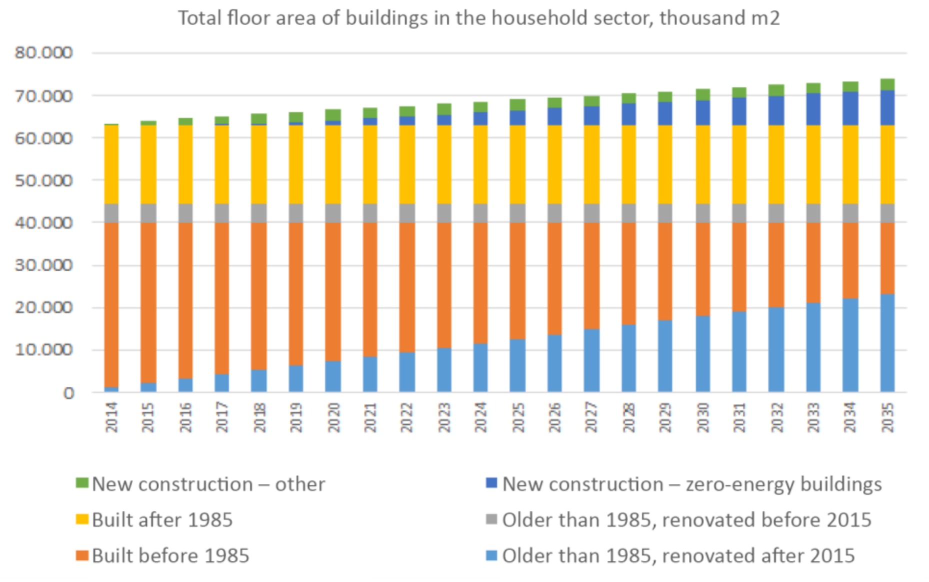

Figure 5: Projections of floor areas of buildings in the household sector by 2035

Total usable heat consumption for space heating and hot water is calculated based on established norms for space heating per m² of heated surface, and norms for hot water consumption per household member. In 2014, the average annual consumption of energy for heating households amounted to around 150 kWh/m^2 of heated area, while the average consumption of a household member amounted to around 720 kWh per year. Heating norms are climatically changed because of significant differences in the number of degree days in 2014, and the average degree days in the thirty-year period.

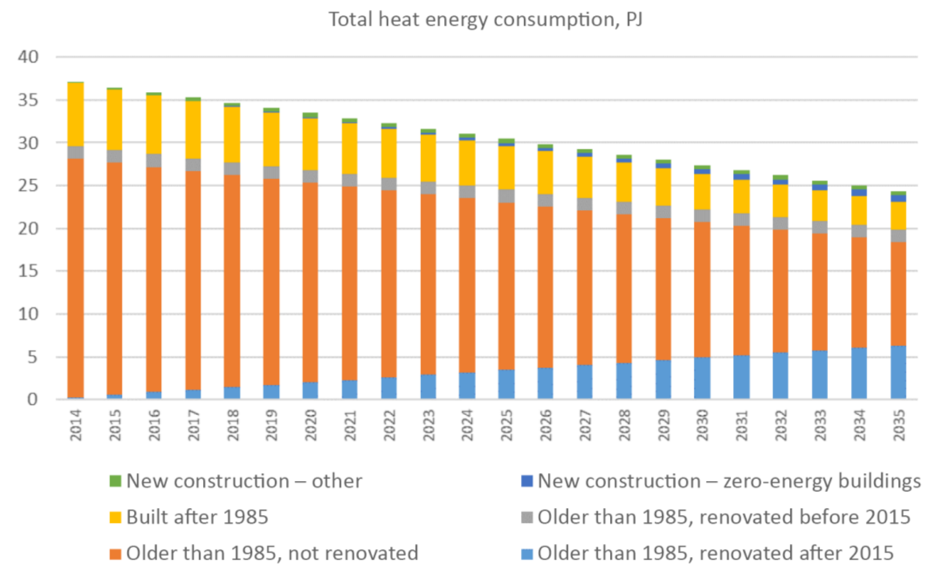

Figure 6: Projections of thermal energy consumption in households by 2035

In the household sector, it is expected that with the implementation of the objectives identified in the *DS EPS* and *AP nZEB*, usable thermal energy consumption will steadily decrease – from 37 PJ in 2014 to approximately 24 PJ in 2035.

The potential for cogeneration in households encompasses all households that are not connected to district heating systems. Such households account for around 86% of the total number of households.

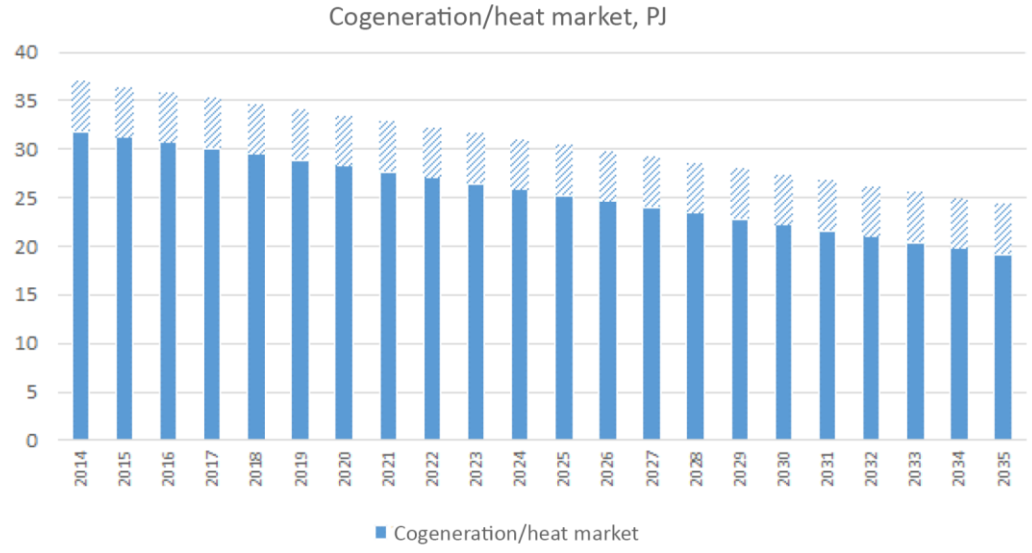

Figure 7: Projections of thermal energy potential in households by 2035

The total heat potential for cogeneration in the household sector in 2014 is estimated at 31.8 PJ. Due to the above factors, it will decrease to 19 PJ by 2035.

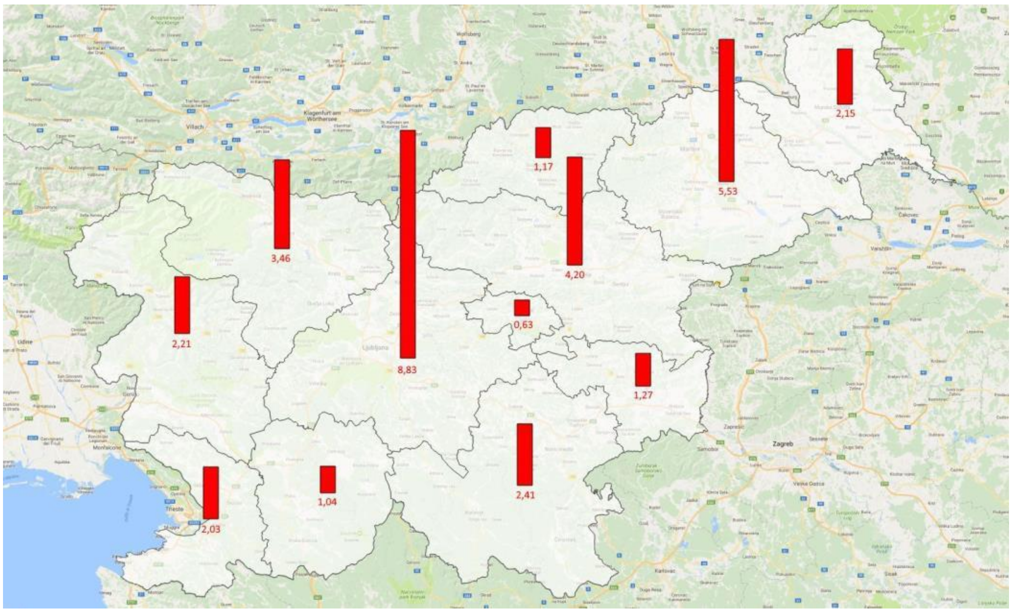

Figure 8: Thermal energy demand in households by temperature level and statistical region

2.3 PROJECTIONS OF ENERGY CONSUMPTION IN THE SERVICE SECTOR

Characteristics of energy consumption in the service sector are the least known of all the sectors with end-use energy consumption, because there is no related research performed systematically in Slovenia. In addition, the SURS determines the end-use energy consumption in its annual energy balance as the difference between total end-use energy consumption and use by individual end-user sector, i.e. households, agriculture, industry and transport. The consumption is determined based on official surveys. Total energy consumption in the service sector is considered as the energy consumption for heating and cooling, and other non-heating purposes. It is structured in such a way that the following sub-sectors of consumption can be identified: tourism and hospitality, public administration, trade, education, health, and other service sectors. This structure certainly allows for the consolidation of the consumption potential and savings in public and other buildings in the Republic of Slovenia.

For the purpose of this study, the assessment of heating and cooling energy consumption is particularly valuable, as it represents the potential for new cogeneration. The basic parameters for calculating energy consumption by sector are floor areas of buildings where certain services are performed, and the energy consumption norm.

Building floor areas for each activity are taken from the real estate register being developed by the MOP and the GURS. According to data from the register, the total floor area of buildings in the service sector was about 26 million m^2 in 2012, which makes for an average of about 12.5 m^2 per capita, placing Slovenia among the EU countries with a higher average area per capita, or rather a more intensive service sector. When looking at the floor areas of buildings, it is particularly interesting that public buildings account for approximately 25% of the total area in the service sector, while the remaining area belongs to other services. The *'Other'* sector has the largest share, accounting for about 38% of the total area, and it is expected that this sector will very likely develop at the fastest pace.

The floor area of buildings in the service sector in Slovenia is shown in the diagram below (Figure 9).

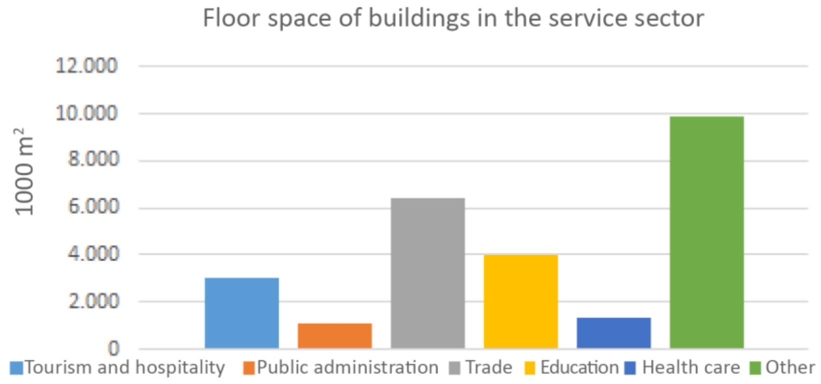

Figure 9: Floor space of buildings in the service sector in 2012

Norms for thermal and cooling energy consumption per unit of floor area are taken from two sources: the norms for energy consumption for non-heating purposes and cooling are taken from a survey on energy consumption in the service sector commissioned by the Republic of Croatia in 2013. With the help of these norms, the heat consumption in Slovenia's service sector is calculated as the difference between energy consumption for non-heating purposes and cooling energy consumption. To verify the acquired norms for heat consumption, we analysed energy performance certificates of 200 randomly selected buildings (30 per each service sector category on average). The analysis of energy performance certificates has shown that the overall energy consumption norm is about 209 kWh/m² of usable area, while electricity consumption amounts to about 110 kWh/m² of usable area. Energy performance certificates have, inter alia, confirmed the doubts related to the consumption of liquefied petroleum gas (LPG) in the service sector. This is because the energy balance of the Republic of Slovenia does not record the consumption of LPG in services, and shows that unclassified consumption accounts for a certain part – about 9% – of the total end-use consumption of LPG. Energy performance certificates show that, nonetheless, a part of this unclassified consumption needs to be included in the service sector. In the aforementioned sample of buildings with energy performance certificates, we found 19 facilities that use LPG (mainly for heating), which accounts for a little less than 10% of the sample.

In order to determine the future potential of thermal and cooling energy consumption, it is necessary to assess the growth of floor areas in the service sector. To this end, we analysed the projections of future growth in population and the number of people employed in the service sector. Projections of surfaces are modelled for each service sub-sector, as well as according to the planned renovation and construction of new buildings, which is described in *DV EPS* and *AP nZEB* for the period up to 2020.

According to these documents, about 61% of non-residential buildings were built before 1985, which makes for a huge potential for renovation. The potential for renovation of buildings until 2035 is shown in the figure below (Figure 10).

It is estimated that the total floor area of buildings in the service sector will increase slightly until 2035 when it will stand at around 30 million m², or about 14.5 m² per capita. The models also take into account the number of people employed in the service sector.

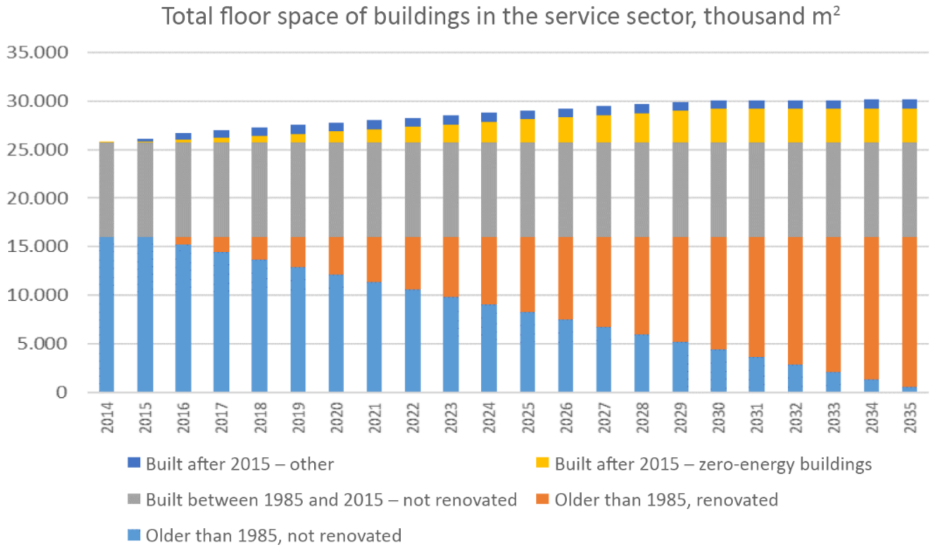

Figure 10: Projected floor areas of buildings in the service sector by 2035

The model that divides the total end-use energy consumption and usable energy consumption into 'end-use' consumption includes all of the above facts. The results have shown that the average thermal energy consumption in 2014, after correcting for climate, amounted to approximately 104 kWh/m^2, including heating, cooking and hot water. On the other hand, the consumption of energy for non-heating purposes, i.e. lighting, operation of electrical equipment and cooling, was approximately 120 kWh/m^2. Electricity consumption for cooling is modelled separately, and stands at approximately 16.6 kWh/m^2. All of the above norms are modelled separately for buildings in the public sector and other sectors, for buildings categorised by year of construction and having potential for renovation.

According to the energy balance and the model, approximately 23% of heat demand is met by district heating systems, while the remaining part is met by other energy sources, mainly by fuel oil and natural gas. This is why energy sources are considered potential sources for high-efficiency cogeneration.

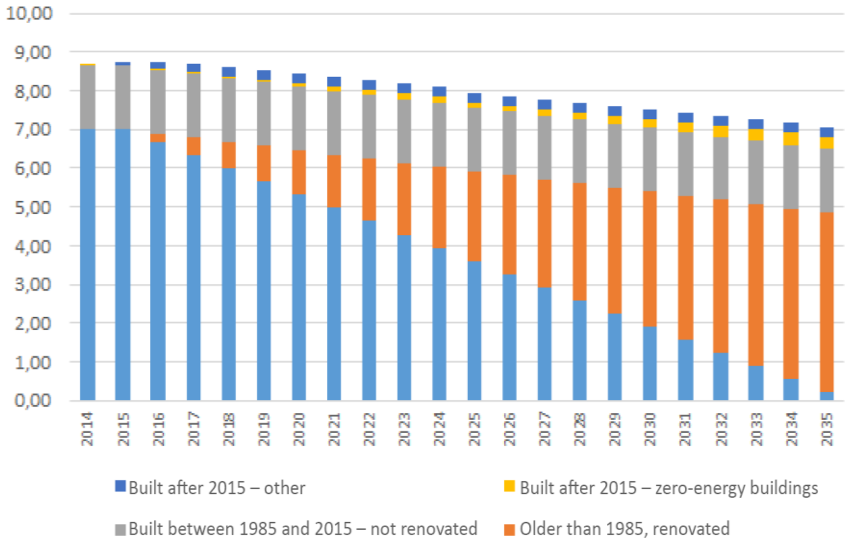

Figure 11: Projections of thermal energy consumption in the service sector until 2035

Potential, or rather, the cogeneration market is established based on the existing prevalence of district heating systems and their share in the total thermal energy consumption in the service sector. The cogeneration market covers the consumption of all energy products except heat from district heating systems. It is considered that the entire projected consumption in new buildings represents a potential for new cogeneration plants. In 2014, the total heat potential for cogeneration stood at approximately 6.66 PJ, while in 2035, it will amount to approximately 5.07 PJ.

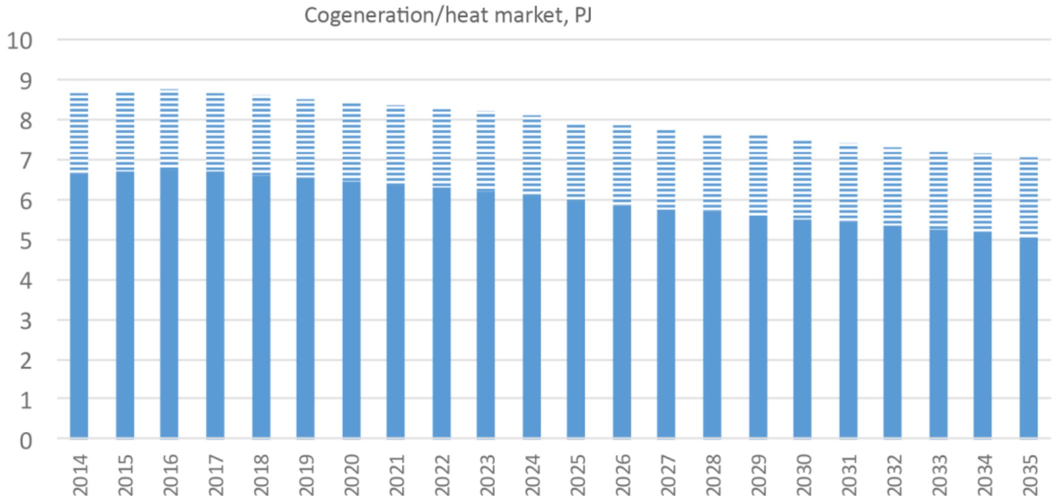

Figure 12: Projections of thermal energy potentials in the service sector until 2035

Total cooling energy consumption has been modelled separately, and special attention has been put to actually cooled areas in buildings in which services are performed. By analysing the survey on energy consumption in the service sector in Croatia and energy certificates in Slovenia, we found that the proportion of cooled areas is approximately 50% of the total floor area. The analysis of future cooling energy potentials gives rise to the prediction that by 2035, the proportion of the total cooled area will not increase significantly, and it is believed that the efficiency of appliances and cooling devices will increase steadily. It is also assumed that there is potential for cogeneration in buildings that are not connected to district heating systems.

In 2014, the total cooling potential amounted to 0.6 PJ, and by 2035 it will have dropped to 0.45 PJ. Projections of cooling energy potential in the service sector are related to electricity and are depicted in the figure below (Figure 13).

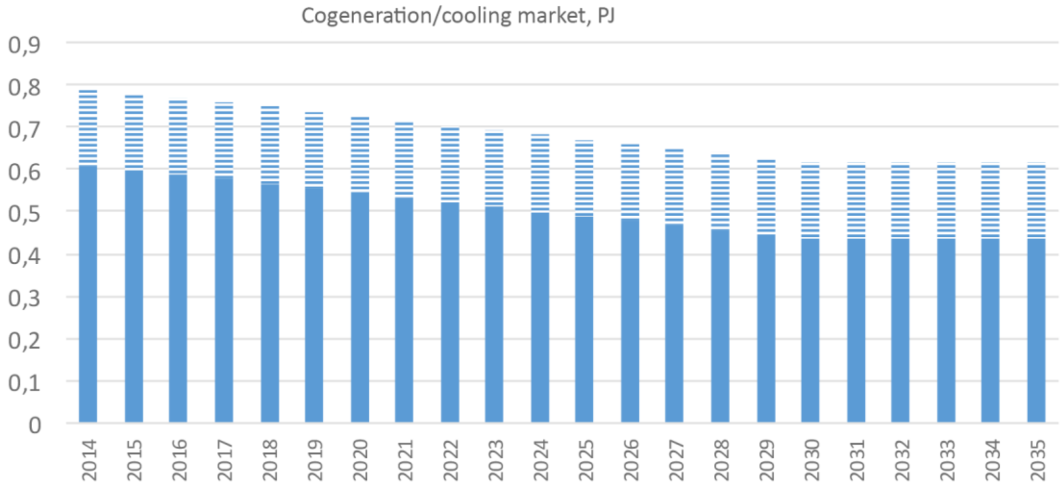

Figure 13: Projections of cooling energy potentials in the service sector until 2035

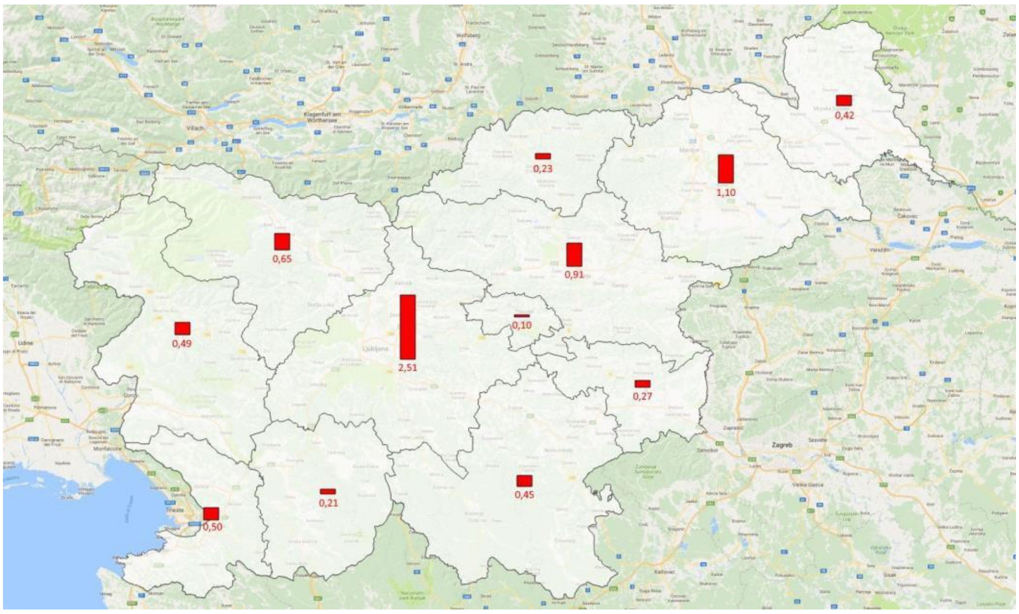

Figure 14: Thermal energy demand in the service sector by statistical region

2.4 PROJECTIONS OF ENERGY CONSUMPTION IN INDUSTRY

Given the fact that industrial plants often have very specific requirements for the heat parameters used in the process, the heat required is divided into high-temperature heat, which comes exclusively from direct combustion of various energy products, and low- and medium-temperature heat, which is produced in a boiler room or a heating plant, and is then used in the technological process, or is produced by direct incineration.

This differentiation is also important in terms of assessing the possibility of meeting heat demand in the industry by using a share of cogeneration. It is important to note here that there is room for efficient heating and cooling mostly at low- and medium-temperature heat levels.

The consumption of low- and medium-temperature heat in industry is calculated and modelled by analysing all energy product consumption in industrial plants, where it is believed that up to 15% of the total electricity consumed is used to satisfy the heat demand.

Low- and medium-temperature heat includes heat generated in boiler rooms and heating plants within an industrial plant, and heat from public boiler rooms and cogeneration plants.

To analyse energy consumption in industry and make projections for the period up to 2035, we used data describing the industrial sector and allowing for modelling of energy consumption allocation at lower administrative units in Slovenia:

- consumption of all forms of energy in industry by statistical region and NACE;
- production volume and gross added value of individual activities, i.e. manufacturing industry branches; and
- temperature levels of usable energy in the industry.

Depending on the specific energy consumption, taking into account the gross added value (GAV), manufacturing industry branches are divided into six groups according to their energy intensity (kWh/EUR). The four most intensive branches of the manufacturing industry have an energy intensity of between 11 kWh/EUR and 3 kWh/EUR of product. The next group comprises activities with an intensity of between 2 kWh/EUR and 0.8 kWh/EUR, and the least energy intensive group includes activities with an energy intensity of less than 0.8 kWh/EUR.

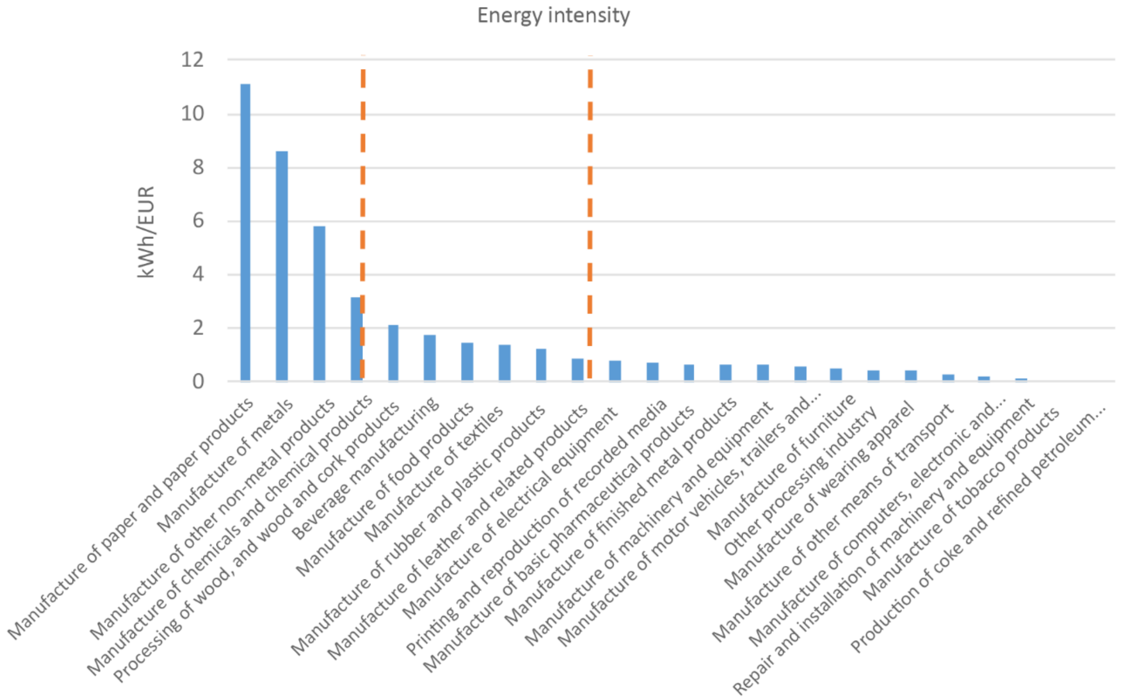

Figure 15: Energy intensity by industrial sub-sector in the Republic of Slovenia

Some activities or groups of activities depending on activity type and energy intensity are very important to consider, because some branches of industry involve specific processes with major or minor potential for improvement at various stages of technological development. It must also be considered that some branches of industry are treated separately according to their contribution to economic development.

The first four groups are the most intensive branches of the processing industry:

- manufacture of paper and paper products
- manufacture of metals
- manufacture of other non-metallic mineral products
- manufacture of chemicals and chemical products. The next group, *'Other industry 1'*, includes the following:
- processing of wood and wood and cork products, except furniture; manufacture of straw and plaited products
- manufacture of food products
- manufacture of textiles
- manufacture of rubber and plastic products
- manufacture of leather and related products.

The last group, *'Other industry 2'*, which is the least energy intensive one, encompasses the following:

- manufacture of electrical equipment
- printing and reproduction of recorded media
- manufacture of basic pharmaceutical products and pharmaceutical preparations
- manufacture of finished metal products
- manufacture of machinery and equipment
- manufacture of motor vehicles, trailers and semi-trailers
- manufacture of furniture
- other processing industries

- manufacture of wearing apparel
- manufacture of other means of transport
- manufacture of computers, electronic and optical products.

Based on the above division, we analysed the historical movement of changes in GAV, and projected the production in individual branches by 2035.

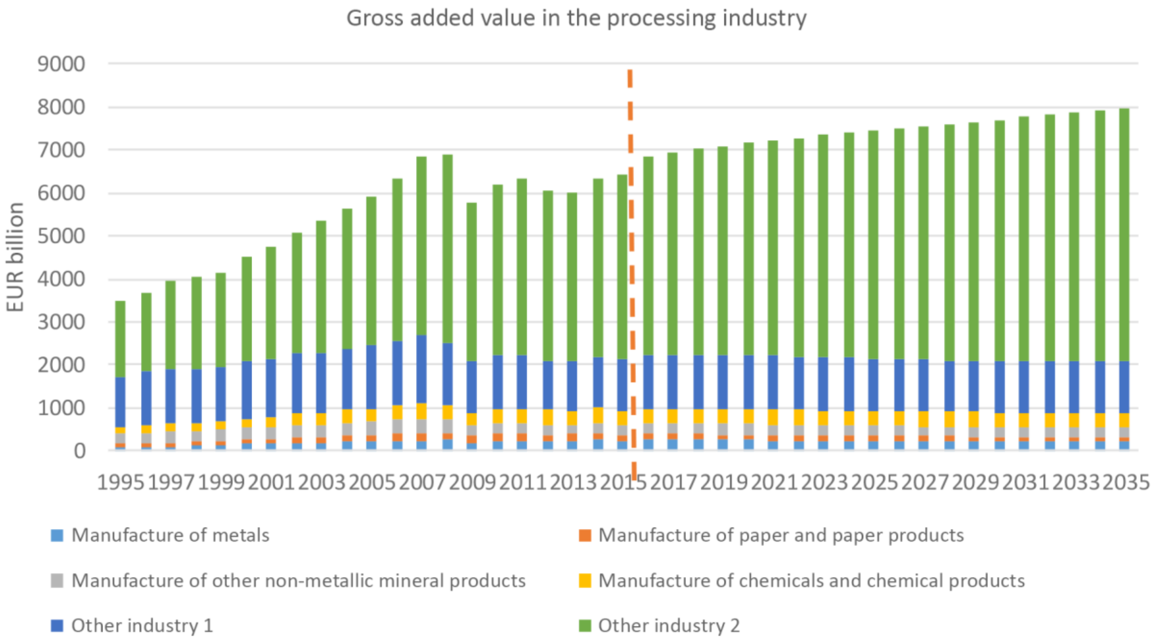

Figure 16: Gross added value in the processing industry in the Republic of Slovenia

Shares of individual processing industry branches are presented in the following figure (Figure 17). In the period until 2035, the downward trend in the proportion of energy-intensive sectors and the growth of energy non-intensive industries are expected to continue, which is reflected in the relative proportions of individual industries in the GDP.

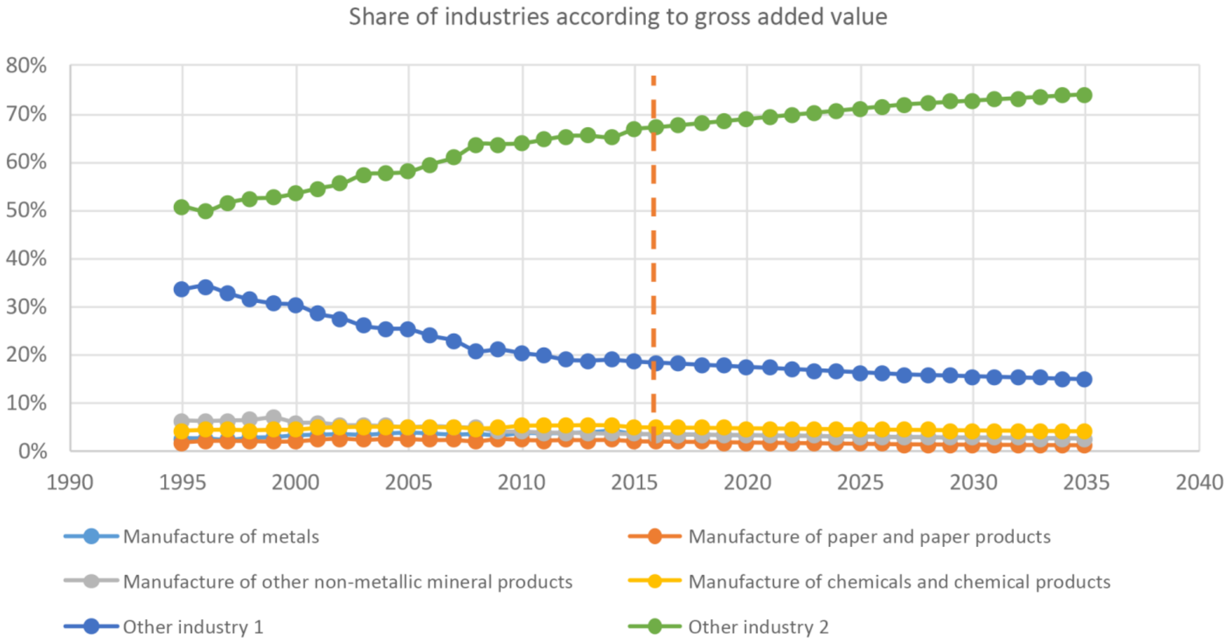

Figure 17: The share of industries in the total gross added value of the processing industry

To make projections of future heat demand in each group within the processing industry, the assumptions about the development of thermal energy are compared to the heat intensity of individual groups of activities in other European Union Member States.

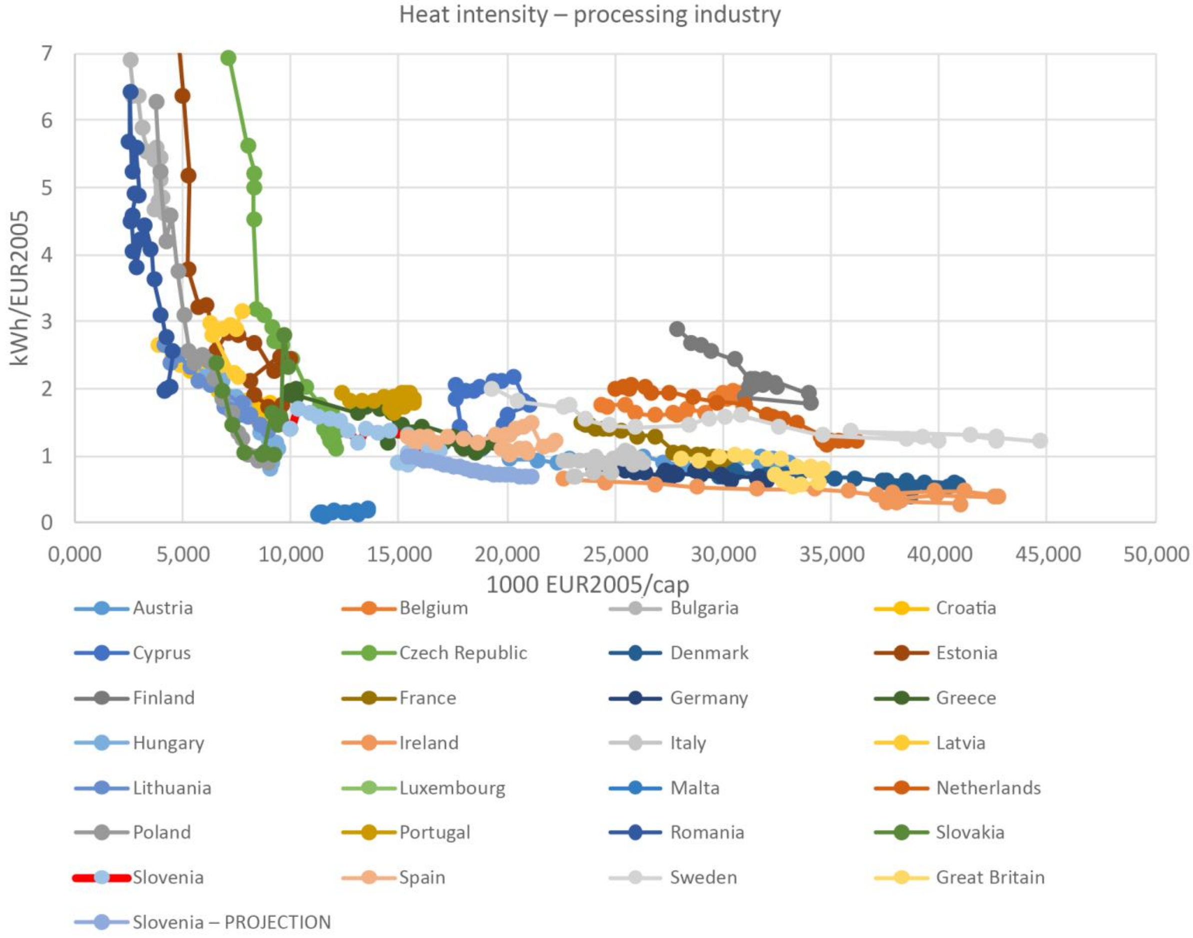

Figure 18: Comparison of heat intensity in the manufacturing industry in the EU Member States

You can see a clear trend of declining energy intensity concurrently with the GDP growth per capita, or rather, increasing efficiency of industrial processes with general economic development. The analysis includes all six groups of activities within the manufacturing industry in Slovenia.

The statistics for Slovenia show the distribution of GDP and energy consumption by activity or in accordance with the NACE up to the second level for all sectors of the economy, including the processing industry.

In order to obtain the basic parameters for projections of energy consumption in the industrial sector, bearing in mind that only official data is data on consumption of energy products by statistical region and by NACE, the distribution of GAV into NACE in Slovenia, and projections of GDP growth in Slovenia, it was necessary to reduce the information available to individual statistical regions and the NACE.

First, it was necessary to calculate the energy intensity of individual activities according to the NACE in Slovenia. Assuming that energy intensity is different in individual industries, but the same across regions, we used data on energy consumption and energy intensity of some of the processing industry branches to estimate the GAV of individual groups according to the NACE in individual statistical regions.

The basic assumption that was used to estimate the share of processing industries in the total GAV in Slovenia by region is that the energy intensity of Slovenia's industry is homogeneous, i.e. that it is the same across regions and in all industry branches.

In the assessment of energy consumption in the industrial sector, it is assumed that each industry branch at national level develops differently and at their own growth rate. To obtain the distribution of consumption by region, we applied individual growth rates separately to each statistical region.

Based on these assumptions, we made an analysis of heat demand in the industrial sector until 2035 for three temperature levels – high-temperature, low-temperature and medium-temperature. The low-temperature level refers to thermal energy at a temperature of 100 °C (212 °F), the medium-temperature level is between 100 and 400 °C (212–752 °F), and the high-temperature level refers to temperatures above 400 °C (752 °F).

High-temperature heat is generated during direct combustion of energy products in an industrial plant, and is therefore not a potential market for providing cogenerated thermal energy. Therefore, the cogenerated thermal energy market comprises only industrial demand for low-temperature and medium-temperature heat.

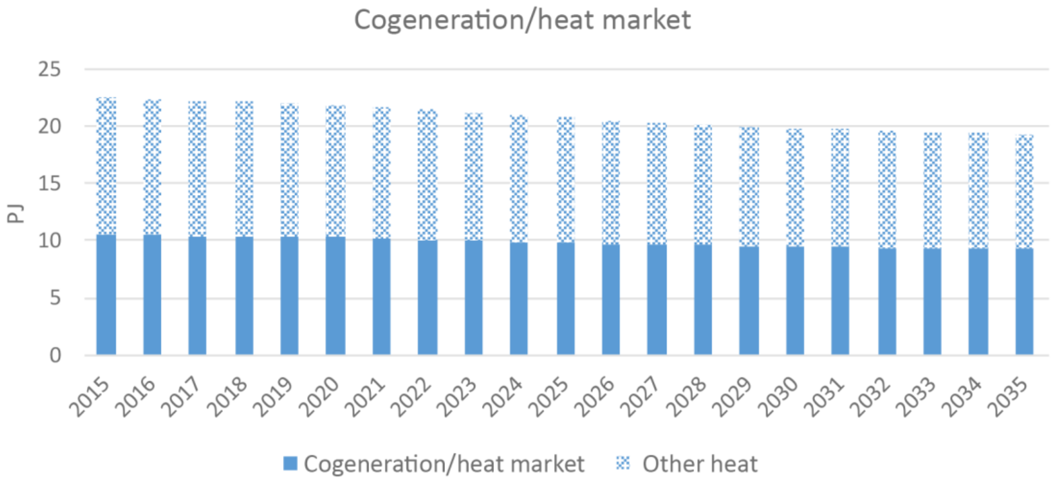

Figure 19: Projections of heat potential in the industrial sector by 2035

At national level, it is expected that the total usable heat needed will fall from 23 PJ in 2015 to 19 PJ in 2035. At the same time, the market for cogeneration plants, i.e. the need for low- and medium-temperature heat, will range between 11 PJ in 2015 and 10 PJ in 2035. For this reason, the cogeneration market will see relative growth from 48% of total usable heat in 2015 to 53% of usable heat in 2035.

The graph (Figure 20) below shows the changing demand for total usable heat by 2035, highlighting the potential for markets that can be satisfied with the production of heat in cogeneration plants, this potential being further distributed by the industrial sector.

Looking at the market potential for cogeneration by the industrial sector, one can see the trends of declining overall share of energy-intensive industries and the growth of less energy-intensive industries (*'Other industry 1'* and *'Other industry 2'*).

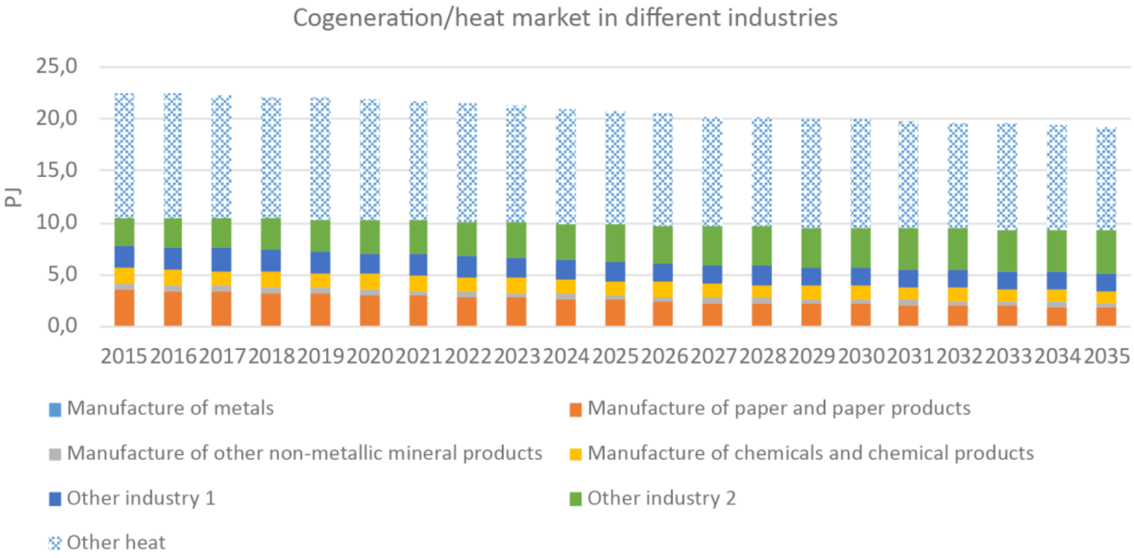

Figure 20: Projections of heat potential in the industrial sector by branch by 2035

In the industrial sector, which represents the market for cogeneration plants, changes in heat demand are very small. The figure below shows the distribution of potentials/markets for cogeneration plants by region for 2015. Detailed projections for the years up to the end of the observation period can be found in the database delivered together with this study.

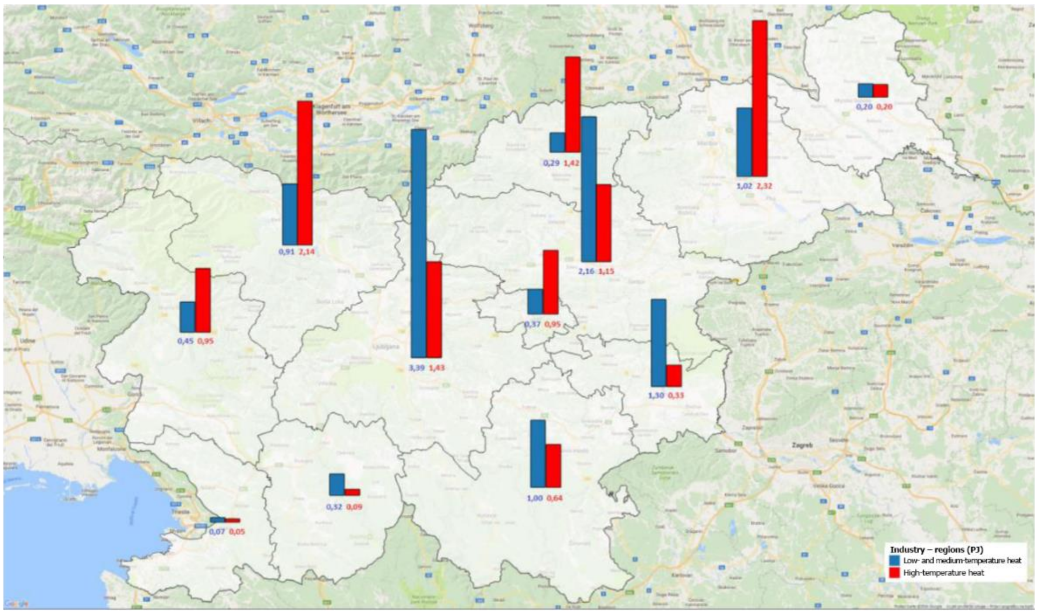

Figure 21: Thermal energy demand in industry by temperature level and statistical region

In the figure below (Figure 21), the blue column shows the demand for low- (<100 °C) and medium-temperature (between 100 and 400 °C) heat, which also represents a potential heat market, which can be satisfied by cogeneration plants, while the red bar indicates the demand for high-temperature (> 400 °C) heat.

Figure 21 shows that in 2015, the statistical regions of Central Slovenia and Savinjska region had the largest market potential for cogeneration in the industrial sector with a demand of 3.39 PJ and 16.2 PJ, respectively. These needs will gradually decrease to 2.7 PJ and 2 PJ by 2035.

3. MAPPING THE REPUBLIC OF SLOVENIA WITH SPATIAL AND ATTRIBUTE DATA

A map showing energy consumption, or rather, projections of heat demand in the territory of the Republic of Slovenia are based on the analyses described in previous chapters. In addition to the results of these analyses, we also used data from spatial-planning documents, databases (adopted by the contracting authority), a list of inhabitants, assumed and adopted industrial and economic trends, and other required information.

The fundamental basis for a comprehensive analysis is the register of buildings / real estate in the Republic of Slovenia.

The contracting authority has delivered several *.txt* files that contain information about all properties in the Republic of Slovenia, such as type, year of construction, being part of a certain plot of land, cadastral municipality, and statistical region, type of heating (if the building is heated), floor area, net internal area, number of independent housing units in a multi-dwelling building, number of floors, year of renovation of the building envelope, and, what is most important for a spatial analysis – geodetic coordinates of the building (an arranged pair of an x-axis and a y-axis).

Given that the contracting authority delivered data for more than 1.8 million entities in different files (i.e. databases), we first performed an analysis of the data obtained, and then merged them into a single database containing basic information (see above) about buildings, i.e. usable units of a building. Due to the amount of data, the analysis was carried out in the *Microsoft Access* program package, in which a single database has been established, and is considered the basis for further analysis.

As already explained in the previous chapters, norms for thermal energy consumption in the form of MJ/m² of usable area are set out for each building type depending on the sector of activity and purpose. These standards are set for the period from 2015 to 2035. Said norms are then applied to each of the buildings belonging to one of the three main sectors (households, service sector, and industry) in such a way that they are multiplied by the corresponding usable area. In this way, each building is assigned a certain amount of usable thermal energy, and thus, spatial distribution of thermal energy in space with an extremely high degree of accuracy is obtained.

Here, it needs to be noted that the industrial sector is not entirely accurate when examined at the level of individual buildings. This is due to the fact that the contracting authority has failed to deliver data on thermal energy consumption for each business entity from the industrial sector, because this information is covered by professional secrecy.

The result of the analysis is a database of all buildings in the Republic of Slovenia with thermal energy consumption. For each building, we have identified the following data, which are also referred to as attributes:

- belonging to a particular sector (households, service sector, and industry)
- purpose of the building
- building type
- belonging to a certain municipality and statistical region
- net internal area
- heat consumption for each year between 2015 and 2035
- arranged pair of coordinates (an x-axis and a y-axis).

The analysis covers a total of 1 107 766 buildings representing heat consumers. Other buildings that are not heat consumers have not been considered. For the spatial analysis of all data, we used *QGIS*, an *open source* package.

For GIS analyses, a reference coordinate system is crucial. Most online maps use a global coordinate system based on the *WGS84* ellipsoid as a reference coordinate system. A degree is a single unit of measurement in this coordinate system. Data received in connection with the register of buildings and utility infrastructure are based on the *EPSG* coordinate system of the Republic of Slovenia – *3912, MGI 1901/Slovene National Grid*.

Before that, the preparation of spatial data in all residential entities in the Republic of Slovenia that are heat consumers is described. In GIS terminology, these data is called *layers*, and they are the first contribution to the spatial analysis of heat consumption. *Feature* refers to a facility within a layer. Taking into account a layer with stippled data in addition to the coordinates, each spotted feature of this layer is joined by a set of data (attributes), including, for example, heated area, facility type, total heat consumption for heating, and other.

The next type of data included in the GIS analysis is a linear data layer, which contains data on utility infrastructure for the distribution of thermal energy and natural gas. This data has been adopted by the contracting authority.

Figure 22 below is a cartographic representation of the aforementioned buildings in the Republic of Slovenia.

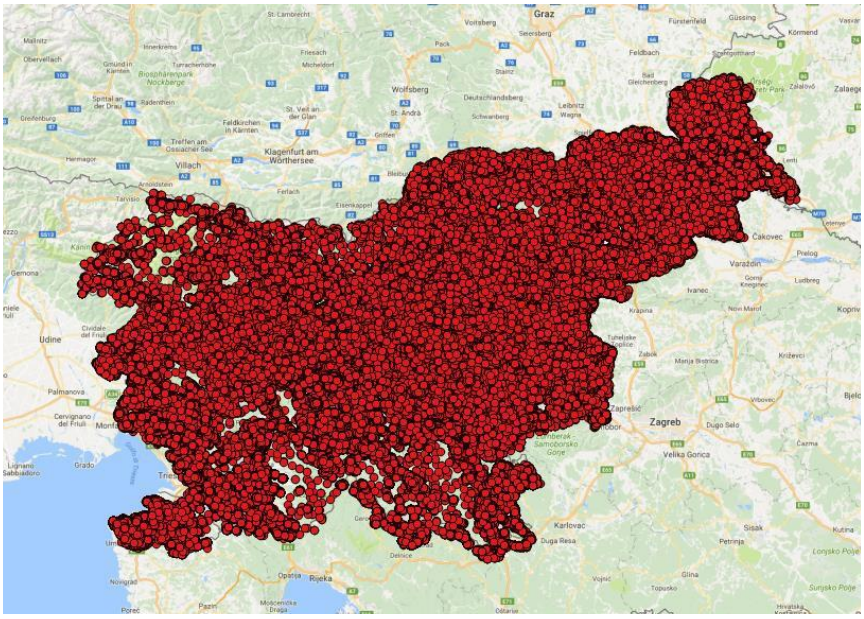

Figure 22: Display of all buildings that are heat consumers in the Republic of Slovenia

Figure 23 below provides a more detailed overview at the level of a single region, and shows heat consumers in the Maribor region.

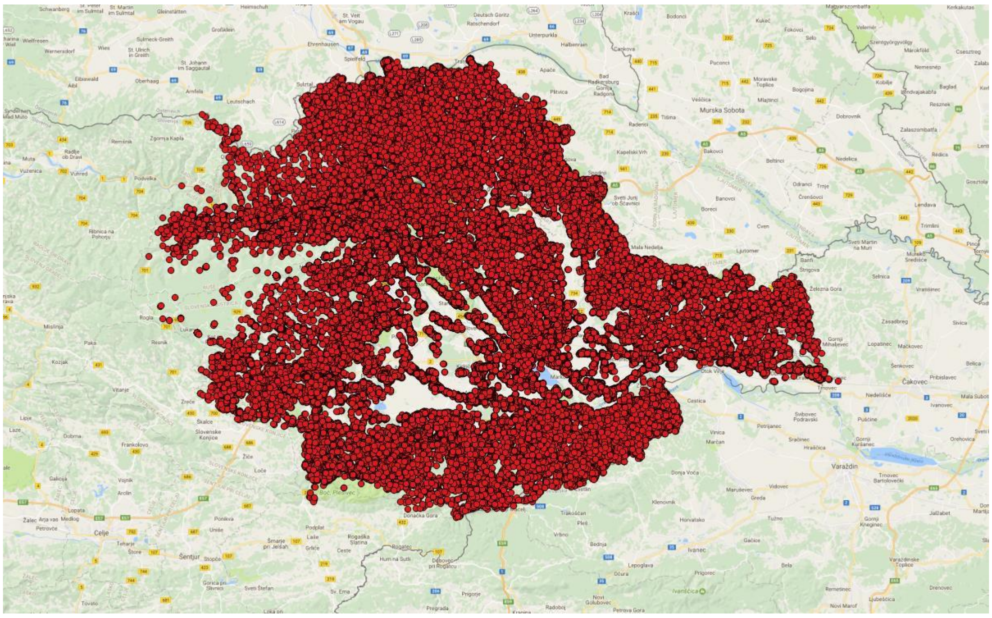

Figure 23: Display of all buildings that are heat consumers in the Maribor region

It is also possible to take into account the heat consumers in a single municipality. Below is an example of the Municipality of Kidričevo (Figure 24).

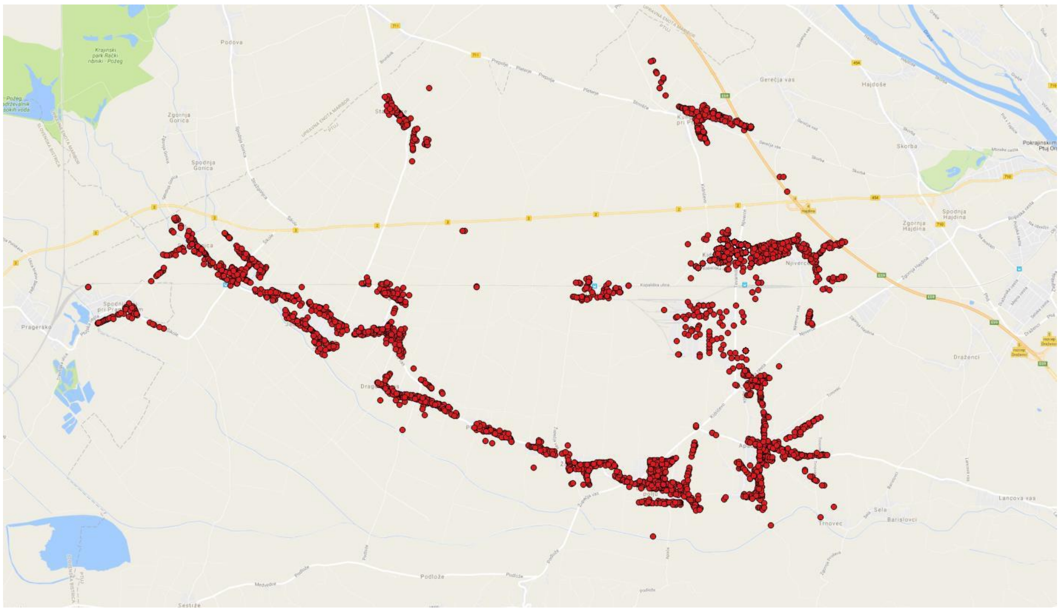

Figure 24: Display of all buildings that are heat consumers in the Municipality of Kidričevo

Data presented so far do not reflect thermal energy consumption. Below are map displays of thermal energy consumption in the Republic of Slovenia as a whole, in the Maribor region, and in the Municipality of Kidričevo. They represent heat atlases, which can be used to identify areas according to their thermal energy consumption. Heat atlases reflect the intensity of thermal energy consumption – red indicates the areas with the highest consumption, while dark purple represents areas with the lowest thermal energy consumption. The displayed intensity of thermal energy consumption in the GIS is relative and depends only on the part of the consumption that is currently displayed. In other words, the thermal energy consumption scale is progressive and varies depending on the part of the area displayed and the heat consumption of the area observed.

The cartographic display of the Municipality of Kidričevo also shows the district heating utility distribution network (in red), and natural gas pipelines (in yellow).

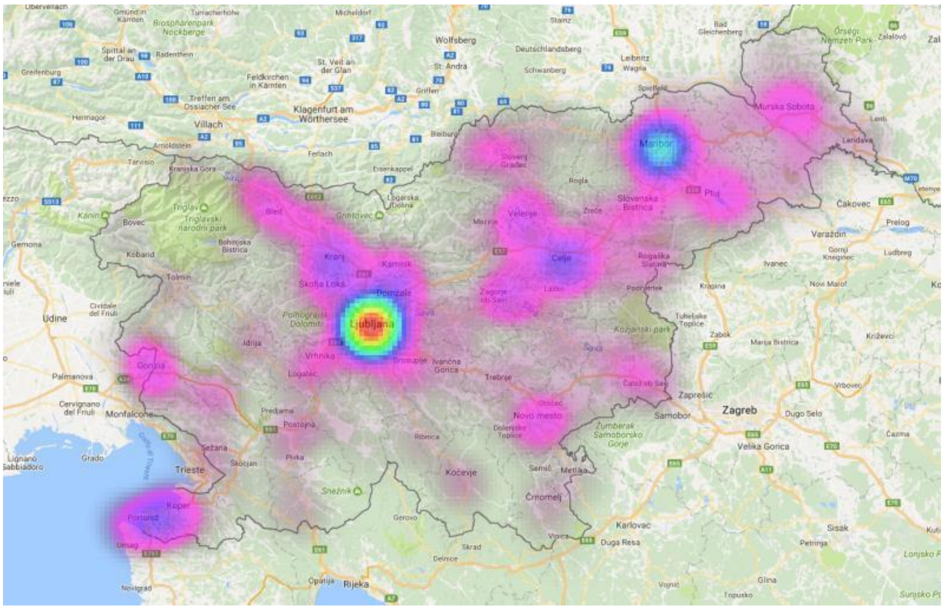

Figure 25: Heat atlas of the Republic of Slovenia

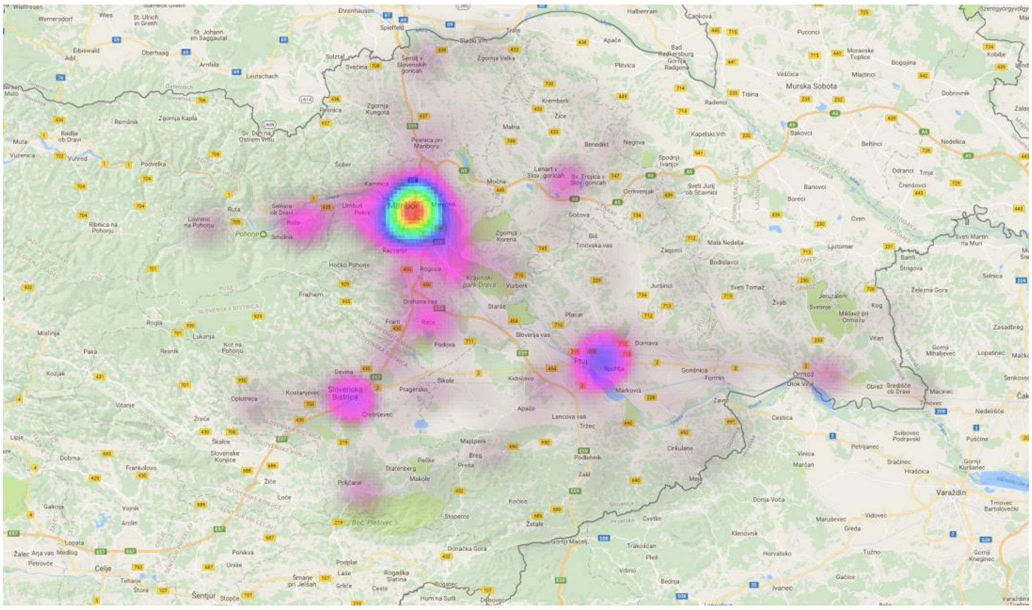

Figure 26: Heat atlas of the Maribor region

Figure 27: Heat atlas of the Municipality of Kidričevo

Figure 28 below shows a detail of the Municipality of Kidričevo. It is clear that the heat distribution system covers the major part of heat consumption in the observed part of the area.

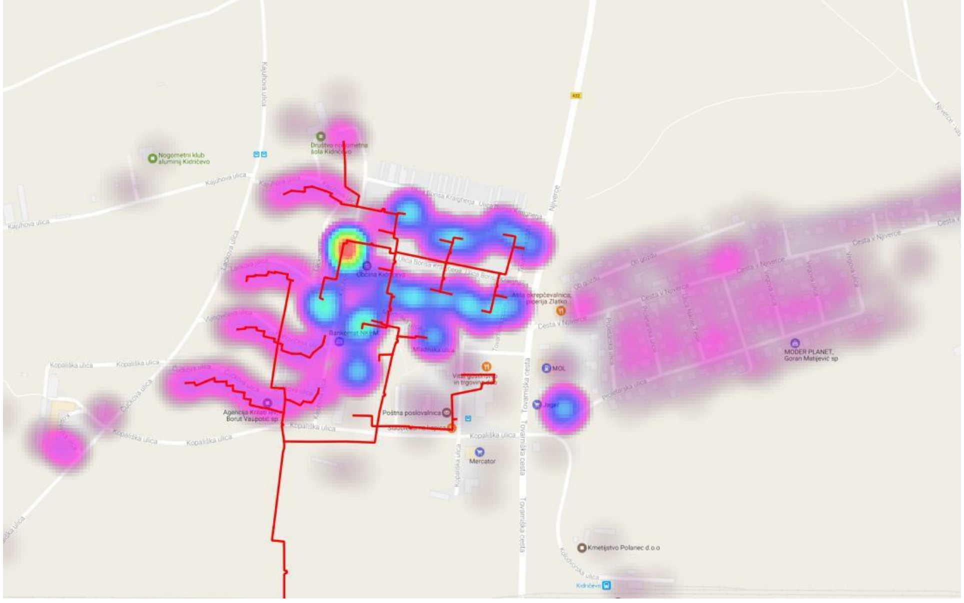

Figure 28: Heat atlas of the Municipality of Kidričevo with related utility infrastructure for thermal energy distribution

In this chapter, heat atlases of selected areas are presented. Using cartographic displays, municipal infrastructure and thermal energy consumption, one can gain a detailed insight into each municipality, town and village, which is the basis for all further analyses of energy consumption and energy system planning.

Given that the above indicative representations are only illustrative, as they display a relative relationship of a certain part of the map rather than an absolute one, below we applied a mapping approach based on heat consumption, which is spatially distributed into a rectangular grid. In the first step, the whole Slovenia is divided into areas of 1 km², or square polygons of 1 x 1 km.

As already described in the introductory part of this chapter, after mapping the heat potential of the entire Republic of Slovenia, we started determining the thermal potential that could be met using high-efficiency cogeneration.

The polygon network on the whole territory of the Republic of Slovenia with the resolution (i.e. square size) of 1 x 1 km is shown in the following figure (Figure 29). The resolution of 1 x 1 km was chosen because it can be assumed that it is sufficiently precise, yet does not require excessive computing power to process data. An additional argument for the selected resolution can be found in the document[2] in which the same resolution was used to make a heat atlas.

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[2] *Connolly, D., Mathiesen, B. V., Lund, H., Møller, B., Hvelplund, F. K., Sperling, K., ... Werner, S. (2015). Heat Roadmap Europe: Inputs for Technical Modelling and Policy Recommendations.*

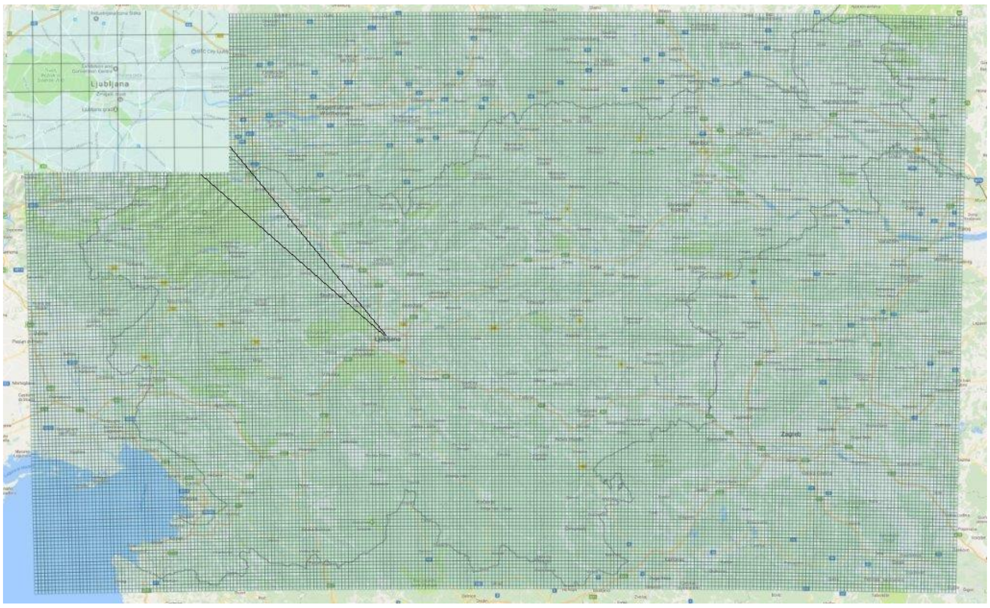

Figure 29: Polygon grid with a resolution of 1 x 1 km for the entire Republic of Slovenia and the City of Ljubljana

After having developed the polygon grid, which represents an additional layer in the analysis, we carried out an operation called

Points in Polygon, applying the heat consumption layer to the polygon grid.

During the *Points in Polygon* operation, each square in the polygon grid was assigned total thermal energy consumption (i.e. total heat consumed in this square kilometre).

In this way, we obtained a heat atlas with a 1-kilometre resolution.

After adding up the thermal energy consumption in individual squares, we obtained a new layer, as shown in Figure 30 below.

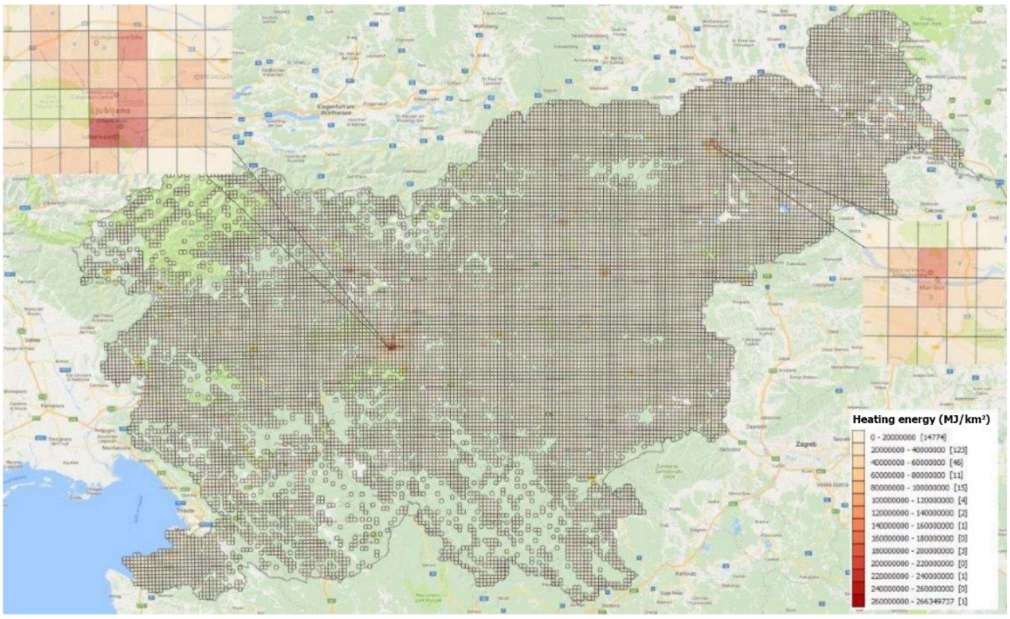

Figure 30: Specific thermal energy consumption in the Republic of Slovenia and the cities of Ljubljana and Maribor

With the new layers that reflect the specific thermal energy consumption (MJ per square kilometre), we could start determining the thermal energy potential that can be met by high-efficiency cogeneration. The areas that are not covered by squares do not have any heat consumption.

This mapping, together with its equivalents in higher resolution, was the basis for further analyses to determine the potentials described in Section 4.2.3. A more detailed kilometre network is used as the first filtering step. The selected areas of the entire Slovenia are then further analysed using more precise methods, as described in the aforementioned section.

4. IDENTIFYING THE HEATING AND COOLING DEMAND THAT COULD BE MET USING HIGH-EFFICIENCY COGENERATION

4.1 ANALYSIS OF EXISTING PRODUCTION FACILITIES

With the aim to perform quality and systematic analysis to determine the potential for additional high-efficiency cogeneration, it is necessary to analyse the underlying conditions. Within this chapter, this primarily means the existing facilities for heat and electricity production. Production units that allow parallel production of heat and electricity are called cogeneration plants.

The related technologies will be described in more detail in the following chapter. Here it is worth noting that cogeneration is beneficial, because, from the aspect of energy, it is not justified to use primary energy of fuels (natural gas, coal, oil, biomass, biogas, etc.) to produce only heat or only electricity. The reason is that the combustion of above fuel types generates high-quality thermal energy at a high temperature level (even above 1 200 °C (2 192 °F)). It is unjustified to use such thermal energy to heat residential, commercial or industrial buildings, as, for such purposes, heat at a substantially lower temperature level (about 100 °C (212 °F) or lower) is more suitable. This is where cogeneration plants enter the picture. They exploit high-quality thermal energy to generate electricity, while using the rest of the thermal energy (which is now at a significantly lower temperature level) for various purposes such as space heating, hot water or use in the processing industry.

According to the information received from the Energy Agency of the Republic of Slovenia (AGEN-RS), there are 466 registered cogeneration plants in Slovenia. In line with the *Decree on support for electricity generated from renewable energy sources (UL RS Nos 37/09, 53/09, 68/09, 76/09, 17/10, 94/10, 43/11, 105/11, 43/12, 90/12, 17/14 – EZ-1 and 74/16)*, size classes of renewable energy source manufacturing facilities are identified as shown in Table 1 below.

Table 1: Division of production units into size classes

Size class	Installed electrical capacity (kW)
Micro	< 50
Small	< 1 000
Medium	< 10 000
Large	<= 125 000
Over 125 MW	> 125 000

Data by the AGEN-RS on cogeneration units in Slovenia are structured in a similar way. Cogeneration units are divided by size into five categories: micro, small, medium, medium-lower and medium-higher. Below is an analysis of the data received. If you take the total installed electrical capacity of all cogeneration units, it can be concluded that all units contribute to the 137 879.07 kW_e gross installed capacity. But if you take net installed capacity, the amount is 130 284.63 kW_e. The distribution of the installed capacity share in accordance with the size classes is illustrated in Figure 31 below.

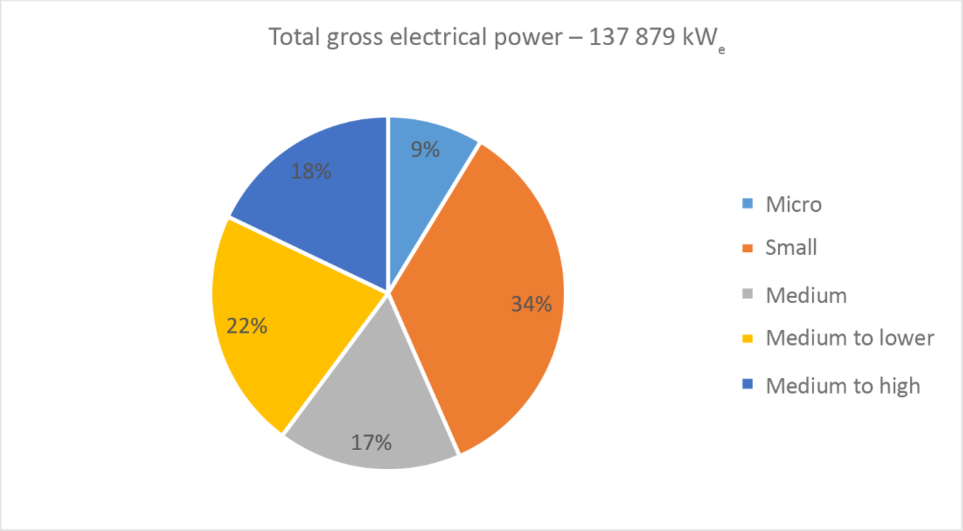

Figure 31: Distribution of gross installed capacity for electricity production in accordance with the size classes

The review of energy production to meet the heat demand has shown that total installed heat capacity of the 466 cogeneration units combined amounts to 152 544 kW$_t$. A detailed overview of installed capacity by size class is shown in the next figure (Figure 32). It can be seen that small cogeneration plants account for the largest share of the installed heat capacity.

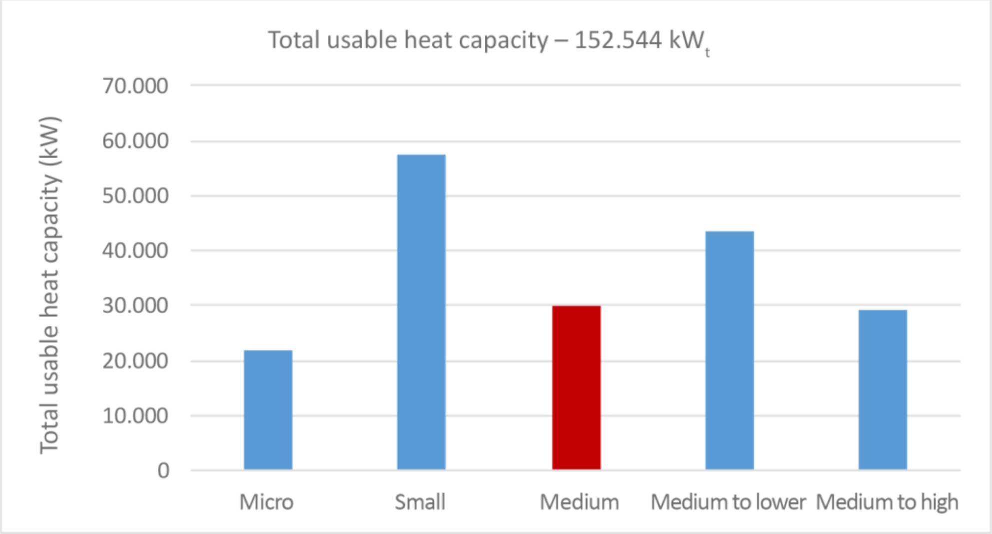

Figure 32: Overview of installed heat capacity of all cogeneration units[3] in accordance with size classes

The following table provides an overview of installed electrical and heat capacity depending on the size class and the type of cogeneration technology used to produce electricity and heat.

The table shows how the data are not entirely consistent when it comes to the installed heat capacity. There are no data regarding medium-sized cogeneration plants. Also regarding small cogeneration plants, there is no data on the installed heat capacity (biomass power plant, landfill gas power plant, sewage sludge gas power plant).

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[3] Here, it should be noted that there was some lack of information. E.g. there was no information delivered on installed heat capacity of medium-sized cogeneration units, while we did receive information about the installed electrical capacity of the same units. For this reason, we assumed that the installed heat capacity of all cogeneration units is higher. Based on experience and good engineering practice regarding expected capacity, we evaluated the actual installed heat capacity of all 466 cogeneration units at approximately 180 000 kW$_t$. Of course, the contractor shall in no way guarantee the accuracy of that amount.

Table 2: Overview of installed cogeneration units in accordance with the size classes and the cogeneration technology

Size classes	Number of plants	Total gross electrical power (kW)	Total net electrical power (kW)	Total usable heat capacity (kW)
Micro	**345**	**12 024.08**	**11 774.10**	**21 830.51**
Microturbine	4	199.60	199.60	455.00
Internal combustion engine	338	11 805.08	11 555.50	21 322.51
Gas turbine with heat recovery	1	7.20	7.00	17.50
Stirling engine	2	12.20	12.00	35.50
Small	**101**	**47 836.99**	**45 574.53**	**57 661.00**
Other production installation generating electricity from RES	2	1 060.00	1 035.00	12.00
Biomass power plant	23	6 532.80	5 897.40	
Landfill gas power plant	4	1 791.00	1 723.00	
Sewage sludge gas power plant	6	1 660.30	1 594.00	
Microturbine	5	3 923.89	3 855.89	6 873.00
Internal combustion engine	58	31 343.00	30 207.24	36 962.00
Steam engine	3	1 526.00	1 262.00	13 814.00
Medium	**5**	**23 121.00**	**20 421.00**	
Biomass power plant	2	8 850.00	8 050.00	
Landfill gas power plant	2	5 931.00	4 371.00	
Co-combustion of biomass (biomass from more than 5% to 90%)	1	8 340.00	8 000.00	
Medium to lower	**12**	**30 212.00**	**29 119.00**	**43 714.00**
Internal combustion engine	11	28 512.00	27 799.00	29 273.00
Steam back pressure turbine	1	1 700.00	1 320.00	14 441.00
Medium to higher	**3**	**24 685.00**	**23 396.00**	**29 338.00**
Internal combustion engine	2	17 885.00	17 338.00	17 978.00
Gas turbine with heat recovery	1	6 800.00	6 058.00	11 360.00
TOTAL	**466**	**137 879.07**	**130 284.63**	**152 543.51**

When examining individual shares of cogeneration technologies, regardless of the unit size, the following table (Table 3) provides a graphic overview of all installed units by technology type. The table shows that the largest share of installed capacity, regarding also the number of cogeneration plants, is attributed to the internal combustion engine (about 65% of installed capacity), followed by biomass power plant technology (around 11% of installed capacity), while all other technologies combined account for less than 10%.

Table 3: Overview of cogeneration units' installed capacity depending on the type of cogeneration technology

Type of cogeneration technology	Number of units	Total gross electrical power (kW)	Total usable heat capacity (kW)
Other production installation generating electricity from RES	2	1 060.00	12.00
Biomass power plant	25	15 382.80	
Landfill gas power plant	6	7 722.00	
Sewage sludge gas power plant	6	1 660.30	
Microturbine	9	4 123.49	7 328.00
Internal combustion engine	409	89 545.08	105 535.51
Steam back pressure turbine	1	1 700.00	14 441.00
Steam engine	3	1 526.00	13 814.00
Gas turbine with heat recovery	2	6 807.20	11 377.50
Co-combustion of biomass (biomass from more than 5% to 90%)	1	8 340.00	
Stirling engine	2	12.20	35.50
TOTAL	**466**	**137 879.07**	**152 543.51**

Also useful is an analysis of final energy consumption by sector for each cogeneration technology size class – see the table below. Apart from the end-use energy consumption, the table also shows temperature intervals of usable heat produced in cogeneration units. As expected, it is evident that the most common industry branch needs higher temperature levels of usable thermal energy.

Table 4: Overview of end-use energy consumption by sector with the corresponding temperature intervals of usable thermal energy

Size classes and division according to the purpose of usable heat	Number of plants	Minimum temperature of usable heat (°C)	Maximum temperature of usable heat (°C)	Total gross electrical power (kW)	Total usable heat capacity (kW)
Micro	**345**	**60**	**289**	**12 024.08**	**21 830.51**
Industry	2	80	90	94.90	195.00
Agriculture	1	90	90	52.00	76.00
Heating	342	60	289	11 877.18	21 559.51
Small	**101**	**50**	**280**	**47 836.99**	**57 661.00**
Industry	6	80	280	3 660.89	7 658.00
Heating	61	50	110	33 242.00	50 003.00
(blank)	34			10 934.10	
Medium	**5**			**23 121.00**	
Declaration issued only for the biomass part of the device	1			8 340.00	
(blank)	4			14 781.00	
Medium to lower	**12**	**85**	**440**	**30 212.00**	**43 714.00**
Industry	1	440	440	1 700.00	14 441.00
Heating	11	85	110	28 512.00	29 273.00
Medium to higher	**3**	**90**	**205**	**24 685.00**	**29 338.00**
Heating	3	90	205	24 685.00	29 338.00
TOTAL	**466**	**-**	**-**	**137 879.07**	**152 543.51**

Data presented so far relate to all cogeneration plants, regardless of the type of heat consumer. Below is an overview of data on cogeneration units that are connected to district heating systems.

Of all 466 cogeneration plants, 27 are connected to district heating systems. If contemplating the installed electrical capacity ratio, district heating systems account for 38% of the installed capacity, while the remainder is attributed to heating requirements outside of this system (Figure 33).

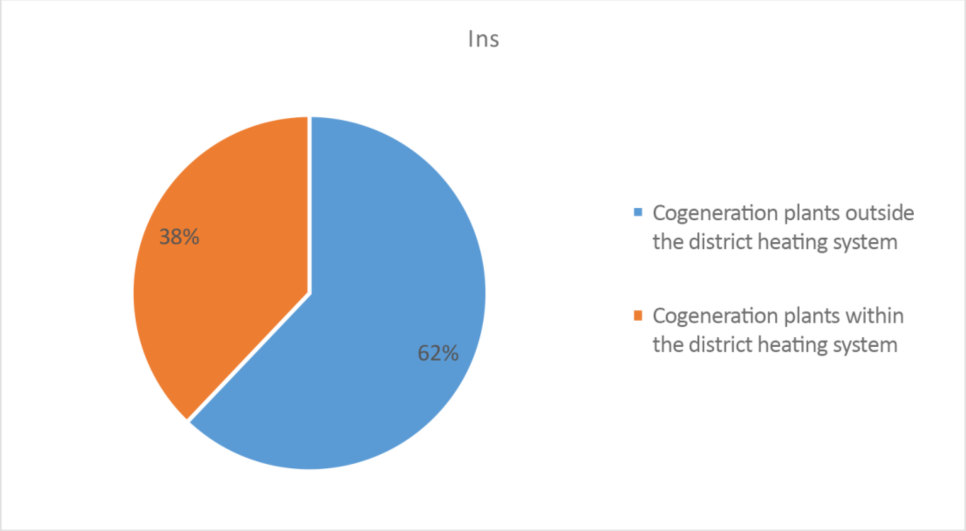

Figure 33: The share of installed electrical capacity of cogeneration plants in and outside the district heating system

The following table (Table 5) gives an overview of the representation of each technology in each size class for cogeneration installations connected to district heating systems. The internal combustion engine is the most common technology used in these systems.

Table 5: Overview of installed cogeneration units in accordance with the size classes, and cogeneration technologies connected to the district heating system

Size class	Number of plants	Total gross electrical power (kW)	Total net electrical power (kW)	Total usable heat capacity (kW)
Micro	**8**	**378.00**	**354.30**	**766.50**
Internal combustion engine	8	378.00	354.30	766.50
Small	**10**	**7 150.00**	**6 744.00**	**18 638.00**
Biomass power plant	1	330.00	294.00	
Microturbine	1	999.00	996.00	1 538.00
Internal combustion engine	6	4 481.00	4 364.00	5 100.00
Steam engine	2	1 340.00	1 090.00	12 000.00
Medium	**1**	**8 340.00**	**8 000.00**	
Co-combustion of biomass (biomass from more than 5% to 90%)	1	8 340.00	8 000.00	
Medium to lower	**5**	**11 702.00**	**11 303.00**	**12 960.00**
Internal combustion engine	5	11 702.00	11 303.00	12 960.00
Medium to higher	**3**	**24 685.00**	**23 396.00**	**29 338.00**
Internal combustion engine	2	17 885.00	17 338.00	17 978.00
Gas turbine with heat recovery	1	6 800.00	6 058.00	11 360.00
TOTAL	**27**	**52 255.00**	**49 797.30**	**61 702.50**

4.2 THE POSSIBILITY OF EXTENDING THE EXISTING SYSTEMS FOR HEATING AND COOLING

4.2.1 Analysis of linear heat density

In accordance with Directive 2012/27/EU of the European Parliament and the Council,[4] only the plot ratio greater than 0.3 is taken into account, which corresponds to a linear heat density of 2.5 MWh/m, assuming that the specific heat demand is 130 kWh/m^2. This threshold indicates the areas for which literature states that district heating is feasible and economically justifiable. Linear heat density of an area is the ratio between the annual amount of thermal energy sold and the total length of the heat network.

$$\text{Linear heat density} = \frac{\text{Annual amount of sold heat}}{\text{Total size of heat network}} \quad (\text{MWh/m})$$

According to data obtained from the AGEN-RS, linear heat density was calculated for all areas for which data was available (91 in total). The results are shown in the following table (Table 6).

Table 6: Linear heat density in areas with heat distribution systems

No	Business entity	Municipality	Name of the distribution system	Linear heat density (MWh/m)
1	**PETROL**	**Bled**	**SDO Bled**	**10.47**
2	ENERGETIKA CELJE	Celje	SDO Celje	1.40
3	TAB-IPM	Črna na Koroškem	SDO obrtne cone Žerjav, Črna na Koroškem	1.15
4	ENERGETIKA ČRNOMELJ	Črnomelj	SDOLB Čardak residential area, Črnomelj	1.95
5	GIIP	Dravograd	SDOLB Dravograd	0.64
6	JKP DRAVOGRAD	Dravograd	SDO Meža residential area, Dravograd	0.85
7	BIOENERGETIKA	Gorenja Vas - Poljane	SDO Todraž	1.34
8	EKO-TOPLOTA	Gornji Grad	SDOLB Gornji Grad	0.33

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[4] *Note on Directive 2012/27/EU, Article 14: Promotion of efficiency in heating and cooling; Implementation of the directive on energy efficiency*

9	JKP GROSUPLJE	Grosuplje	SDO Grosuplje	0.78
10	PETROL ENERGETIKA	Hrastnik	SDO Hrastnik	1.04
11	KOMUNALA IDRIJA	Idrija	SDO ŠRC, Idrija	0.89
12	YDRIA SPORT	Idrija	SDO Ydria, Idrija	0.81
13	**PETROL**	**Ivančna Gorica**	**SDOLB Ivančna Gorica**	**2.89**
14	PETROL	Jesenice	SDO Hrušica, Jesenice	0.26
15	ENOS OTE	Jesenice	SDO Jesenice	1.00
16	PETROL	Kamnik	SDO Kamnik	2.26
17	TISA	Kamnik	SDO Tisa, Kamnik	0.88
18	PETROL	Kidričevo	SDO Kidričevo	0.31
19	TALUM	Kidričevo	SDO Talum d.d., Kidričevo	0.00
20	PETER KOREN	Kobarid	SDO Kobarid	0.38
21	KOMUNALA KOČEVJE	Kočevje	SDO Kočevje	0.88
22	KOMUNALA KOČEVJE	Kočevje	SDO Kočevska reka	0.13
23	**DOMPLAN**	**Kranj**	**SDO Planina residential area, Kranj**	**5.11**
24	DOMPLAN	Kranj	SDO Vodni stolp residential area, Kranj	2.05
25	**ISKRA**	**Kranj**	**SDO Iskra Labore commercial zone, Kranj**	**2.71**
26	ISKRA	Kranj	SDH Iskra Labore commercial zone, Kranj	1.11
27	PETROL	Kranjska Gora	SDOLB Mojstrana, Kranjska gora	0.46
28	**PETROL**	**Kranjska Gora**	**SDOLB Kranjska Gor**	**10.84**
29	EKO-TOPLOTA	Lenart	SDOLB Lenart	0.92
30	PETROL GEOTERM	Lendava	SDO Lendava	1.40
31	EVJ ELEKTROPROM	Litija	SDO Gabrovka, Litija	0.32
32	EVJ ELEKTROPROM	Litija	SDO Jevnica, Litija	1.24
33	**ISTRABENZ PLINI**	**Litija**	**SDO Litija center**	**2.83**
34	EKOEN	Luče	SDOLB Luče	0.89
35	**ENERGETIKA LJUBLJANA**	**Ljubljana**	**SDO Ljubljana**	**3.40**
36	**ENERGETIKA LJUBLJANA**	**Ljubljana**	**Lek steam pipeline, Ljubljana**	**83.66**
37	**ENERGETIKA LJUBLJANA**	**Ljubljana**	**Ljubljanske mlekarne steam pipeline, Ljubljana**	**44.41**
38	**ENERGETIKA LJUBLJANA**	**Ljubljana**	**Steam pipeline – TE-TOL west, Ljubljana**	**6.43**
39	**ENERGETIKA LJUBLJANA**	**Ljubljana**	**Steam pipeline – TE-TOL east, Ljubljana**	**32.51**
40	**PETROL**	**Maribor**	**SDO EPF Maribor**	**4.79**
41	UKC MARIBOR	Maribor	SDO UKC Maribor	1.76
42	ENERGETIKA MARIBOR	Maribor	SDO Maribor	2.46
43	**PETROL ENERGETIKA**	**Maribor**	**SDO Pobrežje**	**2.94**
44	PETROL	Metlika	SDOLB Metlika	0.93
45	TOP LES ENERGIJA	Miren - Kostanjevica	SDO Miren - Kostanjevica	0.46
46	TOP LES ENERGIJA	Mirna peč	SDO Nova šola, Mirna Peč	-
47	**TOP LES ENERGIJA**	**Mirna peč**	**SDO Stara šola, Mirna Peč**	**4.25**
48	ZARJA EKOENERGIJA	Moravče	SDO Ekoenergija	0.84
49	EKOEN	Mozirje	SDO Podrožnik	0.33
50	EKOEN	Mozirje	SDO Mozirje elementary school	1.53
51	**KOMUNALA MSOBOTA**	**Murska Sobota**	**SDO Murska Sobota**	**3.37**
52	ENERGETIKA NAZARJE	Nazarje	SDO Nazarje	0.64
53	E3	Nova Gorica	SDO IC Meblo	0.31
54	E3	Nova Gorica	SDO Elektro Primorska, Nova Gorica	0.42
55	ECO ATMINVEST	Nova Gorica	SDOLB Majske poljane	1.44
56	JP KENOG	Nova Gorica	SDO Nova Gorica	1.75
57	**PARTNER IN**	**Novo Mesto**	**SDO TPV**	**6.72**
58	MG NOVO MESTO	Novo Mesto	SDO naselje Slavka Gruma residential area	0.75

59	PETROL	Oplotnica	SDOLB Oplotnica	1.12
60	PETROL	Piran	SDO Šolska, Lucija	0.50
61	PETROL	Piran	SDO Obala, Lucija	0.82
62	PETROL	Piran	SDO Liminjanska, Lucija	0.53
63	ENERGETIKA DOLENC	Postojna	SDOLB Postojna	0.58
64	PETROL	Postojna	SDO Volaričeva 24	0.70
65	ENERGETIKA PREDDVOR	Preddvor	SDOLB Preddvor	0.37
66	JS PTUJ	Ptuj	SDO Ptuj	2.10
67	EVJ ELEKTROPROM	Radlje ob Dravi	SDO Radlje ob Dravi	1.98
68	PETROL ENERGETIKA	Ravne na Koroškem	SDO Železarna Ravne	2.31
69	PETROL ENERGETIKA	Ravne na Koroškem	SDO Ravne na Koroškem	1.39
70	PETROL	Ribnica	SDOLB Ribnica	0.58
71	ZARJA EKOENERGIJA	Semič	SDO Ekoenergija	0.41
72	TOPLOTNA OSKRBA	Slovenske Konjice	SDO TO	0.41
73	SP KONJICE	Slovenske Konjice	SDO SP	1.02
74	KOMUNALA SLOVENJ GRADEC	Slovenj Gradec	SDO Slovenj Gradec	1.28
75	**PETROL ENERGETIKA**	**Slovenj Gradec**	**Šmartno elementary school**	**2.93**
76	EKOEN	Solčava	SDOLB Solčava	0.60
77	E3	Šempeter - Vrtojba	SDO Podmark residential area, Šempeter Vrtojba	0.72
78	PETROL ENERGETIKA	Šentilj	SDO Sladki Vrh, Šentilj	0.68
79	ENERGOLES BOHOR	Šentjur	SDO Energoles, Šentjur	0.22
80	**ENERGETIKA ŠENTRUPERT**	**Šentrupert**	**SDOLB Šetrupert**	**5.14**
81	EKO LES ENERGETIKA	Tolmin	SDO na Logu, Tolmin	0.59
82	**DOM UPOKOJENCEV (retirement home)**	**Tolmin**	**SDO Podbrdo, Tolmin**	**5.48**
83	KOMUNALA TRBOVLJE	Trbovlje	SDO Trbovlje	1.17
84	KP VELENJE	Velenje	SDH Velenje	0.46
85	KP VELENJE	Velenje	SDO Šaleške doline	1.35
86	ENERGETIKA PROJEKT	Vransko	SDOLB Vransko	0.15
87	JKP RADLJE OB DRAVI	Vuzenica	SDOLB Vuzenica	1.20
88	**KOMUNALA ZAGORJE**	**Zagorje ob Savi**	**SDO Zagorje ob Savi**	**4.54**
89	UNIOR	Zreče	SDO Center, Zreče	0.66
90	SIPRO	Žalec	SDO Žalec	0.85
91	TOPLARNA ŽELEZNIKI heating plant	Železniki	SDOLB Železniki	0.39

Distribution systems with satisfactory linear heat density (the criterion is at least 2.5 MWh/m) are shown in green in the above table (Table 6). It is noted that only 20 of the 91 distribution areas analysed meet the above criterion regarding the recommended linear heat density of 2.5 MWh/m.

The remaining 71 distribution areas, having lower linear heat density than the recommended 2.5 MWh/m, represent an indicator of the thermal potential that could still be used to connect these areas to the existing heating system, and does not exclude other areas when searching and displaying potential.

4.2.2 Analysis of the available distribution system potential using the linear heat density criterion

For the purposes of this analysis, we excluded the heating and cooling distribution systems that did not meet the condition of linear heat density referred to in the previous chapter. Such distribution systems represent the potential to expand the existing heating and cooling systems in such a way that the additional amount of energy needed to meet the condition of linear heat density of 2.5 Wh/m can be calculated. The results are shown in the following table (Table 7).

Table 7: The availability of heat potential for connecting to an existing network using the required linear density criterion of 2.5 MWh/m

No	Municipality	Distribution system	Available potential for new connections by the criterion of linear heat density (MWh)
1	Celje	SDO Celje	31 533.78
2	Črna na Koroškem	SDO obrtne cone Žerjav, Črna na Koroškem	4 197.00
3	Črnomelj	SDOLB Čardak residential area, Črnomelj	659.69
4	Dravograd	SDOLB Dravograd	1 531.42
5	Dravograd	SDO Meža residential area, Dravograd	740.10
6	Gorenja Vas - Poljane	SDO Todraž	1 750.00
7	Gornji Grad	SDOLB Gornji Grad	14 207.95
8	Grosuplje	SDO Grosuplje	16 602.48
9	Hrastnik	SDO Hrastnik	16 072.07
10	Idrija	SDO ŠRC, Idrija	5 257.97
11	Idrija	SDO Ydria, Idrija	4 569.30
12	Jesenice	SDO Hrušica, Jesenice	3 320.00
13	Jesenice	SDO Jesenice	47 781.50
14	Kamnik	SDO Kamnik	433.90
15	Kamnik	SDO Tisa, Kamnik	2 099.96
16	Kidričevo	SDO Kidričevo	26 300.00
17	Kidričevo	SDO Talum d.d., Kidričevo	29 999.60
18	Kobarid	SDO Kobarid	2 464.53
19	Kočevje	SDO Kočevje	17 153.00
20	Kočevje	SDO Kočevska reka	6 273.27
21	Kranj	SDO Vodni stolp residential area, Kranj	929.75
22	Kranj	SDH Iskra Labore commercial zone, Kranj	1 670.00
23	Kranjska Gora	SDOLB Mojstrana, Kranjska gora	1 796.00
24	Lenart	SDOLB Lenart	11 395.38
25	Lendava	SDO Lendava	3 842.13
26	Litija	SDO Gabrovka, Litija	653.71
27	Litija	SDO Jevnica, Litija	100.74
28	Luče	SDOLB Luče	1 211.00
29	Maribor	SDO UKC Maribor, Maribor	441.27
30	Maribor	SDO Maribor	1 579.13
31	Metlika	SDOLB Metlika	4 179.50
32	Miren - Kostanjevica	SDO Miren - Kostanjevica	2 932.52
33	Moravče	SDO Ekoenergija, Moravče	2 235.49
34	Mozirje	SDO Podrožnik, Mozirje	5 631.00
35	Mozirje	SDO Mozirje elementary school, Mozirje	341.00
36	Nazarje	SDO Nazarje	15 855.15
37	Nova Gorica	SDO IC Meblo, Nova Gorica	12 796.00
38	Nova Gorica	SDO Elektro Primorska, Nova Gorica	1 353.00
39	Nova Gorica	SDOLB Majske Poljane, Nova Gorica	1 490.00
40	Nova Gorica	SDO Nova Gorica	7 042.50
41	Novo Mesto	SDO naselje Slavka Gruma residential area, Novo mesto	4 910.65
42	Oplotnica	SDOLB Oplotnica	477.00
43	Piran	SDO Šolska, Lucija, Piran	6 212.69
44	Piran	SDO Obala, Lucija, Piran	3 187.00
45	Piran	SDO Liminjanska, Lucija, Piran	2 558.76
46	Postojna	SDOLB Postojna	17 476.70

47	Postojna	SDO Volaričeva 24, Postojna	4 688.00
48	Preddvor	SDOLB Preddvor	14 160.00
49	Ptuj	SDO Ptuj	2 414.75
50	Radlje ob Dravi	SDO Radlje ob Dravi	135.00
51	Ravne na Koroškem	SDO Železarna Ravne, Ravne na Koroškem	1 131.50
52	Ravne na Koroškem	SDO Ravne na Koroškem	13 355.00
53	Ribnica	SDOLB Ribnica	19 100.00
54	Semič	SDO Ekoenergija, Semič	6 590.43
55	Slovenske Konjice	SDO TO, Slovenske Konjice	3 141.75
56	Slovenske Konjice	SDO SP, Slovenske Konjice	5 004.18
57	Slovenj Gradec	SDO Slovenj Gradec	9 791.58
58	Solčava	SDOLB Solčava	818.00
59	Šempeter - Vrtojba	SDO Podmark residential area, Šempeter Vrtojba	1 069.00
60	Šentilj	SDO Sladki Vrh, Šentilj	5 998.37
61	Šentjur	SDO Energoles, Šentjur	7 149.55
62	Tolmin	SDO na Logu, Tolmin	1 443.08
63	Trbovlje	SDO Trbovlje	27 360.96
64	Velenje	SDH Velenje	532.00
65	Velenje	SDO Šaleške doline	196 640.85
66	Vransko	SDOLB Vransko	56 915.00
67	Vuzenica	SDOLB Vuzenica	869.20
68	Zreče	SDO Center, Zreče	6 439.65
69	Žalec	SDO Žalec	9 220.00
70	Železniki	SDOLB Železniki	61 305.00
TOTAL			**800 518.45**

The above table shows that the total potential for expanding existing heating and cooling systems amounts to 800 518.45 MWh per year. The results are only an indicative display of the available potential. The method of determining the actual potential will be shown in the following chapter, considering the real thermal energy demand for heating and cooling.

4.2.3 Analysis of projected heating demand

4.2.3.1 Methodology description

Based on the analysis in Chapter 3, and the related heat atlas, this chapter presents an analysis establishing the potential heat consumption that can be met by high-efficiency cogeneration plants.

According to document [2], it is noted that conventional district heating systems are not financially viable if the specific thermal energy consumption does not exceed 120 TJ/km^2. If the specific heat consumption is lower, the cost of investment (distribution network of the district heating system, heat substations, etc.) is a significant financial burden. By using the above criteria, i.e. 120 TJ/km^2, we established the potential for additional high-efficiency cogeneration in the Republic of Slovenia. The following figure (Figure 34) shows the potential, or rather areas with specific consumption greater than 120 TJ/km^2. It should be noted that the areas displayed are obtained by analysing energy consumption based on a 1 x 1 km polygon grid. Using this approach, we identified areas with potential for additional high-efficiency cogeneration.

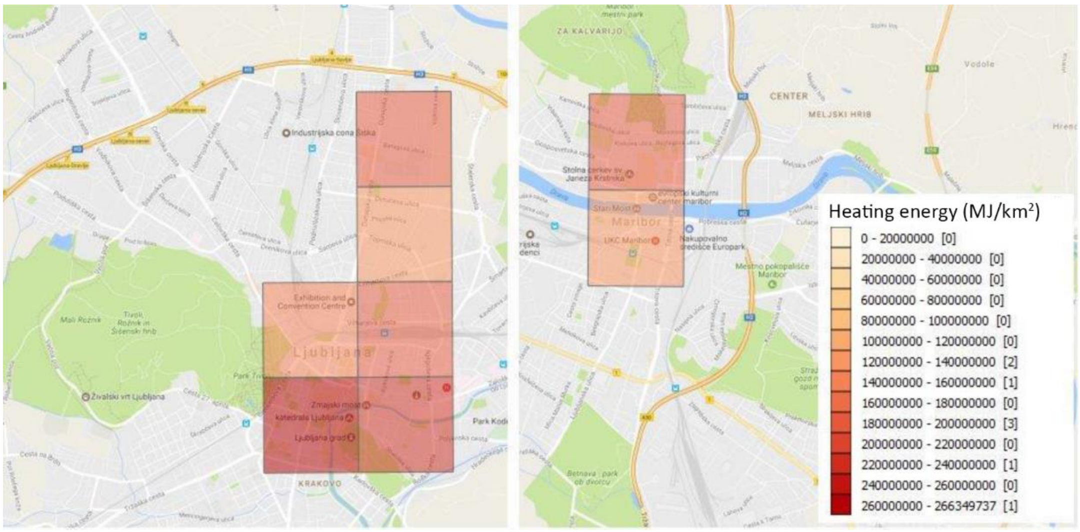

Figure 34: The potential for high-efficiency cogeneration using the criterion of 120 TJ/km^2 for the cities of Ljubljana (left) and Maribor (right) with the polygon grid resolution of 1000 x 1000 m

The graphic display shows data for areas in the cities of Ljubljana and Maribor. The displays below show the potential for additional high-efficiency cogeneration plants in the cities of Ljubljana and Maribor. With the aim to maximize the quality of the analysis of heat consumption in Ljubljana and Maribor, we created a polygon grid with a resolution of 100 x 100 m. This allowed us to evaluate the potential in selected urban areas more accurately. The results of this analysis are shown in the following figures (Figure 35 and Figure 36).

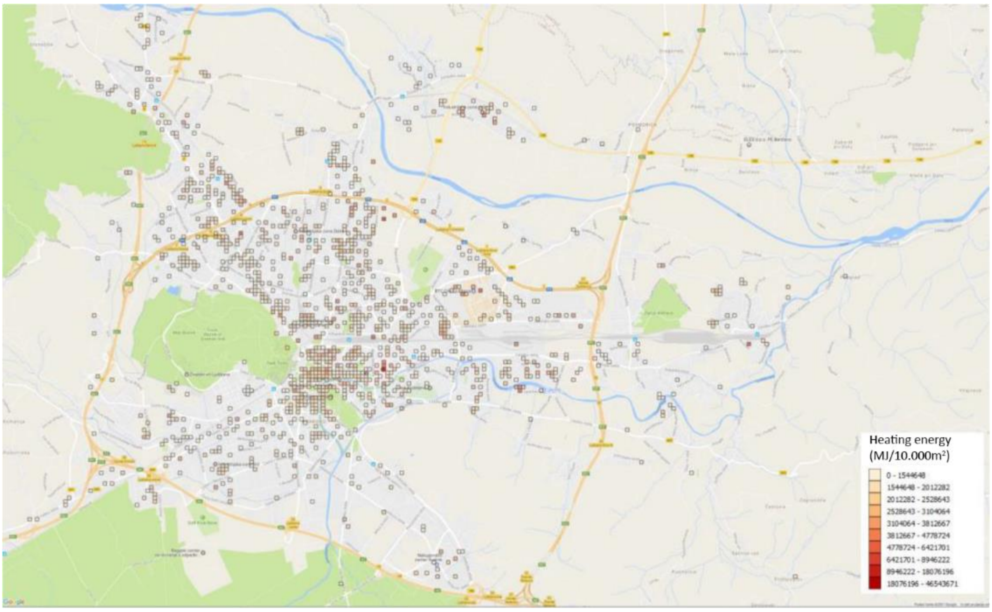

Figure 35: The potential for high-efficiency cogeneration using the criterion of 120 TJ/km^2 for the city of Ljubljana with the polygon grid resolution of 100 x 100 m

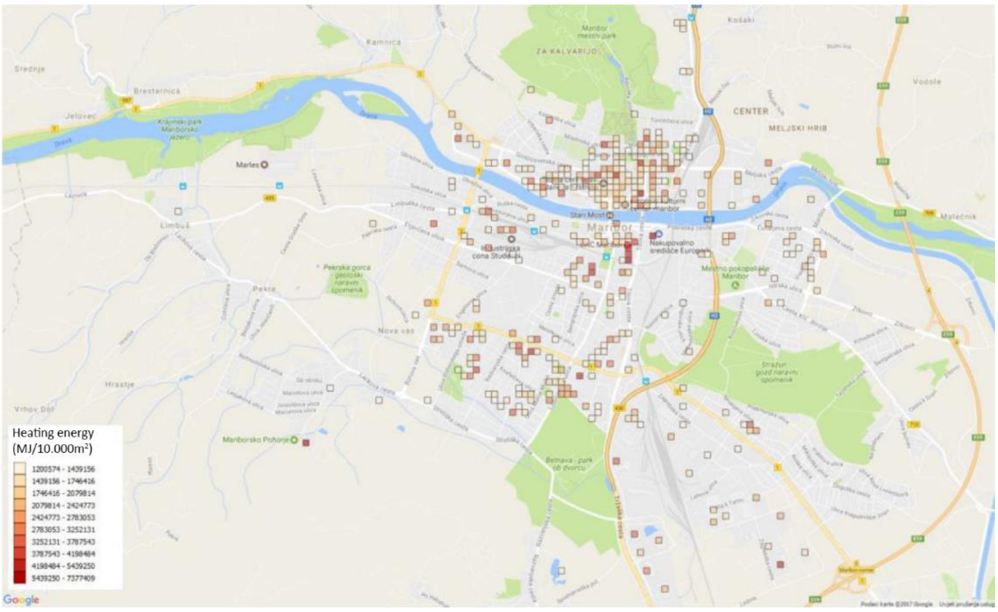

Figure 36: The potential for high-efficiency cogeneration using the criterion of 120 TJ/km^2 for the city of Maribor with the polygon grid resolution of 100 x 100 m

After applying the criterion of specific consumption amounting to 120 TJ/km^2 we noted that the only two areas where there is potential for additional high-efficiency cogeneration are the narrower areas of the cities of Ljubljana (13.34 km^2) and Maribor (3.39 km^2).

In the aforementioned study [2], the second referenced criterion was specific consumption amounting to 48 TJ/km^2, which is a justified potential in the case of a low-temperature district heating system. The following figures (Figure 37 and Figure 38) show the areas of Ljubljana and Maribor where heat consumption ranges from 48 TJ/km^2 to 120 TJ/km^2, and give an overview of the potential for a low-temperature district heating system. Only it is also provided with a network polygon resolution 100x100 m.

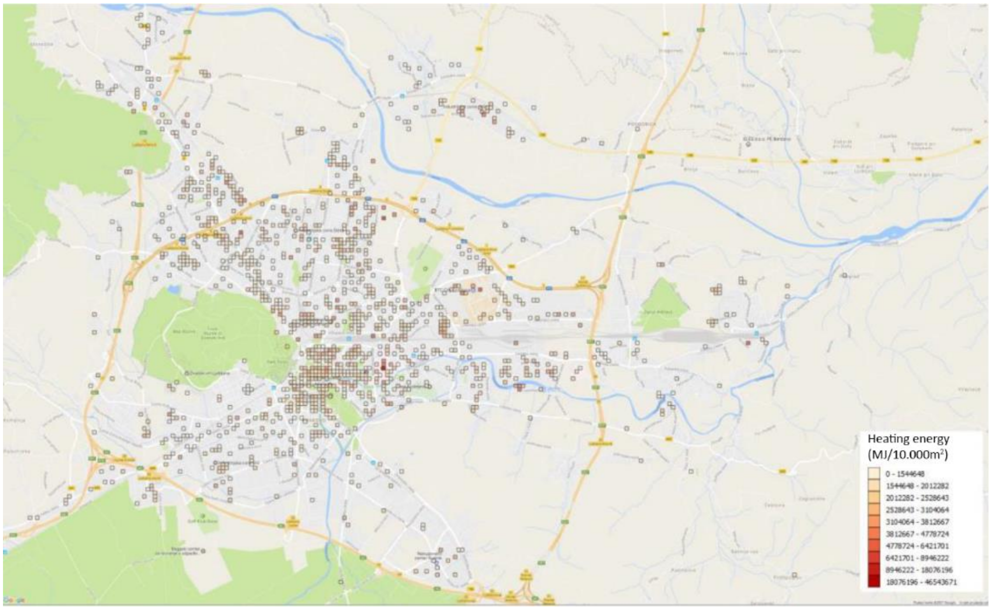

Figure 37: The potential for high-efficiency cogeneration using the criterion of between 48 TJ/km^2 and 120 TJ/km^2 for the city of Ljubljana with the polygon grid resolution of 100 x 100 m

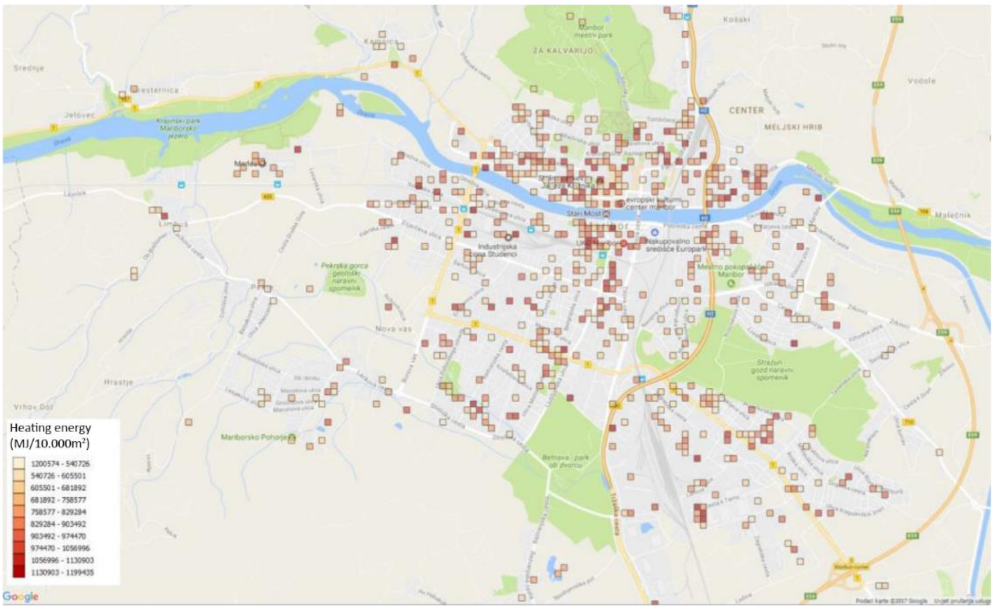

Figure 38: The potential for high-efficiency cogeneration using the criterion of between 48 TJ/km² and 120 TJ/km² for the city of Maribor with the polygon grid resolution of 100 x 100 m

The same potential with a lower criterion (48 TJ/km^2 to 48 TJ/km^2) will not be further analysed, and will be used for informational purposes only.

In the existing district heating systems such as those in Ljubljana and Maribor, one cannot just add up the energy consumption for heating in the identified areas and declare it a potential; a more complex analysis must be performed. Identified areas having potential for high-efficiency cogeneration (meeting the criterion of 120 PJ/km^2), shown as 100 x 100 m squares on the cartographic display, will be hereinafter referred to as reference areas.

In certain parts of the reference areas identified, such as the cities of Ljubljana and Maribor, there are district heating systems that already meet part of the heat demand. However, in order to determine the potential for additional high-efficiency cogeneration plants, it is first necessary to establish how much of the total thermal energy in a certain reference area is currently met by the existing district heating system, and how much from other heat sources. It is this part of the heat demand that is not met by the district heating system that is a potential to be satisfied by additional high-efficiency cogeneration plants. This potential is determined by deducting the amount of heat energy currently met by the existing district heating systems from the total amount of heat needed in the reference areas.

Because the structure of data did not show exactly how consumers' heat demand is met, it was not possible to directly determine the consumption met by the district heating system. This is why we introduced another step into the analysis. With a neighbourhood (*'buffer')* analysis, a heat distribution network is assigned a neighbourhood area. In other words, the heat distribution network is added to an 'area of intervention', which includes the coordinates of the consumers who receive heat from the district heating system. After drafting the intervention areas, we carried out the '*Points in Polygon'* analysis, which summarizes the thermal energy consumption of those consumers whose coordinates are in the intervention area of the heat distribution network.

The main parameter of the neighbourhood analysis is the width of intervention, i.e. the tolerance (in metres) from the line of the distribution network by the end of the intervention. The exact choice of the width of intervention depends on the actual data on thermal energy consumption, based on which the analysis parameters are adjusted. Because the data on total thermal energy supplied by district heating systems of Ljubljana and Maribor are known, the width of intervention is iteratively modified until the width of needed intervention, which will cover as much heat consumption as delivered by the district heating system, is identified. The above analysis was done for the cities of Ljubljana and Maribor. The *buffer* analysis for the city of Maribor is shown in the following figure (Figure 39).

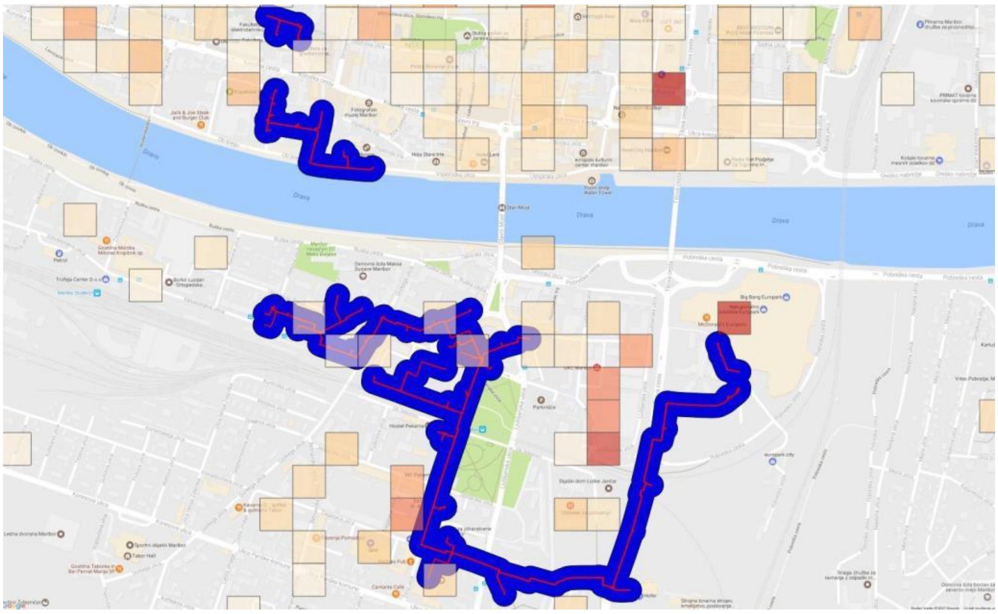

Figure 39: Buffer analysis of the distribution network in Maribor (area of intervention in dark blue; distribution network in red)

After determining the width of interference, one can start determining heat consumption located within the reference area and supplied with thermal energy from the district heating system.

The first step was to define the distribution network in the reference area of Maribor, as shown in Figure 40 below.

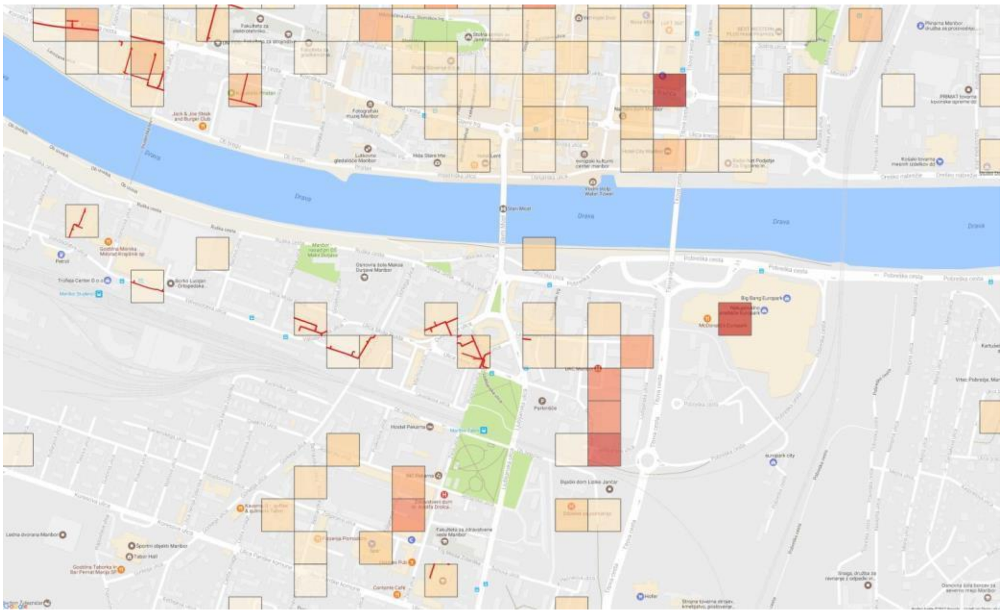

Figure 40: Part of the distribution network in Maribor within the reference area

The same width of intervention that was determined in the previous step based on an analysis of the entire distribution network is then applied to the part of the network located in the reference area, as shown in Figure 41 below.

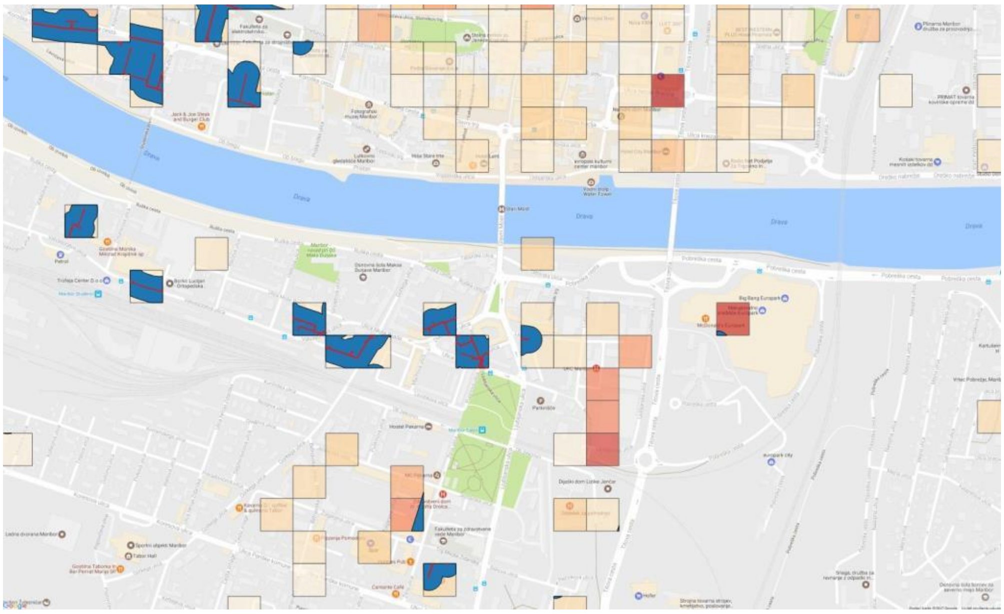

Figure 41: Buffer analysis of the distribution network in Maribor within the reference area (area of intervention in dark blue; distribution network in red)

Finally, the thermal energy consumption of the consumers located within the intervention of the *buffer* analysis and within the reference area is added up. This quantity of heat is deducted from the total heat consumption in the reference area. The difference is the potential for additional high-efficiency cogeneration.
The same procedure was also carried out in the reference area of Ljubljana.

It should be noted that in certain parts of the area having a potential for additional high-efficiency cogeneration, there is a natural gas distribution network. However, the analysis of determining the potential for additional high-efficiency cogeneration did not take the gas distribution network into account. It was thus not considered whether consumers of thermal energy have access to a gas distribution network, but in determining the potential for high-efficiency cogeneration it was assumed that all heat demand of end users is met by new production capacities of high-efficiency cogeneration.

4.2.3.2 Analysis results

Based on the analysis regarding the determination of the potential for additional high-efficiency cogeneration presented in the previous chapter, the following table shows the calculation of the potential for reference areas of Ljubljana and Maribor.

In the reference area of Ljubljana, the additional consumption that is not met by the district heating system is 1 332 451 500.99 MJ of thermal energy, while in Maribor it amounts to 549 738 155.96 MJ.

Table 8: The potential for additional high-efficiency cogeneration in the reference area of Ljubljana

Thermal energy	Volume (MJ)
Consumption at an existing district heating system in Ljubljana	1 627 386 989.53
Consumption in the reference area of Ljubljana (12.34 km^2)	2 959 838 490.52
The potential for additional high-efficiency cogeneration in Ljubljana	**1 332 451 500.99**

Table 9: The potential for additional high-efficiency cogeneration in the reference area of Maribor

Thermal energy	Volume (MJ)
Consumption at an existing district heating system in Maribor	145 169 992.37
Total consumption in the reference area of Maribor	694 908 148.33
The potential for additional high-efficiency cogeneration in Maribor	**549 738 155.96**

It is important to note here that the potential for additional high-efficiency cogeneration is based on the projection of thermal energy consumption in 2035.

5. DEFINING THE POTENTIAL FOR ADDITIONAL HIGH-EFFICIENCY COGENERATION

5.1 OVERVIEW OF HIGH-EFFICIENCY COGENERATION TECHNOLOGIES

Cogeneration plants have long been developed in energy-intensive industries, where there is equal demand for heat and electricity. The most common cogeneration procedure for such purposes is the steam turbine cycle, which allows waste steam to be used for process heat. Intensive development over the past two decades led to a large quantity of available equipment so that currently, there are various usable cogeneration plants suitable for various systems.

Basic components of a cogeneration plant are as follows:

- cogeneration process in the drive (power) unit
- electricity production plant
- system for the use of waste heat
- device for fuel supply and preparation
- gas exhaust system
- control/regulation and supervision system. Factors that determine the system to be used are primarily as follows:
- power capacity of a plant
- plant efficiency
- quality and energy level of heat generated
- ratio of electricity to thermal energy.

As for the connection and drive related to the distribution network, a cogeneration plant is usually operated in parallel with the power distribution network in order to meet their own electricity demand until all potential surpluses are fed into an external grid. Clearly, the cogeneration unit can operate with a special (island) drive, and it is only then that the electricity consumption of the facility is met. Combinations of a parallel drive with the option of a separate drive are also possible.

Cogeneration systems can be designed with different drive units. Depending on the drive unit, there are the following types of cogeneration processes:

- cogeneration based on steam turbines
- cogeneration based on gas turbines
- cogeneration based on an internal combustion engine
- cogeneration based on a combined cycle
- cogeneration based on fuel cells.

Other technologies, such as piston, steam and other engines, are rarely used or are still in the demonstration phase and not in commercial use.

Internal combustion engines or gas turbines with less power are normally used for electrical purposes up to a few megawatts, provided that if demand exceeds 3 MWe, gas turbines are used more frequently. On the other hand, in industrial cogeneration projects with greater power, a combined cycle (most often) and the steam turbine (rarely) are used more frequently.

Internal combustion engines are typically used when thermal energy is required in the form of hot or boiling water. In industrial applications, heat is generally required in the form of steam, and for this reason, gas turbines or a combined cycle are used most frequently. In the case of gas turbines and internal combustion engines, exhaust gases resulting from the process can be used directly. Such systems are often used for drying or in similar processes. The following table shows the main characteristics of each cogeneration process type and its use depending on the quality of thermal energy and capacity of the plant.

Table 10: Basic characteristics of the cogeneration process

Technology	Fuel	Capacity (MWe)	Efficiency		Temperature level	Most frequent use
			Electrical	Total		
Steam turbine	any	500 kW_e–500 MW_e	7–20%	60–80%	120–400 °C	use of biomass (district heating and industry)
Gas turbine	gaseous and liquid	250 kW_e–50 MW_e	25–42%	60–87%	120–500 °C	Industry, district heating
Combined cycle	gaseous and liquid	3 MW_e–300 MW_e	35–60%	70–90%	120–400 °C	Industry (processing), district heating
Gas and diesel engine	gaseous and liquid	3 kW_e–20 MW_e	25–45%	65–92%	80–120 °C	HVAC systems, food and textile industries, greenhouses
Fuel cell	gaseous and liquid	3 kW_e–3 MW_e	~37–50%	~85–90%	80–100 °C	HVAC systems
Stirling engine	any	3 kW_e–1.5 MW_e	~40%	65–85%	80–120 °C	HVAC systems

Considering the use of cogeneration processes for heating, ventilation and air conditioning (HVAC), internal combustion engines are generally used as drive units, and in the future, more frequent use of fuel cells is expected.

Depending on the type of analysis and the applicability of cogeneration plants, below is a more detailed overview of cogeneration plants based on the combined gas-steam cycle, and cogeneration using biomass. Only the technologies below will be approached in detail, because they are the only realistic option for producing electricity and heat, and technological steam from high-efficiency cogeneration for production units with over 20 MW power. In the continuation of the analysis, other technologies are not taken into account for either technological or economic reasons.

5.1.1 Combined cogeneration method using gas and steam turbines (Combined Cycle Gas Turbine – CCGT)

The term 'combined cycle' is used for processes that are composed of two thermodynamic cycles connected with working fluid and operating at different temperature levels. Combined-cycle based cogeneration generally means processes that include both gas and steam turbines. In this type of cogeneration, high-temperature exhaust gases from the gas turbine may be subjected to post-combustion, and can produce steam at high pressure (40–100 bar) in the boiler-utiliser. The steam is expanded in the back-pressure or condensing steam turbine, and produces electricity and steam, which is used in the production process or for heating purposes.

Efficiency is usually is between 35% and 45% (in modern systems up to 60%), while the total energy efficiency of such cogeneration processes ranges from 70% to 88%. Such cogeneration is normally not used in plants with installed electrical capacity of less than 3.5 MW.

The fuel for the gas turbine is natural gas or extra light oil (often used as reserve fuel). Powering a gas turbine requires a high gas pressure, from 13 to 20 bar, depending on the drive unit type and manufacturer. If at a potential location there is low-pressure gas available (e.g. from the city distribution network), a gas compressor needs to be installed in front of the gas turbine.

This type of plant is particularly suitable for use in district heating plants, and is the most energy-efficient. With integrated use of heat at all available temperature levels, one can achieve a very high degree of fuel efficiency (in some cases even more than 90%).

5.1.2 Biomass cogeneration

When talking about biomass cogeneration, there is a number of technologies that are considered viable. Some of them are still in the demonstration phase (pilot projects), while plants using the steam turbine, gas engine and technology based on the *Organic Rankine Cycle* (ORC) are already on the market and are one of the proven technologies. The available technologies for converting biomass into electricity and heat can be divided into three main groups, depending on the size or purpose of the system:

- CHP in district heating plants
- shared boiler rooms

- detached houses.

The basic technologies are as follows:

- gas engine
- ORC,
- Stirling engine
- steam engine
- gas turbine (gasification or direct combustion)
- Steam turbine

Despite all of the above technologies, biomass cogeneration based on steam turbine technology has been evaluated as the most realistic option given the purpose and the required installed capacity, and will be further discussed as a possibility of biomass-based cogeneration.

Modern systems using energy from biomass have extremely high fuel efficiency, which can exceed 90%. Modern biomass plants, which incorporate state-of-the-art energy-transforming technologies in wood production chains, are used in the timber industry, district heating systems, cogeneration and heating of family homes.

In the process of biomass combustion, special attention is paid to flue gases and the solid residue with respect to their impact on the environment. Gaseous emissions of CO, NOx and other harmful substances have been reduced to a minimum in modern plants. Measurements in existing biomass plants confirm that these emissions are well below the statutory limit values.

When using biomass, the term 'small heating system' means a plant with heating power of up to 1 000 kW (1 MW). Such plants are smaller and are partially different from district heating systems. In the EU, there are many such plants. All kinds of biomass can be used as fuel, but the wood-processing plants are predominant. Such plants are mostly automated.

Among district heating systems using biomass, the most common heating systems are those having 1 to 10 MWt power, and are often built to operate within existing systems using fuel oil or coal. Straw or wood mass of different origins is used as fuel.

With regard to the use of thermal energy in the wood industry and agriculture, low-pressure and high-pressure boilers and power plants are available. Biomass boilers are either fire-tube or water-tube types. Fire-tube boilers are mostly used in plants with up to 25 MW of power. Due to the use in industrial installations, especially in the timber industry, fire-tube boilers have a very broad role. Industrial water-tube biomass boilers are designed for larger industrial customers and large plants with 2–50 MW of power. Heat production from biomass in low-pressure boilers is most often used in smaller installations, primarily to meet their own industrial heat demand and technological demand for water or lower-parameter steam. These boilers and installations are either hot-water, boiling-water or low-pressure-steam types.

Heat production from biomass in high-pressure boilers is carried out in larger facilities for heating and to meet technological demand for water or higher-parameter steam. These boilers and plants are hot-water or steam for the production of saturated steam.

Steam boilers with a steam superheater (for parameters of 40 bar and 400–450 °C (752–842 °F)), which tend to operate in contact with the steam turbine, are also used. The usual capacity is between 10 and 50 t/h.

Combustion grates are an established and reliable technology, which allows the use of fuels with different properties (moisture content and particle size). Various versions provide a high level of control and efficiency. However, modern development is aimed at maximum reduction of emissions, and this tendency has led to the development of fluidised bed combustion as the main alternative to grate systems.

Cogeneration using steam turbines involves two main components – a steam turbine and a steam generator, and auxiliary systems. The process is ORC-based and is similar to the conventional steam-turbine process, which runs on fossil fuels (coal, fuel oil, natural gas). However, due to biomass combustion technologies, the parameters of fresh steam are slightly lower, which in turn leads to lower levels of biomass utilisation, i.e. conversion into electrical and thermal energy. For larger biomass plants (20 MW), various performance measures to increase efficiency are implemented, such as superheated steam, regenerative heating and the like, which increases the efficiency to 35% [1]. Same as in the conventional steam-turbine process, there are two types of steam turbine cogeneration when using biomass, depending on the procedure, i.e. steam pressure at the outlet of the turbine:

- cogeneration with a condensing turbine with removal (steam pressure at the outlet of the turbine is lower than the atmospheric pressure), and

- cogeneration with a condensing turbine with removal (steam pressure at the outlet of the turbine is lower than the atmospheric pressure).

5.2 POTENTIAL OF PLANNED COGENERATION PLANTS

According to data supplied by the contracting authority, in the Republic of Slovenia, only one new thermal plant for producing electricity with a total heat output exceeding 20 MW (which is a requirement listed in Article 14(5) of Directive 2012/27/EU) is to be constructed. The plant will be built in Ljubljana and start operating on 1 January 2020.

The technical details of said plant are as follows:

- two gas turbines with 49 MW and one steam turbine with 42 MW;
- heat output for heating: 110 MW;
- combined heat output: 250–270 MW;
- investment cost: around EUR 120 million;
- heat power ratio: 1:0.9;
- estimated annual energy output: 700 GWh of electricity and 720 GWh of thermal energy.

The existing units 1 and 2 are planned to cease operation immediately after the new unit begins to operate. Their combined output is 184 MW.

It is also planned that unit 3 will operate until 2035. The installed power is around 160 MW.

5.3 POTENTIAL OF HEAVILY RENOVATED EXISTING COGENERATION PLANTS

According to available data, in the Republic of Slovenia, no large-scale renovations of existing thermal plants are planned for electricity production with a total heat output higher than the required 20 MW (Article 14(5b) of Directive 2012/27/EU).

5.4 POTENTIAL OF WASTE HEAT FROM INDUSTRIAL SOURCES

According to available data, in the Republic of Slovenia, no existing industrial plants with a total installed heat output higher than the required 20 MW that are used to produce waste heat at a usable heat level are currently planned to be renovated (Article 14(5c) of Directive 2012/27/EU).
The potential of waste heat cannot be accurately assessed at this time due to a lack of data and a missing time frame, but it will be assessed in the future in the scope of existing and new projects that are focused exclusively or concurrently on usable waste heat from industrial plants.

5.5 NATIONAL POTENTIALS FOR HIGH-EFFICIENCY COGENERATION

In accordance with Article 29 of the Energy Act (EZ-1) and the accompanying Rules on the methodology and mandatory content of the local energy concept (UL RS Nos 74/09, 3/11, 17/14 – EZ-1 and 56/16), the Republic of Slovenia has adopted the obligation of producing local energy concepts (hereinafter referred to as LEC) for each of its 212 municipalities. The contracting authority has delivered the data for 87 municipalities, i.e. the associated LECs.

The LEC structure is not standardized, therefore, the data is not always completely transparent. The latter refers mainly to the analysis of energy consumption by sector, purpose, existence of a district heating system, as well as the plans for developing energy infrastructure and energy consumption. The LECs delivered were not made at the same time, but rather were produced in the period from 2006 to 2016. For this reason, the data for individual municipalities from the LECs carried out ten years ago does not fully reflect the actual state of energy indicators in respective municipalities.

Based on the analysis performed on the delivered LECs, the authors have managed to distinguish whether a given municipality has a district heating system, which type of energy product is used, what the production of heat for the district heating system is, and what the production of thermal energy in small and larger boilers is like.

The following figure shows a schematic display of the summarised data. Of the 87 municipalities for which the LEC has been provided, 19 have a district heating system, and among them only two municipalities use waste heat.

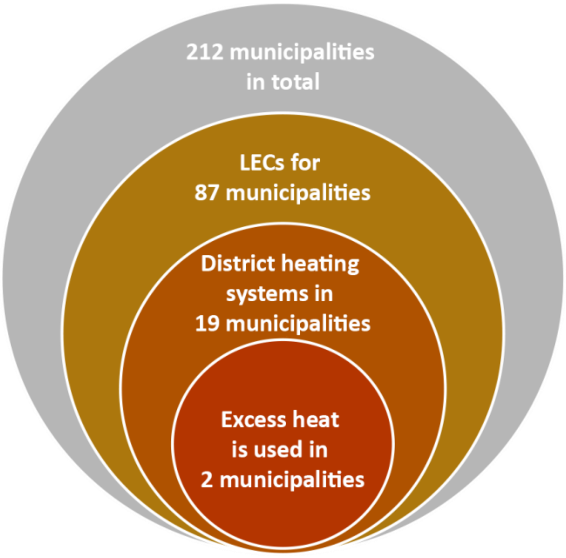

Figure 42: The structure of data obtained from the local energy concepts (LECs)

An analysis of energy products used in the existing district heating systems shows that the following are most commonly used: natural gas, liquefied petroleum gas (LPG), extra light fuel oil (ELFO), lignite, and woody biomass. The following table provides an overview of the use of certain energy products, i.e. combinations of energy sources in municipalities with a district heating system.

Table 11: Type of energy products used in district heating systems

Type of energy product	Number of municipalities
Woody biomass	4
Extra light fuel oil (ELFO)	1
Extra light fuel oil, woody biomass, lignite	1
Natural gas	4
Natural gas, woody biomass, pellets	1
Natural gas, extra light fuel oil – reserve	3
Natural gas, liquefied petroleum gas	1
Unknown / not available	4
TOTAL	**19**

The table below provides an overview of the municipalities with a district heating system for which data on energy consumption of primary energy products and on thermal energy produced is available. In some municipalities, this data was not provided in the LEC, and is therefore not listed in the table. The table also shows how waste heat is used in the municipalities of Nova Gorica and Tolmin, with the highest consumption identified in Velenje.

Table 12: Display of consumed primary energy and heat produced in district heating systems by municipality

Name of the municipality	Primary energy fuel consumption (MWh)	Heat generated in the boiler house (MWh)	Waste heat
Municipality of Maribor	102 125.91	72 721.00	No
Municipality of Murska Sobota	11 333.33		No
Municipality of Nova Gorica	21 709.00	763.00	Yes
Municipality of Velenje	329 016.00		No
Municipality of Gornji Grad			No
Municipality of Grosuplje		25 024.00	No
Municipality of Hrastnik	37 680.21	11 639.00	No
Municipality of Jesenice			No
Municipality of Kamnik	200.73		No
Municipality of Kanal ob Soči			No
Municipality of Luče	9.27		No
Municipality of Naklo			No
Municipality of Postojna		7 000.00	No
Municipality of Ribnica	6 286.39		No
Municipality of Slovenske Konjice	8 528.00	1 286.00	No
Municipality of Šempeter - Vrtojba	1 116.00		No
Municipality of Tolmin	968.00	260.00	Yes
Municipality of Trbovlje	93 500.00		No
Municipality of Zreče	10 036.38		No

6. IDENTIFYING OPTIONS TO INCREASE ENERGY EFFICIENCY OF DISTRICT HEATING AND COOLING INFRASTRUCTURE

6.1 ANALYSIS OF THE EXISTING SITUATION

To identify the potential increase in energy efficiency of district heating and cooling infrastructure, we will analyse all existing district heating and cooling systems for which relevant data has been collected. This will include an analysis of associated heat production plants. The final goal of the analysis is to determine which existing production plants meet or do not meet the efficiency criteria of district heating and cooling systems in accordance with Directive 2012/27/EU. Efficient district heating and cooling means a district heating or cooling system using at least 50% renewable energy, 50% waste heat, 75% cogenerated heat, or 50% of a combination of such energy and heat.

The efficiency of the delivery infrastructure or the distribution system of district heating and cooling is not considered and is not the subject of this project task.

The discovered inefficient production plants represent a potential for heating and cooling that can be met by high-efficiency cogeneration.

6.1.1 Efficiency of existing production facilities

The following table shows the analysis results of the efficiency of existing production plants. During the analysis, wherever possible, production installations are grouped by district heating system supplying heat, or by distribution network to which the production installations supply heat. Some production installations cover their own energy needs and supply heat into their internal distribution systems, therefore, they were not included in the analysis. A special example is the area of Ljubljana, where several production installations combined supply several distribution systems, and they are monitored together.

Furthermore, for some production installations connected to the distribution system of the Ljubljana Technology Park, no data was available, therefore, they were also excluded from the analysis. The analysis was performed with data for 2015. The energy value of the fuel consumed is presented in MWh.

Table 13: Efficiency of existing heat production facilities by distribution system (data for 2015)

Name of the distribution system	RES %	RES type	COGENERATION %	Condition of Directive efficiency met: >50% RES / >75% cogeneration	Amount of heat delivered to end customers (MWh)
SDO Bled	0%		71%	NO	8 953.50
SDO Celje	**88%**	**woody biomass**	**97%**	**YES**	40 143.72
SDO obrtne cone (crafts districts) Žerjav, Črna na Koroškem	0%		0%	NO	3 553.00
SDOLB Čardak residential area, Črnomelj	**100%**	**wood chips**	**0%**	**YES**	2 340.31
SDO Todraž	**100%**	**wood chips**	**0%**	**YES**	2 025.00
SDOLB Gornji Grad	**100%**	**woody biomass**	**0%**	**YES**	2 149.56
SDO Grosuplje	0%		0%	NO	7 495.02
SDO Hrastnik	**0%**		**85%**	**YES**	11 427.93
SDOLB Ivančna Gorica	**100%**	**wood chips**	**0%**	**YES**	1 094.00
SDO Kobarid	**100%**	**wood chips**	**0%**	**YES**	435.47
SDOLB Lenart	**95%**	**woody biomass**	**0%**	**YES**	6 607.12
SDO Lendava	**96%**	**geothermal energy**	**0%**	**YES**	4 907.87
SDOLB Luče	**100%**	**wood chips**	**0%**	**YES**	664.00
SDOLB Metlika	**100%**	**wood chips**	**0%**	**YES**	2 483.00
SDO Miren - Kostanjevica	**100%**	**wood chips**	**0%**	**YES**	667.48
SDO Ekoenergija, Moravče	**100%**	**wood chips**	**0%**	**YES**	1 124.51
SDO Murska Sobota	0%		67%	NO	6 541.00
SDO Nazarje	**100%**	**woody biomass**	**0%**	**YES**	5 409.85
SDOLB Oplotnica	**100%**	**wood chips**	**0%**	**YES**	388.00
SDOLB Preddvor	**100%**	**wood chips**	**0%**	**YES**	2 475.00
SDO Ptuj	0%		66%	NO	12 560.25
SDO Radlje ob Dravi	**100%**	**wood chips**	**0%**	**YES**	515.00
SDOLB Ribnica	**100%**	**wood chips**	**0%**	**YES**	5 780.00
SDO Ekoenergija, Semič	**100%**	**wood chips**	**0%**	**YES**	1 284.57
SDOLB Solčava	**100%**	**wood chips**	**0%**	**YES**	257.00
SDO Podmark residential area, Šempeter Vrtojba	0%		0%	NO	431.00
SDO Sladki Vrh, Šentilj	**0%**		**85%**	**YES**	2 251.63
SDO Energoles, Šentjur	**100%**	**woody biomass**	**100%**	**YES**	700.45
SDOLB Šetrupert	**100%**	**wood chips**	**0%**	**YES**	5 141.50

Name of the distribution system	RES %	RES type	COGENERATION %	Condition of Directive efficiency met: >50% RES / >75% cogeneration	Amount of heat delivered to end customers (MWh)
SDO Trbovlje	**0%**		**91%**	**YES**	24 254.04
SDOLB Vransko	**100%**	**wood chips**	**0%**	**YES**	3 585.00
SDOLB Vuzenica	**100%**	**woody biomass**	**0%**	**YES**	805.80
SDO Zagorje ob Savi	**100%**	**woody biomass**	**0%**	**YES**	6 541.83
SDO Center, Zreče	**0%**		**87%**	**YES**	2 310.35
SDO Žalec	0%		0%	NO	4 780.00
SDOLB Železniki	**100%**	**woody biomass**	**94%**	**YES**	11 270.00
SDOLB Dravograd	**100%**	**wood chips**	**0%**	**YES**	528.58
SDO Meža residential area, Dravograd	0%		0%	NO	379.90
SDO ŠRC, Idrija	0%		0%	NO	2 912.03
SDO Ydria, Idrija	0%		0%	NO	2 180.70
SDO Hrušica, Jesenice	0%		44%	NO	380.00
SDO Jesenice	**0%**		**80%**	**YES**	31 806.00
SDO Kamnik	0%		42%	NO	4 066.10
SDO Tisa, Kamnik	**100%**	**woody biomass – mixed**	**0%**	**YES**	1 150.04
SDO Kidričevo	**0%**		**100%**	**YES**	3 700.00
SDO Kočevje	**96%**	**woody biomass – mixed**	**0%**	**YES**	9 389.50
SDO Kočevska reka	0%		0%	NO	356.73
SDH Iskra Labore commercial zone, Kranj	0%		0%	NO	1 330.00
SDO Vodni stolp residential area, Kranj	0%		0%	NO	4 257.75
SDO Iskra Labore commercial zone, Kranj	**0%**		**86%**	**YES**	3 250.00
SDO Planina residential area, Kranj	0%		74%	NO	36 422.25
SDOLB Mojstrana, Kranjska gora	**100%**	**wood chips**	**0%**	**YES**	404.00
SDOLB Kranjska Gora	**100%**	**wood chips**	**0%**	**YES**	7 124.84
SDO Gabrovka, Litija	**100%**	**wood chips**	**0**	**YES**	96.29
SDO Jevnica, Litija	**100%**	**wood chips**	**0%**	**YES**	99.26
SDO Litija center, Litija	0%		65%	NO	1 583.00
SDO Ljubljana / Steam pipeline TE-TOL east / Steam pipeline Ljubljanske mlekarne/ Steam pipeline TE-TOL west	**21%**	**woody biomass – mixed**	**96%**	**YES**	1 051 530.30
Lek steam pipeline, Ljubljana	**0%**		**100%**	**YES**	52 870.22
SDO EPF Maribor, Maribor	0%		35%	NO	1 040.20

Name of the distribution system	RES %	RES type	COGENERATION %	Condition of Directive efficiency met: >50% RES / >75% cogeneration	Amount of heat delivered to end customers (MWh)
SDO UKC Maribor, Maribor	0%		0%	NO	1 058.73
SDO Maribor	**0%**		**82%**	**YES**	86 168.37
SDO Pobrežje, Maribor	0%		0%	NO	4 707.96
SDO Nova šola, Mirna Peć	**100%**	**wood chips**	**0%**	**YES**	536.64
SDO Stara šola, Mirna Peč	**100%**	**wood chips**	**0%**	**YES**	254.90
SDO Podrožnik, Mozirje	**100%**	**wood chips**	**0%**	**YES**	869.00
SDO Elektro Primorska, Nova Gorica	0%		0%	NO	272.00
SDOLB Majske Poljane, Nova Gorica	**100%**	**wood pellets**	**0%**	**YES**	2 010.00
SDO Nova Gorica	0%		44%	NO	16 360.00
SDO IC Meblo, Nova Gorica	**0%**		**100%**	**YES**	1 784.00
SDO TPV, Novo mesto	0%		0%	NO	1 075.58
SDO naselje Slavka Gruma residential area, Novo mesto	0%		0%	NO	2 089.35
SDO Obala, Lucija, Piran	0%		27%	NO	1 537.31
SDO Šolska, Lucija, Piran	0%		31%	NO	1 563.00
SDO Liminjanska, Lucija, Piran	0%		54%	NO	691.24
SDOLB Postojna	**100%**	**wood chips**	**0%**	**YES**	5 273.30
SDO Volaričeva 24, Postojna	**100%**		**0%**	**YES**	1 812.00
SDO Ravne na Koroškem	**0%**		**93%**	**YES**	16 710.00
SDO TO, Slovenske Konjice	**100%**	**woody biomass – mixed**	**0%**	**YES**	608.25
SDO SP, Slovenske Konjice	**13%**	**wood chips**	**97%**	**YES**	3 465.82
SDO Slovenj Gradec	0%		50%	NO	10 225.92
Šmartno elementary school, Slovenj Gradec	**100%**	**wood chips**	**0%**	**YES**	321.85
SDO na Logu, Tolmin	**100%**	**wood chips**	**0%**	**YES**	441.92
SDO Podbrdo, Tolmin	**100%**	**woody biomass – mixed**	**0%**	**YES**	356.10
SDH Velenje	0%	water heat	0%	NO	120.50
SDO Šaleške doline, Velenje	**0%**		**100%**	**YES**	231 794.15
TOTAL					**1 802 319.31**

We have analysed 85 systems for district heating or cooling. Efficient district heating and cooling envisages a district heating or cooling system using at least 50% renewable energy, 75% waste heat, 50% cogenerated heat, or 50% of a combination of such energy and heat.

Of all analysed production plants, 56 or 66% of them meet the efficiency condition set out by Directive 2012/27/EU. In the table above, the production plants that meet the efficiency criteria are marked in green.

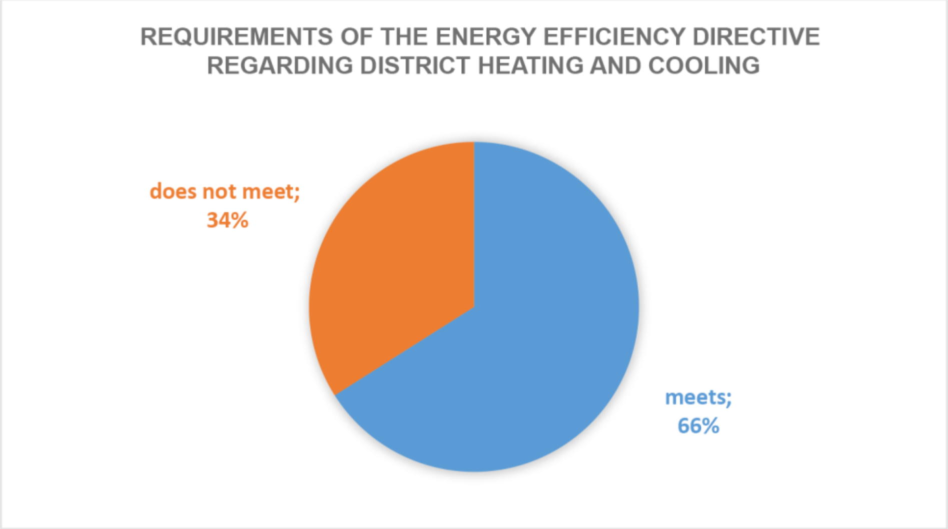

Figure 43: Structure of meeting the requirements of the Energy Efficiency Directive

It is evident that wood chips are the most representative RES, being used in 28 existing heating systems. Not many district heating systems satisfy the conditions laid down in Directive 2012/27/EU. The majority of those meeting the conditions meet only one condition, such as using at least 50% heat from renewable sources and using more than 75% cogenerated heat.

6.2 IDENTIFYING OPTIONS TO INCREASE ENERGY EFFICIENCY OF DISTRICT HEATING AND COOLING INFRASTRUCTURE

In the table below is a list of all plants analysed that did not satisfy the efficiency criteria for district heating and cooling as defined in Directive 2012/27/EU. These plants represent a potential for meeting heating and cooling demand using high-efficiency cogeneration. Some of them produce heat from cogeneration plants, which are very close to the proportion of 75% as defined in Directive 2012/27/EU, and they are expected to quickly meet the requirements set out in Directive 2012/27/EU, e.g. in distribution systems SDO Bled, SDO Murska Sobota, SDO Ptuj, SDO Planina residential area in Kranj, and SDO Litija centre in Litija.

The following table (Table 14) shows the amount of heat delivered to end users, and the percentage of cogeneration. The distribution systems that are very close to meeting the efficiency requirements set out in Directive 2012/27/EU are marked green. For them, it is realistic to assume that they could satisfy the efficiency requirements set out in Directive 2012/27/EU, by incorporating appropriate work regimes.

Table 14: Energy efficiency indicators of district heating and cooling infrastructure (data obtained from the AGEN-RS, 2015)

Name of the distribution system	**Share of cogeneration**	**Amount of heat delivered to end customers (MWh)**
SDO Bled	**71%**	**8 953.50**
SDO obrtne cone Žerjav, Črna na Koroškem	0%	3 553.00
SDO Grosuplje	0%	7 495.02
SDO Murska Sobota	**67%**	**6 541.00**
SDO Ptuj	**66%**	**12 560.25**
SDO Podmark residential area, Šempeter Vrtojba	0%	431.00
SDO Žalec	0%	4 780.00
SDO Meža residential area, Dravograd	0%	379.90
SDO ŠRC, Idrija	0%	2 912.03

SDO Ydria, Idrija	0%	2 180.70
SDO Hrušica, Jesenice	44%	380.00
SDO Kamnik	42%	4 066.10
SDO Kočevska reka	0%	356.73
SDH Iskra Labore commercial zone, Kranj	0%	1 330.00
SDO Vodni stolp residential area, Kranj	0%	4 257.75
SDO Planina residential area, Kranj	**74%**	**36 422.25**
SDO Litija center, Litija	**65%**	**1 583.00**
SDO EPF Maribor, Maribor	35%	1 040.20
SDO UKC Maribor, Maribor	0%	1 058.73
SDO Pobrežje, Maribor	0%	4 707.96
SDO Elektro Primorska, Nova Gorica	0%	272.00
SDO Nova Gorica	44%	16 360.00
SDO TPV, Novo mesto	0%	1 075.58
SDO naselje Slavka Gruma residential area, Novo mesto	0%	2 089.35
SDO Obala, Lucija, Piran	27%	1 537.31
SDO Šolska, Lucija, Piran	31%	1 563.00
SDO Liminjanska, Lucija, Piran	54%	691.24
SDO Slovenj Gradec	50%	10 225.92
SDH Velenje	0%	120.50
TOTAL		**138 924.01**

The table above (Table 14) shows the potential for increasing energy efficiency of district heating and cooling infrastructure, which amounts to 138 924 MWh. Given the fact that five distribution systems are almost achieving the percentage of cogeneration required to satisfy the high-efficiency criteria, a conservative assessment would need to take the total actual potential of these five distribution systems out of the equation. The possible potential for high-efficiency cogeneration is shown in the following table (Table 15).

Table 15: Possible potential for high-efficiency cogeneration

Possible potential for high-efficiency cogeneration (MWh)	
Total potential (MWh)	**138 924.01**
Actual potential for high-efficiency cogeneration, which does not include the production of SDO Bled, SDO Murska Sobota, SDO Ptuj, SDO Planina residential area in Kranj, and in SDO Litija center in Litija	**72 864.01**

Only partial data was available when the current status of plants and installations was being analysed. From this partial data, as well as from the charts below, it is evident that the manufacturing year of the production installations ranges over a wide span of years, with the oldest installation dating back to 1966 and the newest to 2016.

With the aim of obtaining better information about the age of the plants, we calculated the average age of production installations to be 13 years. This characterizes existing heat production plants in district heating systems in the Republic of Slovenia.

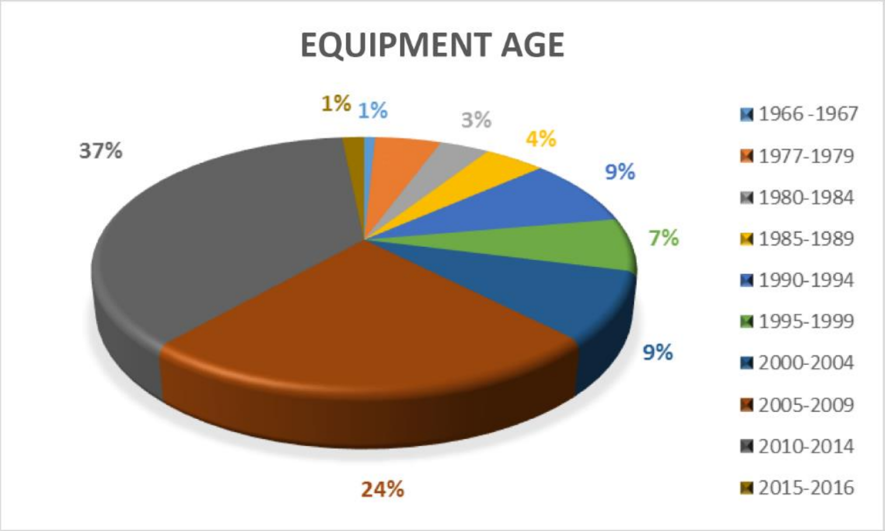

Figure 44: Structure of production plants by age

In accordance with good engineering practice, boiler plants are deemed acceptable if they are not older than 25 years, pumping plants not older than 30 years, and water networks not older than 35 years. This applies only if the condition of the equipment is in accordance with the duration of use and if it shows only minor signs of wear.

The following table provides an overview of good engineering practice in assessing the state of heating system parts.

Table 16: Assessment of the state of heating system parts[5]

Assessment	**State of equipment**	**Statement of facts**	**Age of equipment**
1	Very bad	The equipment is worn out. Bad overall appearance, corroded surface, leaks, mechanical damage, cracks, damaged insulation, etc. Insufficient or a complete lack of maintenance. The plant is non-functional or is functioning with frequent failures and outages. Substantial losses. Inefficiency. Outdated technical solutions. Replacement needed urgently.	Boiler plants: over 25 years Pumping plants: over 30 years Water networks: over 35 years
2	Bad	The equipment is in poor condition due to age or poor maintenance during use. Bad overall appearance. Functional, but with a high risk of failure or outage. Outdated technical solutions. Low efficiency. Losses. Serious repair or replacement is required to make it sufficiently functional. A replacement should be provided as soon as possible.	Boiler plants: over 25 years Pumping plants: over 30 years Water networks: over 35 years
3	Satisfactory	The condition of the equipment is in accordance with its duration of use. Showing only minor signs of wear. While in use, systematic maintenance has been performed (replacements and repairs). It is sufficiently functional with increased monitoring, more attention and maintenance. Replacements necessary only to improve efficiency or to implement modern solutions.	Boiler plants: over 25 years Pumping plants: over 30 years Water networks: over 35 years
4	Good	Barely showing signs of wear. Minor defects and faults in the current operation have been prevented with systematic maintenance. Appropriate functionality, availability, and reliability of operation. Relatively modern solutions and structures. With proper maintenance it can be used for the next 10 to 15 years.	Boiler plants: 10 to 20 years Pumping plants: 10 to 20 years Water networks: 15 to 25 years

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[5] *Development strategy of Croatia's heating industry –Phase 1/3, 2008. 1/3, 2008.*

5	Very good	Showing no signs of wear. No significant defects in the current drive. Systematic maintenance has been performed. Modern technological solutions and suitable efficiency. The equipment is almost new and, with proper maintenance, it can be used for another 15 to 20 years.	Boiler plants: up to 10 years Pumping plants: up to 10 years Water networks: up to 15 years

The size (power) of the plants covered by the analysis has a large variance. The nominal heat output of each production plant ranges from 200 MW in a steam condensing turbine in Velenje to 0.04 MW in a combined liquid fuel boiler in Kočevje, as shown in the figure below. Most boilers have an output of less than 5 MW, meaning that more than 75% of all analysed production plants have a nominal heat output of less than 5 MWt.

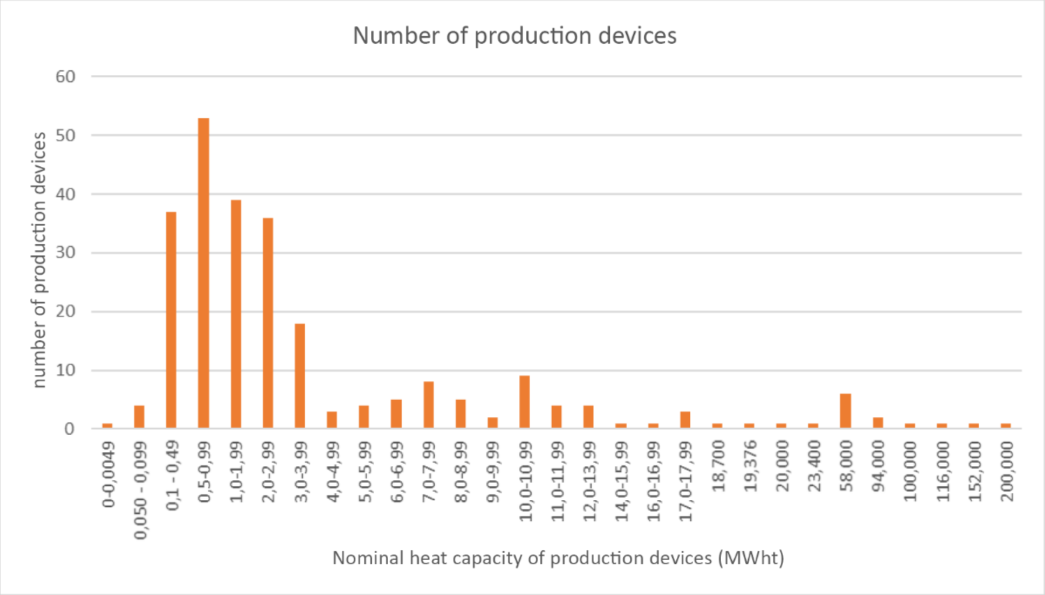


Figure 45: Production plants by rated heat output

6.3 REVIEWING THE POSSIBILITY OF INCREASING ENERGY EFFICIENCY OF THE EXISTING INFRASTRUCTURE

Increased energy efficiency in the building sector already connected to the district heating system would not have a direct positive impact on the development of district heating systems. Renovation and revitalisation of the building envelope would increase the building's energy efficiency, and inevitably lead to a reduced heat demand. This fact does put district heating systems in a commercially favourable position, because it leads to a reduced heat demand and consequently to a reduction in revenue and profit. In this context, increasing energy efficiency in the building sector can adversely affect the future development of district heating systems. Energy efficiency of heating systems refers to the state of the infrastructure and to energy parameters of the heating medium, which is transported by a water network. By reviewing current development and monitoring trends, four generations of district heating systems can be characterised. The biggest difference between them is the temperature regime of the heating medium, which has changed most during the development of district heating systems. It makes sense that there has been a constant tendency of reducing the initial temperature of the heating medium. By reducing the initial temperature, less heat is lost. In addition to reducing the initial temperature, an even greater drop in temperature is desired. The consequences are mostly positive. By increasing temperature drop, i.e. the temperature difference between the initial heating medium and the medium returning from the user, mass flow is reduced and consequently the running costs of the circulation pump are reduced.

Pipelines with a smaller diameter are also beneficial, since the capital cost is lower when investing into new pipelines, and heat loss of piping systems is reduced.

The distribution network, i.e. the pipeline system of a district heating system, is mainly used to transport heat via the heating medium from the heat source to the end users. The requirements set for the distribution network are minimised heat loss, reliable performance, and corrosion resistance. When designing or renewing pipelines, it is necessary not only to select a pipeline having suitable dimensions, but also made out of a suitable material. This is necessary because pipelines of district heating systems are often exposed to high pressure and high temperatures. This is mainly expressed in so-called second-generation systems. Such pipelines need to be renewed in a special way. Nowadays, there are pre-insulated pipes on the market that are installed directly underground. The steel pipe, which transports the heating medium, is coated with an insulating material (most commonly polyurethane foam with good thermodynamic properties, i.e. thermal conductivity). Polyethylene is the final layer, and it prevents moisture from penetrating into the insulating layer and thereby impairing the thermal properties of the insulation. Moisture detectors are installed into the pre-insulated pipes. They signal any damage to the polyethylene or steel pipes. The pipeline system is one of the most important elements for increasing the energy efficiency of a district heating system since the replacement of old, worn-out pipes in concrete channels reduces heat loss to the environment, and it makes it less likely that the use of the pipeline will be discontinued due to corrosion and mechanical damage, which often leads to significant heat losses in existing systems.

Users are the last link in the chain of production, distribution, and supply of thermal energy. End users of thermal energy, which are mostly households, receive heat from heat substations. There are two types of heat substations with respect to the method of connecting end users. The modern way of connecting is the so-called indirect system, in which thermal energy, delivered via a heating medium, is put through a heat exchanger to the heating medium of the secondary circuit. The other way of connecting is via a direct system. In such systems, the heating medium flows directly from the central heat source to end user's heating body (radiator). Direct systems are less common, and they are often avoided due to security and environmental reasons, and because the entire system is easy to manage and control.

During construction of new or renewal of existing systems, it is necessary to ensure optimal system parameters so that the district heating system is as effective and as efficient as possible. Such systems are characterized by very long transit periods, which are a fundamental problem in determining the dynamics, control, and strategy of system management. For example, in more complex networks (e.g. an extensive pipeline network with different elevation points), there is a reasonable possibility for pressure oscillations. Pressure oscillations occur because of incorrectly dimensioned pressure regulators, which are most frequently located in heating substations. The function of pressure regulators is to optimise the total heat source system, including distribution, pipelines, networks and end users. The integral approach in the design of the whole system creates a synergistic operation, which results in optimal system control.

7. SHARE OF HIGH-EFFICIENCY COGENERATION, THE POTENTIAL ESTABLISHED AND PROGRESS ACHIEVED

7.1 OVERVIEW OF MICRO-COGENERATION TECHNOLOGIES

In addition to Section 5.1, where suitable technologies for high-efficiency cogeneration are more broadly presented, the following table shows the appropriate technologies for micro-cogeneration (MC).

7.1.1 Micro-cogeneration based on an internal combustion engine

Cogeneration plants based on internal combustion engines running on natural gas simultaneously produce heat and electricity. They have a large power range and are suitable for residential and commercial buildings as well as other facilities in the service and public sectors.

Important parts of this compact plant are the engine, the synchronous generator, and heat exchangers. The engine has a special design – it runs in the Otto cycle, which is adapted for continuous operation. A schematic representation of micro-cogeneration using an internal combustion engine is given in the following figure (Figure 46).

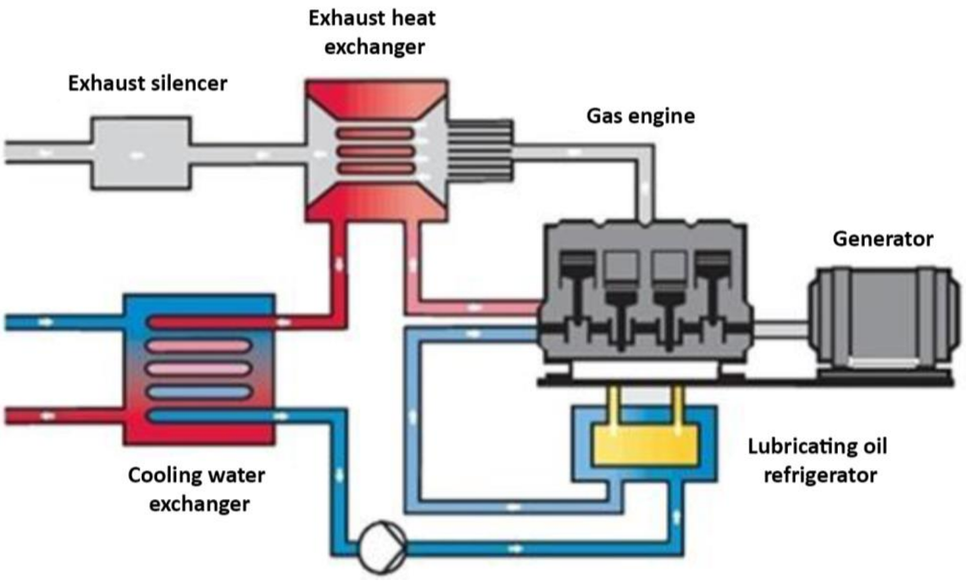


Figure 46: A schematic representation of micro-cogeneration using an internal combustion engine

An engine-powered generator typically produces low-voltage three-phase electric power (typically 0.4 kV). Unused electricity is fed into the distribution grid.

Thermal energy is subtracted from the internal cooling circuit, i.e. from the heat of the lubricating oil, cooling water, and exhaust gas. The available heat from the internal combustion engine has the following approximate proportions:

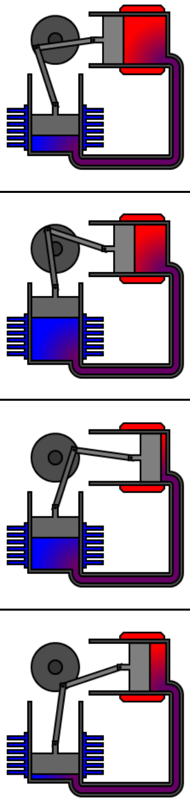
- heat radiation from the engine – 3 to 7% (loss, unusable);
- heat from the lubricating oil – about 3%;
- heat from the exhaust gas – 30 to 40% (less for turbocharged engines, more for naturally aspirated engines);
- heat from the cooling system – 20 to 40% (less for naturally aspirated engines, more for turbocharged engines).

7.1.2 Stirling-engine-based micro-cogeneration

A Stirling engine is a heat engine that operates by cyclic compression and expansion of air or some other gas at different temperatures with the help of an external heat source, such as waste heat from biogas plants. In a Stirling engine, thermal energy is converted into mechanical work that powers an electric generator. The engine runs in a cycle in which cold gas compresses, heats up, expands, and cools down. Then the cycle is repeated. This is a closed-cycle system, meaning that no gas is diverted to the engine, nor is it released; therefore, it is classified as an external combustion engine. Heat transfer takes place via a heat exchanger, which is integral with the engine cylinder.

There are various types of Stirling engines, such as two-cylinder engines (alpha type) and displacer engines (beta and gamma types). To illustrate the principle of the Stirling engine, the four steps of the engine cycle (alpha type) are shown in the figure below (Figure 47). Alpha Stirling contains two pistons in separate cylinders, one hot and one cold. The hot cylinder is located inside the high-temperature heat exchanger, and the cold cylinder is in the low-temperature heat exchanger. This type of engine has a high power-to-volume ratio, and there are technical problems usually associated with the high temperature of the hot piston and the durability of its seals. In practice, the piston is usually well insulated to make some distance between the seal and the hot zone, thus increasing the dead space.

The figure below (Figure 47) shows a schematic representation of how the Stirling engine functions.



1 Most of the working gas is in contact with the hot cylinder walls, the heating/expansion of the working fluid pushing the hot piston to the left. The expansion continues in the cold cylinder, which is 90 degrees out of phase to the hot piston and can extract more work from the hot gas.

2 The gas has now reached its maximum volume. The hot cylinder piston begins to push most of the gas into the cold cylinder, where it is cooled and the pressure drops.

3. Almost all the gas is now in the cold cylinder and continues to cool. The turning flywheel (or the other piston pair on the same axis), pushes the cold piston and thus the remainder of the gas.

4 The gas reaches its minimum volume, and will now be expanded in the hot cylinder, where it will be heated again, and the hot piston's cycle will begin.

Figure 47: A schematic representation of how the Stirling engine functions

Generally speaking, Stirling engines have a much lower efficiency than internal combustion engines, but they are used only in special cases. Using waste heat from biogas plants is of only limited use due to the low temperature level. The engine operates better at higher temperatures (above 900 °C).

In recent years, micro-cogeneration with Stirling engines has started reaching market maturity, and smaller-capacity operations have become available. Typical engine problems are corrosion and accumulation of deposits on heat exchangers, therefore it is better to use natural gas since it is a cleaner fuel.

7.1.3 Fuel-cell-based micro-cogeneration

Fuel cells produce electricity and thermal energy without the usual combustion. They produce it directly from the chemical energy of gas by inducing an electrochemical reaction. The products of this process are direct current electricity and heat, as well as chemically pure water.

This ‘cold combustion’ is based on a chemical reaction between hydrogen and oxygen. Hydrogen is supplied to the anode and separated into positive ions and negative electrons through a catalyst. Electrons travel to the cathode via an electrical conductor, and current is generated. At the same time, positive hydrogen ions pass through the membrane to reach the cathode, react with oxygen and generate water. This also leads to generation of usable heat. The following figure (Figure 48) shows a schematic representation of the electrochemical process in a fuel cell.

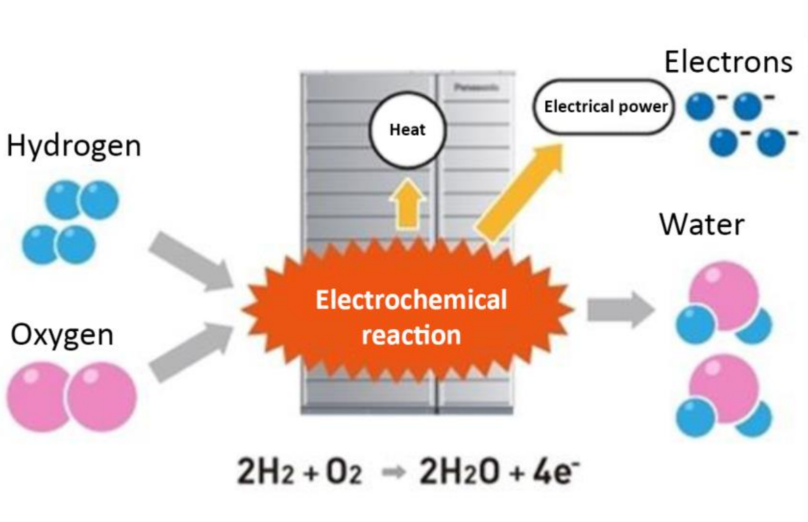


Figure 48: Schematic representation of the electrochemical process in a fuel cell

If the fuel is natural gas, a *'reformer'* is needed to process the gas and produce hydrogen. Another product is generated besides hydrogen – CO_2.

The electrical fuel efficiency of fuel cells is around 37–45%, and it is expected to reach more than 50% with further development. The entire cogeneration process can be 85–90% fuel efficient.

Advantages of fuel-cell-based cogeneration:

- easy to manage and maintain compared to engines or turbines;
- modular design;
- a high degree of fuel efficiency – the size of the unit and load changes are almost negligible;
- quiet operation, since there are no moving and rotating parts;
- minimal pollution (no CO and NOx emissions).

Weaknesses:

- high price;
- availability and handling of the fuel (hydrogen);
- technological developments.

Basic types in practice:

- low-temperature fuel cells – alkaline with a solid polymer electrolyte (*Polymer Electrolyte Membrane* (PEM), around 80 to 100 °C (176 to 212 °F)) or with phosphoric acid (*Phosphoric Acid Fuel Cell* (PAFC), around 200 °C (392 °F));
- medium-temperature fuel cells (around 650 °C (1202 °F)) contain the molten carbonate electrolyte (*Molten Carbonate Fuel Cell (MCFC)*);
- high-temperature fuel cells (about 1 000 °C (1832 °F)) in which the electrolyte is a solid oxide (*Solid Oxide Fuel Cell (SOFC)).*

In recent years, fuel cells developed and became available on a commercial scale, and a number of major manufacturers offer compact micro-cogeneration based on these drive units to be used in construction and other decentralised systems, such as shipping, air transport, etc.

7.2 TECHNICAL REQUIREMENTS FOR THE RATIONAL USE OF ENERGY AND THERMAL PROTECTION IN BUILDINGS

In order to determine the potential for the use of micro-cogeneration in the buildings sector for existing and new buildings alike, an analysis of the required combination of measures has been performed. The analysis includes the external building envelope and technical water-heating systems in buildings. The source of the data is the document in '*cost-optimal levels of minimum energy performance requirements for buildings and building elements*', which describes the classification of buildings according to their age and purpose, and it shows the needed, end-use and primary energy for technical systems. We also included the provisions of a regulation for energy efficiency in buildings; it lays down strict requirements for building envelopes[6] and technical systems[7].

For all new buildings and major renovations of existing buildings, PURES 2010 has determined the following:

- Maximum permitted levels of heat transfer coefficients for elements of the external building envelope.
- At least 25% of the total energy consumption for the operations of all technical systems in the building shall come from renewable energy sources (for all buildings except single-family houses). This provision shall be considered fulfilled if the building uses high-efficiency cogeneration to satisfy at least 50% of the end-use energy demand for heating, cooling, and hot water. In exceptional cases, it is considered that the provision is satisfied if the energy demand of the building (QH, nd) is 30% lower than specified by the regulations. Buildings classified as nearly zero-energy buildings (NZEB), i.e. having at least 50% of energy produced from renewable energy sources and/or using high-efficiency systems, have additional obligations.
- Maximum permitted levels of primary energy for standard and nearly zero-energy buildings that are obliged by the mandatory construction standard after 2018 or after 2020.

7.2.1 Proposed energy efficiency measures

Analysis of possible use of micro cogeneration in buildings was carried out in two versions:

- improving the thermal insulation of the external envelope in accordance with the regulations, and using high-efficiency micro cogeneration, and
- using micro-cogeneration without improving the envelope.

In the improvement of thermal insulation of the external envelope, an optimal level of thermal insulation for all elements of the external envelope is planned (integral reconstruction), which reduces the total primary energy to the PURES 2010 value. The cost per unit to be improved is in accordance with the 'cost-optimal levels' and is shown in the table below (Table 17).

Table 17: Display of measures to improve the outer shell indicating cost per unit and total cost

Outer wall	**Heat transfer coefficient U [W/m²K]**	**Costs €/m²**
Reconstruction (1960)	0.2	48
Reconstruction (1980)		
New construction		38
NZEB	0.15	41
Roof	**Heat transfer coefficient U [W/m²K]**	**Costs €/m²**
Reconstruction (1960)	0.2	102
Reconstruction (1980)		94
New construction		72
NZEB	0.15	97
Flooring on the ground; flooring in unheated space above or outdoor space	**Heat transfer coefficient U [W/m²K]**	**Costs €/m²**
all	0.3	38
Windows	**Heat transfer coefficient U [W/m²K]**	**Costs €/m²**
Reconstruction (1960), reconstruction (1980), new construction	1.4	280
NZEB	1.0	300

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[6] *Technical Guidelines for the Construction of TSG-1-004, Efficient Use of Energy, MOP, 2010.*

[7] *Rules on efficient use of energy in buildings (PURES 2010).*

Total costs of investment in improving the outer shell of the building, classified according to age and purpose, are shown in Table 23 below.

Table 18: Display of investment costs for the outer shell as required by PURES 2010

Costs of investment for outer shell [€]	**ESS1**	**ESS2**	**VSS1**	**JSS1**	**NSS1**	**NSS2**
Reconstruction (1960), reconstruction (1980)	27 034	24 938	166 940	123 040	113 860	153 200
New construction	25 162	23 672	167 006	120 200	110 300	151 660
NZEB	28 922	23 961	187 217	137 900	125 750	171 570

As the initial value for the analysis, the 2010 PURES primary and end-use energy consumption were taken into account for buildings classified by purpose and age, in accordance with the 'Cost-optimal levels' document. A total of 30 combinations were considered. The size of the high-efficiency micro-cogeneration system and the annual heat load curve are based on the total primary energy and specific end-use energy for space heating and hot water.

According to the thus obtained curve, the available micro-cogeneration system turned on so that it functioned for 4 000 hours in the base drive, from which at least 50% of the generated heat is usable. In some cases, two identical units with a different number of annual operating hours are switched on. The fuel is natural gas.

In terms of selected cogeneration units and operating hours, equivalent primary energy was determined by subtracting the electricity produced (converted to primary) from the input fuel energy. In this case, however, the primary energy factor is 2.5 for electricity and 1.1 for gas as input fuel.

After determining the above-mentioned data, the values of selected plants are the following:

- electric power in kW
- thermal power in kW
- fuel input power in kW
- fuel energy per year in kWh
- electricity produced per year in kWh_e
- heat produced per year in kWh_t
- total hours per year
- heat delivered per year in kWh_t
- percentage of usable thermal energy
- equivalent primary thermal energy per year in kWh_t
- equivalent primary specific energy per year in kWh/m^2
- electric and thermal efficiency
- the percentage of meeting the annual heat demand
- specific fuel consumption:
  - fuel energy per year in kWh
  - gas and fuel energy per year for electricity in m^3 and kWh
  - gas and fuel energy per year for heat in m^3 and kWh.

The following table (Table 19) shows the technical characteristics of devices for the specific needs of buildings.

Table 19: Display of selected micro cogeneration systems and backup systems in individual buildings

Selected micro cogeneration systems and backup systems [kW]	**ESS1**	**ESS2**	**VSS1**	**JSS1**	**NSS1**	**NSS2**
MC without reconstruction (1960 and 1980)	0.8 kW$_e$ 5.3 kW$_t$	6.0 kW $_e$ 14.9 kW$_t$	50.0 kW$_e$ 81.0 kW$_t$	20.0 kW$_e$ 39.0 kW$_t$	20.0 kW$_e$ 39.0 kW$_t$	20.0 kW$_e$ 39.0 kW$_t$
Backup system	-	-	-	-	-	-
MC reconstruction (1960 and 1980)	Two units 0.7 kW$_e$ 1.008 kW$_t$	Two units 1 kW$_e$ 3.2 kW$_t$	8.5 kW$_e$ 20.0 kW$_t$	8.5 kW$_e$ 20.0 kW$_t$	8.5 kW$_e$ 20.0 kW$_t$	8.5 kW$_e$ 20.0 kW$_t$
Backup system	11	45	80	-	-	-
MC new construction	1 kW$_e$ 3.3 kW$_t$		8.5 kWe 20.0 kWt	0.8 kW$_e$ 5.3 kW$_t$	1 kW$_e$ 3.2 kW$_t$	0.8 kW$_e$ 5.3 kW$_t$
Backup system	-	-	-	-	45	11
MC NZEB	0.7 kW$_e$ 1.008 kW$_t$	0.7 kW$_e$ 1.008 kW$_t$	6.0 kW$_e$ 14.9 kW$_t$	0.7 kW$_e$ 1.008 kW$_t$	Two units 0.7 kW$_e$ 1.008 kW$_t$	1 kW$_e$ 3.3 kW$_t$
Backup system	-	19	-	-	-	-

Shown below are the necessary investments in different high-efficiency cogeneration systems. If necessary, additional heat is generated in the backup system. The backup system selected for the analysis is a gas condensing boiler.

Table 20: Display of investment costs for micro-cogeneration and backup systems in individual buildings

Investment costs for micro-cogeneration and backup systems [€]	**ESS1**	**ESS2**	**VSS1**	**JSS1**	**NSS1**	**NSS2**
MC without reconstruction (1960)	17 500	42 500	140 000	73 000	50 000	73 000
Backup system cost	-	-	-	-	-	-
MC reconstruction (1960 and 1980)	6 500	17 500	50 000	50 000	50 000	50 000
Backup system cost	1 039	1 979	3 075	-	-	-
MC new construction	3 900	6 500	5 000	17 500	17 500	17 500
Backup system cost	-	-	-	-	1 979	1 039
MC NZEB	3 900	3 900	42 000	6 500	6 500	17 500
Backup system cost	-	1 106	-	-	-	-

The ability of the system to meet the PURES 2010 criterion of at least 50% high-efficiency cogeneration in the production of end-use energy for heating, cooling, and hot water is shown in the table below (Table 21).

It is obvious that most buildings can meet the criterion, except for JSS1 nZEB and NSS1 nZEB. Since these are public or commercial buildings following the nearly zero-energy standard, it can be concluded that, taking into account the low market value of the total end-use energy consumed, they are not equipped with adequately powerful devices for high-efficiency cogeneration that could, under optimal operating conditions, produce all the required end-use energy for the building.

Table 21: Overview of PURES 2010 requirements being met – from 50% share of energy from MKGEN in total end-user demand for heating, cooling and hot water for building classification

End-user energy generated through MC [kWh/m^2]	**ESS1**	**ESS2**	**VSS1**	**JSS1**	**NSS1**	**NSS2**
Reconstruction (1960), reconstruction (1980)	73	64	85	25	35	35
New construction	131	126	132	139	128	132
NZEB	61	82	76	14	14	23
End-user energy for heating, cooling and hot water according to PURES 2010 [kWh/m^2]						
Reconstruction (1960), reconstruction (1980)	75	68	72	44	44	51
New construction	86	104	78	62	62	69
NZEB	61	61	64	32	32	32
Meeting the requirements of PURES 2010 – from 50% of MC in end-use energy for heating, cooling and hot water						
Reconstruction (1960), reconstruction (1980)	98%	94%	118%	57%	80%	69%
New construction	152%	121%	169%	224%	206%	192%
NZEB	100%	134%	118%	45%	44%	71%

Economic analysis of the total costs and benefits for the version with an outer shell in accordance with PURES 2010 is presented in Chapter 10.4.4.

Economic analysis for the version using micro-cogeneration without improving the outer shell is described in the same chapter.

7.3 PROPOSAL FOR IMPROVING THE EXISTING SYSTEM AND MONITORING PROGRESS

Local energy concepts (LECs) give information on the existing district heating system in the municipality, and also address larger boiler rooms. Data for the latter are given only for public buildings (based on data from energy audits); the data on boilers in commercial buildings is usually not as available. Often, there is not enough data on individual systems, and it was therefore not always possible to distinguish whether boiler rooms are supplying one building exclusively (these are not included in the analysis in this document, since they are not a district heating system), or whether there is a common boiler room supplying several buildings.

Since not all LECs were available, it was not possible to determine how many municipalities have district heating systems. However, the National efficiency energy action plan notes that district heating systems operate in 49 municipalities, which was discussed in more detail in the previous chapters. According to the information received from the contracting authority, it is obvious from the LECs that 154 district heating systems are being planned.

As a rule, local energy concepts highlight the main advantages of district heating systems. If the LECs discovered a potential for the use of biomass, they usually predicted a feasibility study for district heating using woody biomass. Unfortunately, it was not possible to determine whether individual municipalities carried out these studies, or what further activities have been carried out, i.e. what progress has been made in preparing for the construction of district heating systems.

According to LEC forecasts of future energy consumption, it is clear that the assumptions on which these forecasts were made are not clearly defined. As a rule, the energy-consumption forecast is based only on the expected increase in the number of buildings; other influential factors were not taken into account. This takes into account the difference only in residential and non-residential buildings that are considered part of the service sector. Some LECs provide data on what percentage of future energy needs will be covered from renewable and what part of non-renewable energy sources, while other LECs divide the predicted energy consumption into different categories: technological requirements, heating, and hot water.

Based on the above, it can be concluded that LECs are an important source of information based on which one can get a picture about the energy situation in each municipality and plans for its future energy development. Unfortunately, different time frames when creating LECs, different data sources and methodological approaches of energy consumption modelling by sector, the lack of precision in individual sectors regarding direct energy consumption, and shortcomings of latest reports on the implementation of LECs have made the data collected from them insufficient for the requirements of this document.

It should be noted that the legal obligation for producing local energy concepts is very positive and that the information necessary for their compilation has to be provided at a national level. The state energy and other statistics (as well as the data needed to forecast future trends in energy consumption) are very good and it is desirable that the data and analyses gathered from individual municipalities be interpreted at one central point. This would give municipalities easy access to analytical bases for planning future activities in their area, rather than having to focus mainly on data collection, analysis, and modelling of energy consumption, each municipality using different methods, as is the case with LECs. A mandatory annual report on progress in implementing LECs has also been proposed since this is the only way to determine the actual current energy status of a municipality. It is important that the reporting system from the municipalities to the central unit be standardised, focused on measures taken, and based on a simple web interface that would allow quick and easy data input and processing. Local energy concepts must be in line with the data made available by the Energy Agency.

Currently, EU Member States have a duty to monitor energy efficiency indicators at a national level. The goal is to perform such monitoring at lower administrative levels in the country – in regions, major cities, and municipalities. The concept of using statistical and administrative data to produce a heat atlas, as developed within this project, could be used at a central location in the country for *top-down* monitoring of energy efficiency indicators in each region and major cities.

8. ESTIMATE OF PRIMARY ENERGY TO BE SAVED

8.1 INTRODUCTION

As mentioned in previous chapters, heat has a special position in the energy balance of the Republic of Slovenia. The implementation of measures to increase energy efficiency, energy savings, and the use of renewable energy sources and high-efficiency cogeneration is in accordance with the energy policy of the Republic of Slovenia. In addition, the chapter of the Energy Act relating to energy efficiency and renewable energy sources states that district heating and cooling systems need to be efficient. On an annual basis, heat distributors must ensure that the provided heat is from at least one of the following sources: at least 50% of heat produced from renewable energy sources, at least 50% waste heat, at least 75% cogenerated heat, or 75% heat as a combination of the three.

One interesting part of this project is the analysis of energy needed to meet the heating and cooling demand in the household, industry, and service sectors. Using energy from primary fuel is the most acceptable way to meet the energy demand of district heating systems. District heating systems often have higher installed power, and cogeneration plants are used as a source of thermal energy. Cogeneration plants produce heat and electricity simultaneously. In accordance with Directive 2012/27/EU, modern cogeneration plants are highly efficient if they generate primary energy savings of at least 10%. *The decree on determining the quantity of electricity generated from high-efficiency cogeneration of heat and electricity and on determining the efficiency of the energy conversion of biomass (UL RS No 37/2009)* establishes the method of calculating primary energy savings. The above-mentioned high-efficiency cogeneration plants, in combination with heating systems, are an essential element for improving energy efficiency.

At the same time, the local government carries significant responsibility since it is required to plan, promote, and approve the construction of heating systems, especially if there are cogeneration units in the analysed area. It is also essential to provide the necessary infrastructure for district heating systems.

8.2 ANALYSIS OF THE CURRENT SITUATION

In accordance with the analyses described in the previous chapters, the savings are assessed if energy use in heating systems is increased, if energy efficiency measures are taken and if all identified adequate high-efficiency cogeneration plants are implemented.

An analysis of end-use energy consumption was carried out in three sectors – households, services, and industry – for Slovenia in its entirety, statistical regions, and municipalities. In addition to the analysis on the energy required for heating air, i.e. for space heating in households and the service sector, an analysis has been carried out on the energy needed to produce hot water. The analysis on energy consumption in the industrial sector is based on a slightly different principle, namely on the analysis of thermal energy.

In 2014, total energy consumption in households stood at 46.51 PJ. The main energy source was wood with a share of approximately 42%, followed by electricity – 25%, oil – 14%, natural gas – 9%, and thermal energy – 7%. Thermal and solar energy consumption amounted to less than 5% of total consumption. Energy consumption for heating and hot water in the household sector is regarded as consumption in residential units that are heated by a district heating system, their own district heating systems, or other forms of heating (mostly heating with individual room furnaces). In parallel with the above calculation, a model was developed that calculates the energy consumption in buildings by their age, i.e. the period in which they were constructed. In Slovenia, the total consumption of usable heat for domestic heating comes in at 31.4 PJ, 3.2 PJ of which are supplied by a district heating system, 24.4 PJ by own district heating systems, and 3.1 PJ from other forms of heating. The average consumption of usable heat for heating is 150 kWh/m² of heated area. The model of usable energy consumption also includes energy consumption for hot water, which is estimated at around 5.6 PJ. The annual rate of heat consumption for hot water preparation is around 710 kWh per capita. In 2014, the total consumption of usable heat in households amounted to about 37 PJ.

In the service sector, a similar analysis was carried out, and heat consumption for heating and hot water was calculated for three administrative units: the entire territory of the Republic of Slovenia, statistical regions, and municipalities. The service sector is divided into sub-sectors, such as education, health, public administration, trade, tourism and hospitality. For each sector, norms for heating- and cooling-energy consumption are determined, along with standards for other forms of energy consumption. In 2014, the total end-use energy consumption in the service sector came in at about 17.8 PJ, of which 63% was electricity, 16% oil derivatives (fuel oil), while natural gas and thermal energy accounted for 9% each. In 2014, total consumption of usable heat in the service sector amounted to 8.65 PJ, while cooling energy stood at about 0.8 PJ. Specific energy consumption for space heating and hot water amounted to 104 kWh/m² of heated area after correcting for climate.

Analysis of the consumption in the industrial sector is most difficult because thermal energy in industrial plants is used for various parameters and comes from different sources. Here, it is important to distinguish between direct heat (which is a direct product of combustion) and indirect heat (produced in boilers and then used in technological processes). In industrial plants in 2014, a total of 23 PJ of usable thermal energy was produced, of which about 10.5 PJ was direct heat and the rest indirect heat.

8.3 ESTIMATE OF FUTURE CONSUMPTION OF USABLE HEAT

An estimate of future consumption of usable heat has been made using the '*end-use*' model in the *MAED* programming environment. The estimate includes the effects of all relevant energy consumption factors, such as demographic changes, population mobility, growth and structure of domestic production, housing standard, climate characteristics of the area, energy efficiency, habits, etc. The main feature of the *end- use* model is to determine specific energy consumption based on the structural analysis of realised energy consumption. Based on this analysis, development scenarios for individual determinants and specific consumption needs are created, thus calculating the total future energy consumption.

The analysis has shown that in the household sector, a decline in the consumption of usable energy is expected for the goals relating to the strategies of renovating buildings and constructing nearly zero-energy buildings. Thus, despite an expected increase in the number and size of residential buildings, a reduction in the use of thermal energy for heating and hot water can be expected, which is a direct result of increased energy efficiency in the household sector. We expect a reduction of heat consumption for heating and cooling from 37 PJ in 2014 to 24 PJ in 2035.

A decline in the total consumption of usable heat is also expected in the service sector. This is primarily due to expected energy-performance improvements of buildings. The analysis has shown that the consumption of thermal energy will be around 7 PJ in 2030. If energy consumption for cooling is also taken into account, a 2.4% annual increase in energy consumption for cooling is expected.

Due to the specifics of the industrial sector, two categories of useful consumption are defined – usable heat and electricity for non-heating purposes. Consumption of usable energy in the industrial sector is modelled based on the projected GDP growth until 2035, strategic documents for economic and industrial development, and based on the recommendations of international organisations and analyses of economic developments in the monitored period. By 2035, the total consumption of usable thermal energy in the industrial sector is expected to decline slightly, from 23 PJ in 2014 to 19 PJ in 2035. This analysis includes both direct and indirect heat consumption.

8.4 REALISING SAVINGS IN ENERGY CONSUMPTION

In the Republic of Slovenia, 7.2 PJ of thermal energy was delivered to end users for heating purposes in 2014. According to the *Report on the Energy Sector in Slovenia in 2015,* produced by the AGEN-RS, in 2015 in the Republic of Slovenia, 53 heat distributors supplied heat in 58 of the 212 Slovenian municipalities from 91 distribution systems with a total length of 912.5 kilometres. Heat distributors supplied 103 459 customers with 1839.5 GWh of heat in 2015. In 2015, the consumption of heat from all the distribution systems was 11.93% higher than the year before. Heat supply includes distribution and supply of heat.

In 2015, for the needs of district heating, hot water and supply of industrial processes, heat distributors with their own production and heat producers who supply distribution systems produced 2324.2 GWh of heat and 718.0 GWh of electricity, and 640.0 GWh of cogenerated net electricity. Cogenerated heat produced to supply distribution systems accounted for 83.8% of all produced heat. The largest share of the total production of usable heat, 36.6%, was supplied to 94 491 household users, 32.5% to 7 731 businesses, and 10% to 1 237 industrial customers.

Energy conservation, which is based, among other things, on increasing energy efficiency, is one of the imperatives for further development of Slovenia's heat sector. In addition, it is necessary to increase the reliability and security of supply by using modern technologies such as high-efficiency cogeneration, biomass and waste as fuel, and by replacing existing, inefficient pipelines with new, pre-insulated ones. In addition, if the savings were realised in one of the ways listed, the existing legal framework would need to be improved, since it does not provide sufficient support to implement various measures.

One of the major obstacles hindering the development of the heat sector and thereby greater energy savings (in terms of primary-energy savings) is the use of natural gas for heating as the main competitor to heating systems. Another major obstacle is the lack of significant investments in the relevant industry, which is also the result of inadequate systematic energy planning.

We must conclude that the best ways are to increase energy savings and raise public awareness of energy-efficiency measures. The population's awareness and their attitude to energy consumption are important, because heat consumption is strongly related to the habits and customs of inhabitants – the main users of thermal energy. Taking into account the heating system, energy efficiency can be viewed from the following two perspectives:

- building sector
- heating systems.

Increasing energy efficiency in the building sector directly lowers energy consumption. Specifically, by renovating and improving the thermodynamic characteristics of building envelopes, savings in heat consumption for heating and cooling can be achieved. However, reduced heat demand by the end users does not have a direct positive impact on the development of heating systems, and in this sense, it is necessary to provide new models to make investing financially viable. Increasing the energy efficiency of the distribution network diminishes heat loss in heat distribution. The savings can be achieved primarily by installing pre-insulated pipes with moisture detectors, which is a modern heat distribution technology. In addition, appropriate measuring and regulating equipment in end-user substations need to be installed to allow a sufficient amount of heat for each end user. When estimating potential savings, the end users or consumers need to be considered. With proper energy management, end users can also help reduce energy consumption, therefore, it is essential to draw up proper plans for educating end users.

Various energy sources have significant energy saving potential. Most of existing heat sources are heating/hot-water boilers and low-efficiency cogeneration plants. By replacing them with modern technologies such as heat pumps with more installed power, biomass and waste boilers, it is possible to reduce primary-energy consumption significantly.

Of course, for further development of district heating systems and greater energy savings, it is necessary to consider all available options and decide on a comprehensive solution that will achieve the best results. Here, it is neither necessary nor possible to have the most radical solution in each segment of the system. It is necessary to bear in mind that significant positive changes cannot be achieved without systematic planning and management. It is also necessary to anticipate trends and technologies that will become financially viable in the coming period of 10 years or more, and based on these assumptions, design the entire system and determine achievable savings.

8.5 POTENTIAL ENERGY SAVINGS

Determining the achieved heating energy savings by 2035 in the Republic of Slovenia, which is calculated based on the results of all analyses described in the following chapters:

- Chapter 2 – Forecast of the changing heating and cooling demand;
- Chapter 4 – Identifying the heating and cooling demand that could be met using high-efficiency cogeneration;
- Chapter 5 – Defining the potential for additional high-efficiency cogeneration;
- Chapter 6 – Identifying options to increase energy efficiency of district heating and cooling infrastructure;
- Chapter 7 – The share of high-efficiency cogeneration, the potential established and progress achieved.

Within Chapter 2 – *Forecast of the changing heating and cooling demand*, we took into account energy efficiency measures in the form of increasing energy efficiency in the building sector, and the applicable statutory regulation, which lays down the criteria for new construction in the future, and thus indirectly influences the heating and cooling demand. In addition, the potential of implementing additional high-efficiency cogeneration and necessary infrastructure for the use of heating systems is analysed.

Within Chapter 4 – *Identifying the heating and cooling demand that could be met using high-efficiency cogeneration*, we addressed the potential for expanding existing heating and cooling systems by 800 518.45 MWh annually. By checking the estimated heat demand in the Republic of Slovenia and by meeting the specific heat consumption equal to or greater than 120 TJ/km^2 (the financial profitability condition), we established real potential for high-efficiency cogeneration as follows.

Table 22: The potential for additional high-efficiency cogeneration in the reference area of the Republic of Slovenia

Thermal energy	**Volume (MJ)**
The potential for additional high-efficiency cogeneration in Ljubljana	1 332 451 500.99
The potential for additional high-efficiency cogeneration in Maribor	549 738 155.96
Total potential for additional high-	**1 882 189 656.95**

efficiency cogeneration in the Republic of Slovenia	

Within Chapter 5 – *Defining the potential for additional high-efficiency cogeneration,* we found the following.

- The construction of a new thermal plant for electricity production with total thermal input exceeding 20 MW (Directive 2012/27/EU, Article 14(5a)) is planned. Chapter 5.2 contains a more detailed description.
- Currently, no extensive renovation of the existing thermal power plants for electricity production with a total thermal input exceeding 20 MW (Directive 2012/27/EU, Article 14(5b)) is planned.
- Furthermore, no extensive renovation of industrial installations with a total thermal input exceeding 20 MW, which produce waste heat at a usable temperature level (Directive 2012/27/EU, Article 14(5c)) is planned.
- From the analysis of LECs (delivered in 87 of the total 212 municipalities) it can be established that district heating systems exist or are planned in 19 municipalities. Two municipalities make use of waste heat.

Within Chapter 6 – *Identifying options to increase energy efficiency of district heating and cooling infrastructure*, we established the potential for high-efficiency cogeneration in the total amount of 138 924.01 MWh, or 500 126 436 MJ. However, taking into account the 5 heating systems that are very close to meeting the efficiency criteria for district heating infrastructure, it is estimated that a more realistic high-efficiency cogeneration potential is 72 864.01 MWh, or 262 310 436 MJ.

8.6 ESTIMATE OF PRIMARY ENERGY TO BE SAVED

Directive 2012/27/EU provides that cogeneration plants and related production can be regarded as highly effective if their primary energy savings reach 10%. These savings need to be achieved according to the separate production of the same amount of heat and electricity in private, separate reference plants.

Assuming that the overall potential for high-efficiency cogeneration is covered from modern CCGT plants[8], the assumed thermal efficiency being 30%, the calculated potential annual primary energy savings are as shown in Table 23 below.

Table 23: An estimate of the primary energy to be saved in the territory of the Republic of Slovenia

Name of potential	Amount of potential for high-efficiency cogeneration (MJ)	Amount of primary energy savings (MJ)
Additional high-efficiency cogeneration in Ljubljana	1 332 451 500.99	493 500 555.92
Additional high-efficiency cogeneration in Maribor	549 738 155.96	203 606 724.43
Options to increase energy efficiency of district heating and cooling infrastructure	262 310 436	97 152 013.33
Total potential for additional high-efficiency cogeneration in the Republic of Slovenia	**2 144 500 092.95**	**794 259 293.68**

Based on data from the previous chapter, we established a total potential for high-efficiency cogeneration amounting to 2 144 500 092.95 MJ.

Total primary energy savings amount to 794 259 293.68 MJ.

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[8] *CCGT technology is explained in more detail in Section 5.1.1*.

9. AN ASSESSMENT OF PUBLIC SUPPORT MEASURES FOR HEATING AND COOLING

9.1 ANALYSIS OF RELEVANT EU REGULATIONS (TREATIES, DIRECTIVES, REGULATIONS AND GUIDELINES) THAT ALLOW THE GRANTING OF STATE AID

9.1.1 Treaty on the Functioning of the European Union

Treaty on the Functioning of the European Union is the basic document that governs the functioning of the European Union (hereinafter the EU). Treaty on the Functioning of the EU sets out the rules of market competition with the aim of establishing or maintaining the functioning of the internal market. The internal market comprises an area without internal borders, in which there is free movement of goods, persons, services and capital in accordance with the provisions of the Treaty on the Functioning of the EU and the Treaty on European Union.

Articles 101 and 102 of the Treaty on the Functioning of the EU set out the conditions for market competition in the internal market by prohibiting any conduct which has the goal or effect to prevent, restrict or impede market competition in the internal market.

Functioning of the internal market in accordance with the principles of market competition is extremely important for the functioning of the Union, and Title VII, Chapter 1, Section 2 of the Treaty on the Functioning of the EU, which regulates state aid, respects the principle of the inviolability of the rules of market competition in allocating government grants for the purposes of the functioning of the internal market.

To ensure the equality of everybody operating in the internal market of the European Union, the Treaty on the Functioning of the EU, as a general rule, prohibits any aid granted by a Member State or through State resources in any form whatsoever which distorts or threatens to distort competition by favouring certain undertakings or the production of certain goods shall, in so far as it affects trade between Member States, be incompatible with the internal market (Treaty on the Functioning of the EU, Article 107, paragraph 1).

The second paragraph of Article 107 lists the allowed types of aid that are not contrary to the internal market, such as:

- aid having a social character, granted to individual consumers, provided that such aid is granted without discrimination related to the origin of the products concerned,
- aid to make good the damage caused by natural disasters or exceptional occurrences, and
- aid granted to the economy of certain areas of the Federal Republic of Germany affected by the division of Germany, in so far as such aid is required in order to compensate for the economic disadvantages caused by that division. Five years after entry into force of the Treaty of Lisbon, the Council, acting on a proposal from the Commission, may adopt a decision repealing this point.

The third paragraph of Article 107 lists the types of aid that may be considered to be compatible with the internal market, as follows:

- aid to promote the economic development of areas where the standard of living is abnormally low or where there is serious underemployment, and of the regions referred to in Article 349, in view of their structural, economic and social situation,
- aid to promote the execution of an important project of common European interest or to remedy a serious disturbance in the economy of a Member State,
- aid to facilitate the development of certain economic activities or of certain economic areas, where such aid does not adversely affect trading conditions to an extent contrary to the common interest,
- aid to promote culture and heritage conservation where such aid does not affect trading conditions and competition in the Union to an extent that is contrary to the common interest, and other categories of aid as may be specified by decision of the Council on a proposal from the Commission.
- Article 108 of the Treaty on the Functioning of the EU defines the policy of the European Commission regarding the granting of state aid. The Commission shall, in cooperation with Member States, keep

under constant review all systems of aid existing in those States. Member States may grant state aid that is not exempted from the notification to the Commission after the Commission's decision approving support and compatibility of aid with the internal market. If the Commission finds that a certain type of incentive is not in conformity with the functioning of the internal market, the Commission may make a decision according to which state aid must be abolished or amended within the specified period. If the Member State fails to comply with the Commission's decision on state aid, the Commission or any other interested Member State may bring the matter before the Court of Justice of the European Union. The Council of Ministers may decide unanimously that the aid be regarded as compatible with the internal market if exceptional circumstances justify it.

Given the fact that state aid – within the meaning of the first paragraph of Article 107 of the Treaty on the Functioning of the EU – is, in principle, prohibited, it is important that all parties can verify whether aid is granted in accordance with the applicable rules. Therefore, transparency regarding state aid is crucial for the proper application of the rules provided by the Treaty on the Functioning of the EU. Transparency also enables better coordination, better accountability, peer review and, ultimately, more efficient public spending.

9.1.2 Guidelines on State aid for environmental protection and energy 2014–2020

Guidelines on State aid for environmental protection and energy 2014–2020 (hereinafter referred to as the Guidelines) apply to State aid granted for environmental protection or energy objectives in all sectors governed by the Treaty on the Functioning of the EU.

State aid for environmental protection or energy objectives shall be considered compatible with the internal market in the meaning of Article 107(3)(c) of the Treaty on the Functioning of the EU, provided that it is assessed – based on common principles set out in the Guidelines – that it may further contribute to environmental protection or energy objectives of the EU without adversely affecting trading conditions to an extent contrary to the common interest.

In order to assess whether the notified aid can be regarded as compatible with the internal market, the Commission analyses whether the positive effects of aid on the objective of common interest outweigh its potentially negative effects on trade and market competition.

The Commission has identified a number of environmental and energy measures for which State aid under certain conditions may be compatible with the internal market under Article 107(3)(c) of the Treaty on the Functioning of the EU:

- aid for going beyond Union standards or increasing the level of environmental protection in the absence of Union standards (including aid for the acquisition of new transport vehicles);
- aid for the early adaptation to future Union standards;
- aid for environmental studies;
- aid for the remediation of contaminated sites;
- aid for energy from renewable sources;
- aid for energy efficiency measures, including cogeneration and district heating and district cooling;
- aid for resource efficiency and in particular aid to waste management;
- aid for CO_2 capture, transport and storage including individual elements of the Carbon Capture Storage (CCS) chain;
- aid in the form of reductions in or exemptions from environmental taxes;
- aid in the form of reductions in funding support for electricity from renewable sources;
- aid for energy infrastructure;
- aid for generation adequacy measures;
- aid in the form of tradable permits;
- aid for the relocation of undertakings.

Indent 6 explicitly states that the aid for district heating and district cooling under certain conditions may be compatible with the internal market.

In order to ensure that aid contributes to a higher level of environmental protection, aid for district heating and district cooling and cogeneration of heat and electricity (CHP) will only be considered compatible with the internal market if granted for investment, including upgrades, to high-efficient CHP and energy-efficient district heating and district cooling.

Operating aid for high energy efficient cogeneration plants may be granted on the basis of the conditions applying to operating aid for electricity from renewable energy sources, and only:

- to undertakings generating electric power and heat to the public where the costs of producing such electric power or heat exceed its market price;
- for industrial use of the combined production of electric power and heat where it can be shown that the production cost of one unit of energy using that technique exceeds the market price of one unit of conventional energy.

9.1.3 Commission Regulation (EU) No 651/2014 of 17 June 2014 declaring certain categories of aid compatible with the internal market in application of Articles 107 and 108 of the Treaty

State funding meeting the criteria in Article 107(1) of the Treaty constitutes State aid and requires notification to the Commission by virtue of Article 108(3) of the Treaty. However, according to Article 109 of the Treaty, the Council may determine categories of aid that are exempted from this notification requirement. In accordance with Article 108(4) of the Treaty the Commission may adopt regulations relating to those categories of State aid. Council Regulation (EC) No 994/98 empowers the Commission to declare, in accordance with Article 109 of the Treaty, that the following categories may, under certain conditions, be exempted from the notification requirement:

- aid to small and medium-sized enterprises (SMEs);
- aid in favour of research and development;
- aid in favour of environmental protection;
- employment and training aid;
- aid that complies with the map approved by the Commission for each Member State for the grant of regional aid.

On the basis of Article 108(4) of the Treaty on the Functioning of the EU, the Commission adopted the Regulation declaring certain categories of aid compatible with the internal market in application of Articles 107 and 108 of the Treaty, relating to those categories of aid. This Regulation should allow for better prioritisation of State aid enforcement activities, greater simplification and should enhance transparency, effective evaluation and the control of compliance with the State aid rules at national and Union levels, while preserving the institutional competences of the Commission and the Member States.

This Regulation shall apply to the following categories of aid:

- regional aid;
- aid to SMEs in the form of investment aid, operating aid and SME' access to finance;
- aid for environmental protection;
- aid for research and development and innovation;
- training aid;
- recruitment and employment aid for disadvantaged workers and workers with disabilities;
- aid to make good the damage caused by certain natural disasters;
- social aid for transport for residents of remote regions;
- aid for broadband infrastructures;
- aid for culture and heritage conservation;
- aid for sport and multifunctional recreational infrastructures;
- aid for local infrastructures.

Aid that fulfils all the conditions laid down in this Regulation shall be exempted from the notification obligation laid down in Article 108(3) of the Treaty. The conditions include a positive analysis of the general conditions (notification thresholds, transparency of aid, incentive effect, intensity and eligible costs, publication and information) and special conditions for the relevant category of aid.

For the purpose of transparency, equal treatment and effective monitoring, this Regulation should apply only to aid in respect of which it is possible to calculate precisely the gross grant equivalent *ex ante* without the need to undertake a risk assessment (*'transparent aid'*).

Directive 2012/27/EU of the European Parliament and of the Council of 25 October 2012 on energy efficiency, amending Directives 2009/125/EC and 2010/30/EU and repealing Directives 2004/8/EC and 2006/32/EC provides that by 31 December 2015, Member States shall carry out and notify to the Commission a comprehensive assessment of the potential for the application of high-efficiency cogeneration and efficient district heating and cooling.

On the basis of Article 40 of this Regulation, Investment aid for high-efficiency cogeneration, and on the basis of Article 46 of this Regulation, investment aid for energy efficient district heating and cooling, shall be compatible with the internal market within the meaning of Article 107(3) of the Treaty and shall be exempted from the notification requirement of Article 108(3) of the Treaty, provided that the general and special conditions laid down in Regulation are fulfilled.

The investment aid for high-efficiency cogeneration shall be granted in respect of newly installed or refurbished capacities only. The new cogeneration unit shall provide overall primary energy savings compared to separate production of heat and electricity as provided for by Directive 2012/27/EU. The improvement of an existing cogeneration unit or conversion of an existing power generation unit into a cogeneration unit shall result in primary energy savings compared to the original situation.

According to paragraphs 41 and 42 of Article 2 of Directive 2012/27/EU, efficient district heating and cooling means a district heating or cooling system using at least 50% renewable energy, 50% waste heat, 75% cogenerated heat or 50% of a combination of such energy and heat. The definition also includes heating/cooling plants and the network (including related facilities) necessary for the distribution of heating/cooling from production units to consumers.

9.1.4 Commission Regulation (EU) No 1407/2013 of 18 December 2013 on the application of Articles 107 and 108 of the Treaty on the Functioning of the European Union to *de minimis* aid

The Regulation on the application of Articles 107 and 108 of the Treaty on the Functioning of the European Union to *de minimis* aid applies to aid granted to undertakings in all sectors. Aid exempted from the application of this Regulation is listed exhaustively as follows:

- aid granted to undertakings active in the fishery and aquaculture sector;
- aid granted to undertakings active in the primary production of agricultural products;
- aid to export-related activities towards third countries or Member States, namely aid directly linked to the quantities exported, to the establishment and operation of a distribution network or to other current expenditure linked to the export activity;
- aid contingent upon the use of domestic over imported goods.

Regarding aid for the establishment and operation of a distribution network, this Regulation in particular should not apply to aid financing the establishment and operation of a distribution network in other Member States or in third countries.

De minimis aid granted per Member State to a single undertaking shall not exceed EUR 200 000 over any period of three fiscal years is exempt from the general prohibition of State aid referred to in Article 107(1) of the Treaty and from the notification requirement, as granting such aid to an undertaking is not considered to have any effect on trade between Member States and not to distort or threaten to distort competition.

Only the sector of road freight transport is an exception to the *de minimis* aid ceiling. In this sector, aid granted to a single undertaking performing road freight transport for hire or reward shall not exceed EUR 100 000. This de minimis aid shall not be used for the acquisition of road freight transport vehicles.

Aid in smaller amounts may be granted for most purposes, including for operational aid. Measures to support district heating and cooling systems may be in accordance with the *de minimis* rules if the ceiling of EUR 200 000 is taken into account.

9.2 ANALYSIS OF REGULATIONS OF THE REPUBLIC OF SLOVENIA GOVERNING STATE AID

The Monitoring of State Aids Act (ZSDrP, UL RS No 37/2004) governs the procedure for notifying the Commission of State aids, drafting of annual reports and recording of State aids from the Ministry of Finance, and the exemption from the notification requirement in relation to *de minimis* aid, which is further regulated by the Decree on data submission and on the reporting of granted state aid and *de minimis* aid (UL RS Nos 61/2004, 22/2007 and 50/2014).

Later in this chapter, energy regulations governing State aid in the field of heating and cooling in the Republic of Slovenia are analysed.

9.2.1 Energy Act (UL RS Nos 17/14 and 81/15)

The Ministry of Infrastructure has prepared amendments to the current Energy Act (EZ-1), which will be submitted for adoption by summary procedure. The objective of the amending Act is to eliminate inconsistencies in the transposition of Directive 2010/31/EU and Directive 2012/27/EU, to supplement and amend the provisions in relation to the decision of the Constitutional Court, and to introduce minor amendments to the Act. Some of the articles of the existing EZ-1 are presented below.

Article 25 of the EZ-1 refers to the mandatory elements of the energy balance, including a plan for the implementation of the programme supporting electricity from renewable energy sources and high-efficiency cogeneration, and to the forecast of available resources to achieve the annual objectives of the aid programme.

In the EZ-1, *'aid programme'* is defined as any instrument, scheme or mechanism that promotes energy efficiency or the use of renewable energy while reducing costs and energy, increasing the price at which energy can be sold, or increasing the amount of energy purchased based on renewable energy sources or in another way. This includes aid for investments, tax exemptions or reductions, tax refunds, aid schemes, it requires the use of renewable energy sources, including programmes using green certificates and direct financial aid, including guaranteed prices (*feed-in* tariffs) and the payment of premiums.

It is important to note that, in principle, aid shall be granted only in cases where the price of renewable electricity and high-efficiency cogeneration is higher than the price that can be achieved on the electricity market (Article 372(1)).

Article 298 obliges distributors of thermal energy to provide a control system of district heating and cooling systems over 10 MW to ensure optimal hydraulic performance and optimise the operation of district heating and cooling systems.

Article 314 obliges the Eco Fund to annually draw up and implement a national programme under which financial incentives to improve energy efficiency will be allocated, according to the energy efficiency programme and according to the procedure prescribed by the act governing environmental protection.

Article 316 provides that the minister responsible for energy determine the types of financial incentives for energy efficiency, district heating and renewable energy sources, conditions and criteria for their allocation, as well as the type of users. Incentives are granted as state aid, as *de minimis* aid, or as other financial incentives. As the ministry responsible for energy, the Ministry of Infrastructure publishes on its website all the financial incentives received, their address and the type and size of the project financed.

Based on Article 351, the Aid centre publishes on its website information on available aid programmes and support mechanisms for the implementation of energy efficiency and RES measures. Funding for the programme referred to in this Article and implemented by the Aid centre is provided from the funds for an Eco Fund's programme to increase energy efficiency as defined in Article 317 of the Energy Act.

Article 372 governs the existing aid for renewable electricity for new plants (up to 50 MW of rated power for wind power plants and up to 10 MW of rated power for other energy sources) for a period of 15 years, and for new high-efficiency cogeneration plants (up to 20 MW of rated power) for a period of 10 years. Aid is awarded through a public call for applications published by the AGEN-RS each year (Article 373 defines the selection criteria for projects entering the aid programme). There are the following types of aid:

- **guaranteed purchase of electricity** for plants with less than 1 MW rated power, and
- **financial (operational) aid for other producers** (over 1 MW).

All plants considered for aid must be new plants, while plants smaller than 1 MW and with a certificate of origin (but not new), can conclude a contract with the Aid centre on the purchase of all energy that is not used for own needs. This right and the calculation of prices are described in Article 372(14) of the Energy Act.

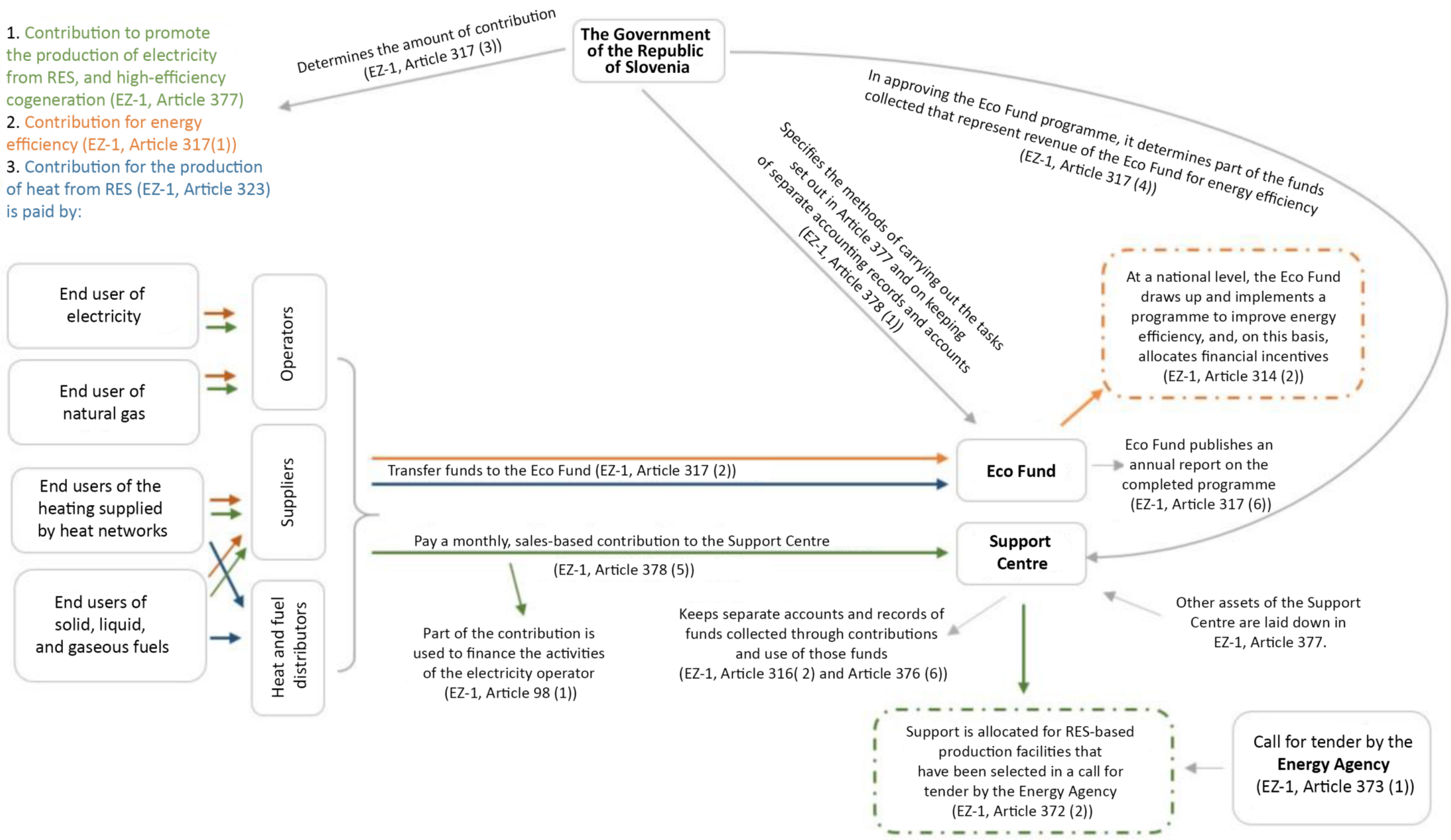
If a producer who has the right to a guaranteed purchase, independently sells the produced electricity on the market instead of making use of the guaranteed purchase, they may exercise the right to financial assistance in the form of operational aid.

If the recipient of aid for the production of electricity from renewable energy sources and high-efficiency cogeneration is obtaining another State aid, the aid the production of electricity shall be reduced in proportion to the amount of the other aid received (Article 372(5)).

Another new addition is the certificate of electricity origin, which is required for all electricity produced for which aid is requested (Article 366(6)). Each year until 31 October, the AGEN-RS shall issue a forecast of the position of the RES and high-efficiency cogeneration system, which serves as the basis for determining electricity prices and the required level of operational aid for the following year.

The Aid centre with its rights and responsibilities, is described in Article 376 of the Energy Act.

Its legal status, structure, functions, operations, acts and other issues relevant to the work and conduct of the AGEN-RS are governed by the provisions of Part Six of the Energy Act (Articles 383 to 450).



1. Contribution to promote the production of electricity from RES, and high-efficiency cogeneration (EZ-1, Article 377)
2. Contribution for energy efficiency (EZ-1, Article 317(1))
3. Contribution for the production of heat from RES (EZ-1, Article 323) is paid by:

Determines the amount of contribution (EZ-1, Article 317 (3))

The Government of the Republic of Slovenia

In approving the Eco Fund programme, it determines part of the funds collected that represent revenue of the Eco Fund for energy efficiency (EZ-1, Article 317 (4))

Specifies the methods of carrying out the tasks set out in Article 377 and on keeping of separate accounting records and accounts (EZ-1, Article 378 (1))

At a national level, the Eco Fund draws up and implements a programme to improve energy efficiency, and, on this basis, allocates financial incentives (EZ-1, Article 314 (2))

Transfer funds to the Eco Fund (EZ-1, Article 317 (2))

Eco Fund

Eco Fund publishes an annual report on the completed programme (EZ-1, Article 317 (6))

Pay a monthly, sales-based contribution to the Support Centre (EZ-1, Article 378 (5))

Support Centre

Part of the contribution is used to finance the activities of the electricity operator (EZ-1, Article 98 (1))

Keeps separate accounts and records of funds collected through contributions and use of those funds (EZ-1, Article 316(2) and Article 376 (6))

Other assets of the Support Centre are laid down in EZ-1, Article 377.

Support is allocated for RES-based production facilities that have been selected in a call for tender by the Energy Agency (EZ-1, Article 372 (2))

Call for tender by the **Energy Agency** (EZ-1, Article 373 (1))

Figure 49: Determining contributions to the Eco Fund and the Aid centre, and utilisation thereof

9.2.2 Rules on support for electricity generated from renewable energy sources and from high-efficiency cogeneration (UL RS No 74/16)

In November 2016, the Government of the Republic of Slovenia issued Rules on support for electricity generated from renewable energy sources (hereinafter referred to as RES) and from high-efficiency cogeneration (hereinafter referred to as CHP), determining a range of electricity and heat production technologies eligible for aid, the amount and duration of aid granted, the conditions and method of obtaining aid and other issues of granting and utilisation of aid.

Article 5 talks about what CHP technology is eligible for aid. Under these Rules, CHP production plants using biofuels or other liquid biofuels derived from biomass are not eligible.

Article 33 of the Rules states that for CHP plants that have applied to the public call for 2016, projects of new production plants are evaluated in the first round for 10% of available funding for CHP production plants using natural gas up to 50 kW of rated power. In the second round, projects of RES and CHP production plants are evaluated for the distribution of the funds available in two competing groups:

- 30% for renovated CHP production plants operating within district heating systems,
- 20% for all other technologies and production plants, and RES and CHP projects that did not succeed in competitive groups in the first round.

9.2.3 Decree on the method of determining and calculating the contribution for ensuring support for the production of electricity from high-efficiency cogeneration and renewable energy sources (UL RS Nos 36/2014 and 46/2015)

The method of determining the amount aid and contributions to the production of electricity using high-efficiency cogeneration and RES, which is determined on the basis of Article 378(7) of the Energy Act, is prescribed by the Decree on the method of determining and calculating the contribution for ensuring support for the production of electricity from high-efficiency cogeneration and renewable energy sources.

In 2014, EUR 103.5 million of contributions were collected to provide aid for the production of electricity from RES and high-efficiency cogeneration, while the current Decree from 2015 prescribes new contribution amounts that will result in the collection of an additional EUR 10 million.

9.2.4 Legal Act on support for the production of electricity from renewable energy sources and high-efficiency cogeneration (UL RS Nos 38/14, 46/15 and 56/15)

In July 2015, the AGEN-RS adopted a legal act determining the contribution amount for each user group benefiting from aid for the production of electricity from RES and CHP. The average contribution per kW of electricity amounted to EUR 1.06397. The legal act is based on Article 378(3) of the Energy Act and Article 5(2) of the Decree on the method of determining and calculating the contribution for ensuring support for the production of electricity from high-efficiency cogeneration and renewable energy sources.

9.2.5 Decree on energy savings requirements (UL RS No 96/14)

The Decree obliges suppliers of electricity, heat, gas, and liquid and solid fuels to end users.

The Decree determines the period and the amount of energy savings, the method for calculating the energy savings, the distribution of energy savings by year within a period, the manner and deadlines to achieve the set energy savings objectives, and the types of energy services and measures to achieve energy savings.

The Decree also sets out the amount of contribution to increase energy efficiency for the implementation of the Eco Fund programme.

The Decree on energy savings requirements specifies the types of energy services and measures. This includes the following:

- measures to improve energy efficiency and increase the use of RES in heat production in the public sector, service sector and industry;
- measures to improve the energy efficiency of buildings;
- measures to increase energy efficiency in transport;

- measures to increase the efficiency of district heating systems.
- It is also important to achieve energy savings in the sectors of energy transformation, distribution and transmission, including infrastructure for efficient district heating and cooling.

Measures to increase the efficiency of district heating systems are as follows:

- a comprehensive renovation of a heating plant, irrespective of ownership of the heating plant or the location of the heat meters;
- efficiency improvement measures for heat distribution systems;
- the installation of plants producing heat for district heating so that district heating systems meet the criteria for energy efficient district heating systems provided for in the Energy Act.

9.3 OVERVIEW OF THE ORGANISATIONAL AID STRUCTURE

9.3.1 Ministry of Infrastructure

The remit of the Ministry of Infrastructure also includes business transactions related to the energy sector, efficient use of energy and renewable energy sources. The Ministry gives proposals to issue and amend energy regulations. Within the Ministry, the Directorate of Energy is concerned with the implementation of measures and drafting of energy documents taking into account energy security, increasing energy efficiency, saving energy and increasing the use of energy from renewable energy sources, which are the basis for setting up an aids programme. Such umbrella documents, associated with cogeneration and efficient heating and cooling, include the following:

- Slovenia's energy concept (Energetski koncept Slovenije – EKS)
- National energy development plan (Državni razvojni energetski načrt – DREN)
- National energy efficiency plan (energy efficiency action plan)
- National plan for renewable energy sources (action plan for renewable energy sources (akcijski načrt za obnovljive vire – AN-OVE))
- Operational programme for the implementation of the cohesion policy in the period 2014–2020
- Operational programme of measures to reduce greenhouse gas emissions by 2020
- Annual energy balance of the Republic of Slovenia.

The construction of new and reconstruction of existing heating systems is supported, and it is encouraged that new users connect to the existing network capacity (biomass boilers in the public sector, heating plants using district biomass heating over 1 MW, local district heating systems up to 1 MW, etc.).

9.3.2 Energy Agency of the Republic of Slovenia

Operations of the AGEN-RS are regulated in Part Six of the Energy Act. The AGEN-RS is a separate and independent legal entity with public authority, and is the only regulatory authority in the field of energy trading in the Republic of Slovenia. The AGEN-RS monitors, directs and supervises entities in the energy sectors of electricity and natural gas, and performs statutory tasks of regulating energy service providers in the field of heat and other energy gases.

Below are some of AGEN-RS' basic objectives:

- promoting a competitive, safe and environmentally sustainable electricity and natural gas market, and control thereof;
- promoting energy production using RES and CHP, efficient energy use;
- controlling the legislative part energy service providers' activities;
- protecting end-user rights;
- removing barriers to entering the renewable electricity and gas market;
- generally operating in accordance with the overall energy policy objectives, energy efficiency objectives, and integrating the production of electricity and natural gas from renewable energy sources (Article 385 of the Energy Act).

EZ-1 gives the Agency an important role in the promotion of electricity produced from renewable energy sources and high-efficiency cogeneration. The main tasks of the AGEN-RS in the aid programme are issuing declarations for production installations, decisions on aid allocation and certificates of electricity origin.

On the basis of Article 373 of the EZ-1, AGEN-RS is required to publish a public call based on which projects to be included in the aid programme are selected once a year (not earlier than 1 October and no later than 1 November of the current year for the following year). The AGEN-RS shall supervise production plants that have obtained or are obtaining a declaration of production (guarantee scheme). At the request of an electricity producer using renewable sources or high-efficiency cogeneration, the AGEN-RS shall issue a certificate of origin. To this end, the AGEN-RS must keep a register of certificates of origin. In 2015, there were 3.896 GWh of *'green electricity'* for which the AGEN-RS issued a certificate of origin and which were used both on the Slovenian and on foreign electricity markets.

9.3.3 Eco Fund, Slovenian Environmental Public Fund

Eco Fund, Slovenian Environmental Public Fund, was established by the Environmental Protection Act. The main purpose of the Eco Fund is to promote development in the field of environmental protection. Eco Fund offers financial assistance mainly through lending from the portfolio of assets, and, since 2008, through grants. The main advantages of lending with regard to commercial banks are lower interest rates and longer repayment periods.

Eco Fund collects funds for its operations as shown in the figure above (Figure 49), and as defined in Article 317 of EZ-1 and the Decree on energy savings requirements. Funds for Eco Fund's operations are obtained based on annual contracts with the MOP, and used to implement measures based on the Energy efficiency programme.

In its business plan for 2016, Eco Fund states that they will continue its policy of low interest rates for investments in environmental protection. Through the Green Fund, legal entities, craftsmen and private parties will be able to obtain a loan at an interest rate that will not exceed the three-month EURIBOR of

+ 0,0 %. Due to the negative impact of state aid in the form of soft loans of the purchase price of *'green electricity'*, there will be a fixed rate set for the loans for investment in production (CHP) equipment. This excludes state aid and must not be less than the reference interest rate from the state aid for the period of allocation.

Apart from soft loans, Eco Fund plans to award grants (EUR 700 000 in total) to heat distributors in order to connect end users to district heating. This measure includes replacing old boilers with new thermal stations connected to district heating. The incentive will be granted to heat distributors through a public call for applications, in order to provide end users (citizens in houses with one or two residential units) with a connection to the existing district heating system at a price reduced by the grant amount. In 2016, 460 connections to district heating were planned, which will help to reduce energy consumption by almost 10 GWh per year.

The grant programme promoting the use of renewable energy sources and increased energy efficiency in residential buildings comprises the following measures:

- encouraging the installation of solar heating systems in order to maximise the use of solar energy for hot water, and thus promote the heating of buildings;
- encouraging the installation of district heating systems, including the installation of heat pumps for hot water or biomass heating plants;
- encouraging the installation of heat pumps for heating residential buildings;
- integrating older residential buildings into district heating systems using a renewable energy source;
- replacing external joinery in older residential buildings with energy-efficient joinery;
- installing thermal insulation for facades, as well as for roofs or ceilings in older buildings;
- providing incentives for the installation of centralised ventilation systems or local heat recovery ventilation devices;
- promoting the construction or purchase of new nearly zero-energy buildings with an emphasis on sustainable construction;
- promoting comprehensive renovation of older buildings in an energy efficient manner;
- optimising the heating system by promoting the installation of thermostatic valves and hydraulic balancing of the heating network duct.

9.3.4 Aid centre

The electricity market operator Borzen d.o.o. performs the activities of the Aid centre, as described in Article 376 of the EZ-1. Apart from Article 376 of the EZ-1, the operations of the Aid centre are also governed by Article 351 of the same Act while activities in a broader sense are regulated in detail by the Rules on the operation of the Centre for RES/CHP support (Official Gazette of RS Nos 86/09, 17/2014 EZ-1). The main activity of the Aid centre is providing the public service of an electricity market operator; however, the centre does not only deal with electricity, but is also devoted to the certification of renewable energy sources, white certificates, certificates of origin, compensation for emissions and natural gas. One of the Aid centre's tasks is implementing a support scheme for the production of electricity from renewable energy sources and high-efficiency cogeneration.

To this end, the Aid centre manages the following funds (Article 377 of EZ-1):

- aid contributions for electricity from renewable energy sources and high-efficiency cogeneration paid by every end user of electricity, natural gas and other energy taken from the network;
- aid contributions for electricity from renewable sources and high-efficiency cogeneration paid by each end user of solid and liquid fossil fuels, liquefied petroleum gas and liquefied natural gas to the distributor;
- funds from electricity sold by the Aid centre and purchased at guaranteed purchase prices,
- budgetary funds intended to support electricity produced from high-efficiency cogeneration and renewable energy sources, from which a special budget line is determined and attributed a specific turnover;
- the climate change fund, as defined in the Environmental Protection Act.

Users gain aid on the basis of an Agreement on the provision of aid (Article 376(4) of EZ-1). The agreement shall be concluded based on a final decision by the AGEN-RS to award aid to beneficiaries, as laid down in the decision (Rules on the operation of Centre for RES/CHP support).

9.3.4.1 Eco Group

Eco Group is a balance group or a sub-group with a special status, which established the Aid centre in accordance with the rules governing the operation of the organised electricity market in order to settle the differences between planned and actual production and sale of electricity from the manufacturer exercising the right to incentives for guaranteed purchase of electricity.

The Aid centre at Borzen sold the electricity bought from the beneficiaries at guaranteed prices for EUR 8.5 million on the market in 2015, while the expected revenue from this source amounts to EUR 7 million in 2016. The deviation from 2014 is attributed to the decreased market price of electricity and the transition of aid beneficiaries from guaranteed purchase to premiums.

9.4 OVERVIEW AND ANALYSIS OF DOCUMENTS RELATED TO AID FOR HEATING AND COOLING

9.4.1 Energy balance of the Republic of Slovenia

The energy balance, produced each year by the MZI, contains a Plan for the implementation of the aid programme for the production of electricity from renewable energy sources and high-efficiency cogeneration, as well as a forecast of available resources needed for the AGEN-RS to carry out the public call for applications, pursuant to Article 373 of EZ-1, in order to reach the annual objectives of the aid programme.

Guidelines for the implementation of the aid programme for the production of electricity from renewable energy sources and high-efficiency cogeneration, and the identification of funds available for the implementation of the AGEN-RS' public call are mandatory parts of each annual energy balance.

The energy balance of the Republic of Slovenia for 2015 states that the implementation of the aid programme for the production of electricity from renewable energy sources and high-efficiency cogeneration in 2016 has EUR 163 million available, which, according to the energy balance for 2015, is sufficient aid both for existing programme users and for the implementation of the AGEN-RS' public call. In the aid system, EUR 10 million is dedicated to new entities.

The funds required for 2016 are planned to be collected from the following sources:

- contributions from end-users of electricity – EUR 123.0 million;
- electricity sold by the Eco Group – EUR 7.0 million;
- climate fund – EUR 0.0;
- fossil fuel contributions – EUR 33.0 million;
- borrowings by Borzen (Aid centre) – EUR 0.0;

- budget funds – EUR 0.0;
- total funds needed – EUR 163.0 million.

The amount of contribution from fossil fuels does not change, and remains the same in 2016 as in 2015. Based on the transitional provisions of Article 535(1) of EZ-1, by 22 September 2014, there were over 25 MW production facilities that were awarded aid pursuant to the old Energy Act connected to the electrical grid. According to AGEN-RS' estimates, only EUR 10 to 12 million annually will be needed for these last production units.

The funds available for pursuing the objectives in 2016 were divided as follows:

- 10% for hydro power plants up to 1 MW;
- 30% for biomass plants up to 1 MW;
- 10% for cogeneration plants using natural gas with up to 50 kW rated power;
- 30% for renovated cogeneration plants that are part of the district heating system;
- 20% for all other renewables, high-efficiency cogeneration technology and production plants not belonging to any of the above categories.

For 2017, the projected amount of funds is higher (about EUR 178.8 million), and will available to the Aid centre (Borzen). The annual balance for 2017 states the following: 'The funds to implement the aid scheme in 2017 amount to EUR 178.8 million, and, based on an assessment by the Aid centre at Borzen, will be collected with no new increases in RES and CHP contributions paid by consumers. The reason for this is an expected increase in the consumption of electricity and fossil fuels due to increased economic activity in 2017, according to trends in 2015/2016.'

The contribution amount for fossil fuels will not change in 2017, and will remain the same as in 2016.

9.4.2 Report on achieving national targets for RES and CHP in the period 2012–2014

9.4.2.1 Achieving objectives

Slovenia has no defined targets regarding high-efficiency cogeneration, except that it recognises the contribution of such technologies towards achieving the national energy efficiency targets with regard to making a more comprehensive assessment of the potential for high-efficiency cogeneration and efficient district heating and cooling under Article 14 of Directive 2012/27/EU of the European Parliament and of the Council of 25 October 2012 on energy efficiency. In accordance with Article 3 of Directive 2012/27/EU, Slovenia has set itself the target of increasing energy efficiency by 2020 so that primary energy consumption in 2020 would not exceed 7 125 million toe (82.86 TWh).

As for the share of renewable energy sources in total heating and cooling demand, the goal has been exceeded already in 2013, when the share of renewable energy sources accounted for 31.7% of gross direct energy consumption for heating and cooling, i.e. 6.5% more than the planned target for 2020.

Considering high-efficiency cogeneration that uses fossil fuels and renewable energy sources included in the aid programme, primary energy savings in 2010 amounted to 178.4 GWh, while in 2014 they amounted to 478.7 GWh, which is 2.7 times more than in 2010. Depending on the installed capacity by energy source, high-efficiency cogeneration using natural gas took the second place in increasing the installed capacity with new plants amounting to 25 MW, while high-efficiency cogeneration using biomass amounted to 14 MW.

In the field of cogeneration, the Action plan for renewable energy sources 2010–2020 (AN-OVE) wants to achieve that 80% of thermal energy in all district heating is generated from renewable energy sources and high-efficiency cogeneration.

The Report on achieving national targets for RES and CHP in the period 2012–2014, published by the AGEN-RS, states that the programmes for promoting the production of electricity from renewable sources and high-efficiency cogeneration are the most important instrument in the field of electricity to achieve the agreed targets under the Energy Efficiency Directive (2012/27/EU) and the Directive on the promotion of the use of energy from renewable sources (2009/28/EC).

9.4.2.2 Overview of aid by 2015

In 2002, a system of guaranteed prices (*'feed-in'* tariffs) was introduced. In 2009 it was upgraded, and in 2010 a new programme provided more funds to accelerate the achievement of objectives in the field of renewable energy sources and high-efficiency cogeneration. Until 2015, there was aid in the form of *'feed-in'* tariffs (stimulated or guaranteed prices) and operational aid. The duration of aid for promoting efficiency in heating and cooling using cogeneration (hereinafter referred to as CHP) was limited to 10 years, and for RES to 15 years. Grants were available for all sectors and were determined according to the annual reference price of electricity production and the reference market price of electricity. Prices remained unchanged for all technologies except for solar power plants, and the necessary aid funding was provided from fees collected from electricity buyers since 2009.

Since 2010, the new aid programme also covers high-efficiency cogeneration, which is divided into micro and small plants (less than 1 MW) and other CHP (up to 200 MW). The aid programme is generally intended for high-efficiency cogeneration plants, which are not older than 10 years, nevertheless, also plants older than 10 years can apply for aid, provided that they undergo a complete reconstruction. The AGEN-RS then assesses whether the reconstruction and renovation of a plant have been performed in such a way that the plant meets the set criteria, and whether the plant can be re-included in the aid programme.

2010 and 2011 are regarded as transitional years given the fact that by the end of 2011, both the old programmes and the new aid programme were in force, while the aid in its new form was available until the end of 2014. The amendment to the Energy Act in 2014 has significantly changed the procedures and conditions for obtaining aid, and was restricted by quotas and calls for applications awarding the contract to the most suitable tenderers. The threshold regarding power plants eligible to participate in the aid programmes decreased, limiting the rated power of high-efficiency cogeneration to a maximum of 20 MW. Since June 2014, the contribution to the aid programme is also collected from solid and liquid fossil fuels, natural gas, liquefied petroleum gas and district heating.

Total aid for the production of electricity and for the production of electricity from renewable energy sources and high-efficiency cogeneration has been increasing substantially every year. Regardless of any aid in the energy sector, aid for the production of electricity from renewable energy sources and cogeneration has been increasing gradually – in 2010, it amounted to 33.6%, while in 2013, it rose to 44%. While in 2010 EUR 11.4 million was dedicated to the production of electricity from high-efficiency cogeneration, the amount rose to EUR 35 million in 2015. The average cost of aid per unit of electricity produced from renewable energy sources and cogeneration in the period 2010–2014 increased by 72%. In 2010, the average cost of aid per unit of electricity produced amounted to EUR 78/MWh, while in 2015 it increased to EUR 142.5/MWh. The reasons for this increase are generally more expensive technologies, the structure of production according to the energy source, and class of installed power (aid for small businesses). In the old aid programme, before 2010, many hydro power plants were included, which received a below-average amount of aid. The share of contribution for energy efficiency has increased over the years, depending on the end-use electricity price – in 2009 it stood at 5%, in 2013 at 14%, while in 2014 it amounted to 13% of the total electricity price paid by the end customer from the household category. Industrial consumers pay a smaller share of contributions than households. The share of contributions from end users that are industrial electricity consumers amounted to only 5% of the total electricity price in 2014. Aid for the production of electricity from renewable energy sources represents 0.26% of GDP, which is still below the EU average (in 2012, EU average stood at 0.34%).

The average price of total aid for high-efficiency cogeneration using fossil fuels in the period 2010–2014 grew by 49%. Promoting cogeneration using fossil fuels over 4 000 hours had the lowest average cost (about EUR 70/MWh on average, 2010–2014), while promoting high-efficiency cogeneration using woody biomass of less than 4 000 hours had the highest average cost (about EUR 290/MWh on average, 2010–2014)
In the period 2010–2014, the largest investments were in solar power plants, followed by biogas power plants and then by high-efficiency cogeneration using fossil fuels.
From the Cohesion Fund and Operational Programme of Environmental and Transport Infrastructure Development (Operativni program razvoja okoljske in prometne infrastrukture – OP ROPI) 2007–2013, EUR 10 million in grants was allocated to biomass district heating systems, and 27 projects with a total investment value of EUR 27.2 million were implemented.

9.4.2.3 Overview of new aid for the period 2014–2020

In addition to the existing aid programme, subsidies to energy suppliers in the form of incentives for the installation of cogeneration units are planned. Other measures to promote high-efficiency cogeneration are the promotion of efficient energy use in green public procurement, exemption from excise duty on energy for CHP (*Excise Duties Act*) and the promotion of high-efficiency cogeneration within the framework of other incentives to use energy and reduce greenhouse gas emissions (EZ-1, a proposal of National Energy Efficiency Action Plan (NEEAP) 2015–2020, Operational programme of measures to reduce greenhouse gas emissions by 2020 (OP TGP 2020), and the Operational programme for the implementation of European cohesion policy (OP EKP));

Among other things, *the* OP EKP 2014–2020 provides that, when granting incentives for heating of buildings and residential areas, priority is given to heat systems using renewable energy sources and high-efficiency cogeneration. Incentives for high-efficiency cogeneration and aid for high-efficiency cogeneration using natural gas are also planned, but only where this helps reduce emissions of greenhouse gases. In the period 2014–2020, there are incentives planned for investment in the production and distribution of energy from renewable sources in the total amount of EUR 26 million from the Cohesion Fund – among other things, to supply heat for heating and cooling and high-efficiency cogeneration using renewable energy sources. This is expected to encourage investment in plants with a total production of 30 MW.

In the field of energy efficiency of public buildings, the *Operational Programme of Environmental and Transport Infrastructure Development* (OP ROPI 2007–2013) plans incentives for the installation of cogeneration units in small and medium-sized enterprises and for increasing energy efficiency in public and residential buildings.

9.4.2.4 Overview of aid costs

The average cost of new aid for high-efficiency cogeneration has grown from EUR 86/MWh for biomass cogeneration in 2010 to EUR 150/MWh in 2014.

The average cost of high-efficiency cogeneration using fossil fuels has grown from EUR 67/MWh in 2010 to EUR 99/MWh. The costs in 2014 and 2015 are almost identical.

The 2015 annual report of the Aid centre shows that in 2015, 3 290 plants with rated power of 433 MW, or about 11% of the installed capacity of the Republic of Slovenia took part in the aid programme. The share of entities within the aid programme that independently sell electricity on the market (and thus receive aid in the form of operational aid) increased slightly compared to 2014. At the end of 2014, 68% of entities were granted operational aid, and at the end of 2015, slightly less than 69

%. Aid for high-efficiency cogeneration using fossil fuels amounted to EUR 35 010 647 for 338 million kWh of electricity produced, and accounted for 23.8% of total aid and 34.5% of the total electricity produced. The share of electricity produced in cogeneration plants has grown from 21.7% to 23.8% of the total aid. This is due to a higher proportion of production from renewable energy sources, as a relatively large number of new production units entered the aid scheme over the last year, the declining share of production by hydro power plants (a bad hydrological year), and the stabilisation of biogas production. Aid for the production of electricity using high-efficiency cogeneration has increased by 25% compared to 2014, and 7.3 million more aid was paid than in 2014.

Aid for high-efficiency cogeneration over the years is shown in the table below.

Table 24: Aid for high-efficiency cogeneration

Year	Cogeneration plants	Number of plants	Installed power (MW)	Aid in line with the regulation governing CHP, new scheme (EUR)	Produced electricity (MWh)
2010	Fossil-fuel-fired	26	42.9	11 426 139	163 028
	RES-based	13	18.1		108 433
2011	Fossil-fuel-fired	46	44.6	14 930 317	183 968
	RES-based	29	36.7		187 871
2012	Fossil-fuel-fired	89	51.8	18 657 555	198 995
	RES-based	36	52.0		233 006
2013	Fossil-fuel-fired	184	62.2	24 356 197	229 770
	RES-based	41	53.0		220 244
2014	Fossil-fuel-fired	270	70.0	28 234 007	270 913
	RES-based	50	55.5		229 412
2015	Fossil-fuel-fired	390	87.0	35 010 647	337 999
	RES-based	15	5.5	17 362 521	119 992

*Data for the period 2010–2014 is taken from the Report on achieving national targets for RES and CHP in the period 2012–2014, while the data for 2015 is taken from the Aid centre's annual report.

10. COST-BENEFIT ANALYSIS

10.1 LEGAL OBLIGATIONS

Directive 2012/27/EU of the European Parliament and of the Council of 25 October 2012 on energy efficiency provides that Member States are obliged to carry out a comprehensive assessment of the potential for high-efficiency cogeneration and efficient district heating and cooling (Article 14 of the Directive). In the event that, based on the analysis, one determines the potential for high-efficiency cogeneration and/or efficient district heating and cooling the benefits of which exceed the costs, Member States shall take appropriate measures to develop infrastructure for efficient heating and cooling and/or to facilitate the development of high-efficiency cogeneration as well as heating and cooling using waste heat and renewable energy sources.

10.2 INPUT ASSUMPTIONS

The aim of a cost-benefit analysis (CBA) is to determine the possible benefits and costs for society as a whole from the use of high-efficiency cogeneration. It is carried out by performing an economic analysis. The basic assumptions of the economic analysis are the following:

- It is carried out with the aim of determining the benefits of the project for society.
- Shadow prices are used instead of market prices, because market prices do not necessarily reflect the ‘opportunity’ costs of certain activities for society.
- It is performed using constant (real) prices.
- It is performed using prices excluding VAT and other taxes.
- Transfers between different social groups (e.g. subsidies) are not taken into account.
- Accounting costs that do not represent actual cash flows are not included (depreciation, reserves, etc.).
- The project is financed exclusively with equity (assumed).
- The social discount rate is used to evaluate cash flows. Pursuant to the recommendation of the European Commission to Slovenia [12], a real amount of 5% is taken as the value.
- The time frame to perform the cost-benefit analysis is set so as to include all relevant costs and benefits.
- 2017 is used as the year of investing in the building of high-efficiency cogeneration and micro-cogeneration.
- High-efficiency cogeneration projects are evaluated for a period of 25 years (2042 being the last year observed), while micro-cogeneration projects are evaluated for a period of 18 years (2035 being the last year observed).
- Investments are carried out within one year (overnight cost).

10.3 HIGH-EFFICIENCY COGENERATION

To identify the version of high-efficiency cogeneration development in Slovenia, we performed an analysis of the current state of heat production plants in Slovenia as well as the current status and future demand for thermal energy.

According to the technical analysis conducted in accordance with the methodology described in Section 4.2.3.1, only Maribor and Ljubljana meet the condition of specific heat consumption being greater than 120 TJ/km^2, which is the limit for financial profitability of conventional district heating systems. In accordance with the results, a cost-benefit analysis for the construction of high-efficiency cogeneration facilities will be performed only for Ljubljana and Maribor.

The geographic boundary is determined as the specified area of Maribor and Ljubljana and the determined system is the heating system at each monitored site. A cost-benefit analysis was carried out using an integrated approach, meaning that all relevant supply resources that are available within the system boundaries and within geographic boundaries were taken into account.

The subject of cost-benefit analysis is the replacement of existing heat production plants that are connected to the district heating system using high-efficiency cogeneration. The analysis took into account only the production of thermal energy, and it is assumed that there will be no interference in the heat network.

10.3.1 Model assumptions

10.3.1.1 Energy consumption

Based on the input data and using the appropriate methodology described in Chapters 1 and 2, which take into account factors such as economic trends, projections of demographic changes, changes in comfort and standard of living, we determined heat consumption until 2035. Since the cost-benefit analysis was carried out for a period of 25 years, and the data on the planned heat consumption were provided only by 2035, we assumed that heat consumption in the period 2036–2042 was the same as in 2035. Using GIS analysis, the resulting future consumption was then assigned to each area to be heated. This was a fundamental step in determining the potential for high-efficiency cogeneration plants.

10.3.1.2 Prices of energy products

Prices of energy products used in cogeneration plants are taken from the Forecast [19] issued each year by the AGEN-RS. The above document specifies the reference prices of energy products, which are then used in plants using renewable energy sources and high-efficiency cogeneration, and based on which the AGEN-RS determines the amount of aid awarded to those plants.

As the document does not prescribe a reference price for extra light fuel oil, this price was taken from the European Commission's Bulletin [14].

Since the analysis is performed at constant prices, in the baseline scenario, the current energy product prices will be used, and it is assumed that the real amount of these prices will remain unchanged until the end of the project evaluation period. In the sensitivity analysis, we will examine the effect of changes in energy prices.

Shown below are the prices of all energy products used in plants connected to district heating systems in the cities of Maribor and Ljubljana.

Table 25: Prices of energy products

Energy product	Unit	Quantity
Natural gas	EUR/kWh	0.0224
Extra light fuel oil	EUR/kWh	0.0452
Coal	EUR/kWh	0.0092
Woody biomass	EUR/kWh	0.0144

10.3.1.3 Carbon dioxide emissions

Estimated amounts of emissions for different fuel types are listed in the table below.

Table 26: Emission factors

Emissions	Unit	Quantity
Natural gas	t_{CO2}/MWh	0.20196
Extra light fuel oil	t_{CO2}/MWh	0.26665
Coal	t_{CO2}/MWh	0.34585
Production of electricity	t_{CO2}/MWh	0.35850

In the cost-benefit analysis, we evaluated the cost of CO_2 emissions, the emissions being monetised in accordance with the instructions of the European Commission [11] and the European Investment Bank [14].

Table 27: Price of CO_2 emissions

Price per unit of CO_2	EUR/t	38.30	in 2017 in EUR from 2017
	EUR/t	25.00	in 2010 in EUR from 2006*

*Initial value is specified in [14]

Based on these documents, the cost per unit of CO_2 emissions increased by 1.185 EUR/t (from 2017) each year, which means a price of 67.92 EUR/t CO_2 in 2042.

10.3.1.4 Investment costs

In an alternative scenario, costs of investment are incurred due to the construction of high-efficiency cogeneration plants and peak boilers.

The cost per unit of investment in high-efficiency cogeneration shall be determined in accordance with the OECD and IEA data [20]. Assumed values are shown in the following table.

Table 28: Cost of investments in high-efficiency cogeneration plants

Type of plant	Unit	Quantity
Cogeneration – CCGT	EUR/kW$_e$	1 175
Cogeneration – woody biomass	EUR/kW$_e$	3 385

The cost per unit of investment in peak boilers fired by gas and woody biomass is determined according to a survey by the Danish regulatory agency [3]. Costs per unit of investment in peak boilers for heat production are shown below.

Table 29: Costs of investment in peak boilers

Type of plant	Unit	Quantity
Boiler – natural gas	EUR/kW$_t$	105
Boiler – woody biomass	EUR/kW$_t$	840

10.3.5.1 Plant operating expenses

Plants' operating expenses are analysed in the baseline and alternative scenarios. The operating cost of cogeneration is determined in accordance with the OECD and IEA data [20] while the operating cost of boilers is determined based on a survey by the Danish regulatory agency [3].

Shown below are the operating costs of cogeneration depending on technology, i.e. CCGT, woody biomass and coal, as well as heat production boilers.

Table 30: Cogeneration operating costs

Type of plant	Unit	Quantity
Cogeneration – CCGT	EUR/kW$_e$	37
Cogeneration – natural gas	EUR/kW$_e$	18
Cogeneration – woody biomass	EUR/kW$_e$	126
Cogeneration – coal	EUR/kW$_e$	41

Table 31: Peak boiler operating costs

Type of plant	Unit	Quantity
Boiler – natural gas	EUR/kW$_t$	3.9
Boiler – biomass	EUR/kW$_t$	31
Boiler – extra light fuel oil	EUR/kW$_t$	3.9

10.3.2 Baseline scenario

The baseline scenario shows the current status of heat production in the district heating system in the two cities observed. In order to construct the baseline scenario, we analysed the current situation and future development of the following parameters:

- types of fuel used in plants that are connected to the district heating system;
- amount of fuel used in plants that are connected to the district heating system;
- amount of electricity produced in plants that are connected to the district heating system;
- amount of heat produced in plants that are connected to the district heating system;
- current status and future development of heat demand;
- maintenance costs of existing plants.

After a change in heat consumption at the time of project evaluation, the rest of the above parameters will change as well.

Shown below are the baseline scenario energy assumptions for Ljubljana and Maribor.

Table 32: Baseline scenario energy assumptions – Maribor

Item	Unit	Quantity
Installed cogeneration capacity	MWe	16.82
Installed boiler capacity	MWt	127.62
Spent fuel – natural gas	MWh	217 780
Heat consumption	MWh	86 996
Produced electricity	MWh	66 875

Table 33: Baseline scenario energy assumptions – Ljubljana

Item	Unit	Quantity
Installed cogeneration capacity	MWe	228
Installed boiler capacity	MWt	570
Spent fuel – natural gas	MWh	166 915
Spent fuel – extra light fuel oil	MWh	7 897
Spent fuel – coal	MWh	1 522 870
Spent fuel – biomass	MWh	275 691
Heat consumption	MWh	1 040 414
Produced electricity	MWh	390 093

10.3.3 Alternative scenarios

For each of the two baseline scenarios, we have constructed two alternative scenarios for the construction of high-efficiency cogeneration plants, which will replace the existing heat production plants. The two alternative scenarios considered are as follows:

- construction of high-efficiency cogeneration plants using the CCGT technology;
- construction of high-efficiency cogeneration plants using woody biomass.

Alternative scenarios are different from the baseline scenario in the following ways.

- Alternative scenarios are an investment in the construction of high-efficiency cogeneration plants.
- Under the alternative scenarios, only one fuel is used – natural gas or woody biomass.
- Under the alternative scenarios, the same amount of heat is produced as under the baseline scenario, as there is no change in heat consumption, while the amount of electricity produced varies.

Shown below are the energy assumptions of two alternative scenarios – for Ljubljana and Maribor.

Table 34: Energy assumptions of two alternative scenarios – Maribor

Alternative scenario I – CCGT		
Assumption	**Unit**	**Quantity**
Installed cogeneration capacity	MW$_e$	125
$\eta_{\text{electricity}}$	%	52
$\eta_{\text{thermal energy}}$	%	33
Installed boiler capacity	MW$_t$	65
$\eta_{\text{thermal energy}}$	%	92
Spent fuel – natural gas	MWh	306 860
Heat consumption	MWh	86 996
Produced electricity	MWh	146 436
Alternative scenario II – woody biomass		
Assumption	**Unit**	**Quantity**
Installed cogeneration capacity	MW$_e$	56
$\eta_{\text{electricity}}$	%	35
$\eta_{\text{thermal energy}}$	%	50
Installed boiler capacity	MW$_t$	65
$\eta_{\text{thermal energy}}$	%	90
Spent fuel – biomass	MWh	211 675

Heat consumption	MWh	86 996
Produced electricity	MWh	65 051

Table 35: Energy assumptions of two alternative scenarios – Ljubljana

Alternative scenario I – CCGT		
Assumption	**Unit**	**Quantity**
Installed cogeneration capacity	MW_e	805
$\eta_{\text{electricity}}$	%	54
$\eta_{\text{thermal energy}}$	%	34
Installed boiler capacity	MW_t	415
$\eta_{\text{thermal energy}}$	%	92
Spent fuel – natural gas	MWh	3 045 186
Heat consumption	MWh	1 040 414
Produced electricity	MWh	1 505 322
Alternative scenario II – woody biomass		
Assumption	**Unit**	**Quantity**
Installed cogeneration capacity	MW_e	375
$\eta_{\text{electricity}}$	%	37
$\eta_{\text{thermal energy}}$	%	50
Installed boiler capacity	MW_t	415
$\eta_{\text{thermal energy}}$	%	90
Spent fuel – natural gas	MWh	2 158 867
Heat consumption	MWh	1 040 414
Produced electricity	MWh	701 368

10.3.4 Economic analysis

The objective of the economic analysis is to determine whether the net benefit in the form of lower costs for society as a whole outweighs the investment cost. If the net present value of the economic analysis is positive, the discounted value of the net benefit is greater than the cost of investment, and, from a social perspective, it is desirable that the investment is made. If the net present value of the economic analysis is negative, the discounted value of the net benefit is lower than the cost of investment, and, from a social perspective, it is not desirable that the investment is made.

Within the economic analysis, costs and benefits arising from the construction of high-efficiency cogeneration plants are determined. In the **two baseline scenarios,** the following costs were used:

- cost of fuel needed to produce thermal energy, calculated based on the prices shown in Section 10.3.1.2;
- cost of maintaining existing plants, calculated based on maintenance costs per unit and shown in section 10.3.1.5;
- social cost of CO_2 emissions, calculated based on the data referred to in Section 10.3.1.3.

The benefit of the baseline scenario stems from the sales revenue of electricity produced in existing cogeneration plants.

Under **Alternative scenario I,** existing heat production plants that are connected to the district heating system would be replaced by high-efficiency cogeneration plants using CCGT technology. Alternative scenario I comprises the following costs:

- cost of natural gas for the production of heat and electricity, which is calculated based on the prices shown in section 10.3.1.2;
- cost of maintaining the newly built high-efficiency cogeneration plants, which is calculated based on the maintenance cost per unit shown in section 10.3.1.5;
- social cost of CO_2 emissions, calculated based on the data referred to in Section 10.3.1.3.

The benefit of Alternative scenario I stems from the sales revenue of electricity produced using high-efficiency cogeneration.

Under **Alternative scenario II,** existing heat production plants that are connected to the district heating system would be replaced by high-efficiency cogeneration plants using woody biomass. Alternative scenario II comprises the following costs:

- cost of woody biomass for the production of heat and electricity, which is calculated based on the prices shown in section 10.3.1.2;
- cost of maintaining the newly built high-efficiency cogeneration plants, which is calculated based on the maintenance cost per unit shown in section 10.3.1.5;
- social cost of CO_2 emissions, calculated based on data referred to in Section 10.3.1.3.

The benefit of Alternative scenario II stems from the sales revenue of electricity produced using high-efficiency cogeneration.

The result of the economic analysis is the economic net present value (ENPV) of the two alternative scenarios. The ENPV is calculated as follows:

- the total social benefit of the baseline scenario and an alternative scenario is established;
- the total social cost of the baseline scenario and the alternative scenario is established;
- the differences between the annual social benefit and annual cost, and between the baseline scenario and the alternative scenario are established.

10.3.5 Results

Shown below are the results of the economic analysis for each observed alternative scenario.

Table 36: Economic analysis results for Alternative scenario I – Maribor

Item	***Unit/year***	***0***	***1***	***2***	***3***	***4***	***5***	***22***	***23***	***24***	***25***
		2017	*2018*	*2019*	*2020*	*2021*	*........*	*2039*	*2040*	*2041*	*2042*
Drive maintenance costs	EUR	0	–4 084 496	–4 084 496	–4 084 496	–4 084 496	....	–4 084 496	–4 084 496	–4 084 496	–4 084 496
Fuel cost	EUR	0	–1 994 766	–1 954 608	–1 914 450	–1 878 353	....	–1 398 319	–1 398 319	–1 398 319	–1 398 319
Cost of CO_2 emissions	EUR	0	415 800	419 659	423 014	426 791	....	475 195	483 944	492 692	501 441
Revenue from electricity	EUR	0	–3 336 779	–3 269 604	–3 202 428	–3 142 047	....	–2 339 062	–2 339 062	–2 339 062	–2 339 062
Investment	EUR	–153 911 337	0	0	0	0	....	0	0	0	0
Net result	EUR	–153 911 337	–2 326 683	–2 349 842	–2 373 503	–2 394 011	....	–2 668 558	–2 659 809	–2 651 061	–2 642 312
ENPV	**EUR**	**–189 391 890**									

Table 37: Economic analysis results for Alternative scenario II – Maribor

Item	***Unit/year***	***0***	***1***	***2***	***3***	***4***	***5***	***22***	***23***	***24***	***25***
		2017	*2018*	*2019*	*2020*	*2021*	*........*	*2039*	*2040*	*2041*	*2042*
Drive maintenance costs	EUR	0	–8 221 154	–8 221 154	–8 221 154	–8 221 154	....	–8 221 154	–8 221 154	–8 221 154	–8 221 154
Fuel cost	EUR	0	1 824 899	1 788 160	1 751 422	1 718 399	....	1 279 243	1 279 243	1 279 243	1 279 243
Cost of CO_2 emissions	EUR	0	1 710 631	1 726 504	1 740 310	1 755 846	....	1 954 985	1 990 977	2 026 970	2 062 962
Revenue from electricity	EUR	0	76 488	74 949	73 409	72 025	....	53 618	53 618	53 618	53 618
Investment	EUR	–242 838 548	0	0	0	0	....	0	0	0	0
Net result	EUR	–242 838 548	–4 762 112	–4 781 438	–4 802 831	–4 818 934	....	–5 040 544	–5 004 552	–4 968 559	–4 932 567
ENPV	**EUR**	**–312 491 282**									

Table 38: Economic analysis results for Alternative scenario I – Ljubljana

Item	**Unit/year**	**0**	**1**	**2**	**3**	**4**	**5**	**22**	**23**	**24**	**25**
		2017	*2018*	*2019*	*2020*	*2021*	……..	*2039*	*2040*	*2041*	*2042*
Drive maintenance costs	EUR	0	–20 045 447	–20 045 447	–20 045 447	–20 045 447	……..	–20 045 447	–20 045 447	–20 045 447	–20 045 447
Fuel cost	EUR	0	–45 879 144	–44 947 565	–44 015 985	–43 212 507	……..	–32 152 621	–32 152 621	–32 152 621	–32 152 621
Cost of CO_2 emissions	EUR	0	14 121 333	14 249 847	14 361 148	14 498 215	……..	16 134 273	16 431 316	16 728 358	17 025 400
Revenue from electricity	EUR	0	–46 772 699	–45 822 976	–44 873 252	–44 054 125	……..	–32 778 834	–32 778 834	–32 778 834	–32 778 834
Investment	EUR	–989 258 400	0	0	0	0	……..	0	0	0	0
Net result	EUR	–989 258 400	–5 030 559	–4 920 189	–4 827 032	–4 705 614	……..	–3 284 960	–2 987 918	–2 690 876	–2 393 834
ENPV	**EUR**	**–1 050 347 332**									

Table 39: Economic analysis results for Alternative scenario II – Ljubljana

Item	**Unit/year**	**0**	**1**	**2**	**3**	**4**	**5**	**22**	**23**	**24**	**25**
		2017	*2018*	*2019*	*2020*	*2021*	……..	*2039*	*2040*	*2041*	*2042*
Drive maintenance costs	EUR	0	–48 752 965	–48 752 965	–48 752 965	–48 752 965	……..	–48 752 965	–48 752 965	–48 752 965	–48 752 965
Fuel cost	EUR	0	–8 814 097	–8 635 126	–8 456 155	–8 301 794	……..	–6 177 018	–6 177 018	–6 177 018	–6 177 018
Cost of CO_2 emissions	EUR	0	27 022 942	27 268 869	27 481 856	27 744 151	……..	30 874 954	31 443 382	32 011 809	32 580 236
Revenue from electricity	EUR	0	–13 054 900	–12 789 819	–12 524 738	–12 296 109	……..	–9 149 021	–9 149 021	–9 149 021	–9 149 021
Investment	EUR	–1 617 697 373	0	0	0	0	……..	0	0	0	0
Net result	EUR	–1 617 697 373	–17 489 221	–17 329 403	–17 202 526	–17 014 500	……..	–14 906 008	–14 337 581	–13 769 154	–13 200 726
ENPV	**EUR**	**–1 851 111 336**									

10.3.6 Sensitivity analysis

The sensitivity analysis is performed for variables that have the greatest impact on the economic profitability of the project. These are the following:

- prices of energy products,
- investment cost, and
- operating costs.

The calculation of the economic net present value depends on the reduction or increase in the amount of these variables ranging from 60% to 140% of the originally assumed amount.

Table 40: Sensitivity analysis results for Alternative scenario I – Maribor

		CHANGES IN ENERGY PRODUCT PRICES								
CHANGES IN COST OF INVESTMENT AND OPEX	**ENPV (000 EUR)**	60%	70%	80%	90%	100%	110%	120%	130%	140%
	60%	–111 153	–109 565	–107 977	–106 389	–104 801	–103 212	–101 624	–100 036	–98 448
	70%	–132 301	–130 713	–129 125	–127 537	–125 948	–124 360	–122 772	–121 184	–119 596
	80%	–153 449	–151 861	–150 273	–148 684	–147 096	–145 508	–143 920	–142 332	–140 744
	90%	–174 597	–173 009	–171 420	–169 832	–168 244	–166 656	–165 068	–163 480	–161 891
	100%	–195 745	–194 156	–192 568	–190 980	–189 392	–187 804	–186 216	–184 627	–183 039
	110%	–216 892	–215 304	–213 716	–212 128	–210 540	–208 951	–207 363	–205 775	–204 187
	120%	–238 040	–236 452	–234 864	–233 276	–231 687	–230 099	–228 511	–226 923	–225 335
	130%	–259 188	–257 600	–256 012	–254 423	–252 835	–251 247	–249 659	–248 071	–246 483
	140%	–280 336	–278 748	–277 159	–275 571	–273 983	–272 395	–270 807	–269 219	–267 630

Table 41: Sensitivity analysis results for Alternative scenario II – Maribor

		CHANGES IN ENERGY PRODUCT PRICES								
CHANGES IN COST OF INVESTMENT AND OPEX	**ENPV (000 EUR)**	60%	70%	80%	90%	100%	110%	120%	130%	140%
	60%	–177 285	–175 216	–173 147	–171 078	–169 008	–166 939	–164 870	–162 801	–160 732
	70%	–213 156	–211 087	–209 017	–206 948	–204 879	–202 810	–200 741	–198 672	–196 603
	80%	–249 026	–246 957	–244 888	–242 819	–240 750	–238 681	–236 612	–234 542	–232 473
	90%	–284 897	–282 828	–280 759	–278 690	–276 621	–274 551	–272 482	–270 413	–268 344
	100%	–320 768	–318 699	–316 630	–314 560	–312 491	–310 422	–308 353	–306 284	–304 215
	110%	–356 639	–354 569	–352 500	–350 431	–348 362	–346 293	–344 224	–342 155	–340 085
	120%	–392 509	–390 440	–388 371	–386 302	–384 233	–382 164	–380 094	–378 025	–375 956
	130%	–428 380	–426 311	–424 242	–422 173	–420 103	–418 034	–415 965	–413 896	–411 827
	140%	–464 251	–462 182	–460 112	–458 043	–455 974	–453 905	–451 836	–449 767	–447 698

Table 42: Sensitivity analysis results for Alternative scenario I – Ljubljana

		CHANGES IN ENERGY PRODUCT PRICES								
CHANGES IN COST OF INVESTMENT AND OPEX	**ENPV (000 EUR)**	60%	70%	80%	90%	100%	110%	120%	130%	140%
	60%	–545 869	–544 811	–543 753	–542 694	–541 636	–540 578	–539 520	–538 462	–537 403
	70%	–673 047	–671 989	–670 930	–669 872	–668 814	–667 756	–666 698	–665 639	–664 581
	80%	–800 225	–799 166	–798 108	–797 050	–795 992	–794 934	–793 875	–792 817	–791 759
	90%	–927 402	–926 344	–925 286	–924 228	–923 170	–922 111	–921 053	–919 995	–918 937
	100%	–1 054 580	–1 053 522	–1 052 464	–1 051 406	–1 050 347	–1 049 289	–1 048 231	–1 047 173	–1 046 114
	110%	–1 181 758	–1 180 700	–1 179 642	–1 178 583	–1 177 525	–1 176 467	–1 175 409	–1 174 350	–1 173 292
	120%	–1 308 936	–1 307 878	–1 306 819	–1 305 761	–1 304 703	–1 303 645	–1 302 586	–1 301 528	–1 300 470
	130%	–1 436 114	–1 435 055	–1 433 997	–1 432 939	–1 431 881	–1 430 822	–1 429 764	–1 428 706	–1 427 648
	140%	–1 563 291	–1 562 233	–1 561 175	–1 560 117	–1 559 058	–1 558 000	–1 556 942	–1 555 884	–1 554 826

Table 43: Sensitivity analysis results for Alternative scenario II – Ljubljana

		CHANGES IN ENERGY PRODUCT PRICES								
CHANGES IN COST OF INVESTMENT AND OPEX	**ENPV (000 EUR)**	60%	70%	80%	90%	100%	110%	120%	130%	140%
	60%	–949 273	–944 251	–939 228	–934 206	–929 184	–924 161	–919 139	–914 117	–909 095
	70%	–1 179 755	–1 174 733	–1 169 710	–1 164 688	–1 159 666	–1 154 643	–1 149 621	–1 144 599	–1 139 576
	80%	–1 410 237	–1 405 214	–1 400 192	–1 395 170	–1 390 148	–1 385 125	–1 380 103	–1 375 081	–1 370 058
	90%	–1 640 719	–1 635 696	–1 630 674	–1 625 652	–1 620 629	–1 615 607	–1 610 585	–1 605 563	–1 600 540
	100%	–1 871 201	–1 866 178	–1 861 156	–1 856 134	–1 851 111	–1 846 089	–1 841 067	–1 836 044	–1 831 022
	110%	–2 101 682	–2 096 660	–2 091 638	–2 086 616	–2 081 593	–2 076 571	–2 071 549	–2 066 526	–2 061 504
	120%	–2 332 164	–2 327 142	–2 322 120	–2 317 097	–2 312 075	–2 307 053	–2 302 031	–2 297 008	–2 291 986
	130%	–2 562 646	–2 557 624	–2 552 602	–2 547 579	–2 542 557	–2 537 535	–2 532 512	–2 527 490	–2 522 468
	140%	–2 793 128	–2 788 106	–2 783 084	–2 778 061	–2 773 039	–2 768 017	–2 762 994	–2 757 972	–2 752 950

10.4 MICRO-COGENERATION

In areas where the consumption is too low to build a remote network through which heat produced in cogeneration plants would be distributed, we analysed the possibility of installing micro-cogeneration plants. A cost-benefit analysis was performed for each of the six reference buildings in Slovenia[9], using the following typology and nomenclature:

1. Residential buildings:
    a. ESS1 single-family building,
    b. ESS2 single-family building, and
    c. VSS1 multi-dwelling building;
2. Non-residential buildings:
    a. JSS1 public buildings, which are divided into public administration buildings and education buildings due to large energy consumption differences in individual consumption subsystems,
    b. NSS1 public buildings, and
    c. NSS2 non-residential building.

Reference buildings fall into the following subcategories:

- buildings built before 1960,
- buildings built between 1960 and 1980,
- buildings renovated in line with PURES
- new buildings, and
- nearly zero-energy buildings.

For the purposes of analysing the cost and benefit of installing micro-cogeneration plants, only renovated buildings and buildings built before 1960 or 1980 (not renovated) will be taken into consideration in the two alternative scenarios. The objective of cost-benefit analysis is to determine whether it is economically viable to install micro-cogeneration plants in the reference buildings concerned.

10.4.1 Model assumptions

10.4.1.1 Energy consumption

Heat demand, i.e. fuel consumption for meeting heat demand, is taken from the document titled *Reporting by the Republic of Slovenia to the European Commission on establishing 'cost-optimal levels of minimum energy performance requirements for buildings and building elements'.* For the purposes of the analysis, we defined the energy consumption of reference buildings classified by purpose, year of construction, characteristics of the building envelope and thermo-technical systems. Table 44 shows the parameters of energy consumption. Because

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[9] *Reporting by the Republic of Slovenia to the European Commission on establishing 'cost-optimal levels of minimum energy performance requirements for buildings and building elements' in accordance with the requirements and guidelines referred to in Article 5 and Annexes I and III of Directive 2010/31/EU and Regulation (EU) No 244/2012, Zavod za raziskavo materiala in konstrukcij Ljubljana (ZMRK) 2014*

the methodology for calculating cost-optimal levels of energy consumption does not include the total end-use energy consumption, but only energy for heating, hot water, cooling, mechanical ventilation (where appropriate) and lighting, we took values on electricity consumption of appliances and cooking referred to in Chapters 1 and 2 to be able to show the total energy consumption in the cost-benefit analysis. Specific information on electricity consumption for non-heating purposes is listed by building type in the table below.

Table 44: Electricity consumption by reference building for non-heat purposes

Building	**kWh/m^2**
ESS1	35
ESS2	35
VSS1	35
JSS1	51
NSS1	110
NSS2	113

10.4.1.2 Prices of energy products

Prices of energy products[10] reflect developments in the local, regional, European and global markets, as energy markets are interconnected and dependent on one another. Given the fact that the cost-benefit analysis is carried out for a relatively long period of time (by 2035), there is an extremely high level of uncertainty about future developments in energy prices, particularly natural gas and electricity. The analysis is carried out at constant prices. Therefore, in the baseline scenario, we will use the current level of energy prices, the real amount of which is estimated to remain constant by 2035. In the sensitivity analysis, we will examine the impact of changes in energy product prices, assuming that energy product prices will change by a certain percentage over the observed period.

10.4.1.2.1 Price of natural gas

The price of natural gas is the price that was used in the first quarter of 2016, excluding taxes and charges for various user categories according to their annual consumption. The table below shows the prices used:

Table 45: Overview of the prices of natural gas in the cost-benefit analysis

		Gas consumption		
Building names	**Code**	**GJ**	**Band**	**Price[11] EUR/kWh**
Single-family building	ESS1	83.9	Band D2: 20 GJ < consumption < 200 GJ	0.0426
Single-family building	ESS2	146.5	Band D2: 20 GJ < consumption < 200 GJ	0.0426
Multi-dwelling building	VSS1	1.167	Band I2: 1 000 GJ < consumption < 10 000 GJ	0.0502
Public building (public administration)	JSS1A	736.1	Band I1: Consumption < 1 000 GJ	0.0429
Public building (education)	JSS1B	736.1	Band I1: Consumption < 1 000 GJ	0.0429
Public building	NSS1	730.2	Band I1: Consumption < 1 000 GJ	0.0429
Non-residential building	NSS2	743.5	Band I1: Consumption < 1 000 GJ	0.0429

Source: Eurostat database

10.4.1.2.2 Electricity prices

The price of electricity is the price that was used in the first quarter of 2016 for various user categories according to their annual consumption. To estimate the electricity produced and delivered to the grid, we used a price that includes the components of production and supply. To evaluate the price of electricity taken from the grid, we used a price that includes the value of electricity generation, transmission, distribution and supply. The table below shows the prices used:

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[10] *It is assumed that the prices used represent shadow prices to the highest possible extent.*

[11] *Prices are from the first half of 2016, excluding taxes and excise duties.*

Table 46: Overview of the electricity prices in the cost-benefit analysis

		Electricity consumption		Price[12] EUR/kWh	
Building names	**Code**	**kWh**	**Band**	**Production + supply**	**Production + network + supply**
Single-family building	ESS1	5.075	Band DD: 5 000 kWh < consumption < 15 000 kWh	0.056	0.1033
Single-family building	ESS2	8.079	Band DD: 5 000 kWh < consumption < 15 000 kWh	0.056	0.1033
Multi-dwelling building	VSS1	55.100	Band DC: 2 500 kWh < consumption < 5 000 kWh	0.0573	0.1126
Public building (public administration)	JSS1A	86.966	Band IB: 20 MWh < consumption < 500 MWh	0.0521	0.0895
Public building (education)	JSS1B	45.430	Band IB: 20 MWh < consumption < 500 MWh	0.0521	0.0895
Public building	NSS1	142.780	Band IB: 20 MWh < consumption < 500 MWh	0.0521	0.0895
Non-residential building	NSS2	147.972	Band IB: 20 MWh < consumption < 500 MWh	0.0521	0.0895

Source: Eurostat database

10.4.1.2.3 Price of thermal energy

In order to evaluate the thermal energy from the district heating system, we used the average price of thermal energy in 56 district heating systems in Slovenia, which amounts to EUR 75.78/MWh excluding VAT [7].

10.4.1.2.4 Price of extra light fuel oil

To set the price of fuel oil, we used the price paid by non-industrial consumers, which stands at EUR 0.045/kWh excluding VAT and excise duties[13].

10.4.1.3 CO_2 emissions

10.4.1.3.1 Emission factors

Estimated amounts of emissions for different fuel types are listed in the table below. Data on CO_2 emissions from electricity production are taken from the Eurostat database on CO_2 emissions and from [16].

Table 47: Assumed emission factors

Emissions	**Unit**	**Quantity**
Natural gas	kg_{CO2}/kWh	0.2020
ELFO	kg_{CO2}/kWh	0.2667
Electricity production in Slovenia	kg_{CO2}/kWh	0.3585
District heating plants	kg_{CO2}/kWh	0.2328

10.4.1.3.2 CO_2 emission

In the economic analysis, we evaluated the cost of emissions, the emissions being monetised in accordance with the instructions of the European Commission [11] and the European Investment Bank [15]. Based on these documents, the cost per unit of CO_2 emissions increased by 1.185 EUR/t each year, which means a price of 59.6 EUR/t CO_2 in 2035.

Table 48: Assumed cost (price) of CO_2

Price per unit of CO_2[14]	EUR/t	38.3	in 2017 in EUR from 2017
	EUR/t	25	in 2010 in EUR from 2006

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[12] *Prices are from the first half of 2016, excluding taxes and excise duties.*

[13] *Source: Author's budget.*

[14] *Initial value is specified in [4].*

10.4.2 Baseline scenario

Under the baseline scenario, parameters of reference buildings are used. A summary of the used energy assumptions for all building types is given in the table below (Table 49). All reference buildings are divided into those built until 1960 and those built between 1960 and 1980. Public buildings are still divided into two groups:

- Public administration, and
- education.

The main difference between the two is electricity consumption.

It is assumed that, under the baseline scenario, heating systems in existing buildings will be renovated. It is also foreseen that the cost of renovating the heating system in a non-renovated building is 2.5 times the cost of installing an auxiliary system in a reconstructed building. This assumption was used for all buildings in which the current heating system runs on natural gas or fuel oil. In case of the VSS1 reference building from 1980, where the heating system is based on the district heating system, it is assumed that the district heating system will remain the heating system used, and in this case, no additional cost is foreseen for the renovation of the heating system.

In all non-renovated reference buildings, the assumed cost of system maintenance is the same as the cost of system maintenance in renovated reference buildings.

Table 49: Baseline scenario energy assumptions

Assumption	**Unit**	**ESS1**		**ESS2**		**VSS1**		**JSS1A**		**JSS1B**		**NSS1**		**NSS2**	
General information															
Year of construction	year	1960	1980	1960	1980	1960	1980	1960	1980	1960	1980	1960	1980	1960	1980
Surface	m^2	147	147	234	234	1 596	1 596	1 298	1 298	1 298	1 298	1 298	1 298	1 298	1 298
Heat consumption	kWh	44 835	37 044	64 818	49 374	325 584	285 684	186 912	150 568	186 912	150 568	186 912	162 250	214 170	184 316
Baseline scenario															
<u>Fuel consumption</u>															
Natural gas	kWh	-	-	-	-	327 180	-	-	163 548	-	163 548	-	163 548	227 150	184 316
	kWh/m^2	-	-	-	-	205	-	-	126	-	126	-	126	175	142
ELFO	kWh	44 688	37 044	64 584	49 374	-	-	186 912	-	186 912	-	186 912	-	-	-
	kWh/m^2	304	252	276	211	-	-	144	-	144	-	144	-	-	-
Biomass	kWh	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	kWh/m^2	-	-	-	-	-	-	-	-	-	-	-	-	-	-
District heating plants	kWh	-	-	-	-	-	285 684	-	-	-	-	-	-	-	-
	kWh/m^2	-	-	-	-	-	179	-	-	-	-	-	-	-	-
Electricity	kWh	5 075	5 075	8 079	8 079	55 100	55 100	86 966	86 966	45 430	45 430	142 780	142 780	147 972	147 972
	kWh/m^2	35	35	35	35	35	35	67	67	35	35	110	110	114	114
Maintenance costs	EUR/year	70	70	70	70	200	0	200	200	200	200	200	200	200	200
Investment costs	EUR	2 598	2 598	4 946	4 946	7 687	0	7 687	7 687	7 687	7 687	7 687	7 687	7 687	7 687

10.4.3 Alternative scenarios

Two alternative scenarios have been considered. Under Alternative scenario I (**AS I**), micro-cogeneration is used to meet the demand for heating and hot water. The alternative scenario is different from the baseline scenario in the following ways:

- Due to the energy efficiency measures implemented, heat demand is reduced (a detailed overview of energy consumption in renovated buildings pursuant to PURES is listed in the Appendix, Table 62).
- Only natural gas is taken into account as fuel.
- By installing micro-cogeneration plants, the investor simultaneously meets heat demand and produces electricity for their own needs, while the surplus is fed into the grid.

When installing micro-cogeneration plants, not only installation costs, but also system maintenance costs needs to be taken into account. It is foreseen that the service life of a micro-cogeneration plant is 18 years, which coincides with the time span of the economic analysis. To carry out a cost-benefit analysis, we used parameters shown in the table below (Table 50).

Alternative scenario II (**AS II**) provides only the installation of a micro-cogeneration plant, but no energy renovation of the building. Compared to AS I, this scenario is different in the following points:

- The fuel consumption to meet the heat demand is higher, since the heat demand is greater under AS II than under AS I.
- There are no envelope renovation costs under AS II.
- Due to a greater heat demand, the cost of investment in cogeneration plants is higher.

In other aspects, AS I and AS II are comparable. Table 51 below shows the assumptions used in AS II.

Table 50: Assumptions of Alternative scenario I

Assumption	**Unit**	**ESS1**		**ESS2**		**VSS1**		**JSS1A**		**JSS1B**		**NSS1**		**NSS2**	
Alternative scenario I															
Heat consumption	kWh	10 450	10 450	21 443	21 443	119 011	138 852	66 700	66 700	66 700	66 700	66 700	66 700	73 721	73 721
Fuel consumption															
Natural gas	kWh	11 956	11 956	29 534	29 534	203 321	203 321	180 600	180 600	180 600	180 600	165 550	165 550	171 570	171 570
	kWh/m^2	81	81	126	126	127	127	139	139	139	139	128	128	132	132
Electricity	kWh	5 075	5 075	8 079	8 079	55 100	55 100	86 966	86 966	45 430	45 430	142 780	142 780	147 972	147 972
	kWh/m^2	35	35	35	35	35	35	67	67	35	35	110	110	114	114
Production of electricity	kWh	4 900	4 900	4 500	4 500	58 450	58 450	50 100	50 100	50 100	50 100	45 925	45 925	47 595	47 595
Electricity	kWh/m^2	33	33	19	19	37	37	39	39	39	39	35	35	37	37
Investment costs	EUR	34 573	34 573	44 417	44 417	220 015	220 015	173 040	173 040	173 040	173 040	163 860	163 860	203 200	203 200
Envelope	EUR	27 034	27 034	24 938	24 938	166 940	166 940	123 040	123 040	123 040	123 040	113 860	113 860	153 200	153 200
Cogeneration	EUR	6 500	6 500	17 500	17 500	50 000	50 000	50 000	50 000	50 000	50 000	50 000	50 000	50 000	50 000
Backup system	EUR	1 039	1 039	1 979	1 979	3 075	3 075	0	0	0	0	0	0	0	0
Maintenance costs	EUR/year	148	148	420	420	1 200	1 200	350	350	350	350	350	350	350	350
Cogeneration		78	78	350	350	1 000	1 000	350	350	350	350	350	350	350	350
Backup system		70	70	70	70	200	200	0	0	0	0	0	0	0	0

Table 51: Assumptions of Alternative scenario II

Assumption	**Unit**	**ESS1**		**ESS2**		**VSS1**		**JSS1A**		**JSS1B**		**NSS1**		**NSS2**	
Alternative scenario II															
Fuel consumption															
Natural gas	kWh	40 691	45 941	111 000	45 941	652 500	0	322 400	322 400	322 400	322 400	322 400	225 750	403 000	279 000
	kWh/m^2	277	313	474	196	409	0	248	248	248	248	248	174	310	215
Electricity	kWh	5 075	5 075	8 079	8 079	55 100	55 100	86 966	86 966	45 430	45 430	142 780	142 780	147 972	147 972
	kWh/m^2	35	35	35	35	35	35	67	67	35	35	110	110	114	114
Production of electricity	kWh	4 960	5 600	29 250	5 600	217 575	0	102 440	102 440	102 440	102 440	102 440	62 625	128 050	88 650
Electricity	kWh/m^2	34	38	125	24	136	0	79	79	79	79	79	48	99	68
Investment costs	EUR	20 035	19 479	42 000	20 035	152 000	0	73 000	73 000	73 000	80 687	73 000	50 000	73 000	73 000
Cogeneration	EUR	17 500	17 500	42 000	17 500	152 000	0	73 000	73 000	73 000	73 000	73 000	50 000	73 000	73 000
Backup system	EUR	2 535	1 979	0	2 535	0	0	0	0	0	7 687	0	0	0	0
Maintenance costs	EUR/year	410	410	504	410	1 824	0	876	876	876	876	876	950	876	876
Cogeneration		210	210	504	210	1 824	0	876	876	876	876	876	600	876	876
Backup system		200	200	0	200	0	0	0	0	0	0	0	350	0	0

10.4.4 Economic analysis

The objective of the economic analysis is to determine whether the savings in the form of lower costs for society as a whole outweigh the investment cost. If the economic net present value (ENPV) of the economic analysis is positive, the discounted value of net benefit is greater than the cost of investment, and, from a social perspective, it is desirable that the investment is made. If the ENPV of the economic analysis is negative, the discounted value of total net savings is lower than the cost of investment, and, from a social perspective, it is not desirable that the investment is made.

Within the economic analysis, costs and benefits arising from the installation of micro-cogeneration plants are determined. The **baseline scenario** considers the following costs:

- cost of fuel for heat production,
- purchasing cost of electricity,
- cost of maintaining the existing system,
- cost of renovation of the existing heating system, and
- cost of CO_2 emissions.

The **alternative scenario** considers the following costs:

- cost of gas for running micro-cogeneration plants,
- cost of electricity to meet the non-heating demand (electricity costs are defined in such a way that the net electricity consumption is calculated as the difference between electricity consumption at the site and cogenerated energy produced),
- cost of investment in micro-cogeneration and envelope renovation (AS-I), or cost of investment in the installation of micro-cogeneration plants (AS II),
- maintenance costs, and
- costs of CO_2 emissions.

The difference between the total cost under the baseline scenario, and the total cost under the alternative scenario represents the net benefit. If the net benefit is positive, the alternative scenario is cost-effective, otherwise it is not.

10.4.4.1 Results

The results of the economic analysis show that, under the given reference building assumptions, none of the alternative scenarios is cost-effective – not even for one of the reference buildings is the net present value positive, nor is the benefit-cost ratio greater than 1 (with the exception of VSS 1 1980). Below is the interpretation of this result.

Alternative scenario I

Within AS I, we analysed the energy efficiency measures aimed at reducing energy demand for heating, and at the same time installing micro-cogeneration plants.

- Despite a significant reduction in fuel consumption for heat production, the savings are not sufficient to justify the investment cost.
- The existing, relatively effective, systems would be replaced by cogeneration plants, which have higher fuel consumption because of electricity production.
- The benefit from micro-cogeneration, which is reflected in electricity production and reduction in CO_2 emissions, is not sufficient to justify the investment in micro-cogeneration.

Alternative scenario II

Main characteristics:

- Due to lack of implementation of energy efficiency measures (reconstructions), larger micro-cogeneration plants must be installed in order to produce the required amount of heat.
- Because of electricity production, the total fuel consumption is even higher under AS II than under the baseline scenario (Figure 50 and Figure 51).

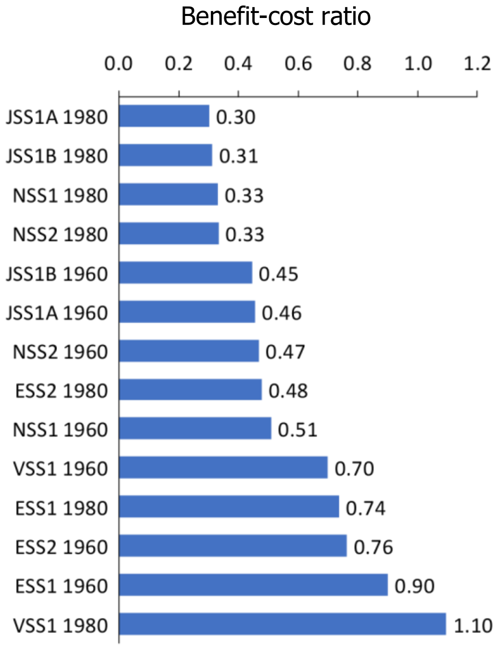

Figure 50: Benefit-cost ratio for AS I

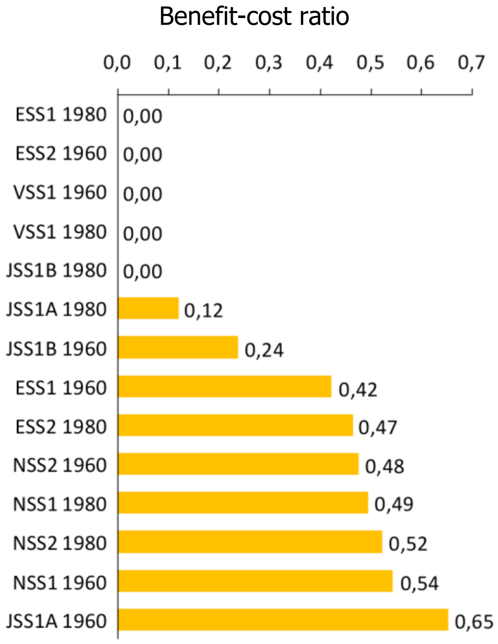

Figure 51: Benefit-cost ratio for AS II

Table 52: Economic net present value (ENPV) of economic profitability for AS I and AS II, in EUR

Building	**Cogeneration and envelope**	**Cogeneration**
	ENPV (EUR)	
ESS1 1960	−3 139	−9 581
ESS1 1980	−8 297	−16 837
ESS2 1960	−11 697	−41 823
ESS2 1980	−21 961	−8 783
VSS1 1960	−63 361	−157 065
VSS1 1980	21 200	8 276
JSS1A 1960	−89 526	−20 841
JSS1A 1980	−115 094	−63 087
JSS1B 1960	−91 307	−53 076
JSS1B 1980	−113 587	−86 247
NSS1 1960	−76 301	−31 617
NSS1 1980	−104 016	−23 942
NSS2 1960	−103 722	−37 940
NSS2 1980	−130 058	−33 723

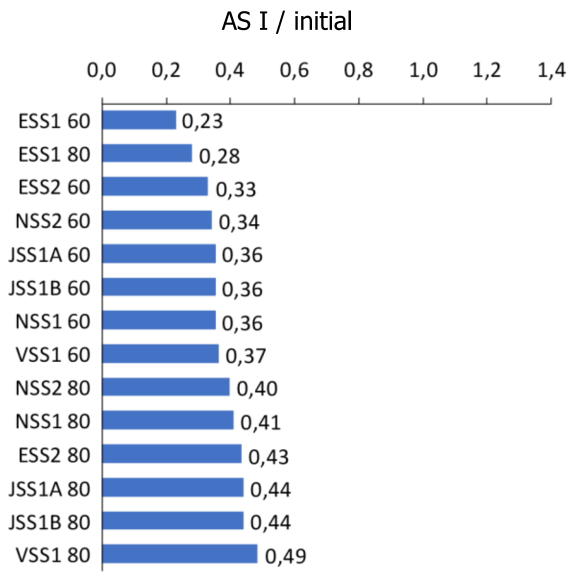

Figure 52: Ratio of fuel consumption (in kWh) in AS I compared to the baseline scenario

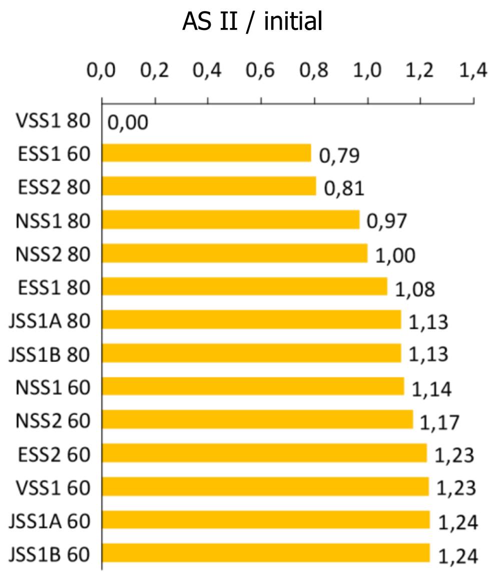

Figure 53: Ratio of fuel consumption (in kWh) in AS II compared to the baseline scenario

10.4.5 Sensitivity analysis

The sensitivity analysis has been carried out considering four parameters:

- cost of investment – cost of investment in reconstruction (renovation) and investment in cogeneration were exchanged in the same amount,
- price of natural gas,
- price of fuel oil, and
- price of electricity: all assumed electricity prices were exchanged in the same amount (e.g. 90% represents the price of electricity taken from the grid and fed into the grid at 90% of the initially assumed price).

The AS I analysis shows that the only significant change in the cost of investment may affect the economic profitability of installing a micro-cogeneration plant. Other parameters have a very limited impact because of the following.

- Changes in the price of fuel oil will only affect the buildings that use fuel oil in the baseline scenario (under the baseline scenario, the higher the prices of fuel oil, the higher the efficiency of micro-cogeneration, *ceteris paribus*).
- Changes in electricity prices also affect the price of energy taken from the grid and the cost of energy fed into the grid. In the case of systems that produce more than they consume (net producers), this effect is positive, while for systems that consume more electricity than they produce (net consumers), the effect is negative.
- Changes in gas prices have a positive impact on the profitability of systems using fuel oil under the baseline scenario. In systems using natural gas under the baseline scenario, the impact of changes in natural gas prices is reflected both in the baseline and in the alternative scenario, so that the net effect is limited.

The sensitivity analysis has shown that under AS II, the impact of changes in key variables on the return on investment is even lower than under AS I. This is mostly due to the fact that the profitability parameters are worse in AS II than in AS I. The following tables present the results of the sensitivity analysis for AS I and AS II. The scenarios where the benefit-cost ratio is greater than 1 are highlighted in grey.

Table 53: Impact of reduction in investment costs in AS I on the benefit-cost ratio

		Building type													
		ESS1 1960	**ESS1 1980**	**ESS2 1960**	**ESS2 1980**	**VSS1 1960**	**VSS1 1980**	**JSS1A 1960**	**JSS1A 1980**	**JSS1B 1960**	**JSS1B 1980**	**NSS1 1960**	**NSS1 1980**	**NSS2 1960**	**NSS2 1980**
Investments by assumed value	100%	0.90	0.74	0.76	0.48	0.70	1.10	0.46	0.30	0.45	0.31	0.51	0.33	0.47	0.33
	90%	1.01	0.83	0.86	0.54	0.78	1.22	0.51	0.34	0.50	0.35	0.57	0.37	0.52	0.37
	80%	1.15	0.94	0.98	0.62	0.88	1.37	0.58	0.38	0.57	0.40	0.65	0.42	0.59	0.42
	70%	1.33	1.10	1.15	0.73	1.02	1.57	0.67	0.44	0.65	0.46	0.75	0.49	0.68	0.49
	60%	1.59	1.30	1.39	0.88	1.20	1.83	0.79	0.52	0.77	0.54	0.88	0.58	0.80	0.57
	50%	1.96	1.61	1.75	1.10	1.46	2.19	0.96	0.64	0.94	0.66	1.08	0.70	0.98	0.70
	40%	2.57	2.11	2.35	1.48	1.85	2.74	1.23	0.82	1.20	0.84	1.38	0.90	1.25	0.89

Table 54: Impact of change in natural gas prices in AS I on the benefit-cost ratio

		Building type													
		ESS1 1960	ESS1 1980	ESS2 1960	ESS2 1980	VSS1 1960	VSS1 1980	JSS1A 1960	JSS1A 1980	JSS1B 1960	JSS1B 1980	NSS1 1960	NSS1 1980	NSS2 1960	NSS2 1980
Natural gas prices according to the initial scenario	100%	0.90	0.74	0.76	0.48	0.70	1.10	0.46	0.30	0.45	0.31	0.51	0.33	0.47	0.33
	90%	0.92	0.76	0.80	0.52	0.67	1.14	0.51	0.31	0.50	0.36	0.56	0.33	0.46	0.33
	80%	0.94	0.78	0.84	0.56	0.64	1.19	0.57	0.31	0.56	0.41	0.62	0.34	0.44	0.33
	70%	0.96	0.80	0.88	0.60	0.62	1.23	0.62	0.32	0.61	0.47	0.67	0.34	0.43	0.32
	60%	0.98	0.82	0.92	0.64	0.59	1.28	0.68	0.32	0.67	0.52	0.72	0.34	0.41	0.32
	50%	0.99	0.83	0.96	0.68	0.56	1.32	0.73	0.33	0.72	0.57	0.78	0.34	0.40	0.32
	40%	1.01	0.85	1.01	0.72	0.53	1.37	0.79	0.33	0.78	0.62	0.83	0.34	0.38	0.32

Table 55: Impact of change in ELFO prices in AS I on the benefit-cost ratio

		Building type													
		ESS1 1960	ESS1 1980	ESS2 1960	ESS2 1980	VSS1 1960	VSS1 1980	JSS1A 1960	JSS1A 1980	JSS1B 1960	JSS1B 1980	NSS1 1960	NSS1 1980	NSS2 1960	NSS2 1980
ELFO prices according to the initial scenario	150%	1.27	1.04	1.23	0.84	0.70	1.10	0.76	0.30	0.74	0.55	0.83	0.33	0.47	0.33
	140%	1.20	0.98	1.14	0.77	0.70	1.10	0.70	0.30	0.69	0.50	0.76	0.33	0.47	0.33
	130%	1.12	0.92	1.04	0.69	0.70	1.10	0.64	0.30	0.63	0.46	0.70	0.33	0.47	0.33
	120%	1.05	0.86	0.95	0.62	0.70	1.10	0.58	0.30	0.57	0.41	0.64	0.33	0.47	0.33
	110%	0.98	0.80	0.86	0.55	0.70	1.10	0.52	0.30	0.51	0.36	0.57	0.33	0.47	0.33
	100%	0.90	0.74	0.76	0.48	0.70	1.10	0.46	0.30	0.45	0.31	0.51	0.33	0.47	0.33
	90%	0.83	0.68	0.67	0.41	0.70	1.10	0.40	0.30	0.39	0.27	0.45	0.33	0.47	0.33

Table 56: Impact of change in electricity prices in AS I on the benefit-cost ratio

		Building type													
		ESS1 1960	ESS1 1980	ESS2 1960	ESS2 1980	VSS1 1960	VSS1 1980	JSS1A 1960	JSS1A 1980	JSS1B 1960	JSS1B 1980	NSS1 1960	NSS1 1980	NSS2 1960	NSS2 1980
Electricity prices according to the initial scenario	150%	0.99	0.83	0.84	0.56	0.87	1.26	0.62	0.46	0.59	0.47	0.67	0.49	0.60	0.46
	140%	0.98	0.81	0.82	0.54	0.84	1.23	0.59	0.43	0.56	0.43	0.63	0.46	0.57	0.44
	130%	0.96	0.80	0.81	0.53	0.80	1.20	0.55	0.40	0.53	0.40	0.60	0.43	0.55	0.41
	120%	0.94	0.78	0.79	0.51	0.77	1.16	0.52	0.37	0.51	0.37	0.57	0.40	0.52	0.39
	110%	0.92	0.76	0.78	0.50	0.74	1.13	0.49	0.34	0.48	0.34	0.54	0.36	0.49	0.36
	100%	0.90	0.74	0.76	0.48	0.70	1.10	0.46	0.30	0.45	0.31	0.51	0.33	0.47	0.33
	90%	0.88	0.72	0.75	0.47	0.67	1.06	0.43	0.27	0.42	0.28	0.48	0.30	0.44	0.31

Table 57: Impact of reduction in investment costs in AS II on the benefit-cost ratio

		Building type													
		ESS1 1960	ESS1 1980	ESS2 1960	ESS2 1980	VSS1 1960	VSS1 1980	JSS1A 1960	JSS1A 1980	JSS1B 1960	JSS1B 1980	NSS1 1960	NSS1 1980	NSS2 1960	NSS2 1980
Investments according to the initial scenario	100%	0.33	0.00	0.00	0.37	0.01	0.00	0.29	0.17	0.21	0.00	0.52	0.49	0.52	0.53
	90%	0.38	0.00	0.00	0.42	0.01	0.00	0.32	0.19	0.24	0.00	0.58	0.55	0.58	0.59
	80%	0.43	0.00	0.00	0.48	0.02	0.00	0.36	0.22	0.27	0.00	0.65	0.63	0.66	0.67
	70%	0.51	0.00	0.00	0.57	0.02	0.00	0.42	0.25	0.31	0.00	0.75	0.72	0.76	0.77
	60%	0.62	0.00	0.00	0.69	0.02	0.00	0.49	0.30	0.36	0.00	0.88	0.85	0.89	0.90
	50%	0.78	0.00	0.00	0.87	0.02	0.00	0.60	0.36	0.44	0.00	1.07	1.05	1.08	1.10
	40%	1.07	0.00	0.00	1.19	0.03	0.00	0.76	0.46	0.56	0.00	1.37	1.35	1.38	1.40

Table 58: Impact of change in natural gas prices in AS II on the benefit-cost ratio

		Building type													
		ESS1 1960	ESS1 1980	ESS2 1960	ESS2 1980	VSS1 1960	VSS1 1980	JSS1A 1960	JSS1A 1980	JSS1B 1960	JSS1B 1980	NSS1 1960	NSS1 1980	NSS2 1960	NSS2 1980
Natural gas prices according to the initial scenario	100%	0.33	0.00	0.00	0.37	0.01	0.00	0.29	0.17	0.21	0.00	0.52	0.49	0.52	0.53
	90%	0.45	0.09	0.07	0.50	0.12	0.00	0.52	0.29	0.44	0.16	0.75	0.56	0.65	0.60
	80%	0.57	0.23	0.21	0.63	0.22	0.00	0.75	0.40	0.67	0.36	0.98	0.63	0.77	0.66
	70%	0.68	0.36	0.35	0.76	0.33	0.00	0.98	0.51	0.90	0.55	1.21	0.69	0.90	0.73
	60%	0.80	0.50	0.49	0.90	0.43	0.00	1.21	0.63	1.13	0.75	1.44	0.76	1.02	0.80
	50%	0.91	0.64	0.63	1.03	0.54	0.00	1.43	0.74	1.36	0.95	1.67	0.82	1.15	0.87
	40%	1.03	0.77	0.77	1.16	0.65	0.00	1.66	0.85	1.59	1.15	1.90	0.89	1.27	0.93

Table 59: Impact of change in ELFO prices in AS II on the benefit-cost ratio

		Building type													
		ESS1 1960	ESS1 1980	ESS2 1960	ESS2 1980	VSS1 1960	VSS1 1980	JSS1A 1960	JSS1A 1980	JSS1B 1960	JSS1B 1980	NSS1 1960	NSS1 1980	NSS2 1960	NSS2 1980
ELFO prices according to the initial scenario	150%	1.01	0.53	0.36	1.11	0.01	0.00	0.98	0.17	0.91	0.46	1.21	0.49	0.52	0.53
	140%	0.87	0.42	0.27	0.97	0.01	0.00	0.84	0.17	0.77	0.36	1.08	0.49	0.52	0.53
	130%	0.74	0.30	0.19	0.82	0.01	0.00	0.70	0.17	0.63	0.26	0.94	0.49	0.52	0.53
	120%	0.60	0.19	0.10	0.67	0.01	0.00	0.57	0.17	0.49	0.16	0.80	0.49	0.52	0.53
	110%	0.47	0.07	0.02	0.52	0.01	0.00	0.43	0.17	0.35	0.06	0.66	0.49	0.52	0.53
	100%	0.33	0.00	0.00	0.37	0.01	0.00	0.29	0.17	0.21	0.00	0.52	0.49	0.52	0.53
	90%	0.20	0.00	0.00	0.22	0.01	0.00	0.15	0.17	0.07	0.00	0.38	0.49	0.52	0.53

Table 60: Impact of change in electricity prices in AS II on the benefit-cost ratio

		Building type													
		ESS1 1960	ESS1 1980	ESS2 1960	ESS2 1980	VSS1 1960	VSS1 1980	JSS1A 1960	JSS1A 1980	JSS1B 1960	JSS1B 1980	NSS1 1960	NSS1 1980	NSS2 1960	NSS2 1980
Electricity prices according to the initial scenario	150%	0.50	0.15	0.23	0.56	0.28	0.00	0.94	0.83	0.55	0.49	1.28	1.19	1.47	1.19
	140%	0.47	0.11	0.17	0.53	0.23	0.00	0.81	0.70	0.48	0.38	1.13	1.05	1.28	1.06
	130%	0.44	0.07	0.11	0.49	0.18	0.00	0.68	0.57	0.42	0.28	0.97	0.91	1.09	0.92
	120%	0.40	0.03	0.05	0.45	0.12	0.00	0.55	0.44	0.35	0.17	0.82	0.77	0.90	0.79
	110%	0.37	0.00	0.00	0.41	0.07	0.00	0.42	0.30	0.28	0.06	0.67	0.63	0.71	0.66
	100%	0.33	0.00	0.00	0.37	0.01	0.00	0.29	0.17	0.21	0.00	0.52	0.49	0.52	0.53
	90%	0.30	0.00	0.00	0.33	0.00	0.00	0.16	0.04	0.15	0.00	0.37	0.36	0.33	0.40

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13. LITERATURE

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[31] Commission Regulation (EU) No 1407/2013 of 18 December 2013 on the application of Articles 107 and 108 of the Treaty on the Functioning of the European Union to *de minimis* aid. Official Journal of the European Union, L 352, 24 December 2013

[32] Decree on determining the quantity of electricity generated from high-efficiency cogeneration of heat and electricity and on determining the efficiency of the energy conversion of biomass (UL RS No 37/2009)

[33] Decree on the method of determining and calculating the contribution for ensuring support for the production of electricity from high-efficiency cogeneration and renewable energy sources (UL RS Nos 36/2014 and 46/2015)

[34] Decree on support for electricity generated from renewable energy sources (UL RS Nos 37/09, 53/09, 68/09, 76/09, 17/10, 94/10, 43/11, 105/11, 43/12, 90/12, 17/14 – EZ-1 and 74/16)

[35] Decree on data submission and on the reporting of granted state aid and *de minimis* aid (UL RS Nos 61/2004, 22/2007 and 50/2014)

[36] Decree on energy savings requirements (UL RS No 96/14)

[37] Monitoring of State Aids Act (ZSDrP) (UL RS No 37/2004)

[38] Environmental Protection Act (UL RS Nos 39/06 – official consolidated text, 49/06 – ZMetD, 66/06 – decision of the Constitutional Court, 33/07 – ZPNačrt, 57/08 – ZFO-1A, 70/08, 108/09, 108/09 – ZPNačrt-A, 48/12, 57/12, 92/13, 56/15, 102/15 and 30/16)

14. ANNEXES

ANNEX A: ANNEX TO THE ECONOMIC ANALYSIS

Table 61: Assumed energy consumption for different types of reference buildings in the baseline scenario

Single-family building – ESS1		m^2	f_0	facade (m^2)	glazing (m^2)	roof (m^2)	floor (m^2)	use (h/day)		
	floor area	147	0.87	155	31	107	76	24		
(kWh/m^2)	end-use energy by subsystem					end-use energy				primary energy PURES 2010
	heating	hot water	mechanical ventilation	refrigeration	lighting	gas	ELFO	RES	Electricity	
1960	278	27			1		304		2	340
1980	225	27			1		252		2	282
Single-family building – ESS2		m^2	f0	facade (m^2)	glazing (m^2)	roof (m^2)	floor (m^2)	use (h/day)		
	floor area	147	0.87	155	31	107	76	24		
(kWh/m^2)	end-use energy by subsystem					end-use energy				primary energy PURES 2010
	heating	hot water	mechanical ventilation	refrigeration	lighting	gas	ELFO	RES	Electricity	
1960	249	28			1		276		2	309
1980	185	26			1		211		2	237
Multi-dwelling building – VSS1		m^2	f_0	facade (m^2)	glazing (m^2)	roof (m^2)	floor (m^2)	use (h/day)		
	floor area	1 596	0.41	787	305	470	470	24		
(kWh/m^2)	end-use energy by subsystem					end-use energy				primary energy PURES 2010
	heating	hot water	mechanical ventilation	refrigeration	lighting	gas	ELFO	RES	Electricity	
1960	175	29			5	211			2	237
1980	157	22			5		179		5	209

Public building – JSS1		m^2	f_0	facade (m^2)	glazing (m^2)	roof (m^2)	floor (m^2)	use (h/day)		
	floor area	1 298	0.39	700	130	520	520	8		
(kWh/m^2)	end-use energy by subsystem					end-use energy				primary energy PURES 2010
	heating	hot water	mechanical ventilation	refrigeration	lighting	gas	ELFO	RES	Electricity	
1960	115	26			2		141		2	165
1980	108	14			1	122			2	144

Non-residential building – NSS1		m^2	f_0	facade (m^2)	glazing (m^2)	roof (m^2)	floor (m^2)	use (h/day)		
	floor area	1 298	0.39	700	130	430	430	8		
(kWh/m^2)	end-use energy by subsystem					end-use energy				primary energy PURES 2010
	heating	hot water	mechanical ventilation	refrigeration	lighting	gas	ELFO	RES	Electricity	
1960	115	26			2		141		2	165
1980	99	23			1	122			2	144

Non-residential building – NSS2		m^2	f_0	facade (m^2)	glazing (m^2)	roof (m^2)	floor (m^2)	use (h/day)		
	floor area	1 298	0.39	570	260	520	520	8		
(kWh/m^2)	end-use energy by subsystem					end-use energy				primary energy PURES 2010
	heating	hot water	mechanical ventilation	refrigeration	lighting	gas	ELFO	RES	Electricity	
1960	160	15			2	175			2	198
1980	113	25			1	138			2	162

Table 62: Assumed energy consumption in households in Alternative scenario I

Single-family building – ESS1		m^2	f_0	facade	glazing	roof	floor	use		
				(m^2)	(m^2)	(m^2)	(m^2)	(h/day)		
	floor area	147	0.87	155	31	107	76	24		
(kWh/m^2)	end-use energy by subsystem					end-use energy				primary energy PURES 2010
	heating	hot water	mechanical ventilation	refrigeration	lighting	gas	ELFO	RES	electricity	
NEW BUILDING	50	20	4	0	1	71			5	89
Reconstruction in line with PURES	57	20	4		1	77			5	97
NZEB	60	20	4		1	80			5	75
Single-family building – ESS2		m^2	f_0	facade	glazing	roof	floor	use		
				(m^2)	(m^2)	(m^2)	(m^2)	(h/day)		
	floor area	147	0.87	155	31	107	76	24		
(kWh/m^2)	end-use energy by subsystem					end-use energy				primary energy PURES 2010
	heating	hot water	mechanical ventilation	refrigeration	lighting	gas	ELFO	RES	electricity	
NEW BUILDING	31	25	11		1			56	12	93
Reconstruction in line with PURES	66	26			1		102		2	117
NZEB	16	25	11		1	41			12	75
Multi-dwelling building – VSS1		m^2	f_0	facade	glazing	roof	floor	use		
				(m^2)	(m^2)	(m^2)	(m^2)	(h/day)		
	floor area	1 596	0.41	787	305	470	470	24		
(kWh/m^2)	end-use energy by subsystem					end-use energy				primary energy PURES 2010
	heating	hot water	mechanical ventilation	refrigeration	lighting	gas	ELFO	RES	electricity	
NEW BUILDING	39	22	9	0	2	61			11	96
Reconstruction in line with PURES	46	29			2	88			2	102
NZEB	26	22	9		2	48			11	80

Public building – JSS1		m^2	f_0	facade	glazing	roof	floor	use		
				(m^2)	(m^2)	(m^2)	(m^2)	(h/day)		
	floor area	1 298	0.39	700	130	520	520	8		
(kWh/m^2)	end-use energy by subsystem					end-use energy				primary energy PURES 2010
	heating	hot water	mechanical ventilation	refrigeration	lighting	gas	ELFO	RES	electricity	
NEW BUILDING	22	9	4	9	1	31			14	69
Reconstruction in line with PURES	25	9	4	9	1		34		14	72
NZEB	9	9	3	9	1	18			14	55
Non-residential building – NSS1		m^2	f_0	facade	glazing	roof	floor	use		
				(m^2)	(m^2)	(m^2)	(m^2)	(h/day)		
	floor area	1 298	0.39	700	130	430	430	8		
(kWh/m^2)	end-use energy by subsystem					end-use energy				primary energy PURES 2010
	heating	hot water	mechanical ventilation	refrigeration	lighting	gas	ELFO	RES	electricity	
NEW BUILDING	22	9	3	9	1	31			14	69
Reconstruction in line with PURES	30	26			1		56		2	72
NZEB	9	9	3	9	1	18			14	55
Non-residential building – NSS2		m^2	f_0	facade	glazing	roof	floor	use		
				(m^2)	(m^2)	(m^2)	(m^2)	(h/day)		
	floor area	1 298	0.39	570	260	520	520	8		
(kWh/m^2)	end-use energy by subsystem					end-use energy				primary energy PURES 2010
	heating	hot water	mechanical ventilation	refrigeration	lighting	gas	ELFO	RES	electricity	
NEW BUILDING	30	9	3	11	1	39			15	80
Reconstruction in line with PURES	54	9				63			2	79
NZEB	9	9	3	9	1	18			14	55

ANNEX 1: INSTRUCTIONS FOR MAKING A COST-BENEFIT ANALYSIS

1.1 Introduction and contents of the instructions

These instructions for making a cost-benefit analysis (*CBA*) are based on Article 14 of Directive 2012/27/EU of the European Parliament and of the Council of 25 October 2012 on energy efficiency, amending Directives 2009/125/EC and 2010/30/EU and repealing Directives 2004/8/EC and 2006/32/EC, OJ L 315 of 14 November 2012, page 1, (hereinafter referred to as Directive 2012/27/EU).

The methodology and the cost-benefit analysis are in accordance with the Guide to Cost-Benefit Analysis by the European Commission and the European Investment Bank[15].

These instructions define the methods, assumptions and time frame of the economic analysis, and the principles to be considered in making the cost-benefit analysis so as to produce clearly understandable results.

The cost-benefit analysis, which includes a financial and an economic analysis, is performed using the *discounted cash flow method*.

All subjects of the cost-benefit analysis are shown on an annual basis. However, for subjects such as the production of electricity and heat, a more detailed (monthly, daily and hourly) view is necessary in order to determine the benefits and costs of planned investments more accurately.

The cost-benefit analysis should show the connection of the proposed and the alternative plant to the energy system of the Republic of Slovenia, thus demonstrating its effect on electricity and heat production in Slovenia.

1.2 Steps of cost-benefit analysis

The following six basic steps are to be followed when making a cost-benefit analysis:

1. identify the baseline scenario that assumes the production in the planned non-high-efficiency plant;
2. identify the alternative scenario that assumes the construction of a cogeneration plant that will
3. produce the same amount of electricity as the plant planned in the baseline scenario, but will also produce heat in the cogeneration process;
4. identify the possible use of heat from the cogeneration plant;
5. conduct a financial analysis;
6. conduct an economic analysis;
7. conduct a sensitivity analysis.

1.2.1 Defining the baseline scenario

In the baseline scenario, which describes the planned investment, it is necessary to define the technical characteristics of the planned investment, which includes, inter alia:

- description of the plant;
- description of the technology – based on project documents provided by the equipment supplier;
- investment costs – based on a bill of costs provided by the equipment supplier;
- maintenance costs – based on the technical documentation provided by the equipment supplier and on the maintenance contract;
- an electricity generation plan – based on documents;
- determining the energy performance of fuels and a fuel plan – based on technical documentation and Annex IV of Directive 2012/27/EU.

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[15] *Guide to Cost Benefit Analysis (European Commission, December 2014), and The Economic Appraisal of Investment Projects at the EIB (European Investment Bank, 2013)*

1.2.2 Identifying the alternative scenario

In the alternative scenario, the construction of a high-efficiency cogeneration plant producing the same amount of electricity as the plant planned in the baseline scenario is estimated. The following attributes need to be specified.

- Technology description – it is necessary to analyse the construction of a high-efficiency cogeneration plant that produces the same amount of electricity as the plant planned in the baseline scenario.
- Investment costs – the ministry responsible for energy will publish investment costs for the reference plants on its website.
- Maintenance costs – the ministry responsible for energy will publish maintenance costs for the reference plants on its website.
- Plan for electricity production – investor's budget.
- Plan of heat production and heat properties – investor's budget. The investor must define the possible usable heat consumption that can be met under the alternative scenario. The plant envisioned under the alternative scenario has to meet only part of the heat consumption in the geographical area defined.
- Proven primary energy savings must reach at least 10%, pursuant to Directive 2012/27/EU.
- Energy properties of fuels and planned fuel use – investor's budget, which is based on energy density of fuels, is specified in Annex IV of Directive 2012/27/EU.

1.3 Financial analysis

The goal of the financial analysis is to determine the consolidated profitability of the project for the investor. The financial analysis should determine whether the project is financially viable, and should provide an overview of the project's cash flows.

1.3.1 Assumptions of the financial analysis

The basic assumptions of the financial analysis are the following:

- Only cash expenditure and receipts are evaluated. This means that accounting articles such as depreciation, reserves, etc., which do not represent actual cash flows, are not included in the analysis.
- The financial analysis is carried out from the investor's perspective. In the event that the owner of the plant (investor) and the entity responsible for the management and operation of the plant (project manager) are not the same entity, a consolidated financial analysis is required, which excludes the cash flows between the owner/investor and the project manager. This is important for determining the feasibility of the project independently from internal cash flows.
- Cash flow projections should cover the period (time frame) in which the benefits and costs of the project (reference period) are realised. The reference period should correspond to the economic life expectancy of the project. The life expectancy of gas-powered plants is 25 years, and 20 years for heating equipment.
- The ministry responsible for energy will publicly release a real financial discount rate, which investors must take into account when making a cost-benefit analysis. When discounting cash flows, real financial discount rate must be used. In the event that no valid discount rate is prescribed in the Republic of Slovenia at the time of making the cost-benefit analysis, the general real financial discount rate prescribed by the European Commission for the period 2014–2020 must be used. It amounts to 4% for Cohesion Member States according to Article 19 of Regulation (EU) No 480/2014.[16]
- The financial analysis is conducted at constant prices, which means that it does not include the cost of inflation. In such cases, it is necessary to establish a baseline year to which all prices in the analysis are bound.

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[16] *Commission Delegated Regulation (EU) No 480/2014 of 3 March 2014 amending Regulation (EU) No 1303/2013 of the European Parliament and of the Council laying down common provisions on the European Regional Development Fund, the European Social Fund, the Cohesion Fund, the European Agricultural Fund for Rural Development and the European Maritime and Fisheries Fund and laying down general provisions on the European Regional Development Fund, the European Social Fund, the Cohesion Fund and the European Maritime and Fisheries Fund.*

This means that interest charges are also determined in the real amount so that the nominal interest rates translate into real rates by approximating the Fischer formula:

$$r_r = r_n - \pi$$

Legend: r_r – real interest rate; r_n – nominal interest rate; π – inflation rate

To evaluate the inflation rate, the consumer price index (CPI) inflation recorded in the year preceding the analysis is used. Eurostat and *Harmonised Index of Consumer Prices* (HICP) for Slovenia are used as data sources.

- All prices in the financial analysis are exclusive of value-added tax (VAT), in terms of both purchase and sales prices.
- Direct taxes (e.g. income tax) are not included in the financial profitability calculations, but only in financial sustainability calculations.

1.3.2 Elements of the financial analysis

1.3.2.1 Investment costs

Investment costs and dynamics are the first element to be analysed in the financial analysis. Investments costs are divided into several categories.

- Initial investment costs are the costs of purchasing and installing the necessary tangible fixed assets. The costs include all work, studies and other activities necessary for equipment to be granted for use. These costs may be transferred from investment studies and must be presented at an incremental level representing expenditures for the acquisition of assets in each accounting period (year). Annual initial investment costs should be in line with the real (physical) implementation of the project.
- Replacement costs include costs incurred during the reference period due to replacement of equipment that has a shorter life span. If a high financial cost arises at the end of the reference period, it is proposed that, in this case, the reference period is shortened, or that the replacement is delayed, assuming that maintenance costs will be higher.
- The residual value represents the project's capacity to generate added value for the owner until its economic life expires. This value will be zero if the reference period, i.e. the time frame in which the project is assessed, is the same as the economic life of the project. If the economic life of the project is longer than the reference period, i.e. the time frame in which the project is assessed, the residual value is calculated as the net present value of cash flows after the reference period (in accordance with Article 18 of Regulation (EU) No 480/2014). The residual value must be clearly highlighted in the cost-benefit analysis as a positive value in revenue or a negative value in investments.

1.3.2.2 Operating and maintenance costs, and revenue

The next step is to determine the drive maintenance costs and the planned revenue, taking into account the following assumptions:

- Drive maintenance costs include all costs that are necessary for the normal operation of the plant. These costs vary from project to project and include the following elements: cost of operation, maintenance materials, consumption of raw materials, fuel, water, energy, services by third parties, building rental costs, equipment, administrative costs, quality control, waste disposal, emission costs and other environmental-protection-related costs, insurance costs. Interest costs are not included in operating and maintenance costs. When displaying operating and maintenance costs, it is desirable that they be divided into a fixed component, which does not depend on energy consumption, and a variable component, which is directly linked to energy production. In the projection of operating costs, the same prices are used for all years, except if it is expected that a part of costs will grow at a different rate than others. Here, it is necessary to pay attention to the cost of CO_2 emissions, as power plants are subject to the EU ETS[17]. The prices of EU ETS emissions expected in the coming period will be published by the responsible ministry on its website.

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[17] *The EU Emissions Trading System (EU ETS, a European scheme for trading with CO_2 emission allowances)*

- Operating revenues are funds paid by final customers for goods or services supplied. Transfers, subsidies or financial revenues are not included in operating income when calculating financial profitability, since they are not a direct result of business operations. As in the case of projecting drive maintenance costs, price projections are made by assuming that the price per unit of product will be identical in all years unless changes in relative price per unit are expected. If so, an additional analysis justifying such expectations must be submitted.

1.3.2.3 Financing sources

In this step, financing sources that will bear the investment cost are determined. Possible financing sources include own funds, loans from commercial or development banks, and grants.

1.3.2.4 Determining financial profitability

After determining investment costs, operating and maintenance costs and revenues of the project, it is possible to determine its profitability, which is measured by the following two parameters:

- financial net present value – FNPV (C), and financial rate of return FRR (C) – on investment;
- financial net present value – FNPV (K), and financial rate of return FRR (K) – on national capital invested.

Financial net present value FNPV (C) of investments is calculated by subtracting discounted operating and investment costs from discounted revenues, following the formula below:

$$FNPV(C) = \sum_{t=0}^{n} a_t S_t = \frac{S_0}{(1+i)^0} + \frac{S_1}{(1+i)^1} + \cdots + \frac{S_n}{(1+i)^n}$$

Legend: *n* – number of years in which the project is valued (time frame); *a*t – annual discount factor *t*; *i* – discount rate (real); *S*t – annual net cash receipts *t* (revenue less expenses and investment costs).

Financial rate of return (FRR) is defined as a level that makes the FNPV equal zero, and is in accordance with the following formula:

$$0 = \sum_{t=0}^{n} = \frac{S_t}{(1+FRR)^t}$$

Financial net present value FNPV (C) of investments does not take into account the financing sources; they are taken into account when determining the financial net present value of the capital invested. Also, as stated above, the budget of financial net present value of investments does not include taxes; taxes are included only when determining the financial sustainability of the project.

1.3.2.5 Determining the return on national capital invested

The aim of the analysis is to determine the return on national capital invested in order to determine the profitability of the project from the investor’s perspective. The analysis does not include grants awarded by the EU or national/regional authorities. When calculating the return on national capital invested, expenditure includes operating costs, equity invested and loan repayments. As revenue comprises operating revenue and residual value only. Subsidies used to cover operating expenses are not included in the calculation, since they represent a transfer from one national entity to another (e.g. from a citizen to an investor).

FNPV (K) represents the net discounted cash flows that belong to investors (public and private) as a result of project implementation. FRR (K) is the return on investment. In determining FNPV (K) and FRR (K), all sources of funds are taken into account. Here, they are presented as expenditure (in the financial sustainability analysis, they are displayed as revenue) rather than investment costs.

1.3.3 Financial sustainability

The project is financially sustainable when the risk of it being insolvent in any phase (investment phase to closing phase) is reduced to a minimum. The risk of insolvency is established by making a cash flow projection, which shows whether the project has sufficient funds available to meet all obligations in all years of operation. This analysis is supposed to show in what way the project will meet its obligations either from internal or external financing sources.

The difference between revenues and expenditures will result in a deficit or a surplus, which accumulates over the years.

Revenues include:

- financing sources,
- operating income, and
- various transfers, subsidies, etc., which are not derived from services paid by end users.

The residual value is not taken into account unless the property is going to be monetised in the last year of the project.

Depending on expenditure, the following is valued:

- initial investments,
- replacement costs,
- operating and maintenance costs,
- repayment of principal and interest,
- corporate income taxes and other tax expenses.

In order to determine the amount of tax, both a profit account and a loss account need to be made. They will include depreciation and interest payments.

1.4 Economic analysis

The objective of the economic analysis is to determine the project's contribution to society. In this context, the main difference from the financial analysis is the use of shadow prices, which reflect the real value of goods and services to end users, rather than market prices. This principle applies because of the assumption that market prices do not reflect the real value of goods and services to end customers due to various market imperfections.

However, when it comes to economic analysis in the context of Article 14(5) of Directive 2012/27/EU, it is assumed that prices in the energy market do reflect the real value for end users. As a result, the following prices are used in the economic analysis.

- Electricity prices – as the production price of electricity we used prices published by Eurostat by selecting the price for Slovenia for the last available half-year, expressed in euros, excluding taxes and fees, and containing only the *energy and supply* component. A corresponding price band is selected in accordance with the planned production of the plant. For example, if the planned production is 80 000 MWh per year, the price for *'Band IF – 70 000 MWh–150 000 MWh' is used.*
- The price of natural gas used as fuel is taken from Eurostat by using the price band for the quantity corresponding to the plant's annual consumption of natural gas. For example, if the plant has an annual consumption of 3 000 000 GJ of natural gas, the price for *'Band I5 – 1 000 000 GJ–4 000 000 GJ'* is used. As in electricity prices, the prices of natural gas used are those for Slovenia for the last available half-year, expressed in euros, excluding taxes and fees.
- The source for other prices (biomass, coal, etc.), will be published by the ministry responsible for energy on their website.

In contrast to the financial analysis, discounting is performed using the economic discount rate. If the ministry responsible for energy does not announce the economic discount rate to be used in economic analyses, one should use the economic discount rate submitted by the EU to Cohesion Member States amounting to 5% in real terms for the period 2014–2020.

When performing an economic analysis, it is of vital importance to exclude the impact of transfers, taxes and subsidies, because they represent a transfer of goods from one social category to another. As a rule, the following applies.

- The prices of input material (*input prices)* and prices of final products (*output* prices) must be shown exclusive of VAT.

- Input prices must be shown exclusive of direct and indirect taxes. This also applies to the cost of operation, which should not include taxes and social security charges.
- Output prices must be shown without subsidies or other transfers from the state budget.

Compared to the financial analysis, the economic analysis needs to assess the positive and negative externalities that occur or are a result of investments. Within the projects referred to in Article 14(5) of Directive 2012/27/EU, key externalities result from greenhouse gases emission into the atmosphere. Therefore, either in the baseline or in the alternative scenario, the economic analysis needs to determine the amount of CO_2 emissions as well the social costs of emissions.

In order to determine the cost of emissions, the following approach needs to be used.

- Based on the planned fuel consumption for producing the gross amount of energy (net power production), the total amount of emissions is determined. The amount of emissions depends on the fuel, which is why emission factors imposed by the IPPC and listed in Annex 2 are used. The amount of CO_2 emissions in tons is used both in the financial and in the economic analysis.
- To get the full cost of emissions, you multiply the amount of CO_2 emissions with the economic costs of emissions. The economic cost of a ton of CO_2 for society amounts at 20 EUR/t_{CO2} (euro value from 2006) (*European Investment Bank, 2013*). *Harmonised Index of Consumer Prices*, published by Eurostat, shows that a price of one ton of CO_2 stood at EUR 30.7 in 2017. Accordingly, for each following year (starting with 2018) one euro is added to the cost of a ton of CO_2.

The impact on secondary markets (e.g. the labour market) cannot be estimated, because the economic analysis uses shadow prices. Including the impact of a project on a secondary market in the calculation would result in a double adding of benefits and costs of the project.

After identifying the benefits and costs of the project, the following economic indicators are calculated:

- economic net present value (ENPV) – the difference between the discounted social benefits and costs;
- economic rate of return (ERR) – rate, which results in ENPV being zero;
- benefit-cost ratio – the ratio between discounted benefits and costs of the project.

The project with a negative ENPV or an ERR lower than the social discount rate, should not be run. Such a project would use up too much social resources, and the results would not be sufficient to cover the social costs.

1.5 Sensitivity analysis

After the financial and economic analysis, a sensitivity analysis must be carried out in order to show to which parameters the project results are most sensitive. The analysis is carried out in such a way that each variable is changed by 1% relative to the starting amount, and the impact on the NPV is determined. The variables that change the NPV for more than 1% can be regarded as critical. In the sensitivity analysis, it is crucial to analyse the scenario in which more than one variable changes.

ANNEX 2: EMISSION FACTORS

Table 1: Emission factors for the cost-benefit analysis

	Content C	Net calorific value	FE	FE
	t_C/TJ	MJ/kg	t_{CO2}/t	t_{CO2}/TJ
Liquid fuel				
Primary fuels				
Crude oil	20.0	41.87	3.07	73.33
Secondary fuels				
Petrol	**18.9**	**44.59**	**3.09**	**69.30**
Jet kerosene	19.5	43.96	3.14	**71.50**
Petroleum/kerosene (other jet fuel)	19.6	43.96	3.16	**71.87**
Diesel	20.2	42.71	3.16	**74.07**
Extra light fuel oil	20.2	42.71	3.16	**74.07**
Fuel oil	21.1	40.19	3.11	**77.37**
Liquefied gas	**17.2**	**46.89**	**2.96**	**63.07**
Naphtha	20.0	44.57	3.27	**73.33**
Bitumen	22.0	33.49	2.70	**80.67**
Petroleum coke	27.5	29.31	2.96	**100.83**
Refinery Gas	18.2	48.57	3.24	**66.73**
Other liquid fuel	20.0	33.57	2.46	**73.33**
Solid fuels				
Primary fuels				
Anthracite	26.8	29.31	2.88	**98.27**
Coking Coal	25.8	29.31	2.77	**94.60**
Stone coal	25.8	25.00	2.37	**94.60**
Lignite	26.2	16.75	1.61	**96.07**
Lignite	27.6	10.89	1.10	**101.20**
Secondary fuels				
Coke oven coke	29.5	29.31	3.17	**108.17**
Coke oven gas	13.0	17.91	0.85	**47.67**
Blast furnace gas	66.0	3.60	0.87	**242.00**
Gas works gas	13.0	15.82	0.75	**47.67**
Gaseous fuels			t_{CO2}/1 000 m^3	
Natural gas	15.3	34.00	1.91	**56.10**
Biomass				
Wood and combustible waste	29.9	9.00		
Liquid biofuels	20.0			
Biogas	30.6			

ANNEX 3: PARAMETER LIST PUBLISHED BY THE MINISTRY RESPONSIBLE FOR ENERGY

On its website, the ministry responsible for energy will publish the following information (assumptions), which investors must use when making cost-benefit analyses:

- cost of investment in high-efficiency cogeneration plants the construction of which is analysed in the alternative scenario;
- maintenance costs for high-efficiency cogeneration plants planned in the alternative scenario;
- real financial discount rate;
- real economic discount rate;
- prices per unit of fuel (biomass, fuel oil, coal, etc.) used in the economic analysis, and their projection;
- projection of EU ETS market prices.