D.5.4.1. Summary report on heat sector analysis

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Introduction

The DARLINGe project is based on the collaboration of geological institutes, universities, development agencies, ministries, and district heating market players of six countries: Hungary, Slovenia, Croatia, Serbia, Bosnia and Herzegovina and Romania. The main aim is to promote the sustainable use of the existing but untapped geothermal resources in the district heating sector. The project covers the Central and South-Eastern parts of the Danube Region, encompassing 92 000 km^2 in the southern regions of Transdanubia and the Great Hungarian Plain, South-Eastern Slovenia, Eastern-Croatia, Central and Northern parts of Bosnia and Herzegovina, Serbia and Western Romania. Envisaged results of the project are the increased share of geothermal energy use in the district heating sector, and a heightened energy independence of the Danube Region.

In addition to many "geo-related" activities of the project aimed at assessing the available geothermal potential and the current utilizations, emphasis is also put on matching the resources with the actual heat demand of the region. A detailed analysis of the current heat consumption habits and heat demands makes it possible to quantify where and to which extent geothermal energy could substitute fossil-fuel based heating, and enable tailor made recommendations for the Transnational Danube Region Geothermal Strategy on how geothermal energy can contribute to the current energy mix and make the best possible impacts (e.g. expressed in the decreased amount of CO_2 emission) on the environment.

This report summarizes the results of heat sector and heat market analyses carried out in all 6 partner countries at 3 levels: (1) national overview of energy strategies with a focus on the heating sector and renewables, (2) assessment of the heating sector and main heat consumers and habits at regional level, (3) detailed analysis at local scale (typically at municipality or user levels). These detailed national reports form appendices of the present report. In the summary Chapter 1 we provide the main conclusions of the national reports. In Chapter 2 an insight into the theoretical issues of heat market analysis is offered and the methodology of calculations as well as the main focus of such a research are highlighted.

1. Main conclusions of the national heat market reports

In the target area, six countries (Bosnia and Herzegovina, Croatia, Hungary, Slovenia, Romania, Serbia) are located, all having some similarities in their geographical, geological, economic and social parameters. As far as the population distribution is concerned, the southern part of the Carpathian Basin is sparsely populated compared to the western regions of Europe, and its economy as well as its infrastructure are underdeveloped. The energy demand of the population in this area is mainly covered by the burning of non-renewable energy sources, mostly coal and natural gas. The renewable energy market in this region needs fundamental developments to reach its full potential. Currently, biomass burning, water power plants and solar collectors cover the bulk of renewable energy use, however energy produced with these technologies combined only cover about 10% of the total energy needs. Our study suggests that both the potential and the success of already running direct use applications pinpoint cascaded geothermal energy utilization as the most effective and practical heating solution for the target area.

Geopotential investigations are followed by considerations of the fundamental parameters of the size and the distribution of settlements, as well as the current sources and types of domestic heating. While the majority of the population is urban (69.2%), the number of significant cities is rather small in the DARLINGe project area, e.g. Tuzla in Bosnia and Herzegovina; Banja Luka, Bijeljina, Doboj, Gradiska, Prijedor, Zvornik in the Republic of Srpska; Zagreb and Varasdin in Croatia; Kaposvár, Pécs, Szeged, Békéscsaba, Orosháza, Baja, Hódmezóvásárhely in Hungary; Arad and Timisoara in Romania; Maribor in Slovenia; Novi Sad, Subotica, Beograd, Zrenjanin, Pancevo, Loznica in Serbia.

In our research, we focused on cities with significant housing projects and/or existing district heating networks. In the target region, the major industrial and/or governmental cities usually have sizeable housing projects, accounting for local domestic heat consumer maximums. These are very often supplied by centralized, fossil fuel based district heating services, which may be converted to geothermal based systems in many cases. Our study concludes that it is these cities with district heating networks located on highly potent reservoirs that should be in the forefront of geothermal expansion. Here, geothermal heat can be used conveniently as an alternative, or supplemental heating source to natural gas /coal.

In the Danube Region, there are a number of operating projects which supply geothermal heat for district heating system. The biggest density of these projects operates in the South Plain Region in Hungary most notably around Szeged. These state-of-the-art systems are efficient and contribute to decreasing CO_2 emissions, they are not well publicized however: all in all, the use of geothermal sources in district heating is uncommon in most participant countries, and geothermal energy is mainly utilized in balneology (Banja Luka, Bijeljina, Gyula, Makó, Murska Krapinske Toplice, Sobota, Szeged, Varasdin, etc.) and in agricultural operations only.

Out of the participant countries, Bosnia and Herzegovina has the most complex policy system. The partly independent regions, called Entities are majority owners of electric power utilities, including most mines, hydro power plants and thermal power plants, and they are responsible for geothermal energy exploration and utilization. In Bosnia and Hercegovina 35% of the total energy is consumed in buildings, where two thirds of energy are used for heating and cooling. Out of this amount, housing and tertiary sectors account for over 65%. However, Bosnia and Hercegovina has significant geothermal resources, geothermal gradient over 50^0C/km, and heat flow over 100 mW m^{-2} in Posavina Canton, Tuzla Canton and especially in the Republic of Srpska. As for future geothermal heating infrastructure development in Bosnia and Hercegovina, Republic of Srpska has the best potential, because of the geothermal resources of it, however the energy strategy did not take geothermal energy into consideration in compliance with its availability. Next to the geological properties, the presence of a sizeable heat market in two big cities (Banja Luka and Bijeljina), with a population over 100,000 (including 40,000 flats with district heating) and experience in geothermal energy utilization, especially in balneology, makes Republic of Srpska to be a potential project area.

The DARLINGe investigation in Croatia and Slovenia brought similar results, partly due to the similar population density, the historical background of industrialization, and the geothermal potential (geothermal gradient is 49^0C/km, heat flow is 76 mW/m^2). Next to these parameters Croatia and Slovenia has a very ambitious national renewable energy strategy to be completed by 2020. The relevant Acts promote the wider use of natural energy resources, reducing long-term dependence on imported energy, efficient use of energy and reducing the impact of fossil fuels on the environment, with the goal of job creation and enterprise development in energy and related sectors. In both countries, geothermal energy has started to gain ground, but as of now, geothermal has only 2% share in district heating utilizations. Geothermal energy is mainly used in greenhouses and in spa's. There are three geothermal district heating plants in Slovenia (Lendava, Murska Sobota and Benedikt), while only two towns (Varasdin and Cakovec) has the geothermal based DH infrastructure in Croatia. However geothermal energy used for district heating at four localities in Slovenia amounted to 6.07 GWh/yr in 2015. It stems from this that district heating systems in Slovenia cover 0.3% of their energy needs from geothermal energy. In our study, we suggest that the cities of Lendava and Ljutomer in Pomurje, Podravje, and Brezice in Posavje region in Slovenia and Krapina-Zagorje, Varasdin and Medimurje in Croatia have favourable conditions for significant geothermal developments.

Serbia's rate of non-renewable / renewable energy sources in energy production is similar to that of the other countries in the region. Primary energy production depends on coal and lignite (68.5%), on oil (10%), on gas (4%), on hydro potential (7%) and on biomass (10%) while RES (geothermal, solar, wind and landfill gas) contribute to 1%. In the Yugoslav era, large district heating system developments took place. Nowadays, district heating systems operate in 57 cities in Serbia. Their total nominal installed capacity is 6,652 MW, total length of district heating networks is around 2 100 km and total number of heating substations is around 23,400. Mostly these systems are based on gas (74%). A few systems rely on oil derivatives (14%), coal (11%) and biomass (less than a 1%). Heating and cooling sector in Serbia will need to increase 10.2% of RES until 2020, achieving an increase from 1,059 Ktoe to 1,167 Ktoe. New facilities are planned to be built with additional 149 Ktoe of energy. RES share in building sector by the year 2020 is projected at 35% (residential 27%, public 5%, industrial 3%). Unfortunately the potential of geothermal is gerenarally underestimated as an energy source for public heating, even though in the Northern part of Serbia (Vojvodina region) the heat flow rate is above 100mW/m^2 and the geothermal gradient is over 50^{0}C/km. At the same time, just across the border on the South Great Plain Region of Hungary, dozens of baths and DH systems utilize geothermal energy and provide examples future Serbian projects. District heating system exists in 17 towns in Vojvodina and one in Macva region, pinpointing Northen Serbia as a promising area for geothermal energy based district heating system development with an average producible heat of 1,800 TJ/year.

The Southern parts of Hungary have excellent geothermal features and geothermal district heating developments have started to gain momentum in recent years. Hungary has the greatest experience in geothermal utilization among the participant countries and an abundance of hydrogeological and geothermal data thanks toformer hydrocarbon exploration. In addition, 15% of Hungarian homes, an overwhelming part of which (650,000 homes) were built with industrial technology, are connected to the district heating systems. Apart from communal consumption, about 12% and 25% of the total volume of district heat are consumed by public and industrial consumers respectively. There are 2 operating geothermal DH systems and 7 new are planned for the next 3-5 years in Szeged alone, plus there are 7 other large cities with operating DH systems in this region. All in all the South Great Plane and Vojvodina have the most significant geothermal resources in the DARLINGe area and they boost some of the largest cities too, which highlight them for future geothermal district heating developments and make them excellent lighthouse projects, that can show the way to the other participant countries.

In Romania the energy sector is represented mainly by hydrocarbons (crude oil, natural gas), coal, nuclear energy and renewable energy. The renewable energy sources in Romania have a big potential, but their use is limited by technology, economic efficiency and restrictions imposed by the environment. Researching the heat market and geothermal potential of the

DARLINGe areas of Romania we conclude that these territories have a small disadvantage against the others discussed. Even though the geothermal potential is significant and the overall population is high, the population density is very low in the Timis, Bihor and Arad regions. Other than two major cities (Arad and Timisoara), small towns and villages dot the area with an average of population of 12,000 and the largest city in Western Romania, Oradea, capital of Bihor with a population of 170,000 is not in the DARLINGe area. The thermal sector in Romania is rather neglected due to insufficient financial resources for operation and maintenance, rehabilitation and modernization. Furthermore the geological formations in the DARLINGe area contain aquifers with varying potential and thermal properties, although the heat flux value is cca. 85 mW/m^2 and the average annual energy potential is $7x10^6$ GJ, which is higher than in other areas of Romania. All in all the DARLINGe area in Romania may prove to be a very prosperous region, due to the favourable geological potential and district heating capacity.

As a result of our investigation and the heat market analysis of the Danube Region we conclude that are several areas with high potential for the cascaded use of geothermal energy. There are sub-regions in all of the participant countries of DARLINGe project where significant geothermal potential coincides with high population density and operating district heating systems, or where best practice projects are easily accessible. These locations listed in the country reports represent the targets of our initiative, while the heat market methodology developed and offered provides the tools for individual assessment of these sites.

2. Technical aspects of heat market analysis

The analysis of the consumer group related to the project (called "heat market" in project terms) consist of several factors, such as:

- assessment and analysis of the heat consumption parameters
- possible equipment, devices and technologies of a thermal project in relation to the consumer networks,
- heat market features in relation to settlement structures

Examples for the assessment of consumption parameters were given in several local-level case studies in the national reports (e.g. Szeged geothermal district heating). The national reports also highlighted the importance of the settlement structures when planning geothermal district heating: e.g. areas characterized by scattered small villages are unfavourable compered to large cities with housing estates and urban agglomerations.

Therefore in the following we focus on the overview of the technological elements and equipments of a thermal project, as decisive parameters of heat markets.

To do that it is important to know the way of utilisation of thermal water for heating, which can happen by two different ways:

- Direct thermal water utilization, where the extracted fluid is used in the heat exchangers of the consumers,
- Indirect thermal water utilization, where the primary "heat recovery" and reinjection happens at the site of extraction, at a pressure above bubble point, insulated from air; the heat content reaches the consumers through a closed secondary heating circuit.

2.1. Technological overview of a thermal project in relation to heat-market assessment aspects, the elements of the surface technology

The technological elements (surface technologies) for the supply of the thermal energy from the extracted thermal medium to the consumers are listed below.

1. Equipment of the production water base
    - Production well head, with water production technology
    - Water treatment technologies of the extracted medium (degassers, equipment of chemical treatments)
    - Equipment for thermal water storage and forwarding
    - Equipment for heavy-current power supply of the production water base
    - Weak-current control system of the production water base
    - Security equipment of the production water base
    - Access structures of the production water base
2. Means of transporting the thermal water
    - Insulated pipeline network
    - Uninsulated reinjection pipeline network
3. Equipment for energy utilization and extraction
    - Units of the power station
    - Heat exchangers
    - Thermal centre aids and fittings
    - Consumer measuring systems
    - Thermal centre control systems
    - Means of "intervention" of the secondary system
    - Equipment for filling the thermal baths
    - Equipment for heat utilization with heat pumps
4. Equipment of the reinjection well
    - Well head for reinjection
    - Means of storage for reinjection
    - Reinjecting pump system
    - Overground filter system
    - Equipment for heavy-current power supply for reinjection
    - Weak-current control system for reinjection
    - Security equipment of the reinjection station
    - Access structures of the reinjection station

The majority of the listed equipment and apparatus are placed underground (e.g. pipelines) or far over the ground (e.g. satellite data transmission), but in the present evaluation they are discussed as surface equipment.

The following chapters – extracted from the list above - describe the technologies directly related to the supply of the heat market, and the main aspects of their design and operation.

Equipment for thermal water storage and forwarding

The size of the *tank* to be installed should be as large as possible – depending on the available space – since the ordered control will be "smoother" for the operation of the submersible pump with frequency changer. The results are the protection of the water-bearing reservoirs of the wells and of the stability of porous rocks, and the avoidance of dynamic forces generated by the direct starts. The tank must be thermally insulated, since every little bit of heat is necessary. During the creation of tank's discharge stud, attention must be paid to the installation level of the forwarding pump's suction port. In order to avoid idle operation, the possibility of free flowing must be ensured.

The dimensions and selection of the *forwarding pump system* (Figure 1) to be installed is influenced by the water quantity to be transported, the pressure drop of the pipeline system, the planned system control and the size of the installation location. In case of certain very deep thermal projects, "man-size" pump dimensions must be taken into account. It can be standing or lying. The former has smaller space and electricity demands, the latter is less sensitive to the gas content. During the design phase, consider the correct ventilation requirements of the electric motors, and the placement of the big motor protection and electric control cabinet.

Figure 1: Installed group of booster pumps

The control of the pumps supplies the mass flow changing according to the demands through the pipeline to the consumers. For a continuous service, a "warm" reserve and the possibility of maintenance and eventual replacement must be ensured.

Means of transporting the thermal water

The title would be more accurate, if it mentioned the transportation of thermal energy, since during the indirect utilization of thermal water as described in the previous chapters, the heat-transferring “auxiliary” heating medium is moved between the thermal base and the consumers.

Whether it is thermal water, or a medium transferring thermal heat, the means of transportation is basically the same: a network of pipelines (Figure 2).

We must add that there are baths, wellness hotels and hospitals, where the thermal medicinal water is delivered in “mobile” tanks from the distant thermal well. The following chapter presents in detail the different pipelines.

A) Insulated pipeline network

Many aspects must be considered when designing, selecting and defining the type and variety of the pipeline. Aspects to take into account: temperature, hydrochemical features and aggressivity of the extractable thermal water, way of installing the pipeline, availability of public utilities on the territories touched by the pipeline, quantity of transported medium, geodesic and technological pressure conditions, “heat market” features and the related heat supply technology (single- or double-line system), accessibility of consumer thermal centres, adjustability aspects of the system, climatic conditions (frost actions), built environment etc.

The pipes transporting the “warm” medium for utilization and further utilization have insulating material and protecting cover. These are called *insulated* pipelines.

Figure 2: Pipeline with uninsulated plastic and insulated steel utility pipe

B) Uninsulated pipeline network

Uninsulated pipelines are usually used for the transportation of completely or partially cooled thermal waters or heat-transferring media. Practically, these are identical with the uninsulated utility pipes of the insulated pipelines.

Regarding their function, we can call them: supply pipes (medium with its heat partially used, can function as a primary medium in systems with low temperature difference), return pipes (for the collection of cooled media) or reinjection pipes (for the transportation of thermal water that is not used and will be reinjected). Uninsulated pipes without extra insulation (with a good coefficient of permeability) are used as supply and discharge pipes for thermal and medicinal pools. They can be installed over or under the ground. They can be made of steel, but currently, the most commonly used pipes are made of different plastics. The latter is easier to mount and its material is resistant to different chemical and wetting effects. When placed under the ground and protected from mechanical damages, it can have an "eternal" lifetime. In case steel is used, the pipeline must be protected against corrosion.

Pipeline location and material

After considering the above-mentioned aspects, the pipeline can be constructed on a surface support structure with dilatation sliders, or under the ground, by securing the dilatation by fixed points and dilatation pillows.

Under the ground, the pipeline network can be placed into a pre-fabricated reinforced concrete channel (this can be constructed on a territory free of public utilities; it is more expensive, but it is easier to maintain and to replace the pipeline), or directly into the ground under the frost-line, into a properly created trench surrounded by a bed of sand to prevent mechanical damages due to earth movement.

Today's modern insulated pipeline is placed under the ground and – depending on the quality and temperature of the transported medium – can be made of steel, or of plastic (PE, KPE, glass-fibre etc.) utility pipes with a polyurethane (or other) thermal insulation and a solid polyethylene protective cover. The protective cover protects the insulation material and the steel pipe from the groundwater. Since sunlight is basically the only "enemy" of plastic, causing its aging, the plastic cover placed under the ground – according to the specifications – and protected from mechanical damages can have an "eternal" lifetime.

The pros and cons regarding the variety of pipes: Plastic is easier, it is easier to mount, has a lower frictional resistance (requires less pump work) and it can "receive" the heat movement without a fixed point. Steel pipelines can guarantee a higher working pressure.

Equipment for the utilization of thermal energy

The previous chapters presented the equipment used for forwarding the thermal energy (geothermal heat) from the place of extraction to the consumer location. This chapter describes the equipment, devices and main technologies used for the reception, transformation and actual utilization of the thermal heat. Geothermal industry, similarly to other renewable sectors, is witnessing remarkable progress these days. Accordingly, we cannot provide a complete overview, but we will present the most important technical and technological features of this field, focussing mainly on the possibilities and features of the region.

According to its appearance and extractability, thermal energy can be used in different ways. In very high-temperature ranges, it can be used directly or indirectly for mechanical purposes. In different locations of the world, explorations with temperatures of several hundred ˚C and pressures of several hundred bar are directly powering steam turbines for power generation, and by lower temperature ranges (120-160 ˚C) and by using auxiliary media evaporating at low temperatures, so-called binary power generators (indirect technology).

However, both on a worldwide and regional scale, the most profitable and increasingly competitive way to use geothermal energy (< 120 ˚C) is for heat supply for heating purposes. This also appears in the secondary energy utilization of geothermal power production technologies, since the technological heat quantities released by steam turbines and power generators (either from the cooling of turbines, or from the remaining heat content of the thermal media) can be used in large-volume heating or, in the summer, cooling (absorption technology) systems (municipal district heating supply, horticultural technologies, baths etc.).

1) Heat exchangers

In the classic sense, heat exchangers are devices connecting two heating circuits with the purpose to transfer the heat content of the circuit with the higher temperature (primary) to the heating circuit with the lower temperature (secondary). Accordingly, the heat exchanger is the most important and essential element of geothermal heat utilization, with the task to transfer the thermal heat to the consumer.

It is installed in the consumer's thermal centre (boiler room), its primary side is connected to the thermal pipeline arriving to the consumer, its secondary side to the returning pipe section of the consumer's internal secondary heating circuit.

Another high-capacity heat exchanger is installed in the previously described indirect thermal heat supply system (or in the secondary heat utilization of geothermal power stations), in the thermal production base (at the thermal well), since this is the place where the heat content of the thermal medium (high-temperature circuit) is transferred to the auxiliary medium (low-temperature circuit.

Based on their type and their heat transfer, there are different varieties of heat exchangers.

- Tubular (the heating medium in the closed tank absorbs the heat from the surface of straight tubes)
- Spiral (the heating medium in the closed tank absorbs the heat from the surface of the densely coiled tube)

- Plate (the transfer of the heat happens between the many thin plates employing more counter current flow) (Figure 3);
- Air-heaters, unit heaters (heat exchangers of air-handling units of halls, bath spaces, the air is supplied into the heated space through a warm-water coil).

The operating principle of these heat exchangers is similar, the difference lies in their efficiency and their size, in favour of the plate heat exchangers.

Considering the fact that the geothermal heat supply project – except for the bilateral or multilateral thermal supply – "will keep" the original boiler heating technology in order to safely maintain a continuous heating service, the thermal heat exchangers will provide pre-heating for the returning heating medium of the secondary heating circuit.

Figure 3: Modern thermal plate heat exchanger

It guarantees the necessary heat quantity for heating for most of the winter (with consumers – depending on their conditions – even by 100%), but additional heating with the original boilers can be possible during the peak periods.

2) Thermal centre aids and fittings

Non-professional project owners and investors usually misunderstand a thermal centre for the existence of a heat exchanger. Therefore, it is necessary to present the auxiliary devices of a heat exchanger station, the thermal centre aids and fittings since their historical cost exceeds by far the price of heat exchangers.

The used HVAC devices and fittings are as follows:

- Connecting pipelines, pipe fittings (bends, elbows etc.)
- Filters
- Check valves
- Mechanical shut-off fittings, taps
- Mechanical and/or electric motorised valves, control fittings, taps, butterfly valves
- Circulating auxiliary pumps
- Manual and remote temperature and pressure measuring instruments
- Flanges, reducers, sealing and other materials
- Isolating and their protective materials
- Etc.

Tens of these devices can be used in a complicated thermal centre. Their purpose can be mainly figured from their names, they are basically used for the adjustment of the way, direction and volume of the primary and secondary heating media and for the protection of the heat exchanger and other installed equipment by minimizing the heat loss.

Only the mechanical ones can function independently, the electronic ones ensuring the automatic operation require auxiliary energy and a control sign.

3) Consumer measuring systems

For the heat market operators of thermal wells and thermal systems and thermal water and energy utilization, the most important measurement and accounting parameter is the quantity of the extracted and used thermal water and thermal energy. Different meters and measuring methods are available for the measurement of this, depending on the size of our wallet.

Quantities to be measured:

- Water quantity extracted from the thermal well (m^3),
- Water quantity used for bathing purposes (m^3),
- Quantity of the reinjected water (m^3),
- In case of indirect heat supply, the quantity of thermal heat transferred to the pipeline (GJ),
- As a consumer, the flow rate of the thermal water (m^3),
- As a consumer, the quantity of used heat (GJ).

In previously constructed systems, we can still find different traditional mechanical measuring devices. However, today’s existing and currently built systems usually use remote traditional or induction measuring devices. The advantage of the latter is their accuracy, they do not contain rotating parts, so they have a longer lifetime and can be used in more "sensitive" areas. Their price however, is much higher than that of the traditional ones. The listed quantitative measurements are the basis for accounting towards environmental authorities and fee-collecting institutions, they can provide important information for the maintenance of wells and technical equipment, and they are the basis for the accounting of the thermal water and energy supply.

Furthermore, there are other quantities to be measured during a thermal project, such as the measurement of eventually added chemicals for water treatment, the measurement of electricity used for water movement (at the thermal base and in the consumer thermal centres), and the measurement of auxiliary energy used for the operation of control systems etc.

4) Thermal centre control systems

When every thermal and hydraulic engineering device and equipment is in its place in a consumer thermal centre, the control system for their operation can be installed according to the control system's execution design.

The motorised adjusting valves and control taps are controlled by a custom-written software for an optimum functioning depending on the weather conditions. The control PLC units collect the signs of the remote meters installed in the thermal centre (internal and external temperature, temperatures of the primary and secondary heating medium, pressure values, positions of motorised valves etc.) and send the control signals to the motorised valves and taps in a harmonized fashion and according to the actual weather conditions.

Without the proper functioning of these systems, there is no automatic mode and a weather-dependent cost-effective energy management.

5) Equipment for filling the bath's (medicinal) pools

We cannot end the introduction of energy utilization and extraction devices with the previous chapter, since several thermal projects include (just like the "cascade" system detailed in the previous chapter) municipal public or private thermal baths or spas that can be connected to the end of the thermal circle.

In baths, where the extractable thermal medium is suitable and approved for balneological purposes, we can calculate with dual utilization: the residual heat content of the thermal medium arriving to the bath can be included in the heat supply of the bath's public (heating of the dressing room) and technological (production of domestic hot water, for holding the water temperature of swimming and experience pools) heat supply, and then for the partial or complete supply of the bath's (medicinal) pools.

The equipment for heating is identical to those presented in the previous chapters. The following list contains the equipment and devices necessary for filling the pools:

- Buffer tank – reception of the thermal water and ensuring the varying filling water quantities, and the maximum filling-discharge demand; its size depends on the size of pools to be filled; it can be installed on the ground surface or can be sunk, and made of thermal insulated steel or reinforced concrete;
- Overflow pumps – refilling the pool's overflow;
- Filling pumps – ensuring the daily water replacement;
- Filters, shut-off fittings, meters;

- Control system – automation of filling and discharge activities.

When installing the pumps, make sure that the medium can flow in properly to the units.

6) Equipment for heat utilization with heat pumps

Ideally, at the end of the thermal circuit, the fluid cooled down during multiple utilization – due to its very low temperature (<27˚C) – cannot satisfy by itself the available low-temperature (e.g. 50/30 ˚C) heat market.

In this case, the completion of the system with heat pump technology can be of great assistance.

For this technology, the following devices and facilities must be installed:

- Buffer tank – collection of thermal media with varying flow rate, ensuring the stationary primary water supply of the heat pump; it can be installed on the ground surface or can be sunk, and made of thermal insulated steel or reinforced concrete
- Forwarding pumps – forwarding the thermal medium into the recipient through the heat exchanger on the heat pump's primary side;
- Heat pump – based on its operating principle (together with auxiliary medium with low boiling point, and modification of the compressed physical state), it can transfer the heat content of a low-enthalpy medium at a higher temperature (see inverted cooler); it is used to transfer the remaining heat content of the cooled thermal medium from the primary side to the secondary side at a temperature of approx. 50 ˚C, connected to the returning heating circuit of the low-temperature heat consumer;
- Filters, shut-off and control fittings, motorised valves, pipe fittings, metres etc.;
- Power supply – guaranteeing the auxiliary energy for the heat pump's compressor
- Control system – automatic functioning of heating with a heat pump.

With this system, the heat content of thermal water can be utilized to a temperature of 0 ˚C. This technology can be especially valuable for the heat recovery of discharged waters from thermal or medicinal pools. Naturally, this technology cannot be used, if the expected heat market is not available.

2.2. The assessment of heat market features

The definition of dimensional parameters of a given heat exchanger – thus the capacity of a thermal project – must be preceded by an accurate and professional assessment of the operators of the respective heat market. *This defines the optimal utilization of a thermal well's (or of a geothermal power station's free) thermal capacity, the saving of water production, the project's viability and competitiveness.*

From a geological point of view, excellent features are worthless without the overground usability of the geothermal heat. This is especially true for locations with enthalpy values, where the resources are sufficient for heat supply "only" (> 100 ^{o}C), meaning that the there is no available heat market or heat consumer at a "reachable" distance from the site of extraction. The "reachable distance" is also defined by the sustainable viability (5-10 km, based on experience).

Therefore, the elaboration of the project concept cannot be complete without the heat market's analysis, in parallel to the geological analyses. In practice, this means the analysis of the heating structure of the potential settlement, including the mapping of large independent and smaller concentrated heat consumers, the existing boiler room and heating systems, the accurate understanding and analysis of the applied heating technologies and habits, modernization possibilities and urban development concepts, and the analysis and evaluation of the adaptability to the thermal features.

As a result of this work, we can draw up a "*temperature variation chart*", which takes into account the heating days and the related external temperatures. It also highlights the expected thermal energy utilization of the heat consumers that can be connected to the planned thermal system in an economical and efficient way, the necessity of the remaining additional heating, the quantity of thermal water and thermal energy used in the heating season, and the volume of the replaced combustibles.

The temperature variation table will be the main direction for the design of the thermal project's overground well engineering (obviously, beside the physical and chemical parameters of the extracted medium) and for the construction designing of consumer thermal centres.

2.3. Means of "intervention" of the secondary system

The reason for this is that the project is rarely coupled with a heat market condition, where the heat content of the extracted thermal medium (e.g. 40-50°C delta T) is utilized in one phase (at one consumer).

Accordingly, it can be necessary to transform consumer (secondary-side) systems, to modify operation technologies within the project that can guarantee the "creation" of the cascade system, thus the secondary, tertiary heat utilization of the thermal medium in heating systems transformed into systems with low temperature differences.

Based on the project's economic capacity, there are several ways to achieve this:

- The modification of heating mass flows by replacing pumps and fittings,
- Preferring low-temperature surface heating with reconnections, creation of new manifold
- Resizing and replacement of heat exchangers
- Resizing and transformation of the system
- Modernization and transformation of the secondary heating control
- Relocation of the DHW supply to a different circuit,
- Etc.

Every intervention should be planned and implemented accurately by taking into account the whole project, "so that the meat will not cost more, than the soup".

3. Methodological proposal for the heat market assessment

The following chapter describes the methodological phases of the assessment of a heat market related to a thermal project. Naturally, aspects generated by unique conditions and special circumstances can complete its template-like utilization.

1) *Project location*

The project location can be defined based on geological and hydrogeological analyses and modelling. The territory, where the project's consumer group can be defined, is determined based on positive analysis results. This can be an existing heat market (settlement, running horticultural nursery, other industrial facility, thermal bath etc.) or a potential concept or development plan.

2) *Project features*

With knowledge of the extractable thermal medium's flow rate, discharge temperature, (or in case of power generation, the parameters and features of the secondary media used for heat utilization), we can outline the project's heat capacity (kW), and its usable technological temperature difference (in deltaT ˚C). An important issue is the disposal method of the utilized thermal fluid ("freed" from its heat content) according to the relevant water rights authorisation. This can influence the exploration of a potential tertiary heat market for heat utilization.

3) *On-site visit*

The on-site visit of the project location includes the interior/exterior visual inspection of the existing buildings and facilities providing and/or utilizing the heating service. This task can be facilitated by an overview of the territory's map (municipal, administrative maps, maps of the land registry office), the preliminary drawing of properties according to the planned thermal well locations and pipeline routes, the preliminary optimization of possibilities, and the measurement of expected distances. The inspection of consumer boiler rooms and thermal centres, and the mapping of neighbouring public and private properties are essential tasks as well. The former enables the definition of the possible installation of devices described in previous chapters (pumps, heat exchangers, control and measurement units etc.), of the technological and technical adaptability of the consumer system to the project (variation of the temperature differences), and we can outline the necessity of intervention or modification of the secondary side. The objective of the latter is the definition of the delivery of thermal energy (heating medium) to the consumer thermal centre through the pipeline.

Other important issues include the structural and thermotechnical visual inspection of the buildings, the discovery of possible heat losses, and the identification of actual operational parameters of the system by involving the operating personnel. This is the foundation of the long-term predictability, development and sustainable viability analysis of the distributable thermal energy.

The on-site visit is followed by the actual and detailed assessment work, when we consider the potential consumers. It is important to consider the leading aspect of energy density: larger buildings or a concentrated consumer network supplied by on thermal centre enjoy advantage from the aspect of viability (e.g. the construction costs of pipelines for one independent residential area of private houses is coupled with a significantly longer return compared to a district-heated area, or metering points must be created for every single consumer in the area of private houses compared to one meter of a concentrated consumer). We would like to demonstrate that the assessment works following the on-site visit include the project's viability analysis as well!

4) *Compilation and request of data and information*

Following the on-site visit and the related assessment, we can compile the information necessary for further analysis activities. The following data and information have to be collected from owners and operators about the potential heat consumers involved in the project:

- Type of the building, its long-term future development, development concept
- Building's energy certificate (if available)
- Main parameters of the buildings' heat supply system (boilers, circulating pumps, heat exchangers, type, number, capacity and operating hours of DHW systems etc.)
- Main parameters of the district heating system (if available) (type, number, capacity, operating hours of boilers, auxiliary equipment and fittings, system description, heating schedule of heating circuits, introduction of the DHW system, number and thermotechnical condition of supplied flats etc.)
- Engineering D plan of buildings and of the district heating system - minimum the engineering wiring diagrams (if available)
- The building's and district heating system's energy consumption data from the past three years (electricity and heating) in quantity and value
- The annual maintenance costs for the gas unit of the building or the district heating system
- The last electricity and gas invoices, and the copies of the relevant service provider contracts
- The settlement's long-term development concept
- The settlement's energy concept

5) Conducting analyses

The visits and data compilation is followed by analytical activities. These include the comparison of the changes of theoretical and actual parameters, the definition of possible alternatives, the drawing of conclusions regarding the project plan, and the elaboration of technical-economic proposals. The detailed analytical criteria – in order of the data requirement of point 4 – are presented below.

- The building's nature of use and its future evolution defines the current and expected consumer demands, temperature demands and the DHW production requirements;
- The energy certificate provides information on the building's thermotechnical status, the loss-minimizing tasks necessary (or unnecessary) in the future, the related modification of the consumer's heat consumption, and the quantity of distributable thermal energy;

- The parameters of the thermal centre equipment define and support the discovery of the changes, modifications and saving possibilities of the eventual secondary side, and the introduction of conditions before and after the development (specified requirement in the tender documentation of supported projects);
- The changes of consumer habits in district heating, the emergence of economic aspects, and the possibilities of subsequent thermal insulation of building renovation programmes make the capacities of originally installed boilers unnecessary; this is coupled with the involvement of local energy sources into the primary energy supply, while we must pay attention to the keeping of reserve and peak-time energy sources; two unique heat supply technologies are installed in the most efficient way possible;

  The existing operating parameters of the district heating system facilitate the performance of these tasks and the design of the combined technology;
- The existing engineering plan documents of the building and district heating system facilitate the work of development planners; the engineering wiring diagram completed with a designer specification provides a clear picture about the technical parameters of the built technology, which compared with the actual data provided by the operating personnel, enables the establishment of an optimal technical development concept for the building or the system;

  In case these are missing, detailed and labour-intensive on-site surveys will be necessary;
- The energy consumption data of more years even the hectic nature of the different heating periods, it provides a real picture on the average heat quantity requirements of the respective consumer; the consumption data are essential for the project’s economic calculations as well, together with the service fees, these are the basis for the development’s return indicators;
- When using renewable energy sources, it is necessary to take care of the maintenance of energy reserves, which can be solved by keeping the previous heat supply technology partially or completely;

  The change (or persistence) of previous maintenance costs must be adjusted to this, which also includes the costs of maintenance;
- The public utility contracts and the last invoices support the saving of expected development costs and create the competitive unit prices of local energy sources, the project’s return calculations, and the definition of its efficiency;
- The owners’ objectives defined in the development concept of the settlement or the district heating supply must be observed for the design of the planned project: potential future consumers can emerge (e.g. bath development, horticultural developments, construction or closing of a new institution, realization of building renovation programmes etc.), that can significantly modify the long-term efficiency and competitiveness of the project concept;
- The knowledge of the energy concept helps the thermal project designers in shaping the owners' opinions, and in the long-term creation of the settlement’s or building's energy structure.

6) *Summary of the heat market features*

By possessing the information, data and documents outlined above, we summarize the heat market possibilities of the geothermal energy utilization project, and the preliminary concept of recommendable heat-supply technologies and intervention necessities.

7) *Investors' consultation*

The composed summary document and the elaborated heat market concept will be presented to the owners, operators, investors and other decision-making forums in detail in a personal consultation. This provides the opportunity for answering the eventual questions and observations, and to discuss the investors' expectations and modification requests.

8) *Elaboration of a final heat market concept*

The finalization of the concept by completing and modifying it with the conclusions of the preliminary concept's presentation.

Finally, it is a part of the task to insert the final documentation into the relevant chapters of the complex plan of the geothermal heat supply project.

9) The role of a professional background

In the case of every heat supply project concept, the assessment of the heat market background, its technological adaptation and the planning of interventions of the secondary side require a building services production engineering and engineering qualification, and a skilled professional background in energy engineering.

The adaptation of developments to heavy- and weak-current controls is an integral part of the construction of heat market systems, which usually requires a professional background in electrical engineering and IT.

The analysis and presentation of the economic impacts of the heat market concept on the complex project require skills in finance, economy and energy management.

The monitoring, analysis and presentation of emission changes of the heat market concept require the involvement of skilled professionals in environmental engineering and energy engineering.

D.5.4.1. Summary report on heat sector analysis

Annex 1. Hungary national report

November 2017

D.5.4.1. Summary report on heat sector analysis

Annex 1. Hungary national report

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Introduction

The development of the geothermal sector for direct use purposes in the project area requires not only the profound geological knowledge of the most prosperous areas (potential reservoirs), but also the information on regions with existing heat demands, overview of the existing heat consumption habits as well as overlook of the countries' energy policies with special attention to renewables and geothermal energy. This will make possible to quantify where and to which extent geothermal energy could substitute fossil fuel based heating, so as to make recommendations for the Transnational Danube Region Geothermal Strategy on how geothermal energy could contribute to the current energy mix and make the best possible impacts (e.g. expressed in the decreased amount of CO2 emission) on the environment.
After thorough discussion of the methodology to be used for the heat sector analysis as well as overview on data and expertise available in the partner countries, the consortium decided to apply a 3-level approach: at (1) national, (2) regional and (3) local level.

Accordingly the present study offers insight into heat sector analysis of Hungary:

1. On a country level we offer an overview of Hungarian energy strategies, planning documents and executive programmes providing a context for regional and municipal level analyses.
2. The heat sector analysis on a regional level discusses the South-Great Plain and South-Transdanubia regions, which are of profound interest of the DARLINGe project, as they are target regions with excellent geothermal features and a number of potential pilot sites. Learning about the energy portfolio, the energy strategies and the recent and planned geothermal projects in these regions offers valuable lessons for stakeholders, especially potential investors and operators.
3. The next level goes a step further and presents a real-world example of a municipal level heat market analysis. This feasibility study level assessment of a district heating circuit in the city of Szeged, Hungary provides valuable information to the implementation of an actual geothermal project.

1. Energy strategy of Hungary – national overview

1.1. Energy supply and consumption

Energy supply in Hungary has remained almost flat over the last two decades, but domestic energy production has rapidly decreased. In 1990, Hungary produced 15 Mt oil equivalent (Mtoe) of primary energy (53% of its total primary energy supply - TPES), while in 2010 the national production had fallen to 11 Mtoe (around 43% of TPES being 25.4 Mtoe). Since 1986, natural gas is the largest primary energy source in Hungary, in 2011 it accounted for 37% of TPES. Oil as the second-largest energy source had a 25% share in the TPES. In contrast, coal use has declined by half from 1992 (11% of TPES). This share has remained fairly constant over the past two decades. Nuclear energy is by far the most important form of electricity generation (16% of TPES and 42% of total electricity generation) exclusively devoted to domestic consumption. The share of renewable energy sources more than doubled from 3.4% in 2000 to 7.9% of TPES in 2010. Biomass is the main renewable energy source, representing 1.8 Mtoe (7.2% of TPES) in 2010 (NES 2011, IEA 2011).

In the 25 years since the fall of Communism, the Hungarian economy has undergone a fundamental structural change, resulting in a rapid decline of energy-intensive industries and resulting the drop of energy utilisation to the level of the 1970's. As the service sector has gained importance and the GDP continued to increase, primary energy use decreased by 17 % between 1990 and 1992, which was followed by an average annual growth of 0.5 % from 1992 to 2007. In 2009, primary energy use declined by 7.6 % from the previous year's level as a result of the economic crisis, resulting total final energy consumption (TFC) of 17.8 Mtoe (NES 2011, IEA 2011). In 2014 the total use of primary energy was 962,5 PJ, 12% lower than predicted in the National Energy Strategy.

During the two decades before the crisis, gross electricity consumption increased by 21 %, which was followed by a decline of approximately 6 % in 2008-2009 compared to previous years. However, consumption increased again in 2010, by 2-3 % (NES 2011, IEA 2011).

In 2009, the residential sector was the largest energy consumer, accounting for 31% of TFC. Transport accounted for a quarter of TFC. Final use of energy for heating and cooling purposes represents almost 50% of all primary energy (NES 2011, IEA 2011). Annual gas consumption of Hungary was 9.2 billion m^3-t in 2013. A major part of this was the residential sector, while electricity production demanded 3 billion m^3 gas.

In Hungary, primary energy intensity, i.e. the primary energy demand of the total domestic output (the nominal GDP) was approximately 2.4 times the average of the European Union in 2007. Converting it to purchasing power parity, however, the ratio is only 1.22. Electricity intensity, again converted to purchasing power parity, is even lower in Hungary (97%) than the EU average. This means that Hungary is simultaneously characterised by very low specific (per capita) energy consumption and relatively high energy intensity.

According to the forecast of the Eurostat, the population of Hungary will decrease by 4 % by 2030, to approximately 9.5 million. Considering that household energy consumption accounts for a significant part of gross final energy consumption, therefore the population decline could even involve the decrease of the energy demand. However the consumption habits of substantial groups of the Hungarian society are below the western standards, therefore their desired catching-up will result in turn the growth of energy consumption. The changing consumption patterns (including the increasing number of electric appliances and air-conditioning) and the increasing level of urbanisation will cause a growth in energy demand, especially manifested in electricity consumption.

Hungary's primary energy consumption between 2010 and 2014 is shown in Table 1.

Energy source	Consumption (PJ) 2010	Share in percentage	Consumption (PJ) 2014	Share in percentage
Natural gas	424.7	40.11	380.6	39.54
Crude oil	399.7	37.75	397.6	41.31
Atomic energy	172.4	16.28	170.7	17.73
Coal	125.8	11.88	117.5	12.21
Biomass	77.7	7.34	82.4	8.56
Geothermal	7.6	0.72	9.5	0.99
Wind energy	1.9	0.18	2.4	0.25
Water	0.7	0.06	1.1	0.11
Other	4.4	0.41	5.0	0.52
Export	-156.1		-204.3	
Domestic utilization	**1058.8**		**962.5**	

Table 1: Hungary's primary energy utilization between 2010 and 2014 (KSH, 2014) (Geothermal assessment of Hungary, 2016)

The fact that Hungarian energy policy is not on a path of inertia yet is due mainly to the still significant hydrocarbon, coal and lignite reserves, the Paks Nuclear Power Plant, the significant renewable energy potential and the outstanding commercial and strategic natural gas storage capacities. In addition to the current capacity of 5.8 billion m^3, there is a potential for the storage of 10 to 12 billion m^3 in certain types of geologic formations. The currently operating storage capacities exceed the average domestic winter demand, opening up a potential for offering such capacities for sale within the region for commercial or strategic purposes.

1.2. Primary energy sources

1.2.1. Fossil resources

The share of fossil fuels in the use of primary energy sources was 80 % in 1990 (958 PJ), as opposed to 75 % in 2009 (789 PJ).

In their natural condition, the country's mineral raw materials are in public ownership. These assets, registered by the Mining and Geological Survey of Hungary (MBFSZ) (before 2017 called Hungraian Office for Mining and Geology – MBFH) constitute part of the country's natural resources and national wealth (Table 2). As an implementation of the National Energy Strategy, a so called "Mineral Resource Assessment and Utilization Action Plan" (ÁCST) was performed by the Geological and Geophysical Institute of Hungary (MFGI) in cooperation with MBFH in 2012, where the geo-energy resources were re-assessed.

	„In situ" resource	Recoverable resource	Prospective resource	Exploited resource	Economically recoverable resource
	[Million t / billion m³]	[Million t / billion m³]	[Million t / billion m³]	[Million t / billion m³]	[Million t / billion m³]
Coal	10574 (Mt)	8506 (Mt)	2530 (Mt)	~1500 (Mt)	6469 (Mt)
Conventional hydrocarbon (oil)	217,7 (Mt)	22,1 (Mt)	641 Mt oil equivalent	99,3 (Mt)	22,1 (Mt)
Conventional hydrocarbon (gas)	181,3 (billion m³)	73 (billion m³)		232,2 (billion m³)	73,0 (billion m³)
Unconventional oil	419 (Mt)	45,6 (Mt)	no data	0,00009 (Mt)	no data
Unconventional gas	3813,6 (billion m³)	1530,8 (billion m³)	500 (billion m³)	0,025 (billion m³)	no data
Deep geothermal	375 000 EJ (total heat in place 0-10 km))	not applicable	105 500 EJ (0-5000 m)	13,5 PJ/y / 500 MW with thermal water abstraction	60 PJ/y / 2000 MW from porous reservoirs + 130 PJ/y / 4127 MW from fractured basement reservoirs
Uranium	31 444 t	17 946 t	3904 t	20 672 t	15768 t
CCS capacity	200 Mt(HC) + 1556 Mt (saline aquifer) (within 50 ys)	not applicable	not applicable	not applicable	108,2(HC) + ?(saline aquifer) (within 10-25 ys)

Table 2: Hungary's geo-energy resources (MBFH 2014)

During the 19th and 20th century, *coal* mining was of decisive importance in the Hungarian energy supply up to the 1960's. Due to the vision of cheap and "infinite" hydrocarbon supply in the 1970-80's, the coal extraction has been decreasing, the former 30 million t/year annual production dropped to 22-25 million t/y, which further diminished to 10 million t/y by 2005. The formerly dominant black coal mining ceased and the last deep brown coal mine was also closed in 2014. Currently only significant lignite mining exists in large surface pits. Nevertheless the significant coal and lignite assets (Table 2) are important strategic reserves. According to recent estimates current production of 9.43 Mt (2014) could be increased up to 14.5 Mt with the expansion of current lignite mining and the re-start of brown- and black coal mining. This could result in a two-fold increase of the primer energy supply deriving from coal that would account to the production of 47 to 67 PJ energy (assuming 41% of power plant efficiency). This increased amount is equivalent with about 1.2 to 1.8 billion m³ gas import that would significantly decrease the energy dependency of Hungary. Furthermore the substantial coal resources hold important potential for future clean coal technologies.

With the degradation of the Hungarian deep coal mining, the fuel structure shifted toward increasing reliance on natural gas. Due to the insufficient domestic resources, the net import of gas increased at a considerable rate between 1990 and 2005, despite the fact that the level of energy consumption hardly changed during the period, and the share of import has remained overwhelming since then. The remaining recoverable resources for *hydrocarbons* are only 22 Mt of oil and 73 billion m³ of gas (Table 2). The accumulated domestic oil production has been as much as 99 Mt, and 232 billion m³ for gas, resulting that 80% of the known recoverable oil resources and 75% of gas resources have been already used up respectively. The domestic annual oil production (1.6 Mt) covers only 10% of the total demand, while the gas production

(2.1 billion m^3/y) only 20 % of the demand. The prospective hydrocarbon resources are 641 Mtoe, the major part of which is gas. Within the next 30 years about 30-50 Mt is expected to be recoverable using cutting-edge technologies. The recoverable unconventional resources are 47 Mt gas-condensate and 1531 billion m^3 gas, however these numbers do not reflect the currently existing technical and economic barriers.

Uranium used to be mined in S-Hungary (Mecsek Mts.) from which uranium oxide was produced locally, processed into fuel in the former Soviet Union. The mine was closed down for economic reasons in 1997, which put an end to Hungarian uranium mining. During its operation 16.4 Mt of uranium ore was mined with 20 672 t uranium content (Table 2 Despite the prospective resources, the re-start of uranium mining is currently not being considered in Hungary.

1.2.2. Renewables

The share of renewable energy in final energy consumption was 6.6 % in 2008, i.e. Hungary ranked in the lowest third among EU member states (2008 EU-27 average: 10.3%) lagging behind the countries of similar level of economic development even (Bulgaria 9.4%, Czech Republic 7.2%, Poland 7.9%, Romania 20.4% and Slovakia 8.4%). The difference is partly due to the more favourable and better exploited hydro energy potential and forestation indicators of the neighbouring countries, as well as their more efficient regulatory systems. Considering Hungary's geographical conditions, energy generation from biogenic sources (forestry and agricultural biomass, biogas and biofuels), geothermal energy and solar energy are the most important.

In terms of the utilization of renewable energy sources, Hungary has so far failed to make full use of the available domestic potential. According to the findings of a survey conducted in 2005 and 2006 by the Renewable Energy Subcommittee of the Hungarian Academy of Sciences, the theoretical annual renewable energy potential is 2,600-2,700 PJ, the full exploitation of which can never be achieved. The actually available level is characterised by the technically and economically feasible potentials. For the latter, however, there are no unequivocal estimates, and this potential keeps growing with the development and gaining ground of new technologies.

Biomass is the most popular renewable energy source in Hungary, accounting for almost 90% of the total renewables. Firewood is the main material of heat and electricity production from biomass, which is usually used for burning or co-burning, mainly for heat production and, to a smaller extent, for electricity generation. The population uses a large amount of firewood, usually in low-efficiency boilers. Vegetable by-products and waste from arable lands and horticultures, such as grape marc and skin of seeds for burning in power plants etc., as well as woody and herbaceous energy crops are further biomass materials for energy production purposes. The utilization of biogas is gaining more and more ground.

Due to the favourable geological conditions, the *geothermal* potential of Hungary is outstanding, however its share in the total RES is low (9% in 2010). In the heating-cooling sector altogether 4.5 PJ/y geothermal energy has been used (2012), the NREAP target is 14.95 PJ/y by 2020. Currently there is no electric power production from geothermal, however the NREAP foresees 57 MWe by 2020. From a resource side the development potential is available. The in situ and prospective resources (Table 2) represent the large amount of heat in-place, of which only a small fragment is recoverable by the abstraction of thermal water. The estimates for economically recoverable resources (Table 2) are based purely on geological considerations and do not take into account other non-technical constrains of drilling some hundreds of new wells / doublets necessary to exploit these resources. The implementation might be further impeded by the lack of financial incentives, technical barriers (e.g. related to reinjection), environmental issues (changes in quality and quantity status of thermal water aquifers) as well as the complicated and time-consuming administrative processes of licensing. Nevertheless geothermal energy could play an important role in reducing dependency on the import gas especially in the heating sector, where it could contribute to the district heating in about 30 Hungarian towns where the pipeline infrastructure already exists.

Our *hydroenergy* potentials are limited due to the low stream gradients of our rivers. Our park of *wind* turbines has a capacity of 328 MW, but it operates with a low load factor due to the hectically changing wind conditions. Our *solar* energy production is growing. Hungary's biggest photovoltaic power station begun its operation at the beginning of October 2015, where the 72 thousand solar panels produce 16 MW of energy.

1.3. Secondary energy sources

1.3.1. Electricity

As at 31 December 2010, the built-in capacity of the Hungarian power plants generating interoperable electricity in the electricity system was 9,317 MW, of which 7,895.9 MW was provided by 20 large power plants, whereas the remaining 1,421.1 MW was provided by small power plants of a capacity below 50 MW, powered mostly by gas or, to a smaller extent, by renewable energy sources. The available capacity was 8,412.7 MW (NES 2011) including 3,061.9 MW and 5,350.8 MW controllable and non-controllable capacities respectively.

Hungarian power plants are obsolete, i.e. their fuel consumption, level of pollution and labour intensity is higher than the European average. While the existing coal-fired power plants still play a significant role in electricity generation, they have already past their envisaged service life by several decades and their efficiency, environmental parameters and CO_2 emission levels do not meet today's requirements.

The Paks Nuclear Power Plant accounts for 43.2% of electricity generation (2011). Currently there are 4 units in operation, with a capacity of 500 MW each. Assuming an extension of 20 years, their life-cycle will expire between 2032 and 2037. The Paks Nuclear Power Plant generates electricity at the lowest sales price (HUF 10.67/kWh in 2009) in Hungary. On the long term, it is an efficient tool for providing electric power at a competitive price and for reducing CO_2 emissions. In 2014 the Hungarian Parliament approved the Act on the expansion Paks Nuclear Power Plant with the building of another two blocks of 1200 MW capacity each.

The safety system and the operation of the Paks Nuclear Power Plant are regularly monitored by both Hungarian and international organisations, including, for example, the World Association of Nuclear Operators, which conducted an on-site audit in Paks in 2005, and later in 2012. The Paks Nuclear Power Plant is currently one of the safest power plants in international comparison, thanks to the safety-increasing improvements carried out in the 1990's, which considerably improved the conditions of the safe operation of the plant.

In 2009, 8 % of all electricity came from renewable sources, 68.5 percent biomass-based. Much of that energy is generated by the co-burning of firewood and coal in low-efficiency, obsolete power plants, which should be replaced for sustainability and energy efficiency reasons. Within renewable electricity generation, wind generators, hydropower, biogas and communal waste-based energy generation account for, respectively, 13.4%, 9.7%, 2.2% and 6.2% (NES 2011). Currently, there is no geothermal-based electricity production in Hungary. The biggest obstacles to the increase of the share of renewable energy sources are the disproportionate conditions of the feed-in tariff system, the unsuitable real-time controllability of the electricity grid and the bureaucratic and uncoordinated system of licences, involving several authorities.

Since the Hungarian electricity system is based mostly on base load units, it is increasingly difficult to control the system through technical means, with particular regard to off-peak load balancing. Non purpose-built, uneconomical and obsolete power plant units running on fossil fuels are currently used for load balancing. These 200 MW capacity units are used to provide secondary reserves within the electricity system.

In a few years' time, a situation may arise when the capacity losses can no longer be managed due to the lack of supplemental reserves. By providing the required cross-border capacities and the integration of day and intra-day markets, the integrated European electricity market, currently under development, may help prevent the disturbances of supply in Hungary.

1.3.2. Heat

The overwhelming part of heating technology is gas-based in Hungary, therefore this is the most vulnerable sector related to security of supply. 40% of the total energy consumption is currently spent in buildings, about two thirds of which goes for heating and cooling. In terms of communal energy consumption, adjusted for climatic differences, Hungary ranks among the ten highest consumers among the EU-27 (compared to the European average of 220 kWh/m^2/year between 2000 and 2007, the Hungarian average figure for retail consumption is 247 kWh/ m^2/year).

The very high ratio of natural gas consumption in winter, mainly for heating purposes, presents particular regulation, reserve, capacity commitment and, consequently, supply security challenges to the Hungarian energy industry and economic diplomacy. The current situation could be considerably improved by an efficient and comprehensive building insulation and efficiency improvement programme for energy saving purposes, plus adequate motivation for a transition to renewable energy sources.

Consumption is uneconomical due to the poor general condition of buildings. 70% of the approximately 4.3 million Hungarian homes fail to meet modern functional technical and thermal engineering requirements, with a similar ratio for public buildings (Table 3). While there has been an improving trend as the result of the communal energy efficiency programs implemented in recent years, no precise data are available due to the lack of a functioning system for the monitoring of the impact of the implemented projects.

	Detached houses	**Prefab blocks of flats**	**Public buildings**	**Recently built homes**
Average floor area (m^2/home)	90	55	1200	80
Average specific thermal energy (kWh/m^2/year)	320	200	340	100

Table 3: Estimated reference figures for the Hungarian building stock (Source: Hungarian Construction Industry Association, KÉK Working Group (National Energy Strategy 2030, 2012)

Heat (space heating, hot water supply and cooking) accounts for about 80 % of household energy consumption, supplied mainly through individual natural gas-powered heating apparatuses, firewood and communal district heating systems. Within final consumption, the share of district heating has declined from 12 % in 1990 to 8 % in 2007. This is attributable mainly to a sharp decline in the district heat demand of industrial consumers (to close to a quarter of the 2003 figure) and a 30% decrease in household demand for heating purposes. The latter is the result of the building energy performance programmes implemented in recent years which had the reduction of the energy consumption of homes supplied with district heat as one of their main objectives. Currently 15% of Hungarian homes, an overwhelming part of which (650,000 homes) were built with industrial technology, are connected to the district heating systems. Apart from communal consumption, about 12% and 25% of the total volume of district heat are consumed respectively by public and industrial consumers.

District heating is the centralised form for satisfying the heat market demands, when the centrally generated thermal energy is supplied to the end consumer through a system of pipelines. Hungary's district heating market of ~63 PJ represents only a small share of total head demands (~one-sixth), two-thirds of which being co-generated with electricity. Unlike in the case of natural gas and electricity supply, the technical features of district heating do not allow a national network or a cooperating system on the level of settlements. In many cases, the settlements operate smaller or bigger independent "isolated" systems.

The distribution of heating methods is shown in Table 4, except for prefab blocks of flats, which are practically 100% district-heated. The share of gas heating in the other flat categories is 55-60%, where the proportion of the central gas boiler, the tankless gas water heater and the gas convector are significantly changing by building types. Beside gas, the proportion of combined and wood burning is also significant, and district heating is pretty much insignificant in case of flats other than prefab block of flats.

Detached houses		**Apartment block with less than 10 flats**		**Prefab blocks of flats**		**Buildings other than prefab blocks of flats with more than 10 flats**	
Tankless gas water heater	36.60%	District heating	6.70%	District heating	99,00%	District heating	14.60%
Gas convector	21.60%	Central gas boiler	3.40%	Other	1,00%	Central gas boiler	7.80%
Wood furnace, boiler	30.30%	Tankless gas water heater	35.20%			Tankless gas water heater	19.80%
Other	11.50%	Gas convector	18.00%			Gas convector	27.40%
		Combined heating	30.40%			Combined heating	26.70%
		Other	6.30%			Other	3.70%

Table 4: Division of heating in residential buildings (National Building Energy Strategy, 2015)

The domestic share of renewables in satisfying the heat demands in 2006 did not reach 10%, so there is a relatively great heat demand to be replaced by renewables on the user side. However, actual replacement has many barriers, the most important ones being as follows:

- The payback period of heat generation projects based on renewables is quite long (usually much longer than 10 years). The average payback period of some characteristic projects is shown on Table 5, by calculating with energy prices from 2006. (We must mention that these payback periods are shorter due to the significant surge of prices of crude oil and other fossil energy sources in recent times.)
- The relatively high temperature level of building heating and district heating systems is disadvantageous from the point of view of the usability of mainly geothermal energy (and solar energy),
- In case of using renewable-based heat generation solutions, the application of traditional heat sources could be necessary to cover the peak demands,
- The physical access of (district) heating consumers with some renewable energy sources (e.g. thermal water) is usually impossible by rational investment costs,
- Transportation and the creation of storages with serious space demand are significant limiting factors of the utilization of solid biomass, which is the most promising energy source for heat generation,
- Their applicability is often excluded by the observance of strict environmental provisions (e.g. reinjection requirement of the extracted thermal water, electricity demand),
- The majority of Hungarian district heating systems use modern combined energy production, thus the realization of renewable heat generation – unless we count with the exclusion of cogeneration – can only be realized by a small-scale exploitation, which further deteriorates the return indicators of the expensive investment.

Heat generation systems	**Payback period (years)**
Solar collector	20-25
Geothermal energy (thermal water)	12-15
Heat pump (terrestrial heat)	15-20
Biomass (wood chips)	10-12

Table 5: Payback period of renewables-based heat generation system by calculating with energy prices from 2006 (Strategy for increasing the use of renewable energy sources in Hungary 2008-2020, 2008)

In heat generation renewable energy sources represent only 1.5%. Biomass represents the most significant volume– just like for green electricity generation - and the share of geothermal heat generation is relatively significant as well. About 6,000 homes are heated by geothermal energy.

The implementation of objectives regarding the increase of the utilization and share of renewable energy sources in not possible without the proper inclusion of renewable energy sources in the field of heat supply. Based on the existing supply structure, district heating alone does not offer enough potential for the inclusion of renewables, thus the renewable energy sources must have a crucial role in decentralised heat generation, the other important segment of the heat market.

Despite of the significant volume of the heat market, heat energy is the statistically "hidden" segment of final energy utilization, since heat is mainly (a five-sixths share) generated locally, in a decentralised way at the end consumers. Only district heating and technological heat utilization appear as independent categories in statistics, while energy statistics shows only the energy sources used for heat generation form the point of view of the majority of energy that has been used as heat in a decentralised manner.

1.3.3. Transport

In Hungary, transport accounted for 68 % of the total petroleum consumption in 2009. Transport-related CO_2 emissions accounted for 23.1 % of the total in 2007. In Hungary the number of cars per thousand persons (2009: 300) is still well below the average of the EU-27 (2009: 473). The average age of the Hungarian vehicle fleet is over 10 years. Another unfavourable effect is that the weight of road transport, causing more pollution and using more energy per unit, has increased significantly compared to rail transport. The volume of road transport exceeded 35,000 million tonne-kilometres by 2009 and the diesel consumption increased to 1696 million litres (NES 2011).

Rail transport plays an indispensable role in reducing the energy consumption, environmental load and GHG emissions of the transport sector. In 2008, 63 % of the energy consumption of the Hungarian rail transport system was electricity, whereas oil products accounted for the rest. Of the 7,718 km-long railway network, currently 35 % is electrified, a great deal less than the 52 percent in the railway system of the EU-27 (NES 2011).

1.4. Energy policy concepts, its main provisions and goals

The ultimate document of Hungary's energy policy is the **„National Energy Strategy 2030"** which was elaborated by the Ministry of National Development in 2010-2011 based on an extensive consultation with nearly 110 important stakeholders as well as considering the recommendations of the International Energy Agency and the energy policy concepts of the European Union. The objective of the Hungarian Government was to reconcile its energy and climate policies while keeping economic development and environmental sustainability in mind, to determine an acceptable level of energy demand and the future directions of energy improvements, and to frame a vision of the future for Hungarian energy policy. Hungarian Parliamentary Decision 77/2011 (X.14.) granted a mandate for the implementation of the National Energy Strategy.

The National Energy Strategy's ultimate goal is to seek ways out of the country's energy dependency and ensure the long-term sustainability, security and economic competitiveness of energy supply. The ways to achieve the above goal include energy savings, increasing the share of renewable energy sources, use of safe nuclear energy, the establishment of bipolar agriculture enabling to shift between food production and energy-geared biomass production, and integration to the European energy infrastructures.

During setting up a vision for 2030 and beyond, the National Energy Strategy investigated 3 possible scenarios: (1) the BAU scenario (conserving the current situation), (2) the Policy scenario (joint efforts), and (3) the Green scenario (giving increased priority to sustainability considerations). However, during the revision of the National Energy Strategy only the BAU and the Policy scenarios were considered as realistic and their target numbers have been re-assessed (Table 6).

PJ	2012	2020		2030	
		BAU	Policy	BAU	Policy
Primary energy use	992	1101	1009	1217	1028
Final energy consumption	677	766	693	840	692
Industry	96	124	114	139	126
Transport	157	161	147	173	151
Communal	215	247	207	284	187
Trade and services	116	126	118	135	121
Agriculture	17	18	17	19	17
Non-energy use	77	90	90	90	90
Electricity	153	170	164	197	181

Table 6: Forecasts of energy use based on the revised National Energy Strategy (source: Parliamentary decision 5/2015. (III. 20.)

Following the energy demand trends of the Policy scenario, various energy-mix scenarios have been analysed, of which the 'Nuclear-Coal-Green' meets best the requirements of safe energy supply, the fundamental objective of the Energy Strategy in terms of electricity generation. Its most important elements are as follows:

• the long-term preservation of nuclear energy in the energy mix;

• the maintenance of the current level of coal-based energy generation, with full compliance with the committed sustainability and GHG emission criteria (carbon capture and clean coal technologies);

• the linear extension of Hungary's National Renewable Energy Action Plan (NREAP) after 2020.

The main areas of the Energy Strategy where different actions will contribute to the sustainable and secure energy supply are the following:

In terms of **energy savings** the aim is preferably to reduce the 2010 level of domestic primary energy use of 1085 PJ or, at worst, that it should not exceed 1150 PJ, the level typical of the years prior to the economic crisis, by 2030. Hungary's National Reform Programme set an indicative, voluntary energy saving target of 10 % up to 2020.

The key components of energy savings comprise the building energy programme, replacing of obsolete, low-efficiency coal- and gas-based power plants, reducing grid-loss and replacing low-efficiency renewables and the reduction of the energy needs of industrial workflows and transport. Altogether it could result in 189 PJ primary energy savings by 2030. Energy-efficiency projects in the building sector are key components. The goal is to reduce, the heating energy requirements of buildings by 30 % by 2030 through energy-efficiency programs in the building sector in accordance with European Union targets. This will enable an over 10 % reduction of the overall primary energy demand in Hungary.

The **increase** of the **share of renewable energy** in primary energy use from the current 7 % to the vicinity of 20 % by 2030 is a key component of the sustainable energy supply. The estimates for growth until 2020 (the target set being a share of 14.65 % in terms of gross final energy consumption) are described in detail in Hungary's NREAP. In terms of renewable energy sources, combined heat and power biogas and biomass power plants and geothermal energy utilisation will be treated as priorities. In addition to the above, solar energy-based heat and electric power generation and wind-generated electric power generation are also expected to increase. Another important question is the energy utilisation of communal and industrial wastes and of waste waters.

For the **modernisation of community district heating and private heat generation**, the competitiveness of the district heating services must be ensured, for which technology development and the use of renewable energy sources are indispensable. District heating systems will play a very important role in the renewal of heat energy supply due to their ability to admit heat from virtually any heat source, transmitting it to the end users. Based on the scenario investigated by the National Energy Strategy 2030, the share of the generation of renewable heat energy within the total heat energy consumption will increase to 25% from the current 10 % by 2030, including the individual heat energy-generating capacities (biomass, solar and geothermal energy).

Expected indicators in the field of **transport** are related to increased use of renewables, as well as energy-efficiency measures. Increasing the share of electric (road and railway transport) and hydrogen-based (road transport) transport to 9 % and that of the share of biofuels to 14 % by 2030 serves the purpose of reducing the oil dependency of transport. The electrification of transport may primarily be based on nuclear-generated power.

2. Heat sector analysis of the South Great Plain and South Transdanubia – regional overview

2.1. South Great Plain Region

2.1.1. Geographical setting

The South Great Plain region is located at the southeastern and southern parts of Hungary, encompassing counties of Bács-Kiskun, Békés and Csongrád (Figure 1). Its majority is a lowland below 200 m asl, being rich in natural resources.

Figure 1: Location of the South Great Plain Region within Hungary

The South Great Plain Region is composed of 3 large geographic provinces: the Duna-Tisza Interfluve, the Lower Tisza Plain and the Körös-Maros Interfluve. These three provinces provide different geographical conditions for the development of the settlement structures, agriculture, water resource management as well as nature protection. They are all plain / lowland areas, where the main geomorphological processes controlling land surface development are wind and fluvial processes. The northern part of the region is characterized by shifting sand dunes, whilst the majority of region's territory is alluvial plains. The physical properties of the soil are impacted by the climatic changes: droughts, lowering of the groundwater table, warmer winter periods. These affect the entire territory of the region.

The South Great Plain is rich in surface waters, in addition to the major rivers crossing this area (Duna, Tisza, Maros, Körösök, Berettyó), there are numerous owbow lakes, dead channels and sodic lakes (e.g. Fehér-tó) providing good facilities for fishing. The region is also rich is groundwaters, including thermal and mineral waters.

The region's climate is dry, continental with occasional Mediterranean and oceanic impacts. The numbers of hours with sunshine in above 2600/year and the mean annual temperature is 10,5-12 ºC, which is above the country average. The annual fall is 500-600 mm, with a great variety both in space and time. According to the favourable climatic conditions, the heating season is relatively short from the beginning of October till the end of April.

2.1.2. Population and settlement structure

The South Great Plain region is one of the largest regions of Hungary, and in terms of population it has the 3rd highest number of inhabitants. Nevertheless the density of population is fairly low (71,3 people/km^2). The decrease of population is continuous and shows a disproportion within the region. Considering the number of settlements (total of 254) and the territory of the region, it has the lowest density and network of settlements in Hungary. Nevertheless it has 47 towns, and as such has the 2nd highest number of towns among the Hungarian regions. Its settlement network is rather characterized by agricultural towns surrounded by farms and large villages. The proportion of population living in farms and small villages is very low (2,5%). The majority of population (44,7%) is living in large villages with 2000-10000 inhabitants and in agricultural town (21,3%) with 20000-50000 inhabitants. The most extended network of farms is found in this region. The settlement network does not reflect the distribution of the statistical small regions, but is characterized by rather homogenous groups of settlements, such as the county towns and their suburban agglomerations, which are the largest and most dynamically developing areas of the region. The "mid-Békés centrum" (Békéscsaba, Békés, Gyula) composes 30% of the total population of Békés county, whilst Szeged and its agglomeration accommodates nearly 50% of the total population of Csongrád county (together with the territory of Hódmezővásárhely this proportion is as high as 60 %).

The region's main data are summarized in Table 7.

Area	18337 km^2
Population	1 308 474 people
Cenrte of region	Szeged
Counties	Bács-Kiskun, Békés, Csongrád
Small regions (within Bács-Kiskun county)	Bácsalmás, Baja, Jánoshalma, Kalocsa, Kecskemét, Kiskőrös, Kiskunfélegyháza, Kiskunhalas, Kiskunmajsa, Kunszentmiklós
Small regions (within Békés county)	Békéscsaba, Békés, Gyula, Mezőkovácsháza, Orosháza, Sarkad, Szarvas, Szeghalom
Small regions (within Csongrád county)	Csongrád, Hódmezővásárhely, Kistelek, Makó, Mórahalom, Szeged, Szentes
Agglomerations	Kecskemét (8 settlements out of which 2 are towns) Szeged (15 settlements out of which 2 are towns) Békéscsaba (9 settlements of which 5 are towns)
Towns within Bács-Kiskun county	Bácsalmás, Baja, Dunavecse, Hajós, Izsák, Jánoshalma, Kalocsa, Kecel, Kerekegyháza, Kiskőrös, Kiskunfélegyháza, Kiskunhalas, Kiskunmajsa, Kunszentmiklós, Lajosmizse, Mélykút, Solt,

	Soltvadkert, Szabadszállás, Tiszakécske, Tompa
Towns within Békés county	Battonya, Békés, Csorvás, Dévaványa, Elek, Füzesgyarmat, Gyomaendrőd, Gyula, Körösladány, Medgyesegyháza, Mezőberény, Mezőhegyes, Mezőkovácsháza, Orosháza, Sarkad, Szarvas, Szeghalom, Tótkomlós, Újkígyós, Vésztő
Towns within Csongrád county	Csanádpalota, Csongrád, Kistelek, Makó, Mindszent, Mórahalom, Sándorfalva, Szeged
Flats connected to district heating systems	48791
Flats connected to hot water supply	46694

Table 7: Main data of the South Great Plain Region

2.1.3. Agriculture and industry

Although a significant economic transition started after the political changes, agriculture remained the dominant sector providing 11% of the GDP. The most valuable natural resource of this region is the rich soil. The region possesses 22% of the total agriculture land of Hungary, 33% of the total arable lands, field vegetable production and wineyards, and 16% of orchards.

The South Great Plain has never been an industrial area which has been further emphasized after the political changes. The main industrial activities are associated with victual industry (mill industry: Kiskunfélegyháza, milk industry: Szeged, meat-packing industry: Gyula, Békéscsaba, Szeged). The only significant heavy industry is represented by the Mercedes factory in Kecskemét. The region is rich in hydrocarbons with exploitations concentrated around Algyő, Makó and Szeged (KSH, 2016).

2.1.4. Geothermal conditions

The potential geothermal resources of the South Great Plain Region are considerable even at a European scale due to the favourable geological conditions (geothermal gradient 5 ºC/100 m, average heat flow 90,4 mW/m2), however the current utilization is far below the potentials. The thickness of the Quaternary and Upper Pannoninan thermal water aquifers reach their largest thickness in this region, therefore the South Great Plain is considered as the most important hydrogeothermal area of Hungary. The amount of low-enthalpy (<130°C) resources suitable for direct heat purposes are practically unlimited in this region, nevertheless high-enthalpy systems (130-250°C) with potentials for power generation are also know.

The potential use of geothermal resources in the South Great Plain Region are the following:

- balneology including spas, wellness centres and medicinal purposes as great potential for health-tourism (e.g. Algyő, Ballószög, Békéscsaba, Dávod, Gyula, Makó, Mórahalom, Kecskemét, Kiskunmajsa, Kiskunhalas, Szarvas, Szeged, Orosháza)
- direct use in agriculture (e.g. heating of greenhouses)

- heating (-cooling) of public buildings with use of heat-pumps
- potential use for power generation

There is an increasing investors'need and interest at municipal and small region level, as well as from the market side as well (especially for power generation projects).

The South Great Plain Region is in the lucky situation of having great hydrogeological-thermal energy features and a significant demand and a heat market to be supplied. Many organizations in the South Great Plain Region have started performing widespread professional activities for better utilization of geothermal energy, and an increasing number of complex geothermal projects were implemented over the past years. According to the regional features and the demands coming from local governments, we can say that this region with an important heat market is only waiting for political and professional stakeholders to be informed about these facts. However, for an optimum utilization, the heat markets owned and/or managed by local governments cannot be sold below their real value without listening to the opinions of professional organizations, or the professional society.

It is important to mention that we are talking about local heat markets and local heat supply demands. The legal background allows local governments to have control over this "wealth" within their administrative limits. Accordingly, it is especially alarming to see the activities that may result in the selling of the local heat market, as property, below its real value due to the alarming levels of significant investment items and the relatively high risk of implementation.

We must also remember that due to the increasing demand for water, we can come to a point, where these water resources will supply not only heat and thermal water, but also drinking water at a level of production higher than the current one. The protection, natural replacement, proper professional utilization of local thermal water resources and the sale at real value of its profit-oriented supply is an especially important priority.

2.1.5. District heating sector in the South Great Plain Region

The rich geothermal energy resources of the region are mainly utilized in the agriculture sector (heating of greenhouses, poultry yards and stables, as well as fish farms). The direct use for heating flats or the industrial use is less. Considering energy consumption the majority of users are the residentials. The settlement structure described in chapter 2.1.2. is favourable for district heating systems. The low number of farms and small villages and the large agglomeration areas accommodating the majority of the region's population are well in line with the relatively high number of settlements with operating district heating infrastructures (Algyő, Baja, Csongrád, Hódmezővásárhely, Makó, Kiskunhalas, Kiskunfélegyháza, Kecskemét, Szeged, Szentes). This represents a 8,2% share of the total flats. The rate of flats using pipeline gas supply is 77,8%. The annual gas consumption of one household is 851,4 m3, while the electricity consumption is 1976,1kWh.(KSH 2015).

Using the outstanding geothermal potentials, this region is a leader in using geothermal energy for directs use, shown by the gradually increasing number of new and enlarged older cascade systems (e.g. Csongrád, Hódmezővásárhely, Szeged, Szentes).

2.2. South Transdanubian Region

2.2.1. Geographical setting

The South Transdanubian Region is located in the south-western part of the country, encompassing counties of Baranya, Somogy and Tolna (Figure 2). It is bordered by Lake Balaton on the north, by the Danube river on the east and by the Dráva river on the south.

Figure 2: Location of the South Transdanubian Region within Hungary

The South Transdanubian Region has a wide range of geomorphological conditions and landscape heterogeneity: it has hilly areas (e.g. Somogy Hills), mountains (e.g. Mecsek Mountains) as well as lowland areas (Danube Plain).

The region is rich both in surface and in groundwaters. Its main rivers (bordering the Region) are the Danube and the Dráva rivers. The discharge of the Danube at Paks is 2300m3/sec. The rivers of the region belong to the catchment areas of the Danube, Dráva and Kapos rivers. Its biggest lake – which is the largest lake of Central Europe – is Lake Balaton. On top of that there are several hundred small lakes in the region, the majority of them are artificial, which are important for fishing.

The climatic conditions of South Transdanubia are heterogeneous. Its southern parts have a sub-mediterranean climate resulting in higher annual average temperature (11ºC) and number of hours with sunshine (2130 hours/year) than the country average. The northwestern part of the region is impacted by atlantic climate resulting in relatively high annual precipitation (720-760 mm. The heating season starts at the end of September, beginning of October when temperature drops below 18 ºC. The heating season normally finishes at the end of April. In Baranya county the heating season can be shorter by 0,5 months due to the mediterranean climate impact.

2.2.2. Population and settlement structure

The territory of the South Transdanubian Region is 14 169 km^2. At the same time, it has a low rate of population (66,4 people/km2). The centre of the region is Pécs, the other major cities are Kaposvár and Szekszárd. These cities are the economic, and cultural centres of the region.

The settlement structure of the region is unfavourable, it has a low rate of cities and a high number small settlement / minor villages. The total number of settlements is 655, more than a half of them are minor villages (346), which accommodates 10% of the region's population. The minor villages are especially characteristic to Baranya county, where 70% of the population live in villages which have less than 500 habitants. This ratio is 28% for Tolna county and 14% for Somogy county. Mid-size cities are practically missing. Important regional centres are represented by the towns of Kaposvár, Pécs and Szekszárd, where city agglomerations have also started to develop.

The region's main data are summarized in Table 8.

Area	14169 km^2
Population	940585 people
Cenrte of region	Pécs
Counties	Baranya, Somogy, Tolna
Small regions (within Baranya county)	Komló, Mohács, Pécs, Pécsvárad, Sásd, Sellye, Siklós, Szentlőrinc, Szigetvár
Small regions (within Somogy county)	Balatonföldvár, Barcs, Csurgó, Fonyód, Kaposvár, Lengyeltóti, Marcali, Nagyatád, Siófok, Tab
Small regions (within Tolna county)	Bonyhád, Dombóvár, Paks, Szekszárd, Tamási
Agglomerations	Pécs (41 settlements out of which 2 are towns) Kaposvár (23 settlements out of which 1 is town) Szekszárd (10 settlements out of which 1 is town)
Towns within Baranya county	Bóly, Harkány, Komló, Kozármisleny, Mágocs, Mohács, Pécsvárad, Sásd, Sellye, Siklós, Szentlőrinc, Szigetvár, Villány
Towns within Somogy county	Balatonboglár, Balatonföldvár, Balatonlelle, Barcs, Csurgó, Fonyód, Igal, Kadarkút, Lengyeltóti, Marcali, Nagyatád, Nagybajom, Siófok, Tab, Zamárdi
Towns within Tolna county	Bátaszék, Bonyhád, Dombóvár, Dunaföldvár, Gyönk, Nagymányok, Paks, Simontornya, Tamási, Tolna
Flats connected to district heating systems	59912
Flats connected to hot water supply	56213

Table 8: Main data of the South Transdanubian Region

2.2.3. Agriculture and industry

According to its geographical position, the South Transdanubian Region is in a peripherial setting compared to other regions of Transdanubia, especially from the point of view of transport, which decreases its economic potential. Mining (coal, lignite, uranium) - which had a great economical potential for the region - has been stopped by today. Now the only mining activity is at Berend (cement factory). The industry is not well developed, rather characterized by food industry (Pécs: milk-, meat- and mill industry, Szekszárd: milk industry, Kaposvár: sugar-, mill-, meat- and meat industry, Szigetvár: preserving industry, Nagyatád: preserving industry, Dombóvár: milk industry). The region accommodates the only nuclear power plant of Hungary (Paks), which accounts for 43,2 % of electricity production of the country. Regional developments building on the local natural, economic, or cultural potential started to develop only at a few micro-regions, such as the Balaton recreational area, or the Harkány-Siklós-Villány area. In both areas the main driving force is tourism, characterized by a significant seasonality.

The agricultural-ecological potential of the South Transdanubian Region is excellent, it has a leading role in growing several cultivated plants. The region has 5 wine regions, all characterized by top-quality wine making. Due to the favourable soil conditions, the region has an outstanding role in growing forage plants, and as a consequence it is characterized by significant animal farming. Fish-farms (lakes) are also important.

2.2.4. Geothermal conditions

The geothermal gradient and the density of heat flux characteristic for the South Transdanubian region provide proper conditions for the utilization of geothermal energy, but this great geothermal potential is yet to be exploited. There are nearly 200 thermal wells in the region, the majority of which is not used for energy generation purposes. Some wells are used for balneological purposes, for example in Harkány, Kaposvár or Nagyatád. In addition, some agriculture use also exists (heating of greenhouses, fish-farming). Space heating with geothermal energy, as well as heating of communal buildings in cascade systems exist at several towns (Bóly, Harkány, Kaposvár, Kapuvár, Nagyatád, Pécs). Geothermal district heating exists at Szentlőrinc. Other geothermal heating systems are planned for Bonyhád, Csurgó and Tamási. In places, where geothermal energy is used for balneological purposes, the usability of the discharged warm water from thermal baths is an unexploited potential.

2.2.5. District heating sector in the South Transdanubian Region

Pipeline energy carriers have a decisive role in energy consumption in Southern Transdanubia. As a basic energy carrier, natural gas is used by the population, public institutions and companies of the area. It is used by connecting to the pipeline directly as individual consumers or in groups (organized into small or big district-heating networks).

The main energy consumer is the residential sector, which mainly means gas consumption, but the use of wood for burning is also significant. The heating of the houses, flats and public buildings is mostly gas-based. 59,2% of the Region’s households is using pipeline gas, the average annual gas consumption per household is 837,2 m3. The number of settlements with district heating infrastructure is proportional to the country average (Bonyhád, Dombóvár, Kaposvár, Komló, Mohács, Nagyatád, Siklós, Siófok, Szekszárd, Szentlőrinc, Szigetvár, Pécs). 14,8% of the flats are connected to district heating systems (KSH, 2015).

Apart from the two large electricity-generating power station premises (Paks Nuclear Power Plant and Pannon Power Plc. of Pécs), there are several, a lot smaller gas engines, which produce electricity for the companies and institutions of Southern Transdanubia. Favourably, power generation is connected to heat energy supply for example through meeting district-heating needs or technological heat needs of companies. Energy needs of populous settlements, institutions are (also) met by heat power station capacities, their role is to supply housing estates and large institutions with heat energy (e.g. Kaposvár, Szekszárd, Mohács).

Certain plants with a large energy need have their own energy-generating base, e.g. Cement Works of Beremend. Smaller enterprises have also thought of establishing a decentralized energy source, but their primary energy source is still gas coming into the region through pipelines.

2.2.6. Other renewables in the South Transdanubian Region

The major renewable energy sources in the South Transdanubian Region are biomass, geothermal energy, solar energy and wind energy. Currently, their share in the total energy utilization is low.

The South Transdanubian Region includes 12 micro-regions. In order to decrease energy costs and achieve at least partial self-sufficiency, all micro-regions find it important to replace energy from fossil energy sources with renewable energy sources. In 2010, 80% of the micro-regions had one or more settlement that utilized solar energy for supplying its institutions with heat or electricity. In terms of prevalence, solar energy was followed by biomass (9 micro-regions) and geothermal energy (7 micro-regions). Several developments were launched in the region in the field of biofuels as well: six micro-regions produced bioethanol, three produced biogas, and one produced biodiesel (Figure 3).

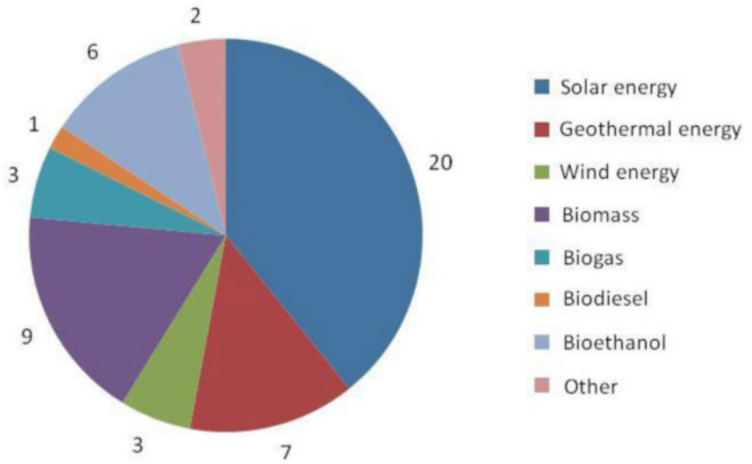

Figure 3: Utilization frequency of renewable energy sources in the micro-regions of the region, 2010 (South Transdanubian Regional Energy Strategy, 2012)

Despite the above, energy produced from alternative energy sources amounts to only 2% in the energy use of these micro-regions according to the responses received within the surveys. The lowest value was observed in Somogy County, where seven micro-regions claimed this rate was 0%. The highest share, 5–10% was reported by one micro-region in Baranya County (Mohács) and three in Tolna County (Dombóvár, Szekszárd, Paks). It should be noted, however, that respondents often projected the characteristics of their own local government onto their micro-regions, therefore these reports may be distorted – but the figures show the importance of developments. The types of energy sources to be used in the course of planned developments reflect the share of currently used energy sources almost three quarters of micro-regions set their sights on solar energy use. The number of micro-regions planning to exploit geothermal and wind energy doubled (Figure 4).

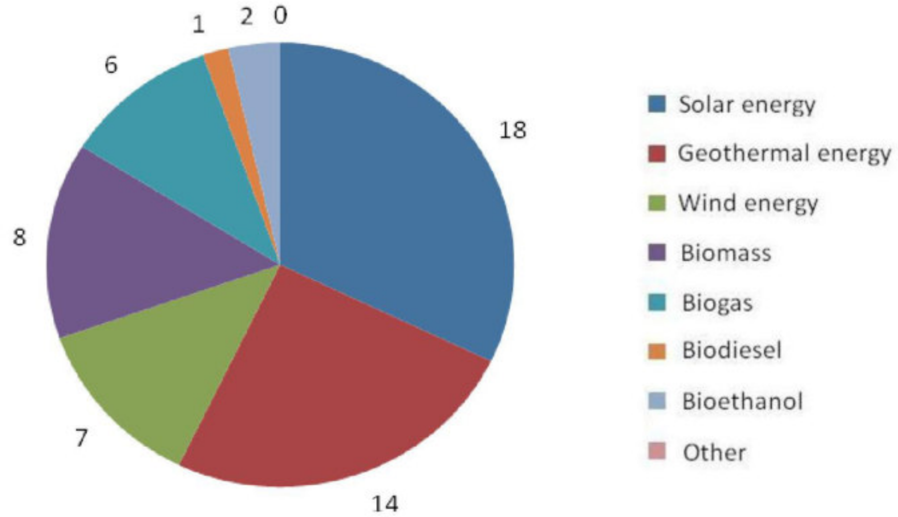

Figure 4: Planned utilization of renewable energy sources in the micro-regions of the region, 2010 (South Transdanubian Regional Energy Strategy, 2012)

3. Heat market analysis at local level: a district heating circuit to be converted to geothermal in the city of Szeged

3.1. The current situation

The city of Szeged is a university city and the economic and cultural centre of southern Hungary. In the city with a population of 170,000, almost half of the inhabitants live in 27,000 district-heated households. The "Odessza" housing estate is one of the isolated district heating areas with a built-in boiler capacity of 20 MW. The housing estate itself is a huge heat consumer with dozens of buildings.

The classic urban environment of the housing estate includes a great territory covered with solid pavement. However, due to its location on the bank of the Tisza River and on the edge of the city, it also has a serious amount of green open spaces.

Similarly to other cities in the South Great Plain, Szeged's first thermal well was drilled almost 60 years ago and it is still functioning (the first thermal well in Hódmezővásárhely was drilled in 1954 and it supplies thermal water with an unchanged yield to the public bath, and in Szentes, 20 thermal wells have been supplying thermal water to the world's biggest continuous thermal horticulture for five decades). The thermal well on Székely sor in Szeged is used for district heating since 1962. There are several horticultural drillings operating for decades in distant parts of Újszeged, and geothermal energy has been used for heating the Sport's Hall, the university dorms and a number of public buildings for the past two years. Another thermal cascade system was constructed on the other side of the Tisza River for the heat supply of the university hospital buildings.

3.1.1. Facility/technology to be modernized

The thermal well on the "Székely sor" Street contributed to the district heating supply of the "Odessza" housing estate located in the part of the city called Újszeged. The yield of the well drilled in 1962 was gradually reducing, its surface technology became outdated, and it requires a complex renovation. According to the well test documents, the pipe liner is damaged at a depth of approximately 1,700 m. This is where the moderate yield is coming from, and the yield of the perforated production layers is equal to zero. The static water level has dropped by 120 m during the lifetime of the well.

The surface control equipment is outdated, the means of compressor extraction are not able to produce a major yield, and the reservoir made of reinforced concrete has to be checked as well.

There was a significant risk in the extension of the well's operating license due to the disposal of the used fluid into the Tisza River. The well was shut down in 2014.

The objective of the project concept presented in the current feasibility study is the replacement of the thermal well with an uncertain fate on "Székely sor" by a modern, automated, and – even from the point of view of the disposal of used water - environmentally friendly, prospective and sustainable water supply technology (reinjection).

3.1.1.1. Type, age, condition and efficiency of equipment

This project does not include the district heating system and technology of the "Odessza" housing estate. The planned geothermal heat supply system will be connected to the consumer heating circuits returning to the district heating plant, by installing a plate heat exchanger. Accordingly, the project will not intervene in the existing state of the heating plant's assets, they will be not replaced.

The evaluation of the heating plant equipment is therefore not relevant for the project. Table 9 summarizes the main thermotechnical units installed in the heating plants.

Number	Unit	Capacity (kW/pc)	Number of pieces
1.	*Heating plant "Odessza 1"*		
	TP-1200/6M gas boiler	1.628	3
	TP-1400/6M gas boiler	1.628	3
	Plate heat exchanger for DHW	250	1
	Plate heat exchanger for heating	2.000	1
	Plate heat exchanger for heating	650	1
	Plate heat exchanger for heating	1.300	1
	Plate heat exchanger for heating	800	1
	Plate heat exchanger for heating	1.200	1
2.	*Heating plant "Odessza 2"*		
	SLT-3 gas boiler	2.326	5
	Plate heat exchanger for DHW	250	1
	Plate heat exchanger for heating	1.750	1
	Plate heat exchanger for heating	1.550	1
	Plate heat exchanger for heating	1.180	1
3.	*District heating substation "Odessza 3"*		
	Plate heat exchanger for heating	700	1
	Plate heat exchanger for heating	1.000	1

Table 9: Main thermotechnical units installed in the heating plants of the Odessza housing estates

3.1.1.2.Evaluation of the thermal well on "Székely sor" to be replaced

- Type: Thermal water production well

- Registry ID: B-384 OKK (national cadastral number)

- Age: 54 years

- Condition: damaged pipe liner, inappropriate perforations, outdated surface machinery – the well requires complex renovation

· Efficiency: capable of producing one quarter (20 m^3/h) of the original water yield (90 m^3/h), the static water level dropped by 120 m

3.2. Mass and energy balances

The planned thermal project contributes to the diversification of the district heating energy base of the "Odessza" housing estate, to the extent of the thermal system's energy capacity. This results in the partial replacement of natural gas, which is currently used in the boilers. The evolution of the district heating plants' energy consumption in the past three years is summarised in Table 10. Changes of the total heat supply are summarised in Table 11, while the heat losses is Table 12.

	Natural gas			Electricity		
	2013. (GJ)	**2014. (GJ)**	**2015. (GJ)**	**2013. kWh**	**2014. kWh**	**2015. kWh**
"Odessza 1"	40 220	35 182	37 485	314 515	292 124	296 935
"Odessza 2"	47 417	40 856	44 771	318 284	303 137	320 553

Table 10: Summary of the district heating plants' energy consumption

	2013. (GJ)	**2014. (GJ)**	**2015. (GJ)**	**2013.**		**2014.**		**2015.**	
				m^3	(GJ)	m^3	(GJ)	m^3	(GJ)
"Odessza 1"	27 051	22 559	25 160	15 449	7 261	16 773	7 665	15 883	5 658
"Odessza 2"	32 496	26 776	30 304	28 044	8 413	27 608	7 897	26 919	7 329

Table 11: Evolution of heat energy supplied (sold) to the housing estate's consumers

	2013 (GJ)-(%)	2014 (GJ)-(%)	2015 (GJ)-(%)
"Odessza 1"	5,908-14.7	4,958-14.1	6,667-17.8
"Odessza 2"	6,508-13.7	6,183-15.1	7,138-15.9

Table 12: Evolution of the heat loss of systems

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3.3. Operating costs

The purchasing costs of natural gas and electricity are the most relevant ones among the costs related to the new project. Other operating costs will remain unchanged with the activation of the thermal project. The trends in costs of natural gas utilization in the past three years (EUR net) are summarized in Table 13. Changes in specific gas costs are shown on Table 14. Calculation of the electricity unit price, without performance fee is shown in Table 15. The changes of electricity costs (saveable cost units) (in EUR) are summarized in Table 16.

	2013		**2014**		**2015**	
	Network access fee	**Gas charges**	**Network access fee**	**Gas charges**	**Network access fee**	**Gas charges**
"Odessza 1"	64,087.00	439,709.59	69,128.34	354,346.54	58,336.55	320,076.89
"Odessza 2"	85,129.13	517,312.77	86,411.01	411,482.95	71,956.20	38,215.41
Total	149,216.13	957,022.34	155,539.36	765,829.50	130,292.76	701,625.63
Grand total	1,106,238.48		921,368.85		831,918.39	

Table 13: Costs of natural gas utilization in the past three years (EUR net)

	2013		2014		2015	
	Gas charges	Total	Gas charges	Total	Gas charges	Total
"Odessza 1"	10.93	12.52	10.073	12.036	8.54	10.096
"Odessza 2"	10.91	12.70	10.07	12.186	8.523	10.13

Table 14: Specific gas costs

System services fee	EUR 0.00328 /kWh
Transmission system operation fee	EUR 4.11 /kWh
Distributor service fee	EUR 14.6 /kWh
Distributor loss fee	EUR 9.83 /kWh
Total	EUR *31.89 /kWh*

Table 15: Calculation of the electricity unit price, without performance fee

	2013	2014	2015
"Odessza 1"	10,029.88	9,315.83	9,469.26
"Odessza 2"	10,150.08	9,667.04	10,222.44
Total:	20,179.96	18,982.87	19,691.69

Table 16: Changes of electricity costs (saveable cost units) (in EUR)

The electricity demand is mainly reflected in the pipeline transport activity of heating media and the air injection of boiler gas burners. After the development, the operation of the gas burners will decrease significantly, resulting in the reduction of electricity consumption.

Based on the gas consumption of the past three years, the peak heat demand of consumers of "Odessza 1" was 5.35 MW, demanding the functioning of 3.2 boilers of the installed six units. The peak heat demand of the consumer group of "Odessza 2" is 6.43 MW, demanding the functioning of 2.7 boilers of the installed five units.

The electricity demand of the gas boiler plant in case of TP boilers is 20 kW, and 23 kW for SLT boilers. By defining the working coefficient as an experimental value of 0.35 in the average of the heating season, the electricity consumption of boilers can be calculated as shown in Table 17 (measured consumption was not available):

"Odessza 1"	3.2 pc x 18 kW x 4,300 hours x 0.35 = 86,688 kWh
"Odessza 2	2.7 pc x 23 kW x 4,300 hours x 0.35 = 93,461 kWh
Total	180,149 kWh

Table 17: electricity consumption of boilers

Electricity costs in the savings of the boiler plants is summarized in Table 18.

"Odessza 1"	86,688 h x EUR 0.03189 /kWh = EUR 2,764.48
"Odessza 2	93,461 h x EUR 0.03189 /kWh = EUR 2,980.47
Total	EUR 5,774.95

Table 18: Electricity costs in the savings of the boiler plants

In conclusion, the net cost of purchase of energy sources from the district heating supply of the "Odessza" housing estate in Újszeged – in relation to possible cost elements in cost reduction – are as follows for the past three years:

- In 2013, EUR *1,126,418.44*
- In 2014, EUR *940,351.7*
- In 2015, EUR *851,610*

The average of the three years, ***EUR 972,793***

3.4. The location of the new facility

3.4.1. Aspects of location selection

The new geothermal heat supply system has three main units:

- Thermal wells for the extraction of thermal energy and the disposal of used fluids (production-reinjection doublet),
- The pipeline network necessary for the transportation of the fluids,
- The thermal centres for the transfer of the extracted and transported thermal energy to the consumer.

The un-built state of the territory owned or obtainable (purchasable) by the local government played a major role in the selection of the *thermal well location*. Furthermore, the location of the wells as close as possible to the consumers is another important cost-related aspect.

An important aspect for the selection of the two reinjection wells was their linear distance from the production well to be as long as possible, but minimum 1,000 m in order to minimize their interaction. It is important for the two reinjection wells to be at least 500 lm far from each other. The actual distances are defined for sandstone aquifers.

Another aspect was that the territory should be accessible with a custom-sized drilling system, which could be installed according to the mining officer's provisions regarding the drilling technology (placement of anchors, observance of inclination of distances etc.) and operated (ensuring the noise load according to provisions). The vicinity of the necessary construction and operation infrastructure (electricity, waste water disposal, accessibility, protection and security etc.) was another important aspect. Furthermore, since the territory is within city limits, the expectations and provisions of the town's chief architect, of town bodies and architectural authorities had to be observed as well.

The main aspects during the definition of the *pipeline network's* route were: there should be public areas with as few public utilities as possible, as much green working areas as possible, as few solid-surface public roads as possible to cross, the optimal accessibility of the institutions' boiler rooms, and the observance of traffic-technical provisions during the construction and operation-maintenance activities.

The main aspects for the selection of *thermal centres* were: existence of the space demands for the facilities to be created without building extension, if possible; and the possibility to connect the system to the existing heating system in an optimal and economic way.

Another important aspect is the definition of places for operation and maintenance, and ensuring the possibility for regular measurements.

3.4.2. Description of the location

The housing estate and its area were visited by taking into account the aspects described in the previous chapter. The housing estate is located in the southern part of the city, surrounded by small green zones with gardens. It includes the unused industrial territory of the former Hemp Factory, and Szeged's Botanical Garden, which offers pleasant leisure opportunities.

The location of the production thermal well is the green area near the former hemp factory, at the intersection of "Alsó kikötő sor" and "Kertész Street" (EOV (Uniform National Projection system of Hungary) coordinates: 99 945 and 735 381).

The reinjection thermal wells are placed in the small-garden area. The coordinates of the well (VS-1) at the end of Kendergyári Street (EOV coordinates: 99 536 and 736 601), and of the well at the intersection of Újszögedi Street – Kertész Street – and Vadrózsa Street (EOV coordinates: 99 045 and 736 790).

Two circuits of pipelines will be constructed within the project: one is connecting the thermal wells (thermal pipeline), while the other is connecting the consumer district heating stations with the thermal centre located near the production well (heat-supply heating circuit).

The route of the *thermal pipeline:* Production well engine room – Kertész utca – Füvészkerti út – Kendergyári utca – VS-1 reinjection well –Vadrózsa utca – VS-2 reinjection well.

The route of the *heat supply heating circuit:* production well engine room – Alsókikötő sor – Herke utca – "Odessza 1" district heating plant – Herke utca – Vedres utca – "Odessza 2" district heating plant – Vedres utca Odessza 3" district heating plant – Herke utca – Alsó kikötő sor – production well engine room. The pair of pipelines will be installed in the same trench.

The heat and water engineering fittings transferring and receiving the thermal heat are placed in the existing district heating plants, within the buildings.

In case of optional consumers (office building on the territory of the hemp factory, undertakings connected to the heat supply circuit, the Botanical Garden connected to the reinjection pipeline), the connection is created in their thermal centres.

The heavy- and weak-current control equipment and devices of the project will be installed in the same locations as the afore-mentioned units.

3.4.3. Road and public utility connections

The existence of the public utility infrastructure and its economical "accessibility" were important aspects during the selection of the location. Since the project locations are within city limits, the necessary road and public utility connections are available in an optimal way. Each location can be accessed on a solid-surface road, and electricity, water and waste water supply are available within a distance of maximum 200 m.

3.4.4. Analysis of the landscape potential

<u>Hydrogeology</u>

The hydrogeological modelling confirms the favourable geological features. According to it, the expected values in the area of Szeged are: a depth range of 1,800-2,100 m, good water-bearing Upper Pannonian sandstone aquifer, a discharge temperature of 90-95 ˚C, and a yield of 70-80 m^3/h. The expert's opinion confirms the long-term sustainability of the water resources, especially in the case of reinjection of the used fluids into the layers close to the production layers. The evolution of standing water levels of functioning wells also confirms the stability of thermal water resources of the region and their long-term sustainability.

<u>Ecology</u>

The planned project elements are located within city limits, in public areas, over the surface (well machinery) or under the ground (thermal well and pipelines), and the thermal centre and system control units will be installed in the boiler rooms of the existing buildings. The related areas are not nature conservation areas, the installation and operation of project elements will not cause any modification of the ecological environment. In case the Botanical Garden will be connected, every requirement for the protection of the flora and the fauna will be observed during implementation.

<u>Meteorological conditions</u>

The region's climate is identical with the country's temperate climate and is free of extreme weather conditions. The project elements are not exposed to extreme weather conditions, the change of meteorological conditions is practically without effect for the project.

3.5. Regulatory environment

3.5.1. International level

The expansion and efficiency increase of the utilization of renewable energies, including geothermal energy is a global interest for the replacement of fossil energy sources causing the greenhouse effect. There are a great number of international agreements, treaties and directives dealing with this issue: the Kyoto Protocol (1997), the declaration of the Earth Summit in Johannesburg, the findings of the Bali Climate Change Conference or the (2007), or the conclusions of the EU Water Framework directives. The newest climate agreement was signed by the participants of the world conference held last fall in Paris.

3.5.2. Compliance with national, regional and local regulations

<u>Norms regarding surface and groundwaters</u>

Act No. LVII of 1995 on Water Management and Act No. LIII of 1995 on the General Rules of Environmental Protection contain the legal norms regarding the utilization of geothermal energy coupled with water extraction. This involves the collaboration of the construction and operation approving authority with the locally competent Disaster Management authority including the Inspectorate for Environmental Protection, Nature Conservation and Water

Management, and the cooperation of territory owners (local governments) with the Office for Mining, the Office for Cultural Heritage, the Water Management Directorates, and the local bodies for public hygiene, health and work safety and law enforcement authorities and public-sector bodies (operators of public roads, rail systems, telecommunications, local public utility companies etc.).

Other important decrees on water management:

- Government Decree No. 219 of 2004 (VII.21.) on the protection of groundwater;
- Government Decree No. 220 of 2004 (VII.21.) on the rules of protecting the quality of surface waters;
- Decree No. 28 of 2004 (XII. 25.) KvVM of the Ministry of Environmental Protection and Water Management concerning emission standards of water-pollutant substances and laying down rules of application.

The Technical Inspection Department of the Hungarian Trade Licensing Office is also an authorising authority in issues regarding district heating pipelines and networks and heat-producing establishments.

<u>Environmental norms</u>

Act No. LII of 1995 contains the general rules of environmental protection, and government decree No. 314 of 2005 (XII. 25.) regulates the procedures of environmental impact assessment and the uniform authorisation procedure of utilization of the environment.

According to Act LIII of 1995 (on the General Rules of Environmental Protection), the Government defines in Decree No. 314 of 2005 (XII. 25.) the rules of environmental authorization procedure for subsurface water resources and water disposals.

Accordingly, an annual quantity of 5 million m^3 of extracted water, or the reinjection of the used fluids into deep reservoirs, automatically requires an environmental impact assessment. Annex No. 3 of the Decree contains the compulsory activities for the preliminary environmental impact assessment.

The reinjection activities of the proposed project indicate the obligatory implementation of a preliminary environmental impact assessment.

The project company, as the authorised project entity, submitted the preliminary assessment documents to the Lower Tisza District Environmental Protection, Nature Preservation and Water Management Inspectorate (ATIKÖTEVIFE) and the decision of the authority became definitive on 8 October 2012, according to which "the activity does not have a significant environmental impact, an environmental impact assessment must not be conducted".

<u>Mining norms</u>

Heat mining without water production is regulated in Act No. XLVIII of 1993 and in the Government Decree No. 203 of 1998 (XII.19.) issued for its execution.

<u>Local regulation</u>

The local features and specialities are specifically regulated on local and local government level. These could be location-specific local government regulations, legal rules, environmental provisions etc. affecting the project (e.g.: break-up of public areas, authorization for construction and urban planning of the engine room etc.).

Since the project is established within city limits, the concept should be submitted to the architectural and environmental committee of the Local Government Council. The necessary building permits are issued by the city's notary; however, there will be no overground facility established on classical public area within the project. The engineering units will be established on territories owned by the local government and/or the IKV (Real Estate Managing and Trustee Company Limited by Shares). The project does not conflict with the city's long-term urban development concept.

The local notary issues the permit for the break-up of public areas for the construction of pipelines, and the winning contractor is the permit holder.

The lightweight engine rooms and security fences do not require building permits.

3.6. Capacity, mass and energy balances

The previous chapters of the study, and the hydrogeological expert opinions confirm the possible establishment of a thermal well with an expected long-term and sustainable capacity of 70 m^3/h and a discharge temperature of 90°C. This is also confirmed by the thermal systems of Szeged and area that have been operating successfully and in a sustainable way for decades.

The conclusions drawn from an analysis on the evolution of the thermal medium's temperature and the theoretical consumption data, and their thermal coverage in the consumer circle in relation to the average weather conditions of 50 years are te following:

- In 3 of the 12 consumption locations, thermal energy "covers" almost the total heat demand for heating purposes,
- At an outside temperature higher than -2°C, the gas boilers do not light up in the "Odessza 1" plant,
- Starting from an outside temperature value around + 2 and 3° - including almost 80% of heating days – geothermal energy covers 9 consumption locations,
- At an outside temperature of around +7 and 8°C, every consumer can be completely supplied with geothermal energy,
- On a system level, 70% of the winter heat demand can be covered with thermal energy (63,850/91,027),
- The total geothermal heat quantity technically extractable in the system is 63,850 GJ, by a thermal water production of 304,789 m^3.

Changes in heat capacities are summarized in Tables 19, 20, 21.

"Odessza 1" heating plant	9,678 kW
"Odessza 2" heating plant	11,630 kW
Total	*21,308 kW*

Table 19: Built-in gas boiler capacity

“Odessza 1” heating plant	5,350 kW
“Odessza 2” heating plant	6,430 kW
Total	*11,780 kW*

Table 20: Current, functioning boiler capacity

“Odessza 1” heating plant	*3,456 kW*

Table 21: Heat capacity covered by geothermal energy

The new thermal system is able to cover ***~30%*** *of the housing estate’s peak heat demand.*

Based on average conditions of the actual gas consumption of three years, the heating plants will show the following thermal energy utilization values (during the calculation of thermal energy, we took into account a 10% efficiency improvement with the replacement of gas with a thermal plate heat exchanger) (Table 22).

	Institution	Natural gas utilization (GJ)	Thermal share (%)	Replaced natural gas (GJ)	Used thermal energy (GJ)
1.	“Odessza 1”	37,629	97.4	36,651	32,986
2.	“Odessza 2”	44,348	47.2	20,932	18,839
	Total	81,977	70.2	57,583	51,825

Table 22: Thermal energy utilizations

Notes to Table 22:

- The referenced temperature table deducts the heat utilization to the weather conditions of 50 years and the theoretical interior heat demands. The theoretical thermal share is transposed to the actual utilization based on real consumer habits.
- By reviewing the thermotechnical condition of the consumer buildings, we can see that the doors and windows were replaced in 18 % of the 1,144 households belonging to heating plant “Odessza 1” and external insulation was applied in 46 % of them. In case of the 1,163 households of the “Odessza 2” district, these values are significantly higher: 65 % of doors and windows were replaced, and 59 % of them had thermal insulation. This shows that there are significant reserves in the building renovation programmes, the complete implementation of which will result in a significant reduction of the heat demand with a heating circuit temperature difference of 60/40 °C and a significant increase of the rate of annual utilization of thermal energy (forecasted to 90% and higher!).

Geothermal energy currently available for the planned project

51,825 GJ.

According to the previous chapters and the parameters of the pumps moving the thermal water, we can calculate with the following electricity utilization values – as the auxiliary energy demand of the thermal system (4,300 hours for the heating season and we calculated with a coefficient of experienced downtime of the electrical systems) (Table 23).

Description	Calculation	Consumption (kWh)
Submersible pump	30x4,00x0.6	77,400
Circulation pump	44x4,300x0.6	113,520
Reinjection pumps	52x4,00x0.6	134,160
Thermal centre control	3x4,00x0.4	5,160
Outdoor lighting, maintenance	7x4,300x0.2	6,020
Total		336,260

Table 25: Auxiliary energy demand of the thermal system

Other functioning thermal projects (e.g.: based on the referenced geothermal public utility system of Hódmezővásárhely with a 15 years of successful operation) produced the following values: the production of 1 m^3 of thermal water requires electricity of 0.2kWh/m^3, the movement in the pipeline – considering the pressure demand due to the great thermal centre pressure loss – 0.8kWh/m^3, and reinjection another 0.375 kWh/m^3 electricity. As an average of the calculation, the calculated annual water consumption of 304,789 m^3 in the referenced temperature table (304,789x1.375) results in a consumption value of *419,080 kWh*.

The feasibility study considers the following value as the standard value of auxiliary energy utilization:

419,080 kWh

A 70-% thermal coverage results in a similar downtime increase in boiler operation. Accordingly, the saving of electricity consumption of boilers adds up to a value of 180,0149 kWh. This results in a total of (180,149 kWh x 0.7) *126,104 kWh*.

On that basis, the project has the following energy balance (Table 26, 27).

Description	Natural gas consumption (m^3)	Consumption (GJ)
Before the development	2,411,088	81,977
Replaced quantity	1,693,618	57,583
After the development	717,470	24,394

Table 26: Utilization balance of natural gas

Description	Electricity consumption (kWh)
Before the development, for heating purposes	615,183
Saving with the development at the boilers	-126,104
Electricity consumption of the development (thermal system)	419,080
Electricity utilization after the development	908,159

Table 27 Utilization balance of electricity – in relation to the average of the past three years

D.5.4.1. Summary report on heat sector analysis
Annex 2. Slovenia national report

November 2017

D.5.4.1. Summary report on heat sector analysis

Annex 2. Slovenia national report

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Table of contents

1. National energy policy and balance overview

1.1. Slovenian energy policies focused on heating and cooling sectors

1.1.1. Introduction

This chapter is a summarizes publicly available information from various state organizations such as the Ministry of Infrastructure, the Energy Agency, etc.

At the moment the validity of umbrella "national energy and development documents" has expired, and the new strategy, the Energy Concept of Slovenia (EKS) and the Long-Term Development Strategy of Slovenia until 2050 are under preparation.

The Energy Act (EZ-1) defines the EKS as the basic development document representing the national energy program. EKS's headline targets are the reduction of greenhouse gas (GHG) emissions by at least 20% in 2030 compared to the 1990 levels and the reduction of GHG-related energy use by the target of 80% in 2050 compared to the level of the year 1990.

In addition, the past long-term development strategy of Slovenia has already been based on the principles of sustainable development and the integration of development policies. Sustainable development as a horizontal principle is also defined by the Operational Program for the Implementation of the European Cohesion Policy for the period 2014-2020 (OP EKP) (IJS, 2017).

In the subchapters below we will try to list all the relevant (valid and in preparation) State documents and emphasize their relevance for heating and cooling sector.

1.1.2. Slovenian Energy concept

The Slovenian Energy concept is currently (December, 2017) in public hearing. In accordance with the Energy Act, the Energy Concept of Slovenia (EKS) gives directions and vision of Slovenia's energy policy, which will be determined in the more concrete form of measures in future action plans. The energy concept of Slovenia is a document of a directional nature and therefore does not define until individual concrete projects. It defines strategic objectives and guidelines by 2030 and indicative targets by 2050, and in such a way sets the starting points for further decisions in providing reliable supply of energy in a sustainable and competitive way (MZI, 2017c).

In EKS several screening scenarios were prepared for energy balances that lead towards meeting the long-term goal of a low-carbon society. A benchmark scenario was also prepared to allow comparison of the scenarios of decarburization given the situation that would be with current measures, i.e. without future new policies and measures.

The revised scenarios are very similar to the time horizon of the Energy Concept. Scenarios show an intensive introduction of renewable energy sources (RES), especially in the period after 2030. Already previously, or gradually by 2030, it will be necessary to prepare appropriate technical and legislative environment for the exploitation of RES and intensive investments in energy efficiency, energy systems and services. With regard to the necessary investments in energy, the prepared scenarios are very similar to situation in 2030.

Thus, the share of RES in the balance of primary sources will increase significantly. The speed of changing the structure of the use of primary resources will largely depend on the success of implementing measures to achieve direction and the objectives of the EKS, as well as the future decision on the use of nuclear energy after the termination of operation existing nuclear power plant. In the period up to 2030, coal will have still important role, while taking into account the assumptions of the scenarios, it will no longer be in a set of energy sources aftermath 2050.

The goals for energy efficiency use and renewable energy sources in year 2020 (Table 1) are set on national level, also the target for reduction of emission of GHG:

Adopt objectives for 2020	
Reduction of GHG emissions relative to 1990 (%)	13%
Share of RES in gross final energy consumption (%)	25%
EEU - primary energy savings (%, TWh) according to PRIMES 2007 projections	23%, 83 TWh

Table 1: The goals for energy efficiency use and renewable energy sources

In the EKS, certain orientations and goals will be achieved by pursuing key measures, namely:

• Increasing energy efficiency,

• Raising awareness among consumers and providers of sustainable supply and energy management,

• Supporting the development of knowledge in the area of sustainable energy supply and energy management,

• Abandoning fossil resources and gradually switching to renewable and low carbon sources,

• Introduction of advanced energy systems and services.

Concrete measures to achieve the objectives of the EKS, which will be added to the current policies and measures (reference scenario) that will be specified in subordinate implementation documents - action plans for individual areas of supply and energy management. Slovenia will comply with EU legislation and will carefully define the objectives and measures for the year 2030 within the Integrated National Climate Energy Plan (CNEPN), which will bring together existing sectors action plans.

According to scenarios of energy balance projections, the share of RES in all areas of energy use will be constantly increasing. Solar energy will take over a big share of the burden of abandoning fossil fuels. Therefore, Slovenia will even more intensively increase the use of solar energy in the period after 2030, especially for the production of electricity. It is solar energy that will presumably play an important role in the self-handling of buildings, neighbourhoods, wider communities.

The transition to a low-carbon society will require the use of all available renewables in the long run sources, including the use of heat from geothermal aquifers and the use of shallow geothermal energy. The priority will be to promote the use of geothermal energy, especially for heating and cooling in a sustainable environment friendly way, even using geothermal heat pumps.

Approximately 40% of the final energy is consumed for heating and cooling of buildings, including the heat consumption in industrial processes. Due to new standards and, consequently, better energy efficiency of buildings, this proportion will gradually decrease. In buildings, consumption will be reduced by 30% of final energy by 2030 compared to 2005 and at least two thirds of the energy consumption will be from RES. Heating systems will adapt and become more energy efficient and environmentally friendly.

All district heating systems will have to be energy efficient and to the greatest extent possible will have to include local excess heat. We will encourage them in particular in areas of a concentrated settlement. In the heating and cooling of buildings and in industrial processes, the use of RES and excess heat will be further promoted.

1.1.3. Operative program of European Cohesion policy

Analyses of Slovenia's progress in fulfilling national targets for the 2020 indicate gaps in more efficient use of energy sources (SVLK, 2015) (Table 2).

EU 2020 targets for smart growth	Current situation (2015)	Goals by 2020 (NRP)
20% less greenhouse gas emissions (GHG)	emissions which are not included in the emission coupons scheme 11.5% (2012)	Emissions of GHG from areas which are not included in the emission coupons scheme dealing can be increased by 4% compared to 2005
20% renewable energy sources (RES) in the final consumes	22.0% (updated NREAP, 2016)	increase of the share of RES in final consumption to 25%
A 20% increase in energy efficiency (EEU)	5.7% of the final energy savings under the Directive 2006/32/EC (2012)	achieving 9% energy savings until 2016 in accordance with Directive 2006/32/EC and a 20% improvement in EEU 2020 by 2020 Directive 2012/27/EC

Table 2: Contribution of Slovenia in achieving the goals of the EU 2020 strategy

Despite the investments made so far in energy rehabilitation of buildings, in renewable energy sources (RES) and efficient use of electricity, the needs for continuing and upgrading such investments in both cohesion regions are high.

Improvement of the energy efficiency of the building fund will be a key measure of a future energy policy for the supply of heat. At the same time, an ambitious transition to low carbon resources will be undertaken, namely the accelerated introduction of RES systems for heat production, with the priority promotion of the use of wood biomass, solar and geothermal energy, and the exploitation of wood biomass in high efficiency cogeneration or combined heat and power (CHP) and district heating systems (CHPDH). Incentives will be in line with the requirements of Directive 2008/50/EC and the clean air package in Europe, since the construction of new individual systems on wood biomass will not be encouraged in areas with already introduced remote systems and with the air of contaminated degraded areas.

Efficient use of resources and energy is essential for improving the competitiveness of the economy and reducing environmental pressures. Within the priority axis 4 - Support to the transition to a low-carbon economy in all sectors, investments will also target the measures that will contribute to reducing environmental pressures and adapting to climate change.

According to Directive 2012/27/EU, a target of a 20% improvement in energy efficiency should be achieved by 2020.

Directive 2012/27/EU also imposes an annual energy restoration of 3% of the total floor area of the buildings that are heated / cooled and owned and used by the public sector (central government), and therefore the renovation of these buildings.

According to Directive 2010/31/EU, all new buildings, owned and used by the public sector, should be virtually non-exhaustive from 2018, and in other sectors from 2020.

According to Directive 2009/28/EC Slovenia is obliged to achieve at least a 25% share of renewable energy sources (RES) in the use of gross final energy by 2020.

Available unofficial data for 2012 indicate the fulfilment of the intermediate annual target of the RES share identified by NREAP, but further investments in this area are urgently needed to meet the 2020 targets.

In order to increase the use of renewable energy sources, investment incentives should be introduced in the renewal of the RES scheme for the production of electricity from RES in order to relieve the final consumers of energy.

In the field of RES targets in the heat sector, the greatest effects are in promoting efficient district heating from RES (biomass, geothermal energy).

40% of urban emissions come from buildings, and cities are encouraged to take measures to increase the energy efficiency of the building fund.

Slovenia will find it difficult to achieve the set national targets under the climate package, therefore, for the thematic objective 4, priority axis 2.4 Sustainable use and energy production and smart grids in the period 2014-2020 Slovenia will spend 281 million EUR (9.38% of total assets, EUR 260 million from KS, and EUR 21 million from the ERDF), which will be a combination of the use of return and non-refundable resources to provide multiplier effects.

The reduction in greenhouse gas emissions in Slovenia is mainly due to a decline in economic activity. The available data indicate that intermediate targets for renewable sources (NREAP) have been met and are effectively used up to 2016 (AP-EEU), but there has been no significant systemic shift in this area over the past period. Promotion of measures to improve energy efficiency and the use of renewable energy sources in the public sector, households and businesses, is all the more urgent in Slovenia due to the pressure of increasing greenhouse gas emissions from transport. If Slovenia wants to achieve national commitments by 2020, it has to create an ambitious program of national measures for efficient energy use (EEU) and renewable energy (RES).

In this priority investment, the emphasis will be on promoting investments in energy rehabilitation of buildings, which is a great potential for reducing energy consumption. An important role will be played by the public sector, especially the central and / a narrower government, which should serve as an example of renewal towards greater energy efficiency in households. Smart grids are also contributing to the reduction of greenhouse gas emissions and efficient energy use, enabling the development of new high value-added products and services and helping to create highly qualified jobs. Investments will be supported by the cohesion funds through a single approach in both cohesion regions, as it is reasonable that RES is used where technical potential is, and the demand for investment in efficient use of energy is high in both cohesion regions.

Promotion of energy efficiency, smart energy management and the use of renewable energy sources in public infrastructure, including public buildings, and the housing sector. With this priority investment, Slovenia contributes to improving energy efficiency by 20% by 2020 in line with Directive 2012/27/EU.

Promotion of the production and distribution of energy from renewable sources, with the aim of increasing the share of renewable energy sources (increased electricity, heat and cooling from RES) in end-use energy. With this priority investment, we aim to achieve the goal of increasing the share of renewable energy sources (RES) in end use of energy (Table 3). According to Directive 2009/28/EC, Slovenia has the obligation to achieve at least a 25% share of renewable sources in the use of gross final energy by 2020. In order to achieve the goal it will also be necessary to limit the growth of final energy consumption, to enforce efficient energy use (EEU) and to promote the use of RES more rapidly as a priority for economic development.

Indicator	Unit	Region category	Baseline value (2013)	Target value (2023)	Data source	Frequency of reporting
share of the use of gross final energy from RES in heat supply	%	Slovenia	31.7	34.0	Projections of long-term energy balances 2014	Annual
share of the use of gross final energy from RES in electricity consumption	%	Slovenia	32.8	40.0	Projections of long-term energy balances 2014	Annual

Table 3: Indicators of results

In order to achieve the target share of RES in the use of gross final energy in the field of electricity and heat, the use of all environmentally acceptable RES should be encouraged. In the context of a priority investment, support is intended for these actions with respect to each area:

- Heat for heating and cooling and high efficient cogeneration: To increase the production of heat from renewable sources, investments in the construction of new and reconstruction of existing heating systems and incentives for connecting new users to existing facilities will be supported (geothermal heating systems, solar collectors, wood biomass in the public sector, services and industry, district heating systems on wood biomass over 1 MW, local district heating systems on wood biomass up to 1 MW of power, heat pumps). High potential is the remote heating systems for wood biomass where the synergic effects are expressed both from the point of view of the use of available energy source, the reduction of dust particles emissions and the construction of the wood processing chain, and the associated creation of new jobs.

When selecting the projects, horizontal principles will be taken into account in order to prioritize projects that will:

- Be cost-effective;
- Have clearly stated environmental performance (maximum emission reductions, maximum energy savings and nature conservation) and cost-effectiveness, as well as

projects that, with minimal financial support, will generate the greatest possible positive synergy effects for the economy;

- Enable district heating / cooling through cogeneration,
- Be placed in a space so that individual units of heritage, including their influence area, will not be affected. In addition, the following aspects will be taken into consideration when selecting projects,
- Biomass heating projects will also take into account parameters affecting air quality, thus achieving the synergic effects of reducing greenhouse gas emissions and improving air quality in cities. Such solutions will be selected for the emission of total dust from combustion plants that will comply with the restrictions of the revised NEC directive. When using biomass, special attention will be given to the sustainable use of forests whenever possible,
- When designing and operating geothermal heating systems, projects will be selected to ensure that the use of a geothermal energy source will not have a significant impact on groundwater and surface water, while placing the objects in space will be in line with EU environmental legislation,
- The placement of the RES objects in the room will be in accordance with the NREAP, for which a comprehensive environmental impact assessment will be carried out, whereby, where appropriate, priority will be given to those that can be placed on degraded areas or on building objects.

1.1.4. Energy efficiency Action Plan

Energy efficiency Action Plan for a period 2017–2020 (AP-EEU 2020) is the second action plan prepared by Slovenia within the framework of Directive 2012/27/EC on energy efficiency and the fourth Action Plan since 2008.

The Action Plan covers essential measures to improve energy efficiency, including the expected and achieved energy savings, with a view to achieving the national objective of increasing energy efficiency by 2020, and Slovenia's contribution to achieving a common EU target - increasing energy efficiency by 20%. The goal is that the use of primary energy in Slovenia in 2020 will not exceed 7,125 Mtoe, which means that it should not increase by more than 2% compared to the base year 2012.

In the heating and cooling sector two measures are foreseen:

- Measure D.1 Co-financing program for the construction and extension of district heating systems on RES. The program enables the granting of grants for the co-financing of district heating (DH) projects on RES. Financial incentives are intended for investments in new DH-RES and micro-systems DH-RES, as well as expansion of existing DH-RES systems and construction of new boiler rooms with wood biomass boilers, wood biomass or solar systems. The program is conducted under the Operational program for the implementation of the European Cohesion Policy for the period 2014-2020 (4. Thematic objective). In this measure the geothermal DH is not mentioned directly.

- Measure D.2 Financial incentives for the Eco-Fund for the sustainable development of the DH schemes. The Eco-Fund will prepare a comprehensive program of financial incentives to promote the sustainable development of existing DH systems and increase their competitiveness by implementing various measures: connecting new users to the DH system; introduction of RES in the supply of heat and cooling; exploitation of excess heat from industry; construction of heat accumulators, etc.

As an additional measure in the period 2017-2020 for the development of the heating and cooling sector, a comprehensive strategy for heating and cooling in Slovenia will be developed, which will provide clear medium and long term goals and criteria for the development of an effective DH, DC and the use of CHP, which will be a good basis for establishing the necessary support environment for the further development of these systems and local planning (preparation of local energy concepts - LEK). Particular emphasis will be put on the future development of DC systems and their sustainable transition (increasing efficiency, increasing RES and excess heat and increasing their competitiveness). The need to conduct comprehensive assessments of options for the use of CHP and efficient district heating at the local level, including cost-benefit analyses, shall be considered and the framework for the preparation and implementation of the LEK shall be defined accordingly.

The operationalization of the goals of the heating and cooling strategy will be defined in the action plan for district heating, which will determine the necessary activities, operators, timetable of implementation and the necessary financial resources for the implementation of the activity.

In order to support planning at the national, local and project level, a uniform collection and updating of the required databases and publicly accessible tools will be established. A thermal map of Slovenia will be prepared, which will include data on buildings, energy infrastructure, energy systems, energy use, etc. A heat map maintenance system will be in place, comprising an iterative process of data collection and processing, database structuring, GIS mapping, definition of accessibility and regular map evaluation. The training for heat map users will be carried out, in particular, for energy system planners, energy service providers and LEK preparers, and for the Sustainable Energy Action Plans (SEAP) and the Sustainable Energy and Climate Action Plans (SECAP) elaboration.

1.1.5. National Renewable energy action plan for period 2010 – 2020 (NREAP) (Update 2017)

The National Renewable Energy Sources Action Plan (NREAP) for the period 2010-2020 has been prepared on the basis of Directive 2009/28/EC of the European parliament and of the council of 23 April 2009.

The goals of the Slovenian energy policy for renewable energy sources are:

- Provide a 25% share of renewable energy in end-use energy and 10% renewable energy in transport by 2020,
- Stop the growth of final energy consumption,
- To promote the efficient use of energy and renewable energy as a priority for economic development,
- Long-term increase in the share of renewable energy in end-use energy by 2030 and beyond.

The sectoral objectives of the NREAP for 2020 are achieving the following target shares of RES in gross final energy consumption:

- RES - Heating and cooling 30.8%
- RES - Electricity......................39.3%
- RES - Transport......................10.5%

In 2017 the Slovenian NREAP 2010-20120 was updated (MZI, 2017a, 2017b). The update was needed, because even Slovenia is achieving the intermediate targets from AN OVE-2010, the current practice will not be enough to reach the goals of 25% RES in 2020 from Directive 2009/28/EC. The RES share increased only by 1.5 % between 2010 and 2015, and it has to be increased by 3.0 % until 2020.

The share of RES for heating and cooling as the target for 2020 was 30.8% in gross final energy consumption, but already in 2016 the estimated share reached 32.7 %. The renewed goal is 34.5 %, with overall share of RES in all three sectors (electricity, heating and cooling and transport) staying at 25 %. The renewed share of electricity dropped from 39.3 % to 38.6 %.

The heating and cooling sector share of renewable energy sources was 18.9% in the reference year 2005 and 32.7% in 2015. In the field of heat supply, it is noticeable a positive long-term trend of improving the share of renewable energy sources. Great penetration of sustainable buildings is expected through tight regulations on energy properties' buildings and removing barriers to renovating buildings at all levels. Similarly there is potential of use of RES in district heating and cooling systems. Most instruments are already set. It's a sectoral goal set at 34.5% level, with additional measures in the field of renewable energy sources and efficient use of energy, the goal for this sector could even be increased. Sectoral the target is 3.2 percentage points higher after the program revision than in the NREAP 2010.

Estimated costs and benefits of the RES support measures in the period 2017-2020 (Table 4) for the use of geothermal energy for heating and cooling (without heat pumps) are set to:

Measure/ technology	Enlargement use renewable resources [ktoe/year]	Costs of support in period 2017-2020 [mio EUR]	Investments in period 2017-2020 [mio EUR]	Reduction of CO2 emissions (2020) [ktCO2/ year]	Created working places for operation and maintenance (2020) [no. w.places]	Created working places (production, construction, installation) (2017-2020) [man years]
Geothermal energy	2.8	5.87	12.1	6.4	9	35

Table 4: Estimated costs and benefits of the RES support measures 2017 - 2020

The financial resources for promotion of measures of NREAP between 2017 and 2020 are:

- A contribution into providing support to the production of electricity in cogeneration with high efficiency and renewable energy, paid by the final energy consumers based on EZ-1;

- A contribution to energy efficiency paid by energy consumers based on EZ-1 and providing the means for implementing the energy efficiency improvement program Eco Fund. The program is part of the Eco Fund's business and financial plan, a set of measures program is defined in NREAP;

- Funds of the Climate Change Fund of the Republic of Slovenia, which are dedicated budget funds in accordance with Environmental protection Act (ZVO-1). Revenue from the fund is revenue from the sale of emission coupons at the auction and is dependent on the market price of allowances on the European market;

-EU Structural Funds and Investment Funds to implement European Cohesion policies in the financial perspective 2014-2020. Consumption of funds from the regional development, the European Social Fund and the Cohesion Fund planned in the current Operational Program for the implementation of the European cohesion policy in the period 2014-2020 (OP ECP). The program identifies the priority investments in which will Slovenia have invested funds from European cohesion policy in the 2014-2020 with a view to achieving the national and EU 2020 targets. Consumption of funds The European Rural Development Fund is planned in the adopted Development Program for the period 2014-2020;

- Budgetary funds of the Republic of Slovenia to provide Slovenian participation in the implementation of the European cohesion policy;

- Resources of the Water Fund are dedicated budget funds; revenue of the Fund is revenues from water rights payments and water reimbursement in accordance with the Water Act. Significant parts of the fund's revenues are concessions for the production of electricity in hydroelectric power plants. The funds are also used for the construction of infrastructure within the construction of Hydropower plants on Sava River in accordance with the Water Act and The Act on the Conditions of the Concession for the Exploitation of the Energy Potential of Lower Sava.

The Updated NREAP states that the effectiveness of implementing measures to promote RES will have to be substantially intensified and improved. The support scheme, similar as for production of electricity from RES, is also foreseen for heat.

1.2. Energy balance of Republic of Slovenia

The energy balance of the Republic of Slovenia (EBRS) for 2017 (Energy Directorate, 2017) is made according to the internationally comparable OECD/IEA methodology, so the data provided are comparable with the EU countries. The annual EBRS forecasts the total annual consumption of individual energy sources and ways of ensuring energy supply in the country. The Energy Ministry, in accordance with the second paragraph of Article 25 of the Energy Act (EZ-1) (Official Gazette of the Republic of Slovenia, Nos. 17/2014 and 81/2015), submits an annual energy balance to the Government. The EBRS consists of the following sets:

1. **Energy supply**
   Domestic production, import, export, international marine warehouses, stock change
2. **Transformations**
   Entrance to transformation, exit from transformation, reclassifications, transfers and returns
3. **Own use and losses**
4. **Final energy consumption**
   Energy and non-energy end (final) use.

The supply of domestic energy sources was in 2016 also be based on lignite, hydro energy, wood biomass and electricity from the nuclear power plant (NPP). Because Slovenia's energy needs are greater than domestic production capacities, in 2016 Slovenia covered slightly less than half of the energy needs (43.3%) with sources of imports. In total, Slovenia imported brown coal, black coal and anthracite, coke, petroleum products and natural gas.

Energy supply or gross domestic consumption (e.g. TPES - Total Primary Energy Supply or Gross Inland Consumption) is the consumption of energy within the country (Formula is: domestic production + import + change stock - export - international marine warehouses).

Energy supply or Gross Inland Consumption (GIC) amounted to 281.7 PJ in 2016 and increased by 4.3% compared to 2015. It was obtained from: 3,787 kt of solid fuels (4.3% compared with 2015), 2,273 kt of petroleum products (5.0%), 865 million Sm3 of natural gas (+6.0%), 62,340 TJ of nuclear energy (1.1%), 4,503 GWh of hydro energy (8.3%), 1,177 GWh of electricity as the difference between import and export (it was exported), and 32,744 TJ of renewable energy including waste (1.7%). The Republic of Croatia received 2,857 GWh, which is half of the Krško NPP production of electricity.

Slovenia's **energy dependence** on imports amounted to 45% in 2016.

Final energy consumption (FEC) or Energy final consumption is energy used in the sectors of industry (manufacturing and construction), transport, households and other consumers, and does not include consumption in transformation, own consumption of the energy sector and non-energy use. The final energy consumption consists of the following sets (according to the standard classification of activities SKD 2008, which is harmonized with the international classification of activities according to the EU NACE Rev. 2):

1. Manufacturing and construction
2. Transport
3. Households
4. Other consumption (services and other consumption)

Final consumption in 2016 was 206.4 PJ and was 3.8% higher than in 2015. Out of this, final energy consumption (FEC) amounted to 204.0 PJ, own consumption of the energy sector was 0.5 PJ, and for non-energy purposes 1.9 PJ was used in 2016. Some 52.0 PJ was spent in manufacturing and construction (industry), 79.7 PJ was used in transport, in households 48.0 PJ, while in other consumption 24.4 PJ was used. In the structure of final energy consumption, in 2016 the share of petroleum products stranded at 46.7% share, followed by electricity (23.0%), renewable energy sources (13.0%), natural gas (12.3%), heat (3.6%), solid fuels (0.7%) and non-renewable industrial waste (0.7%).

Final consumption or Available for final consumption (Total Final Consumption, TFC) is the sum of energy consumption, non-energy use and own use of the energy sector.

The generation of **electricity** on the generator of all power plants on the territory of the Republic of Slovenia amounted to 16,500 GWh in 2016 and increased by 9.3% compared to 2015. The final consumption of electricity amounted to 13,121 GWh and was by 1.8% higher than in 2015. In the industrial sector, 6,235 GWh was spent (+0.6% compared to 2015), 3,260 GWh in households, 3,366 GWh in the rest of the sector and 166 GWh in traffic.

In accordance with the third paragraph of Article 25 of the EZ-1, the annual energy balance also contains a plan for the operation of a support scheme for electricity from renewable sources and from high-efficiency cogeneration and a forecast of available financial resources for achieving the anticipated annual objectives of the support scheme.

The compulsory component of the annual energy balance is also the plan for the operation of a support scheme for electricity from renewable energy sources (RES) and from high-efficiency cogeneration (CHP), as well as a forecast of available financial resources for achieving the anticipated annual objectives of the support scheme. Every year until 1 October, the Energy Agency must publish a public invitation on the basis of Article 373 of the Energy Act (EZ-1) inviting the investors to register projects for production facilities with which they apply for entry into the support scheme. Funds in the amount of 183 million € will be provided for the implementation of the support scheme on the basis of the provisions of Article 377 of the Energy Act in 2017.

In 2016 a total of 9,003 TJ of **district heat** was produced, which is +3.7% more than in 2015. The final consumption amounted to 7,394 TJ, and its own use and losses amounted to 1,608 TJ. Most heat was used in the household sector, namely 3,435 TJ, which is 7% more than in 2015.

The **energy supply from RES** (without hydro power) amounted to 32,744 TJ in 2016, which was -1.8% more than in 2015. The supply of non-renewable industrial waste (NRIW) amounted to 1,876 TJ in 2016, which was by + 4.1% more than in 2015. In the structure of supply with RES and NRIW, wood and other solid biomass are predominant with a 77.8% share (+1.0% compared to 2015). The following are geothermal energy with 5.7%, NRIW 5.7%, solar energy 4.3%, other biogas 3.1%, biodiesel 1.9% and other RES (biobenzine, landfill gas, sewage gas and wind energy) with a 1.4% share.

Due to the successful ecological rehabilitation of large fireplaces and the implementation of the program of gradual closing of domestic coal mines, the share of imported, more environmentally-friendly fuels with a lower sulphur content increases over the years. The use of coal in transformation takes place only in large thermal power plants for combined cogeneration of heat and power (electricity) (CHP), equipped with appropriate cleaning devices.

The share of RES in total gross final energy consumption was 22.1% in 2016 and will be 22.2% when the trend of stabilization of final consumption in 2017 continues.

1.2.1. Primary energy

A consolidated balance at the level of primary energy supply in Slovenia, according to the individual energy source per individual items of energy supply (domestic production, imports, exports, stock changes, international maritime warehouses), shows that Gross Domestic Consumption amounted to 281.7 PJ in 2016 and increased by 4.3% compared to 2015. It was obtained from: 3,786.8 kt of solid fuels (+4.3% compared with 2015), 2,273.3 kt of petroleum products (+5.0%), 865.3 million Sm3 of natural gas (+6.0%), 62,340 TJ of nuclear energy (+1.2%), 4,503 GWh (16,212 TJ) of hydro energy (+8.3%), 1,177 GWh (4,236 TJ) of electricity as the difference between import and export, and 32,744 TJ of renewable energy including waste (+1.8%). The Republic of Croatia received 2,857.5 GWh (10,287 TJ), which was half of the Krško NPP production of electricity in 2016.

At the level of primary energy supply in 2016, the share of domestic solid fuels represented 82.1% of all planned demand for solid fuels. The share of domestic natural gas was 0.6% of all necessary quantities of natural gas and oil products in its entirety, were imported to Slovenia.

In 2016 petroleum products dominated with 34.5% of structural share at the level of primary supply with energy, following by: nuclear energy (22.1%), solid fuels (17.1%), RES (11%), natural gas (10.5%), hydro energy combined with net exports of electricity (7.3%) and NRIW (0.7%) (Figure 1).

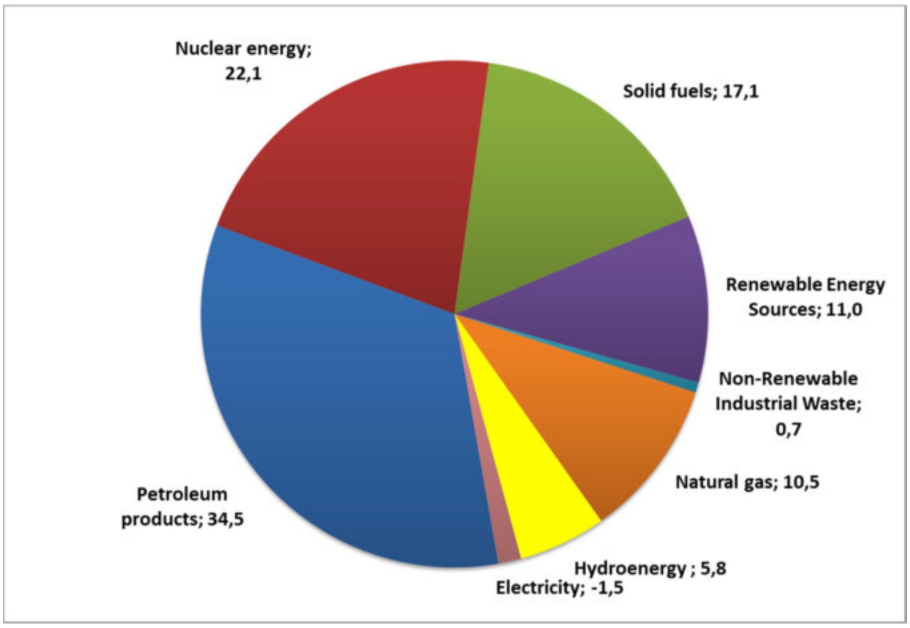

Figure 1: Structure (%) of primary supply with energy by sources in Slovenia in 2017 (Energy Directorate, 2017).

Final consumption in Slovenia in 2016 was 206.4 PJ and was 3.8% higher than in 2015. Out of this, final energy consumption (FEC) amounted to 204.0 PJ, own consumption of the energy sector was 0.5 PJ, and for non-energy purposes 1.9 PJ was spent in 2016. Some 52.0 PJ (+01.1% over 2015, structural share 25.5%) was spent in manufacturing and construction (industry), 79.7 PJ was used in transport (+ 5.7%, share 39.1%), in households 48.0 PJ (+3.3%, share 23.5%), while in other consumption 24.4 PJ (+5.5%, share 11.9%) was used. Final energy consumption for a period 2015 to 2017 is presented in Figure 2. In the structure of final energy consumption, the share of petroleum products stands at 46.7% share, followed by electricity (23.0%), renewable energy sources (12.9%), natural gas (12.3%), heat (3.6 %), solid fuels (0.7%) and non-renewable industrial waste (0.7%). These shares are shown in Figure 3.

With regard to individual energy sources the petroleum products are presented in Figure 4 in a detailed breakdown from which it is obvious that at the level of primary supply with petroleum products in 2016 a majority share of 65.0% was contributed by diesel fuel.

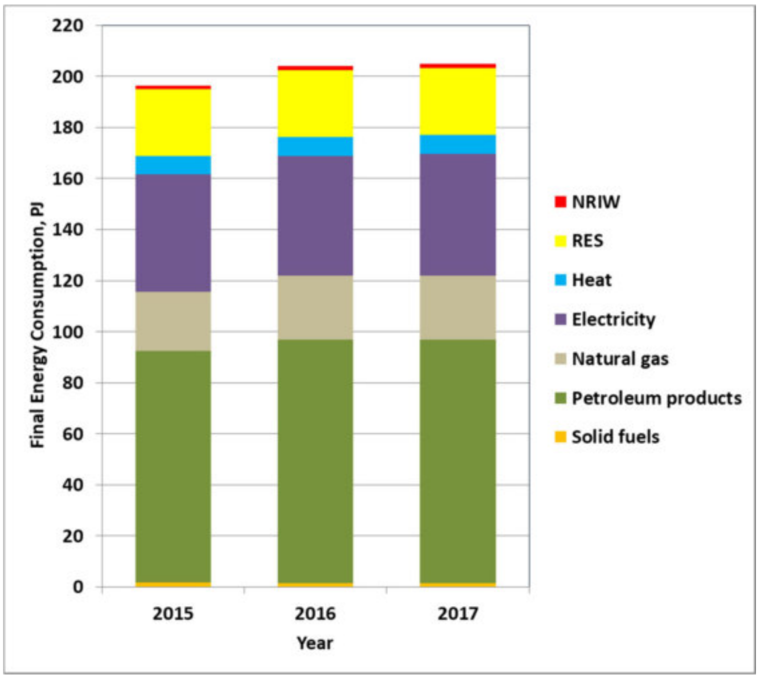

Figure 2: Slovenia's final energy consumption (in PJ) by sources in 2015 - 2017 (Source: Energy Directorate, 2017); RES: renewable energy sources, NRIW: non-renewable industrial waste.

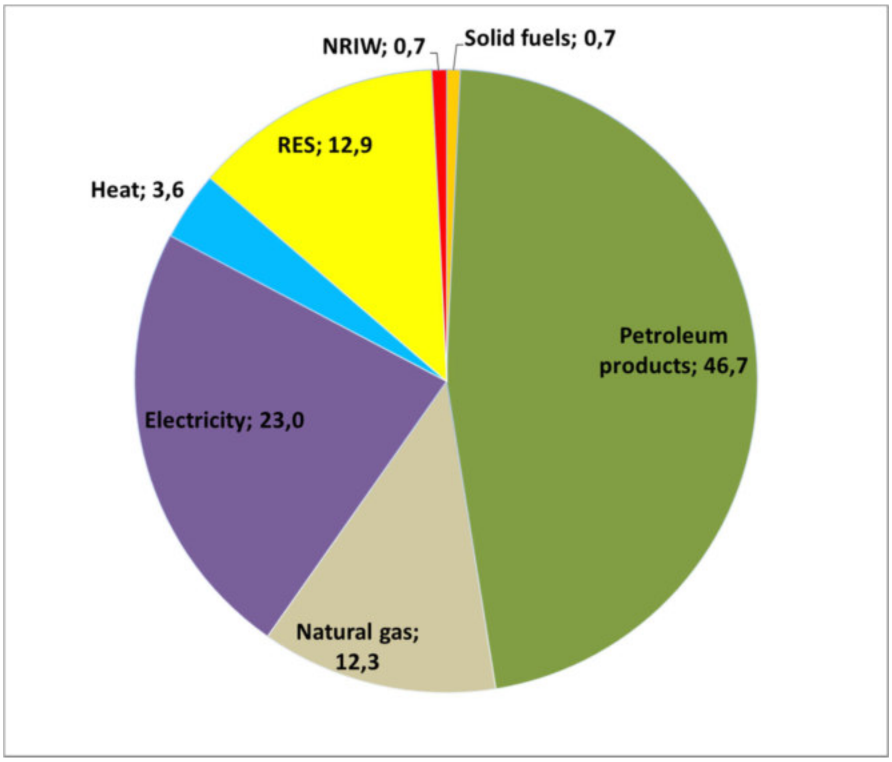

Figure 3: Structure (%) of final energy consumption by sources in 2017 (Source: Energy Directorate, 2017); RES: Renewable energy sources, NRIW: non-renewable industrial waste.

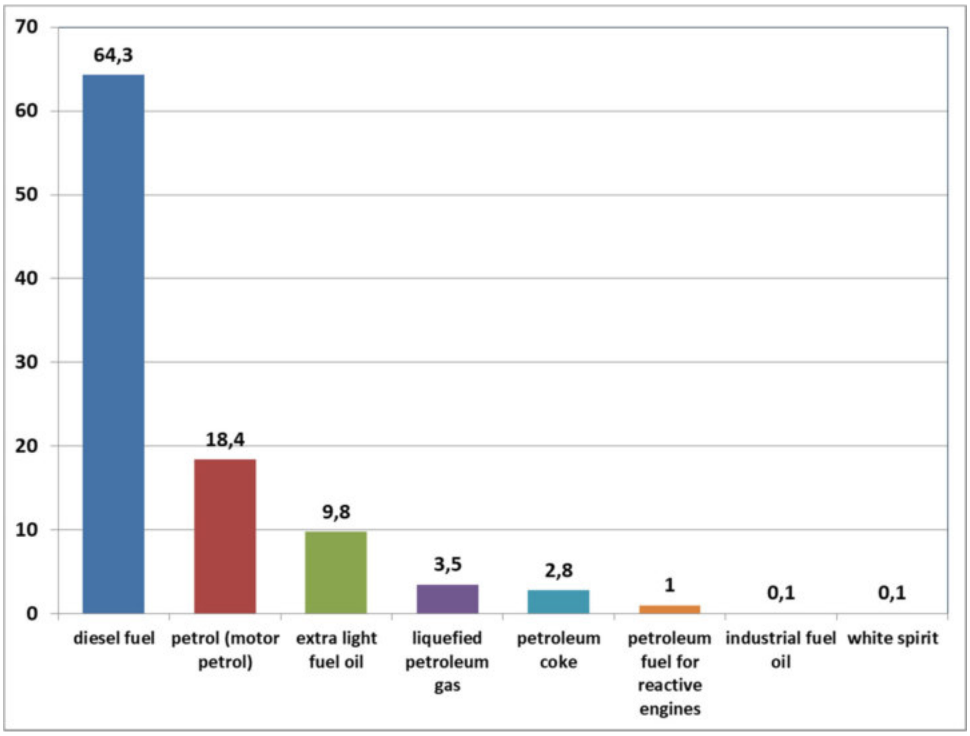

Figure 4: Structure (%) of energy supply with petroleum products in 2017 in Slovenia (Source: Energy Directorate, 2017)

1.2.2. The use of renewable energy sources in Slovenia (NREAP targets and performance)

Energy supply with renewable energy sources (excluding hydro power) together with non – renewable industrial waste (NRIW) amounted to 32,744 TJ in 2016, which was by 1.8% more than in 2015. Final consumption of RES + NRIW was 27,938 TJ in 2016 and was by 1.5% more than in 2015. The energy supply from RES and NRIW in relation to the individual energy source is shown in Table 5 (see also Figure 5).

Energy supply from RES and NRIW (TJ)	**2015**	**2016**	**2017**
	realization	realization	forecast
Geothermal energy	1654	1877	1942
Solar energy	1443	1420	1528
Wind energy	22	21	23
Wood and other solid biomass	24708	25475	25218
Landfill gas	210	153	142
Gas from the treatment plants	101	92	84
Other biogas	931	1018	1116
Biodiesel	1013	634	558
Biobenzine (biopetrol)	277	178	168
RES	**30359**	**30868**	**30779**
NRIW	**1802**	**1876**	**1898**
RES + NRIW	**32161**	**32744**	**32677**

Table 5: Energy supply from RES and NRIW by energy sources in Slovenia in 2015 - 2017 (Source: Energy Directorate, 2017).

In 2016, the supply of renewable energy (without hydro power) amounted to 30,868 TJ, which was by 1.7% more than in 2015. Most of the renewable energy from RES is derived from wood and wood biomass, whose domestic production amounted to 25,475 TJ in 2016 and was by 3.1% more than in 2015. In 2016, the supply of non-renewable industrial waste (NRIW) amounted to 1876 TJ, which was by 4.1% more than in 2015.

Primary energy supply from RES and NRIW is dominated in Slovenia by the share of wood and other solid biomass with a 77.8% share. Following are: geothermal energy (5.7%), NRIW (5.7%), solar energy (4.3%), other biogas (3.1%), biodiesel (1.9%), biobenzine (0.5%), landfill gas (0.5%), gas from the treatment plants or sewage gas (0.3%), wind energy (0.1%).

Final consumption of energy from RES and NRIW with regard to individual energy sources in Slovenia is shown in Table 6 (see also Figure 6).

Final consumption of energy from RES and NRIW (TJ)	**2015**	**2016**	**2017**
	realization	realization	forecast
Geothermal energy	1749	1816	1879
Solar thermal	456	457	459
Wood and other solid biomass	22521	23294	23188
Landfill gas	44	33	31
Gas from the treatment plants	20	20	18
Other biogas	15	15	16
Biodiesel	975	606	536
Biobenzine (biopetrol)	277	178	168
RES	**26057**	**26419**	**26295**
NRIW	**1472**	**1519**	**1552**
RES + NRIW	**27529**	**27938**	**27847**

Table 6: Final consumption of energy from RES and NRIW with regard to individual energy sources in Slovenia in 2015 - 2017 (Source: Energy Directorate, 2017).

Final energy consumption from RES + NRIW was 26,419 TJ in 2016 and increased by +1.4% as of 2015. The largest share (77.8%) of RES and NRIW represents wood and other wood biomass, while geothermal energy stands in second place.

In the structure of final energy consumption, the share of RES (without hydro power) is 12.9% and the share of NRIW is 0.7%. Their total share (RES + NRIW) is 13.6% (see Figure 3).

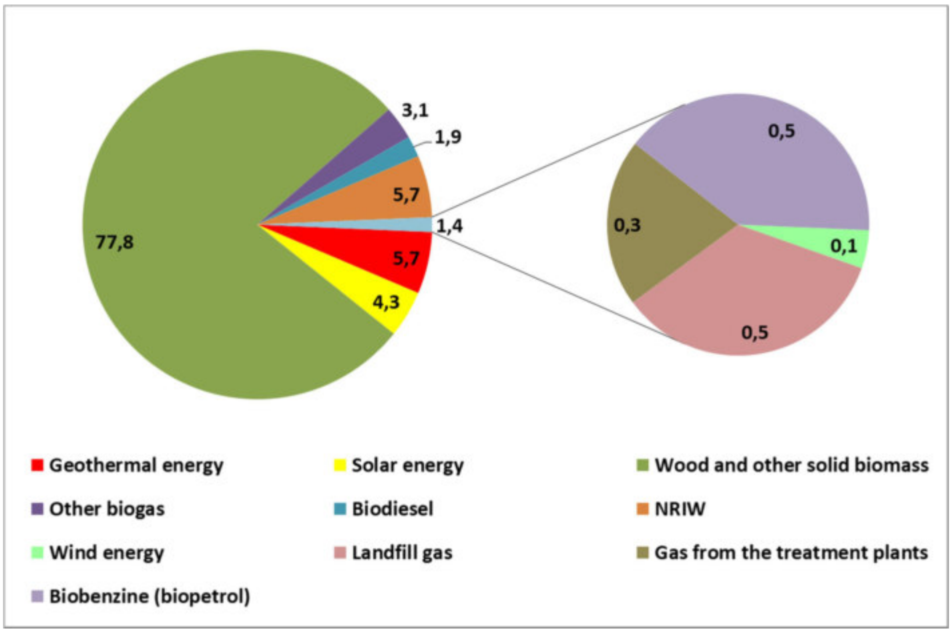

Figure 5: Structure (%) of primary energy supply with energy from RES and NRIW in 2017 in Slovenia (Source: Energy Directorate, 2017) (see Table 5)

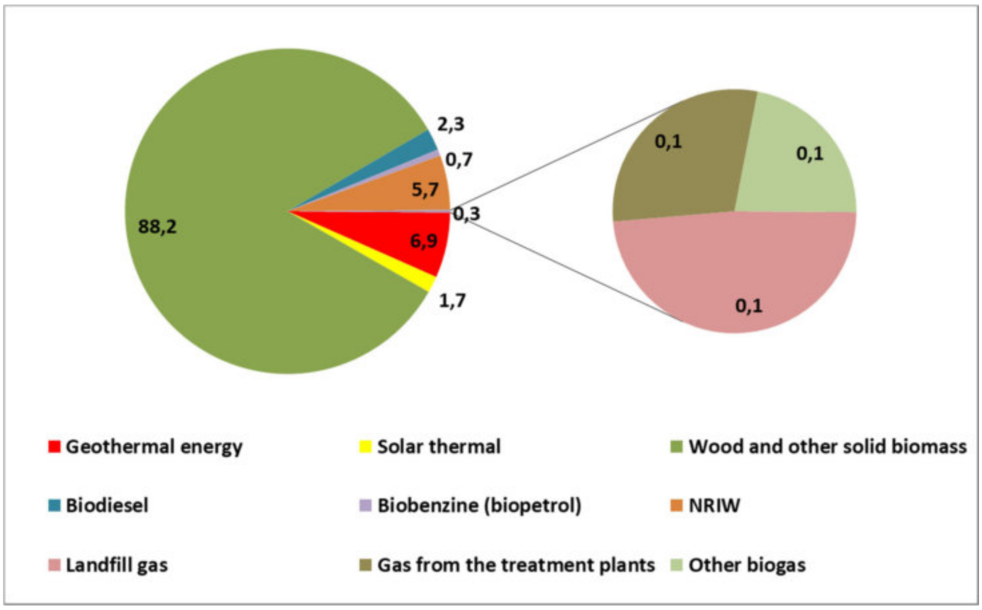

Figure 6: Structure (%) of final consumption of energy from RES and NRIW in 2017 in Slovenia (Source: Energy Directorate, 2017) (see Table 6)

The annual shares of all RES in the total gross final energy consumption for the period 2015-2017 are calculated on the basis of Directive 2009/28/EC of the European Parliament and of the Council on the promotion of energy use from renewable sources.

Also considered is the production of electricity from hydroelectric power plants in the share of RES. Electricity, generated in hydroelectric power plants and wind farms shall be taken into account in accordance with normalization rules set out in Annex II to the Directive.

Gross final energy consumption includes the consumption of the energy sector and the losses in the electricity and heat distribution.

Final gross energy consumption from RES is the sum of final gross electricity consumption from RES, final gross energy consumption from RES for heating and cooling and final energy consumption from RES in traffic (transport).

The share of RES in gross final consumption in Slovenia was 22.0% in 2015, which is approximately the same as the planned annual objective from NREAP (Government of RS 2010).

In 2016 the share of RES in gross final consumption very probably reached 22.1%, in particular at the expense of exceeding with the NREAP determined annual sectoral target for heating and cooling and at the expense of fulfilment of the planned annual target from the electricity sector.

In the energy balance for 2017, with the stabilization of final consumption for 2017, it is planned that share of RES in total gross final energy consumption will reach 22.2%.

1.2.3. Geothermal Energy

The main fields of geothermal energy (thermal water) utilization in Slovenia are (values show the status as of Dec. 2015; Rajver et al., 2016a,b):

Geothermal district heating: Only three geothermal district heating (DH) plants were considered in Slovenia in Dec. 2015 (in Lendava, Murska Sobota and Benedikt). The total geothermal energy used for district heating was 21.85 TJ/yr (6.07 GWh/yr).

Agriculture (greenhouses) and industry: The total geothermal energy used in the greenhouses (13.5 ha) was 117.18 TJ/yr (32.55 GWh/yr), with new user at Renkovci, besides those at Čatež, Tešanovci and Dobrovnik.

Individual space heating of buildings with domestic hot water heating: Space heating was implemented at 19 localities, predominantly thermal spas and resorts, mostly through heat exchangers (e.g. Moravske Toplice, Banovci, Terme Lendava, Ptuj, Maribor, etc.) or geothermal heat pumps (GHPs) (e.g. Cerkno, Hotel Diana in Murska Sobota, Izlake, Vrhnika, Dobova Paradiso, etc.). The GHP units usually of bigger capacity are installed only in case of too low thermal water temperature for this type of use. The total geothermal energy used for space heating was 212.7 TJ/yr (59.1 GWh/yr). The heating of domestic (sanitary) hot water is included in these values at nine localities, while for 6 other users it was possible to get separate values, some 10.18 TJ/yr (2.83 GWh/yr) of used geothermal heat.

Bathing and swimming pools with balneology, air conditioning and snow melting: There are 18 thermal spas and health resorts, and additional 9 recreation centres, where swimming pools with a surface area of about 50,174 m^2 and volume of 66,322 m^3 were heated by geothermal water directly or indirectly through heat exchangers or GHPs. Wellhead water temperatures in thermal spas range from 23 to 62 °C. The total geothermal energy used for bathing and swimming amounted to 103.5 TJ/yr (28.75 GWh/yr). Also snow melting of the sidewalks using geothermal heat from the already utilized thermal water is applied within the doublet system in Lendava, with about 0.014 TJ/yr only. Snow melting under two football grounds is applied also at Hotel Vivat at Moravske Toplice, with 0.653 TJ/yr. Altogether the used geothermal heat was 0.667 TJ/yr (0.185 GWh/yr). Air conditioning (cooling) of the hotels' spaces using geothermal energy was not well documented as it is operational only at few localities: Moravske Toplice Terme 3000, Mala Nedelja BioTerme, hotels at Bled, Dolenjske Toplice and Rimske Terme, contributing about 19.93 TJ/yr (5.53 GWh/yr) of extracted energy.

The main utilization types for direct heat use of geothermal energy in Slovenia are shown in Figure 7.

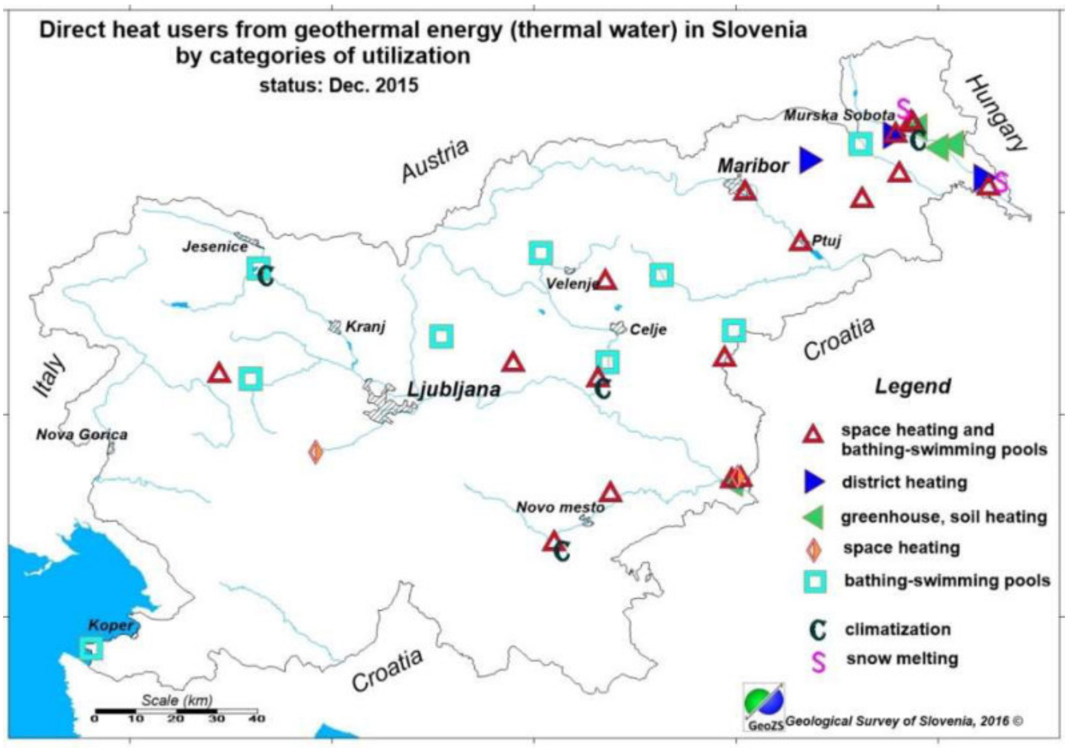

Figure 7: Main utilization types for direct heat use of geothermal energy (thermal water) in Slovenia (status Dec.2015)

However, the GSHP sector exhibited the largest share (60.1%) in direct use in 2015, compared to 49.7% in 2012 (Figure 8, Figure 9 and Figure 10).

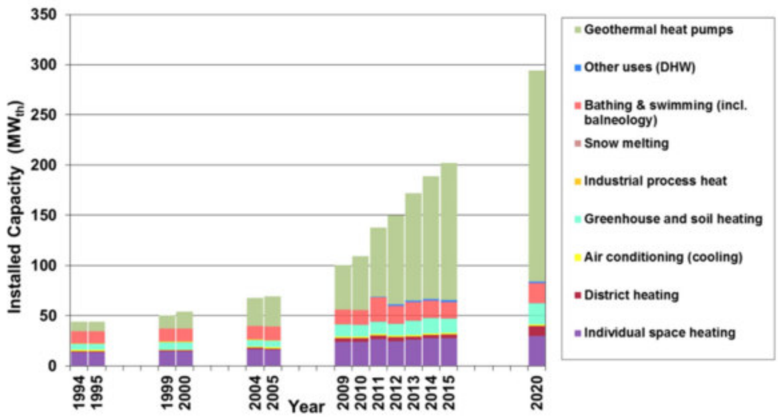

Figure 8: Geothermal direct use applications in Slovenia in a period 1995-2015 (total capacity in 2015: 202.25 MWt).

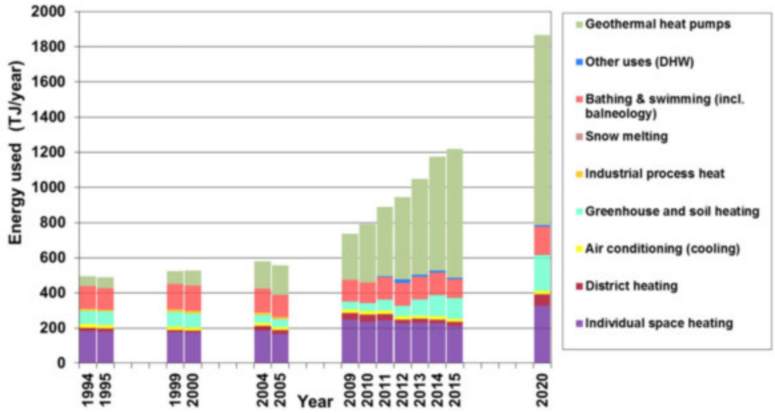

Figure 9: Geothermal direct use applications in Slovenia in a period 1995-2015 (total energy used in 2015: 1218.09 TJ).

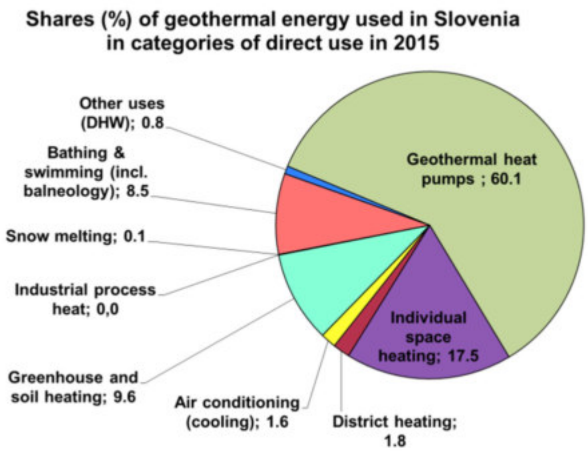

Figure 10: Shares (%) of geothermal energy used in Slovenia in categories of direct use in 2015 (status Dec. 2015).

1.2.4. District heating

1.2.4.1. Share of geothermal energy in district heating

Final consumption of district heat in Slovenia amounted to 7,166.3 TJ in 2015. Geothermal energy used for district heating at four localities in Slovenia amounted to 21.85 TJ/yr (6.07 GWh/yr) in 2015. It stems from this that district heating systems in Slovenia cover 0.3 % of their energy needs from geothermal energy. If transformations (8,685.5 TJ) are instead taken into account, then the district heating systems cover 0.25% of their energy needs from geothermal energy.

The energy balance of production and consumption of heat for 2017 is shown in the Table 7.

DISTRICT HEAT (TJ)	2015	2016	2017
	realization	realization	forecast
Transformations	-8685,5	-9002,7	-9151,4
Own use and losses	1519,2	1608,3	1634,9
Final consumption	7166,3	7394,4	7516,5
Energy sector	80,7	85,3	86,7
Manufacturing (industry) and construction	2057,3	2129,4	2164,5
Households	3211,1	3435	3491,8
Other consumption	1817,3	1744,7	1773,5

Table 7: The balance of district heat in Slovenia in 2015 – 2017 (Source: Energy Directorate, 2017).

In 2016 a total of 9,002.7 TJ of heat was produced, which was by 3.6% more than in the year 2015. Final consumption in Slovenia amounted to 7,394.4 TJ, and its own use and losses were 1608.3 TJ. Households used 3,435 TJ of heat, manufacturing and construction spent 2,129.4 TJ, while in the other consumption sector spent 1744.7 TJ, and spending in energy sector amounted to 85.3 TJ. In 2015 a total of 8,685.5 TJ of heat was produced in Slovenia. Final consumption amounted to 7,166.3 TJ, and its own use and losses were 1,519.2 TJ. Households used 3,211.1 TJ of heat, manufacturing and construction spent 2,057.3 TJ, while in the other consumption sector 1,817.3 TJ was used, and spending in energy sector amounted to 80.7 TJ.

1.2.4.2. Modular district heating and cooling systems based on renewable sources

While preparing this report, we have found a project called CoolHeating, which aims to support the implementation of "small, modular district heating and cooling systems based on renewable sources" (http://www.coolheating.eu/en/). In this project, they did not deal with proving the potential of individual renewable energy sources (sun, biomass, geothermal energy, waste heat, heat pumps, etc.), but how implementation of these small modular remote heating and cooling systems look like, and what should be considered when designing such a system (economic-technological calculations and business models). The DARLINGe and CoolHeating projects are complementary.

2. Heat sector analysis - regional level

The Slovenian part of project area spreads over statistical regions Pomurje, Podravje and partly Posavje and Savinja statistical regions. Each statistical region had an obligation to prepare the regional development plan 2014 -2020 (RRP). RRP is the basic strategic and program document of the region, which coordinates development goals in the region, and determines the instruments and resources for their implementation. In following subchapters we will describe the regions, their heat consumption and specific fasts related to use of geothermal energy.

The basis for regional analysis in Slovenia are collected data on the field, data from some major distributors, data from the Local Energy Concepts, which are obligatory documents for each local community/municipality in Slovenia and from the Sustainable Energy Action Plans in the frame of the Covenant of Mayors initiative. Local Energy Concept is a concept of the development of local community (or more local communities) in the field of supply and use of energy, which includes solutions for future energy supply and also measures for rational use of energy, combined production of heat, electric power and use of renewable energy sources. A certain percentage of some missing data for the entire picture (regional analysis) was obtained through a professional assessment / energy estimation, using correction factors based on actual comparative analytical data (the ratio between the person / area).

In EU the national average specific heat demand values range from approximately 3 to 13 MWh per-capita, with a EU28 national average at ~7.8 MWh per-capita. In Slovenia the average per-capita heat demand is around 6.5 MWh. Total consumption (2nd column) divided by number of inhabitants (4th column) gives a region's consumption per head. In Podravje region we register the lowest consumption per-capita value (4.8 MWh) and the highest in Pomurje region (10.7 MWh) – if we taking into account the four regions concerned.

Region	Heating Energy Consumption	Surface	Inhabitants	Consumption per km²	Consumption per capita
Pomurje	1,246,880,285 kWh	1,337 km²	116,078	932,596 kWh/km²	10.741 MWh
Podravje	1,549,821,553 kWh	2,168 km²	322,513	714,862 kWh/km²	4.805 MWh
Posavje (partly)	494,954,758 kWh	644 km²	53,980	768,563 kWh/km²	9.169 MWh
Savinja (partly)	654,710,491 kWh	756 km²	70,736	866,019 kWh/km²	9.255 MWh

Table 8: Heat consumption per capita in selected regions

From the data in Table 8 is it seen that Podravje region has much lower (by the half!) Heat consumption per capita and Pomurje exceed all other regions. There are many rural settlements in Pomurje, and the largest cities (Murska Sobota, Lendava) are small in comparison with the size of Maribor and Ptuj, which are the biggest "culprit" for this result because the number and density of the population is much larger there. Far more people live there in smaller apartments in block-of-flats so heat per capita is also reduced proportionally at the regional level. In Pomurje the value of the dwellings per inhabitant is higher. In addition, the fact that the facilities in the Podravje region are better isolated than in Pomurje, which is evident from the use of subventions from Eco Fund. The level of development is partly responsible for the results, on the other hand, the fact that a large share of the rural population (especially in the Goričko part of Pomurje region) has its own source of wood - its forests, and thus people still do not monitoring the heat consumption.

We also prepare the map of the average temperature deficit of heating seasons between 1971/1972 – 2000/2001 in Kday in the Pomurje, Podravje, Savinja and Posavje region (Source: ARSO, 2017) (Figure 11).

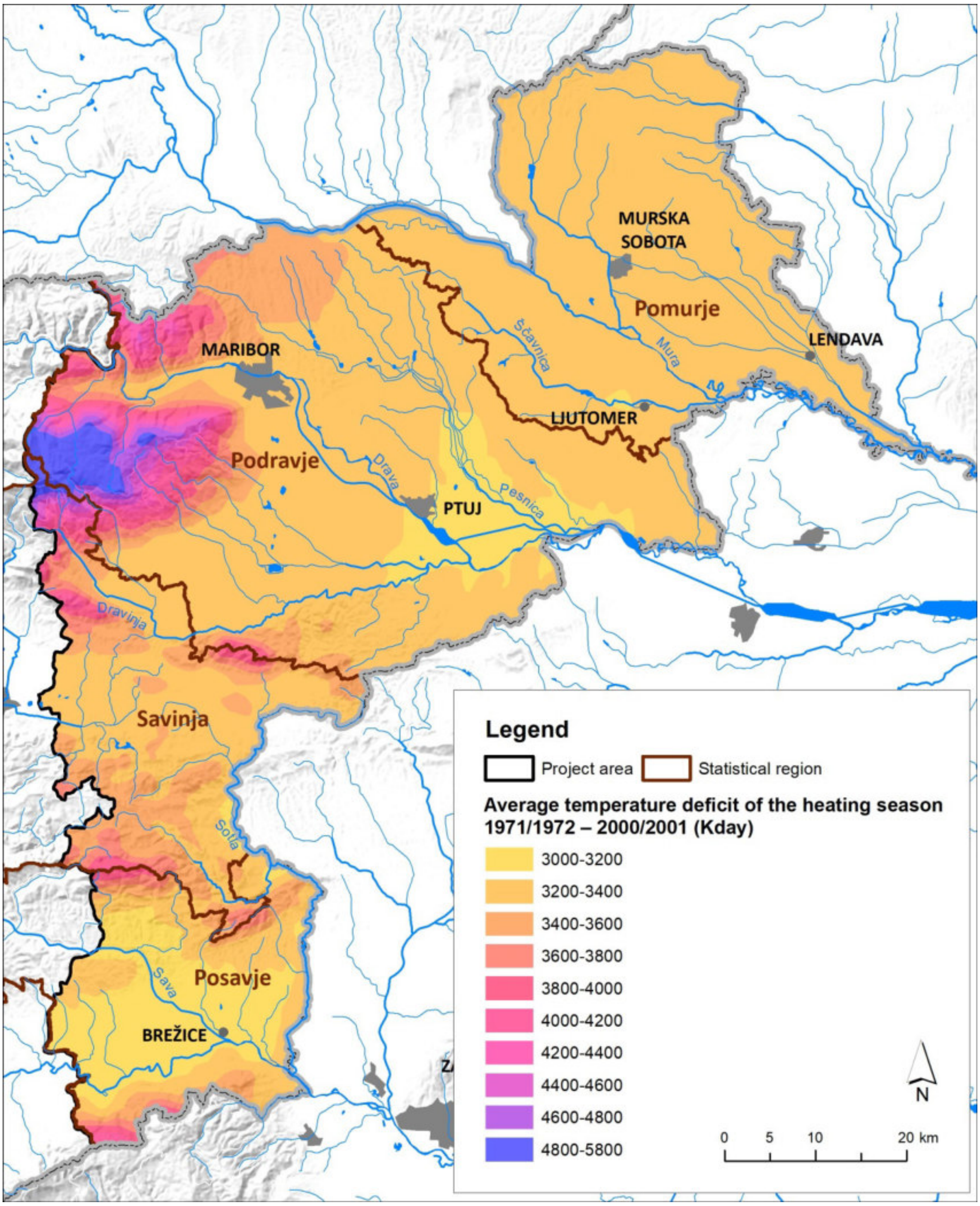

Figure 11: Average temperature deficit of the heating seson 1971/1972 – 2000/2001 in Kday in the Pomurje, Podravje, Savinja and Posavje region (Source: ARSO, 2017).

2.1. Pomurje region

2.1.1. General territory description

Pomurje is a region on the north-eastern part of Slovenia with a central watercourse, the river Mura, and it borders Austria, Hungary and Croatia. It is predominantly flatland along river Mura. The hilly area on the north of region is Goričko, two small hilly areas are in the west - the Radgona hills - and near Lendava (Lendava hills). More than three quarters of all utilized agricultural area occupy arable land in this part of Slovenia. The relatively limited territory is 1,337 km² (6.6% of the total territory of Slovenia), with around 116,078 inhabitants, representing about 6.3% of the total population of Slovenia. Pomurje has 27 municipalities and does not have a regional government, but the Regional Development Council, which adopts priorities, programs and measures for development. There are four bigger agglomerations in the region: Murska Sobota (11,679 inhabitants, the 11th largest city in Slovenia) is the largest and central city in the region, Ljutomer, Gornja Radgona and Lendava. The deteriorating economic situation of this region is affected by remoteness and poor transport links with the rest of the country, a negative natural increase in the population, a sub-average educational structure of the population, which is reflected in low GDP per capita and the highest registered unemployment rate in the country.

The average annual rainfall is around 900 mm. On the left bank of the Mura, rainfall is everywhere below 900 mm, on the far eastern part even below 850 mm. The highest precipitation in the river basin receives the area of Slovenske Gorice, where precipitation is about 1,000 mm a year. Precipitation maximum is typical for summer and autumn, and the precipitation minimum for the winter period. The fluctuation in the average air temperature is high, which is a characteristic of the sub-panonnian climate. In January the average air temperature is below 0 °C, while in July the average air temperature exceeds 20 °C. The average annual evaporation is 693 mm, which is high compared to the amount of precipitation. The basic information's for Pomurje region are shown in Table 9.

Table 9: Basic information for Pomurje region

Region	Pomurje
Region headquarter	Murska Sobota
Surface area	1,337 km²
Number of habitants	116,078
Population density	86.8 /km²
Number of cities (above 20 000 habitants) with district heating system	0
Number of cities (above 20 000 habitants) without district heating system	0
Number of towns (habitants: 5000-20 000)	1
Number of rural settlements (habitants less than 5000)	346

2.1.2. Regional development plan for Pomurje region 2014 – 2020

From SWOT analysis it is seen that the region has big potential of RES (geothermal energy, water, biomass, sun). The geothermal energy should be used in agriculture and for spa tourism, which are also the main development area in the region. Further development of geothermal district heating with at least one new borehole is also foreseen (RRA Mura, 2015). Three project proposals dealing with geothermal energy are included in RRP: coordinated and sustainable exploitation of geothermal energy, encouraging the integrated use of geothermal energy and encouraging the integrated use of geothermal energy in Prlekija.

Until now there is no activity for realisation of project idea.

2.1.3. The use of energy for heating and heat generation in Pomurje region

Table 11 shows a consumption of energy for heating and technological heat for residential, tertiary and municipal buildings in Pomurje region in one year.

2.1.4. District heating systems in Pomurje region

In Pomurje region only four district heating systems exists (

Table 10). Location of them is presented in Figure 12. Delivered heat from distribution systems in 2016 was less than 10 GWh for each of the DH systems.

Settlement	Description
Lendava	PUBLIC SERVICE - Primary fuel is geothermal energy, reserve fuel is natural gas.It is described in detail in the last chapter.
Murska Sobota	PUBLIC SERVICE - The DH system in the city of Murska Sobota has been operating by Komunala Murska Sobota, d.o.o., since 1981 and covers the northern part of the city, with an area of 1 km^2 and is among the smaller in the RS. The heat is produced in the boiler room "Lendavska - north". The hot water network, 1,6 km long, operates with a temperature range of 90/60 °C. Primary fuel is natural gas. In case of failure, the reserve fuel is an extra light fuel oil. At present, 22 DH stations are connected to the DH system, with installed power of 9.3 MW.
Martjanci	MARKET ACTIVITY - DH on wood biomass Martjanci includes wood biomass boiler with wood chip warehouse and remote distribution of insulated pipes to nearby facilities (kindergarten, church, parish house, post office, guest house and pension facility).
Kuzma	MARKET ACTIVITY – Company Biohica d.o.o. operates two boilers on wood biomass of power of 500 and 220 kW. The latter will be heated in particular during the summer months. In phase 1, 23 facilities are connected to DOLB Kuzma. These are larger consumers (the Elderly House, the Kuzma, Primary School with the kindergarten, shop Mercator, the church with a parish house and several business facilities), and several smaller households are also connected. DH with wood biomass replaces energy of over a thousand litres of light fuel oil, which would release 320 tons of CO_2 when used in the atmosphere. A more ecologically friendly way of heating, with the use of modern technology, releases 24 tons of CO_2 into the atmosphere. The plan is also the second phase of the construction of district heating, which will enable heating for further 35 smaller households.

Table 10: District heating system in Pomurje

Table 11: Consumption of energy for heating and technological heat in Pomurje region

CONSUMPTION OF ALL ENERGY IN MUNICIPALITIES IN ONE YEAR

Consumption of energy for heating and technological heat

	FOSSIL FUELS								RENEWABLE ENERGIES									ELECTRICITY	TOTAL
	Heating oil		LPG		Natural gas		Coal		WOOD BIOMASS						GEOTHERMAL	SOLAR ENERGY	BIOGAS		
									WOOD		PELLETS		CHIPS						
	l	kWh	m3	kWh	Sm3	kWh	kg	kWh	m^3	kWh	kg	kWh	nm^3	kWh	kWh	kWh	kWh	kWh	kWh
Residental buildings	32,307,589	323,075,894	272,957	7,642,810	2,538,067	24,035,497	1,199,591	7,463,856	219,829	529,788,774	1,079,222	5,104,720	2,096	1,676,800	2,659,140	643,370	431,250	15,486,922	918,009,033
Tertiary buildings	4,873,371	48,733,708	255,570	7,155,967	14,246,827	134,917,455	223,810	1,392,543	4,827	11,633,300	0	0	139	111,220	51,303,000	0	22,360,000	319,350	277,926,543
Municipal buildings	2,304,326	23,043,256	72,225	2,022,305	2,545,587	24,106,707	940	5,850	243	585,000	0	0	89	71,340	703,620	0	0	406,632	50,944,710
TOTAL	39,485,286	394,852,858	600,753	16,821,082	19,330,481	183,059,658	1,424,341	8,862,249	224,899	542,007,074	1,079,222	5,104,720	2,324	1,859,360					
	603,595,847								548,971,154						54,665,760	643,370	22,791,250		
									627,071,534									16212904	
																		TOTAL energy and heat in kWh	1,246,880,285

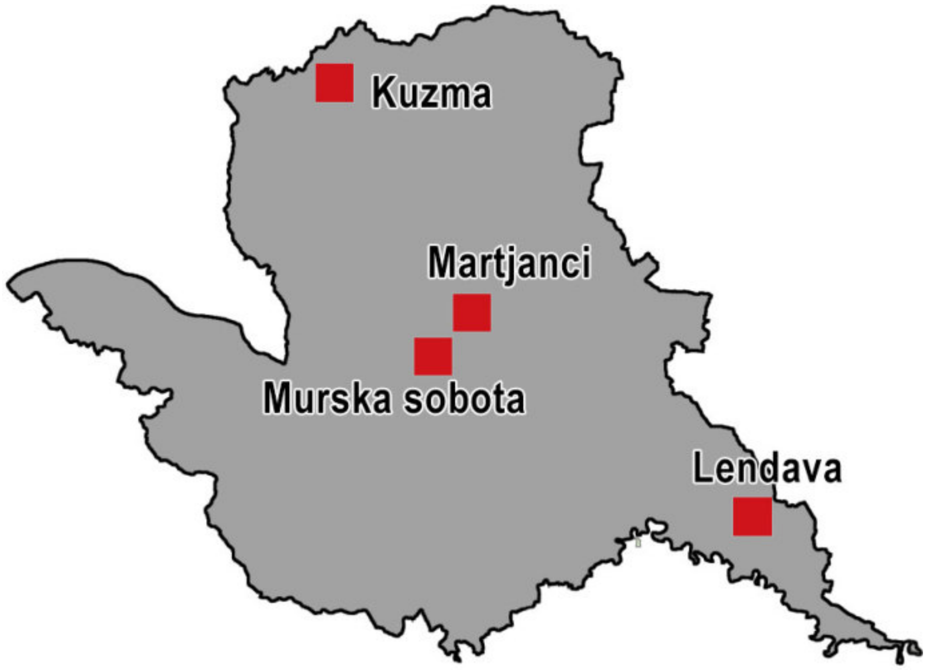

Figure 12: Location of district heating systems in Pomurje region

2.2. Podravje region

2.2.1. General territory description

The Podravje region with 2,168 km^2 comprises a good tenth (10.7%) of the Slovenian territory and is the fifth largest among the Slovenian regions. The region lies in the north-eastern part of Slovenia and borders to the west of Carinthia and the Savinja region, and in the east to Pomurje. In the north it borders on the neighbouring state of Austria, and in the south to Croatia.

The Podravje region is naturally geographically marked by hills in the northeast, subalpine forested hills (Pohorje and Kozjak) in the west, and the Dravsko-Ptujsko field from the Drava river. Water resources are exploited by the region for electricity generation (the chain of HPPs on the Drava River), and fertile soil is for agricultural activity, since the largest land area of agricultural land is in use throughout Slovenia (83,000 ha). The region is in second place after contributing to Slovenian GDP, for the Osrednjeslovenska region. The largest share of gross value added is generated by service activities. 51.6% of all the population aged 15 years or more is actually also employed, which is the least in the country. The share of job vacancies from all posts (free and occupied) is among the highest in the country. It is one of the regions with a positive net migration, but a greater negative natural increase on the other hand affects the decline in the number of inhabitants.

The Podravje statistical region comprises 41 municipalities with 322,513 inhabitants at the end of December 2015 (16% of the entire Slovenian population). According to the population density of 148.7 inhabitants per km2, it is third in Slovenia. The municipality of Slovenska Bistrica is the largest in terms of surface area, while the largest number and density of inhabitants is the Municipality of Maribor. The smallest area is the municipality of Miklavž na Dravskem polju, the municipality of Žetale is the least populous, while the least populous is the municipality of

Trnovska vas. The average population density in municipalities in the Podravje region is almost 8% higher than the average population density in Slovenia. The basic information about Podravje region are shown in Table 12.

The climate has moderate continental characteristics, with an average annual rainfall of about 1000 mm, with hot summers and cold winters.

Table 12: Basic information for Podravje region

Region	Podravje
Region headquarter	Maribor
Surface area	2,168 km^2
Number of habitants	322,513
Population density	148.7 / km^2
Number of cities (above 20 000 habitants) with district heating system	1
Number of cities (above 20 000 habitants) without district heating system	0
Number of towns (habitants: 5000-20 000)	3
Number of rural settlements (habitants less than 5000	678

2.2.2. Regional development plan for Podravje region 2014 – 2020

In the RRP Podravje the geothermal energy is just mentioned as a renewable energy source with big potential (Mariborska razvojna agencija, 2015).

2.2.3. The use of energy for heating and heat generation in Podravje region

Table 13 shows a consumption of energy for heating and technological heat for residential, tertiary and municipal buildings in Podravje region in one year.

Table 13: Consumption of energy for heating and technological heat in Podravje region

CONSUMPTION OF ALL ENERGY ONE YEAR																			
Consumption of energy for heating and technological heat																			
	FOSSIL FUELS								RENEWABLE ENERGIES									ELECTRICITY	TOTAL
	Heating oil		LPG		Natural gas		Coal		WOOD BIOMASS						GEOTHERMAL	SOLAR ENERGY	BIOGAS		
									WOOD		PELLETS		CHIPS						
	l	kWh	m3	kWh	Sm3	kWh	kg	kWh	m^3	kWh	kg	kWh	nm^3	kWh	kWh	kWh	kWh	kWh	kWh
Residental buildings	37,346,214	373,462,140	994,405	27,843,336	17,109,647	162,028,358	2,450,085	15,244,428	107,072	258,044,143	0	0	0	0	0	364,650	3,363,047	66,017,750	906,367,851
Tertiary buildings	5,226,149	52,261,488	471,667	13,206,665	46,134,726	436,895,858	56,252	350,000	7,246	17,461,800	0	0	0	0	0	0	0	314,400	520,490,210
Municipal buildings	3,029,062	30,290,618	184,747	5,172,923	8,030,905	76,052,671	0	0	30	73,400	0	0	0	0	600,000	0	10,276,830	497,050	122,963,491
TOTAL	45,601,425	456,014,246	1,650,819	46,222,923	71,275,278	674,976,886	2,506,337	15,594,428	114,348	275,579,342	0	0	0	0					
	1,192,808,483								275,579,342						600,000	364,650	13,639,877		
									290,183,869									66829200	
TOTAL energy and heat in kWh																			1,549,821,553

2.2.4. District heating system systems in Podravje region

In Podravje region seven district heating systems exist (

Table **14**). Their location is represented in Figure 13. Delivered heat from distribution systems in 2016 was higher than 500 GWh in Maribor and less than 10 GWh for other DH systems.

Settlement	Description
Sladki vrh, Vranji vrh	PUBLIC SERVICE – Company Petrol distribute the heat for DH Sladki Vrh and Vranji vrh, and partly for the needs of the factory Paloma, from an cogeneration plant and a hot water boiler installed in the boiler room of the factory Paloma. With the cogeneration unit for cogeneration (power of 626 kW) and electricity (527 kW power) of the Austrian manufacturer GE Jenbacher, baseload needs for DH provided. Top heating needs are covered by a 1,500 kW hot water boiler from Bosch. To achieve high efficiency, the boiler is equipped with an economizer to utilize the latent heat of flue gases. Basic fuel is natural gas. Spare heat source is still provided by Paloma with heat production on a steam boiler. For the needs of DH Sladki vrh, Vranji vrh, the average heat consumption in the heating season is 1,890 MWh. The length of the hot water (branch east and branch west together) of the network is 3.3 km, the connection power of customers is 3.42 MW.
Lenart	PUBLIC SERVICE - In the biomass DH, Eko toplota d.o.o. installed a biomass boiler with a power of 3.5 MW and an extra light fuel oil boiler with a power of 3.5 MW to cover the peaks. The currently constructed heating network is around 5 km long and in the final construction will be delivered about 13 GWh to around 600 households, as well as public buildings in the Municipality of Lenart.
Maribor	PUBLIC SERVICE – company Energetika Maribor: a hot-water network has been built so far, with a total length of 34 km. Most of the network was built in earth in concrete kinets, but recently the system of direct laying of pre-insulated pipelines into the ground is used. The development of DH and the preparation of hot sanitary water were initially followed by the construction of new residential settlements on the right bank of the Drava River, which according to energy concepts was envisaged for such heat supply. Thus, all newly built residential buildings in settlements S 23, Nova vas I, Nova vas II, Borova vas and Studenci I. were connected to DH. At the same time, larger boiler rooms were connected to the system, which provided accommodation in the settlement Jugomont and on the northern branch (that is from Energetika Maribor to the river Drava). Recently, when new buildings were stalled, mainly older residential blocks that did not have central heating, as well as many commercial and some industrial facilities (Mercator dd, Merkur dd, Tuš center, Qlandia, Europark, Bauhaus, Elektro remont, etc. .), schools and kindergartens, banks, business facilities and business premises are being connected to the DH. In 2003 Energetika Maribor testablish the DH also on the left bank of the Drava (the acquisition of the Pristan power plant with the basic assets of Energetika Maribor), where several public buildings and residential buildings are connected (Pristan swimming pool, Faculty of Technology, Drava terraces, Ribiška ulica 2-6). In 2003 a cogeneration plant was constructed for simultaneous production of heat and electricity. The electrical power of the device is 3 MW. MARKET ACTIVITY - There are also two other DH systems in Maribor DH system of University Medical Centre Maribor and DH system of Petrol Energetika d.o.o. - Pobežje
Ptuj	PUBLIC SERVICE - In City of Ptuj, the DH system is managed by Javne službe Ptuj d.o.o., which has 3 boiler rooms in operation. The supply of heat has been in operation since 1981 and covers an area of 6.26 km^2. They use only primary fuel (natural gas and extra light fuel oil) as fuel. Production sources (boiler rooms) serve only for the production of heat for heating without the preparation of sanitary hot water, the operation of boiler rooms is seasonal. The total number of boilers in DH boiler rooms and in joint boiler rooms is 18 with a built-in power of 32.55 MWh. Together, in the DS

	system, 51 heat stations have a built-in power of 28.24 MW. The number of housing outlets that are connected to the DH is 33. The total heating surface of the dwellings is 112,296 m^2. In 2010, the total energy used to heat users from the DH system was: housing consumption of 10,652 MWh; other consumers 8,396 MWh; The consumed electricity for operating devices in the heat stations was 291,345 kWh/a (1.5% of the electricity per consumed heat).
Kidričevo	PUBLIC SERVICE - Petrol Energetika d.o.o. company take heat for DH from the existing production resource of Silkem d.o.o. and the supply of heat to final customers through an existing distribution network. The scope of the concession includes 465 units or 40 buildings in the resident sector and 8 units and 7 buildings on a contractual base. The estimated annual heat consumption is 4,500 MWh. Within the boiler house on Volkmajer street, a cogeneration plant JENBACHER with a nominal heat capacity of 2.3 MW and a year of manufacture 2006, which owns the company Top Energija d.o.o. In 2010, the production of thermal energy from the cogeneration plant amounted to 7,815 MWh.
Hoče-Slivnica	MARKET ACTIVITY - Petrol Energetika d.o.o. completed the construction of a 450 kW boiler room and a micro system DH for a biomass utilisation in 2014 and started to supply heat to the buildings of the Elementary School and the Kindergarten Slivnica. Recently the clients of the newly built facility of the Healthcare Station Slivnica started to supply heat from the system.
Oplotnica	PUBLIC SERVICE - The municipality of Oplotnica and Petrol ENergetika d.o.o., have signed a contract for the implementation of an optional local public utility service for the supply of thermal energy from the local network and the production of heat from wood biomass for DH in the municipality of Oplotnica. In 2014, Petrol Energetika built a new, modern boiler room and a completely new DH system for wood biomass intended for the needs of the heating of the OŠ Pohorski bataljon Oplotnica, sports hall Milenij and ZD Oplotnica, Post Office of Slovenia, Nova KBM and food stores Mercator market Oplotnica. The heating system is in the length of about 350 m. The total rated power is 500 kW. The annual heat consumption from the DH system is expected to be around 850 MWh, which is expected to consume around 1,080 nm^3 of wood chips.

Table 14: District heating systems in Podravje

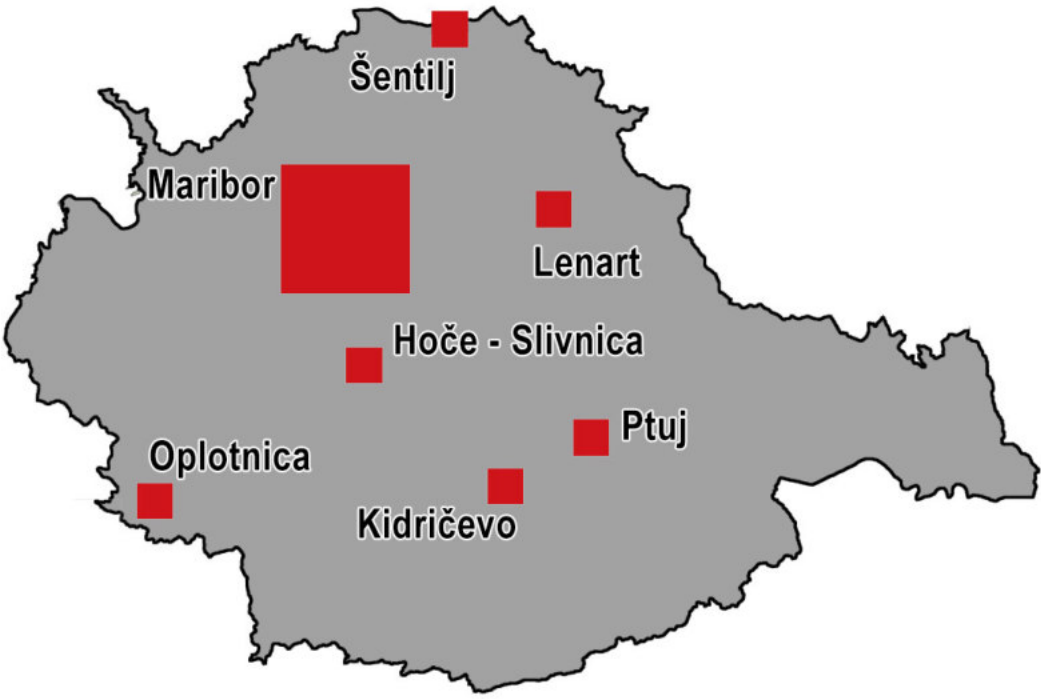

Figure 13: Location of district heating systems in Podravje region

2.3. Savinja region (Eastern part)

2.3.1. General territory description

The eastern part of Savinja region along the border with the Republic of Croatia, which is included in DARLINGe project area covering 756 km^2 with 70,736 inhabitants of the municipalities of Zreče, Slovenske Konjice, Rogaška Slatina, Šmarje pri Jelšah, Šentjur pri Celju, Podčetrtek, Rogatec, Kozje and Dobje.

This is a hilly region with altitudes up to 500 meters, called Kozjansko. On the north part the Haloze hills with Boč (978 m) and Donačka gora (884 m) are the main relief features. Towards the south-east, the hills gradually descend into the flatlands of border River Sotla. In Table 15 are represented the basic information about eastern part of Savinja region.

Eastern part of Savinja region has a moderate continental (subpannonian) climate of eastern Slovenia. January temperatures are a bit below zero (average January temperature for the period 1961-1990 is -1.6˚C, July is 18.0˚C); autumn temperatures are fairly high. The relatively large forest areas contribute to the relatively warm and humid atmosphere. The average annual temperature is 9.2˚C. The annual rainfall is between 1000 and 1100 mm.

Region	Savinja (partly)
Region headquater	Celje (outside of DARLINGe project area)
Surface area	756 km^2
Number of habitants	70,736
Population density	93.5 /km^2
Number of cities (above 20 000 habitants) with district heating system	0
Number of cities (above 20 000 habitants) without district heating system	0
Number of towns (habitants: 5000-20 000)	0
Number of rural settlements (habitants less than 5000	380

Table 15: Basic information about Savinja region

2.3.2. Regional development plan for Savinja region 2014 – 2020

The RRP for Savinja region is not foreseen the investment in geothermal energy sector in the period between 2014 and 2020 (RASR, 2015).

2.3.3. The use of energy for heating and heat generation in Savinja region (partly)

Table 16 shows a consumption of energy for heating and technological heat for residential, tertiary and municipal buildings Savinja region in one year.

Table 16: Consumption of energy for heating and technological heat in Savinja region

CONSUMPTION OF ALL ENERGY ONE YEAR																			
Consumption of energy for heating and technological heat																			
	FOSSIL FUELS								RENEWABLE ENERGIES									ELECTRICITY	TOTAL
	Heating oil		LPG		Natural gas		Coal		WOOD BIOMASS						GEOTHERMAL	SOLAR ENERGY	BIOGAS		
									WOOD		PELLETS		CHIPS						
	l	kWh	m3	kWh	Sm3	kWh	kg	kWh	m³	kWh	kg	kWh	nm³	kWh	kWh	kWh	kWh	kWh	kWh
Residental buildings	16,290,549	162,905,490	293,878	8,228,584	4,579,832	43,371,009	966,716	6,014,910	78,062	188,129,178	224,733	1,062,988	436	349,171	553,729	313,729		17,406,598	428,335,385
Tertiary buildings	2,477,752	24,777,524	167,935	4,702,170	14,154,568	134,043,756	1,320,488	8,216,076	3,209	7,733,708	0	0	178	142,362	10,683,146	0		131,970	190,430,712
Municipal buildings	1,164,975	11,649,749	58,437	1,636,229	2,317,267	21,944,515	196	1,218	67	161,727	0	0	114	91,315	271,461	0		188,179	35,944,393
TOTAL	19,933,276	199,332,763	520,249	14,566,983	21,051,666	199,359,280	2,287,400	14,232,204	81,338	196,024,612	224,733	1,062,988	729	582,847					
	427,491,230								197,670,448						11,508,336	313,729	0		
									209,492,513									17726747.5	
																		TOTAL energy and heat in kWh	654,710,491

2.3.4. District heating systems in Savinja region (partly)

In Savinja region three district heating system exists (Table 17). Their location is represented in Figure 14. Delivered heat from distribution systems in 2016 was between 10 and 50 GWh in all three DH.

Table 17: District heating system in Savinja region

Settlement	Description
Šentjur	From DH system in Šentjur, 332 dwellings with the heated area of 18,821 m^2, which is a 5% share in the whole municipality and some industrial facilities, are heated. The type of energy source for heating is natural gas and wood.
Zreče	PUBLIC SERVICE - Central Boiler Plant Dobrava, owned by Unior d.d. and in the management of Spitt d.o.o., is located in Zreče center. In the Dobrava boiler room there is a cogenerator, which produces 783 kW of thermal power and 500 kW of electric power at full charge from natural gas. Two boilers with a power of 3.5 MW and a boiler of 2.5 MW are operated if necessary. In 2010-11, a CHP unit of 634 kW of electric power was additionally installed. From central boiler plant Dobrava, multi-residential buildings are heated by larger business facilities. Heated buildings: Road to Rogla 11a, 11b, 11c, 11d, 11e, 11f, 11g, 11h, 11k, 11l, m, 17, 17a, 17b, 17c, 17d, 19, 21, Pohorska 1, 3, Tržnica Mercator, Kindergarten (until 2014), Bazar and Unitur Zreče. The supply of natural gas is done by the concessionaire of the city gas pipeline d.o.o. Length of the pipeline network is 12 km. There is 255 connected users. The boiler room has enough potential to connect additional facilities to the DH system.
Slovenske Konjice	PUBLIC SERVICE - Housing company Konjice d.o.o: The development of district heat supply began in 1979. Today, the DH network to which thermal energy users are connected is produced in the Prevrat boiler room and Thermokon industrial boiler room. 29 multi-purpose buildings, 5 family houses and 33 business entities are included in the district heating district heating system. In 2011, in the Boiler Room Prevrat, investment works were carried out in which the boiler was replaced with extra light fuel oil with a boiler on natural gas, and a completely renewed pumping station for the distribution of heat energy. Installed thermal power of the boiler room is 11,575 MW, and as the primary energy source, natural gas and extra light fuel oil is used today. In Thermokon Industrial Boiler, heat energy is produced from low-sulphur coal and wood biomass. In the town of Slovenske Konjice, a hot water network of the regime of 90/70 °C has been built up, with a total length of approximately 3 km. Most of the networks were sometimes built in earth in concrete kinets, but recently the system of direct laying of pre-insulated pipelines into the ground is used. Such a way is universally established and cheaper than the classic. Also second DH system exist which is run by company Toplotna oskrba d.o.o., also as public service.

Figure 14: Location of district heating systems in Savinja region

2.4. Posavje region (South-eastern part)

2.4.1. General territory description

The part of Posavje region along the Sava River, which is included in DARLINGe project area covering 644 km^2 with 53,980 inhabitants of the municipalities of Brežice, Krško, Kostanjevica na Krki and Bistrica ob Sotli.

Due to the small territorial extent and the humble population, the region has a weak gravitational hinterland, and a large regional centre has not been developed, but today the function is shared by the municipal centers of Krško and Brežice. About one third of the urban population is located in the region, while the largest part of the region forms a rural area, which includes a hilly world, as well as the area of Krško-Brežiško field, where numerous settlements are located. In addition to the above-average agricultural representation, in the economic structure, according to the Slovenian situation, there is an above-average orientation towards secondary activities - the region still has a highly developed industry. The basic information are shown in Table 18.

In the western part of the region is one of the pre-Alpine hills (Posavje hills). Towards the south and east are the Pannonian hills (Krško, Senovsko, Bizeljsko and Sotelje hills), Pannonian plain (Krško field) and the dinaric karst plateaus and hills (Gorjanci). The river denudation relief prevails, in hilly areas, the prevalence of erosion and denudation, and in the flat regions the accumulation relief. The karst relief is characteristic for the southern part of the region (Gorjanci) and for the higher regions of the Posavje hills.

Posavje has a moderate continental (subpannonian) climate of eastern Slovenia in the east. The average annual rainfall is around 800-1000 mm. In the west there is a moderate continental climate of central Slovenia. The average annual rainfall is 1000-1300 mm. The annual quantity of rainfall decreases from west to east. The annual temperature amplitude is in the west 20 °C, and in the east it is 22 °C.

Table 18: Basic information for Posavje region

Region	Posavje (partly)
Region headquater	Krško
Surface area	644 km^2
Number of habitants	53,980
Population density	83.7 / km^2
Number of cities (above 20 000 habitants) with district heating system	0
Number of cities (above 20 000 habitants) without district heating system	0
Number of towns (habitants: 5000-20 000)	2
Number of rural settlements (habitants less than 5000	307

2.4.2. Regional development plan for Posavje region 2014 – 2020

Within thematic objective 4 (OP ECP), the support for pilot projects which predict the utilisation of RES (including geothermal energy) is expected (RRA Posavje, 2015). The project "District heating from various sources in Posavje" is planned according to heating needs and opportunities with wood biomass, geothermal water and cogeneration of Nuclear power plant Krško.

2.4.3. The use of energy for heating and heat generation in Posavje region (partly)

Table 19 shows a consumption of energy for heating and technological heat for residential, tertiary and municipal buildings in south-eastern part of Posavje region in one year.

Table 19: Consumption of energy for heating and technological heat in south-eastern part of Posavje region

CONSUMPTION OF ALL ENERGY ONE YEAR

Consumption of energy for heating and technological heat

	FOSSIL FUELS								RENEWABLE ENERGIES									ELECTRICITY	TOTAL
	Heating oil		LPG		Natural gas		Coal		WOOD BIOMASS						GEOTHERMAL	SOLAR ENERGY	BIOGAS		
									WOOD		PELLETS		CHIPS						
	l	kWh	m3	kWh	Sm3	kWh	kg	kWh	m^3	kWh	kg	kWh	nm^3	kWh	kWh	kWh	kWh	kWh	kWh
Residental buildings	12,319,178	123,191,781	222,235	6,222,589	3,463,343	32,797,862	731,047	4,548,573	59,032	142,266,344	169,947	803,849	330	264,048	418,739	237,247		13,163,153	323,914,184
Tertiary buildings	1,873,717	18,737,167	126,995	3,555,858	10,703,914	101,366,068	998,574	6,213,130	2,427	5,848,356	0	0	22	17,514	8,078,769	0		99,798	143,916,659
Municipal buildings	880,973	8,809,730	44,191	1,237,343	1,752,355	16,594,799	148	921	51	122,300	0	0	14	11,234	205,283	0		142,304	27,123,915
TOTAL	15,073,868	150,738,677	393,421	11,015,790	15,919,612	150,758,730	1,729,769	10,762,624	61,509	148,237,000	169,947	803,849	366	292,797					
	323,275,820								149,333,645						8,702,791	237,247	0		
									158,273,683									13405254.75	
TOTAL energy and heat in kWh																			494,954,758

2.4.4. District heating systems in south-eastern part of Posavje region

In Posavje region only one district heating system exists (Table 20). Its location is represented in Figure 15. Delivered heat from Senovo DH in 2016 was lower than 10 GWh.

Table 20: District heating system in south-eastern part of Posavje region

Settlement	Description
Senovo	The new boiler room for district heating on wood biomass for the village of Senovo is located in the area of the business zone Senovo.

Figure 15: Location of district heating system in Posavje region

3. Heat market analysis at local level

In the scope of Heat market analysis we also prepared in-depth review of heat market for three selected settlements from DARLINGe project area. First example is settlement of Lendava in North-East of Slovenia in Pomurje region with active geothermal district heating. Second is the settlement of Ljutomer, also from Pomurje region, where certain geothermal potential exists and municipality itself in the past express the wish to explore and utilize it. The third location is settlement of Brežice in South-east Slovenia in Posavje region where the geothermal potential also exist.

For Lendava, we prepared the description of the geothermal district heating and the estimation of the heat demands, while for Ljutomer and Brežice we prepared just heat demands. Methodology for this is developing in the frame of Alpine Space Interreg project GRETA (Jež et all., 2017 in progress) and will be described after publishing the methodology in the Project GRETA (www.alpine-space.eu/projects/greta/en/home).

3.1. Settlement of Lendava

3.1.1. Introduction

The settlement and its energy needs is shown on Figure 16 and in Table22.

	Energy needs for heating (MWh/year)	Usable area (m^2)	Number of inhabitants (year 2016)	Netto surface (m^2)	Consumption per capita (MWh/year)
Lendava	**43,108.6**	**260,539.9**	**2,945**	**315,888.9**	
Public buildings	4,022.7	31,603.4		30,587.7	
Commercial building	19,382.8	127,041.8		139,548.7	
Residential buildings	19,703.0	101,894.7		145,752.5	6.69 MWh

Table 21: Energy needs for heating in Lendava settlement, separately for public, commercial and residential buildings

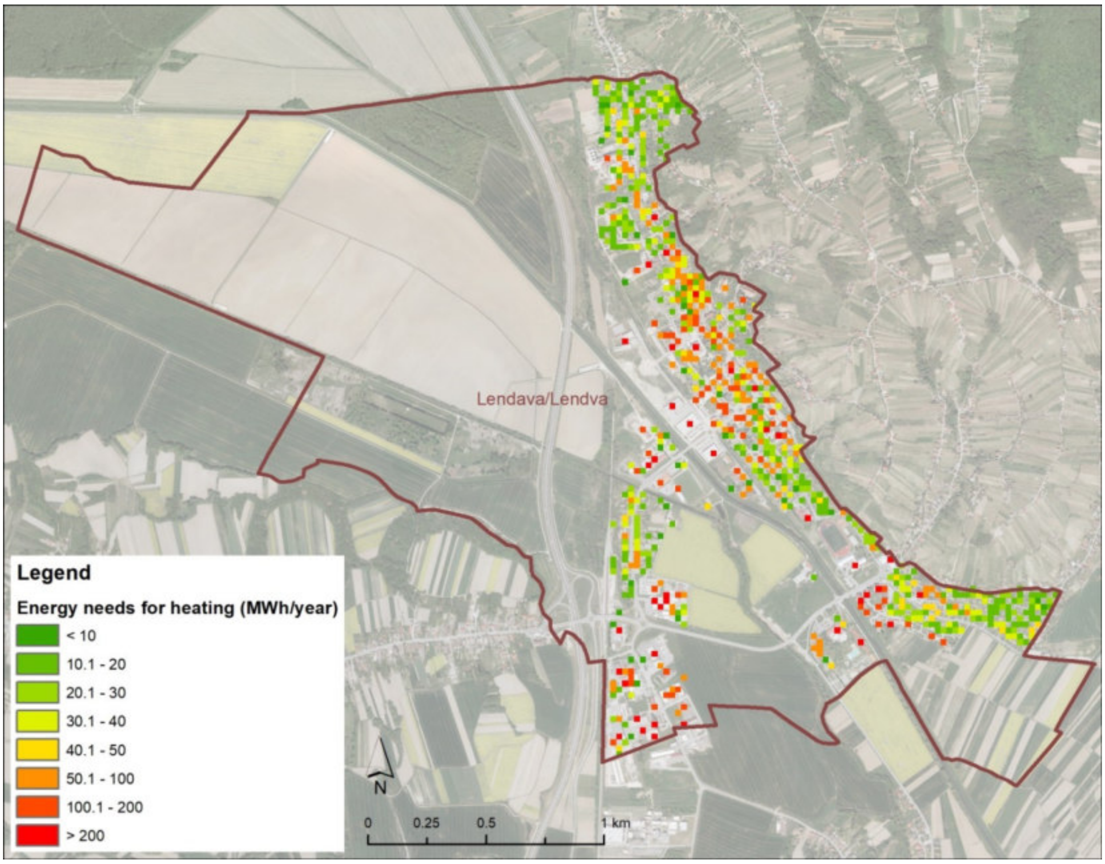

Figure 16: Lendava settlement - spatial distribution of energy needs for heating in MWh/y

3.1.2. District Heating System of Lendava

In Lendava Petrol Geoterm d.o.o. built a district heating system with geothermal energy (geothermal energetic source) on the basis of Mining Act (Official Gazette of the Republic of Slovenia no. 56/99 and 46/04). After the construction of entire district heating system with geothermal energy system, this is the first and so far the only system of its kind in Slovenia.

The principle of operation of the district heating system is as follows: thermal water is pumping from aquifer with the production well, transfer heat through heat exchangers to consumers and then cooled water is injected back into the aquifer.

The entire area of district heating with geothermal energy with all consumers, production and (re)injection well is shown in Figure 17.

Facilities, connected to the district heating system, are built in different time periods and are poorly isolated. Annual specific heat varies between 28-170 kWh/m^2. For the rational use of heat, most of the facilities should be renovated.

In some existing facilities, hot-water boilers on standard fuels are installed. They are used as reserve for operation at extremely low temperature and in the events of thermal system failures.

The total installed heat power of district heating system is 6.65 MWt with total heating area of 65,000 m2. Consumers connected to the district heating system are residential (residential blocks), business (shops and business facilities) and educational (school and gym). All consumers have built-in calorimeters to measure heat supplied by the heat distributor.

Annually the heat consumption of all consumers come approximately 5,000 MWh, which means about 1,500 tons of CO_2 less greenhouse gas emissions, than in the case if the heat would be provided by incineration of 600,000 litres of extra light heating oil.

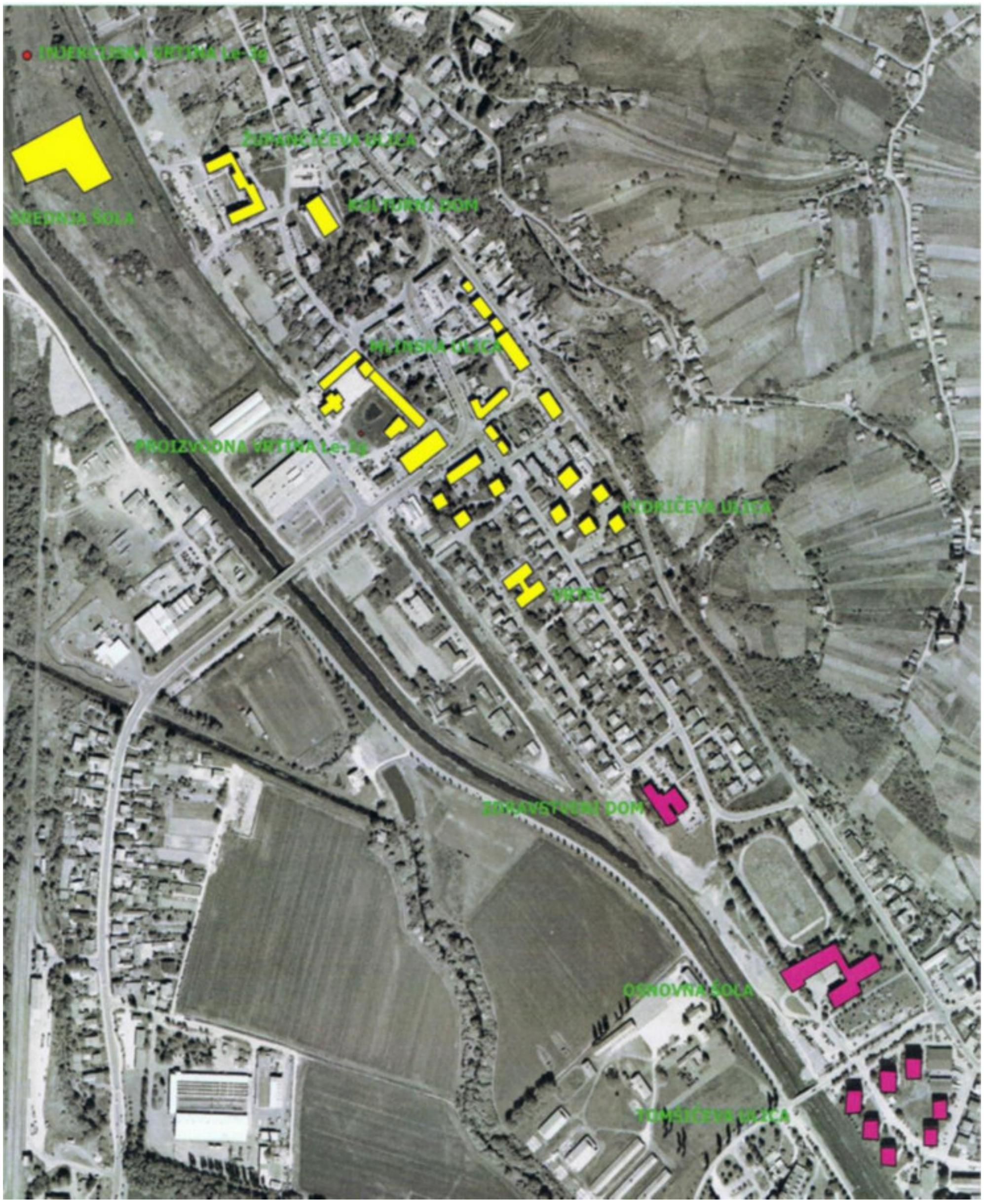

Figure 17: Area of district heating with geothermal energy with all consumers, production and (re)injection well

On a basis of article 284 of the Energy Act (EZ-1) (Official Gazette of the Republic of Slovenia no. 17/14 and 81/15) the activity of heat distribution can be conducted as:

- An optional economic public service or
- Market distribution.

If the heat distributer supplies or intends to supply more than hundred household consumers, heat distribution is conducted as an economic public service.

For the area of Lendava, Petrol Geoterm d.o.o. and the Municipality of Lendava, sign a concession contract to manage economic public service of district heating in the area of Municipality of Lendava. The concession was signed on a basis of the Services of General Economic Interest Act (Official Gazette of Republic of Slovenia no. 30/1998-ZZLPPO, 127/2006-ZJZP, 38/10-ZUKN, 57/2011), Public-Private Partnership Act (Official Gazette of Republic of Slovenia no. 127/2006), Local Self-Government Act (Official Gazette of Republic of Slovenia no. 94/2007-UPB2, 27/2008, 76/2008, 100/2008, 79/2009, 14/2010, 51/2010, 84/2010, 40/2012), Energy Act (EZ-1, Official Gazette of Republic of Slovenia no. 17/2014, 81/2015), Public Procurement Act (ZJN-2-UPB5, Official Gazette of Republic of Slovenia no. 12/2013, 19/2014), The Statute of Municipality of Lendava (Official Gazette of Republic of Slovenia no. 75/2010, 48/2011, 55/2011, 56/2012, 112/2013, 74/2015), Ordinance on the economic public services in the Municipality of Lendava (Official Gazette of Republic of Slovenia no. 45/2009, 61/2010, 101/2011) and the Decree on activity and concessions for local economic public service of district heating in the area of the Municipality of Lendava (Official Gazette of Republic of Slovenia no. 56/2014, 62/2014 in 8/2015).

Energy agency issued agreement for the starting price of heat distribution of district heating system in Lendava on the request from distributer with own heat production, Petrol Geoterm d.o.o., on the basis of the first paragraph of Article 302 of the Energy Act (EZ-1, Official Gazette of Republic of Slovenia no. 17/2014, 81/2015) and Article 207 of the General Administrative Procedure Act (Official Gazette of Republic of Slovenia no. 24/2006-UPB, 105/2006-ZUS-1, 126/2007, 65/2008, 8/2010, 82/2013). The starting price of heat is formed as the highest price, on the basis of which distributor with own production forms a heat price for district heating. The starting price of heat is in line with Article 300 of the EZ-1 and Article 9 of the Act on heat supply pricing methodology (Official Gazette of Republic of Slovenia no. 27/2015, 47/2015, 61/2015) formed by individual elements of the price in line with criteria for determination eligible costs. The starting price of heat consists of a fixed and variable part of the price.

On a basis of Article 311 of the Energy Act (EZ-1) is necessary annually report to Energy Agency about distribution network and devices, produced and distributed quantities of heat, tariffs and prices, ...

3.1.2.1. District Heating Facilities

The first phase of district heating in Lendava, with exploitation of geothermal energy, started with a well and boiler room for the needs of hotel Elizabeta and business facilities in Mlinska Street in Lendava. In boiler room the heat exchanger with power of 435 kW is operating with temperature difference around 10 °C and a regime 50/40 °C.

In second phase, the well was rehabilitated and a pumping-transport water system was made with partially implemented hot water system to the Secondary school, the block in Župančičeva Street and the Cultural home. Gas boiler room with power of 2.6 MW was completed and an additional heat exchanger for covering peaks and reserve was installed.

In the system was used the existing heating system of Mlinska Street, the regulation and connection of residential blocks in Square Ljudske pravice and Krajnčeva Street in Lendava was made. At the same time, the heating of the Secondary school in Lendava was made.

Residential settlements - residential blocks (Kranjčeva TLP, Župančičeva in Tomšičeva) with a total power of 4.54 MW, connected on district heating system, are older and inappropriately isolated. Temperature heating regime is 60/40 °C.

Residential settlement Krajnčeva includes residential blocks and business facilities (Administrative office, companies ...).

Residential settlement Župančičeva was built in 1980. Heating is conducted through heat exchanger from boiler room. In the building pipeline for thermal water and return of the DN 150 were made. The distribution station is set in basement entrance 1 and had installed distribution board with connection, automatic and pumps for each entrance in the building.

Residential settlement Tomšičeva Street was built 1978 with poor isolation. In existing boiler room two hot-water boilers were installed. The newer boiler has a heat power of 700 kW and older boiler has heat power of 1,500 kW. Heating with geothermal energy was performed.

The Secondary school was built in 2004 and is quite well isolated. The installed heat power is 480 kW. The heat exchanger is used for heating and as a reserve they use hot-water gas boiler Buderus. The system is designed in a way that the thermal water is heated by a system which, if necessary, is warmed up by a hot-water gas boiler.

The Cultural home is newer building, already designed for low temperature regime of 50/40 °C. For heating, a Buderus hot-water boiler with heat power 270 kW is used. After the connection to the thermal water system, the boiler is needed for warming up the system at extremely low temperatures and for reserve.

The Elementary school was built in 1968. In 2004 windows were partially changed and in 2008 the renovation of whole building furniture and isolation of building was carried out. The heating of the building is made from hot water system, which leads to Tomšičeva Street. In boiler room were installed two hot-water boilers with power of 2 x 580 kW and for preparation of hot sanitary water a hot-water boiler with power 28 kW. All boilers use ELKO.

A Health Centre was built in 1975. Building is quite well isolated, if we look a year of construction. Connection on heating system is carried out from hot water system, which leads to Tomšičeva Street.

3.1.2.2. Heat Production

We need to consider the fact that for the heat production for heating the buildings is primary used energy of the geothermal water. The heat sources for heating are:

Thermal water

Buderus SK725 (2 x 1.32 MW) boilers and boilers in some boiler rooms

Heat pump (0.5 MW)

For the heating of existing buildings, in some boiler rooms, hot water boilers are set, which are used as a reserve for operation in extreme conditions and in the event of thermal system failures.

Heating is continuously, 24h/day, every day in a week. The heating temperature diagram is determined to abide daily and nightly heating regime, outdoor temperature, return temperature...

Distribution heat system consists of three connected distribution systems:

Hot-water system of district heating with thermal water, which is distributed through the connected hot-water network to the customers in the heat stations,

Hot-water system of district heating with hot water heating medium, which takes heat from heat exchanges, gas boilers and heat pump and distributes it through the connected hot-water network to the customers in the heat stations,

Hot-water system of district heating with under floor heating and hot water heating medium, which takes heat from the heat exchanger and distributes it through the connected hot-water network to the customers in the heat stations.

Considering on the selected system, outdoor temperature, peaks and other factors, the use of different heat sources is optimized, including gas boilers and heat pump.

Production well Le-2g (Figure 18) was drilled in summer of 1994 with depth of 1,503 m. With the maximum amount of pumping 90 m3/h (25 l/s) the thermal water at the wellhead has temperature of 66 ˚C. Thermal water is low mineralized, Na-HCO3 type. The hot-water district heating system with thermal water is set up to the customers in the heat station, where the facilities are heated by heat exchangers. In the heat stations are located all automatic devices, necessary for the system to function smoothly, as well as equipment for data transfer and system optimization.

Figure 18: Production well Le-2g

(Re)injection well Le-3g (Figure 19) was drilled in summer of 2007, it is 1,223 m deep and is specially build to return water to the aquifer. In the well are installed 100 meters of Johnson filters with 0.5 mm slots, around 7" liner there is a sand pack granulation of 1-2 mm. Before (re)injection, the thermal water is mechanically filtered through sand filters, 20 and 10 µm filters (Figure 20).

Both wells and all consumers are interconnected with pre-isolated pipelines with total length of around 2,000 m.

Figure 19: (Re)injection well Le-3g with engine house

Figure 20: 20 in 10 µm filters in engine house near the (re)injection well

3.1.2.3. Heat pump

In the boiler room Mlinska Street a heat pump Mycom (Figure 21) is installed with MYCOM piston compressor, manufactured by MAYEKAWA MGG.CO., LTD. Tokyo, Japan, type N6HK (6 cylinders single-stage water cooled piston compressor) with frequency regulation of the rotational speed of the electric motor at 33%, 66% and 100% for 970, 1,450 and 1,600 min-1. It is composed of an evaporator, a compressor, a condenser and an expansion valve. The coolant in the evaporator receives heat from the surrounding area. At low temperatures regasification of the coolant occurs. The coolant vapours goes into the compressor, where they because of inserted mechanical part compresses to the pressure and temperature to the extent, to emit heat flow that can be used for heating. Liquid coolant then goes from condenser through expansion valve, where the pressure is lowered, back to evaporator. The circle process is repeated as long as the heat pump operates.

The heat source for the high temperature heat pump is partially cooled thermal water by heat exchangers. The heating rate is very high (even up to 9).

Figure 21: Installed high temperature heat pump

The characteristic of the Lendava district heating system are gathered in the Table 22.

District heating system (DH)	Yes operating
Flow temperature (in case of DH)	66°C
Total installed power (of heat power plant)	7 MW
Estimations of total installed power in individual systems	6.65 MW
Type of heat production	thermal water, gas boiler, heat pump
Energy source	Geothermal energy
Annually sold heat to households	18,000 GJ
Annually sold heat to industry	/
Share of heat loss in the DH	7 %
Total flat (heated) area surface	260,539 m²
Flat (heated) area surface on DH	65,000 m²
Flat (heated) area surface out of DH	195,539 m²
Share of Flat (heated) area surface on DH (m²)	25 %
Share of Flat (heated) area surface out of DH	75 %
Estimated specific heat load per square meter (in average)	3.333 W/m²

Table 22: Basic information of Lendava district heating system

3.2. Settlement of Ljutomer

The energy needs of Ljutomer are summarized in Table 24 and Figure 22.

	Energy needs for heating (MWh/year)	Usable area (m²)	Number of inhabitants (2016)	Neto surface (m²)	Consumption per capita (MWh/year)
Ljutomer	**53,100.1**	**339,452.9**	**3,367**	**399,832.4**	
Public buildings	2,892.6	28,880.2		25,813.8	
Commercial building	30,186.3	200,107.1		210,662.8	
Residential buildings	20,021.1	110,465.6		163,355.8	5.95

Table 23: Energy needs for heating in Ljutomer settlement, separately for public, commercial and residential buildings

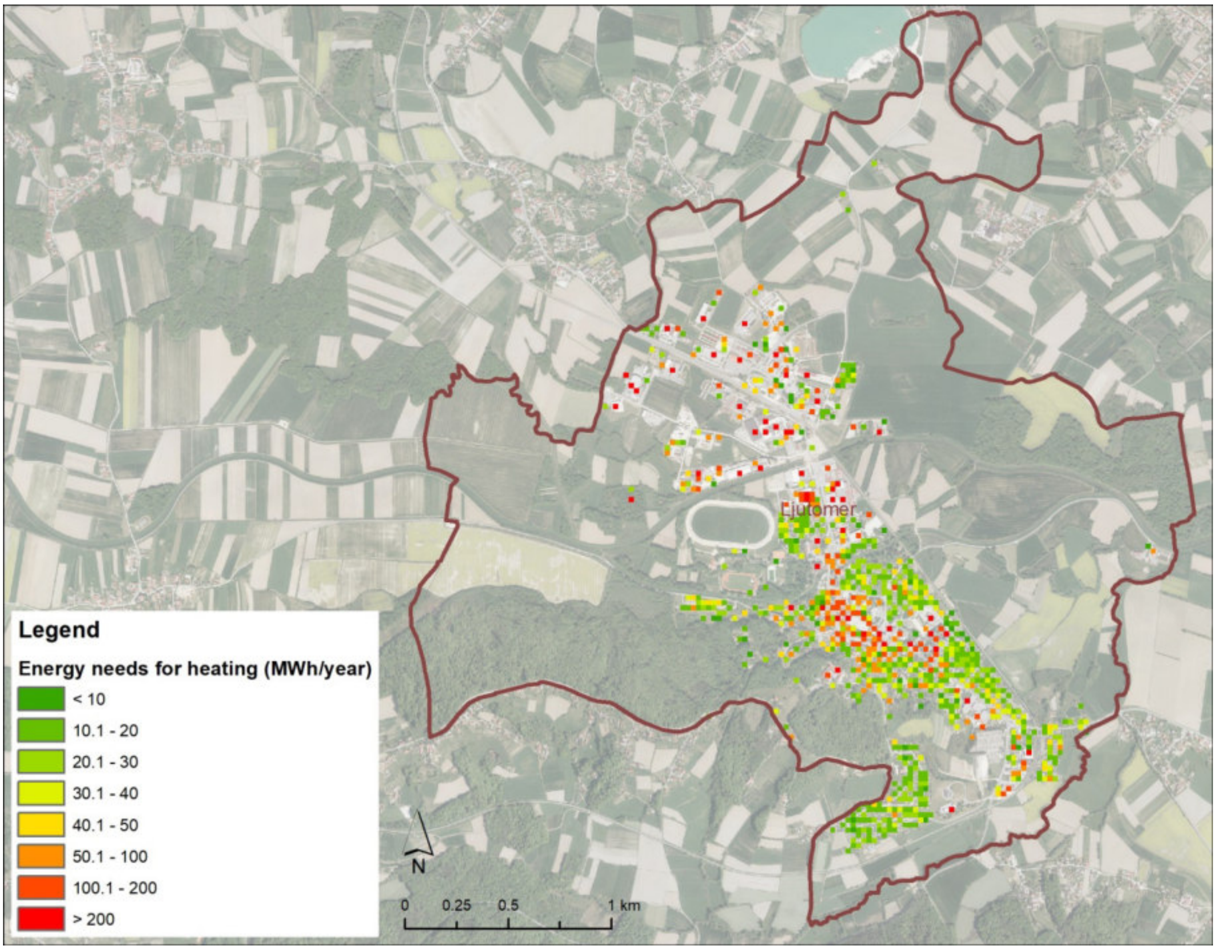

Figure 22: Ljutomer settlement - spatial distribution of energy needs for heating in MWh/y

3.3. Settlement of Brežice

The energy needs of Brezice are summarized in Table 25 and Figure 23.

	Energy needs for heating (MWh/year)	Usable area (m^2)	Number of inhabitants (2016)	Neto surface (m^2)	Consumption per capita (MWh/year)
Brežice	**76,301.2**	**468,945.2**	**6,759**	**602,261.8**	
Public buildings	8,694.6	69,806.9		74,094.1	
Commercial building	27,079.7	177,186.9		196,135.1	
Residential buildings	40,526.9	221,951.4		332,032.6	6.00

Table 24: Energy needs for heating in Brežice settlement, separately for public, commercial and residential buildings

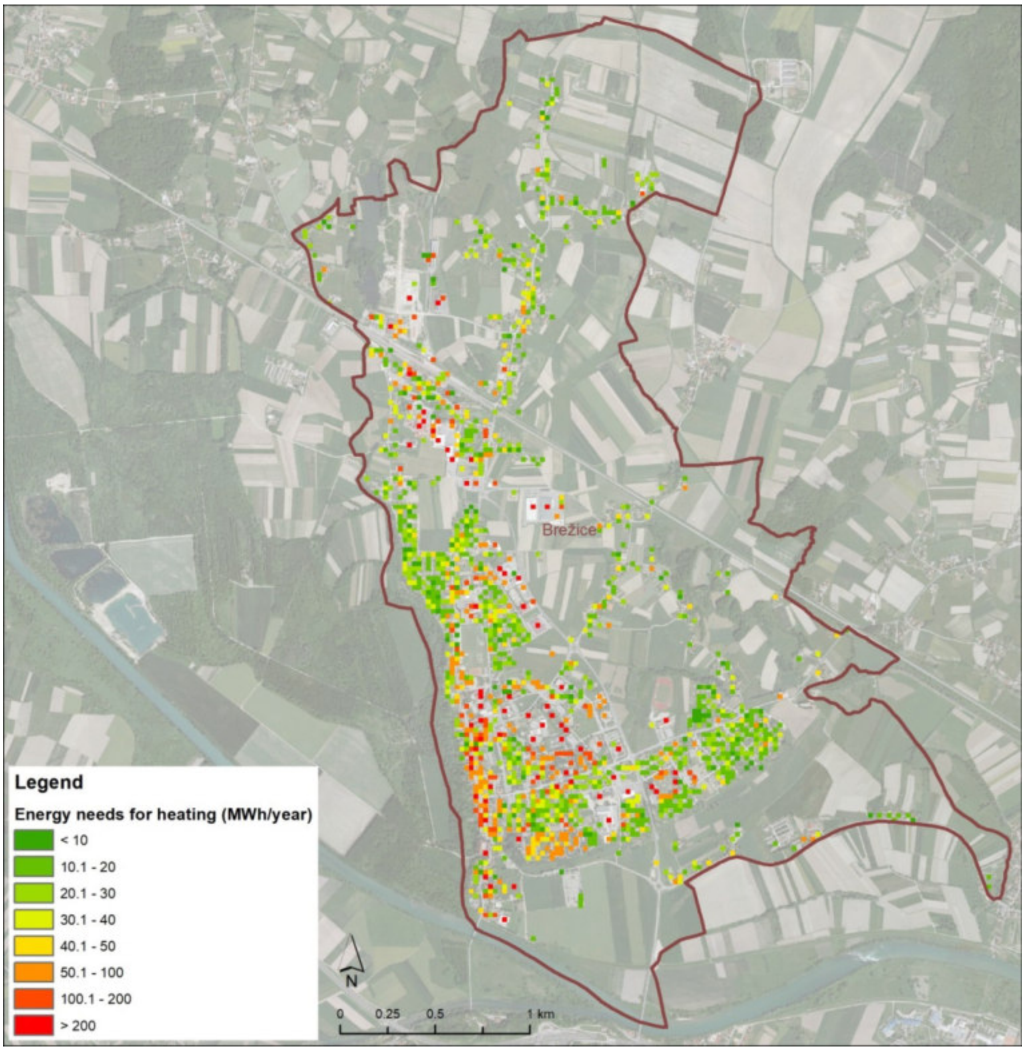

Figure 23: Brežice settlement - spatial distribution of energy needs for heating in MWh/y

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ABERRAVATIONS

IJS-CEU – Institute Jožef Stefan – Centre for energy efficiency

MZI – Slovenian Ministry for Infrastructure

RASR – Savinja region development agency

RRA Posavje - Regional development agency Posavje

RRA Mura – Regional development agency Mura

SVRK - Government Office for Development and European Cohesion Policy

D.5.4.1. Summary report on heat sector analysis

Appendix 3. Croatia national report

November 2017

D.5.4.1. Summary report on heat sector analysis

Appendix 3. Croatia national report

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Contents

Executive summary

Our present study offers insight into 4 aspects of heat sector analysis.

On a **country level** we offer an overview of Croatian energy sector with special attention to the heat market, providing a context for regional and municipal level analyses. This review encompasses the information and characteristic values of the Croatian energy sector regarding the production and consumption of energy at all levels. It gives an analysis of energy flow as well as a number of information on capacities, reserves, prices and individual energy balances of electricity, heat and renewable energy sources.

The heat sector analysis on a **regional level** discusses about the Northern Croatian Counties (Krapina-Zagorje County, Varaždin County and Međimurje County) and explains examples of current utilization of geothermal features.

The third chapter presents a real example of a **municipal level heat market analysis** providing a detailed description of the facility/technology of current utilization of thermal water and futures plans on activities in the field of geothermal energy.

1. Energy utilization in Croatia – national overview

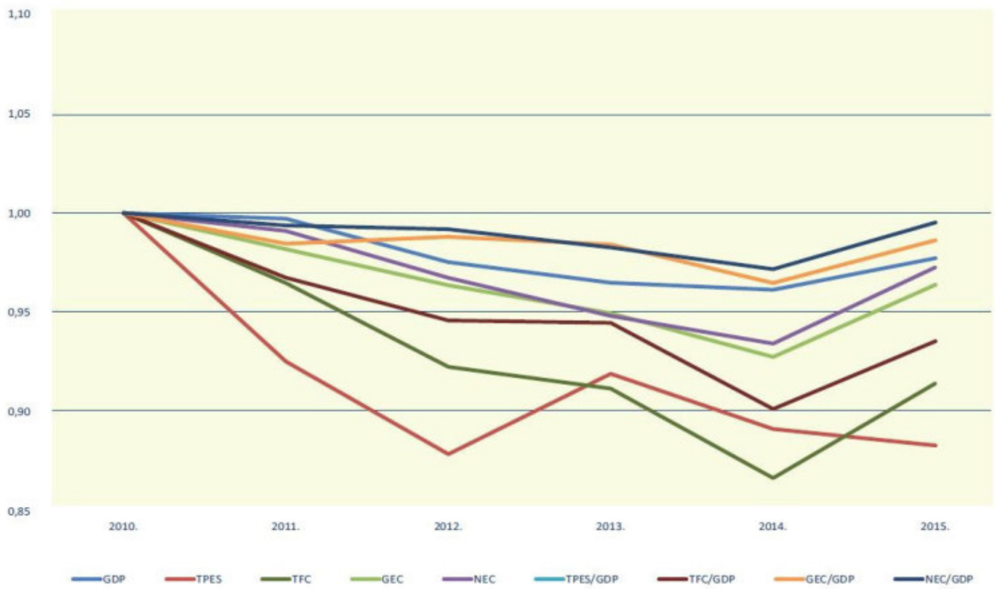
In 2009 (''Official Gazette" OG 130/09), the Energy Strategy was adopted by the Croatian Parliament pursuant to Article 80 of the Constitution of the Republic of Croatia and Article 5, Section 3 of the Energy Act (OG 68/01, 177/04, 76/07, 152/08). The Energy Strategy is adopted for the period until 2020. The goals of the Strategy are to build a sustainable energy system that makes a balanced contribution to security of energy supply, competitiveness and environmental protection and provides for security and availability of energy supply to the Croatian citizens and business sector as this is a prerequisite for economy and social development. The new Strategy is now being developed.

The origin of the total consumed energy is approximately 47% from oil and petroleum products, 22% from natural gas, 13% from hydroenergy, 7.5% from coal, 5.5% from nuclear energy, while other energy sources account for 5%. Croatia currently imports 40% of its energy demand. One third of the total consumed energy is transformed into electrical energy. Hydroelectric power plants cover approximately 45% of the electricity production, followed by thermal power plants with approximately 25% and nuclear power plants with approximately 20%. The net electricity import is about 10% of the total consumption.

Since Croatia's primary energy reserves are limited (particularly fossil fuels) and because of environment protection requirements, Croatia started to explore the potentials of renewable energy sources for electricity production (Feretić et al, 1999). One of them is geothermal energy, which has significant geothermal potential, especially in the Pannonian region. Enhanced and sustainable utilization of this resource could significantly contribute to the forecasted geothermal development and achievement of Croatia's National Renewable Energy Action Plan (NREAP) target. NREAP predicts a 39% Renewable Energy Source (RES) share in electricity production and 19.6% in heating and cooling from geothermal sources.

1.1. Primary energy

In 2015, gross domestic production increased by 1.6% compared to the previous year. The total primary energy supply decreased by 0.9%. Total final energy consumption increased by 5.5 % and gross electricity consumption as well by 3.9% (Ministry of Environment and Energy [MEE]: Energy in Croatia 2015, 2016). Net electricity consumption increased by 4.1%, without transmission and distribution losses, which increased by 2.2% in 2015. In the period from 2010 till 2015, gross domestic product decreased at an average annual rate of 0.5%, while the total primary energy supply decreased at an average annual rate of 2.5% and the total final energy consumption at an average annual rate of 1.8%. Electricity consumption also showed a negative trend, with the gross electricity consumption decreasing at an average annual rate of 0.7%, and net consumption decreasing at a rate of 0.6% annually. Transmission and distribution losses decreased at an average annual rate of 2.3%. Figure 1 shows the trends in the total energy consumption.



GDP - Gross Domestic Product; TPES - Total Primary Energy Supply; TFC - Total Final Energy Consumption; GEC - Gross Electricity Consumption; NEC - Net Electricity Consumption (losses excluded); TPES/GDP - Total Primary Energy Supply/Gross Domestic Product – the ratio showing the energy intensity of the total primary energy supply; TFC/GDP - energy intensity of the final energy consumption; GEC/GDP - Gross Electricity Consumption/Gross Domestic Product – the ratio showing the energy intensity of gross electricity consumption; NEC/GDP - Net Electricity Consumption/Gross Domestic Product - the ratio showing the energy intensity of net electricity consumption.

Figure 1: Main indicators of development. Source: MEE: Energy in Croatia 2015, 2016

The stated trends in gross domestic product, total primary energy supply, final energy consumption and electricity consumption resulted in the decrease of energy intensity of the total primary energy supply and in the increase of energy intensities of the final energy consumption, gross electricity consumption and net electricity consumption in 2015 as compared to 2014. Energy intensity of the total primary energy supply decreased by 2.5%. Energy intensity of the final energy consumption increased by 3.8%. Energy intensities of gross electricity consumption and net electricity consumption increased by 2.2% and 2.4% respectively. In the period from 2010 till 2015, energy intensity of total primary energy supply decreased at an average annual rate of 2% while the energy intensity of the final energy consumption decreased at an average annual rate of 1.3%. Energy intensities of the gross and net electricity consumption decreased, so that energy intensity of the gross electricity consumption decreased at an average annual rate of 0.3%, and the energy intensity of the net electricity consumption at an average annual rate of 0.1% (Figure 1.).

Figure 2 shows the trends in the total primary energy supply in the period from 1988 till 2014. As compared to the previous year, the total primary energy supply in 2015 decreased by 0.9%. In the period from 2010 till 2015, the total primary energy supply decreased at an average annual rate of 2.5%. From 1992, when Croatia's energy consumption was at its minimum, until 2015, the total primary energy supply grew at an average annual rate of 0.8%.

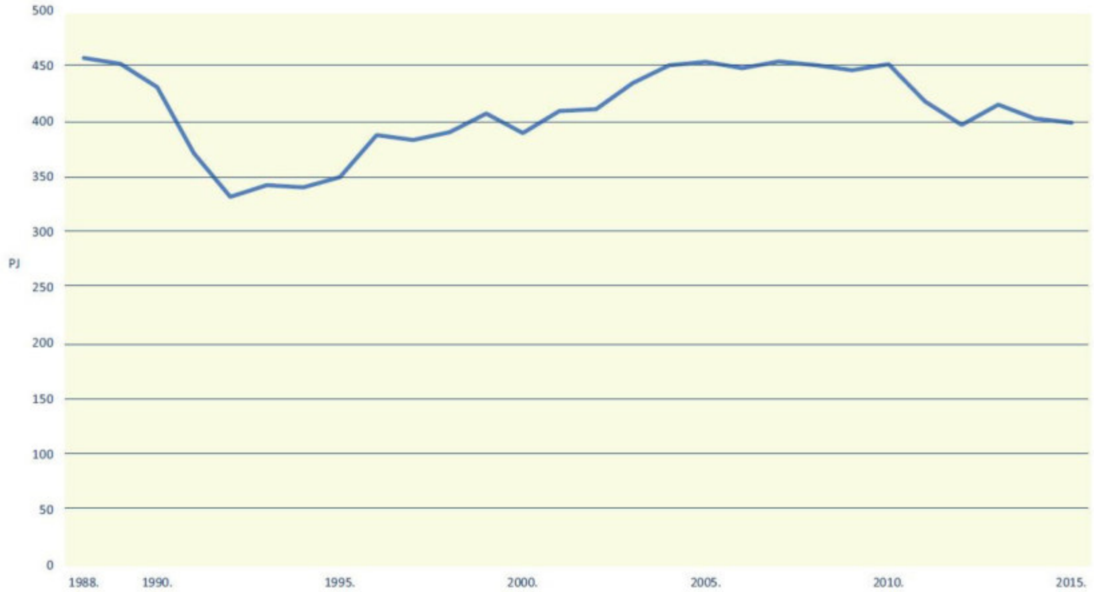


Figure 2: Total primary energy supply. Source: MEE: Energy in Croatia 2015, 2016

Figure 3 shows the trends in the gross and net electricity consumption in the period from 1988 till 2015. In the period from 2010 till 2015, gross and net electricity consumption decreased at the average annual rates of 0.7% and 0.6% respectively. Since 1992, when Croatia had the lowest energy consumption, gross electricity consumption grew at an average annual rate of 1.9%; whereas net electricity consumption had a slightly faster growth at an average annual rate of 2.1%. In the same period electricity losses increased at a slower rate, on average by 0.8% a year. In 2015, electricity consumption in Croatia increased compared to the previous year,, so that the gross consumption amounted to 18 190.4 GWh, whereas net consumption amounted to 16 388.9 GWh.

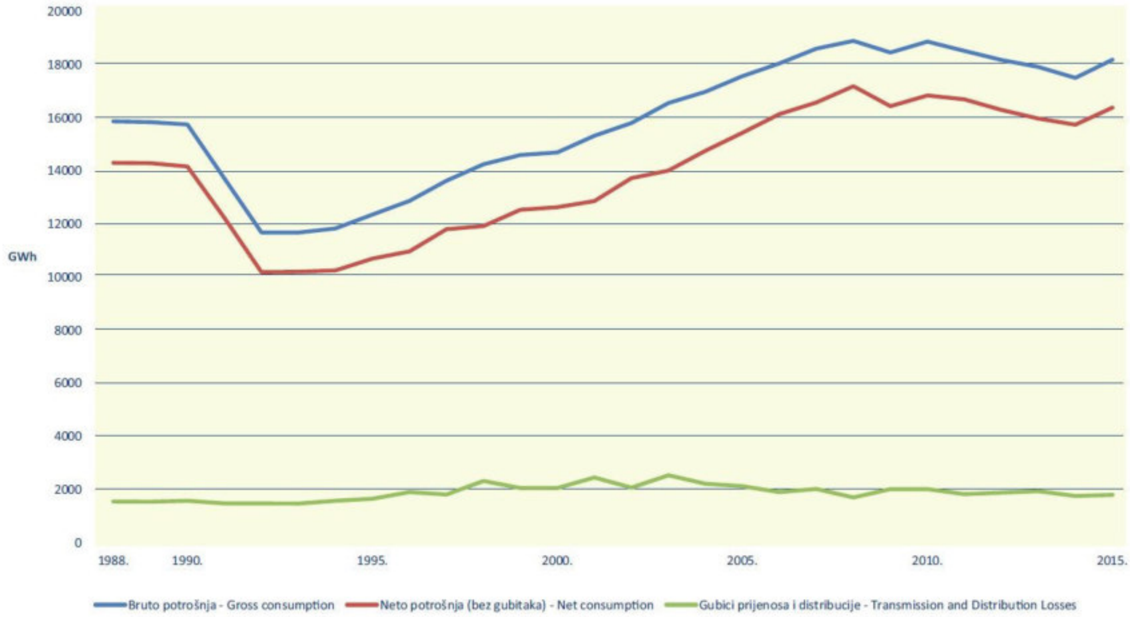


Figure 3: Electricity consumption. Source: MEE: Energy in Croatia 2015, 2016

Gross domestic product is determined by the application of purchasing power parities and in 2015 the Croatian GDP amounted to 16 423 US$ 2005 per capita. In relation to the average GDP in the European Union (EU 28), GDP per capita in Croatia was 45.6% lower. Thirteen European countries had GDP lower than the Croatian, while all the other EU countries shown in the figure below had higher GDP levels. Figures 4 and 5 present values of energy intensities of the total primary energy supply and gross electricity consumption. They are calculated by the use of gross domestic product determined by the application of purchasing power parities and expressed in US$ 2005. In 2015, for the realization of one thousand US$ 2005 determined by PPP, 138 kg of oil equivalent of total energy was used in Croatia, which is 29.4% above the European Union average (EU 28). More favorable values of energy intensity of the total primary energy supply were recorded in 28 observed countries (including the average for EU 28), whereas other countries had less favorable energy intensity. In 2015, the gross electricity consumption for 1000 US$ 2005 of GDP, determined by PPP in Croatia amounted to 263 kWh, which is 26.1% above the European average (EU 28).

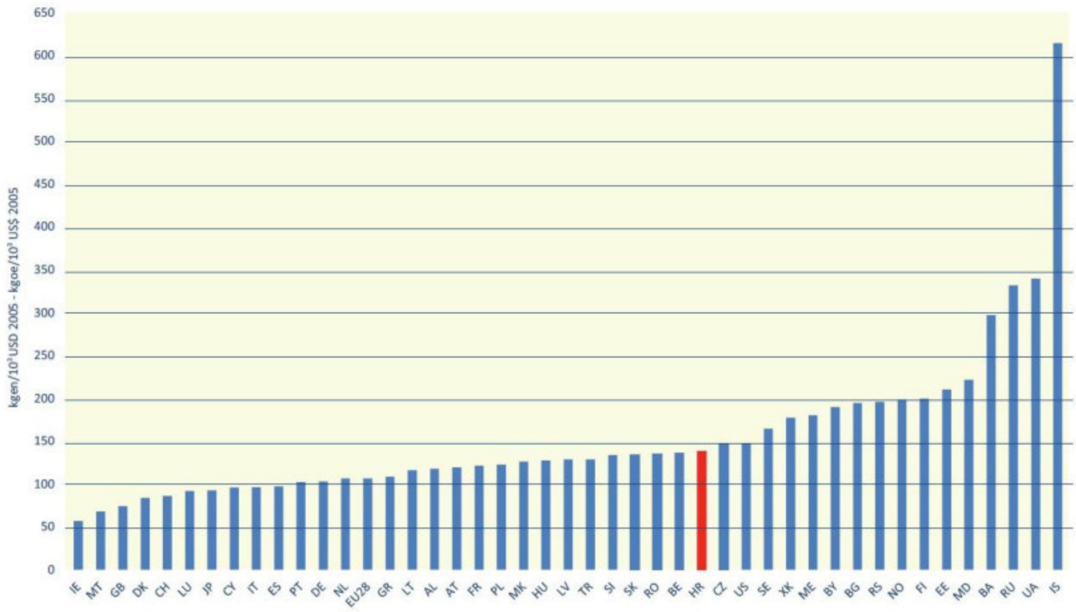


Figure 4: Total primary energy supply intensity - PPP. Source: MEE: Energy in Croatia 2015, 2016

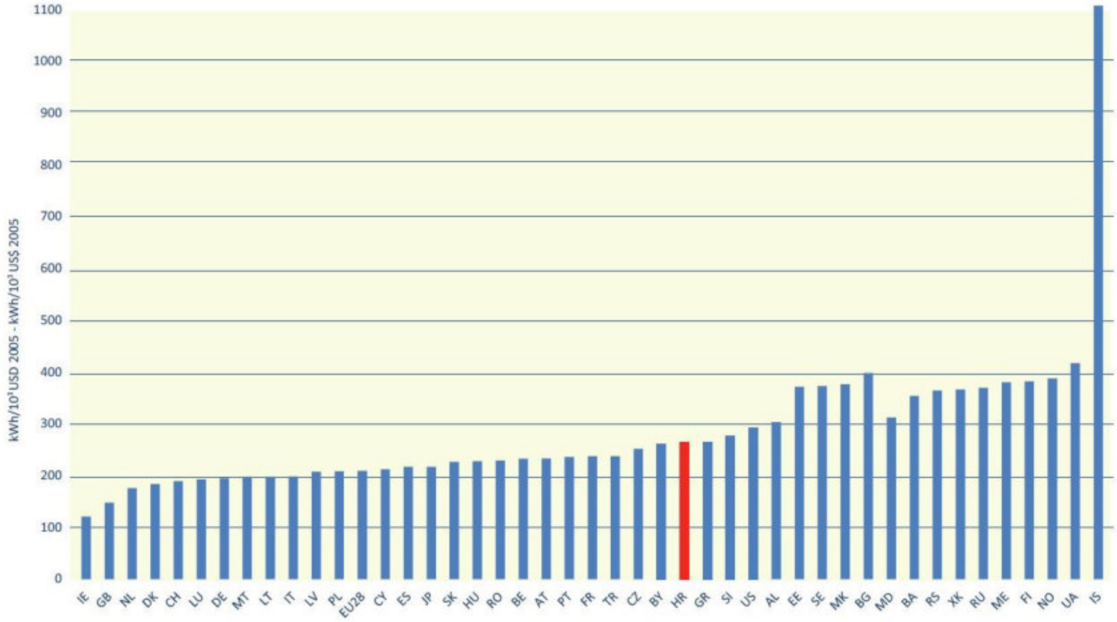


Figure 5: Gross electricity consumption intensity - PPP. Source: MEE: Energy in Croatia 2015, 2016

<u>Primary Energy Production</u>

Primary energy production in the period from 2010 till 2015 is described in the Table 1. In 2015, the primary energy production decreased by 6.7% compared to the previous year (MEE: Energy in Croatia 2015, 2016). Decrease is realized in usage of hydro power for 30.7%, while the production of all other primary energy commodities increased. Increase for the other renewable sources (such as the wind energy, solar energy, biogas, liquid biofuels and geothermal energy), amounted to 3.4%. Also, the production of the fuel wood and other types of biomass increased by 10.7 %.

	2010.	2011.	2012.	2013.	2014.	2015.	2015./14.	2010.-15.
	PJ						%	
Ogrjevno drvo i biomasa Fuel Wood and Biomass	56,20	59,01	60,39	61,45	57,67	64,19	10,7	2,7
Sirova nafta Crude Oil	30,69	28,37	25,62	25,71	25,38	28,62	12,7	-1,4
Prirodni plin Natural Gas	93,88	85,02	69,19	63,11	60,52	61,61	1,8	-8,1
Vodne snage Hydro Power	87,24	47,58	47,32	84,92	88,99	61,63	-30,7	-6,7
Toplinska energija Heat	0,63	0,61	0,62	0,63	0,53	0,64	20,3	0,4
Obnovljivi izvori Renewables	2,63	2,97	5,66	7,71	10,70	11,06	3,4	33,3
UKUPNO TOTAL	271,26	223,56	208,79	243,53	244,09	227,75	-6,7	-3,4

Table 1: Primary energy production. Source: MEE: Energy in Croatia 2015, 2016

Production of crude oil increased by 12.7% and of the natural gas by 1.8%. Also, the production of the heat from heat pumps increased by 20.3%. During the six-year period, from 2010 till 2015, primary energy production in Croatia decreased at an average annual rate of 3.4%. Decreasing trend was recorded in the production of crude oil and natural gas and hydro power, whereas the production of other primary forms of energy increased. The production of crude oil and natural gas decreased annually on average by 1.4% and 8.1% respectively. Hydrological conditions were such that there was a decrease of hydropower at an average annual rate of 6.7%. The fastest growing production was that of renewable energy with an average annual growth rate of 33.3%. Heat from heat pumps also increased in the observed period, with an average annual rate of 0.4%, while the production of fuel wood and other solid biomass had an average annual growth of 2.7%. In the period from 2010 till 2015, the trends in the production of primary energy forms were such that the share of natural gas dropped from 34.6% to 27.1% and the share of hydro power decreased from 32.2% to 27.1%, while the shares of all other primary energy forms increased. The share of crude oil grew from 11.3% to 12.6%, and the share of fuel wood and solid biomass from 20.7% to 28.2%. In 2015, other renewables (wind energy, biodiesel, solar energy, geothermal energy and biogas) increased their share to 4.9%, and the share of heat from heat pumps increased for 0.1%, thus amounted at 0.3%.

Total Primary Energy Supply

The shares of specific energy forms in the total primary energy supply during the period from 2010 till 2015 are given in Table 2. In 2015, the total primary energy supply in Croatia decreased by 0.9% as compared to the previous year (MEE: Energy in Croatia 2015, 2016). The consumption of coal and coke decreased by 5.5% and of hydropower decreased by 30.7% due to unfavorable hydrological conditions. Also, the consumption of other energy sources increased, and the consumption of the imported electricity also increased by 71.7%. The consumption of heat from heat pumps increased by 20.3%, of fuel wood and biomass by 14.2% and of other renewable energy sources by 7.4%. The consumption of natural gas increased by 3.0% and the consumption of liquid fuels increased by 4.1%. In the period from 2010 till 2015, the total primary energy supply decreased at an average annual rate of 2.5%. In this period, there was an increase in the consumption of other renewable energy sources, imported electricity, heat from heat pumps and fuel wood and biomass, while the consumption of other energy sources decreased. The consumption of renewable energy sources increased at an average annual rate of 36.6%, and the consumption of imported electricity at an average rate of 11.3% annually. The consumption of the heat from heat pumps and of fuel wood and biomass increased much slower, at an average annual rate of 0.4%, and 0.2%, respectively. The consumption of natural gas decreased at an average annual rate of 4.8%, the consumption of liquid fuels decreased at an average annual rate of 3% and the consumption of coal and coke decreased at an average rate of 0.7%. Hydropower decreased at an average annual rate of 6.7% with variations in some years, depending on hydrological conditions.

	2010.	2011.	2012.	2013.	2014.	2015.	2015./14.	2010.-15.
	PJ						%	
Ugljen i koks Coal and Coke	30,92	31,66	28,37	32,18	31,59	29,86	-5,5	-0,7
Drvo i biomasa Biomass	52,29	51,50	52,10	51,67	46,12	52,69	14,2	0,2
Tekuća goriva Liquid Fuels	152,54	149,30	134,17	128,37	125,80	130,92	4,1	-3,0
Prirodni plin Natural Gas	111,37	108,60	101,78	95,54	84,62	87,16	3,0	-4,8
Vodne snage Hydro Power	87,24	47,58	47,32	84,92	88,99	61,63	-30,7	-6,7
Električna energija Electricity	14,28	25,76	26,75	13,93	14,23	24,44	71,7	11,3
Toplinska energija Heat	0,63	0,60	0,62	0,63	0,53	0,64	20,3	0,4
Obnovljivi izvori Renewables	2,24	2,83	5,72	7,80	10,65	11,44	7,4	38,6
UKUPNO TOTAL	451,50	417,84	396,83	415,04	402,53	398,77	-0,9	-2,5

Table 2: Total Primary Energy Supply. Source: MEE: Energy in Croatia 2015, 2016

Liquid fuels had the largest share in total primary energy supply in Croatia amounting to 33.8% in 2010, which decreased to 32.8% until 2015. In addition to liquid fuels, shares of natural gas and hydropower which share varies depending on hydrological conditions also decreased. Listed shares decreased by 2.8% and 3.8%, respectively so the share of natural gas amounted to 21.9% in 2015 and the share of hydropower amounted to 15.5%. Shares of all other energy forms increased. The share of imported electricity in 2010 amounted to 3.2%, whereas in 2015 it amounted to 6.1%. The share of other renewable sources (wind energy, solar energy, geothermal energy, biodiesel and biogas) increased from 0.5% to 2.9%, as well as the share of fuel wood and solid biomass from 11.6% to 13.2%. The share of heat from heat pumps increased in the total primary energy supply from 0.1% to 0.2% in 2015, whereas the shares of coal and coke increased from 6.8% to 7.5%.

The average consumption of liquid fuels per capita was 744 kg of oil equivalent; a lower per capita consumption was realized in sixteen countries, and consumption was 22.7% below the European average. Similar relations were recorded in the consumption of natural gas where the consumption per capita was 23% lower than that of the European Union. Croatia lagged far behind the European countries in coal consumption. In 2015, coal consumption per capita in Croatia amounted to 170 kg of oil equivalent, which is 66.2% below the average coal consumption in the European Union, which amounts to 502 kg of oil equivalent.

Figure 6 presents the trends in energy self-supply in the observed period. Energy self-supply is the relation between the total primary energy production and the total primary energy supply. In 2015, it amounted to 57.1 %, which represents the decrease of 5.8 % compared to the previous year.

Figure 6: Primary energy self-supply in Croatia. Source: MEE: Energy in Croatia 2015, 2016

1.1.1. Electricity

1.1.1.1. Electricity generation capacities

The installed electricity generating capacities in the Republic of Croatia include hydro and thermal power plants owned by the HEP Group, increasing number of wind power plants and other power plants on renewable energy sources and certain number of industrial power plants.

<u>HEP's electricity generation capacity</u>

Electricity generation capacities within the HEP Group consist of 16 locations with hydro power plants, 7 locations with thermal power plants and one half of the installed capacities of the nuclear power plant Krško (located in the territory of Slovenia) (MEE: Energy in Croatia 2015, 2016). Thermal power plants are gas-fired, coal-fired and fuel oil-fired.

The majority owner over the generation capacities in the Republic of Croatia is HEP d.d. The facilities that are not fully owned by HEP d.d. are the following:

- NE Krško d.o.o. (Nuclear power plant Krško Ltd.) under the joint ownership of the HEP d.d. (50%) and the Slovenian company ELES GEN d.o.o. (50%)
- TE Plomin d.o.o. (Thermal power plant Plomin Ltd.) under the joint ownership of the HEP d.d. (50%) and the German company RWE Power (50%). HEP Proizvodnja d.o.o. (HEP Generation Ltd.) won a management and operation and maintenance contract for the thermal power plant Plomin. Total available capacities of all HEP's power plants in the Republic of Croatia amount to 4 107.5 MW (including TPP Plomin and excluding NPP Krško) i.e., total capacities serving the needs of the Croatian electric power system amount to 4 455.5 MW (with 50% of Krško capacities). Out of this amount, 1 906 MW is placed in thermal power plants (including TPP Plomin and excluding NPP Krško), 2 201.5 MW in hydro power plants and 348 MW in the nuclear unit Krško (50% of total available capacity).

These capacities do not include generating units in other countries from which the Croatian electric power system has the right to withdraw electricity on the basis of capacity lease and share-ownership arrangements. The capacities in other countries are the following:

- Thermal power plant Gacko (Bosnia and Herzegovina) – total installed capacity of 300 MW, coal-fired. Legal basis – shared ownership (1/3 of capacity and power for a 25-year period)
- Thermal power plant Obrenovac (in the Republic of Serbia) – installed capacity 305 MW, coal-fired. Legal basis – capacity and power lease on the basis of a credit for construction

The capacity and power from the above-mentioned facilities is not available, as the status of these facilities has not been resolved yet. The open issues regarding the agreements on investments in these facilities refer to the duration period, the way of treatment of the invested funds and what pricing methods should be applied to electricity deliveries. In Table 3 and Figure 7 total electricity production capacities in HEP Group ownership are shown. In Tables 4 and 5 all hydro and thermal power plants are listed.

Kapaciteti za proizvodnju električne energije Electricity generation capacity	Raspoloživa snaga Available power (MW)	Udio Share (%)	Proizvedena električna energija u 2015. Electricity produced in 2015 (GWh)
Hidroelektrane (HE) Hydro power plants (HPP)	2 201,5	52,0	5 672,9
Termoelektrane (TE) Thermal power plants (TPP)	1 714	35,2	1 861,6
TE Plomin d.o.o. (B) TE Plomin Ltd.	192	4,6	1 295,3
Ukupno u Republici Hrvatskoj Total in the Republic of Croatia	4 107,5	91,7	8 829,9
Nuklearna elektrana Krško (NE Krško) – 50% Nuclear power plant Krško (NPP Krško) – 50%	348	8,3	2 684,9
UKUPNO TOTAL	4 455,5	100	11 514,8

Table 3: Electricity generation capacity of the Republic of Croatia (HEP Group ownership). Source: MEE: Energy in Croatia 2015, 2016

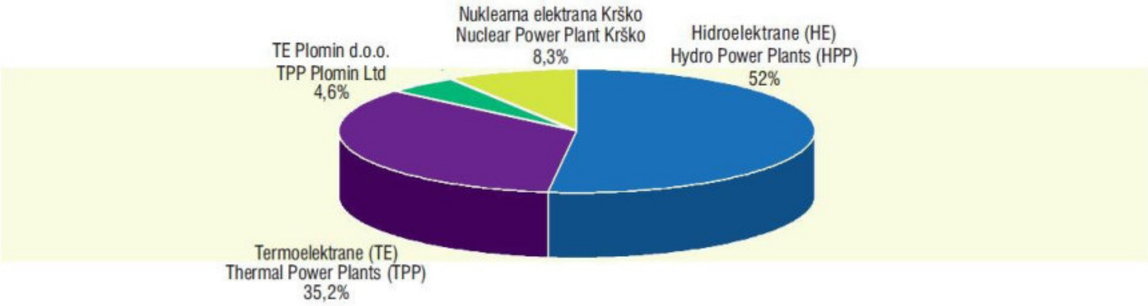


Figure 7: Available electricity generation capacity in the Republic of Croatia (HEP Group ownership). Source: MEE: Energy in Croatia 2015, 2016

Hidroelektrane Hydro power plants			
	Raspoloživa snaga Available power (MW)		Raspoloživa snaga Available power (MW)
Akumulacijske hidroelektrane Storage plants		**Protočne hidroelektrane Run-of-river plants**	
HE Zakučac	535	HE Varaždin	92,5
RHE Velebit	276/(-240)	HE Čakovec	77,4
HE Orlovac	237	HE Dubrava	79,8
HE Senj	216	HE Gojak	55,5
HE Dubrovnik	228	HE Rijeka	36,8
HE Vinodol	90	HE Miljacka	24
HE Kraljevac	46,4	HE Lešće	41,2
HE Peruća	61,2	**Male protočne hidroelektrane | Small run-of-river plants**	
HE Đale	40,8	HE Jaruga	7,2
HE Sklope	22,5	HE Lešće ABM	1,1
RHE Buško Blato	11,7/(-15)	HE Golubić	6,5
Male akumulacijske hidroelektrane | Small storage plants		HE Ozalj	5,5
		HE Krčić	0,3
RHE Fužina	4,6/(-5,7)	**Ukupno protočne Total run-of-river**	427,08
HE Zavrelje	2	**Ukupno male HE Total small HPP**	29,7
RHE* Lepenica	0,8/(-1,2)		
HE Zeleni Vir	1,7		
Ukupno akumulacijske HE Total storage HPP	1 773,7		
*RHE – reverzibilna HE | reversible HPP		**Ukupno HE Total HPP**	2 188,5

Table 4: Hydro power plants in the Republic of Croatia (HEP Group ownership). Source: MEE: Energy in Croatia 2015, 2016

Teremoelektrane Thermal power plants	Raspoloživa snaga na pragu Available net capacity (MW)	Proizvedena električna energija tijekom 2015. Electricity produced during 2015 GWh	Gorivo Fuel
TE Sisak	631	213,7	loživo ulje / prirodni plin fuel oil / natural gas
TE-TO Zagreb	422	535,2	prirodni plin / loživo ulje natural gas / fuel oil
TE Rijeka	303	39,3	loživo ulje fuel oil
TE Plomin (A)	105	794,3	ugljen coal
EL-TO Zagreb	89	212,3	prirodni plin / loživo ulje natural gas / fuel oil
KTE Jertovec	74	5,6	prirodni plin / ekstralako ulje natural gas / extra light oil
TE-TO Osijek	90	61,2	loživo ulje / prirodni plin / ekstralako ulje fuel oil / natural gas / extra light oil
TE Plomin d.o.o. (B)	192	1 295,3	ugljen coal
UKUPNO TOTAL	1 906	3 156,9	

Table 5: Thermal power plants in the Republic of Croatia (HEP Group ownership). Source: MEE: Energy in Croatia 2015, 2016

<u>Electricity production from Renewable Energy Sources</u>

In the Republic of Croatia there is about 520 MW installed capacity for electricity generation from RES in private ownership (Table 6) and 165 MW of installed capacity in other cogeneration plants (Table 7) (MEE: Energy in Croatia 2015, 2016).

Instalirana snaga | Installed capacity (MW)		Proizvodnja u 2015. | Produced in a 2015 (GWh)
Elektrane na biomasu | Thermal Power Plants (biomass)		
24,6		89,1
Elektrane na bioplin | Thermal Power Plants (biogas)		
27,2		176,1
Male hidroelektrane* | Small hydro power plants*		
6,3		17,2
Sunčane elektrane | Solar power plants		
47,8		57,1
Vjetroelektrane (VE) | Wind power plants (WPP)		
418		796,3
Ukupno OIE Total RES	525,7	1135,8

* - ne uključuje male HE (< 10 MW) u sastavu HEP grupe
* - does not include Small HPPs (< 10 MW) in HEP group ownership

Table 6: RES Power plants in the Republic of Croatia (not in HEP Group ownership). Source: MEE: Energy in Croatia 2015, 2016

Elektrana Plant name	Instalirana snaga Installed capacity (MW)	P 201 in
Termoelektrane (plin, tekuća goriva, ugljen, drvo) | T		
Belišće d.d., Belišće	31,0	
Viro d.o.o, Virovitica	8,0	
INA Rafinerija nafte, Rijeka	40,5	
Tvornica Šećera Osijek d.o.o.	18,5	
INA d.d. Naftaplin CPS Molve, Đurđevac	11,1	
INA d.d. Pogon Etan,	8,0	

Table 7: Other CHP plants in the Republic of Croatia. Source: MEE: Energy in Croatia 2015, 2016

1.1.1.2. Network capacities

Power network is part of the power system as a whole. Its purpose is connecting the generators to end-users and combining the generation from power plants within the system with customer supply pattern under given security criteria. Power network is divided in two parts: transmission network and distribution network. HEP TSO transmission network capacities are shown in Table 8. while HEP DSO distribution network capacities are given in Table 9 (MEE: Energy in Croatia 2015, 2016).

Naponska razina Voltage level	400 kV	220 kV	110 kV	Srednji napon Medium voltage
Duljina vodova Lines length (km)*	1 247	1 213	5 108	11
Broj TS Number of substations	6	14	151*	

* total length of lines, number of substations, number and power of transformers refer to the operational voltage levels coordinated by TSO

Table 8: TSO transmission network capacities. Source: MEE: Energy in Croatia 2015, 2016

Naponska razina Voltage level	110 kV	35 (30) kV	20 kV, 10 kV	0.4 kV	Priključci Connections
Duljina vodova Lines length (km)*	10	4 668,3	8 591 27 712	62 524	33 313
Broj TS Number of substations	151*	307 (35(30)/10(20) kV)	25 307 (10(20)/0,4 kV)		

* length of lines is a sum of lengths of overhead lines, cables and marine cables of the same voltage level

Table 9: HEP DSO distribution network capacities. Source: MEE: Energy in Croatia 2015, 2016

1.1.2. Heat energy

1.1.2.1.Energy companies in Heat Sector

All energy entities operating in the district heating sector need to obtain a permission to perform these activities from the Croatian Energy Regulatory Agency and must meet the requirements determined by the Rules on Permits for Performing Energy Activities (MEE: Energy in Croatia 2015, 2016).

Data on energy operators who have been issued permissions to perform district heating activities can be found on the official website of the Croatian Energy Regulatory Agency (www.hera.hr).

In the Republic of Croatia, twelve companies in 17 towns were engaged in activities of production, distribution and supply of heat for tariff customers in 2015. The companies provided the service of space heating and sanitary hot water preparation for more than 154 000 customers in the larger cities of Continental Croatia, as well as in Rijeka and Split, with more than 96 % of the total number of customers belonging to household's category. Heat is produced in cogeneration plants in the cities of Zagreb, Osijek and Sisak or in heating plants, block and boiler houses for various settlements, and is distributed through over 415 km of district heating network to the facilities where it is supplied to the customers. In the cities of Zagreb, Osijek and Sisak process steam is also produced and delivered for industrial purposes and partially for space heating. More than 2 TWh of heat was delivered in year 2015 in the Republic of Croatia.

General data on energy companies in the district heating sector is given in Table 10.

Tvrtka, grad Company, town		Ukupan broj potrošača | Total number of consumers	Grijana površina kućanstava | Heated area - households	Grijana površina ostalih potrošača | Heated area - other consumers	Ukupna isporučena toplinska energija | Total heat delivered	Ukupna duljina distribucijske mreže | Total network length	Broj novih potrošača priključenih u 2015. | No. of new consumers connected in 2015	Grijana površina novih potrošača | Heated area of new consumers	Gorivo | Fuel**
			m²	m²	MWh	km		m²	
HEP - Toplinarstvo d.o.o.*	Sisak	4 140	229 159	3 800	65 185	10,00	-	-	PP
	Osijek	11 702	589 305	n/p	232 648	56,29	7	969	PP, LU, LUEL
	Zagreb***	108 980	5 651 180	n/p	1 627 816	289,20	182	26 904	PP, LU, LUEL
Brod plin d.o.o.	Slavonski Brod	3 762	175 300	22 368	35 481	7,05	-	-	PP
Plin VTC d.o.o.	Virovitica	442	21 973	6 530	2 720	0,84	-	-	PP
Energo d.o.o.	Rijeka	9 940	533 500	34 852	59 137	16,04	-	-	PP, LU, LUEL
Vartop d.o.o.	Varaždin	1 273	66 385	2 416	5 287	1,57	-	-	PP
Komunalac d.o.o.	Požega	417	19 839	-	2 208	0,80	-	-	PP
GTG Vinkovci d.o.o.	Vinkovci	1 697	86 938	2 757	8 627	1,60	-	-	PP, LU
Tehnostan d.o.o.	Vukovar	3 670	186 342	17 977	17 462	7,25	-	-	PP, LUEL, PEL
Gradska toplana d.o.o.	Karlovac	8 002	407 968	97 963	57 516	21,00	-	-	PP
Top-terme d.o.o.	Topusko	182	8 356	23 018	4 486	1,70	-	-	GEO
Ivakop d.o.o.	Ivanić Grad	3	-	6 451	742	1,00	-	-	PP
SKG d.o.o.	Ogulin	104	4 266	2 896	1 212	0,40	-	-	LUEL
	UKUPNO TOTAL	154 314	7 980 512	221 028	2 120 527	415	189	27 873	

* Also included is delivered process steam
** natural gas, fuel oil, light heating oil, geothermal, pellets
*** HEP Toplinarstvo Zagreb also includes Velika Gorica, Zapresic and Samobor

Table 10: General data on major energy entities in the district heating sector in the Republic of Croatia. Source: MEE: Energy in Croatia 2015, 2016

1.1.2.2.Heat Prices

In accordance to the provisions of the Act on Heat Market, for all central district heating systems (CTS) Croatian energy regulatory agency adopts tariff item amounts for heat production and tariff item amounts for heat distribution. Decisions may be found at: http://www.hera.hr/hrvatski/html/propisi_tenergija.html.

The Act on Heat Market stipulates that energy activity of heat supply and activity of heat customer are market activities, and that a fee for the heat supply and the fee for the customer of heat are freely determined in accordance with market conditions.

In central district heating systems amounts of tariff items for the heat production and distribution represent the regulated part of the heat price, while the fees for the heat supply and for the activity of heat customer are freely contracted.

The heat price in closed heating systems (ZTS) and independent heating systems (STS) is freely determined in accordance with market conditions.

The amounts of tariff items for central district heating systems (CTS) in force at the end of 2015 are shown in Tables 11 and 12.

Grad | Town	Kućanstva | Households		Industrija i poslovni potrošači | Industry and bussines consumers	
	Energija | Energy	Snaga | Capacity	Energija | Energy	Snaga | Capacity
	HRK/kWh	HRK/kW	HRK/kWh	HRK/kW
Sisak	0,1800	7,5500	0,3400	12,2600
Osijek	0,1600	8,4300	0,3100	13,2100
Zagreb CTS	0,1700	5,7500	0,3400	12,0300
Dubrava (Zagreb)	0,1700	6,6000	0,3400	12,2600
Velika Gorica	0,3000	11,1500	0,3400	12,7000
Samobor	0,3000	10,9700	0,3400	11,6600
Slavonski Brod	0,3800	16,8000	0,4800	16,8000
Rijeka: Gornja Vežica	0,4150	13,5000	0,4150	13,5000
Rijeka: Krnjevo	0,4150	15,0000	0,4150	15,0000
Rijeka: Vojak	0,4600	16,5000	0,4600	16,5000
Vukovar	0,4150	14,5000	0,4950	14,5000
Karlovac	0,3740	16,0000	0,4910	17,0000

Table 11: Tariff items (without tax) for central district heating system of some companies effective at the end of 2015. Source: MEE: Energy in Croatia 2015, 2016

Tvrtka | DH Company	Grad | Town	Tehnološka para | Process steam Industrija i poslovni potrošači | Industry and commercial consumers	
		Energija | Energy	Snaga | Capacity
		HRK/t	HRK/t/h
HEP - Toplinarstvo d.o.o.	Zagreb	288,26	8 175,21
	Osijek	265,57	8 175,42
	Sisak	288,26	14 138,38

Table 12: Tariff items (without tax) for process steam for HEP – Toplinarstvo d.o.o. effective in year 2015. Source: MEE: Energy in Croatia 2015, 2016

Figures 8. and 9. show comparison of tariff items for central DH systems of some companies in Croatia for tariff elements of delivered energy and capacity.

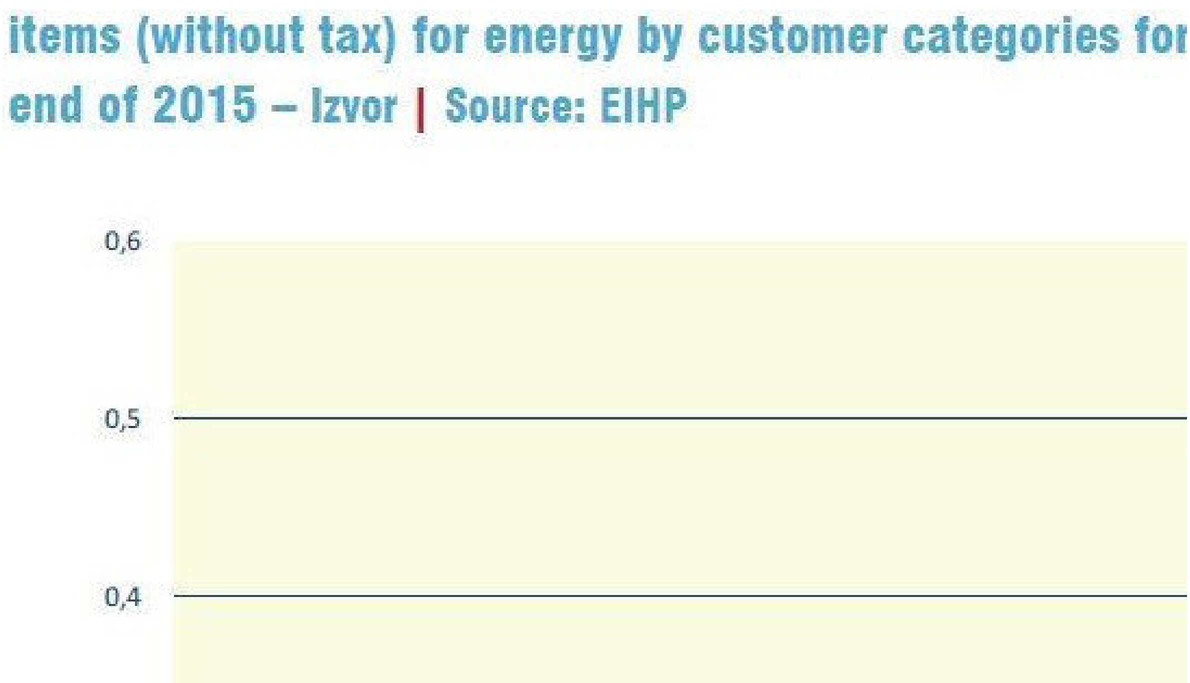


Figure 8: Comparison of tariff items (without tax) for energy by customer categories for central DH systems of district heating companies, at the end of 2015. Source: MEE: Energy in Croatia 2015, 2016

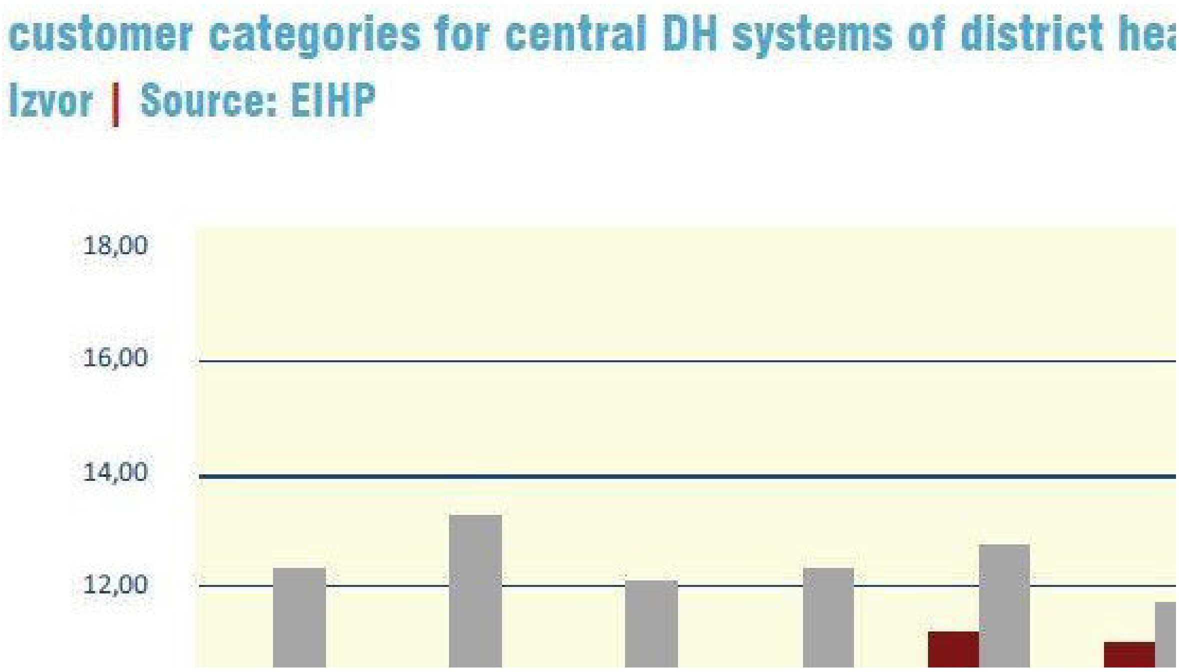


Figure 9: Comparison of tariff items (without tax) for capacity by customer categories for central DH systems of district heating companies, monthly cost, at the end of 2015. Source: MEE: Energy in Croatia 2015, 2016

1.1.3. Transport

Table 13 shows the trends in the consumption of specific energy forms in the transport sector in the period from 2010 till 2015. Figure 10 shows the same trends in the period from 1988 till 2015. In 2015, energy consumption in transport increased by 4.5 percent as compared to the consumption in 2014. The consumption of diesel oil, LPG, electricity and natural gas increased, while the consumption of other energy generation products decreased (MEE: Energy in Croatia 2015, 2016). The consumption of motor gasoline decreased by 0.2%, jet fuel by 2.9% and liquid biofuels by 18.4%. The consumption of diesel oil increased by 7.8%, LPG by 10.9% and electricity by 5.7%. Natural gas had a consumption growth by 2.6%, but in the total energy consumption in transport still has a really low share.

During the period from 2010 till 2015, the transport sector increased its energy consumption at an average annual rate of 0.4%. There was a decreasing trend in the consumption of motor gasoline and electricity, whereas the consumption of other energy forms increased. The consumption of motor gasoline decreased at an average annual rate of 4% and the consumption of electricity decreased at an average annual rate of 1.4 %. The consumption of diesel oil increased by 1.9% and the consumption of jet fuel increased by 3.1%. The consumption of LPG increased at an average rate of 2.7% per year, and the consumption of liquid biofuels and natural gas increased at an average annual rate of 54.9% and 9.4%, respectively.

	2010.	2011.	2012.
			PJ
Tekuća biogoriva Liquid biofuels	0,11	0,14	1,51
Ukapljeni plin LPG	2,75	2,62	2,57
Prirodni plin Natural Gas	0,09	0,03	0,03

Table 13: Final energy consumption in transport by fuels. Source: MEE: Energy in Croatia 2015, 2016

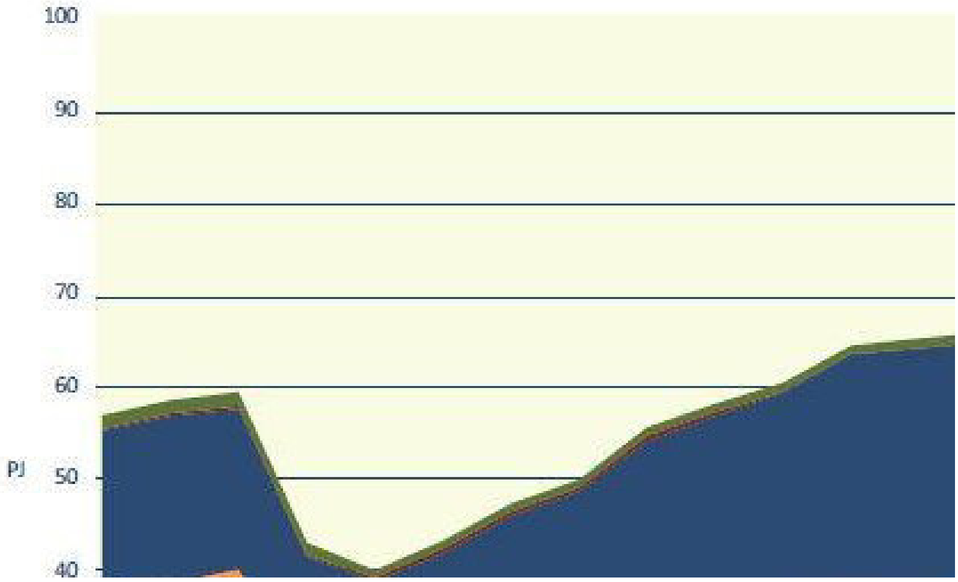


Figure 10: Final energy consumption in transport. Source: MEE: Energy in Croatia 2015, 2016

The shares of specific energy forms in total final energy consumption in transport in 2010 and 2015 are presented in Figure 11. In this period the structure of final energy use in transport sector went through the following changes: the shares of diesel oil, jet fuel, LPG, natural gas and liquid biofuels increased, whereas the share of other energy forms used in transport decreased. The share of diesel oil increased from 57.2% in 2010 to 61.7% in 2015. The share of jet fuels increased from 5.2% to 6% in 2015, and the share of LPG increased from 3.2% to 3.6%. The share of liquid biofuels increased from 0.1% to 1.2%, and the share of natural gas increased to 0.2% in 2015. The share of motor gasoline decreased by 6.4% so in 2015, it amounted to 26.3%, whereas the share of electricity decreased from 1.3% to 1.2%.

The trends in energy consumption by means of transport in the period from 2010 till 2015 are given in Table 14, show the same trends in the period from 1988 until 2015. In 2015, energy consumption in rail transport, sea and river transport and air transport decreased, while in all other means of transport, it increased. Energy consumption in road transport increased by 5.7%, the consumption in non-specified means of transport increased by 21.6% and in public city transport by 0.04%. Energy consumption in rail transport decreased by 9.1% and in sea and river transport it decreased by 5%. Energy consumption in air transport decreased by 2.8%. In the period from 2010 till 2015, there was a growing trend in energy consumption in most means of transport, while energy consumption in rail and public city transport decreased. The consumption in rail transport decreased at average annual rate of 6.8% and in public city transport at average annual rate of 1.3%. The average annual rate of energy consumption increase in air transport amounted to 3.1%, whereas the energy consumption in road transport increased at an average annual rate of 0.3%. Energy consumption in sea and river transport, as well as in the non-specified means of transport, increased at average annual rates of 2.2% and 6.1%, respectively.

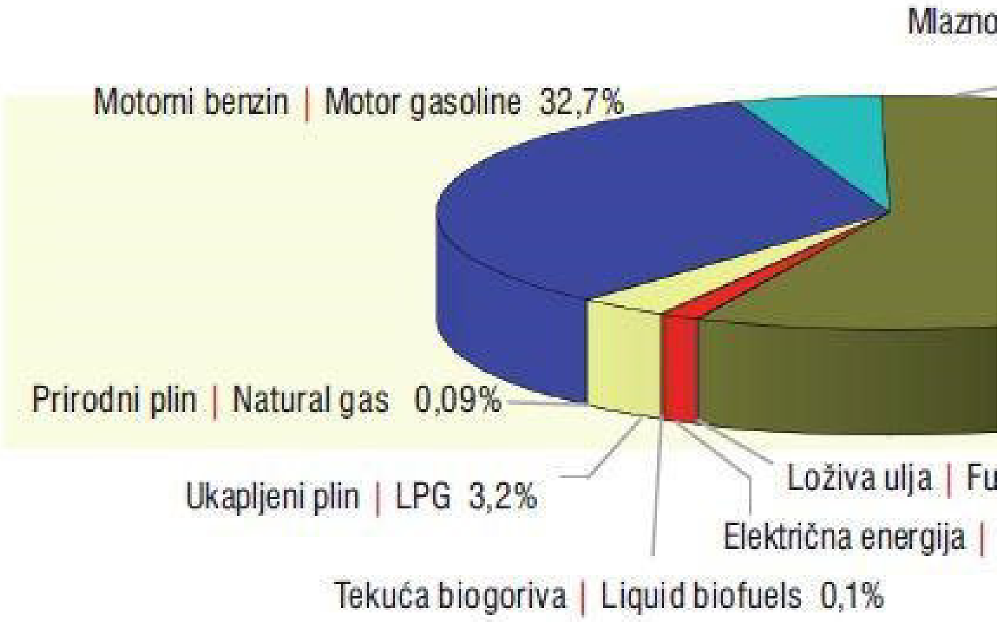


Figure 11: Final energy consumption in transport by energy forms. Source: MEE: Energy in Croatia 2015, 2016

transport

	2010.	2011.	2012.
Željeznički promet Rail Transport	1,84	1,75	1,65
Cestovni promet Road Transport	77,13	75,59	74,30

Table 14. Final energy consumption by means of transport. Source: MEE: Energy in Croatia 2015, 2016

In the period 2010 – 2015 only minor structural changes took place. The shares of road transport, rail transport and public city transport decreased, the shares of air transport and sea and river transport increased and the shares of other types of transport remained the same. The share of air transport increased by 0.7%, and in 2015 it amounted to 6.1%. The share of sea and river transport increased from 1.9% to 2.1%. Most of energy consumption in transport is realized in road transport whose share decreased from 88.9% to 88.7% in 2015. The share of rail transport decreased from 2.1 % to 1.5 % and the share of public city transport decreased from 1.7% to 1.5%.

1.2. The use of renewable energy sources in Croatia

Table 15 provides estimated data on installed capacities for heat generation from the renewable energy sources (RES-H) and statistical data on installed capacities for electricity generation from RES (RES-E) for 2015 (MEE: Energy in Croatia 2015, 2016). When interpreting data on installed capacities on RES-H, it is necessary to bear in mind that there are no reliable statistical data on installed capacities for solar and biomass heating systems while heat from geothermal sources includes two methodologies for reporting the values. Installed heat capacity of solar systems has been estimated according to the surface and type of collectors as recommended by the European Solar Thermal Industry Federation (ESTIF) and data from the EIHP's survey on installed capacities. Heat capacity data of the heating power plants using biomass refer to biomass-fired industrial facilities and do not contain information on small heating furnaces heat capacity and hot water preparation in households. Professional literature mentions two methodologies of expressing the used geothermal energy: one for the energy used for space heating only and the other for the energy used for heating and hot water preparation. Total installed capacities of geothermal sources in 23 locations used in Croatia amount to 52.79 MWt when space heating is concerned, and 124.65 MWt when geothermal energy for space heating and hot water preparation in spas and recreational centers is concerned. Installed power capacity of photovoltaic systems differs from the value provided by HROTE as it refers to grid connected systems including autonomous PV systems. Installed capacity of autonomous PV systems that supply facilities without grid connection (lighting houses, holiday houses, GSM bases, parking machines etc.) is estimated to 500 kW. Installed capacities growth trend for RES-H and RES-E is shown in Table 15 and Figure 12.

energy sources in Croatia for 2015

OIE RES	Instalirana toplin Installed heat cap
Sunce Solar	128,12*
Vjetar Wind	0

* estimation
** systems connected to the grid

Table 15: Installed capacities for heat and electricity generation from renewable energy sources in Croatia for 2015. Source: MEE: Energy in Croatia 2015, 2016

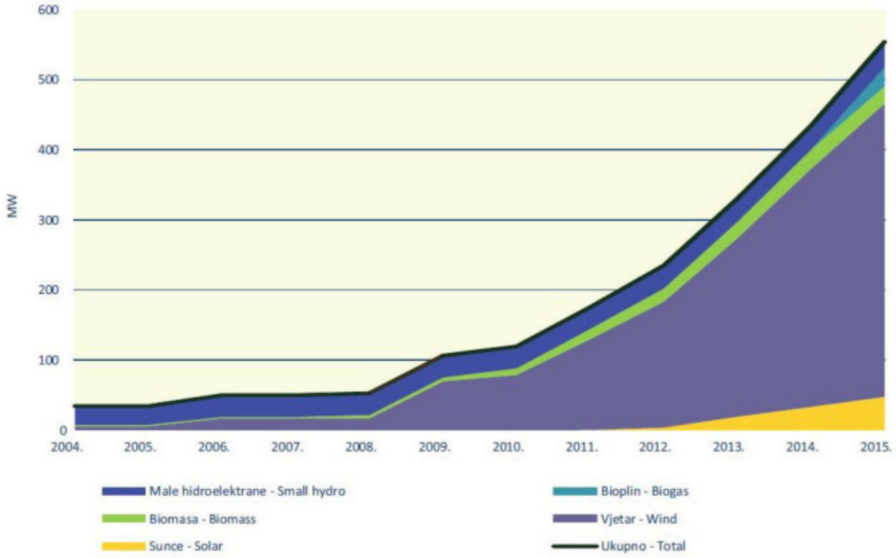


Figure 12: Installed capacities for RES-E generation in Croatia. Source: MEE: Energy in Croatia 2015, 2016

1.2.1. Electricity Generation

Table 16 shows electricity production from RES for 2015. In 2015 RES-E share of the total electricity generation was 10.7 percent, excluding large hydro power plants.

RES in Croa

Vrsta izvora Type of renewable energy source
Sunce Solar
Vjetar Wind
Biomasa

Table 16 Electricity generation from RES in Croatia. Source: MEE: Energy in Croatia 2015, 2016

1.2.2. Solid Biofuel Production

Table 17 shows production of solid biofuels in 2015. In 2015, pellets were produced in 15 facilities. Total installed capacity for the pellet production is 376 900 t/yr, out of which 56% is utilized during 2015. Around 89% of the total pellets production was exported while little was placed on the domestic market. Wooden briquettes capacity is estimated to 61 400 t/yr while its actual production is usually done periodically depending on the feedstock availability – waste from wood processing industry. Around 66% of the total briquettes production was exported during 2015. Data on production of charcoal are collected in direct contact with producers. There is only one industrial charcoal producer in Croatia, that has produced more than 2/3 of the total annual charcoal production, and the rest of the production belongs to a dozen middle and numerous small charcoal producers.

of Croatia for 2015

Vrsta krutog biogoriva Solid bioefuels
Drveni peleti Wood pellets
Drveni briketi*

* estimation

Table 17: Solid biofuel production in Republic of Croatia for 2015. Source: MEE: Energy in Croatia 2015, 2016

1.2.3. Liquid Biofuel Production

Total capacities for liquid biofuels in Croatia in late 2015 were at the level of 63 838 tons per year of biodiesel. During 2015, in Croatia, 17 373 t of biodiesel was produced or 0.648 PJ, out of which 96% ended up in the domestic market.

1.2.4. Heat generation based on renewable energy sources

Table 18 shows heat production from RES for 2015. Produced heat from the solar heating systems data are extension of questionnaire survey of the EIHP and ESTIF methodology, calculated as final usable heat, taking into account spatial distribution of the solar heating systems, conversion losses and consumer behavior. Heat generation from both solid and gaseous biomass including the generation in industrial heating facilities and heat generation from fuel wood for heating and hot water preparation in households was in total 52 927 TJ.

Vrsta izvora Type of renewable energy source	Proizvodnja toplinske energije Heat production (TJ)
Sunce Solar	435,1
Biomasa Biomass	52 927
Geotermalna* Geothermal*	449,3 1 069,76

* During 2015 for heat production from geothermal energy 449,3 TJ was used exclusevely for space heating purposes, respectively 1069,76 TJ if space heating and warm wtaer preparation is considered

Table 18: Heat generation from RES in Croatia for 2015. Source: MEE: Energy in Croatia 2015, 2016

2. Heat sector analyses at regional level (Krapina-Zagorje County, Varaždin County and Međimurje County)

2.1. Krapina- Zagorje County

2.1.1. General territory description of the region

Krapina-Zagorje County is located in the northwestern part of the Croatia, and belongs to the central part of Croatia. It's a separate geographical unit extending from the peaks of Macelj and Ivanščica in the north to the southeast of Medvednica. In the west the County borders with the Republic of Slovenia and the river Sutla, and the eastern boundary make rivers Krapina and Lonja.

It is one of the smaller counties (1 229 km^2), but with higher demographic significance because it has a population density of 108.1 pop/km2 which is above republic average of 75.8 pop/km2. According to the official statistics and population census in 2011, 132 892 inhabitants live in the County, which makes up 3.1% of the total population of the Republic of Croatia (Table 19).

The high traffic significance of the county provides an international highway route from north to the south of the County.

The climate of the County is continental-humid climate characterized by moderate warm summers, quite rain and cold winters. The temperatures above 30°C were recorded in June, July and August. Minimum annual temperatures, below 10°C, were recorded in January (-20.5°C), February (-22°C), March (-15.5°C) and December (-17.2°C). The ice days of the year are predominantly occurring in January, February and December.

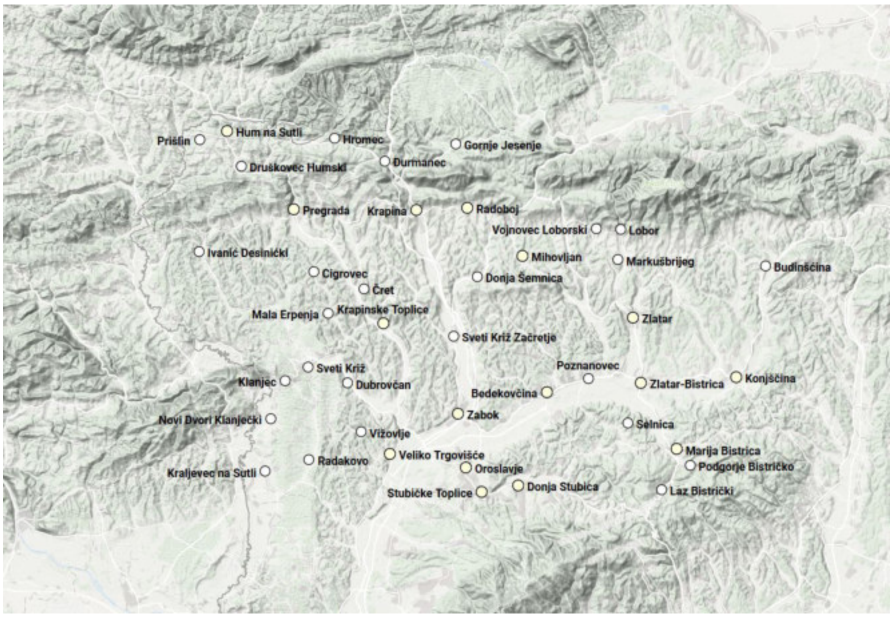
Region	Krapina-Zagorje County
Region headquarter	Krapina
Surface area	1 229 km^2
Number of habitants (2011)	132 892
Population density	108.13 pop/km^2
Number of cities (above 20 000 habitants) with district heating system	0
Number of cities (above 20 000 habitants) without district heating system	0
Number of towns (habitants: 5000-20 000)	7
Number of rural settlements (habitants less than 5 000	25
Administrative map of the region	

Table 19: Summary data of Krapina-Zagorje County

2.1.2. Energy characteristics

Annual energy consumption

-by type of use in 2012 (Source: CBS)

- Heating/Cooling – district heating: 1 925 557 MWh/23 573 MWh
- Domestic hot water: 231 950 MWh
- Electrical power: 316 150 MWh

-by sector type in 2011 (Source: REGEA)

- Housing sector: 2.259 PJ
- Public and commercial building: 0.792 PJ
- Industry: 3.128 PJ
- Agriculture: 0.122 PJ

The main heat users: the City of Krapina, Donja Stubica, Klanjec, Oroslavlje, Pregrada, Zabok, Zlatar. M-Profil d.o.o., Niskogradnja Hren d.o.o., Vetropack Straža d.d., Tondach Hrvatska d.d., Schiedel proizvodnja dimnjaka d.o.o., Jedinstvo d.d., Omco Croatia d.o.o., Dunapack, Aquafilcro, Regeneracija, MI Hršak, Kvadra, TPK Orometal, Bezak MTO, Zaštitna oprema Oroslavlje, Nanotec Zlatar Bistrica, Detmers kontejneri, Kostelpromet, El se Zlatar Bistrica, institutions for education and healthcare institution.

2.1.3. Economic analysis

The heat price in district heating systems in closed heating systems (less than 2 000 meters of distribution network, according to the Law on Heat Market) and independent heating systems (systems supplying only one building) is freely determined in accordance with market conditions. The amounts of tariff items for central district heating systems (distribution networks with longer the 2 000 meters, according to the Law on Heat Market) in force at the end of 2015.

In accordance with the General Conditions for the Supply of Heat Energy (OG 35/14, 129/15), the heating season begins with a period of readiness, the earliest on September 15, it starts on the basis of a decision of the heat energy distributor according to the weather conditions. The heating season lasts no later than May 15 next year (HEP-TOPLINARSTVO d.o.o.). The mean number of degree days of heating in Croatia in the heating season is 2 294 (Pravilnik o metodologiji za praćenje, mjerenje i verifikaciju ušteda energije u neposrednoj potrošnji (OG 77/12).

2.1.4. Current situation of geothermal energy utilization in the Krapina- Zagorje County

In Krapina-Zagorje County there are numerous natural springs of thermal waters that have been used for balneological purposes since the late 18th century.

Thermal springs of Krapinske toplice occur in a narrow valley of the stream Topličica and there are three main springs and a few springs of lower yield with a temperature of 39-40°C. The main occurrence of thermal springs is in the area of Pučka and Jakobova kupelj. Total yield of all springs in Krapinske Toplice, according to Bać & Herak (1962) measurement, ranges from 69 to 81 L/s. The majority of springs occur along the boundary between dolomite and limestone. In 1985 deep well was drilled about 250 m north of the thermal springs. The well passed through limestone and dolomite before it ended up in calcarenites and shale at a depth of 861 m (Šimunić, 1986). The well discovered shallower and deeper aquifer layer, where deeper layer at depths 491-494 m and 640-646 m had yield of 5-8 L/s and temperature of the water was estimated to 56-60°C. The well was tested with a total yield of 30 L/s and the water temperature was 45°C. Thermal waters from springs in Krapinske Toplice are used for recreation, balneotherapy, space heating and sanitary water in Special hospital for medical rehabilitation Krapinske Toplice, Clinic Magdalena and aquapark Aquae vivae, and in water supply distribution system connecting 277 households. The water discovered in the well is still not being used.

Company Samek Ltd. uses geothermal water for heating of greenhouses for vegetable production (~33°C) in a well in Jurjevac, 5 km from the centre of Krapinske Toplice. The capacity of the well is 8 kg/s.

Stubičke Toplice is one of the most famous thermal spa in Croatian Zagorje. The thermal water with temperature of 30 to 49.7°C at the springs has been used since the early 19th century. The water originated from two larger and several smaller springs that had dried out after drilling deep wells. St-3 well showed that in Stubičke Toplice up to a depth of 505 m there are 3 aquifer horizons. In the upper horizon (upper Badenian limestone) the water temperature is 40°C and in the lower two horizons (Triassic dolomites) it reaches 65°C. Today thermal water from the wells is used for recreation, balneotherapy, water and space heating and sanitary water.

Jezerčica is the spring in Donja Stubica where thermal water occurred in the swamp. At the end of the 1960s the well was drilled, and the water temperature was 38.4°C Afterwards recreational complex with two pools was built, which has been upgraded in time. Today Jezerčica is a modern complex with a hotel and a total of 8 swimming pools with thermal water, spa center and water park.

Thermal springs of Sutinske toplice are located in the canyon of the Sutinska stream. Water emerges from fractured dolomites with temperature ranging from 30 to 37.4°C. In 1988 a well was drilled in the southern exit of Sutinska canyon and dolomite aquifer was detected in the interval between 75 and 385 m. Pumping test was carried out with the yield of 112 L/s and the water temperature at the wellhead varied from 38 to 39°C (Britvić, 1988). The water had been used for swimming pool during the summer, but it was closed in the summer of 2013.

Tuheljske toplice springs are located nearby Krapinske toplice thermal water source, 4.5 km to the southeast. The surrounding area of Tuheljske toplice consists of limestone, dolomite, sandstone, marl, clay, gravel and sand. Thermal springs are ascending springs and they occur in several places, from which the most important are Dadino vrelo and Vrelo u bari springs. Total yield of thermal springs was 85 L/s (Bać & Herak, 1962) and the temperature varies from 32.5 to 33.1°C. Thermal waters have so far only been used for recreational purposes. The borehole Tuh-1 was drilled in the 1980s about 700 m north from the thermal springs, with total depth of 706 m. The borehole ended at the border of the Triassic dolomites and upper Badenian limestone. The water temperature in the borehole was 41°C and further work related to its exploitation did not prove to be profitable.

The thermal spring at Šemnicke Toplice has a water temperature of 31°C, with a capacity of about 6 L/s. During 1981/82 detailed geological exploration and drilling was carried out to a depth of 40-50 m. The yield of the borehole without pumping is 4 L/s of thermal water with temperature of 39°C.

The spring Topličica in Gotalovec is located on the southern slopes of the central part of the Ivanščica massif. The yield of the spring ranges from 15 to 18 L/s and the water temperature is 25-26°C. The spring occurs at the contact between the fractured dolomite aquifer and eruptives and clastic sediments. The water is being used for bottling as natural spring water.

In Harina Zlaka there was a natural thermal spring with a water temperature of 32.8°C (Miholić, 1940a). The spring dried up after 1966, following exploitation of thermal water from the well on the opposite bank of the Sutla River for Atomske toplice spa in Podčetrtek, Slovenia. The well is drilled in the carbonate sediments (dolomites). In 1998, near the dried up spring, the well HZL-1 was drilled, also in dolomites. It has been tested with a yield of 45 L/s, and the water temperature at the wellhead was 19-20°C (Mraz & Krsnik, 2005).

The subthermal water with temperature of 17.4°C was found in the canyon of the Topličina stream, south of Marija Bistrica and Zajezda. In 1980s, detailed geological surveys have been conducted, which resulted in finding large amounts of thermal water in the Kum-1 borehole at a depth of 448m. Water temperature is 25°C with yield of 47 L/s at the border of the Triassic dolomites and upper Badenian limestone.

Deep geothermal aquifers together with heat pumps, in the Krapina-Zagorje County, can be used for heating and/or cooling systems and heating hot water. Their application is possible for smaller and larger objects.

2.2. Varaždin County

2.2.1. General territory description of the region

Varaždin County is a county in northern Croatia. It covers an area of 1 262 km2 and had a population of 175 951 in the 2011 census. Varaždin County borders Slovenia to the northwest, Međimurje County to the north, Krapina-Zagorje County to the southwest, Zagreb County to the south, and Koprivnica-Križevci County to the southeast, with a small portion of the latter separating it from Hungary (Table 20).

The Drava flows along the northern border of the county. There are three reservoirs on the river – Lake Ormož, Lake Varaždin and Lake Dubrava. All of them are partially located within the county. Another river flowing through the county is the Bednja, which also confluences with the Drava within the county. There are also the mountains of Ivanščica (also known as Ivančica) and Kalnik.

The highway A4 (part of Pan-European Corridor Vb and European route E65) passes through the county, connecting the Hungarian border (in the north) with Zagreb (in the south), and which has exits in Varaždin, Varaždinske Toplice and Novi Marof. In the longitudinal (west-east) direction, a magistral road passes along the Drava River, which connects Maribor (Slovenia) and Osijek. The railway connects also the county with the south (Zagreb), north (Čakovec, Budapest) and east (Koprivnica).

The climate of the whole county is moderate to warm-to-rain climate with average annual temperature around 10°C.The warmest month is July with the mean at a monthly temperature of about 19°C but temperatures can reach as high as 40°C in July and August. The coldest is January with mean monthly temperature of -1°C.

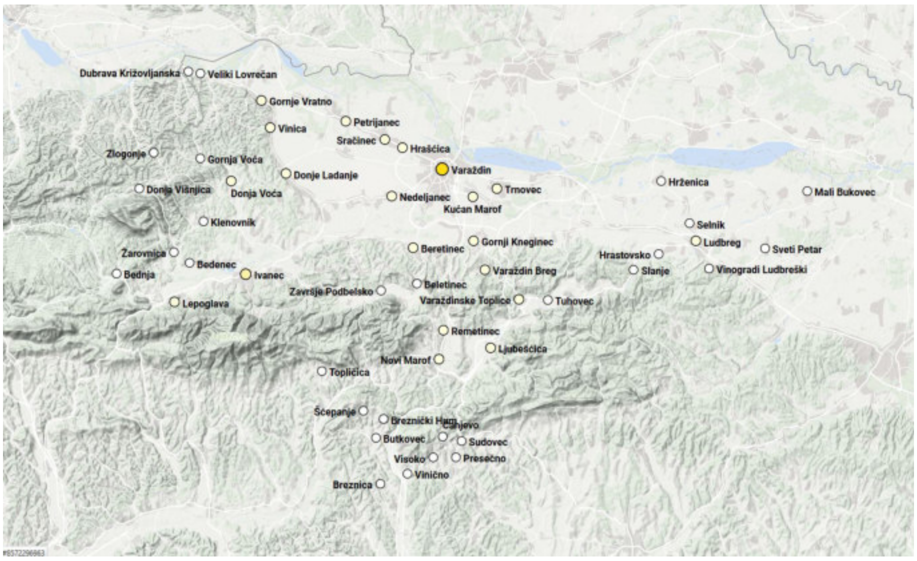
Region	Varaždin County
Region headquarter	Varaždin
Surface area	1 262 km^2
Number of habitants (2011.)	175 951
Population density	108.13 pop/km^2
Number of cities (above 20 000 habitants) with district heating system	1
Number of cities (above 20 000 habitants) without district heating system	0
Number of towns (habitants: 5 000-20 000)	5
Number of rural settlements (habitants less than 5 000	22
Administrative map of the region	

Table 20: Summary data of Varaždin County

2.2.2. Energy characteristics

Annual energy consumption

-by type of use in 2012 (Source: CBS)

- Heating/Cooling – district heating: 969 752 MWh/7 598 MWh
- Domestic hot water: 170 765 MWh
- Electrical power: 156 070 MWh

-by sector type in 2012 (Source: AZRA d.o.o.)

- Housing sector: 4.728 PJ
- Public and commercial building: 0.937 PJ
- Industry: 2.024 PJ
- Agriculture: 0.723 PJ

The main heat users amongst industry and service sector are: the City of Ivanec, Lepoglava, Ludbreg, Novi Marof, Varaždin and Varaždinske Toplice; Aquacity d.o.o., Centar kompetencije za obnovljive izvore energije d.o.o., Čistoća d.o.o., Gradska tržnica d.o.o., Parkovi d.d., Razvojna agencija Sjever dan d.o.o., Slobodna zona Varaždin d.o.o., Tehnološki park Varaždin d.o.o., Termoplin d.d., Varaždin Airport d.o.o. (in bankruptcy), Varaždinske Vijesti d.d., Varkom d.d., Vartop d.o.o., Dječji vrtić Varaždin, Galerijski centar Varaždin, Gradska knjižnica i čitaonica, Gradski bazen Varaždin, Gradski stanovi Varaždin, HNK Varaždin, Javna vatrogasna postrojba grada Varaždina, Koncertni ured Varaždin, Pučko otvoreno učilište Varaždin, Regionalna energetska agencija sjever.

2.2.3. Economic analysis

The heat price in district heating systems in closed heating systems (less than 2 000 meters of distribution network, according to the Law on Heat Market) and independent heating systems (systems supplying only one building) is freely determined in accordance with market conditions. The amounts of tariff items for central district heating systems (distribution networks with longer the 2 000 meters, according to the Law on Heat Market) in force at the end of 2015.

In accordance with the General Conditions for the Supply of Heat Energy (OG 35/14, 129/15), the heating season begins with a period of readiness, the earliest on September 15, it starts on the basis of a decision of the heat energy distributor according to the weather conditions. The heating season lasts no later than May 15 next year (HEP-TOPLINARSTVO d.o.o.). The mean number of degree days of heating in Croatia in the heating season is 2 294 (OG 77/12).

District heating systems exist in City of Varaždin. The type of distribution networks are closed heating systems (less than 2 000 meters of distribution network, according to the Law on Heat Market) and independent heating systems (systems supplying only one building. The district heating system in the City of Varaždin has following characteristics:

- Number of consumers: 1 272
- Length of distribution network: 1 570 m
- Total installed capacity: 26.42 MWt
- Annual production in 2016: 10.56 GWh
- Heat supplied in 2016: 7.05 GWh
- Total heated area: 68 920 m2
- Fuel type: natural gas

The competing fuels on the market are natural gas and wood.

2.2.4. Current situation of geothermal energy utilization in the Varaždin County

In pursuit of hydrocarbon reservoirs in the northwest part of the Drava area, INA - Naftaplin discovered the geothermal field Kutnjak - Lunjkovec, which was drilled with the three boreholes Kt-1, Kt-2 and Lun-1. Research conducted on the Kt-1 and Lun-1 boreholes, during the year 2004, gave us data for the calculation of the C1 reservoir reserve. The geothermal reservoir is at 2 010 m depth, the average thickness is 117 m and the surface area is 83 km^2. It lies predominantly in the area of Legrad and Mali Bukovec. The geothermal water temperature is 140°C, the pressure in the reservoir is 217 bar and the pressure at the well is 6 bar. The yield of the well Kt-1 is 53 L/s with self-extinguishing. The geothermal reservoir contains 688 million m^3 of water with accumulated heat of 518 000 kJ/m^3. Geothermal water is medium mineralized salt water with 4.5 m^3 of dissolved gas per cubic meter of geothermal water, predominantly with CO_2 and some methane. The reservoir is without natural water inflow and all utilized (chilled) geothermal water must be reinjected to the reservoir. Geothermal water has balneological properties suitable for health prevention and post-traumatic rehabilitation.

According to the Feasibility study of the Geothermal Program 2006, the first phase of the program was conceived with existing wells: Kt-1 as production and Lun-1 as reinjection well. However, after further analysis it has been shown that geothermal water production does not provide sufficient security for the existing exploration and that new borehole Kt-1T has to be drilled for the production, while the existing borehole Kt-1 can be used for reinjection of utilized water.

The Government of the Republic of Croatia declared the Geothermal Program as a demonstration example of Geothermal Energy Utilization. The program is planned to be realized in two phases, depending on the availability of geothermal water (phase I with 70 L/s, phase II with 300 L/s), and includes the cascade system of geothermal energy utilization with the geothermal power plant as the main object. The program is at the same time an energy project, a food production project and a tourist offer project.

The utilization of geothermal energy at the Kutnjak - Lunjkovec site includes: production and distribution of transformed forms of energy from geothermal energy, industrial production - drier, production of vegetables in protected/closed areas, production of ornamental plants, aquaculture concept in the area and program and concept of tourist development of the complex. Geopodravina d.o.o. (founders: Croatian Privatization Fund on behalf of the Government of the Republic of Croatia, Koprivničko-križevačka County, Legrad Municipality, INA, HEP and Podravka) was founded for the realization of the program.

In Podevčevo there are two thermal springs, whose temperatures vary, depending on the hydrological cycle, from 16.3 to 20.0°C. The aquifer is fractured dolomite. The total yield of both springs does not exceed 1 L/s. The springs are not used.

The Topličica springs in Mađarevo occur at the foot of the steep slopes of the Ivanščica massif near Novi Marof. There are four major springs and several smaller ones. The water temperature is inconsistent: during the summer it varies from 18 to 22.5 °C, and during winter temperatures are lower. Significant fluctuations in temperature and yield indicate mixing of cold and thermal water. The total yield of all springs has not been measured. Thermal water is used for heating of a fish farm nearby and for recreation in the summer.

Varaždinske toplice springs are located in the northeastern part of the County, nearby Varaždin. It is among the best known, the longest used and the largest spas in Croatia. It had been used since the 1st century as spa. The water temperature varies from 56.5 to 57.5°C with a high mineralization and high sulphur content and the yield ranges from 45 to 50 L/s. The thermal waters occur in the brecciated dolomites which are covered by clastic sediments (Šimunić, 2008). The largest spring in Varažidnske toplice is Klokot, accompanied by three smaller hypothermal springs with temperatures of 24-25°C. A number of wells were drilled close to the spring in order to secure thermal water supply for growing spa. Thermal waters form spring and wells are used for recreation, balneotherapy, water and space heating (Kovačić et al, 2011).

In the late 80's, geothermal exploratory well VTT-1 was drilled to depth of 605.04 m next to primary school in Varaždinske Toplice, about 500 m from the main well. At the contact of effusive breccia and graphite schist an overflow of water of 28°C was recorded in lesser amounts, up to 1 L/s.

2.3. Međimurje County

2.3.1. General territory description of the region

Međimurje County is a triangle –shaped county in the northernmost part of Croatia. Despite being the smallest Croatian county by size (729.5 km^2), it is the most densely populated (164.2 pop/km^2) (Table 21). The county borders Slovenia in the northwest and Hungary in the East. The southeastern part of the county is near the town of Legrad and the confluence of the Mura into the Drava. There are slopes of the Alpine foothills in the northwestern part of the county, the Upper Međimurje, making it suitable for vineyards. The southeastern part of the county, the Lower Međimurje, touches the flat Pannonian Plain. The flat parts of the region are also largely used for agriculture. There are two major hydroelectric power plants along the southern border of the county on the Drava River.

The climate is continental with quite hot summers. Daily temperatures during the summer months usually range between 20°C and 30°C, but can reach as high as 40°C in July and August, when they can also stay above 30°C for several days. Thunderstorms and rapid weather changes are common throughout the summer months, as well as in late spring, with a particularly stormy period being between mid-June and mid-July, when they often occur on a daily basis. Winters can be very severe, with early-morning temperatures sometimes reaching as low as -20°C. During the winter months, daily temperatures usually range between -10°C and 10°C. January is usually the coldest month, during which daily temperatures can stay below 0 C for several days. Snowfall usually occurs between late October and early March.

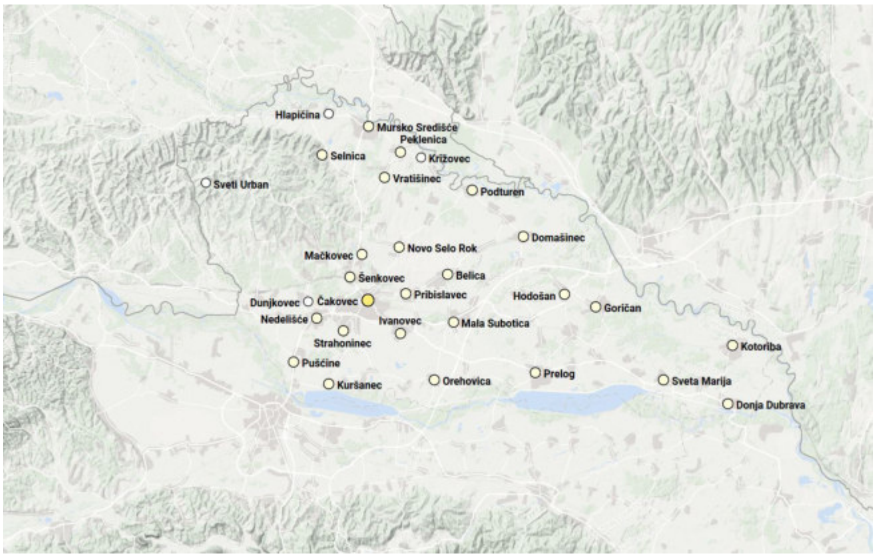
Region	Međimurje County
Region headquarter	Čakovec
Surface area	729 km^2
Number of habitants (2011)	113 804
Population density	156.11 pop/km^2
Number of cities (above 20 000 habitants) with district heating system	1
Number of cities (above 20 000 habitants) without district heating system	0
Number of towns (habitants: 5 000-20 000)	2
Number of rural settlements (habitants less than 5 000	22
Administrative map of the region	

Table 21: Summary data of Međimurje County

2.3.2. Energy characteristics

Annual energy consumption

-by type of use in 2012 (Source: CBS)

- Heating/Cooling – district heating: 590 634 MWh/3 713 MWh
- Domestic hot water: 48 077 MWh
- Electrical power: 184 014 MWh

-by sector type in 2010 (Source: MENEA and REGEA)

- Housing sector: 2.430 PJ
- Public and commercial building: 1.053 PJ

- Industry: 0.014 PJ
- Agriculture: 0.089 PJ

The main heat users in industry and service sector are: the City of Čakovec, Mursko Središće and Prelog; HEP ODS d.o.o. - Elektra Čakovec, INA d.d., Međimurje plin d.o.o., Moharić Commerce d.o.o., Euro petrol d.o.o., Petrol trgovina d.o.o, OMV d.o.o., ROB TONI d.o.o., VECTUM d.o.o., RUDI-EXPRESS d.o.o., Autobusni prijevoznik Mirko Horvat d.o.o., Autobusni prijevoznik Marko Turist d.o.o., Jakopić d.o.o., Autobusni prijevoznik Josip Baliga d.o.o., Jambrošić tours d.o.o., Ivo Express d.o.o., Prijevoz i parketarstvo Miljenko Rusak d.o.o., Prijevoz stvari i putnika Ljubomir Lukić d.o.o., Eko Međimurje d.d., Ferro-Preiss d.o.o., Pana stolarija d.o.o., Promming d.o.o., institutions for education and healthcare institution.

2.3.3. Economic analysis

The heat price in district heating systems in closed heating systems (less than 2 000 meters of distribution network, according to the Law on Heat Market) and independent heating systems (systems supplying only one building) is freely determined in accordance with market conditions. The amounts of tariff items for central district heating systems (distribution networks with longer the 2 000 meters, according to the Law on Heat Market) in force at the end of 2015.

In accordance with the General Conditions for the Supply of Heat Energy (OG 35/14, 129/15), the heating season begins with a period of readiness, the earliest on September 15, it starts on the basis of a decision of the heat energy distributor according to the weather conditions. The heating season lasts no later than May 15 next year (HEP-TOPLINARSTVO d.o.o.). The mean number of degree days of heating in Croatia in the heating season is 2.294 (OG 77/12).

2.3.4. Current situation of geothermal energy utilization in the Međimurje County

There are several geothermal areas in the Međimurje County: borehole Vučkovec-2 (St. Martin Municipality), Merhatovec (Selnica Municipality) and borehole Draškovec-1 in the Drava basin (Prelog municipality).

The thermal source Vučkovec was discovered in 1913/14 when E-17 borehole was drilled. The water temperature was 33.4°C and the yield at the beginning was 26.6 L/s, but it's gradually decreased to 1.7 L/s. Stratigraphic profile of the borehole is not known, and data about the depth of the aquifer horizon (or multiple horizons) are diverse (450-550 m, 700- 800 m), depending on the source. In the past, a small pool was built and water was bottled by the name "Međimurska kiselica" for a short time. In 1953 was noticed that water flowed periodically with interruptions of 1-1.5 hours, when flammable gas with H2S. Revitalization of the former thermomineral bath started in 1996 and now is transformed into a modern sports and recreational center called Sv. Martin. Today, the thermal water is utilized from borehole Vučkovec-2 which was drilled in 1972 and the water temperature is between 32-34°C.

The borehole Merhatovec-1 is drilled in the municipality of Selnica and the total depth is 4 193 m with water temperature of about 150°C.

The borehole Draškovec-1 (Prelog Municipality near the Cirkovljan) was drilled to the total depth of 4 200 m. The geothermal aquifer occurs in interval between 1 827 and 1 878 m in Miocene sand. The yield of the borehole on the surface is about 8 L/s and when it is pumped the yield increases to 25 L/s. The temperature at the bottom of the borehole is 113°C, while the water temperature at the wellhead is 70-77°C. At the location an innovative geothermal project is being developed, with planned electricity production.

The borehole Hodošan-2 (Donji Kraljevac Municipality), was drilled in 1978/1979 to the total depth of 4 542m. The temperature at the bottom of the borehole is about 180°C.

In addition to these boreholes, hyperthermal waters have been found in several other boreholes during oil and gas exploration, but have to be tested for geothermal water assessment of potential.

3. Heat market analysis of a district heating circuit to be converted to geothermal in the Krapinske Toplice Municipality

3.1. The current situation of thermal water utilization

3.1.1. General data

Krapinske Toplice Municipality is one of the 32 local governments of the Krapina-Zagorje County. Based on data from the Census carried out in 2011, in the Municipality 5 367 residents live. The Municipality consists of 17 settlements: Čret, Donje Vino, Gregurovec, Hršak Breg, Jasenovac Zagorski, Jurjevec, Klokovec, Klupci, Krapinske Toplice, Lovreća Sela, Mala Erpenja, Maturovec, Oratje, Selno, Slivonja Jarek, Viča Sela and Vrtnjakovec.

In the Municipality, as well as in the whole County, a humid continental type of climate prevails. This type of climate is characterized by moderately warm and rainy summers and cold winters. The lowest temperature recorded is in January and the highest in July.

The area covered by the Krapinske Toplice Municipality belongs to the western part of the Pannonian basin of diverse geological composition and development. Therefore, there are elements of Alpine structure and relief and, to a lesser extent, elements of Pannonian material.

Three geomorphological elements can be distinguished in the area of Krapinske Toplice. The first element are the hills up to 300 meters above sea level with vineyards, the second element are the valleys along the streams of the rivers covered with meadows, and the third element are the slopes of hills covered with arable land and forests.

Krapinske Toplice Municipality is characterized by good traffic position precisely because is located in the central part of the County. The Municipality is located relatively close to larger centers so that the road distance to Krapina, Zabok and Pregrada is about 14 kilometers.

3.1.2. Natural resources

The main natural resources on which development of Krapinske Toplice is based are thermal water springs. The water from three and several other springs along the stream Topličina has a temperature of 40°C, stable capacity of 81.6 L/s. In the mid-1980s further research and drilling has proven that there is more water-bearing horizon and the total source yield upon these studies is estimated at 110 L/s. The water temperature of the well was increased in relation to the water from the source by 5°C. When only 5-8 L/s of water from the deeper aquifer would be used, the temperature would rise to 56-60°C which would be sufficient for heating the hospital and other facilities. Unfortunately, since 1986 when the well has been completed so far nothing has been done to make use of the found warmer water.

Although the targeted research and drilling goals in the 1980s have not been fully met, this research has shown there is a possibility of increasing the total amount of thermal water and its temperature in Krapinske Toplice.

Today, in Krapinske Toplice thermal water is mainly used for balneological purposes. There are some exceptions that, to a greater or lesser extent, use thermal water for heating. These are: Water Park Aqua vivae, Spa & Wellness center Villa Magdalena, Special Hospital for Medical Rehabilitation Krapinske Toplice and Samek Ltd.

Figure 13: Krapinske Toplice Spa

3.1.3. Economy

The number of registered crafts in the Municipality is around 115. Most of these are engaged in the construction industry (29 trades), manufactures (23 trades) and service trade (22 trades). Most of the companies are engaged in the construction industry (11 companies), retail and wholesale (11 companies) and professional, scientific and technical activities (10 companies).

The area of the Krapinske Toplice Municipality has very valuable tourist resources (thermal springs, preserved landscape). These resources have enabled the municipality to develop into a well-known tourist resort. The municipality has a specially developed health tourism:

- Special Hospital for Medical Rehabilitation Krapinske Toplice- is intended for the rehabilitation of patients with cardiologic, neurological, rheumatic and orthopedic illnesses and for the rehabilitation of children. The hospital is known for its healing thermal water, temperature from 39 to 41°C with a high proportion of calcium, magnesium and hydrocarbons. In the hospital are four indoor pools. For treatment and rehabilitation of patients, water is used in pools and tubs.
- Magdalena, Cardiovascular Disease Clinic- its main activities are prevention, complete non-invasive and invasive diagnostics, and percutaneous and surgical treatment of cardiovascular diseases.
- Hospital Akromion is the largest private orthopedic hospital in the Republic of Croatia. It provides every medical service in the field of orthopedics and traumatology.

Figure 14: Special Hospital

From the point of view of smart specialization at the national level, efforts should be made to specialize the area of the Municipality for dealing with health tourism, which certainly represents the backbone of further development.

The development of tourism has been based on the very beginning on the use of thermal springs, so the first bath in the Municipality was built in 1772. Real momentum tourism development started in 1862 when Jacob Badl bought existing baths and built new baths, hotel and health resorts. In that period, Krapinske Toplice became a modern health resort within the Austro-Hungarian Monarchy with significant tourist results. The era of modern tourism development began in 1956 when a hospital department for rheumatic diseases and orthopedic rehabilitation is established. Today's tourist offer of the Municipality is based on health and recreational facilities.

3.1.4. Further development

Starting from the achieved degree of development, the existing economic structure, demographic forecasts and natural conditions, the basic features of spatial development of Krapinske Toplice Municipality are focused on the development of tourism and complementary activities (craftsmanship, small entrepreneurship), ecological agriculture for production of healthy food, communal infrastructure and social infrastructure. Long-term development of the Municipality Krapinske Toplice must be based on respect for interdependence and functional links between certain activities and the need to ensure better living conditions for the population.

3.1.5. SWOT analysis

Strengths	Weaknesses
Recognition of the destination due to the long tradition in thermal, health and excursion tourism as well as quality staff in these industries	The Fragmentation of agricultural surfaces which prevents commercialization of agricultural production
Developed and competitive craftsmanship	Unused capital for completing the tourist offer
Export oriented businesses	Lack of incentive mechanisms and retention projects Employment of young people
A high quality network of healthcare institutions represents the foundation of tourism development as the main activity	Unsufficient valorisation and exploitation of natural, cultural and other potentials for the development of tourism and catering activities
Opportunities	**Threats**
Support for the development, commercialization and specialization of agricultural production through the Unique Agricultural EU policy	Increased competition from manufacturers and service providers from EU
The merging of craftsmen and entrepreneurs into clusters makes it easier presentation and sales of products	Unsustainable entrepreneurs in market opening opportunities towards the European Union
An increase in demand for selective forms of tourism	Increased competition in the area of development aid projects in national and European levels

Development goals

- ✓ GOAL 1: Sustainable local economy and smart specialization
- ✓ GOAL 2: Rural development
- ✓ GOAL 3: Local community progress
- ✓ GOAL 4: Revitalization and sustainable management of natural resources and infrastructure

3.2. Description of the facility/technology

In Krapinske Toplice, there are three natural spa pools and the heat source is 80 L/s of 39-41°C from free flowing, "artesian" geothermal wells. The health center and hotel is using ground source heat pumps to feed thermal water to the floor heating system for seven months a year. The area is known for greenhouses and they have been using hot water from artesian geothermal wells which are flowing 8 L/s at 32-33°C.

In the center of Krapinske Toplice there are 3 hyperthermal sources (39-41°C, 81.6 L/s). There is also one borehole in the center of the settlement about 200 m away from surface springs (56-60°C, 30 L/s) and one well 5 km away from the center (38-39°C, 8 L/s).

Currently 227 users are connected to the water supply system (total consumption approx. 4 000 m^3/month).

There are four main users of geothermal water on the area of the Municipality: Special Hospital for Medical Rehabilitation Krapinske Toplice, Water park Aqua Vivae, Spa& Wellness center Villa Magdalena, and Samek d.o.o.

Samek d.o.o. uses geothermal water for heating of greenhouses for vegetables production.

3.2.1. Special Hospital for Medical Rehabilitation Krapinske Toplice

The government of the Republic of Croatia adopted in 1998 the Decision to award a concession for the extraction of thermo-mineral water to the Special Hospital for Medical Rehabilitation. In accordance with the concession, Special Hospital has the right to harvest thermomineral water from springs "Pučka kupelj", "Jakobova kupelj", and the KRT-1 geothermal well at the Krapinske Toplice site, in the total amount of 534 500 m^3/y (for water supply up to 183 950 m^3, for technological needs up to 287,300 m^3, for health and recreational needs up to 63,250 m^3) or at most 51.0 L/s from heat and up to 23.0 L/s from the well. The facility has heat pumps: GEA HAPPEL type EUWH 240FSD - 1992.god. - COP 3.6 - use geothermal water as a source of heat, are used only for space heating and only at night in the period of lower electricity tariffs.

Special Hospital for Medical Rehabilitation Krapinske Toplice is known for natural healing water temperature of 39 to 41°C with a high proportion of calcium, magnesium and hydrocarbons. The Hospital has four indoor pools. The famous "Jakob" swimming pool (Figure 15) was built at the very source of thermal water and is one of the few such examples in the world. In the treatment and rehabilitation of patients, water is used in pools and baths, where bathing is carried out by medical exercises using the physical effects of water: heat, hydrostatic pressure, lift and friction resistance. The centuries-old experience and completed medical reports speak of her healing properties.

Figure 15: Jakos swimming pool

3.2.2. Water Park Aqua Vivae

Park Aqua Vivae uses geothermal water for heating of entire complex of 18.000 m^2 (Figures 16, 17).

The water inlet temperature of the water park has a temperature of 40.5°C. The outlet water leaving the center is 28°C. In the water park, the energy difference of water is 12.5°C. For 12.5°C, in the winter it takes up to 100 m^3 of water to keep running for normal operation. Since 1 cubic meter of water has approximately 1.1 kWh of energy, multiplied by 100 m^3 of water and 12.5°C of difference, 1.2 MW of thermal power is obtained in the water park. Water used for swimming in swimming pools first goes to the hottest pool, then to less hot and finally to the coolest swimming pool. The water in the water center also cools because it warms the air. The air is vented out when it becomes denser with special recuperators (mechanical) so that the warm air through the inside of the tube goes out into the surrounding area, and around these pipes enters fresh air into the water center. Recuperators due to their size have 80% utilization, which means that only 20% of the energy obtained from the thermal source is lost. In addition to the recuperators, there are heat pumps that work at night when no room ventilation is required, while heating the water will heat the floors to a temperature of 32-33°C. The system works in such a way that the heating condensators (accumulators) use the bottom plate of the water park in which 50 km of pipes were built-in for under-floor heating. The bottom plate is made of concrete, and has a mass of 5 000 tons and a volume of 2 700 m3. It is heated during the night (when the prices for electrical energy are at their lowest) to a temperature of 33°C, and during the day it cools off to 30°C. This way the thermal energy is stored at the lowest part of the premises which ensures the natural circulation of hot air from the floor to the ceiling, where the air conditioning chambers suck in the heated air and transport it to the previously mentioned recuperators. Then there is a roof and wall thermal insulation that reduces mechanical and static losses to a minimum. The primary construction goal is to achieve the building of a complex with an integrated thermal insulation which ensures very low thermal conductibility. The insulation of the outer walls is designed in such a way as to achieve a high very coefficiency in the passing of warmth through the wall's material. This coefficiency is = 0.26 W/m^2K. On the vertical walls we have 60 mm thick glass bricks, with a coefficiency of: 0.9 W/m^2K. The roofs are made up of a laminated wood construction and are insulated in such a way that they have a coefficiency of: 0.2 W/m^2K. The glazed areas of the roof are designed with triple-glazing to lower emission so that the coefficiency of the passing of heat in that part of the roof is 1.1 W/m^2K.

From the heat leaving the water center, which still has a temperature of 28°C and which can be cooled by 8°C, 20°C further, taking into account 100 m3 of water per day, another 2.2 MWh energy can be obtained for some another object. Water temperature is exploited to a temperature of 8°C when it can no longer be used.

The Water park „Aqua vivae" uses geothermal water based on the 2003 Consent on the transfer of part of the concession rights granted to a Special Hospital for Medical Rehabilitation Krapinske Toplice.

Figure 16: Water park „Aqua vivae

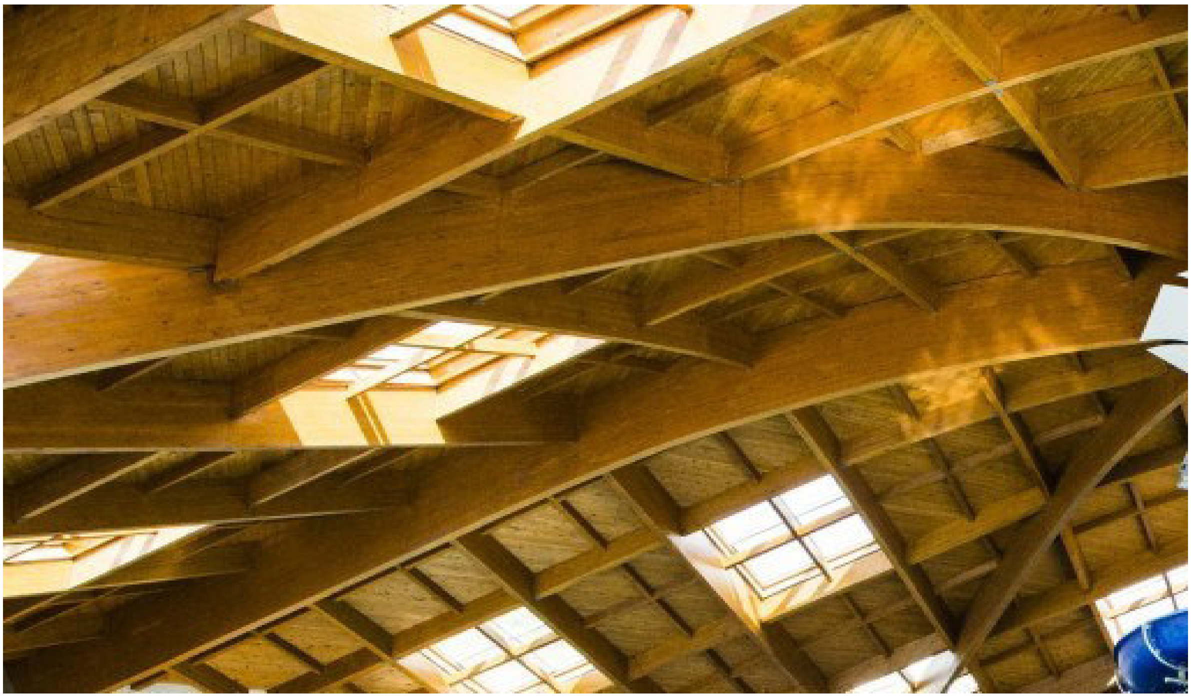


Figure 17: Water park „Aqua vivae

3.2.3. Spa & Wellness center Villa Magdalena

All the apartments at Villa Magdalena Hotel have jacuzzis with a direct access to one of the thermal water sources around 39°C (Figure 18). The wellness facilities at Hotel Villa Magdalena are also connected to a direct thermal water line.

Thermal water is used only for heating the jacuzzis in accommodation units. The thermal water enters the tank of hot sanitary water where the condensing boiler warms her up to a temperature of 60°C. Spa& Wellnes Center in this way saves the energy, as the heating time of the water is shorter.

Annual consumption of thermal water for the needs of the Center is 4 000 m^3.

Unfortunately, Spa & Wellnes center Villa Magdalena has no built infrastructure to exploit the sources of thermal water that has direct access to heating the whole building. Currently, from the economic aspect, the required technology is too expensive, so the use of thermal water is unprofitable for the Center. The potential of the Center for heating with thermal water could be used in the case of availability of financial resources that would support the project of installing the necessary technology and heat pumps.

Figure 18: Spa & Wellnes center Villa Magdalena

3.3. Future development plans

The mission set up in the Development strategy of the Municipality Krapinske Toplice is read as: „Krapinske Toplice is positioned as a national and international place of health tourism and the place of development of successful entrepreneurship. By maximizing its natural resources, intact nature and stable springs of thermal water, Krapinske Toplice will become a safe place for a healthy life in a calm, natural environment."

Research carried out in the 1980s has shown that there is a possibility of increasing the total amount of thermal water in Krapinske Toplice as well as increasing its temperature. It is a very worthwhile cognition that could serve in the future for the further development of the Municipality. In addition, it is important to emphasize that the thermal water from borehole is not exposed to surface contamination, as is the case with spring water.

The most common use of thermal water in the Municipality, as well in the whole Krapina-Zagorje County, is for the balneology purposes, for both swimming pool water and space heating. Depending on the temperature level, heating is possible directly or by the heat pumps, as in the case of Special Hospital Krapinske Toplice. After taking heat energy, it is necessary to have geothermal water returned back to the injection well, while ensuring that water contamination does not occur. Systems that are currently in functions do not always follow this principle (the hot water is released into the water stream or in the sewage system).

In addition to exploiting thermal energy, as a guideline for future activities in the field of geothermal energy it can also be recommended to use heat pumps in heating systems for public buildings and households.

A very significant limiting factor for increased use of geothermal water for heating is obsolete or insufficiently built infrastructure and technology. The limiting factor is also the insufficient financial resources to overcome this problem. The Municipality of Krapinske Toplice intends to overcome these obstacles gradually by obtaining financial resources from national and European sources to build the necessary infrastructure to exploit geothermal water potential in the heating sector.

Appendix: Heat market Legal framework

The overview in this chapter is based on the document "Geothermal Energy Utilisation Potential in Croatia" (Orkustofnun and Energy Institute Hrvoje Požar, 2017)

Energy Development Strategy of the Republic of Croatia (OG 130/09)

The Energy Devolvement Strategy is a document that defines the national energy programs, the necessary investments in energy, the incentives for investing in renewable resources and cogeneration, and the increase of energy efficiency, as well as the development of environmental protection measures.

The Strategy recognizes the development guidelines for central heating systems, they include systems for production and distribution of steam and hot water that is used in industries and systems for the production and distribution of cooling energy.

Energy Act (OG 120/12, 14/14, 95/15 and 102/15)

The Energy Act is the general act that regulates the relations in the energy sector and contains general definitions for all energy forms. Specific topics are regulated in specific sectoral acts.

Energy politics and development of the energy sector

Based on the Energy Development Strategy the Government publicizes a Program for the execution of the Energy Development Strategy that, for a period of 10 years, determines the measures, the participants in activities and dynamics of the realization of energy policies and implementation of national energy programs, the manner of stimulating cooperation between local and regional bodies of government with energy subjects and international organizations.

Based on the mentioned strategic documents energy subjects publicize their own programs and plans for construction, maintenance and usage of energy objects and other necessities for conducting energy activities, bearing in mind all obligations defined in international agreements.

Energy efficiency and renewable energy sources

The Energy Act states that efficient use of energy is of interest to the Republic of Croatia and that efficient use of energy or the use of renewable energy sources will be laid down in special acts. Pursuant to that, adopted are the Act on Energy Efficiency (OG 127/14) and the Act on Renewable Energy Sources and Cogeneration (OG 100/15).

Energy activities

The law determines energy activities and conditions for their performance – license for conducting energy activities that is handed out by the Croatian Energy Regulatory Agency under the conditions and in the manner, that is defined in the Energy Act, special acts for certain energy markets and in accordance with the Rulebook on Licenses for the Performance of Energy Activities and on the Register for License (OG 88/15 and 114/15).

Prices of energy and tariff systems

The price of energy for final customers contains a part that is freely agreed, a regulated part that can be determined using a tariff system and fees and other determined charges.

The Tariff System contains a prescribed methodology and amount of the tariff items, they should provide incentives to improve energy efficiency and demand management, including increased use of renewable energy sources and cogeneration. The methodology is determined by the regulatory agency and is based on justified costs of operation, maintenance, replacement, construction or reconstruction of facilities and environmental protection and must provide an adequate return to reasonable investments, and may be based on a method of incentive regulation or other methods of economic regulation. Tariff items are included in the methodology, and are determined by the type of energy services, power / capacity, quantity, quality and other elements related to the supplied energy. The application to determine or change the amount of tariff items are submitted by an energy undertaking to the regulatory agency.

Administrative supervision and inspection

Supervision regarding the application of this act and other energy regulations is executed by the ministry competent for energy and inspectors in accordance with special regulations.

Act on the thermal energy market (OG 80/13, 14/14, 102/14 and 95/15)

As the special act for the thermal energy market, this Act regulates measures for the safe and reliable supply of heat, thermal systems for the use of thermal energy for heating and cooling conditions to obtain concessions for the distribution of heat and concessions for the construction of the distribution network, policies and measures for the safe and reliable production, distribution and supply of heat energy in heating systems and measures to achieve energy efficiency in heating systems.

Interest of the Republic of Croatia

Heating systems are considered an essential element of energy efficiency and of interest to the achievement of the objectives of energy efficiency in Croatia. Encouragement of the development and use of new, innovative and sustainable technologies in the energy sector is in the interest of the Republic of Croatia.

Energy activities

Energy activities that are subject to the Act are production and supply of thermal energy that are performed as market activities and distribution of thermal energy, which is performed as a public service. Production of thermal energy in the Central Heating Systems is considered a public service as long as the share of production is thermal energy is less than 60% of the heat requirement of the Central Heating System, when this share is more than 60 % this energy activity will be performed as a market activity.

Energy activities are carried out based on a license issued by HERA allowing the performance of the activity.

Facilities to produce thermal energy

Facilities to produce thermal energy are being built and used in accordance with the regulations on urban planning and construction, the regulations governing the energy sector, the regulations governing environmental protection and special technical and safety regulations. Producers of thermal energy can use facilities if they have proof of ownership, or right to use, or the right to lease or any other contract with the owner of the building and / or equipment for the performance of such energy activities.

Production of thermal energy

A producer of thermal energy can be any legal or natural person that obtained a license for performing the energy activity of production of thermal energy from the Agency. The license is required to produce thermal energy in a heat system with an installed boiler with output power greater than 2 MW.

The status of an eligible producer of thermal energy and electricity can be acquired by any energy service company that uses a cogeneration unit and uses waste, biodegradable waste or renewable energy sources to produce thermal energy in an economically viable manner, in accordance with the regulations governing environmental protection and waste management. Natural or legal persons who have acquired the status of eligible producer of electricity and heat from cogeneration pursuant to the Electricity Market Act, are obliged to obtain a license to produce thermal energy. For efficient use of energy in cogeneration plants, and at the same time to meet the needs of customers for thermal energy, the planned production of electricity that depends on simultaneous consumption of thermal energy for heating and / or cooling, has priority admission to the electricity network.

Energy approval

Production facilities can be built by legal or natural persons if the manufacturing plants that they intend to build meet the criteria laid down in the procedure for issuing energy in accordance with the Electricity Market Act. The criteria for the procedure for issuing energy approval for the construction of production facilities are public, based on the principles of objectivity, transparency and impartiality, and some of them are based on criteria of energy efficiency and contribution to generating capacity in achieving the overall target share of energy from renewable energy sources and energy efficiency in the gross final energy consumption in 2020 in the European Union, in accordance with fulfilment of international obligations of the Republic of Croatia for the energy sector and in accordance with acquis regulations. When choosing energy solutions, when deciding on the construction of production facilities, the construction of a production plant for cogeneration and / or renewable energy has an advantage over other production facilities.

The potential of thermal energy for heating and cooling

In order to achieve greater use of national resources of thermal energy for heating and cooling, the Croatian Government committed to a program on the use of the potential for efficiency in heating and cooling in accordance with the Energy Efficiency Directive.

Distribution of thermal energy

Local governments and distributors of thermal energy shall ensure the efficient performance of energy distribution of thermal energy according to the principles of sustainable development, to ensure maintenance of the distribution network and to ensure the transparent operation of thermal energy distributors.

The right of distribution of thermal energy is based on a concession agreement for the distribution of thermal energy or on a concession agreement for the construction of a distribution network and by obtaining a permit for the distribution of thermal energy.

Supply of thermal energy

The energy activity of heat supply is carried out on the basis of a license issued by HERA.

The supplier of thermal energy guarantees the continuity and reliability of the thermal energy supply system together with the energy entity performing the energy activity of thermal energy distribution and is responsible for providing sufficient quantities of thermal energy for end customers and the proper performance of the energy activity of heat supply.

The Act on Renewable Energy Sources and Cogeneration (OG 100/15 and 123/2016)

The Act on Renewable Energy Sources and Cogeneration implemented 2009/28/EC on the promotion of use of renewable energy sources and Directive 2012/27 on energy efficiency.

The Act regulates the planning and encourages the production and consumption of electricity produced by generating installations using renewable energy sources and high-efficiency cogeneration (OIEiVUK), defines measures to encourage the production of electricity from OIEiVUK, contains a system for promoting the production of OIEiVUK, encourages building plants to produce electricity from the OIEiVUK on state-owned land, keeps a OIEiVUK registry for projects, project developers and privileged power producers, international cooperation in the field of renewable energy.

This Act established that the use of OIEiVUK is of the interest to the Republic of Croatia in the field of energy. Which was confirmed by the Energy Strategy of Croatia, other acts and regulations governing energy activities, especially in terms of achieving the national goal of using energy from renewable energy sources in connection with the total final energy consumption in Croatia in 2020. This Act also promotes the wider use of its natural energy resources, reducing long-term dependence on imported energy, efficient use of energy and reducing the impact of fossil fuels on the environment, with the goal of job creation and enterprise development in energy and other sectors. This all initiated the development of energy projects with concrete results in the local community, encouraging the development of new and innovative technologies and contributions to the local community and the diversification of energy production and increase security of supply.

Abbreviations and Acronyms

AZRA – Agencija za razvoj Varaždinske županije / Varaždin County Development Agency

CBS - Croatian Bureau of Statistics

CHP – Cogeneration power plants

EIHP - Energy Institute Hrvoje Požar

ESTIF - European Solar Thermal Industry Federation

EUROSTAT – European statistics

HEP – Hrvatska elektroprivreda / Croatian Electricity Company

HERA - Hrvatska energetska regulatorna agencija / Croatian Energy Regulatory Agency

HNB - Hrvatska narodna banka / Croatian National Bank

HOPS - Hrvatski operator prijenosnog sustava / Croatian Transmission System Operator

HROTE - Hrvatski operator tržišta energije / Croatian energy market operator

MENEA – Međimurska energetska agencija / Medjimurje Energy Agency ltd.

NREAP - National Renewable Energy Action Plan

OG – Narodne Novine/ Official Gazette

REGEA – Regionalna energetska agencija Sjeverozapadne Hrvatske / North-west Croatia Regional Energy Agency

REPAM - Renewable Energy Policies Advocacy and Monitoring

RES - Renewable energy sources

WGC - World Geothermal Congress

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D.5.4.1. Summary report on heat sector analysis

Annex 4. Serbia national report

November 2017

D.5.4.1. Summary report on heat sector analysis

Annex 4. Serbia national report

Authors: Ana Vranješ
Co-authors: Dejan Milenić, Zoran Stevanović

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Table of contents

Executive summary

The heat market analysis gives an overview of total energy utilization with projected scenarios of future energy sector development in Serbia. Focus was directed towards the heat demands and current state in the field of district heating system, but some part of the report is dealing with production of electricity, too. Also, the transport section is briefly introduced. The analyses have two parts. The first part is based on data for the whole territory of the Republic of Serbia, giving numbers and figures of final and primary energy production as well as utilization. Basic energy policy is introduced in the first part, too. The second part is dedicated to heat demands in AP Vojvodina: heat utilization in building sector, main characteristics of existing district heating systems and share of geothermal energy in heat energy production.

The main information sources for the analysis are following:

- *Energy Sector Development Strategy of the Republic of Serbia for the period by 2025 with projections by 2030*
- *National renewable energy action plan of the Republic of Serbia (In accordance with the template foreseen in the Directive 2008/29/EC- Decision 2009/548/EC)*
- *Progress Report on Implementation of the National Renewable Energy Action Plan of the Republic of Serbia*
- *Serbian Energy Sector Report - Annual and Financial Report Belgrade, 2015*
- *Republic of Serbia energy balance for 2016*
- *Republic of Serbia energy balance for 2017*
- *Autonomous Province of Vojvodina energy balance for 2011*
- *Information on annual needs for energy, and energy sources in the area of AP Vojvodina for 2014*
- *2011 Census of Population, Households and Dwellings in the Republic of Serbia, Number and the floor space of housing units-Data by settlements*

1. Energy utilization in Serbia - general overview

Energy sector is organized under policy framework consisting of a number of regulations, where The Energy Law (*Official Gazette of the RS, No. 145/2014*) is recognized as umbrella law. Energy sector is a very important part of Serbian's economy (accounting to some 10% of the Serbian GDP) with constant growth, consequently sustainable and stable development is one of the priorities for the government. The Energy Law is based on principals to provide safe, quality and reliable supply that is in the same time recognized as main principles for the sustainable energy development. Aiming to safe future energy The Energy Law defines the measures and activities to be undertaken for achieving the long-term targets. Among the other measures, competitive energy market, reliable and sustainable energy-related systems, energy efficiency and production of energy from renewable energy sources (RES) and combined electricity and heat production need to be emphasized.

Although, renewable energy sources is just about 11% of total primary energy consumption, they have a key role for energy sector advancement in forthcoming years, not only as a possibility to increase energy independency, but to meet goals of European Energy Strategy. Therefore, Republic of Serbia by signing the "Law on the Ratification of the Treaty establishing the Energy Community ", have accepted to apply different directives in the field of RES, in accordance with Directive 2009/28/EC. Along with the Directive 2009/28/EC and the Decision of the Council of Ministers of the Energy Community, targets for renewable energy sources share in the gross final consumption of energy consumption in 2020 amounted to 27% and share of energy from renewable sources in transport is targeted to 10%. Further, set of energy sector development strategy documents have been established: National renewable energy action plan of the Republic of Serbia (In accordance with the template foreseen in the Directive 2008/29/EC-Decision 2009/548/EC); Energy sector development strategy of the Republic of Serbia for the period by 2025 with projections by 2030; The Third action plan for energy efficiency of the Republic of Serbia for the period by 2018.

Energy savings, energy efficiency and green energy implementation also going under The Law on the efficiency use of energy (*Official Gazette of the RS, No. 72/09, 81/09 – correction, 64/10-US and 24/11)* along with the Law on Planning and Construction (*Official Gazette of the RS, No. 25/2013)* and its by-laws which regulate the energy efficiency in the field of construction of buildings. Mentioning those regulations is very important since building sector is the hugest energy consumption sector in Serbia (in 2005, share of the building sector in the total consumption of final energy amounted to 48%, out of which 65% in the residential sector).

The Serbian energy sector consists of oil and natural gas industry, coal-mines, and an electric power system, district heating system and industrial energy. Energy resources include fossil (conventional and unconventional), as well as the renewable energy sources (ESDS, 2016):

- Reserves of oil and gas are symbolic and make less than 1% of geological reserves with high exploration level, while remaining 99% of energy reserves include various types of coals, with the highest share of lignite, over 95% in the proved reserves. Oil and gas production is happening from 59 oil fields with 815 exploration wells. Domestic oil production and oil import ratio is 42%/58%.
- Remaining balance reserves of crude oil at the end of 2010 amounted to 10.14 million tons, i.e. 4.23 billion m^3 of natural gas. These reserves have low exploitation quality;
- Estimated total renewable energy sources potential, technically available, is estimated to 5.65 million toe per year. 1.054 million toe of biomass and 909 thousand toe of hydro energy of this potential are already in use.

Final energy consumption in Serbia in 2010 was 9.7 Mtoe (Figure 1). Numbers for final energy in 2014 and 2015 show decline in consumption, but structure stays in the similar shares. Final energy consumption projection, by the end of 2030 is shown on Figure 2.

a) b)

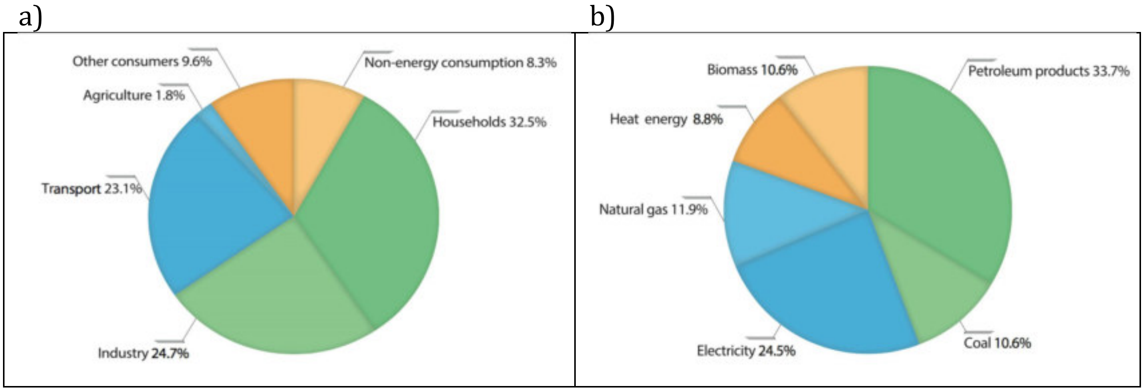


Figure 1: Structure of final energy consumption in 2010 a) by sectors, b) by energy products

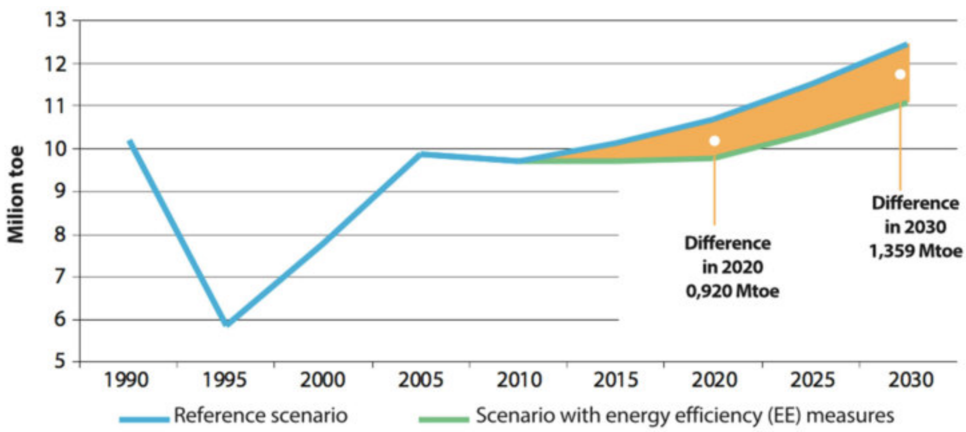


Figure 2: Projection of final energy consumption

An important difference in the final energy consumption structure in comparison to the European Union lies in the high consumption share in households in Serbia and much higher energy consumption share in transport than in the EU (Figure 3).

In addition, one should bear in mind that industrial consumption in Serbia is much lower than at the end of 80s.

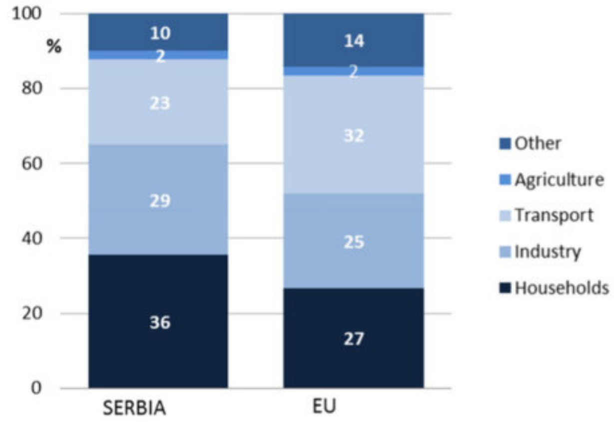


Figure 3: Final consumption structure (without non-energy-related consumption) in 2013

Unbreakable part of energy sector and energy production is greenhouse gas emission. Renewable energy plays crucial role for making the energy sector development with less emission. Streaming to clean energy technologies and achieving targets for keeping GHG on the acceptable level (Republic of Serbia as developing country does not have international obligations to reduce the GHG emission, for now) measures have been defined as: changing the structure of energy products for electricity generation (increasing share of RES and natural gas), decommissioning of old and inefficient plants, commissioning new, more efficient lignite-fired thermal power plants and mitigating loss reduction in distribution and transmission. The predictions of CO_2 emission level after measures implementations are shown on Figure 4.

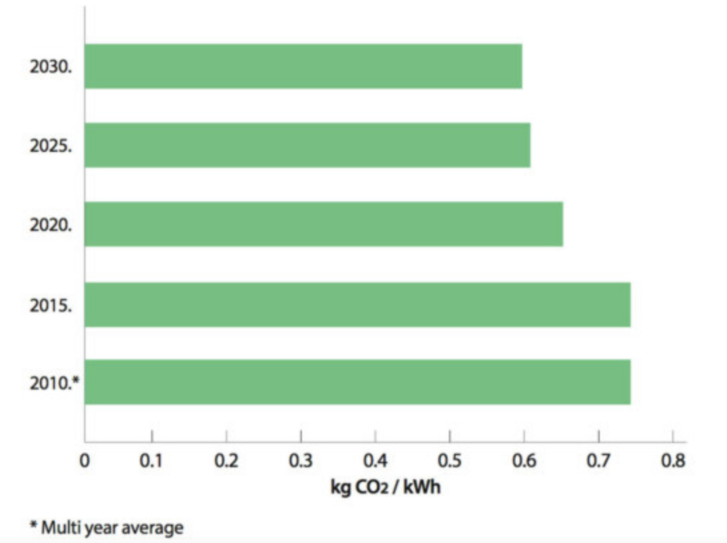


Figure4: Change of specific CO2 emission (ESDS, 2016)

1.1. Primary energy

The latest available data on total primary energy consumption are introduced in this chapter. Data and figures are given for Republic of Serbia without the Autonomous Province of Kosovo and Metohija (APKM). For beater understanding current state of energy market in Serbia data comparisons with the European Union has done.

Primary energy consumption in Serbia in 2014 amounted to around 13.3 Mtoe. Due to meet energy needs, around 30% of energy comes from import (57% oil and oil derivate, 29% natural gas and 17% coal), and the rest comes from domestic production. In comparison to European countries (53.2%), net energy import dependence of Serbia is low, mainly thanks to high share of coal used for electricity generation and to increasing local production of oil and natural gas in past few years. The cost of the net energy imports present 35% of the net import and export trading balance of the Republic of Serbia in 2015.

In 2016 primary energy production is predicted to be 10.9 Mtoe, which is 2% higher than production in 2015. Primary energy production is 68.5% from coal, 10% from oil, 4% from gas, 7% from hydro potential and 10% from biomass while other RES (geothermal, solar, wind and landfill gas) contribute to 1%.

	Measurement unit	Year			
		2011	2012	2013	2014
Population number, in midyear	thousands	7,234	7,199	7,182	7,147
GDP per capita, per spending power parity	Fixed $ from 2011	12,571	12,505	12,892	12,717
Primary energy consumption	Million toe	16.19	14.53	14.91	13.34
Final energy consumption	Million toe	9.25	8.51	8.19	7.67
Import dependence	%	30.3%	27.7%	24.1%	27.9

Data: RZS, World Bank, MRE, AERS

Table 1: Energy sector of Serbia (without APKM) - some indicators for 2011-2014

Total primary energy consumption per domestic product unit (energy intensity) was 1.7 times higher than the European average (Figure 5), as a consequence of low efficiency in consumption in households, industry, due to low rate of capacity use and old technology, as well as due to inevitable technical losses in the process of transformation of lignite into electricity. Gross domestic product of Serbia per purchasing power parity in 2013 was on the level of 37%, consumption of total primary energy per capita – 63% and final electricity consumption – 69%.

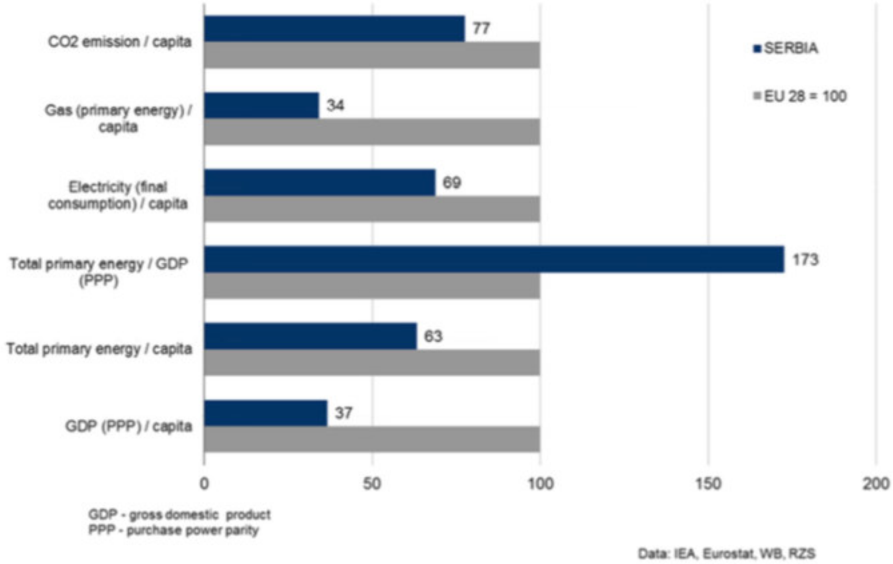


Figure 5: Comparative indicators of Serbia and the European Union in 2013 (CO_2 emission in 2012)

1.1.1 Electricity

Electric power sector includes electric power sources for electricity generation and electricity transmission system used for electricity distribution. Electricity generation comes from: thermal power plants, combined heat and power plants and hydro power plants. The Serbian energy sector is dominated by two energy companies: PE EPS (Elektroprivreda Srbije) and NIS (Naftna Industrija Srbije), which are the largest power producer and distributor, and the largest oil and gas producer, importer and distributor, respectively.

PE EPS have complexly organized electricity production and distribution, within daughter companies. Apart from production capacities of PE EPS, other legal and natural persons were connected to the power distribution grid, owning 185 small power plants with total installed capacity of 76.6MW. Also, a small-scale generation facilities are connected to the distribution grid operated under a dozen licensed companies for electricity production or for combined power and heat production.

The total net installed capacity of the power plants in Serbia amounts to around 8 364 MW. Electricity generation capacities within PE EPS are: 5 171 MW in lignite-fired thermal power plants; 2 835 MW in hydro power plants**;** 353 MW in natural gas- fired or oil-fired thermal power plants**;** 22.3 MW in small hydro power plants. The total net installed capacity of the power plants including small power plants of independent producers, but excluding APKM, in 2015 amounts to around 7 192 MW. The structure of production capacities of PE EPS are between 60% of thermal power plants (TPP) and combined heat and power plants (CHPs), 40% of hydro power plants (HPPs), including small HPPs and one pumped-storage hydro power plant with 2x307 MW capacity.

Technology	Installed capacity MW
Hydro power plants	2.835
Thermal power plants (coal)	3.905
Combined heat and power plants (gas, fuel oil)	353
Gas fired power plants	-
Nuclear power plants	-
Other sources (renewable sources) – small PE EPS power plants	22
Small power plants – independent producers	77
TOTAL INSTALLED CAPACITY	**7.192**

Table 2. Electricity generation capacities in 2015 (without APKM)

In 2015, **electricity generation** amounted to 35.9 TWh (Figure 6), while in 2013 the maximum production was 37.5 TWh. In the same time around 1 730 GWh was imported in Serbia and over 2 000 GWh of electricity was exported. Year 2014 should be considered as an exception because of big floods that caused lacked access to coal and limitation in power generations. Power generation was reduced to the total production to 32.1 TWh. The production in small power plants in 2015 amounted to 321 GWh, achieving almost 20% higher production than in 2014. However, the highest production increasing coming from small power plants occur in 2014 (2.5 times higher than in 2013) due to new regulations in area of energy transmission and distribution (from 1 January, 2015 it is allowed to the households to freely choose their power supplier).

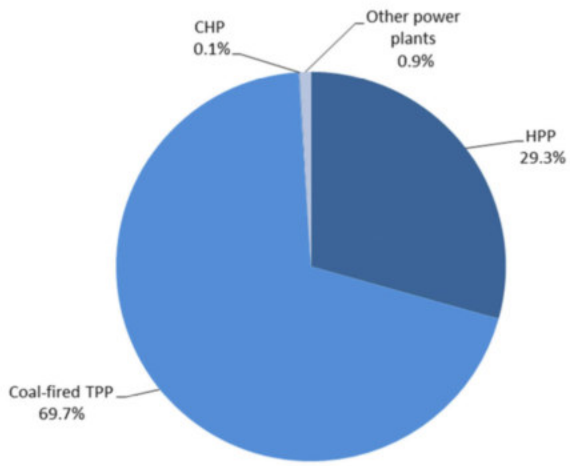


Figure 3-4: Generation structure in 2015 (without APKM)

Figure 6: Generation structure in 2015 (without APKM)

Subsidy system for the electricity generation from renewable sources is supported with the widely used model of feed-in tariff, with the period of guaranteed supply of electricity of 12 years. Developing models for future electricity projections among the fossil fuels took into consideration electricity generation from RES as well. Building scenario is given on Figure 7.

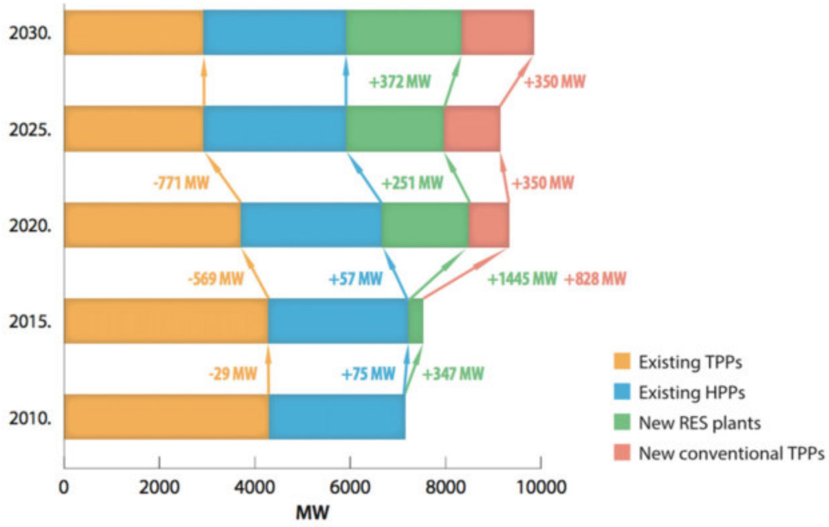


Figure 7: Production capacities in the period until 2025/2030

Electricity consumption is given in detailed electricity generation-consumption table for ten years period (Table 3).

GWh

	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
GENERATION										
Hydro power plants	10,850	9,930	10,011	11,045	12,420	9,145	9,808	10,729	11,366	10,529
Coal fired thermal power plants	23,361	24,016	24,661	24,880	23,162	26,462	24,275	26,537	20,455	25,017
Combined heat and power plants	180	483	367	139	222	408	390	167	63	45
Other power plants	53	40	40	48	61	46	73	104	267	321
Total generation	**34,444**	**34,469**	**35,079**	**36,112**	**35,865**	**36,061**	**34,546**	**37,537**	**32,151**	**35,912**
Other (UNMIK)	21	88	0	44	93	184	144	0	0	15
IMPORT										
Import by EPS and suppliers' import meant to cover customers' demand in Serbia	853	792	616	121	755	1,106	1,170	640	2,869	1,677
Long-term contract with EP Montenegro	993	647	797	1,116	1,463	630	737	1,294	0	0
Annual contracts	0	249	121	85	86	64	125	218	311	55
Import – total import of EPS and for supply purposes	**1,846**	**1,688**	**1,534**	**1,322**	**2,304**	**1,800**	**2,032**	**2,152**	**3,180**	**1,732**
TOTAL AVAILABLE QUANTITY	**36,311**	**36,245**	**36,613**	**37,478**	**38,262**	**38,045**	**36,722**	**39,687**	**35,331**	**37,659**
EPS – export and sales to suppliers for export	812	249	173	1,442	1,286	764	251	3,140	936	2,086
Long-term contract with EP Montenegro	1,201	1,235	1,220	1,184	1,204	1,210	1,214	1,235	0	0
Annual contracts	23	246	115	94	69	90	127	100	85	56
Total – EPS export and sales to suppliers for export	**2,036**	**1,730**	**1,508**	**2,720**	**2,559**	**2,064**	**1,592**	**4,475**	**1,021**	**2,142**
Pumping	852	864	878	903	1,049	860	875	1,007	902	1,102
Other (UNMIK)	99	133	59	71	145	199	196	207	180	300
Gross consumption	**33,324**	**33,518**	**34,168**	**33,784**	**34,509**	**34,928**	**34,059**	**34,000**	**33,228**	**34,115**
Transmission network losses	1,295	1,286	1,224	1,106	1,065	1,096	1,022	1,013	948	932
Distribution network losses	4,434	4,583	4,671	4,864	4,957	4,747	4,580	4,486	4,215	4,236
Total losses	**5,729**	**5,869**	**5,895**	**5,970**	**6,022**	**5,843**	**5,602**	**5,499**	**5,163**	**5,168**
Losses to gross consumption ratio	17.2%	17.5%	17.3%	17.7%	17.5%	16.7%	16.4%	16.2%	15.5%	15.4
Final consumption	**27,595**	**27,649**	**28,273**	**27,814**	**28,487**	**29,085**	**28,457**	**28,501**	**28,065**	**28,947**

** Final consumption in this Report included both the total consumption of all final customers and the consumption of hydro power plants and thermal power plants for production purposes.*

Table 3: Electricity generation and consumption in 2005- 2015 (without APKM)

Electricity prices. Households in Serbia pay 5,3 €cent/kWh, which is four times lower than the EU average. It is a very similar price for the industry sector, where for one kilowatt per hour 4,8 €cent is paid. Prices comparison of electricity for household in Serbia with other countries is given in Figure 8.

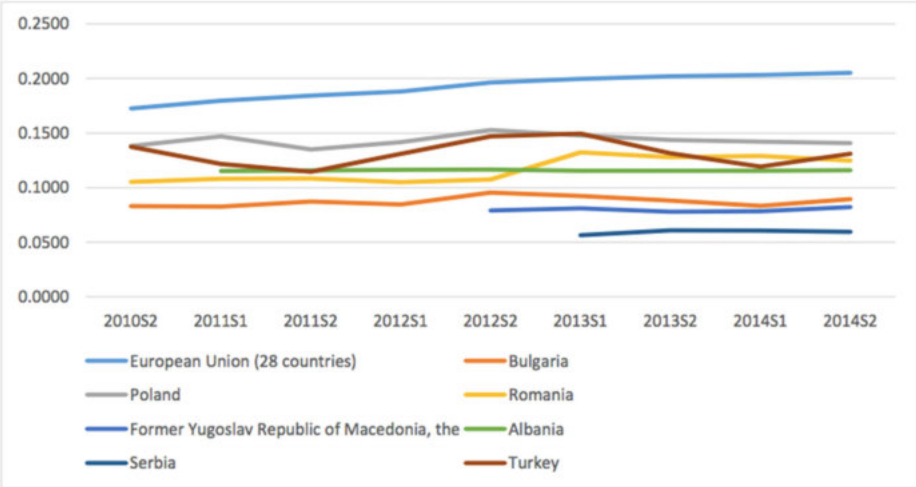


Figure 8: Household electricity prices (EUR/KWh) (Eurostat)

1.1.2. Heat energy

District heating systems exist in 57 cities/ municipalities in the Republic of Serbia. Their total nominal installed capacity is 6 652 MW, total length of district heating networks is around 2 100 km and total number of heating substations is around 23 400. Average age of heating sources, heating substations and distribution network is over 25 years.

Total nominal installed capacity in the **industry energy system** is around 6 300 MW. There are 30 industrial companies in Serbia that enable combined production of heat energy and electricity.

Wide-range of fuels are used for heat generation. According to data from 2013, the largest contributor to heat supply was electricity followed by district heating and renewables (Figure 9). This energy resources structure is justified due to the low cost of electricity and high share of biomass for single home usage.

Heating production in district heating systems is mostly based on gas (74%). Other energy resources share is between oil derivatives (14%), coal (11%) and biomass less than a 1%.

Projected heating production for 2016 was 3 6391 TJ, that is 3% higher compering to year before, while final heating consumption projection is amounted to 30 690 TJ. Approximately one third of consumption is in industry and rest goes to householders and other sectors.

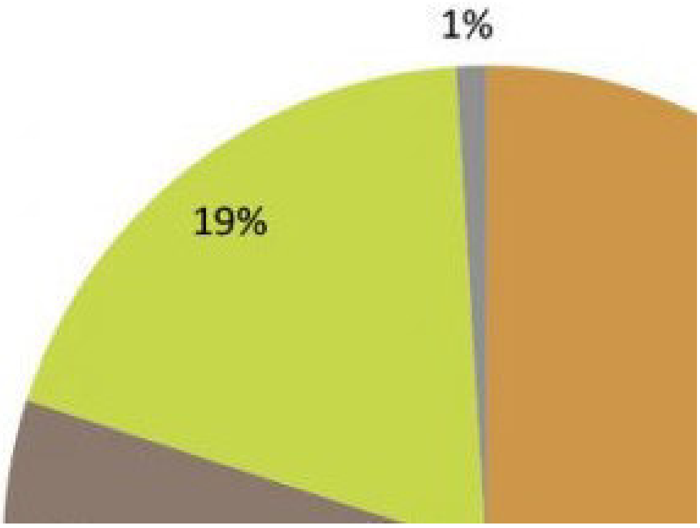


Figure 9: Energy sources used to satisfy heat demand

Building sector in Serbia, which is estimated to around 200 million square meter, is the most energy-consuming sector that is characterized by high percentage of the energy losses. Nearly the half of total energy consummation in Serbia is in building sector, from which 65% goes just to heating. Most of the buildings (around 70% of total building fund) were built during 1970s and 1980s, without proper insulation. Total number of dwelling connected to district heating system is around to 609 000 and the total heated area is 36 227 261 m^2. In the same time developed countries of EU have 40% more apartments connected to district heating system. In order to achieve that level, according to national developing strategy in the period until 2025, it will be necessary to connect around 100.000 new households.

The average annual consumption of heat in Serbia amounts to: residential buildings – 171 kWh/m^2 – district heating (DH) 55 kWh/m^2 – preparation of hot water (PHV), or for non-residential buildings – 194 kWh/m^2 – DH and 12 kWh/m^2 –PHV (NREAP, 2013).

Future development of heating sector is recognized as the priority that demands "systems rehabilitation and modernization, heat source equipment renewal, replacement of obsolete elements within distribution networks, as well as continuous promotion of the equipment of heating substation". The National Renewable Energy Plan projection for energy consumption, 2010-2020 has two scenarios. First one is the Reference (baseline) scenario that is based on the gross final energy consumption in compliance with envisaged economy growth in the given period and second scenario is the one that includes energy efficiency measures. In case of both scenarios the largest part of energy consumption lies in the heating and cooling sector (45.3 % in 2009 i.e. 45.5 % in 2020) (Figures 10,11).

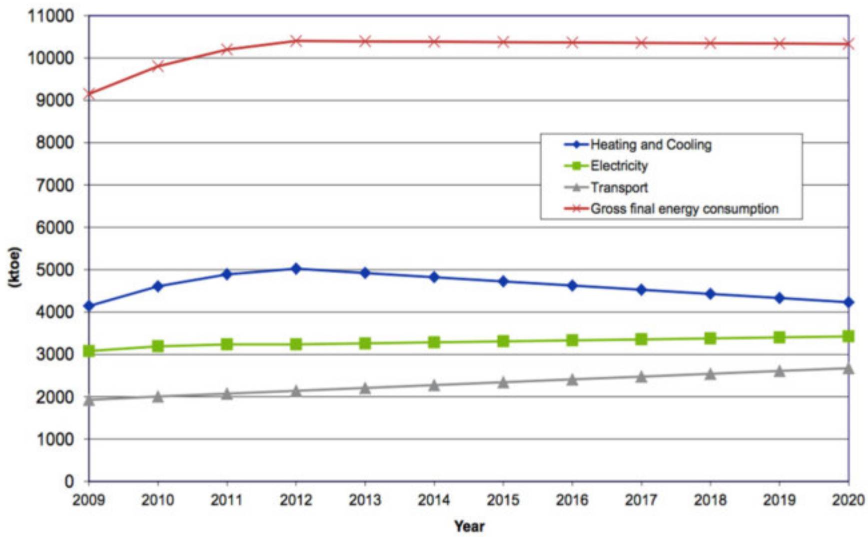


Figure10: Projection for gross final energy consumption in case of Scenario 1

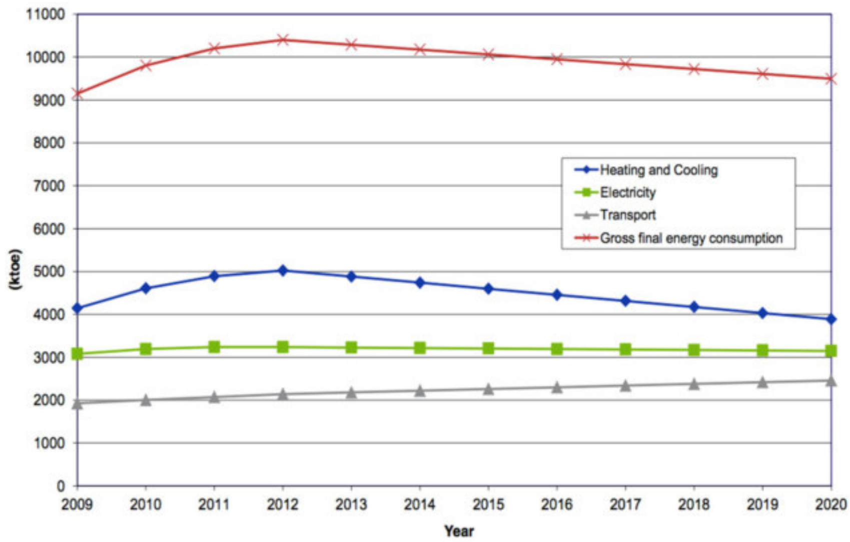


Figure 11: Projection for gross final energy consumption in case of Scenario 2

In the past decade needs for cooling energy are increasing and some recent data show that it is not unusual for a building to have higher cooling demands than heating demands. This kind of energy demanding relations are consequence of higher life standards and impact of climate change, especially in big city areas where heat island effect is present. For this very moment cooling energy consumptions data are not available.

Organized and centralized system for cooling energy distribution on the territory of Serbia is not developed yet.

1.2. The use of renewable energy sources in Serbia

Potentials of renewable energy sources of the Republic of Serbia are estimated at 5.65 Mtoe per year. The vast majority of this potential lies in biomass. According to estimations more than 60% is biomass potential, respectively biomass potential amounts to approximately 3.4 Mtoe per year (2.3 Mtoe per year is unused, and 1.1 Mtoe is used). The rest of RES structure is the following (Figure 12): 1.7 Mtoe lies in hydro potential (0.8 Mtoe per year is unused, and 0.9 Mtoe per year is the used hydro potential), 0.2 Mtoe per year in geothermal energy, 0.1 Mtoe per year in wind energy, 0.2 Mtoe per year in solar energy and 0.04 Mtoe per year in biodegradable part of waste.

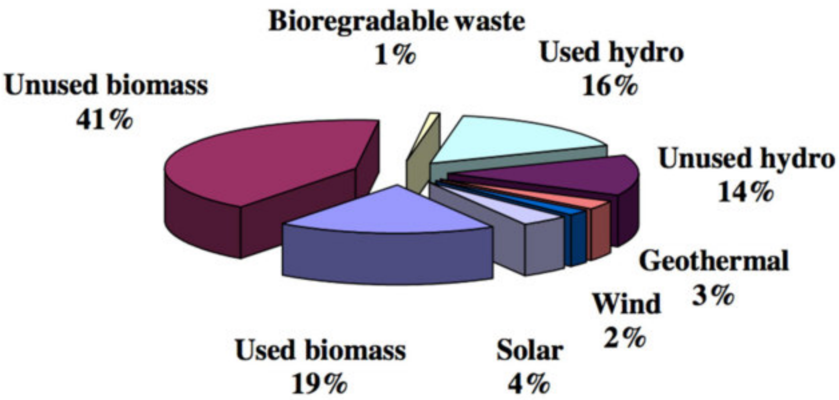


Figure 12: Structure of RES in the Republic of Serbia

Share of RES in gross final consumption is amounted to 20,1%. Currently 35% of the estimated total available technical potential of RES is in use (0.9 Mtoe of used hydro potential and 1.06 Mtoe of used biomass and geothermal potential).

Energy developing strategies carefully calculated potential scenarios for renewable energy resources shared by sectors. In accordance to Reference (baseline) scenario increase of RES are following:

- **electricity sector** will need to increase 30% of RES until 2020, achieving an increase from 884 ktoe to 1151 ktoe. Expressed with respect to gross final energy consumption, this increase amounts to 2.4% (from 9.7% electricity from RES in 2009 to 12.1% in 2020. New power plants are planned to be built with 1020 MW of total installed capacity (Table 4).
- **heating and cooling sector** will need to increase 10.2% of RES until 2020, achieving an increase from 1 059 ktoe to 1167 ktoe. New facilities are planned to be built with additional 149 ktoe of energy (Table 5). RES share in building sector by the year 2020 is projected on 35%: residential 27%, public 5%, industrial 3%.

Type of RES	(MW)	Assumed number of working hours (h)	(GWh)	(ktoe)	Share (%)
HPP (over 10 MW)	250	4430	1108	95	30.3
SHPP (up to 10 MW)	188	3150	592	51	16.2
Wind energy	500	2000	1000	86	27.4
Solar energy	10	1300	13	1	0.4
Biomass – CHP plants	100	6400	640	55	17.5
Biogas (manure) – CHP plants	30	7500	225	19	6.2
Geothermal energy	1	7000	7	1	0.2
Waste	3	6000	18	2	0.5
Landfill gas	10	5000	50	4	1.4
TOTAL planned capacity	1092	-	3653	314	100.0

Table 4: Production of electricity from RES from new plants in 2020

Type of RES	(ktoe)	Share in additionally planned production of heat until 2020 (with respect to the base 2009 year)
Biomass – CHP plants	49	33%
Biomass (DHS)	25	16%
Biogas (manure) – CHP plants	10	7 %
Geothermal energy	10	7 %
Solar energy	5	3%
Biomass in individual households	50	34 %

Table 5: Energy production in the heating and cooling sector from the new facilities that use RES

- In compliance with the Directive on Renewable Energy Sources and defined percentage of RES share for Serbia (10%), by the year of 2020, **transport sector** will amount to 246 ktoe. That amount will represent 2.6% of RES in gross final energy consumption. Currently there is no recorded data of RES use (to be more precise of biofuels) in Serbian transport sector. However, some data of biofuels existent on the market in 2009 can be found in European statistical data, amounted to 0.21 ktoe. Achieving 10% target in biofuels share will be real challenge for Serbian industry, since Serbia currently has capacities only for production of bio fuels from biomass of first generation, not for the second generation, and absence of legal regulation in this field may represent an obstacle too. To meet demands of the Directive on RES Serbia has to plan the import of bio-fuel as well as to invest in infrastructure (investment estimation for biorafinery construction ranges from 100 to 120 million €).

1.2.1. Geothermal energy in Serbia

Geothermal key findings:

- On the territory of Vojvodina, central part of Serbia and in central part of south Serbia Heat flow density is above 100 mW/m^2
- More than 160 occurrences are registered on the territory of Serbia with temperature ranging from 20 to 96 °C;
- Capacity of the heat stored in geothermal fields up to 3 000 m is larger than the amount of heat that could be achieved by burning coal in all known deposits in Serbia;
- It is assumed that in period of 10 years ahead share of geothermal energy in heat energy consumption could be 10%;
- Energy potential in the area of known spas on the territory of Vojvodina, Posavina, Macva, Podunavlje and wider area of central Serbia is amounted to 0.2 Mtoe, which leads to conclusion on great geothermal potential.

In the Serbian part of the Pannonian Basin, the first designated geothermal borehole, 1454 m deep, was drilled in 1969, and the second 2509 m deep was drilled in 1974. From 1977 to 1988, 58 additional boreholes were drilled with a total cumulative drilled depth of about 50 000 m. The overall yield of all these geothermal wells is about 550 l/s, and the heat potential about 48 MWth (calculated for ΔT=T – 25 °C as reinjected T) (Milivojević *et al.* 1995).

In other geothermal provinces, 45 boreholes were drilled mainly before 1992. The total drilled depth is about 40 000 m. The total yield of these wells is about 500 l/s, while the total heat capacity of all these wells is estimated to be about 108 MWth (Milivojević *et al.* 1995).

After 1992, due to the economical and political situation in country and in the ex-Yugoslavia region, the use of geothermal energy decreased. The budget funds for realization of programmes of geological exploration were cut down and almost all the interest in further investments in geothermal resource development was lost. Furthermore, decreased financial capability of final users of energy, as well as unsolved property issues after privatization process led to abandonment of the existing projects, and caused transfer back to use of electric power and fossil fuels (oil, coal, gas etc.). A great number of existing objects are temporarily closed and protected, while at others the thermal water is freely flowing out.

However, after year 2000, the interest in the use of geothermal energy have been revoked caused by the misbalance of petrol energy products and permanent growth of demand on one side coupled with the deficit of fossil and nuclear fuels, growth of transport costs, regional separation, environmental degradation due to the global, regional and local influences, and increasing costs of environmental protection.

From 2000 to date in total 128 hydrogeothermal boreholes were drilled in Serbia, out of which 81 are in the Pannonian basin, while 47 are in other provinces. The total heat capacity of all hydrogeothermal drillholes in Serbia is assumed as much as about 188 MWth, out of which 80.3 MWth are in Pannonian basin.

As the result, total available heat capacity of geothermal resources that were in operation in 2013 and at beginning of 2014 was 104.5 MWth, of which 24.1 MWth is in the Pannonian basin. Total installed capacity of heat pumps in Serbia in 2013 was 11 MWth.

The most common use of geothermal energy in Serbia are the traditional ones: balneology and recreation. In Serbia nowadays there are 59 spas that use thermal water for balneology, sport and recreation. Geothermal energy utilization for heating, as well as in agriculture and industrial processes is present, but only at a few locations. According to Milivojević *et al.* (1995) the total heat potential of all natural springs and wells is about 352 MWth (calculated for $\Delta T = T - 12° C$).

Most of the thermal waters are used for balneological purposes in spas (55.6MWth installed capacity and 258,4 GWth/y production). The direct heat use in agriculture (16,95 MWth/82,88 GWth/y) and for space heating with heat exchangers and heat pumps (53,64 MWth/231,25 GWth/y) are considerable, however there are significant still untapped resources (Oudech & Djokić, 2015). Some estimates found that prospective geothermal resources in the reservoirs of the geothermal systems amount to 400 x 10^6 tons of thermal-equivalent oil (Milivojević *et al*., 1995).

Most of available data of actual use of geothermal energy are from Milivojević's textbook *Geothermology and Geothermal Energy* (2012) and his previous work (Milivojević *et al*., 1995) with some recent updates as of Oudech & Djokić (2015). However, these data should be treated with caution and need updating.

Figure 13 shows the share of hydrogeothermal energy consumptions. Use of geothermal energy for fish farming, animal farming, agricultural drying (grain, fruit, vegetables) is negligible while use for balneology and spaces heating are prevailing.

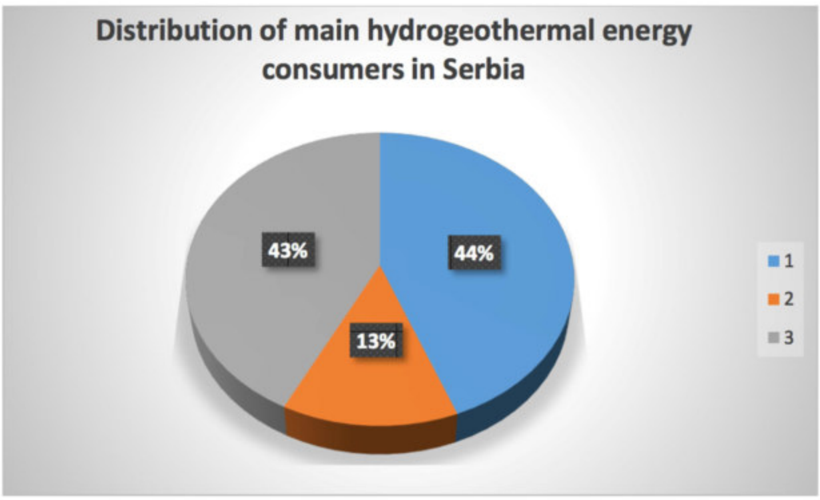


Figure 13: Hydrogeothermal energy consumers. Legend: 1- Balneology (hydrotherapy) and recreation; 2. Greenhouses and soil heating; 3. Space heating

1.2.2. Heat generation based on the renewable energy sources

Total RES share in heat generation is amounted to 19% of all energy resources (Figure. 9). Renewables are included into district heating with total share less than 1%. The vast majority of those renewables are biomass, actually in district heating system the biomass is the only renewables that is used. As seen from Figure 14. biomass is the only renewables with potential to be used in district heating systems. On the other hand, there is a potential and strong intention for the use of geothermal resources in district heating systems as well, but for now just on a small scale. In this very moment one of the district heating geothermal systems is under construction on the location of Bogatic (Macva region). Capacity expected to be installed is 2.1 MW of thermal power.

Biomass potential is estimated at 3.448 million tons. The largest part of this potential is biomass wood (1.53 Mtoe) and agricultural biomass (1.67 Mtoe). Wood biomass is mostly located in the area of the central Serbia and agricultural biomass in the area of Vojvodina. Level of use of wood (forest) biomass potential is relatively high (66.7%) unlike to agricultural biomass potential that is used only about 2%.

Table 6 gives an overview on technical usable potential of renewables form 2012, by resource type. As seen from Table 6. total available technical potential for geothermal energy for heat production is amounted to 0.180 Mtoe/y and for the solar energy potential is amounted to 0.194 Mtoe/y.

Figure 15 shows projected changes in the structure of fuel for heat production in district heating systems, while Figure 16 shows projections of energy use in general from different renewables until 2030

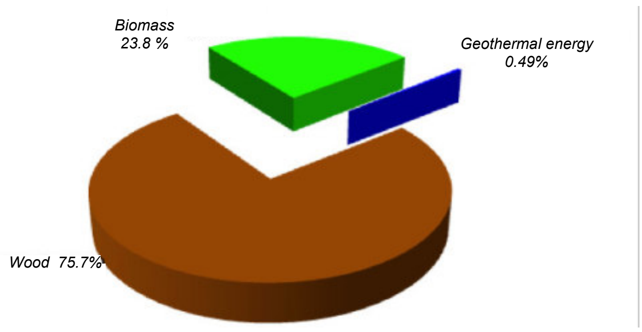


Figure 14: RES structure in primary energy production - projected for the year 2014

RES type	Available technical potential in use (million toe/per year)	Unused available technical potential (million toe/per year)	Total available technical potential (million toe/ year)
BIOMASS	1,054	2,394	3,448
Agricultural biomass	0,033	1,637	1,67
Parts of agricultural species	0,033	0,99	1,023
Parts in fruit growing, wine growing and fruit processing	-	0,605	0,605
LiquidManure	-	0,042	0,042
Wood (forest) iomass	1,021	0,509	1,53
Energy crops	-	-	not available
Biodegradable waste	0	0,248	0,248
Biodegradable municipal waste	0	0,205	0,205
Biodegradable waste (except municipal waste)	0	0,043	0,043
HYDRO ENERGY	0,909	0,770	1,679
For installed capacities up to 10 MW	0,004	0,151	0,155
For installed capacities from 10 MW up to 30 MW	0,020	0,102	0,122
For installed capacities over 30 MW	0,885	0,517	1,402
WIND ENERGY	≈0	0,103	0,103
SOLAR ENERGY	≈0	0,240	0,240
For the electricity generation	≈0	0,046	0,046
For the production of heat energy	≈0	0,194	0,194
GEOTHERMAL	≈0	0,1	0,180
For the electricity generation	≈0	≈0	≈0
For the production of heat energy	0,005	0,175	0,180
Total from all RES	1,968	3,682	5,65

Table 6: Overview of technical usable potential of renewables form 2012

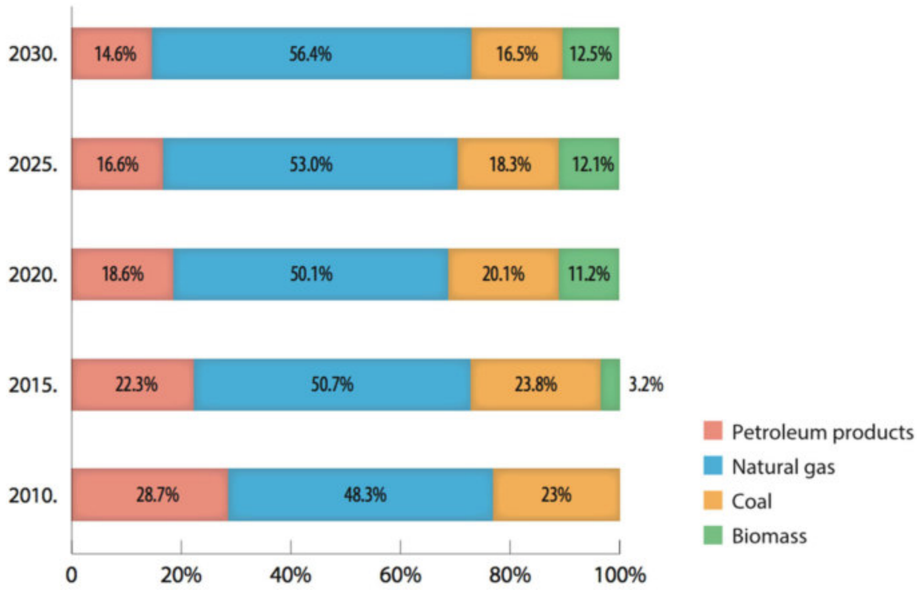


Figure 15: Projected changes in the structure of fuel for heat production in district heating systems

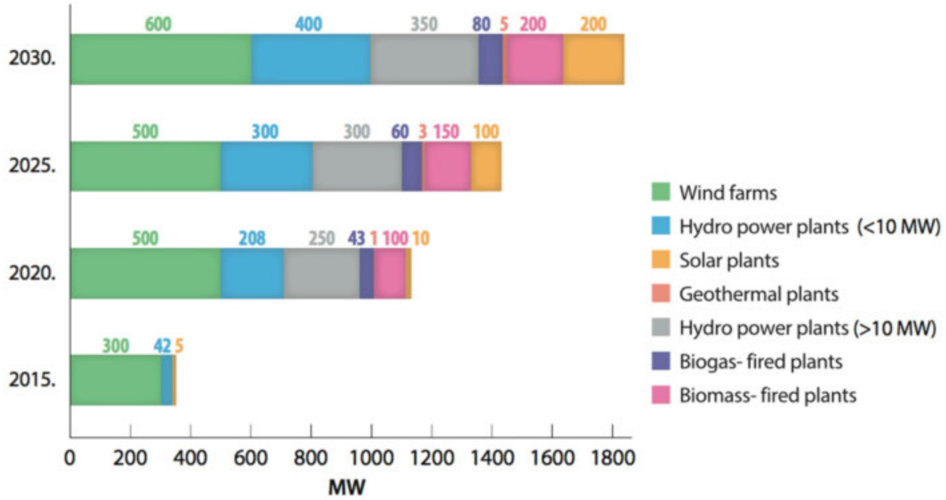


Figure 16: Projection of energy use from renewable energy source in general

2. Heat sector analyses at regional level, (Autonomous Province of Vojvodina)

2.1. General territory description

Autonomous Province of Vojvodina (AP Vojvodina) is situated in the northern part of Serbia, covering the surface of approximately 21 500 km^2 and represents the southernmost part of the Pannonian basin, which is also known as the Great Hungarian Plain. It borders Hungary to the north; Croatia to the west and Romania to the east. The region is divided by Danube and Tisa rivers into: Backa in the northwest, Banat in the east and Srem in the southwest. One part of the Macva region is also located in Vojvodina, in the Srem district. Along the Srem district, six more districts are distinguished, three in Backa region and three in Banat region. Administrative organization within district is on municipality level, i.e. on city level (45 municipalities and 6 cities). Novi Sad is the largest city and the administrative center of Vojvodina and the second largest city in Serbia. Total number of habitants in Vojvodina Province amounted to 1 931 809.

Relief is represented mostly with lowland (altitude 70-90 a.s.l), except in the south and southeast part of the region where hilly areas are formed: Fruska Gora mountain (538 a.s.l) and Vršacke planine mountain (640 a.s.l). The most dominant geomorphological type is fluvial and eolian. The largest catchment belongs to the Danube river with two main tributaries: Sava and Tisa river. Along the river network, and canal network is developed as well.

In AP Vojvodina, the climate is moderate-continental, with cold winters and hot summers. The annual precipitation sum varies from 1200 mm to 223 mm, with total average amount of 600 mm. The highest rainfall occurs in the summer, about 30%, while 26% in the winter, 24% in the spring, and 20% in the fall. The largest amounts of precipitation are recorded in mountains of Fruska Gora and Vrsac-about 900 mm. The average air temperature annual sum is 11 °C. The coldest month is January (average air temperature: 0.21 – 0.78 °C) and July has the highest air temperature (average air temperature: 21.96 – 22.78 °C).

2.2. Overview of heat energy needs/consumption

The main administrative characteristics of each district along with population and settlements information are given in Table 7. The most populated region is South Backa district with more than 600 000 habitants. South Backa district is organized over eleven municipalities and one city (Novi Sad). District with the smallest number of inhabitants is Central Banat district (147 770) and district with smallest density of population is Central Banat (53/km^2).

The heating energy production in the area of AP Vojvodina is carried out in heating plants, combined heat and power plants and in industrial plants. The total planned gross production of thermal energy in 2014 is 16 001 TJ (0.382 Mton), i.e. the total planned final consumption of heat energy amounted to 10 631 TJ (0.254 Mton). The most common energy source in the production of heat energy in Vojvodina is natural gas.

District heating system exists in 17 towns in Vojvodina and one in Macva region. Overview of dwellings categorized by heating system type and by type of energy sources used for heating is shown in Table 8. Total occupied dwellings connected to district heating system in Vojvodina is 123 230. Number of dwellings out of organized heating system, running on their own is amounted to 384 766 and the most used energy for heating is wood. Information on installed heating plant capacities, number of dwellings, total heated areas and average duration of heating season is represented in Table 9.

2.3. The use of renewable energy in Vojvodina

In the territory of AP Vojvodina renewables as biomass, geothermal energy and solar energy are used mostly of the purpose of heating generation. In the year 2014, for heating 0.239 Mtoe of biomass is planned followed by 0.001 Mtoe of geothermal energy. The share of solar energy is negligible. Total RES share in primary energy production in 2014 was approximately 6%, from which 99.5% is biomass, and rest is a geothermal (Figure 14).

Table. 7: The main administrative characteristics of each district

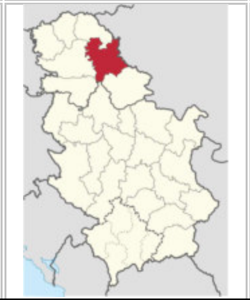
District	North Backa District	West Backa District	South Backa District	North Banat District	Central Banat District	South Banat District	Srem District
Region headquater	Subotica	Sombor	Novi Sad	Kikinda	Zrenjanin	Pancevo	Sremska Mitrovica
Surface area (km^2)	1 784	2 420	4 016	2 329	3 256	4 245	3 486
Number of habitants	186 906	188 087	615 371	147 770	187 667	293 730	311 053
Population density (st./km^2)	104	77.5	151.4	63	57.4	68.6	89.2
Number of cities (above 20 000 habitants) with district heating system	2	2	3	0	2	1	3
Number of cities (above 20 000 habitants) without district heating system	0	2	3	3	0	4	3
Number of towns (habitants: 5000-20 000)							
Number of rural settlements (habitants less than 5000	42	32	61	43	51	84	102
Administrative map of the region							

Table. 8: Overview of dwellings categorized by heating system type and by type of energy sources used for heating

Region	North Backa District	West Backa District	South Backa District	North Banat District	Central Banat District	South Banat District	Srem District	Vojvodina Province
	1.	2.	3.	4.	5.	6.	7.	
Total number of occupied dwellings	69 789	66890	217967	55218	66601	99197	101897	677 559
Number of occupied dwellings with district heating	9 817	3879	75679	5182	7932	13061	7680	123 230
Number of occupied dwellings with central heating	20 002	17087	54721	13151	12960	24385	26917	169 223
Number of occupied dwellings without district and central heating installations	39 964	45901	87460	36868	45675	61735	67163	384 766
Unknown	6	23	107	17	34	16	137	340
Occupied dwellings by the type of energy source used for heating								
coal	2124	29043	32599	13836	16945	23906	17257	154 830
wood	41781	48153	82247	33692	35976	57390	63227	362466
fuel oil and heating oil	9940	4512	2192	308	63	10508	6287	33810
gaseous fuels	18133	6088	139131	25372	41315	41596	40527	312162
electricity	10886	9494	22444	7112	9033	13184	8686	80839
other type of energy	1722	1309	3200	2853	1437	1567	715	12803
gas	8722	2528	64721	20512	33558	28831	33218	192090

Table. 9: installed heating plant capacities, number of dwellings, total heated areas and average duration of heating season

District heating system/region	Total installed capacity (MW)	Total connected capacity (MW)	Number of heat sources	Number of flats	Total heating area (m^2)	Total heating area– public buildings (m^2-MW)	Total heating area – residential (m^2-MW)	Heating season average duration (days)
Backa Palanka/ 3.	12.1	9.2	2	577	56 259	29 883 - 4.8	26 376 - 4.3	187
Becej/3.	24.0	20.0	1	1 040	125 000	50 000 - 11	75 000 - 9	177
Beocin/3.	11.4	5.9	1	630	45 000	10 000 - 4.7	35 000 - 1.2	200
Kikinda/4.	58.8	32	3	3 150	221 574	59 785 - 20	161 699 -12	180
Kovin/6.	8.0	7.8	1	825	71 000	5 000 -0.8	66 000 - 7.0	n.a
Novi Sad/3.	892	648	5	90 912	4 593 825	n.a- 253	4 593 825 - 639	185
Odzaci/2.	5.5.	n.a	n.a	n.a	12 000	n.a	n.a	180
Pancevo/6.	114	105	2	11 683	801 817	159 390 - 20	64 227-85	186
Pecinci/7.	3.9	3.4	1	101	119 000	13 533 - 2.7	5 469 - 0.6	n.a
Ruma/7.	26.5	22.5	5	1 895	138 985	33 559 - 10.7	105 426 - 11.8	183
Sabac/Macva	70	73	3	7 605	470 278	100 246 - 19	370 071 -54	183
Srbobran/3.	6.9	n.a	n.a	177	n.a	7 725	n.a	n.a
Sremska Mitrovica/3.	8.8	34.8	3	3 343	259 889	79 306 - 24.4	180 583 - 34.8	185
Subotica/1.	85.0	108.0	1	10 205	798 000	235 000 - 35.3	553 000 -72.7	182
Temerin/3.	8.8	3.8	3	267	33 663	21 188 - 1.6	12 475 -2.3	185
Vrbas/3.	16.5	12.0	5	1 209	77 452	11 674 - 2.0	65 789 -10.0	180
Zitiste/5.	6.0	4.4	4	177	n.a	11 017	n.a	n.a
Zrenjanin/5.	70.0	92.0	1	7 928	580 095	143 328 -22.0	436 767 -70.0	184

2.3.1. Geothermal energy in Vojvodina and Macva region

AP Vojvodina is considered as the area with the highest prospects for the use of geothermal energy. According to the 2010 energy balance, estimated total potential of geothermal energy in AP Vojvodina is amounted to 22Ktoe/y, while the amount of heat produced is up to 1800 TJ/year. The direct use began not so long ago, in 1981, when 23 wells were operating in multipurpose use: heating green-houses, heating pig farms, for industrial process, for spas and for sport and recreation facilities. Nowadays there is a high interest for geothermal use in aqua-parks and wellness centers. In the last 5 years several projects have started in the field of geothermal utilisation for wellness and recreation purposes: Aqua park "*Petroland*" Backi Petrovac (hydrothermal well-810 m, 16 l/s using a pump or 3.3 l/s of free outflow, water temperature 45 ^{0}C); wellness center in Becej (hydrothermal well- 1100 m, 20 l/s of free outflow, water temperature 65 ^{0}C), wellness center and outdoor pool in Senta (hydrothermal well-920 m, 20 l/s of free outflow, water temperature 55 ^{0}C), hydrothermal well for sport and recreation in Indjija (depth 1 050 m, 15 l/s, water temperature 60 ^{0}C)

Geothermal energy is used in medical treatments as well, with great success for many years from now. Spas that are worthwhile to be mentioned are: Banja Kanjiza Spa, Banja Junakovic Spa (2.4 MW_t), Banja Vrdnik Spa (2.5 $MW_{t)}$, Banja Rusada Spa, Banja Becej Spa (4.7 MW_t). In the medical centers geothermal is not used just for treatments, but for energy purposes as well. Good example is Banja Kanjiza where geothermal waters from three wells are used for balneology, outdoor and indoor swimming pools, domestic warm water, as well as for space heating and cooling and greenhouse heating. Total installed capacity is around 3.2 MW. Installed heating system in Banja Kanjiza Spa produces 4.16 GWh of CO_2 emission-free thermal energy annually and substitutes more than 495 000 m^3 of natural gas (Demic, 2005).

In the Macva region (Debrc) geothermal energy is used for greenhouses. Annual utilisation for greenhouse and soil heating is to more than 70TJ. Also, new recreational complex will drive on geothermal energy (hydrothermal well-771 m, 10 l/s of free outflow, water temperature 70 ˚C). Utilisation in Macva region compared to the available potential is still on very low level.

3. Local level analysis - Bogatic Municipality

Bogatic area is very promising, with confirmed geothermal potential: boreholes depth ranges from 178 m up to 1500 m. The highest temperatures were achieved on geothermal well BB-1 (75 °C) and well BB-2 (78°C). Depth of well BB-1 is 470 m and yield is 25 l/s of free flow. Five kilometers further on the north well BB-2 tapped 35 l/s geothermal fluid, reaching 618 m depth. Last year Municipality of Bogatic with Faculty of Mining and Geology has started developing project for geothermal district heating of the public city buildings (Figures 17, 18)

In Bogatic municipality, local authorities support construction of geothermal district heating system. This will be the first district heating system in Serbia running on geothermal resources. Total investment cost around 850 000 euro and the expected investment return period is 5,65 years. Future geo-DH system will be operating as an open indirect system. For that purposes 25 l/ of geothermal energy will be put in the operation. The system will supply public buildings, as kindergarten, schools, and other public buildings including house of municipality. In total, substitution of fossil fuels wiht geothermal resources will be available in ten buildings. Expected installed capacity is 2.1 MW of thermal power. System will operate as a cascade. At the stage one inlet temperature is 75 °C and outlet 55 °C, providing heat for buildings. At the second stage geothermal energy will be used for heating an open space area (city square and pedestrian zones) and on the third stage future users along the disposal pipe will use the cooled thermal water for multipurposes as green housing, heating for housing in combination with heat pumps, for sports and recreation.

Bogatic	
Region	Sumadija and Western Serbia
District	Macva
Municipality	Bogatic
Surface area	384 km^2
Population	28.843

Figure 17: Location and main data of Bogatic

Connection scheme and objects

	Object	Area [m^2]
1	Kinder garten	1.253
2	Primary school	3.918
3	High school	4.060
4	Municipal building	3.080
5	Court house	700
6	Center for Social Work	176
7	Communal and police building	230

Summary = 13.417 m^2

Figure 18: Planned geothermal facilities at Bogatic

D.5.4.1. Summary report on heat sector analysis
Annex 5A. The Federation of Bosnia and Herzegovina, Bosnia and Herzegovina national report

November 2017

D.5.4.1. Summary report on heat sector analysis
Annex 5A. The Federation of Bosnia and Herzegovina, Bosnia and Herzegovina national report

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Contents:

List of abbreviations

B&H	Bosnia and Herzegovina
FB&H	Federation of Bosnia and Herzegovina
RS	Republika Srpska (Republic of Srpska)
DB	District Brčko
MVTEO B&H (MOFTER B&H)	Ministry of Foreign Trade and Economic Relations of Bosnia and Herzegovina
NREAP B&H	National Renewable Energy Action Plan of B&H
EE	energy efficiency
BFPE (GFCE)	Gross final consumption of energy
DERK (SERC)	State Electricity Regulatory Commission
FERK	Regulatory Commission for Energy in FB&H – FERK
ktoe	Kilo tons of oil equivalent
OIE (RES)	Renewable sources of energy
EPBiH (EMCB&H)	Elektroprivreda BiH (Electric Power Utility of B&H)
ERS	Electric Power Utility of RS
EPHZHB	Electric Power Utility of Croatian Community Herzeg-Bosnia
CARG	Compound Annual Growth Rate
LPG	Liquid petroleum gas

Executive Summary

Bosnia and Herzegovina (B&H) is a state consisting of two Entities, the Federation of Bosnia and Herzegovina (FB&H) and the Republika Srpska (RS), as well as Brčko District (BD) as a separate administrative unit. Energy sector falls within the competence of the Entities. The aim of the present study is to analyze the heating sector of Bosnia and Herzegovina with a special focus on renewable energy sources and geothermal energy at national, regional and local levels. Considering the complex administrative structure of Bosnia and Herzegovina and aiming to harmonize the methodology with other countries participating in the DARLINGe project, we treated the state of Bosnia and Herzegovina and the Federation of Bosnia and Herzegovina at national level. Republika Srpska Zvornik, covered the Republika Srpska Entity is discussed in a separate report.

An overview of energy strategies, planning documents and implementation programs is discussed at the level of the state and Federation of Bosnia and Herzegovina, offering insight into energy characteristics with a particular focus on renewable sources of energy.

The project area in the territory of FB&H covers Posavina Canton and Tuzla Canton; therefore, the analysis of heating sector in these two Cantons is provided at the regional level characterization, since they have significant geothermal potentials.

For the local community level, an example is given of energy consumption for heating in Gračanica Municipality, which is located in Tuzla Canton.

1. Analysis of energy sector of B&H and FB&H with a special focus on the heating market

According to the Dayton Peace Accords, Bosnia and Herzegovina has several administrative levels. The first level includes the institutions of Bosnia and Herzegovina with jurisdiction across the entire territory of the state. The second, important level includes the two Entities: the Federation of Bosnia and Herzegovina and the Republika Srpska, as well as a district - District Brčko. The third administrative level includes Cantons (only in the Federation of Bosnia and Herzegovina), while the fourth one consists of municipalities in the entire territory of Bosnia and Herzegovina (Figure 1).

Administrative levels	Administrative (territorial) unit/s		
I - state level	Bosnia and Herzegovina		
II - entities and district	Federation of Bosnia and Herzegovina	Republika Srpska	Brčko District
III – cantons (only in Federation B&H)	1- Una-Sana Canton 2- Posavina Canton 3- Tuzla Canton 4- Zenica-Doboj Canton 5- Bosnian Podrinje Canton 6- Central Bosnia Canton 7- Herzegovina-Neretva Canton 8- West Herzegovina Canton 9- Sarajevo Canton		
IV – cities/municipalities	79	64	

Figure 1: Administrative (territorial) units and levels in Bosnia and Herzegovina

This study covers the heating sector in B&H, FB&H, Posavina Canton and Tuzla Canton and Gračanica Municipality (Figure 1a).

The result of this specific political system in Bosnia and Herzegovina is the fact that energy sector falls within the competence of the Entities, while the state level is responsible for energy transport and coordination with respect to international integration and obligations.

The Entities are majority owners of electric power utilities, including most mines, hydro power plants and thermal power plants. The Entities are responsible for geothermal energy exploration and utilization.

Private ownership in the energy sector is currently present on a small scale; these private owners were granted concessions from the competent authorities for mining exploitation, construction and operation of hydro- and thermal power plants, and utilization of deep geothermal energy potential, or the construction of wind farms or solar power plants.

Thermal power plant (TE) Stanari near Doboj is the only privately-owned thermal power plant in B&H. The construction of the second one is planned in Ugljevik.

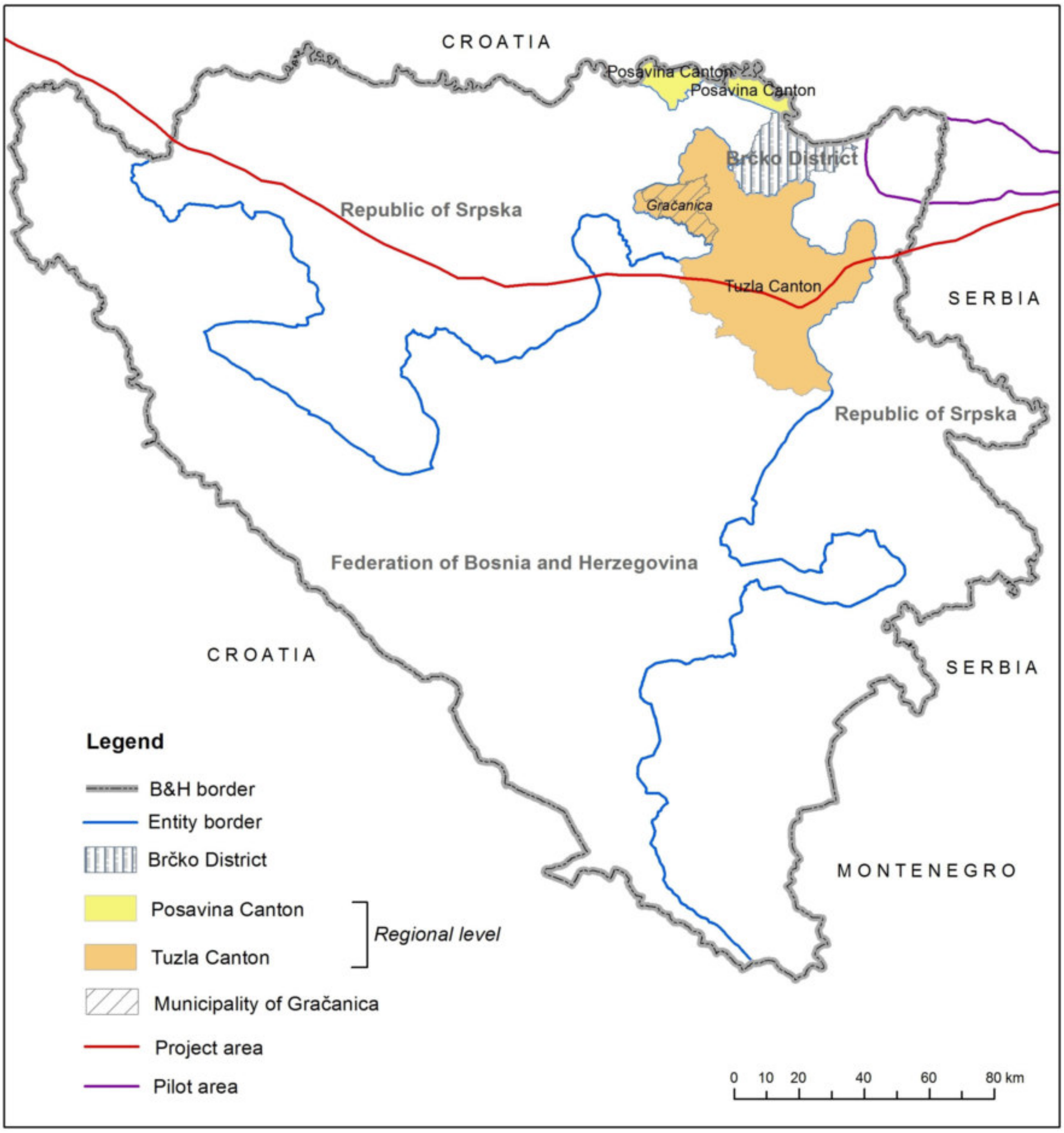

Figure 1a. Geographic location of territorial units covered by the Study

1.1. Bosnia and Herzegovina, national level overview

The Ministry of Foreign Trade and Economic Relations of Bosnia and Herzegovina (MVTEO B&H/MOFTER B&H)) is responsible for energy sector at the level of Bosnia and Herzegovina. The MOFTER B&H is, *inter alia*, responsible for tasks and duties falling within the jurisdiction of the State of B&H including defining policies and basic principles, coordinating activities and consolidating Entity plans with those of international institutions in the energy area. The MOFTER B&H also has responsibility in the area of concessions for the use of water resources of border rivers, as well as in the cases where concession property spreads across the territory of both Entities.

Based on the Action Plans of the two Entities and aimed at implementing the Directive 2009/28/EC (on the promotion of the use of energy from renewable sources), MOFTER B&H developed "Renewable Energy Action Plan of Bosnia and Herzegovina" (NREAP B&H), adopted by the Council of Ministers of Bosnia and Herzegovina in 2016.

The expected energy consumption in Bosnia and Herzegovina in the fields of heating and cooling, electricity and transport until 2020, according to the 2016 Renewable Energy Action Plan of Bosnia and Herzegovina is shown in Table 1.

1.1.1. Energy use

Bosnia and Herzegovina has considerable energy resources. The estimated hydropower potential amounts to around 6,800 MW, of which only about 35% is utilized in terms of capacity, or about 38% relative to the maximum possible electricity generation. According to some documents, the balance-sheet coal reserves amount close to 4 billion tons and they allow for considerable electricity generation in thermal power plants. Figure 2 shows electricity generation from renewable and non-renewable energy sources, respectively.

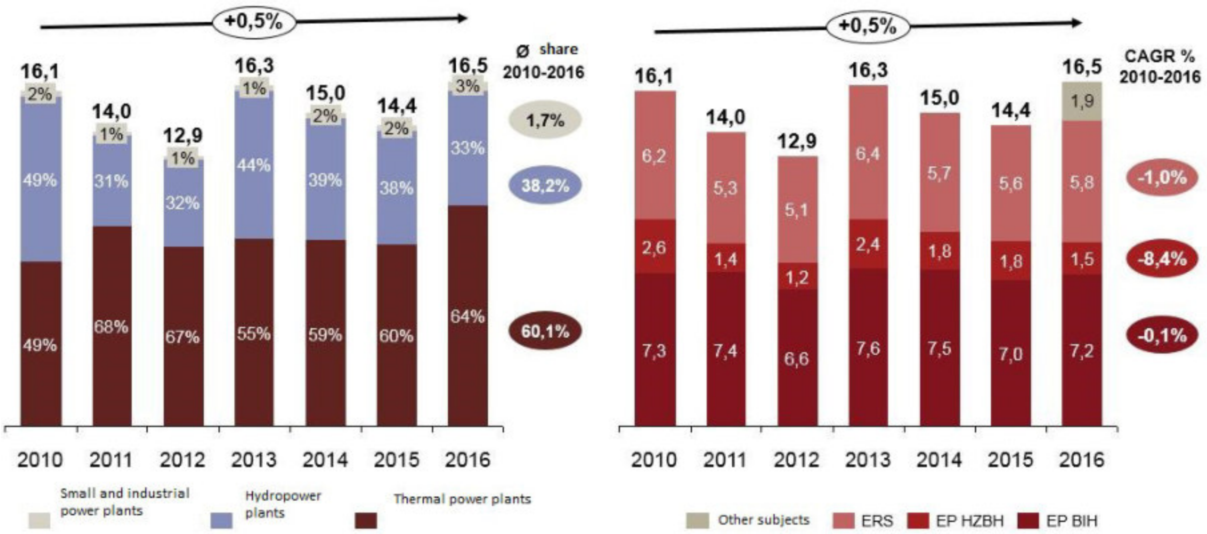

Figure 2: Electricity generation in B&H, per sources in TWh, 2010-2016 (Source: SERC (DERK) - Performance Reports for 2014, 2015, and 2016)

The Federation of B&H currently has no oil and gas production, nor does it have any crude oil processing facilities; thus, it is completely dependent on imported oil derivatives. Figure 2a shows the imports of oil derivatives in the Federation of B&H. The highest consumption of oil derivatives in is transport sector, where petrol and diesel oil are most consumed fuels (Figure 2b).

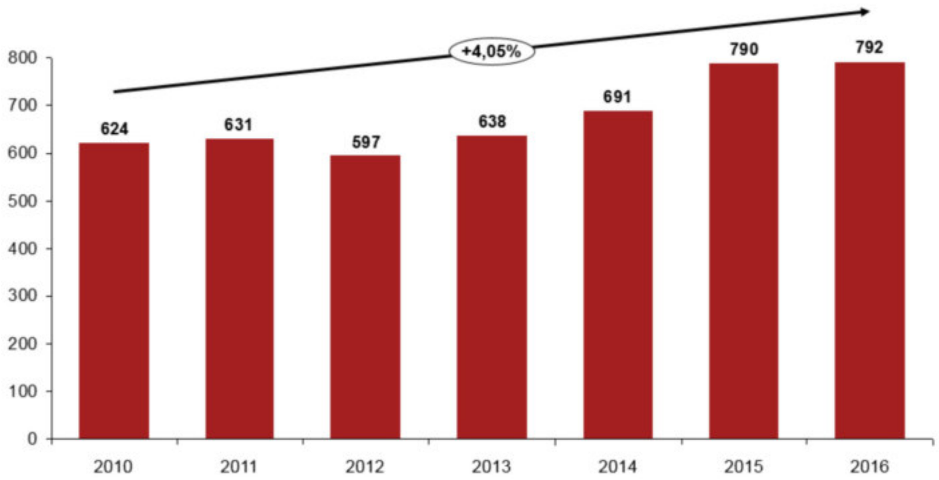

Figure. 2a: Imports of oil derivatives in FB&H in kt, 2010-2016

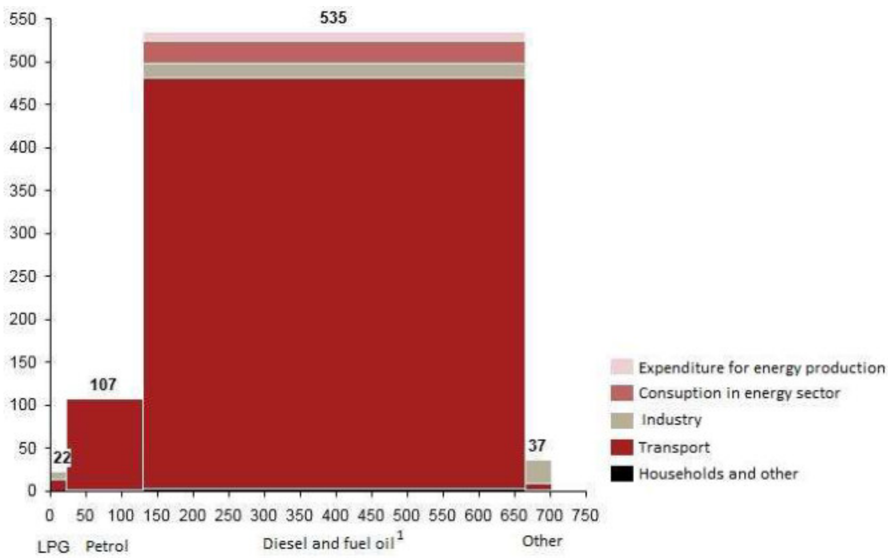

Figure 2.b: Total consumption of oil derivatives per sectors in FB&H, in kt, 2015

The share of natural gas as energy source in the total consumption in B&H is low, amounting to approximately 2%. Bosnia and Herzegovina does not produce natural gas and it is, thus, completely dependent on imports. Figure 2c shows the total natural gas consumption in B&H, Figure 2d for the Federation of B&H, and Figure 2e price-wise. In the period 2010 - 2016, natural gas consumption in the Federation of B&H amounted to approximately 160 – 213 million m^3 per annum (Figure 2d). Natural gas consumption by households in the Federation of B&H amounted to 107 – 157 million m3, where the share of households was 70% – 80% of the total natural gas consumption. Industrial consumption in this period ranged between approximately 35 and 57 million m^3.

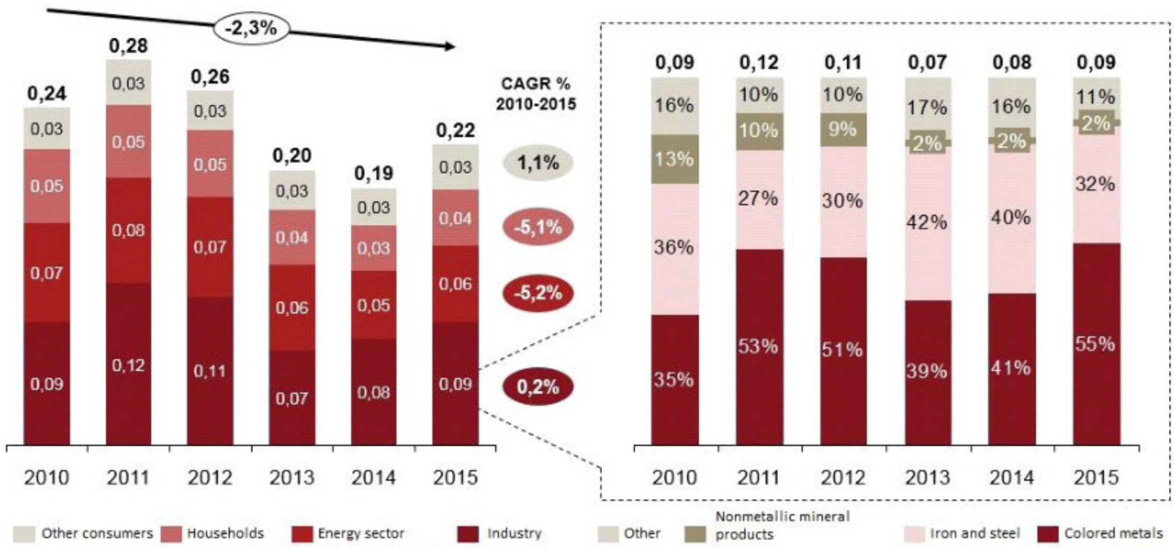

Figure 2c: Total natural gas consumption in B&H, per categories, in billion m3 (bcm), 2010 - 2015
Source: Agency for Statistics of B&H – Statistics for energy - natural gas 2010 - 2015

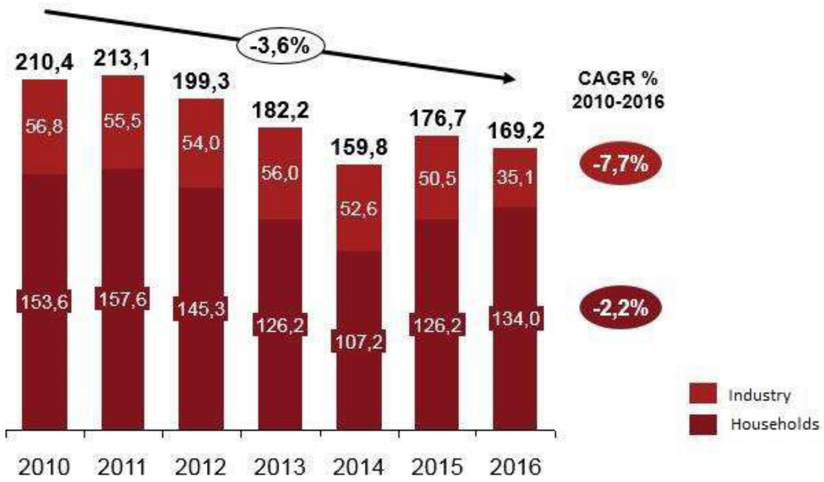

Figure 2d: Natural gas consumption in the Federation of B&H in million m³ (mcm), 2010 – 2016
(Source: BH-Gas)

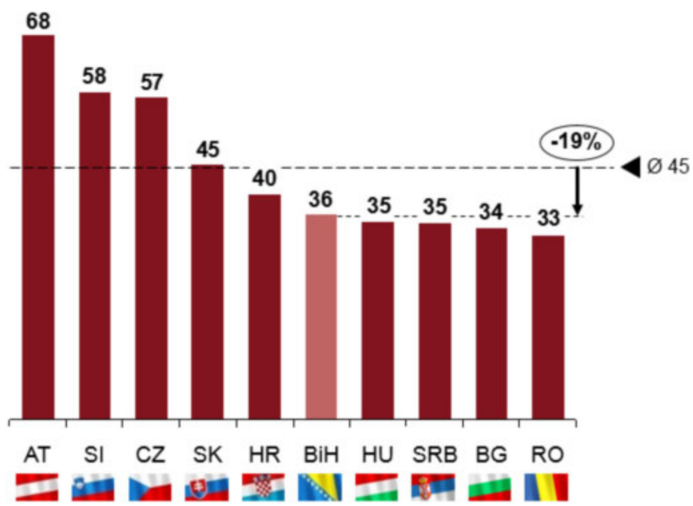

Figure 2e. Natural gas prices for household consumers in B&H and wider region, including VAT and other charges in EUR/MWh, 2010 – 2016 (Source: Eurostat)

Sector	Baseline year	2010		2011		2012		2013		2014	
		Reference scenario	Additional EE	Reference scenario	Additional EE	Reference scenario	Additional EE	Reference scenario	Additional EE	Reference scenario	Additional EE
Heating and cooling (ktoe)	1861.5	1881.7	1877.3	1897.5	1897.5	1917.1	1913.1	1936.7	1898.8	1957.2	1899.5
Electricity (ktoe)	985.1	1035.8	1035.8	1073.3	1073.3	1083.4	1080.1	1082.5	1075.7	1113.4	1096.2
Transport (ktoe)	689,0	787.2	763.7	820.7	795.8	853.2	826.4	886.7	858.5	920.3	888.3
Gross final energy consumption (GFEC - BFPE) (ktoe)	3839.8	4039.6	4039.6	4133.0	4133.0	4192.3	4178.3	4251.6	4121.8	4338.0	4166.5

Sector	2015		2016		2017		2018		2019		2020	
	Reference scenario	Additional EE	Reference scenario	Additional EE	Reference scenario	Additional EE	Reference scenario	Additional EE	Reference scenario	Additional EE	Reference scenario	Additional EE
Heating and cooling (ktoe)	1977.8	1900.1	1996.5	1898.3	2014.9	1896.0	2033.1	1893.2	2051.2	1889.3	2069.8	1886.1
Electricity (ktoe)	1137.4	1115.3	1169.3	1140.1	1201.8	1165.8	1235.0	1192.3	1268.9	1219.7	1303.6	1243.9
Transport (ktoe)	953.2	916.9	985.0	947.9	1017.0	975.9	1048.7	1004.4	1090.3	1042.8	1129.1	1081.2
Gross final energy consumption (GFEC - BFPE) (ktoe)	4417.1	4205.0	4503.0	4248.8	4588.9	4290.1	4675.6	4331.7	4763.0	4372.3	4851.3	4407.7

Table 1[1]: Expected gross final energy consumption in the fields of heating and cooling, electricity and transport until 2020.

[1] The values presented in the table represent sums of values from Entity action plans (Federation of Bosnia and Herzegovina and Republika Srpska) and evaluation for the Brčko District of B&H

1.1.2. Renewable sources of energy

In B&H, electricity is generated from the following renewable sources: hydro power plants (16), mini hydro power plants (59), solar power plants (95), wind farms (1), and biogas power plants (2). Table 2 and Figure 3 show electricity generation, consumption, imports and exports in B&H in period 2010-2016, according to SERC-DERK.

According to the data from the State Electricity Regulatory Commission (SERC - DERK), 5,469 GWh of electricity were generated in hydro power plants in 2016; 400.8 GWh were generated from small renewable sources (small hydro power plants, solar power plants, wind farms), with small hydro power plants accounting for the biggest share (374.27 GWh, or 93.3 %), while generation from solar plants accounted for 26.5 GWh (6.6 %), and only 0.03 GWh (0.007 %) from wind farms.

Year →	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**
Total production (GWh)	16,068.40	14,049.93	12,934.54	16,302.55	15,029.84	14,408	16,508.7
Production from renewable sources (GWh)	8,199.61	4,462.16	4,315.33	7,358.2	6,084.62	5,672.9	5,869.8
Consumption (GWh)	12,265.82	12,592.57	12,624.24	12,558.64	12,209.79	12,605.66	12,865.1
Imports (GWh)	1,056	No data	No data	No data	953	1,308	1,525
Exports (GWh)	4,898	2,586	1,569	5,097	3,716	3,445	5,287

Table 2: Data on the total electricity production in B&H, the share of renewable sources in total production, imports and exports in the period 2010-2016 (Source: Annual Reports of SERC - DERK for 2010-2016)

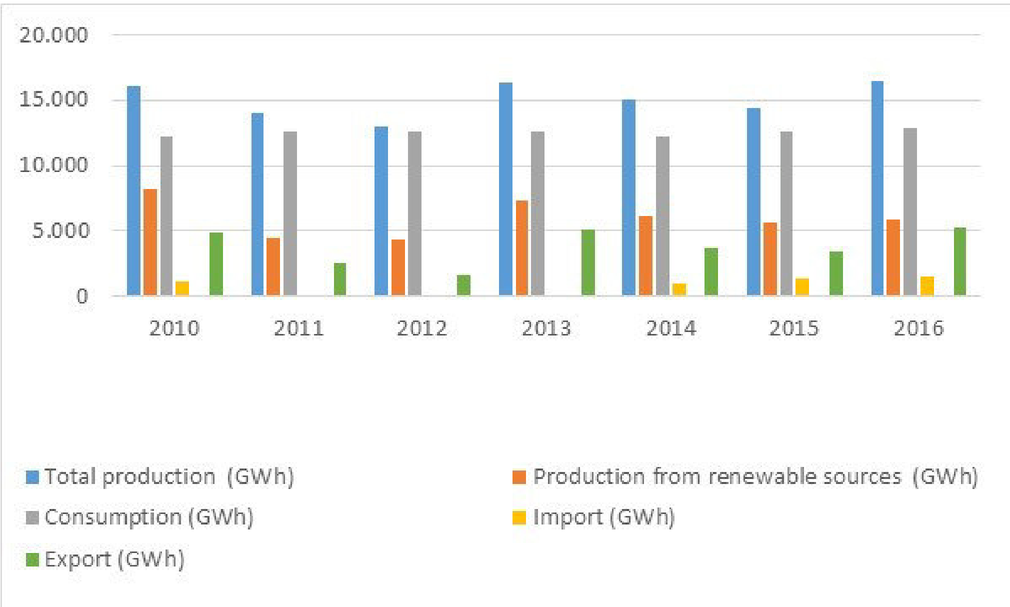

Figure 3: Share of renewable energy sources in total electricity production and data on imports and exports of electricity in B&H (Source: Annual Reports of SERC - DERK for 2010-2016)

In B&H, electricity is not generated from geothermal sources, nor is it foreseen by the Entity Action Plans until 2020. However, the northern region of Bosnia (Posavina, Semberija) is considered as having the potential for finding geothermal sources for electricity generation (120°C or higher) or installing such plants, which may use water having the temperature of 96°C (Domaljevac) for electric power generation.

The gross final energy consumption for Bosnia and Herzegovina for 2009 amounted to 3839.8 ktoe, of which 1,306.9 ktoe were produced from renewable sources. Thus, the share of energy from renewable sources in the gross final energy consumption in 2009 was 34.0 %.

In accordance with the Decision on implementing the Directive 2009/28/EZ and with amendments to Article 20 of the Treaty establishing Energy Community, Bosnia and Herzegovina issued a decision on the binding target of 40% share of energy from renewable sources in the gross final energy consumption in B&H in 2020 (Table 3). Figures 4 - 8 show the planned electricity generation from renewable sources.

Share of energy from renewable sources in the gross final energy consumption in 2009	**34.0 %**
Target share of energy from renewable sources in the gross final energy consumption in 2020	**40.0 %**
Expected total adjusted energy consumption in 2020	**4,851.3 ktoe**
Expected amount of energy from renewable sources corresponding to the 2020 target	**1,940.5 ktoe**

Table 3: Share of energy from renewable sources in the gross final energy consumption for baseline year and for 2020 for Bosnia and Herzegovina (Source: National Renewable Energy Action Plan of Bosnia and Herzegovina)

The Federation of B&H has committed itself to a 95% reduction in SO_2 emissions by 2028, compared to 2014. In the same period, the emission of NOx gases has to be reduced by 64% and of solid particles by 77%. In terms of CO_2 emission reduction, the target has been set for the level of B&H only. There are two scenarios for the reduction by 2030, in line with UNFCC INDCs (Intended Nationally Determined Contributions):

1. "Soft" scenario of 18% higher level of CO_2 emissions compared to that in 1990.

2. "Hard" scenario of 3% lower level of CO_2 emissions compared to that in 1990, with international support (Table 4).

Guidelines	Deadline	Federation of B&H
Energy efficiency	Reduction by 2020 compared to 2010	Underway
Share of energy from renewable sources in the gross final energy consumption	Share in 2020 compared to 2009	41%
Reduction of SO_2, NOx and solid particles	Reduction by 2028 compared to 2014	95% SO_2 64% NOx 77% particles
Level of CO_2 emissions 1	Share by 2030 compared to 1990	18% higher / 3% lower (indicative for B&H)

Table 4: Federation of B&H targets according to EU 2020 Energy Strategy (Sources: European Commission – BIH Progress Report 2014, World Bank – Rebalancing BIH, Systematic Country Diagnostic 2015, National Renewable Energy Action Plan in B&H 2016, Ministry of Foreign Trade and Economic Relations, USAID – National Emission Reduction Plan for B&H 2015, World Bank – BIH Energy Efficiency Project 2014, UNFCC)

Bazna godina = Baseline year

Figure 4: Planned installed power for electricity generation using hydro-potential in Bosnia and Herzegovina for the planning period 2010-2020 (MW) - (Source: NREAP B&H, 2016)

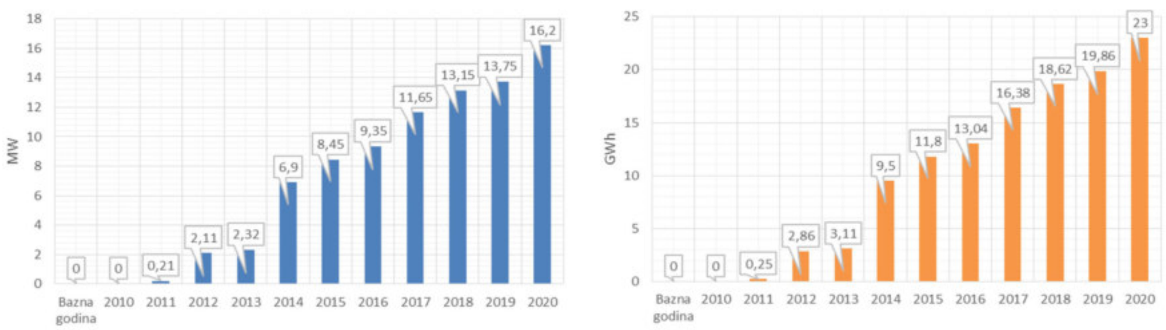

Figure 5: Planned electricity generation in hydro power plants in Bosnia and Herzegovina for the planning period 2010-2020 (Source: NREAP B&H, 2016)

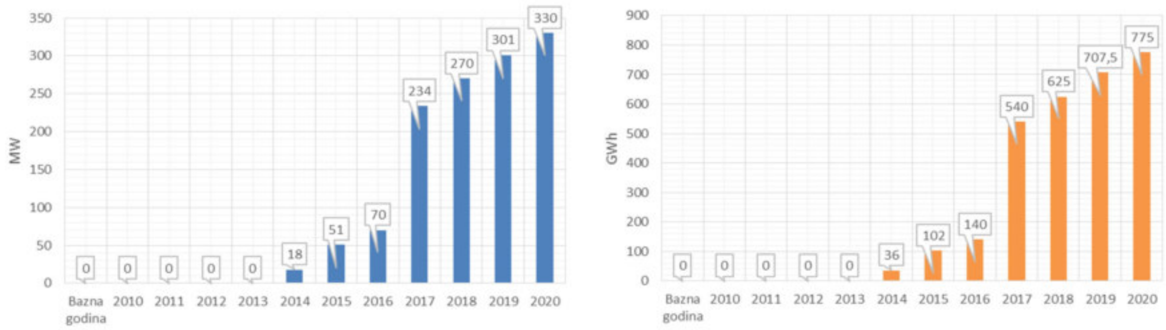

Figure 6: Planned electricity generation in wind farms in Bosnia and Herzegovina for the planning period 2010-2020 (Source: NREAP B&H, 2016)

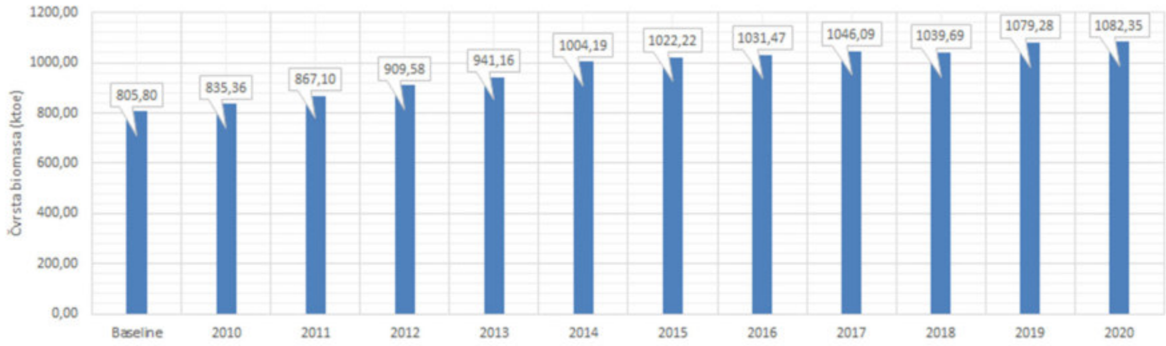

Figure 7: Planned production of heat energy using solid biomass in Bosnia and Herzegovina for the planning period 2010-2020 (Source: NREAP B&H, 2016)

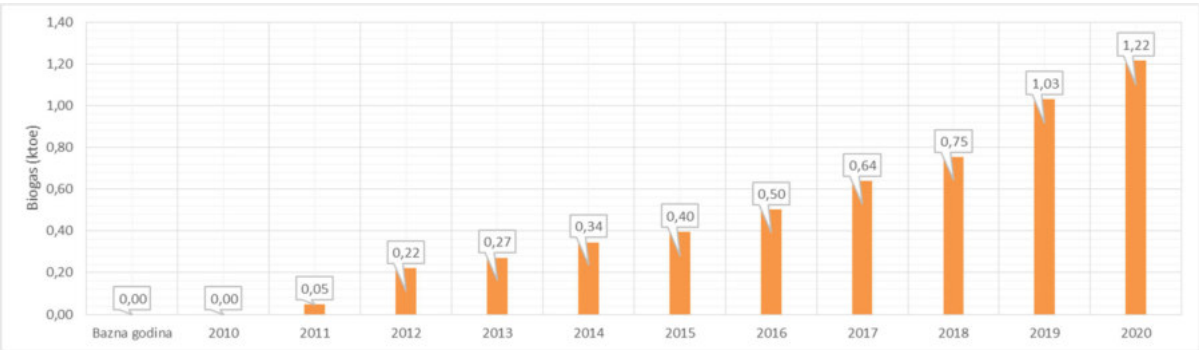

Figure 8: Planned production of heat energy using biogas in Bosnia and Herzegovina for the planning period 2010-2020 (Source: NREAP B&H, 2016)

In the heating and cooling sector, an increase in the share of renewable energy sources is envisaged, from 805.8 ktoe in the baseline year to 1,085.2 ktoe in 2020. This will increase the share of energy from renewable sources from 43.3 % to 52.4 %, meaning a 9.1 % increase. The target for the heating and cooling sector for Bosnia and Herzegovina is based on the parameters from the Entity Action Plans, where the above-mentioned targets for 2020 are set.

In order to achieve the targets set in the heating and cooling sector in Bosnia and Herzegovina by 2020, in addition to using biomass for the heating of households, it is necessary to use other forms of renewable energy that have so far been underutilized, aiming at reducing the share of fossil fuel energy.

In electricity sector, an increase in the share of renewable energy sources is envisaged, from 495.2 ktoe in the baseline year to 741.4 ktoe in 2020. This will increase the share of energy from renewable sources from 50.3 % to 56.9 %, meaning a 6.6 % increase. The target for the electricity sector for Bosnia and Herzegovina is based on the parameters from the Entity Action Plans.

In accordance with the commitments within the Energy Community, the binding target for the share of renewable energy sources in transport sector amounts to 10% by 2020; this target is very hard to achieve in B&H and the country cannot reach it using its own potential, considering the current legislative framework in the Entities and the structure of available capacities.

It is estimated that energy produced from renewable sources will reach the level of 8,846 GWh in 2020, assuming 3,082.2 MW of installed capacity for electricity generation from water flows, solar energy, wind energy and biomass, of which 32.7 MW from cogeneration plants. Out of that, hydroelectric power generation has the major share; wind power generation has a significant share, while biomass and solar power generation account for a small share. The shares of various types of renewable energy sources (RES) in the generation of electricity by the end of the planning period are shown on Figure 9.

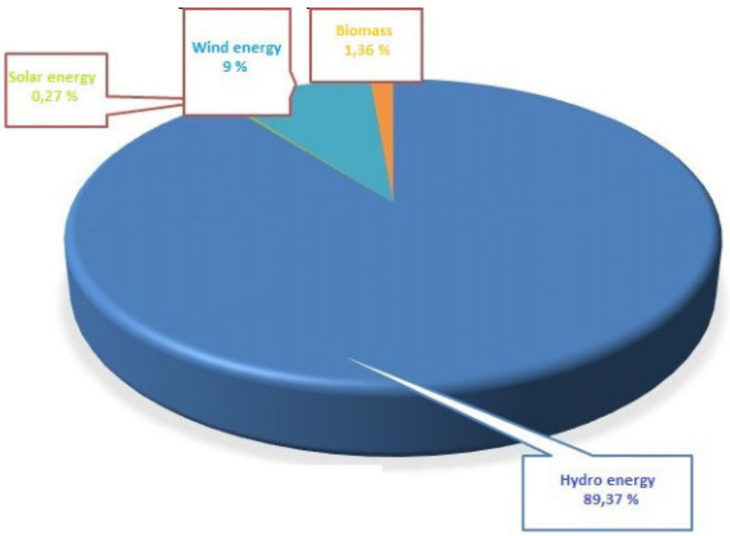

Figure 9: Shares of different types of renewable sources of energy in the generation of electricity in Bosnia and Herzegovina in 2020 (Source: National Renewable Energy Action Plan of Bosnia and Herzegovina)

A survey of electricity generated from renewable sources that will be promoted in the period until 2020 is shown in Tables 5 and 6. The survey is cumulative for Bosnia and Herzegovina, based on Entity incentive plans.

			MW	GWh	MW	GWh	MW	GWh	MW	GWh	MW	GWh
Hydropower			1.10	4.50	6.55	29.00	43.63	188.72	49.08	213.25	55.98	247.61
< 1 MW			0.00	0.00	0.45	2.03	9.63	43.43	10.08	45.46	11.37	47.82
1 - 10 MW			1.10	4.50	6.10	27.00	34.00	145.29	39.00	167.79	44.61	199.79
Geothermal			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Solar			0.00	0.00	0.21	0.25	2.11	2.86	2.32	3.11	6.90	9.45
Photovoltaic			0.00	0.00	0.21	0.25	2.11	2.86	2.32	3.11	6.90	9.45
concentrated			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tidal and wave energy			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Wind energy			0.00	0.00	5.00	10.00	20.00	40.00	25.00	50.00	30.00	60.00
onshore			0.00	0.00	5.00	10.00	20.00	40.00	25.00	50.00	30.00	60.00
offshore			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Biomass			0.00	0.00	0.83	2.23	3.30	8.91	4.13	11.14	5.87	19.37
solid			0.00	0.00	0.83	2.23	2.00	5.91	2.50	7.39	3.92	14.87
biogas			0.00	0.00	0.00	0.00	1.30	3.00	1.63	3.75	1.95	4.50
bioliquids			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	MW	GWh	MW	GWh	MW	GWh	MW	GWh	MW	GWh	MW	GWh
Hydropower	66.72	293.09	79.14	348.04	97.30	426.99	110.89	486.24	135.05	593.76	162.36	712.12
< 1 MW	13.32	56.66	15.88	67.86	20.58	88.20	23.66	101.78	26.97	116.70	32.88	70.00
1 - 10 MW	53.39	236.43	63.27	280.18	76.72	338.79	87.24	384.46	108.08	477.06	129.48	570.12
Geothermal	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Solar	8.48	11.75	10.90	14.80	14.50	19.73	16.33	22.33	17.17	23.92	20.00	27.52
Photovoltaic	8.48	11.75	10.90	14.80	14.00	19.14	15.33	21.14	15.67	21.64	18.00	25.14
concentrated	0.00	0.00	0.00	0.00	0.50	0.59	1.00	1.19	1.50	1.78	2.00	2.38
Tidal and wave energy	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Wind energy	35.00	70.00	45.00	90.00	79.00	170.00	95.00	205.00	123.00	265.00	142.80	307.00
onshore	35.00	70.00	45.00	90.00	79.00	170.00	95.00	205.00	123.00	265.00	142.80	307.00
offshore	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Biomass	7.63	27.60	9.12	32.70	11.29	40.86	13.13	48.27	16.37	58.82	19.45	70.04
solid	5.35	22.35	3.19	25.95	7.71	32.61	9.23	39.27	11.49	47.58	13.61	56.56
biogas	2.28	5.25	2.93	6.75	3.58	8.25	3.90	9.00	4.88	11.24	5.84	13.48
bioliquids	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL												

Table 5: A survey of electricity generated from renewable sources that will be promoted in the period until 2020 in Bosnia and Herzegovina

			GWh	%	GWh	%	GWh	%	GWh	%	GWh	%
Hydropower			4.50	100.0%	29.00	69.9%	188.72	78.5%	213.25	76.8%	247.61	73.6%
Geothermal			0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%
Solar			0.00	0.0%	0.25	0.6%	2.86	1.2%	3.11	1.1%	9.45	2.8%
Tidal and wave energy			0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%
Wind energy			0.00	0.0%	10.00	24.1%	40.00	16.6%	50.00	18.0%	60.00	17.8%
Biomass			0.00	0.0%	2.23	5.4%	8.91	3.7%	11.14	4.0%	19.37	5.8%
TOTAL												
	GWh	%	GWh	%	GWh	%	GWh	%	GWh	%	GWh	%
Hydropower	293.09	72.8%	348.04	71.7%	426.99	64.9%	486.24	63.8%	593.76	63.1%	712.12	63.8%
Geothermal	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%
Solar	11.75	2.9%	14.80	3.0%	19.73	3.0%	22.33	2.9%	23.92	2.5%	27.52	2.5%
Tidal and wave energy	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%
Wind energy	70.00	17.4%	90.00	18.5%	170.00	25.9%	205.00	26.9%	265.00	28.1%	307.00	27.5%
Biomass	27.60	6.9%	32.70	6.7%	40.86	6.2%	48.27	6.3%	58.82	6.2%	70.04	6.3%
TOTAL												

Table 62: A survey of electricity generated from renewable sources per technology shares that will be promoted in the period until 2020 in Bosnia and Herzegovina

1.1.3. Geothermal energy

In Bosnia and Herzegovina, 87 deposits of thermal and thermo-mineral waters are registered with a total yield of springs and drillholes of 2,921.1 l/s and available thermal power of 251.49 MWt and energy of 3,965.47 TJ/year (calculated at reference temperature of 10°C) and potential power of 795.24 MWt and energy of 12,539.33 TJ/year (Miošić, 2010; Miošić, Samardžić, Hrvatović 2010, 2015). Larger-scale investigations, which included drilling, were conducted on 26 thermal water deposits and 21 thermo-mineral water deposits (Table 7).

Kind of phenomena → Type of waters↓	Number of deposits	Number of deposits with springs only	Deposits with springs and drillholes	Deposits with drillholes only	Deposits with springs and drillholes/ wells (4+5)	Yield of springs and drillholes / wells (l/s)	Present power of springs and drillholes/wells (MWt)	Possible power of springs and drillholes/ wells (MWt)
1	2	3	4	5	6	7	8	9
Thermal	57	31	18	8	26	1,828	106.8	315.4
Thermo-mineral	30	9	16	5	21	1,093	144.6	479.8
Total	**87**	**40**	**34**	**13**	**47**	**2,921**	**251.4**	**795.2**

Table 7. Data on springs, drillholes/wells and water deposits in Bosnia and Herzegovina (Source: Miošić and Samardžić, 2013)

According to 2015 data, gathered for the purpose of the paper titled "Geothermal Energy Use - Country Update Report for Bosnia and Herzegovina", published at the European Geothermal Congress 2016, direct use of geothermal energy was applied at 21 locations, 18 of which use it for balneology and recreation purposes (spas and recreation centers). Heating of individual buildings is present at 10 locations, including 6 spas (Slatina, Laktaši, Dvorovi, Višegrad, Fojnica, and Ilidža). A total of 22.8 MWt of thermal energy from deep horizons were used in 2015, which represents about 9 % of the total potential available, proved and present in sources and drillholes.

The use of geothermal energy in 2015, expressed in GWht/year, is as follows:

- Geothermal energy used for the heating of individual buildings 53,30 GWhth/year (64.5 % of the total direct use)
- Geothermal energy used for balneology and recreation purposes 29.34 GWhth/year (35.5% of the total direct use).

Number	Location	Type of use	Geoth. capacity installed (MW_{th})	Total capacity installed (MW_{th})	2015 produc-tion (GW_{th}/yr)	Geoth. share in total prod. (%)
1.	Mala Kladuša Ilidža	Recreation	2.51	2.51	0.18	100
2.	Gata	Balneology and individual space heating (GSHP*)	0.10	0.10	2.14	100
3.	Lješljani	Recreation	0.15	0.15	0.99	100
4.	Sanska Ilidža	Recreation	0.12	0.12	0.34	100
5.	Slateks-Slatina	Individual space heating (heat exchangers)	0.53		1.54	60
6.	Slatina-Banjaluka	Balneology, recreation and individual space heating (heat exchangers)	2.3		12.09	60
7.	Laktaši	Balneology, recreation and individual space heating (GSHP*)	0.25	0.25	7.1	100
8.	Vrućica	Balneology	0.09	0.09	0.51	100
9.	Terme Ozren	Recreation	0.67	0.67	1.96	100
10.	Gračanica PEB-4	Recreation	2.58	2.58	7.62	100
11.	Gradačac (Spa Ilidža)	Balneology	0.005		0.025	85
12.	Dvorovi	Balneology and individual space heating (heat exchangers)	1.32	1.32	7.69	100
13.	Višegradska Banja	Balneology, recreation and individual space heating (GSHP*)	0.0955	0.0955	6.51	100
14.	Tičići-Kakanj	Recreation	3.68	3.68	0.81	100
15.	Olovo	Balneology and recreation	0.13	0.13	0.84	100
16.	Sedra Breza	Recreation	0.19	0.19	0.61	100
17.	Fojnica FB-1 and FB-2	Balneology (well FB-1) and individual space heating (GSHP*)-well FB-2	0.205	0.205	5.65	100
18.	Toplica Lepenica	Recreation	0.24	0.24	0.7	100
19.	Ilidža Termalna rivijera	Individual space heating (heat exchangers)	3.22		14.84	95
20.	Ilidža Terme	Balneology and individual space heating (heat exchangers)	0.83		7,33	95
21.	Slobomir	Individual space heating (heat exchangers)	3.66	3.66	9.16	100
Total			**22.875**		**88.64**	

* Geothermal heat pump with geothermal source temperatures >25 °C.

Table 8: Existing geothermal direct use other than DH, individual sites (Source: Samardžić and Hrvatović, 2016)

Major changes and developments in the use of geothermal energy in the period from 2015 to 2017 are as follows:

- After renovation, Kulaši Spa in Prnjavor started to operate; this spa is using thermal water for the purpose of balneology, heating of premises and bottling;
- Ilidža Spa in Gradačac installed 2 heat pumps and thermo-mineral water in the spa is now used for the purpose of balneology and heating of premises;
- In Olovo Spa, heat pumps have also been installed and thermal water is used for district heating, in addition to being used for the purpose of balneology and recreation;
- Outdoor swimming pools Terme Ozren ceased to operate;
- Terme Recreation Center in Gračanica (PEB-4) started to operate all year round (before 2017 the center was operational on a seasonal basis only – 3 to 4 months a year);
- In 2016, an outdoor pool with water circulation system was built and seasonal use of water for recreation purposes started at Zeleni vir locationy in Olovo. The user is Aquaterm Spa in Olovo. A water spring was captured with yield of around 5 l/s and temperature around 30°C.
- A spa in Domaljevac locality is currently under construction;
- New users of geothermal water in Gradačac have been registered; they use the geothermal water for industrial purposes (in production process):
    - Dairy industry 99 (BZ-1) – in the process for producing milk and dairy products;
    - Inmer Gradačac (BMI-2) – sanitary water in buildings;
    - Swity - Gradačac (EB-1 –Bosnaprodukt) – in the process for fruit and vegetable processing (thermal water is used only for the washing of fruits and vegetables).
- Following good results obtained at new drillholes in Boljanić, funded by the Czech Development Agency and Doboj Municipality, through the project titled "Utilization of renewable geothermal energy in the municipality of Doboj" (3 new 183-438.5-m deep drillholes were completed in 2015 with the water temperature of 24-33°C and the yield of Q>10 l/s), activities to provide heating for the school and sports hall in Boljanić were launched. At the Boljanić location, there were a water spring and a shallow drillhole before, with the temperature of 25°C and the total yield of around 5 l/s.

In addition to using geothermal energy from deep horizons, the use of shallow geothermal energy (< 200 m) has been increasingly present over the past 5 to 7 years for the heating of individual buildings (houses, schools, business premises, etc.), i.e. the use of geothermal energy by heat pumps, whose heat source are waters at the temperature lower than 25°C or dry rock. It is estimated that about 200 heat pumps have been installed in B&H, namely, that 2-3 MWt of thermal energy from shallow horizons are used.

Experiences from the region show that there will be an expansion in the use of heat pumps in heating and cooling systems. However, the heat pumps already installed are not being recorded in B&H, and there is no regulatory requirement for their registration as well. Furthermore there is no requirement in implementing regulations either for issuing any permit for using geothermal energy from shallow horizons, or for recording drillholes, if created in order to introduce this heating system. It is, therefore, necessary to initiate such activities that will result in recording the use of geothermal energy from shallow horizons. The reason why heat pumps are not used to a larger degree for individual housing and business premises lies in the fact that a lot of people in Bosnia and Herzegovina are not able to afford it, given that the price of technological system for the use of shallow geothermal energy ranges from EUR 13,000.00 to 15,000.00.

1.2. Federation of Bosnia and Herzegovina level

1.2.1. General information

The Federation of B&H is the Entity consisting of ten Cantons (Una-Sana, Posavina, Tuzla, Zenica-Doboj, Bosnian Podrinje, Central Bosnia, Herzegovina-Neretva, West Herzegovina, Sarajevo and Livno Cantons), which are further administratively divided into 79 municipalities.

Responsibility for energy sector at the level of the Federation of Bosnia and Herzegovina lies with the Federal Ministry of Energy, Mining and Industry**.**

Cantons in the FB&H, according to cantonal constitutions, have their own competences in the field of energy with regard to passing legislation on local power generating plants and ensuring their availability.

The DARLINGe Project covers the entire territory of Posavina Canton and a part of Tuzla Canton located along the southern perimeter of Pannonian Basin. Table 9 provides basic information on the Entity Federation of Bosnia and Herzegovina and Cantons in the project area, covered in Chapter 2.

Entity	**Federation Bosnia and Herzegovina**
Region capital	Sarajevo
Surface area (km^2)	26,109.7
Population	2,334,348
Administrative arrangements (structure)	10 Cantons and 79 municipalities
Project area	
Canton	**Posavina Canton**
Region capital	Orašje
Surface area (km^2)	324,6 km^2
Population	48,089
Population density pop/km^2	90
Number of cities (more than 20,000 inhabitants) with district heating system	-
Number of cities (more than 20,000 inhabitants) without district heating system	1
Number of towns (inhabitants: 5,000-20,000)	3
Number of rural settlements (fewer than 5, 000 inhabitants)	41
Canton	**Tuzla Canton**
Region capital	Tuzla
Surface area (km^2)	2,652 km^2
Population	477,278
Population density pop/km^2	188
Number of cities (more than 20,000 inhabitants) with district heating system	2
Number of cities (more than 20,000 inhabitants) without district heating system	2
Number of towns (inhabitants: 5,000-20,000)	13
Number of rural settlements (fewer than 5, 000 inhabitants)	363

Table 9: Basic information about the Entity and Project Area

1.2.2. Fossil energy sources

The Federation of Bosnia and Herzegovina has considerable deposits of brown coal and lignite. According to general assessment, the volume and quality of reserves allows a long-term planning of coal-based electricity and thermal energy generation in FB&H for the next 100 years at least, based on the ratio of 65%:35% realized so far, compared to other resources.

Coal accounts for more than 90% of the country's total energy potential; thus, it is currently the dominant energy resource. In the Federation of B&H, coal reserves are identified in several basins, as follows: Tuzla (the area covered by the DARLINGe project), Central Bosnia (coal mines: Kakanj, Breza, Zenica, and Bila), Bugojno (coal mine: Gračanica), southwestern Bosnia (Livno-Duvno). Currently, there are eight actively operating mines whose production is mainly used for power generation. The installed generation capacity and coal-based electricity consumption are shown on Figures 10 and 11.

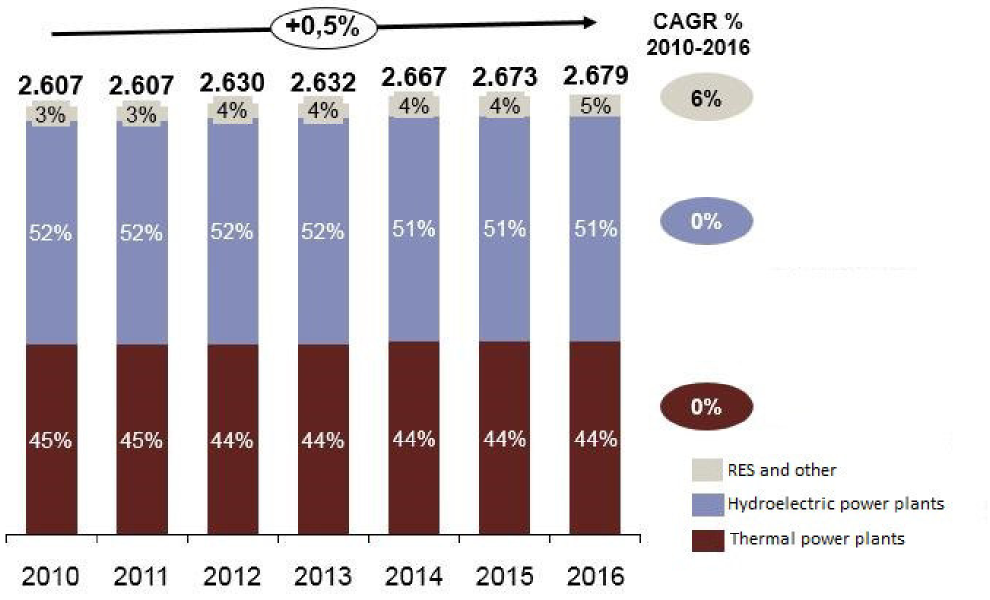

Figure 10: Installed generation capacity in FB&H, per source, in MW, 2010 – 2016 (Source: FERK Performance Reports 2010 - 2015, SERC (DERK) 2016 Performance Report)

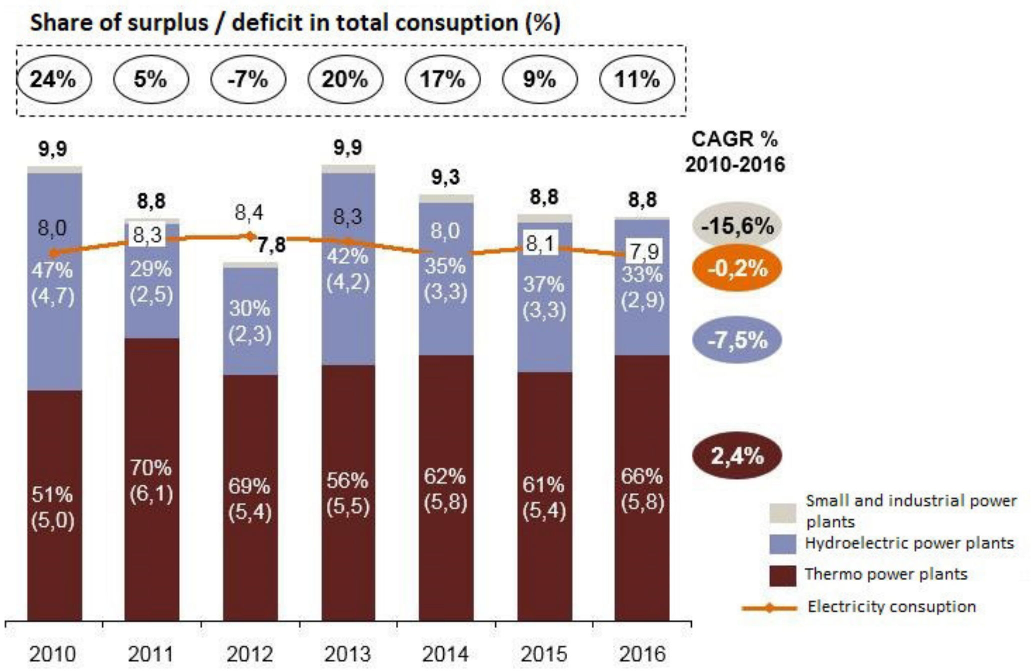

Figure 11: Electricity generation and consumption in FB&H in TWh, 2010 – 2016

1.2.3. Renewable energy sources

Based on the Decision on implementing the Directive 2009/28/EC, the binding target has been set for 40% share of energy from renewable sources in the gross final energy consumption by 2020 for the whole of Bosnia and Herzegovina. In the Federation of B&H, Action Plan of the Federation of B&H for the use of renewable energy sources (APOEF) was adopted in 2014. According to the Action Plan, the FB&H should aim to achieve the target of 41% share of renewable energy sources in the gross final energy consumption, namely 1,450 ktoe in 2020. Targets to increase the share of RES in the gross final energy consumption have been set down to the following three key sectors:

- electricity;
- heating and cooling;
- transport.

The heating and cooling sector should contribute most to the achievement of the target set for 2020 with a 68.3% share of the total renewable energy consumption. It is expected that the share of electricity sector will be 26.9%, and that of transport sector 4.8% (Figure 12).

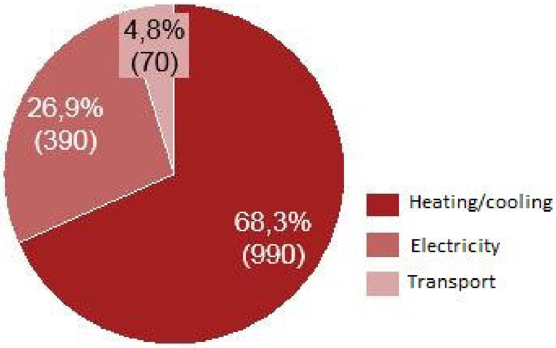

Figure 12: Contribution of sectors relative to the share of energy from renewable sources in the gross final energy consumption in FB&H, 2020

The Action Plan provides an estimated trajectory of renewable energy sources in the gross final energy consumption, according to which the share for 2017 and 2018 amounts to 39%; for 2019 it amounts to 40%, while for 2020 the share amounts to 41%.

The total hydro-potential available for electricity generation is 5,555.4 MW, i.e. 21,840 GWh. The installed capacity of hydro power plants built so far amounts to 2,725 MW with the potential annual generation of 10,365 GWh, which is less than 50% of the possible potential.

Development plans envisage the construction of new generation facilities with installed capacity of 442.5 MW, i.e., annual generation of 1,281.68 GWh; thus, the utilization of the total available potential will then amount to 57.03 % in terms of capacity, and 53.31 % in terms of generation.

According to the surveys on possibilities of using wind potential for electricity generation, which were conducted on twenty locations and for which feasibility studies were prepared, and where measurements are continuously performed, significant potential was identified that would, according to the study results, provide an annual generation of more than 1,621 GWh of electricity.

The FB&H Action Plan provides for incentives for electricity generation from renewable sources by 2020; thus, this Entity will incentivize the following in 2020: 50 MW capacity from hydro power plants generating 205 MWh of electricity, 12 MW capacity from solar power plants expected to generate 18 MWh of electricity, and about 43 MW from wind farms expected to generate 107 MWh of electricity annually. The Federation of B&H will also incentivize, by 2020, 4.6 MW from biomass power plants that would generate about 30 MWh of electricity annually. No incentives are foreseen for electricity generation from geothermal sources.

1.2.4. Heat energy

For the heating and cooling sector, projections of the share of renewable energy sources in the final consumption are given. For heating and cooling, the target share of renewable energy sources is set at 49%, with the foreseen increase of the share of renewable energy sources to 990 ktoe in 2020. The share planned for 2015 amounted to 44%, i.e. 883 ktoe of energy from renewable sources (Figure 13)

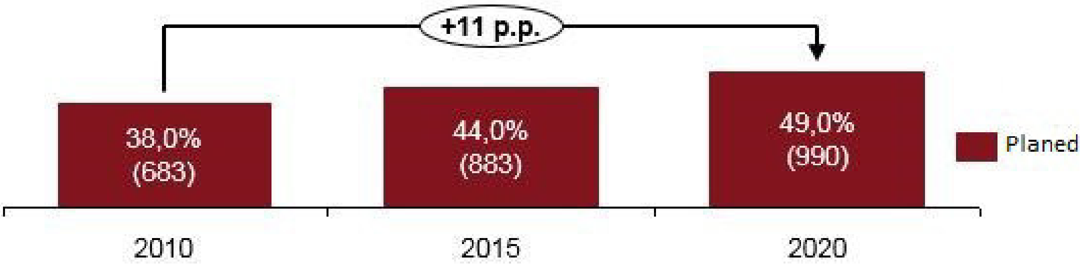

Figure 13: RES share in the final energy consumption for heating and cooling sector, in ktoe, 2010-2020 (Source: Action Plan of the Federation of B&H for the use of renewable energy sources)

The Strategic Energy Framework of FB&H (working draft v.02) envisages an increased share by 2035 of renewable energy sources (biomass, geothermal, solar and other technologies) in the entire energy sector.

In the renewable energy based cogeneration scenario, the focus should be placed on district heating systems. The Federation of B&H has a considerable geothermal potential that has so far not been adequately explored and utilized. Given that it is planned that the share of geothermal energy in the heating sector final consumption should be approximately 0.5%, the geothermal potential of FB&H should be further explored and commercialized. It is estimated that the share of solar energy by 2035 will amount to approximately 1% - 4%. A wider use of solar panels, primarily for household heating, is expected due to a continuous drop in prices. Considering the rapid development of technologies and price drop at the global level, new commercial technologies used for heating and/or cooling can be expected to appear on the market by 2035 with a share of approximately 0.5% of the total final consumption of the sector (Table 10).

Tehnology	Vision up to 2035.	
	Share in RES Heating / cooling	Contribution in final consumption
Biomass	~ 98 %[1] – 95 %[2]	↗
Geothermal energy	~ 0,5 %	↗
Solar energy	~ 1 %[1] – 4 %[2]	↗
Other	~ 0,5 %	↗

Table 10: Contribution of RES technologies to the final energy consumption in the heating and cooling sector (Source: Strategic Energy Framework of the Federation of Bosnia and Herzegovina until 2035 - working draft of the document (v.02)

In the Federation of Bosnia and Herzegovina, 35% of the total energy is consumed in buildings, where two thirds of energy are used for heating and cooling. Out of this amount, housing and tertiary sectors account for over 65% (Tables 15 and 16).

In the Federation of B&H, district heating system is available in larger towns and cities like Sarajevo, Zenica, Doboj, Tuzla, Lukavac, Kakanj, and Gračanica, while the remaining housing units have heating from energy plants – fire beds mainly based on biomass, electricity, rarely gas – in Sarajevo only. Tables 11 and 12 provide average surface area of houses, apartments, public buildings and newly built (modern) houses in the Federation of B&H and energy consumption for heating purposes.

No.	DESCRIPTION	Individual houses	Apartment buildings	Public buildings	Newly built houses
1.	Average surface area of buildings (m^2/year)	100	55	1,200	110
2.	Average specific energy (kWh/m^2/year)	300	200	340	100

Table 11: A survey of average surface area of housing units and buildings for the territory of the Federation of B&H (Source: Strategic Energy Framework of FB&H, 2017)

The consumption of energy for heating in the Federation of Bosnia and Herzegovina for 2015 and 2016 amounted to 250 kWh/m^2/year.

No.	Individual housing units - houses		Apartment buildings having fewer than 10 apartments		Renovated buildings		Apartment buildings having more than 10 apartments	
1.	Water heater	36.60%	Central heating	6.70%	Central heating	99.00 %	Central heating	14.60%
2.	Gas converter	21.60%	Central gas boiler	3.40%	Other	1.00%	Central gas boiler	7.80%
3.	Wood furnace - boiler	30.30%	Tankless water heater	35.20%			Tankless water heater	19.80%
4.	Other	11.50%	Gas converter	18.00%			Gas converter	27.40%
5.			Combined heating	30.40%			Combined heating	26.70%
6.			Other	6.30%			Other	3.70%

Table 12: Energy consumption by type of facility (Source: Strategic Energy Framework of FB&H, 2017)

1.2.5. Geothermal energy

In the Federation of B&H, there are 73 deposits of thermal and thermo-mineral waters, i.e. 43 thermal and 32 thermo-mineral deposits (Table 13). These deposits are located in 7 Cantons (Una-Sana, Posavina, Tuzla, Zenica-Doboj, Bosnian Podrinje, Central Bosnia, and Sarajevo Cantons), while no deposits are identified in 3 Cantons (Herzegovina– Neretva, West Herzegovina, and Canton 10). Geothermal energy is used from only 14 deposits, by a total of 16 users.

The total available capacity of the deposits of thermal and thermo-mineral waters in FB&H amounts to 196.79 MWt (calculated on the basis of definitely proved quantities of thermal and thermo-mineral waters that are possible to capture and use on the existing springs and drillholes or in case they are reconstructed or drilled again on the same location and to the same depth). The possible (predictive) capacity of identified deposits is 409.14 MWt (calculated including new quantities of water provided by new drillholes on already identified deposits, along with larger quantities of water [already proved water temperatures] or by pumping from the existing drillholes with no pumps installed, but only active artesian outflow, included in the calculation of the available capacity). It should be noted that, on some locations where springs are present but no drillings have been performed, higher temperatures are likely to be found; also, by drilling deeper than the existing drillholes on some locations new deeper deposits will be identified with probably higher temperatures. Also, it is realistic to assume that new deposits of thermal and thermo-mineral waters will be identified in areas where there are no springs and no drillings have been performed. It can be assumed with quite some certainty that shallow geothermal potential is present in the entire territory of Domaljevac, Odžak and Orašje municipalities, notably in Pliocene sands where temperatures of 20-25°C are expected to be found at the depth of up to 200-300 m. Figure 14 shows the relation between available and possible (predictive) thermal capacity.

Cantons ↓	Number of deposits with thermal water	Number of deposits with thermo-mineral water	Available thermal capacity up to 10°C (MWt)	Possible (predictive) thermal capacity up to 10°C (MWt)	Available thermal energy up to 10°C (TJ/god)	Possible (predictive) thermal energy up to 10°C (TJ/god)	**Current utilization**	
							Number of locations in use	Installed thermal capacity (MWt)
Una-Sana Canton	10	4	34.2	76.42	1,082.29	2,512.9	3	2.73
Posavina Canton	2	1	8.58	34.52	267.43	1,085.21	0	0
Tuzla Canton	7	7	34.42	69.81	1,091.61	2,198.43	5	3.0
Zenica-Doboj Canton	11	12	30.78	70.81	968.28	2,309.45	4	2.89
Bosnian Podrinje Canton	1	0	1.78	5.96	59.35	189.93	0	0
Central Bosnia Canton	7	3	24.54	52.87	669.38	1,563.08	2	0.45
Sarajevo Canton	5	5	62.49	98.75	1,969.51	3,106.24	2	4.06
Total Federation of B&H	**43**	**32**	**196.79**	**409.14**	**6,107.85**	**12,965.24**	**16**	**13.13**

Table 13. Basic data (number of deposits, available and predictive capacity, installed capacity) about deposits of thermal and thermo-mineral waters in the Federation of B&H

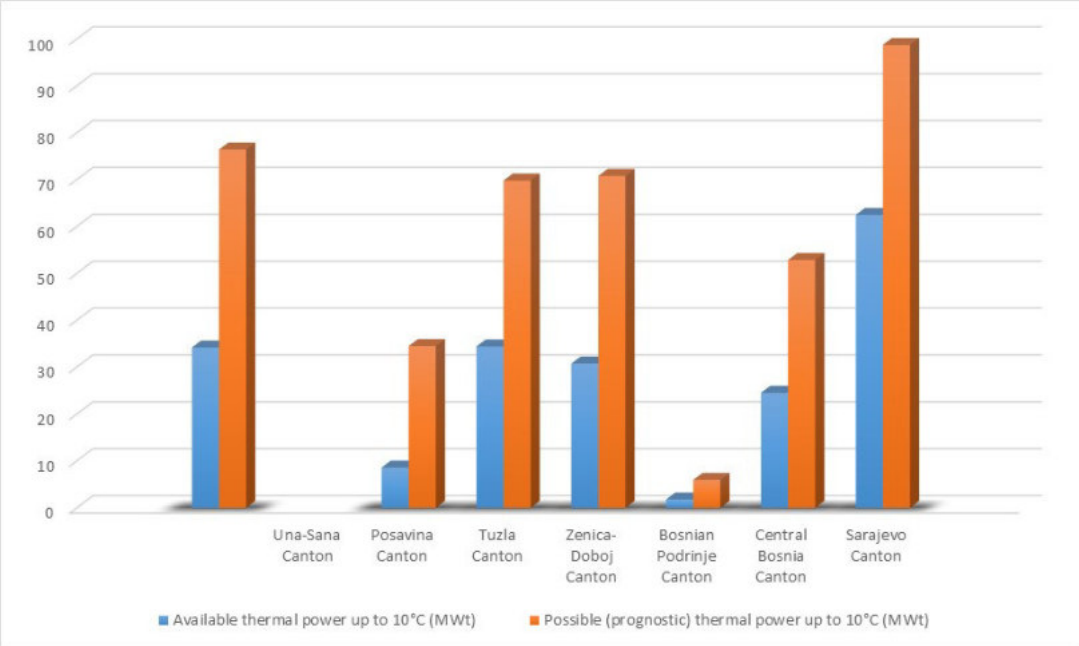

Figure 14. Available and possible thermal capacity of thermal and thermo-mineral water deposits in FB&H (MWt)

Geothermal energy in the Federation of B&H is used at 16 locations with the total installed capacity of 13.13 MWt, amounting to only 7.7 % of the available capacity of 196.79 MWt (Table 14, Figure 15). On these 16 locations, thermal and thermo-mineral waters are used for the purposes of balneology, recreation, heating of premises and industrial processes. Spas are major users, and their intense development has been observed over the past 10 years, compared to the period immediately after the 1992/95 war, including expanding accommodation capacity, introducing new therapeutic and recreational services, installing heat pumps, etc.

In addition to geothermal utilization, thermal and thermo-mineral waters in FB&H are also used for water supply (9 locations), bottling (2), and removal of CO_2 from water (1).

Number	Location	Type of use	Geoth. capacity installed (MWt)
	UNA-SANA CANTON		
1.	Mala Kladuša Ilidža	Recreation	2.51
2.	Gata	Balneology and individual space heating (GSHP*)	0.10
3.	Sanska Ilidža	Recreation	0.12
	TUZLA CANTON		
4.	Gračanica PEB-4	Balneology, recreation	2.56
5.	Banja Gradačac	Balneology and individual space heating (GSHP*)	0.13
6.	Mliječna industrija 99-Gradačac (BZ-1)	Industrial use (dairy industry)	0.16
7.	Inmer Gradačac (BMI-2)	Sanitary water	0.08
8.	Swity –Gradačac (EB-1)	Industrial use (for the washing of fruits and vegetables)	0.07

	ZENICA-DOBOJ CANTON		
9.	Tičići-Kakanj	Recreation	2.51
10.	Banja Olovo	Balneology, recreation and individual space heating (GSHP*)	0.13
11.	Zeleni vir-Olovo	Recreation	0,06
12.	Sedra Breza	Recreation	0.19
	CENTRAL BOSNIA CANTON		
13.	Fojnica FB-1 and FB-2	Balneology (well FB-1) and individual space heating (GSHP*)-well FB-2	0.205
14.	Toplica Lepenica	Recreation	0.24
	SARAJEVO CANTON		
15.	Ilidža Termalna rivijera	Individual space heating (heat exchangers)	3.22
16.	Ilidža Terme	Balneology and individual space heating (heat exchangers)	0.84
Total Federation of Bosnia and Herzegovina			**13.13**

* Geothermal heat pump with geothermal source temperatures >25 °C

** Beside balneology and recreation, PEB-4 wells are used for CO_2 removal too.

Table 14: Current utilization of geothermal energy in the Federation of B&H

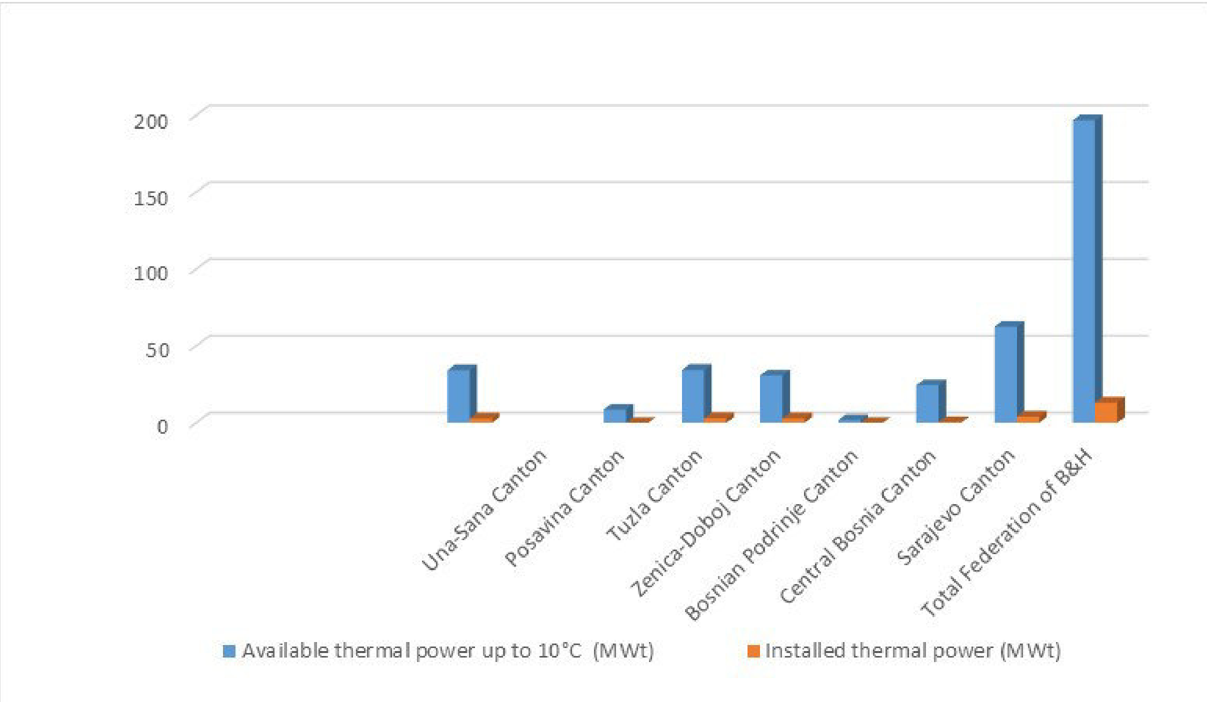

Figure 15: The ratio of available thermal power and installed thermal power (MWt) in Cantons and the total in the Federation of B&H

The above-mentioned data indicate that Sarajevo Canton has the biggest geothermal potential, but that the utilization of geothermal energy is insignificantly higher compared to other Cantons. In Sarajevo Canton, the total installed thermal capacity amounts to only 4.06 MWt, while the available capacity is 62.49 MWt, meaning that about 6.5 % of the available potential of geothermal energy is being utilized.

1.2.6. Cost-benefit analysis

In FB&H, commercial customers at voltage level 0.4 kV pay the highest price for electricity, while customers at 110kV and 35kV voltage levels pay the lowest price (Figure 16).

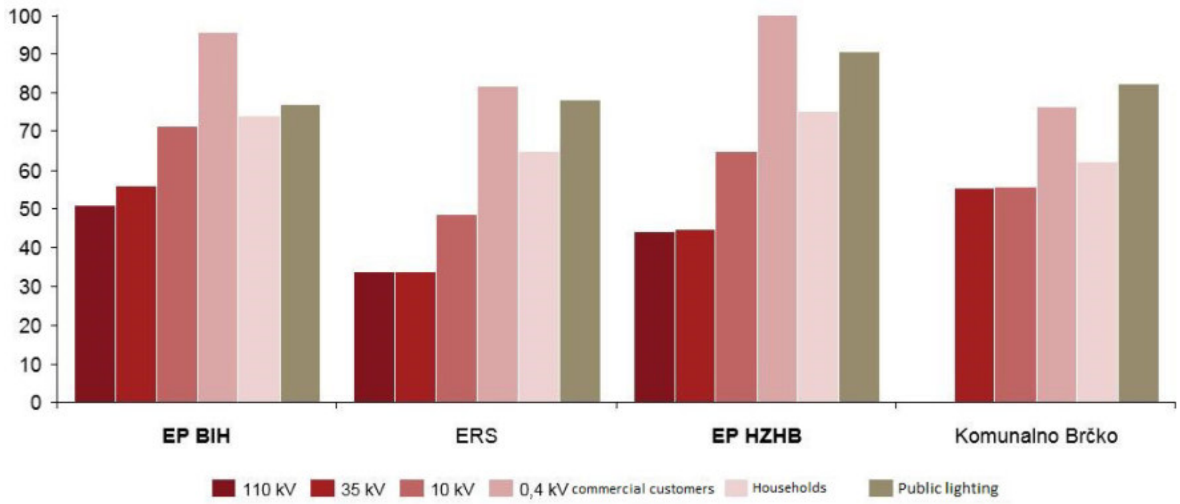

Figure 16: Average price of electricity in Electric Power Utilities in EUR/MWh, 2016

In 2016, the price of electricity, excluding VAT and tax for industrial sector, amounted to 61 EUR/MWh.

2. Analysis of heating sector at the regional level (project areas – Posavina Canton and Tuzla)

The basic information (surface area, population, population density, etc.) on Posavina and Tuzla Cantons is provided in Table 9, while Figure 1a shows the geographic position of these two Cantons.

2.1. Posavina Canton

2.1.1. Energy characteristics

Electric Power Utility "JP Elektroprivreda HZHB Mostar" is responsible for electricity distribution in Posavina Canton. The total number of electricity customers in this Canton in 2013 was 17,467, with this region accounting for 8% of the total electricity delivered by the above-mentioned operator. The supplier estimates that the current capacity of electricity transmission and distribution networks in this Canton meet, to the full extent and in the long run, the demand for electricity supply.

There are neither fossil fuel electric power generation plants nor hydro power plants in the territory of this Canton. The only generating facility is 30 kW photovoltaic plant (in the territory of Domaljevac–Šamac municipality), connected to the electric power network in 2013. Thus, it is evident that there is much room for the development of new generation facilities, primarily those based on renewable energy sources.

Posavina Canton is located in the northernmost parts of the Pannonian basin in B&H, characterized by geothermal gradient of 45-55°C/km and heat flow from 90 to 110 mW/m^2 (Čičić and Miošić, 1986). The highest temperature of artesian outflow in B&H was proved on drillhole Do-1, amounting to 96°C at Q= 22 l/s. Geothermal energy is not used in Posavina Canton, although the available thermal capacity amounts to 8.58 MWt, and predictive one 34.52 MWt.

The territory of Posavina Canton is considered as having potential for electricity generation from geothermal sources, as well.

2.1.2. Thermal energy supply

In the territory of Posavina Canton, there is no infrastructure for central heat supply to the population or industry; therefore, the thermal energy is supplied via individual boilers both in housing units and public service buildings, and industrial facilities. According to the latest population census, the population in the territory of Posavina Canton amounts to 48,089 inhabitants, of whom there are 13,563 households, or about 3.55 inhabitants per household.

The thermal energy is mainly supplied by a system of local stations, individual boiler rooms 30% of which use eco fuel of biomass-wood pellet origin, 40% use wood, 25% use coal, and 5% use other energy sources for the production of thermal energy. The price for heating 1 m^2 of residential space amounts to 1 KM/month.

On the basis of above-mentioned indicators, it is cost-effective to invest funds in the utilization of energy from renewable sources, notably solar and wind energy, and geothermal energy sources in particular, given the proven geothermal potential of deep drillholes (drillhole Do-1 with water temperature of 96°C at Q= 22 l/s) and still active drillhole Do-3/B with temperature >80°C).

2.1.3. Energy efficiency and renewable energy sources

The practice in the territory of Posavina Canton has shown that there are positive examples of applying energy efficiency principles, more as individual activities, and less as a result of systemic action. From economic point of view, the results of such activities clearly indicate multiple benefits of using renewable energy sources, both from the perspective of cost-effectiveness and reliability of energy supply, and opportunities for job creation for the population, engaging local economic operators, attracting investment, and income generation. On the other hand, these programs also have multiple environmental impacts, starting from reducing the pressure on environmental parameters, to reducing harmful effects on public health. For all these reasons, it is quite clear that in this Canton, there is much room in all sectors (construction, economy, transport) for the implementation of measures to improve energy efficiency within the bounds of their ability.

2.1.4. Cost-benefit analysis

Thermal energy in Posavina Canton is mainly supplied by a system of local stations, individual boiler rooms 30% of which use eco fuel of biomass-wood pellet origin, 40% use wood, 25% use coal, and 5% use other energy sources for the production of thermal energy. The amount of 1,200.00 KM/year has to be spent for the heating of one housing unit in an individual house having an average surface area of 100 m^2; this requires the provision of the total of about 1,627,200.00 KM on annual basis. The unit price for heating 1 m^2 of residential space amounts to 1 KM/month. It is estimated that about 2 million KM need to be spent for the heating of all housing and collective units in the territory of this Canton, which is sufficient to demonstrate the need to build hot water systems. As this Canton is densely populated, investment into the above-mentioned projects would certainly pay off in the long term.

2.2. Tuzla Canton

2.2.1. Energy characteristics

The basis for the operation and development of electric power sector in Tuzla Canton is made up of the only cogeneration plant in B&H – Thermal Power Plant "Tuzla" (715 MW) and Electric Power Distribution Company "Elektrodistribucija" Tuzla, a subsidiary of Electric Power Utility "JP Elektroprivreda BiH, and small hydro power plants "Modrac" (1.9 MW) and "Snježnica" (0.4 MW). Some quantities of electric power are supplied by "GIKIL" company, and a small number of photovoltaic plants with total installed capacity of 0.284 MW. The average annual electricity generation of Thermal Power Plant "Tuzla" in 2014 amounted to 3,696 GWh.

In addition to the generation of electricity for the electric power system, the TPP "Tuzla" also produces and supplies thermal energy for district heating systems in urban areas of Tuzla and Lukavac, steam used for industrial purposes, and industrial water for the proper area of the Canton. The replacement of cogeneration block 7 in TPP "Tuzla" and the construction of Thermal Power Plant "Banovići" with the capacity of 350 MW are in the initial phase of implementation.

The total number of customers in this Canton for all voltage levels in 2013 was 180,071, while the total consumption was 1,082 GWh. Over the past 5 years, the number of customers has been increasing on both voltage levels: on high-voltage level by 5.5% per annum and on low-voltage level by 1.12% per annum (households), and by 2.32% per annum (other consumers).

2.2.2. Thermal energy supply

Tuzla Canton is, in terms of heating, in a more advantageous position than other Cantons because TPP "Tuzla" is located in the close vicinity of large urban and industrial areas. The total surface area supplied by the district heating system in this Canton (the city of Tuzla and Lukavac and Gračanica municipalities) amounts to 1,792,640 m^2. The average price for heating in this Canton ranges between 1.80 and 3.00 KM/m^2. In energy sector, reconstruction and expansion of electric power plants (primarily TPP Tuzla) are planned in the future, as well as the expansion of the district heating system of the city of Tuzla and Lukavac municipality, and initial steps toward introducing district heating system in Živinice municipality. Some of the major development issues in this field are as follows: the lack of funds for the modernization of district heating network (15-20 years "old"), low coverage of population with district heating services, system for calculation of thermal energy consumption for consumers (still per surface area, rather than energy consumption), and the lack of data collection system on district heating.

2.2.3. Energy efficiency and renewable energy sources

The main energy sources in Tuzla Canton are coal, wood and, to a lesser extent, hydro power, followed by oil, while natural gas is not used. The share of renewable energy sources in the total energy generation is negligibly low (around 0.2%). In addition to small hydro power plants on Modrac and Snježnica reservoirs, in early 2012 the first solar 0.13 MW power plant in B&H started operating in Kalesija, while the total installed capacity of solar power plants in the territory of this Canton currently amounts to around 0.285 MW.

The territory of Tuzla Canton is in part situated along the southern margin of the Pannonian Basin and has a considerable geothermal potential. In the Tuzla basin, the average conductive heat flow is 84.6 mW/m2, while the average conductive temperature gradient is 36.6 °C/km (Miošić, Samardžić and Hrvatović, 2003). The available thermal capacity up to 10°C of Tuzla Canton amounts to 34.42 MWt, while the predictive one is 69.81 MWt. The total installed geothermal capacity in Tuzla Canton amounts to 3.0 MWt.

2.2.4. Cost-benefit analysis

According to statistical data, the population of Tuzla Canton is 472,278 with an average population density of about 75 inhabitants per km^2, while for the city of Tuzla it is around 448 inhabitants per km^2. The total surface area covered by the district heating system amounts to 1,792,640 m^2. The price for thermal energy distributed is calculated per heated surface area, i.e. per unit - m^2, rather than per energy consumption. There are several price levels depending on the social structure of the population, ranging from 1.8 KM/m^2 to 3.00KM/m^2, with the weighted price of around 2.4 KM/m^2. The lower price applies to households, and the higher to business premises. In Lukavac municipality, heating price for housing is 1.60 KM/m^2, and for business premises 2.50 KM/m^2.

Public Company “Centralno grijanje” (District Heating) Tuzla utilizes the thermal energy produced by Thermal Power Plant “Tuzla“. The Public Company “Centralno grijanje” Tuzla generates an annual income based on energy supply to households of 1,631,303 m^2 x 1.6 KM/m^2, or 2,610,084.80 KM monthly or 31,321,017.60 KM annually. The total income generated on the basis of thermal energy supply for the purpose of heating business premises in the city of Tuzla of the total surface area of 161,337 m^2 at the price of 3.00 KM/m^2 amounts to 484,011.00 KM per month, or 1,452,033.00 KM per annum, totaling to 32,773,050.60 KM. Of the above-mentioned income, 17% accounts for the collected indirect taxes amounting to 5,571,418.60 KM, of which net income amounts to 27,201,632.00 KM.

3. Municipality level (Gračanica Municipality)

3.1. General characteristics of Gračanica Municipality

Gračanica municipality is located in the northwestern part of the Tuzla Canton, bordering on municipalities Lukavac, Srebrenik, Gradačac, Doboj Istok and the Entity Republika Srpska (Figure 1).

The territory of Gračanica municipality is located between longitude 18° 10′ and 18° 26′ and latitude 44° 36′ and 44° 48′ at an altitude between 150 and 700 m. The spatial framework of Gračanica municipality is composed of hilly and mountainous area of Trebava to the north and lowland area in the Spreča river valley to the south.

Gračanica municipality has a surface area of 215.3 km^2, 8.11% of the total surface area of Tuzla Canton (2,651.91 km^2). According to statistical data, the population living in this area amounts to 53,381 inhabitants, with population density of 249 inhabitants per km^2. The total surface area of agricultural land is 13,026 ha, the total surface area of forest land is 7,245 ha, total housing surface area is 911 ha, while total surface area of industrial zones is 96.4 ha, the remaining area occupied by infrastructure.

3.2. Analysis of energy consumption in residential buildings

In the territory of Gračanica municipality, only the town of Gračanica has a developed infrastructure for district heating system. Other settlements use individual sources for heating, i.e. small boiler rooms or furnaces.

For the purpose of the analysis of energy consumption in the housing sector, all residential buildings are divided into two groups, as follows:

- Apartments;
- Private houses.

The total number of housing units in the territory of Gračanica municipality amounts to 15,022, of which 817 are apartments, and 14,205 private houses (Table 15). The average surface area of an apartment is 60 m^2, and of private houses 130 m^2. The surface area of all apartments is 49,020 m^2, and of private houses 1,846,650 m^2. The total surface area of buildings having individual heating systems in Gračanica municipality amounts to 1,895,670 m^2.

No.	Residential buildings having individual heating systems	Number of housing units	Surface area of housing units m^2	Surface area m^2
1.	Apartments	817	60	49,020
2.	Houses	14,205	130	1,846,650
TOTAL		15,022		1,895,670

Table 15: The total surface area of buildings having individual heating systems in Gračanica municipality in 2005 (Source: Akcioni plan energetski održivog razvoja Općine Gračanica (Sustainable Energy Action Plan for Gračanica Municipality - SEAP), 2015 - 2020, February 2015)

The total installed capacity of the district heating system in Gračanica amounts to 20 MW, of which 6 MW account for biomass heating; this has so far been sufficient to meet the needs of all consumers connected to the district heating system, while there is reserve installed capacity including 11 MW fuel-oil plant and 3 MW other energy sources (www.eko-toplane.ba). The system is managed by "Eko-toplane" Gračanica; annual production and distribution amounts to around 7,000 MWh/year of thermal energy, of which around 60 % for industry and around 40 % for households. Table 16 shows that only 4.35 % of heated areas are connected to the district heating system.

District heating system (DH)	yes/no	yes
Flow temperature (in case of DH)	°C	88 - 95
Total installed power (of heat power plant)	kW/MW	20 MW*
Estimation of total installed power in individual system	kW/MW	150-200 MW**
Type of heat production	cogeneration/boiler	boiler
Energy resources	For district heating system:	Biomass, fuel oil, other
	For individual systems:	Coal, electricity, fuel oil, firewood
Annually sold heat to households	GJ	10,080 GJ/yr
Annually sold heat to industry	GJ	15,120 GJ/yr
Share of heat loss in the DH	%	10-20
Total flat (heated) surface area	m^2	1,954,216.23
Flat (heated) surface area on DH	m^2	85,000 (in 2017)
Flat (heated) surface area out of DH	m^2	1,869,216.23
Share of modern buildings in DH	%	25-30 (estimated)
Share of modern buildings outside DH	%	30 (estimated)
Estimated specific heat load per square meter (on average)	W/m^2	135

* Total installed boiler power in the central heating system (6 MW biomass, 11 MW fuel oil and 3 MW-others)-in 2017
** Estimated installed capacity of the facilities out of the heating system-in 2017

Table 16: Basic information about heating in the municipality of Gračanica (Source: Eko-toplane Gračanica; Akcioni plan energetski održivog razvoja Općine Gračanica (Sustainable Energy Action Plan for Gračanica Municipality - SEAP), 2015 - 2020, February 2015 – 2020 and Population Census 2013 (Book 5-Apartments, building and housing conditions)

Brown coal is the most used energy source for heating of buildings having individual heating systems, with a share of 39.34% (Table 17, Figure 17).

No.	Specific energy consumption kWh/m² Energy source	Share %	Energy consumption MWh
1.	Wood	31.54	169,277.50
2.	Coal - lignite	18.84	101,111.11
3.	Coal - brown	39.34	211,111.11
4.	Fuel oil	0.21	1,111.11
5.	Electricity	10.08	54,079.20

Table 17: Specific energy consumption (Source: Akcioni plan energetski održivog razvoja Općine Gračanica (Sustainable Energy Action Plan for Gračanica Municipality - SEAP), 2015 - 2020, February 2015)

Total energy consumption in households, including electricity used for heating, amounts to 54,079.20 MWh (Table 18).

No.	Surface area (m^2)	Electricity (MWh)	Fuel oil (MWh)	Coal-lignite (MWh)	Coal- brown (MWh)	Wood – biomass (MWh)	Total (MWh)
1.	1,895,670	8,100	1,111	101,111	211,111	169,277	490,711
2.	1,895,670	54,079	1,111	101,111	211,111	169,277	536,690

Table 18: A survey of energy consumption in residential buildings, MWh (Source: Akcioni plan energetski održivog razvoja Općine Gračanica (Sustainable Energy Action Plan for Gračanica Municipality - SEAP), 2015 - 2020, February 2015)

Figure 17 shows that the largest share in heating energy consumption and in general has coal-lignite (43%).

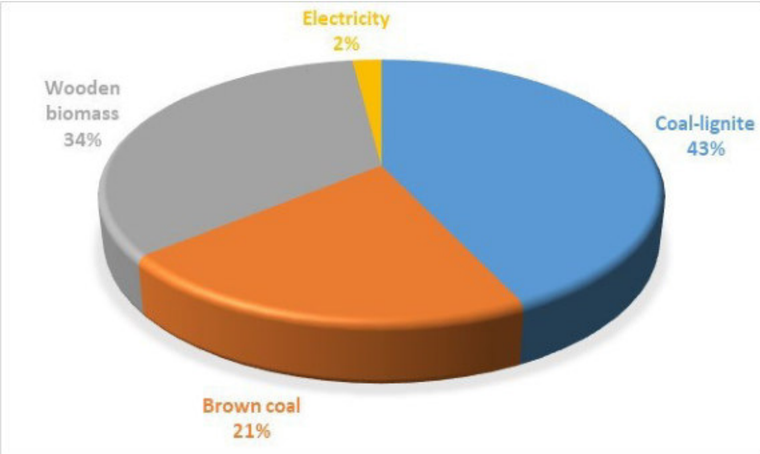

Figure 17: The share of energy sources in the total energy consumption for heating purposes for the territory of Gračanica municipality (Source: Akcioni plan energetski održivog razvoja Općine Gračanica (Sustainable Energy Action Plan for Gračanica Municipality - SEAP), 2015 - 2020, February 2015)

The total consumption for all residential buildings in the territory of Gračanica municipality can be presented in tabular form, as shown in Table 19, which clearly shows that for one year around 536,689,830 kWh are needed.

No.	Energy consumption per energy source	Consumption kWh/year
1.	Consumption of electricity kWh/year	54,079,200
2.	Specific electricity consumption kWh/m^2 annually	30.55
3.	Fuel oil heating energy kWh/ annually	1,111,110
4.	Brown coal heating energy kWh/ annually	211,111,110
5.	Lignite heating energy kWh/ annually	101,111,110
6.	Biomass-wood heating energy kWh/ annually	169,277,500
7.	Total heating energy consumption kWh/ annually	482,690
8.	Specific energy consumption kWh/m^2 annually	292.47
TOTAL kWh/ annually		536,689,830
TOTAL kWh/m^2 annually		323

Table 19: A survey of energy consumption for all energy sources for residential buildings, Gračanica (Source: Akcioni plan energetski održivog razvoja Općine Gračanica (Sustainable Energy Action Plan for Gračanica Municipality - SEAP), 2015 - 2020, February 2015)

In the building sector, the largest consumption is in residential buildings. This consumption is 536.690,03 MWh (Table 20). The total consumption of the building sector is 552.725,44 MWh.

No.	Responsibility for buildings	Surface area (m²)	Electricity (MWh)	Fuel oil (MWh	Coal-brown (MWh)	Coal-lignite (MWh)	Wood – biomass (MWh)	Total (MWh)
1.	Municipality responsible	14,786	796	61	4,246	36	40	5,195
2.	Municipality not responsible	35,227	544	274	10,022	0.00	0.00	10,840
3.	Residential buildings	1,895,670	54,079	1,111	211,111	101,111	169,277	536,690
TOTAL		1,945,683	55,419	1,445	225,380	101,147	169,317	552,725

Table 20: Total energy consumption for the heating of entire heating sector, Gračanica (Source: Akcioni plan energetski održivog razvoja Općine Gračanica (Sustainable Energy Action Plan for Gračanica Municipality - SEAP), 2015 - 2020, February 2015, p.26.)

3.3. Geothermal energy in Gračanica Municipality

In the territory of Gračanica municipality, there is a deposit of thermo-mineral CO_2 and HCO_3 waters with artesian outflow temperature of 37.7°C at Q=75 l/s (drillhole PEB-4) and Q=20 l/s (drillhole GB-4). The available thermal capacity up to 10°C on these two drillholes is 9.27 MWt. In the territory of this municipality, there is also a deposit of thermal water, Seljanuša, used for water supply. The available capacity of Seljanuša deposit (Qcrp.=10 l/s tv=18°C) is 0.33 MWt. The predictive capacity of all registered deposits in Gračanica municipality is around 20 MWt. Geothermal energy in Gračanica municipality is used on one location (Terme Gračanica PEB-4), with installed capacity of 2.56 MWth and thermal energy of 0.68 TJ/god; in addition to geothermal, the PEB-4 drillhole is also used for the purpose of CO2 removal.

3.4. Cost-benefit analysis of thermal energy market

Table 16 shows the total energy consumption for residential buildings of a total surface area of around 1,945,683 m2, while the total production of biomass thermal energy amounts to 169,277,500 (kWh) annually.

The heating of housing units of a total surface area of around 1,945,683 m2 requires biomass (wood) thermal energy of 169,277,500 kWh, which at the price of 0.098 km/kWh annually would generate net income of 16,589,195.00 KM.

In local communities where there are energy plants for the heating of individual housing and public buildings (schools, hospitals, etc.), prices are determined based on local community decisions. As there is no market competition in such communities, the ratio between energy sources demand and supply does not reflect market values. The influence of internal and external forces on the market with respect to the utilization of energy sources mainly comes down to social policy, rather than market policy.

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D.5.4.1. Summary report on heat sector analysis

Annex 5B. Republic of Srpska, Bosnia and Herzegovina national report

November 2017

D.5.4.1. Summary report on heat sector analysis

Annex Annex 5B. Republic of Srpska, Bosnia and Herzegovina national report

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Table of contents

Executive summary

The study provides study insight into 3 aspects of heat sector analysis:

- country level
- regional level
- municipality level

On a country level it offers an overview of the Republic of Srpska energy strategies, planning documents and executive programmes providing a context for regional and municipal level analyses. The heat sector analysis on a regional level examines the Semberija and Banja Luka regions of profound interest of the DARLINGe project, as they are target regions with excellent geothermal features and a number of potential pilot sites. The municipal level heat market analysis is represented by a feasibility study level assessment of a district heating circuit in the city of Bijeljina, Republic of Srpksa, Bosnia and Herzegovina.

1. Energy utilization in the Republic of Srpska (RS)

The Energy Strategy of RS has been adopted by the Parliament during 2012. The strategy defines aims and measures of government policy implementation in the energy sector.

The basic principle defined in the strategy is sustainable development of the energy sector, or in other words meeting current needs without endangering the needs of future generations. It further requests establishing conditions for reasonable use of local energy resources for electricity production for domestic purposes as well as for export.

The strategy insists as much as possible on domestic resources, increasing of renewable energy utilisation, introduction of support measures for energy efficiency and application of modern technologies. It also insists on minimization of negative impacts of the sector on the environment.

The development of the energy sector is currently in the phase of gradual opening to the market, strengthening competition and establishing economically acceptable energy prices.

Up to 2030 it is planned that RS finishes economic transition, provides necessary harmonisations and becomes an EU member.

The energy sector must provide enough energy, assure technological development, increase the energy efficiency and increase the utilisation of renewable energy resources. These activities must be accompanied with contemporary environmental protection standards.

One of the key goals emphasized in the strategy is the utilization of renewables, in accordance with defined goals and duties necessary in the process of accession to the EU.

Today, energy demand in RS is covered by coal, liquids, gas, hydro-energy and firewood. The strategy did not take geothermal energy into consideration in compliance with its availability. Considering serious problems, especially in the heating sector, this kind of renewable should be considered more seriously.

DARLINGe project and this report are very good opportunities to highlight the importance of geothermal potential of RS, especially its potential role in the heating sector.

For modernisation of community district heating and private heat generation, the competitiveness of the district heating services must be ensured. Development of the technical elements of the service and use of renewable energy sources are indispensable. District heating systems will play a very important role in the renewal of heat energy supply due to their ability to admit heat from virtually any heat source, transmitting it to the end users.

1.1. Primary energy

Energy in the Republic of Srpska is provided from different natural resources: coal, liquid fuels, gas, hydroenergy and firewood. The share of natural resources in energy production is given in Figure 1. The highest rate covers coal - about 40%. The share of liquid fuels is about 30% and firewood represents 20%. The rest of production is dominantly based on hydro energy.

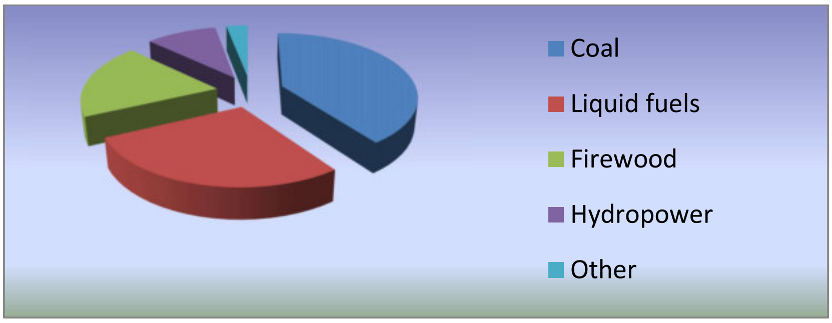

Figure 1: The share of natural resources in energy production (source: Energetic Development Strategy of RS up to 2030)

In the period 2000-2005 total energy consumption increased 1.3% per year. The highest share in final consumption is firewood - 35%. It is mostly used for house heating. This is followed by liquid fuels (30%). The rest of consumption is covered by coal and gas.

The share of electricity in final consumption is 19%. The share of the industry in final energy consumptions in the period 2000-2005 varies in range of 12% - 24%. The shares of other sectors are uniform per years. It is about 21% for transport, 50% for households, 5% for services and about 2.5% in agriculture. This consumption is mostly covered by domestic production, to a less extent by import from other countries. Certain quantities of the energy resources – mostly coal – are exported.

Own supply in primary energy is increased from 70% in 2000 up to 75.9% in 2005. The production of coal is higher than consumption. Electricity production is also higher than consumption. Entire consumption of natural gas is provided from import. Regarding the liquid fuels, situation has rapidly changed after start of production in oil refinery in Brod. Crude oil for refinery is entirely provided also from import.

1.1.1 Electricity

Regarding the electricity, the Republic of Srpska is quite "independent" (Table 1). It is generally export orientated, with negligible import rate. Electricity production per year, from 2006-2015 is given in Figure 2.

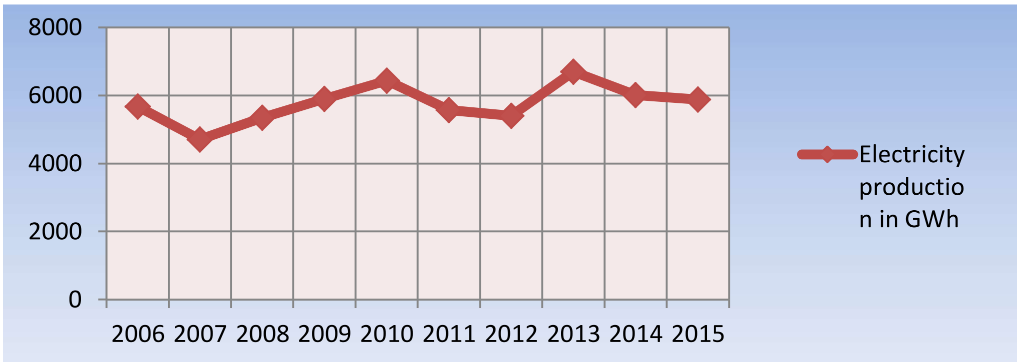

Figure 2: Electricity production in GWh in the Republic of Srpska from 2006 to 2015 (source: Statistic Journal of the RS for 2016)

The structure of the sources of electricity production is given in Table 1 and Figure3.

Year	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Total Gross Production	5674	4703	5346	5897	6430	5573	5396	6693	6014	5881
Hydro Power Plants	2624	1868	2003	2649	3330	1856	1886	3014	2621	2276
Thermal Power Plants	3050	2835	3343	3239	3091	3717	3510	3657	3381	3560
Other	0	0	0	9	9	0	0	22	12	45

Table 1: Electricity production in GWh in the Republic of Srpska from 2006 to 2015 (source: Statistic Journal of the RS for 2016)

Due to the surplus in production vs. consumption, significant percentage of produced electricity is exported (significant in comparison with production and domestic consumption). From 2006 to 2015 the electricity production was 122%-140% in comparison with consumption. The record year regarding electricity export was 2013 with export of 2713 GWh.

Because of the rather high rate of hydroenergy production, the production and export is very dependable on hydrologic conditions and repair of thermal power plants.

Average annual consumption of electricity in B&H is about 4500 kWh, without significant differences regarding consumption in urban, semi-urban and rural areas. Consumption in urban areas in the Republic of Srpska per household is about 15% higher than in FB&H *(Agency for Statistics of Bosnia and Herzegovina, Preliminary results on survey on household energy consumption, The first release, 2015).*

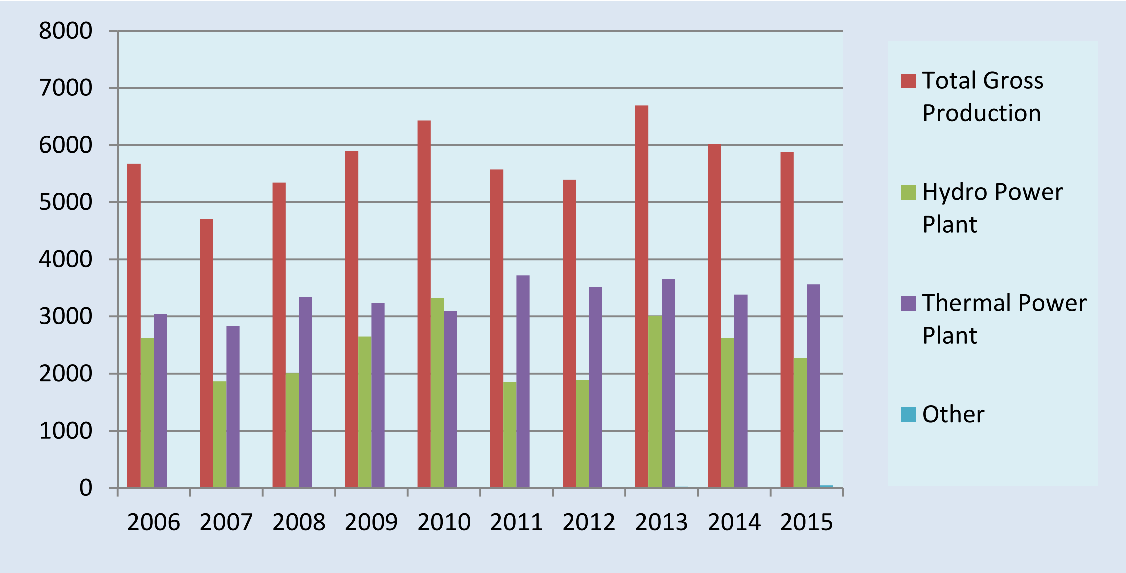

Figure 3: Electricity production in GWh in the Republic of Srpska from 2006 to 2015 (source: Statistic Journal of the RS for 2016)

1.1.2. Heat energy

In the Republic of Srpska, 50% of the total energy consumption is consumed for heating. It covers individual (mostly with firewood and coal) and district heating (oil fuel, firewood and gas) of households. It is very similar to the EU, where also 50% of final energy consumption in 2012 (546 Mtoe) covered heating and cooling and it is expected to remain so (*European Commission, Overview of support activities and projects of the European Union on energy efficiency and renewable energy in the heating & cooling sector, 2016*).

Year	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Export	1982	1041	1618	2076	2531	1632	1471	2713	2067	1760

Table 2: Electricity export in GWh in the Republic of Srpska from 2006 to 2015 (source: Statistic Journal of the RS for 2016)

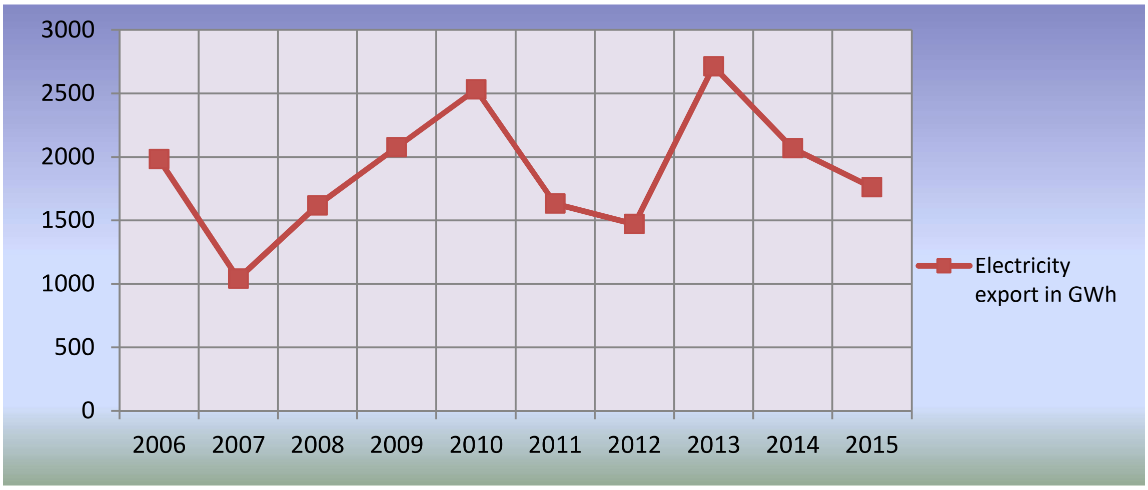

Figure 4: Electricity export in GWh in the Republic of Srpska from 2006 to 2015 (source: statistic Journal of the RS for 2016)

District heating sector in the Republic of Srpska comprises 40000 flats with total area 2300000 m² and 460000 m² business place. The rest belongs to own heating systems, 16.3 to central heating system and 78.2 to rooms heating. The average size of housing units heated in RS is given in the Table 3. The way of house heating is given in Table 4 (A major part of heating is currently based on fuel oil, natural gas, coal and firewood.

Type	Urban	Rural	Total
Area (m^2)	51.8	37.3	42.9

Table 3: The average size of housing units heated in RS

Way	not heated	rooms heating	central heating - own	central heating - heating plant
%	0.4	78.2	16.3	5.2

Table 4: The way of house heating in RS (source: Agency for Statistics of Bosnia and Herzegovina, Preliminary results on survey on household energy consumption, first release, 2015).

In accordance with 2013 Census in B&H, in the Republic of Srpska there are 584261 flats. About 40000 is connected to district heating systems. It means that more than 500000 dwellings are heated by individual systems fuelled by firewood and coal. The ratio between district heating covered flats and the total number is 6.8%. Anyhow, it should be considered that less than 7% of total population is covered by heating plants. The rest provides its consumption in own systems (central or room heating).

Entity	Total	Central heating		
		Yes	Not plugged	No
Republic of Srpska	584261	130553	8609	445099

Table 5: Heating structure in the Republic of Srpska

53% of all flats in the Republic of Srpska are shared by 9 municipalities (Table 6). The structure of central heating connection in these municipalities is given Table 6. The highest number of plugged flats is in the capital Banja Luka (about 46%). Among all other municipalities just Doboj has more than 30% plugged flats (35.07%). In municipalities Zvornik and Laktaši less than 20% of flats are connected.

Today, district heating sector in the RS is in very complex and is in difficult situation. Basic problems identified in the Energetic Development Strategy of RS up to 2030 are:

- aged, low efficient and poorly maintained production capacities
- aged, bad conditions and big losses in heat pipelines
- difficulties in measurements, calculation and payment of delivered energy
- low price of the energy and bad financial conditions in the heating companies.

Furthermore, consumption is uneconomical due to the generally poor energy efficiency of buildings. More than 80% of the above mentioned 40000 flats with total area 2300000 m² fail to meet modern functional technical and thermal engineering requirements, and similar ratio for public buildings.

No	Municipality	Total number	Central Heating		
			Yes	Not plugged	No
1	Banja Luka	87644	40612	1340	45692
2	Bijeljina	47946	11723	1643	34580
3	Gradiška	23788	5108	238	18442
4	Doboj	35978	12618	194	23166
5	Zvornik	23336	4528	113	18695
6	Laktaši	16928	3334	248	13346
7	Prijedor	38112	9142	489	28481
8	Prnjavor	18565	3889	282	14394
9	Teslić	19838	3200	126	16512
Total		312135	94154	4673	213308

Table 6: Municipalities with number of dwelling more than 15000 and connection to central heating system

In the period up to 2030 an expansion of supply in the district heating is expected (Figure 5). In comparison with 2008, the highest increase in final heat consumption in district heating systems is expected for Scenario 1 (S1) - High GDP - increasing of 75%, then for Scenario 3 (S3) - low GDP - about 53%. For scenario 2 (S2) - high GDP with appropriate measures, expected increase is the lowest one (38%) as result of intensive measures regarding energy efficiency (Figure 5).

It is important to emphasize that the Energetic Development Strategy of RS up to 2030 was prepared during the period of very intensive activities for construction of the Russian gas pipeline "South Stream". According to this project, one pipeline from Serbia was planned to stretch to the territory of the Republic of Srpska. It was a main reason why natural gas was considered as driving force for future district heating systems development already in 2020 (Figure 5). Gradually substitution of oil (today main source of district heating) by gas was planned in all systems. In all scenarios given in Figure 5, development of high-efficient gas cogeneration in capitol Banja Luka was foreseen.

In accordance with prediction, at the end of the considered period (2030), the highest rate as resource for district heating in RS covers natural gas. Coal consumption should be on similar level like in the start year of consideration (2010). The highest reduction rate is planned for oil fuel.

After the delay of the "South stream" construction, many cities are compelled to find new solution than gas, to substitute oil fuel.

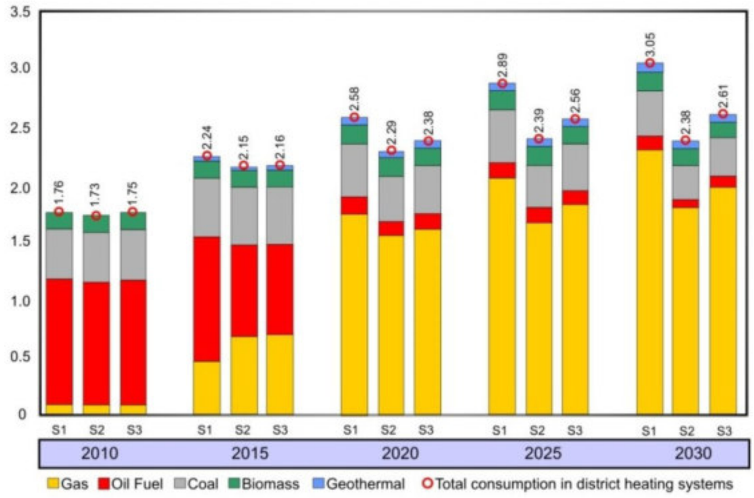

Figure 5: Structure of final heat consumption from district heating systems(source: Energetic Development Strategy of RS up to 2030)

Very important fact for DARLINGe project is that the Strategy envisages share of geothermal energy, especially from 2020.

Favourable fact is that areas of the highest interest (previously mentioned 9 municipalities with the highest consumers concentration) in the same time represent most perspective areas regarding geothermal energy. Each of these municipalities is part of the DARLINGe project area as well.

1.2. The use of renewable energy sources in the Republic of Srpska

The most important renewable energy sources are hydro-energy (huge HPP) and firewood (for household heating). Hydro-energy potential is huge and not utilised enough yet. Regarding the renewable sources in the last decade emphasis was on smaller water courses and construction of HPP with install capacity less than 5 MW. Taking into consideration data given in the Table 1, the percent of electricity production from renewable resources (exclusively hydro-energy) for the period 2006-2015 increased from 33.3% to 55.7% and it is high dependable on hydrological-hydrometeorological conditions. This percent will be probably reach the lowest level for 2017 because of the draught.

In accordance with the Energetic Development Strategy of RS up to 2030, significant renewable energy resources are also wind power, solar energy, biomass and geothermal energy, today almost unused. The Strategy provides information to define aims regarding renewable energy resources, size of construction/facilities and application (e.g. for electricity production, for heating etc.). In addition incentives will be establish taking into account domestic economy capacities for realisation of projects related to renewable energy, acceptance of the energy price for end users and adopted international standards.

Figure 6: Planned electricity production from renewable energy resources (without huge HPP)

From Figure 6 it is obvious that production of electricity from geothermal sources is not planned up to 2030, despite the fact that in some areas hydrothermal systems with temperature about 100°C exist (e.g. borehole BIJ-1 in Semberija, near Bijeljina town).

1.2.1. Geothermal energy in the Republic of Srpska

In geothermal sense RS is characterized by two drastically different zones. The first zone, the zone of External Dinarides covers southern parts of RS (about 25% of the territory) and it is not interesting regarding geothermal energy, where the geothermal gradient is up to20 ^{0}C/km.

Figure 7: Geothermal gradient distribution map of RS

In contrast, in most parts of the Inner Dinarides and especially in the Pannonian Basin (its overall southern edge) the geothermal gradient is higher than the European average (33 ^{0}C/km). Maximum values in the Pannonian basin exceed 50 ^{0}C/km.

In the Semberija region (one of the DARLING pilot sites) conductive geothermal gradient is more than 50^{0}C/km. Beside this zone, increased values of are registered in the Ophiolitic belt (central parts of the RS). In this zone the highest number of thermal springs is registered.

The areas of increased heat flow are expected north from the line Novi Grad-Banja Luka-Zvornik, and in some zones it is above 100 mW m^{-2}.

The most prospective areas regarding geothermal energy are located in the overall NE and N-ern territories. Semberija area (overall north-eastern part of the territory in the Figure 7) is the best explored and most promising one. This area is a part of the DARLING pilot areas which RS shares with Serbia.

Central parts of the territory, in the contact zone of the Ophioltic belt and the Tertiary basins, are also very important rom a geothermal perspective. East and south from Doboj (Figure7) thermomineral waters with high content of CO_2 and temperature about 38^{0}C are registered.

There are also very perspective geothermal zones around the capital Banja Luka. Within radius of 20 km, three zones of thermal water discharge are registered (water temperature at the surface 30-43^{0}C).

1.2.2. Heat generation based on renewable energy sources

Most important renewable energy sources regarding heating is biomass (firewood) (Figure 8).

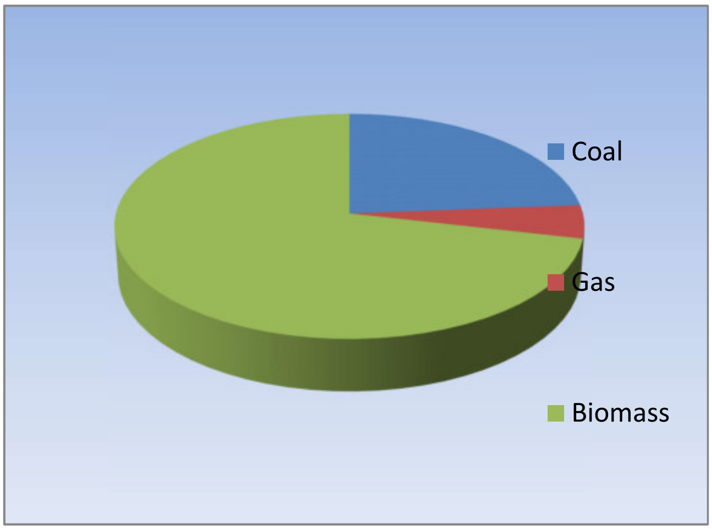

Figure 8: Share of heat source in central heating systems, towns with more than 15000 dwelling

From total number of analysed dwellings connected to central heating systems (94154), about 70% are heated from biomass, less than 5% from gas and about 25% from coal.

It is obvious that high share for heating from renewable in RS comes exclusively from biomass. But biomass in this case should be considered as renewable with huge question mark! Biomass (firewood) consumption e.g. in 2003 was 1464400 tones. Such consumption cannot be considered as renewable because unsustainability (Report on status of environment technologies and renewable energy sources in B&H, 2012).

Currently there is no central heating system based on geothermal in the RS. Rough estimation is that heating from geothermal in RS cover less than 0.5%, exclusively of individual households (heat pumps).

1.2.3. Geothermal energy production in the Republic of Srpska

Estimation of geothermal energy production given in the Table 7 is based on the current exploitation in 7 active sites. Active means that company that uses thermal water possesses necessary permission in accordance with domestic legal framework. This calculation excludes thermal power in Višegrad spa because the spa is out of project area (current production in this locality is 0.7 MWt).

Borehole	Exploration site	Type of the reservoir	Available thermal power (MWt)	Available geothermal energy (TJ/year)
S-1	Dvorovi	Basement reservoir	1.80	56.84
GD-2	Slobomir	Basement reservoir	10.90	345.97
GB-6	Sočkovac	Basement reservoir	5.63	177.63
Borehole E	Teslić	Basement reservoir	0.70	21.95
SB-4	Slatina	Basement reservoir	3.61	113.71
B-6	Kulaši	Basement reservoir	0.90	28.29
L-1	Laktaši	Basement reservoir	1.65	51.97
	TOTAL		25.19	796.36

Table 7: Estimated geothermal energy production in RS in 2016.

On the other side, there are still many inactive (unused) boreholes in localities given in the Table 7, but also in other localities (e.g. Lješljani) without concession contract yet.

Based on the calculation given in the Geothermal Atlas of RS (Jolović et al., 2012) all boreholes in the RS could give thermal power of 40.9 MWt. The referent temperature for the calculation was 20^{0}C.

In comparison, the total capacity (25.19 MWt) in Table 7, represents about 61% of total power in active boreholes. Furthermore, it is assumed that an additional 15 MWt should be obtained in Semberija just with two boreholes as deep as about 2500 m. It means that the potential for geothermal production is much greater than currently. Key problem is the low level of investment into geothermal exploration in last 30 years.

1.2.3.1. Balneology

It is traditionally the main kind of thermal water utilisation in the Republic of Srpska, usually combined with recreation pools (Table 8, Figure 9).

No	Site	Utilization
1	Lješljani	Recreation
2	Šeher	Recreation
3	Slatina	Balneology
4	Laktaši	Balneology, recreation
5	Kulaši	Balneology
6	Teslić	Balneology, recreation
7	Sočkovac	Industry (CO_2)
8	Dvorovi	Balneology, recreation
9	Slobomir	Heating, recreation
10	Višegrad	Balneology

Table 8: Thermal water utilisation in RS in 2016

Despite this fact, just two spas could be categorised as modern balneology centres - Teslić and Slatina. Other spas need improvement in the infrastructure and services. Also, it is important to emphasize that these two spas are in major government ownership.

Figure 9: Laktaši spa

1.2.3.2 Agriculture

There is no organised use of geothermal energy in agriculture production in RS.

1.2.3.3. Geothermal district heating, space heating

Geothermal district and space heating are not yet part of the any strategic documents despite the fact of increasing interest in the role of renewable energy. Just two initiatives were triggered in the past.

The two biggest towns of the Republic of Srpksa - with the biggest geothermal potential - had serious problems in heating. In 2010 Bijeljina town prepared a study on planned transition in heating source from coal to geothermal. Five hydrogeothermal boreholes were planned, each deeper than 2000 m. Project was stopped in the first year without serious results.

In 2012 officials of Banja Luka town and Mannvit Company signed a contract on geothermal explorations of Banja Luka basin, with intention to provide heating from geothermal. Despite huge expectations, there is no any activity after contract signing.

Data about individual geothermal space heating are not available. From personal experience, it is obvious that numerous projects of this kind are completed in last five years. The users of this kind of heating are mostly hotels, but also individual households.

Expansion of geothermal heating can be expected in next 5 years in individual space heating. It is not realistic to expect it in district heating.

Unfortunately, current strategies were not recognised this kind of heating correctly. It should be changed as soon as possible.

1.2.4 Current situation of thermal water utilization in the Republic of Srpska

In 10 localities given in the Table 8, utilisation for balneology is primary. It is usually accompanied with recreation. Just one geothermal space heating project is triggered (Slobomir). In Sočkovac, thermal water is just used for extraction of CO_2, a huge amount of water (38^{0}C) and energy is released in surface stream without any addition utilisation.

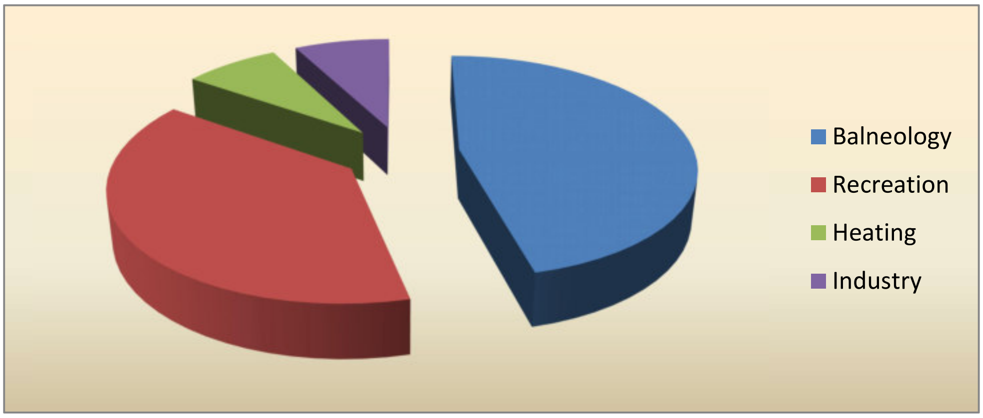

Figure 10: Share of thermal water utilisation in RS

1.2.5. Proposed measures encouraging geothermal energy production

At the state level, serious improvements should be achieved to provide important share of geothermal energy, especially in the heating sector. The measures can be split in the following groups:

- strategic
- legal

- expert
- promotional

The future strategy on energy must take into consideration geothermal energy more seriously both because of proven resources and huge potential. Current strategy and proposal of incentives almost totally neglected this fact.

Legal measures should include geothermal projects especially those related to heating. It is not realistic to expect that electricity produced from geothermal can be competitive to abundant hydro-energy.

Investors in geothermal projects should be encouraged with tax incentives, lower concession fees etc. Also, loan and grant programs should ncourage geothermal and other renewable technologies.

Expert measures should provide more sensitiveness regarding geothermal projects and financially support these kind of explorations. Fund for Environment Protection and Energy Efficiency of RS must provide stronger initiatives for this kind of projects. Also, some key institutions dealing with energy efficiency and renewables must provide more quality staff dealing with renewables.

Promotional measures should be based on preparation of different guidances, workshops, materials on good practices in geothermal energy (audio-video, brochures, etc.). This should encourage people to invest into this kind of heating on real economical basis. It is a well-known fact that one good example can trigger numerous similar projects. The good examples and practices in neighbouring countries (e.g. Serbian most popular ski resorts) represent good practise in geothermal energy use.

2. Analysis of the renewable energy use and potential of Semberija and Banja Luka regions

2.1. Semberija region

Semberija is a geographical region in the NE-ern part of the Republic of Srpska (Figure 11), Bosnia and Herzegovina. The biggest city of the region is Bijeljina. Semberija represents a plain located between the Drina and the Sava river and Majevica mountain. The Drina river is in the border with Serbia, the Sava river with Croatia. The plain forms the southern edge of the Pannonian basin.

Today, about 200,000 people live in the area of Semberija, most of those in the municipality of Bijeljina. Smaller parts of Semberija region belong to municipalities Ugljevik and Zvornik. The region has big economical importance for the Republic of Srpksa. It is most intensive agriculture area in the entity.

The climate is characterized with modest-continental conditions, with dry and hot summers and cold and dry winters. Average annual precipitation is 780 mm, average annual temperature 10°C.

Agriculture is the main economic activity of the region. Other important activities are wood processing industry, tourism and other different services.

Figure 11: Position of Semberija region

2.1.1. Geothermal features of Semberija

According to the current knowledge, Semberija represents the most perspective geothermal area in the Republic of Srpska. It represents the best explored area in geothermal sense as well. At the surface of 200 km^2 six boreholes were drilled, each deeper than 1.300 m (in total 10.460 m). The deepest one is BIJ-1 (2479 m) was finished in 1984.

The highest values of geothermal gradient (> 50^0C/km) and heat flow (> 100 mW m^{-2}) in RS are registered in Semberija.

The results of the explorations in the past indicate that Semberija together with Mačva (in Serbia) represents a unique huge geothermal reservoir (probably has extension also in parts of Srem in Serbia). Milivojević and Perić (1986) assumed a minimal extension of this thermal transboundary aquifer as 2.000 km^2. It is the reason why it has been selected as one of the three pilot areas in DARLINGe project.

The first deep borehole in Semberija, S-1, was drilled in 1957 in village Dvorovi. The borehole (1345 m) is only in use today (Dvorovi spa). Up to 1962 boreholes S-2 and S-3 were drilled as well (S-2 in Popovi 1591 m and S-3 in Svinjarevac 1746 m).The last two boreholes were not artesian, like S-1.

Borehole S-1 represents "backbone" of Dvorovi spa during the last 40 years. Water temperature is 75°C and discharge 7.5 l/s, with artesian level. This is the only borehole finished in the Cretaceous sediments (limestone layer within the flysch).

In 1983 drilling of borehole BIJ-1 started, again in purpose of exploration of oil and gas. The borehole was finished at 2479 m after crash and not completed to the designed depth (4000 m). At depth 2410 m borehole passed into Triassic limestone. Because of the crash, qualitative and quantitative characteristics of thermal water were not tested (Miošić N., 1985). Results obtained during the borehole drilling provided numerous useful geothermal data about the western part of Semberija plain. Based on it, we can assume that it is possible to obtain water T>100°C deeper than 2500 m (Miošić N., 1985).

In 1988 drilling of borehole DV-1 started, one kilometre southern from borehole S-1. It was a first "pure" geothermal borehole in Semberija, not an oil-gas exploratory borehole. Expectation was to obtain three times more thermal water than in S-1. But similar thermal water quantity, artesian level and temperature as in S-1 were registered. Because of the financial obstacles, the borehole has not been completed (not cased till the bottom, pumping test is not provided, etc.). The borehole was conserved in 1989 and its current status is unknown.

GD-2 was completed in 2010 in the locality Slobomir. The borehole is completed at 1800 m, screened for last 200 m of borehole. The borehole passed the Tertiary sediments and reached the Triassic carbonate rocks. Temperature on well head is 73^{0}C, yield 44 l/s (pumping). Mineralisation is about 0.7 g/l. The borehole is planned for cascade use: heating, pools and agriculture.

Except for S-1, each borehole was drilled in the Triassic carbonate rocks. Based on available data Jolović (2012) constructed a map of depth of the Triassic limestone, which represents the most important geothermal reservoir in Semberija region (Figure 12).

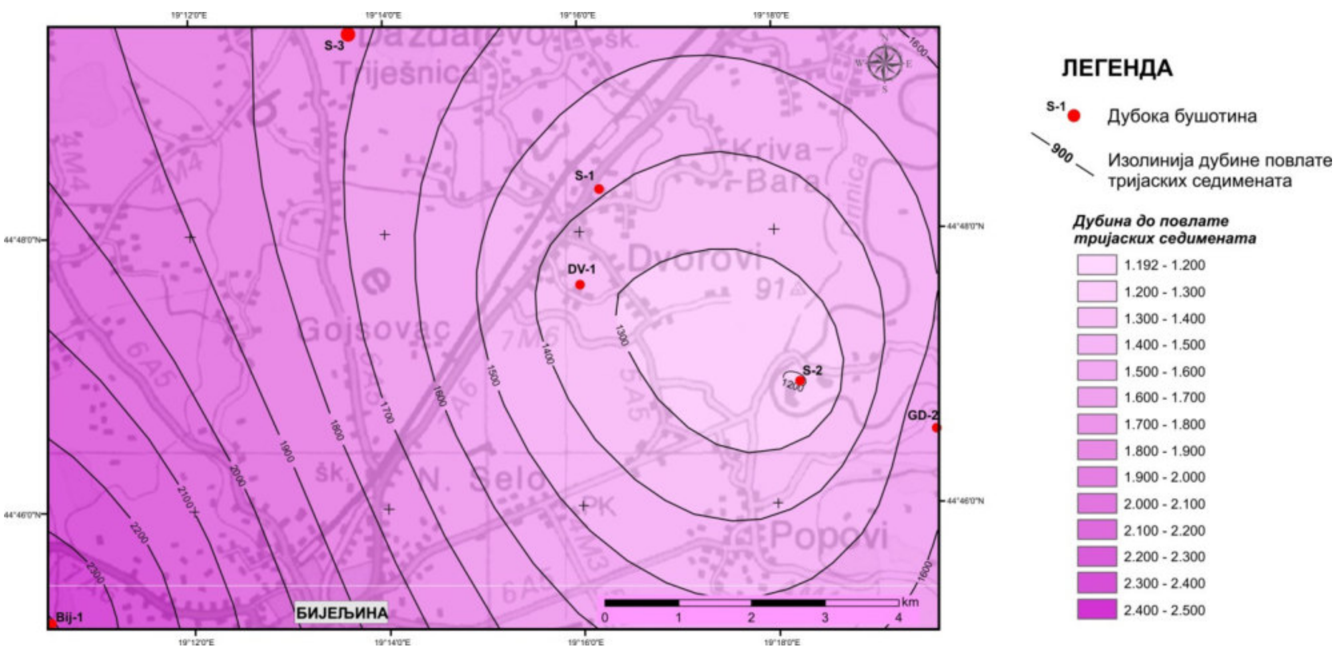

Figure 12: Isolines of depth of the Triassic limestone in Semeberija region (Jolović, 2012)

2.1.2. Current situation of geothermal energy utilization in Semberija

Just two sites are active today regarding geothermal use. The first one is spa Dvorovi, the second is Slobomir village.

Dvorovi spa operates from 1957, just after discovering the thermal water from deep reservoirs in Smeberija (borehole S-1). Borehole was drilled as a part of the programme of oil-geological explorations of Bosnia and Herzegovina. The borehole (1345 m) was oil negative, but with thermal water (75°C, 7l/s, artesian level). Based on this findings a modern spa, for that period, was established in early 60s. Thermal water is used for balneology and swimming pools.

Because Semberia is also well-known as agriculture area, plans for greenhouse heating were emphasised in the past as one of the key step in cascade use, but not yet introduced till the date.

Geothermal project Slobomir was established in 2008. The first planned borehole (GD-2) was completed in 2009. The results are impressive. Borehole was completed at 1800 m, yield is 44 l/s (pumping) and temperature is 75°C, with mineralization less than 700 mg/l.

A detailed hydrogeological research was done in wider area of Slobomir, which confirmed an extended geothermal reservoir formed in Mesozoic carbonate rocks. The temperature of the water in borehole in Dvorovi, located 10 km NE from Slobomir is 73^{0}C at the depth of 1200 m. Available technical documentation shows expectations of temperature 80^{0}C at the depth of 1800m and 95^{0}C at the depth of 2500m in Slobomir. Lower temperature is probably caused by tectonic conditions and recharge of the aquifer with cold fresh water along faults. The results of the geothermal project at Slobomir indicate on one of the richest sources of thermal water in the region. The borehole could provide heating for cca. 80.000 m^2 of residential and commercial space (Figure 13).

Figure 13: Planned aqua-park in Slobomir

The existing geothermal borehole GD-2 in Slobomir is already being used for the heating of the constructed facilities in Slobomir, and there is a plan to use it for the following projects:

- Drinking Water Bottling and Fruit Juice Production Plant which is to be constructed in Slobomir
- Tourist and sport-recreation centre – Aqua Park
- Additional heating of the residential and business space
- Greenhouse heating (production of health food, medicinal herbs and flowers)
- Spa and recreation purposes

There are plans even for the utilization of the geothermal resources for electricity production, especially by binary plants.

Thermal water is not utilised in accordance with is economic value in Semberija region. Huge potential (consumers) of different kind of services based on thermal water (district heating, recreation, industry, agriculture etc.) is not valorised yet.

2.2. Banja Luka region

Banja Luka covers some 96.2km^2 territory inthe Republic of Srpska, Bosnia and Herzegovina around the Vrbas River. The city is located at 44.46°N 17.11°E (Figure 14). Banja Luka's downtown is at 163 m above sea level, surrounded by hills.

The area around Banja Luka is mostly woodland, although there are mountains around the city. The city itself is built in the Banja Luka valley, which is located at the transition between high and low mountain areas. The most notable of these mountains are Manjača (1,214 meters), Čemernica (1,338 meters), and Tisovac. Differently from Semberia, the area is part of theDinaric orogeny.

In accordance with 2013 census there are 199.191 inhabitants.

Climate elements indicate modest-continental conditions, with dry and hot summer and cold and dry winter. Average annual precipitation is about 1000 mm, average annual temperature 10.6°C.

Figure 14: Locationof the Banja Luka region

2.2.1. Geothermal features of Banja Luka region

It is the second most important area regarding geothermal energy in the Republic of Srpska. The geothermal potential is not confirmed yet, as the primary aquifer in basement rocks - opposite to Semberija - is not drilled yet.

Geothermal gradient is about 40^0C/km and heat flow about 60-70 mW m^{-2}.

Past explorations confirmed thermal water in three locations: Laktaši, Slatina and Šeher.

In Laktaši, thermal spring (30^{0}C) has a minimal discharge about 15 l/s. Two boreholes (L-1 and L-2) provide an additional 30 l/s. Mineralisation of water is up to 1 g/l, with slightly increased concentration of CO_2. Thermal water discharge is controlled by the deep Vrbas fault.

In Slatina (locality Park) a thermal spring (43^{0}C) is well-known from the Austrian-Hungarian monarchy period. In the mid-80s of the 20th century two boreholes were drilled in the same locality, and another one in 2008. The deepest borehole in Slatina is SL-1 (270 m), the last one SB-4 is 205 m deep. Groundwater level is very close to surface and pumping of three wells in parallel work provide a discharge of 60 l/s. Chemical and physical properties of water are different than in Laktaši, with much higher mineralisation (3.5 g/l) and CO_2 content. The chemical content and temperature of thermal water in Slatina is more similar to those in Teslić and Sočkocac, because Slatina area belongs to the ophiolitic belt (like Teslić and Sočkovac). Thermal water discharge is controlled by a fault passing through the Slatina park.

The temperature of thermal water in two boreholes and in numerous thermal springs (total discharge about 25 l/s) in Šeher is 30^{0}C. This thermal water is quite similar to the thermal water in Laktaši (HCO_3-SO_4-Ca-Mg), with slightly increased mineralisation (about 1 g/l) and sulphate content. The boreholes are very shallow (47 m and 74 m) and were drilled into the Triassic dolomites in the mid-70s of 20th century. It is possible to pump about 40 l/s from both wells.

There a still numerous unsolved questions regarding the thermal water reservoir. Some authors think that the limestone drilled in Laktaši represents olistolites in diabase-chert formation and the depth of the primary aquifer is more than 1000 m (Miošić, 1984). Other authors (Perić and Milivojević, 1992) assume that the limestone is not part of the mentioned formation but form the basement of the Banja Luka Tertiary basin. Two boreholes were drilled in the Banja Luka Tertiary basin - the deepest one is 437 m. These boreholes, after Tertiary sediments, reach the Cretaceous flysch sediments. Based on current knowledge there is an assumption that the Triassic geothermal reservoir in Banja Luka lies at a depth of more than 2000 m. Some geophysical investigations (Geofizika Zagreb, 1984) indicate the smallest depth to the reservoir rocks (Triassic limestone) in the Slatina area (about 600 m below surface).

2.2.2. Current situation of geothermal energy utilization in Banja Luka region

Thermal water is most intensively utilised in the Slatina spa. Currently, about 20 l/s (pumping, 44^{0}C) is used for balneology and in smaller degree for heating. In 2017 accommodation capacities of the spa significantly extended as well as level and number of balneological services. A higher pumping rate (additional 40 l/s) will be necessary in the future, especially after new buildings will be connected to geothermal heating.

In Laktaši, thermal water is used in balneology and swimming pools. For balneology about 10 l/s is average consumption during the whole year, in pools about 15 l/s during the summer season. There is also a simple and not sufficiently effective heating system, and its improvement is planned soon.

In Šeher there is no utilisation of thermal water currently. Recreation centre was closed in 2015.

The first initiative about geothermal district heating of Banja Luka was triggered in last decade of the 20th century. It is re-initiated in 2011. The representatives of the Banja Luka and company Mannvit signed a memorandum about geothermal exploration. Mannvit also signed concession contract for exploration of geothermal energy in Banja Luka region with the government of the RS. Exploration has not started yet and concession contract can be terminated.

Similarly like in Semberija, thermal water of the Banja Luka region is not utilised in accordance with is economic value. There is a huge potential (reserves and consumers) for establishing different kinds of services based on thermal water (district heating, recreation, industry, agriculture etc.) but not valorised yet.

3. Heat market analysis at local level: a district heating circuit to be converted to geothermal in the city of Bijeljina

3.1. The current situation

Bijeljina is a university city and the administrative, economic and cultural centre of Semberija region, located in the NE part of the Republic of Srpksa, Bosnia and Herzegovina.

Situated in the border zone with Serbia, with the city population of 41,291 and 107,715 in the municipality, it is the second largest city and municipality in the Republic of Srpska. About 28.3% of total city population (11,723) is connected to district heating system and only 10.8% at the level of municipality.

The classic urban environment of the housing estate includes a great territory covered with solid pavement. However, due to its location on the bank of the Drina River and on the edge of the city, it also has a serious amount of green open spaces.

3.1.1. Description of the facility/technology to be modernized

In accordance with a report on activities and finances for 2016, heated space increased from 61500 to 63000 m^2 (residential buildings and business places). Total number of heated residential units is 1070-1100 and 80-89 business units. In addition there is a 3437 m^2 area of heated school buildings. Total length of the distributive network is 4759 m. The duration of the heating season is 183 days annually(Figure 15).

The heating source is coal. Annual consumption of this non-renewable energy source is 4000 tonnes per season.

Figure 15: "Gradska toplana " Bijeljina

3.1.1.1. Type, age, condition and efficiency of equipment

During the last 20 years the heating system deteriorated and did not follow intensive city development and heat energy demands. Current equipment for heat production and the distributive network is mostly outdated (30 or more years) and it does not guarantee continuous and quality heating in the future. Some parts of the heating system are high vulnerable (e.g. in the street M.D. Gladović) and endanger the functionality of heating of huge numbers of consumers. Some key parts of boilers ("screen pipes", expansion container etc.) are also very aged and its failures could cause total interruption in heating.

Current situation significantly hampers planning activities and company development. It is especially related with planned growth in production and extension of distributive networks.

Equipment	Characteristic	Remark
2 boilers	2x3.84 MW=7.68 MW	Maximal power
Pipeline	No 400, system 140/75 °C, current transmission power 30-35 MW, total length 4759 m	Conditions for extension provided; reconstruction of some parts necessary as soon as possible
Other	Additional Facility recline on existing boilers	For instalment of one unit of the same power (7.68 MW

Table 9: Available equipment and distribution network of Bijeljina heating system

3.1.2. Mass and energy balance

The main energy source of the heating system is coal. Annual consumption of coal in Bijeljina heating system is about 4000 tones.

Boiler capacities of Bijeljina heating systems are 7,68 MW.

In accordance with development plans, up to 2023 it is necessary to provide energy for heating of residential buildings of 21 MW (on basis of 210000 m^2) and additionally 29 MW for public buildings. It means that total requested install power for future district system development is about 50 MW.

Currently installed capacity represent just 15,36% of total needs given in the development plans or 36,57% of necessary heat demand for residential building.

3.1.3. Operation costs

According to the Annual Report for 2016 the following table show the structure of the costs of the Public Company "Gradska toplana" Bijeljina for the mentioned year and year ago.

No.	Position	2016		2015		Index
	1	2	3	4	**5**	6
	Cost type	Costs in €	%	Costs in €	%	2/4*100
1.	Operating Costs	581514	97,20	584087	99,66	99,56
2.	Financial Costs	4896	0,82	728	0,12	683
3.	Other Costs	11842	1,98	1214	0,21	942
4.	TOTAL	598252	100,00	586029	100,00	

Table 10: Costs of the Public Company "Gradska toplana" Bijeljina for 2016 and 2015

It is obvious from Table 10 that operating costs are very similar for 2015 and 2016. The index of costs is 0.97. It is 581514 € for 2016 and 584087 € for 2015. Also, operation costs represent more than 97% of total costs in each year. Detail structure of the costs for 2016 is given in the Table 11 and Figure 16.

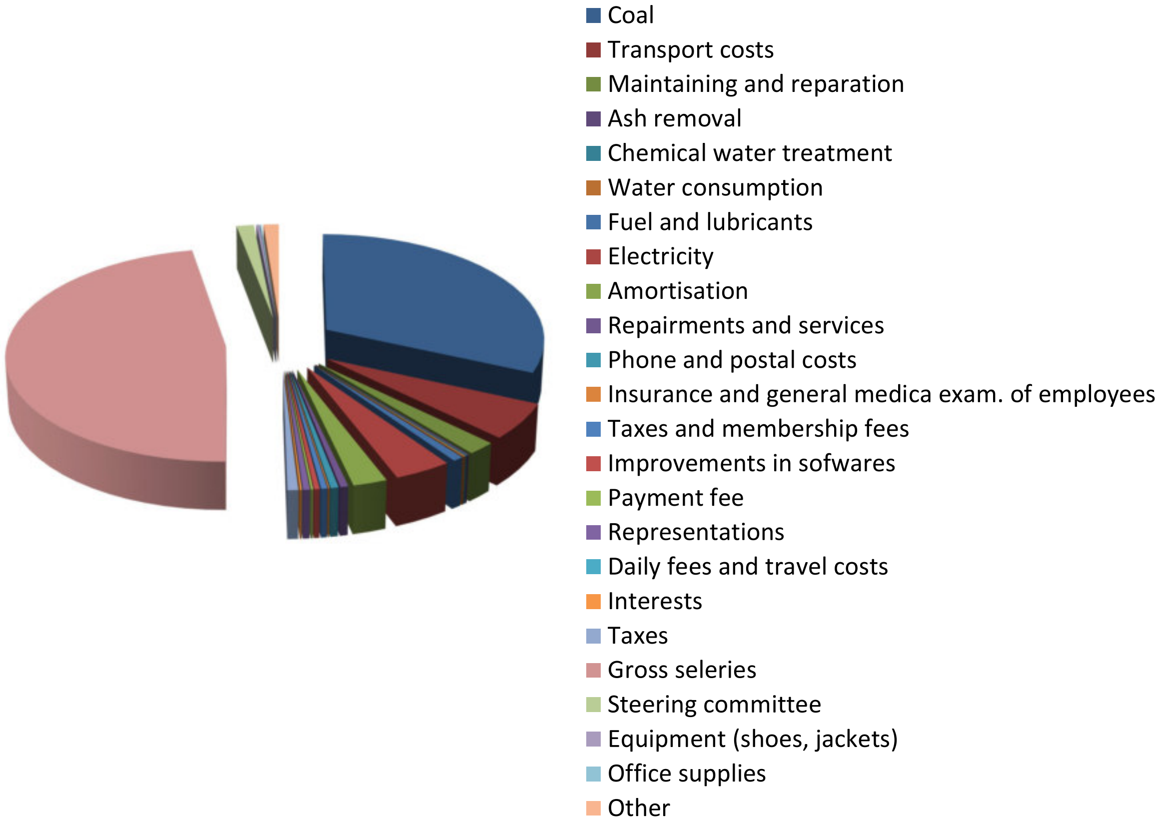

Figure 16: Structure of the operating costs of Public Company "Gradska toplana" Bijeljina for 2016

No	Position	Cost
1.	**Coal**	185173
2.	**Transport costs**	32315
3.	**Maintaining and reparation**	11262
4.	Ash removal	826
5.	Chemical water treatment	648
6.	Water consumption	900
7.	Fuel and lubricants	4190
8.	**Electricity**	22611
9.	**Amortisation**	13440
10.	Repairs and services	3071
11.	Phone and postal costs	3069
12.	Insurance and general medical exam. of employees	482
13.	Taxes and membership fees	2387
14.	Improvements in software	2121
15.	Payment fee	895
16.	Representations	2607
17.	Daily fees and travel costs	20
18.	Interests	737
19.	Taxes	4223
20.	**Gross wages**	276691
21.	Steering committee	8212
22.	Equipment (shoes, jackets)	1365
23.	Office supplies	668
24.	Other	7209
TOTAL		**585133**

Table 11: Detail structure of costs of Public Company "Gradska toplana" Bijeljina for 2016

The gross salaries take share of 47.28% of total operational costs. Costs of coal (with transportation costs) cover 37.17%. It means that these three categories (salaries, coal and coal transportation) make 84.45% of operational costs.

The average annual operating cost (based on 2015 and 2016 reported costs) is 582800 euro.

3.2. The location of the new facility

3.2.1. Aspects of location selection

The selected exploration area, aimed to define the presence of thermal waters in deep rock layers and potential for their exploitation and use, is located in the urban zone of the city of Bijeljina. Three potential macro-locations for the exploration were identified.

In order to select potentially the most prospective macro-location in terms of presence of thermal waters in deep zones of the rock massif of the exploration area, as well as presence of a favourable structural composition of the rock massif to accommodate the accumulation segments of the water capture exploration and exploitation borehole facility, it is necessary to conduct previous geophysical explorations by applying the reflection seismology method.

In addition to identifying the most prospective micro-location, the geophysical reflection seismology explorations should be conducted in the potential macro-locations. It would be aimed also to collect other missing data about the lithostratigraphic and structural and tectonic characteristics of the rock massif and other information about the conditions of natural deposition of rock masses in the exploration area, which are of great importance as input data for the phase of preparation of a detailed hydrogeological exploration project.

3.2.2. Description of the location

Five boreholes are planned on the periphery of Bijeljina town. Two boreholes are located on the western edge of the town (BGT-1 and BGT-5), two in eastern edge (BGT-4 and BGT3) and one 1 km northern from the town, near to Popovača (BGT-2) (Figure 17).

3.2.3. Road and public utility connections

The existence of the public utility infrastructure and its economical “accessibility” were important aspects during the selection of the location. Since the project locations are within city limits, the necessary road and public utility connections are available in an optimal way. Each location can be accessed on a solid-surface road, and electricity, water and waste water supply are available within a distance of maximum 500 m.

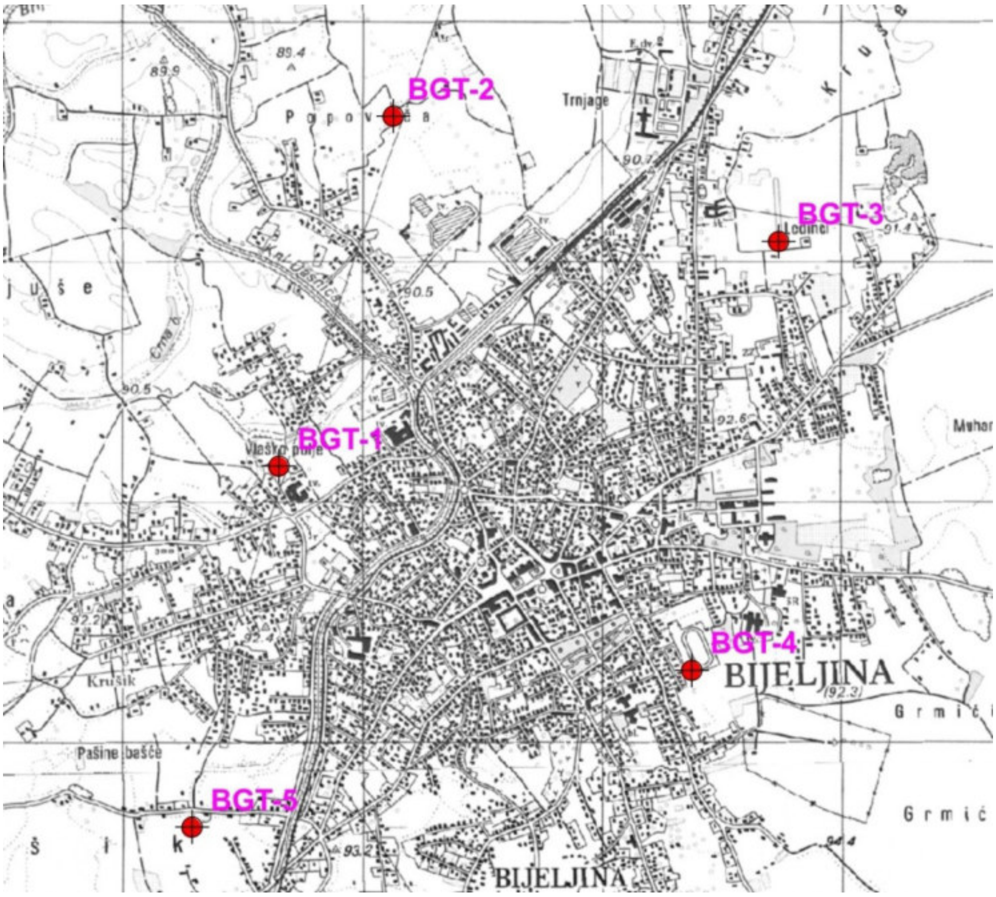

Figure 17: Planned locations of five geothermal boreholes

3.2.4. Analysis of the landscape potential

3.2.4.1. Hydrogeological analysis

The first thermal well was drilled in Semberija almost 60 years ago (1957) and it is still functioning (borehole S-1, supply Dvorovi spa for the decades ago). This borehole was a part of hydrocarbon explorations of Semberija, but oil was not found and borehole is converted into geothermal. Water temperature is 75°C (borehole depth 1345 m), with artesian level and yields 7.5 l/s. The reservoir is determined as a basement reservoir in Cretaceous limestone. The Cretaceous limestone is overlain by hydrogeological seals like marls and sandstones (some kind of flysch formation). The thermal water is utilised for balneology and recreation in adjacent swimming pools.

Further investigations (beginning of 60s, boreholes S-2 and S-3) showed negative results regarding oil, furthermore test results about thermal water are unknown. The documents about drilling and borehole tests are unavailable. Some papers mentioned thermal water in S-2 and S-3, but these boreholes are inactive today without relevant data about their yield and temperature.

Drilling of borehole BIJ-1, the closest one to Bijeljina (2475 m) confirmed favourable geological and geothermal properties. Unfortunately the crash of drilling equipment at 2475 m disabled obtaining more reliable data, however the conclusion was that beneath 2500 m it is possible to obtain water T>100°C in the Semberija region. The reservoir rocks were identified as Upper Triassic limestone. Assumption about the age of the aquifer was proven by borehole DV-1 (drilled close to S-1 in 1990) and GD-2 (2009, eastern from S-1 and DV-1, Slobomir village). The outflow temperature of borehole GD-2 is 75°C,optimal yield about 40 l/s, without artesian level.

In general, results of the previous explorations obviously confirm very favourable geological and geothermal properties of the Semberija Region.

3.2.4.2. Ecological analysis

The planned project elements are located within city limits, in public areas, over the surface (well machinery) or under the ground (thermal well and pipelines), and the thermal centre and system control units should be installed in the boiler rooms of the existing buildings. The related areas are not nature conservation areas, the installation and operation of project elements will not cause any modification of the ecological environment.

3.2.4.3. Meteorological analysis

The region's climate is identical with the country's temperate climate and is free of extreme weather conditions. The project elements are not exposed to extreme weather conditions, the change of meteorological conditions is practically without effect for the project.

3.2.5. Regulatory environment

3.2.5.1. International level

The expansion and efficiency increase of the utilization of renewable energies, including geothermal energy is a global interest for the replacement of fossil energy sources causing the greenhouse effect. There are a great number of international agreements, treaties and directives dealing with this issue: the Kyoto Protocol (1997), the declaration of the Earth Summit in Johannesburg, the findings of the Bali Climate Change Conference or the (2007), or the conclusions of the EU Water Framework directives. The newest climate agreement was signed by the participants of the world conference held last fall in Paris.

3.2.5.2. Compliance with national, regional and local regulations

The national Law on Water (Official Gazette of RS 50/06) is entirely harmonised with provisions of the European WFD. In accordance with this law the water management is under jurisdiction of the PC "Vode Srpske" as a part of the Ministry of Agriculture, Forestry and Water Management. This PC, together with Ministry is responsible for water permits and fees related with water utilisation. But the Law on Water consider just fresh groundwater, use for water supply of inhabitants and industry. It means that this legal policy document does not recognise thermal water as its part. The explorations are in fully jurisdiction of the Low on Geology (Official Gazette of RS 113/10) and exploitation in jurisdiction of Low on Mining (Official Gazette of RS 59/12).

Taking into account definition of a mineral resource given in article 3 of Law on Geology (Official Gazette of RS 113/10) geothermal energy is considered as mineral resource. Further, accordingly to article 6 of Low on Concessions (Official Gazette of RS 50/06) each mineral resource is the subject of concession. Procedure for concession approval could be triggered in three ways (article 11 of Law on Concessions): a) initiative of responsible authority; b) initiative of interested subject and c) negotiation procedure.

Before concession procedure is triggered, geological explorations and elaboration of the reserves must be provided (as it prescribed in Law on Geology) (Figure 18).

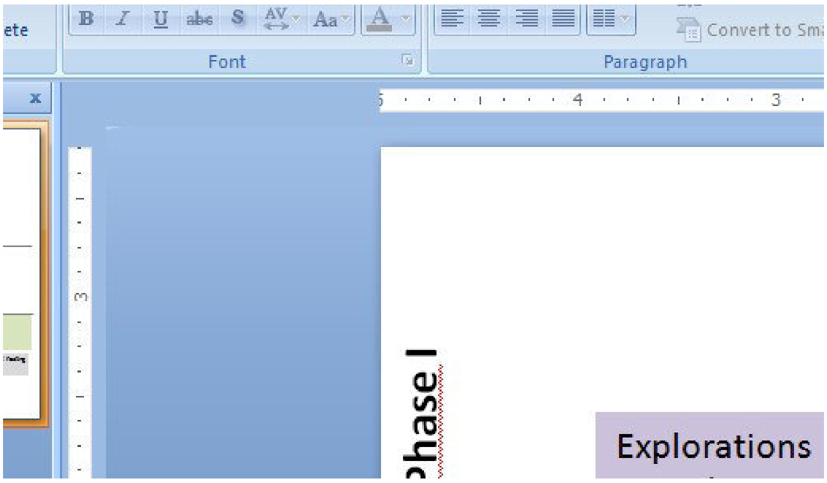

Figure 18: Procedure necessary for obtaining of the concession for exploration of geothermal energy

3.2.5.3. Environmental norms

For the projects which could impact on environment, based on their nature, size and location, estimation of possible impacts is defined in the Study of environmental impact (further: Study) The Study preparation is prescribed by article 61, paragraph 1 of Law on Protection of the Environment (Official Gazette of RS 71/12 and 79/15).

This document deals with the identification and analysis of direct and indirect impacts of a project regarding the following elements and factors:

- human, plants and animals
- soil, water, air, climate and landscapes
- goods and cultural heritage
- interaction of the factors listed above.

Also, the Study is a basic document for issuing an ecological permission. Moreover, any institution in charge of issuing a construction permission, cannot provide it before the Study has been prepared.

It is prepared in a two-stage procedure:

- within the first step the Ministry of Spatial Planning, Construction and Ecology decides about the necessity of the Study. If the study is necessary, the scope of the analysis is also defined in this step.
- the second step is the Study preparation, in accordance with content defined in the previous step (article 66, paragraph 2).

The Law on Environment Protection (Official Gazette of RS 71/12) prescribes mandatory preparation of the Study (article 63, paragraph 1) of impact on environment (further: Study) for all facilities listed in the Rule on projects for which it is being implemented, estimation on environment impact and criteria for decision, and scope of estimation of impact on environment (Official Gazette of RS 124/12).

This kind of Study is mandatory for groundwater extraction or reinjection of more than 10,000,000 m^3. (more than 315 l/s). Taking into account seasonal character of heating (6 months) it is not realistic to expect exploitation of thermal water more than 10,000,000 m^3 for the cities in the Republic of Srpska.

For drilling of any deep boreholes, especially geothermal ones, the Ministry of SPCE decides about the necessity of the Study (also in the case if abstraction is less than 10,000,000 m^3/year) (article 3 of the above mentioned Rule).

3.2.5.4. Mining norms

In accordance with article 38, paragraph 1 of the Law on Mining (Official Gazette of RS 59/12) an exploration borehole is defined as a mining object.

For this kind of the object a Simplified Mining Project is requested (article 37). The content of this kind of the project is defined by a separate rule.

3.2.5.5. Local regulation

The local features and specialities are regulated on local and local government levels. These could be location-specific local government regulations, legal rules, environmental provisions etc. affecting the project (e.g.: break-up of public areas, authorization for construction and urban planning of the engine room etc.).

It is mostly related to different permits in the stage between exploration and construction activities (location and construction permits).

Since the project is established within city limits, the concept should be submitted to the Division for Spatial Planning.

The department for urbanism and documentation defines location conditions and the department for construction issues the permit for construction activities.

3.2.6. Capacity, mass and energy balances

3.2.6.1. Evolution of heat capacities

The built-in gas boiler capacity is shown in Table 12

In accordance with development plans (up to 2023) it is necessary to provide energy for heating of residential buildings of 21 MW (on basis of 210000 m^2). Additionally 29 MW is requested for public buildings (today mostly use autonomous heating systems). Total requested install power for future district system development is about 50 MW. It comprises heating of residential and public buildings (Table 13).

The Bijeljina geothermal project includes drilling of 5 production boreholes in the city and in its surroundings. From each borehole 20-25 l/s of thermal water is expected (T=80-90°C). Expected pressure on well head is 3 bar and mineralization 0.5-1.0 g/l.

Assuming a temperature gradient of ΔT=65 °C (85°C-20°C) expected thermal power is 25 MWh or 7 MWh for ΔT=20 C (85°C-65°C). In the first case the thermal equivalent is $210 \cdot 10^6$ kWh/year or 15000 tons of oil fuel, in the other $60 \cdot 10^6$ kWh/year or about 5.000 tons of oil fuel. The value of substituted energy is about 3,000,000 euro (the first case) and 1,000,000 euro (the second case).

"Gradska toplana" Bijeljina	Boiler 1	3,840 kW
	Boiler 2	3,840 kW
Total		7,680 kW

Table 12: Current capacities of Bijeljina heating system

New plant (same location)	For residential building	21,000 kW
	For public buildings	29,000 kW
Total		50,000 kW

Table 13: Future demands of Bijeljina heating system

One of the most realistic scenarios for fulfilling additional heating energy demand is based on geothermal energy.

More favourable exploitation parameters are expected for those wells equipped with submerged pumps or ground pump aggregates with vertical axes for thermal water pumping. In accordance with estimations, from each borehole about 50 l/s of thermal water (temperature 80-90°C) is expected. In this case it is possible to obtain 95 MWt for ΔT=65°C (85°C-20°C) and 29 MWh for ΔT=20°C (85°C-65°C), or thermal equivalent $840 \cdot 10^6$ kWh/year (Table 14).

Thermal equivalent in the first case is about $840 \cdot 10^6$ kWh/year (substitution of thermal equivalent oil fuel of 56,000 tonnes) and $255 \cdot 10^6$ kWh/year (substitution of thermal equivalent oil fuel of 17,000 tonnes). The value of substituted energy is about 12,500,000 euro (the first case) and 4,000,000 euro (the second case).

The project of geothermal heating, based on the above presented calculation, is high Return of Investment (ROI) project because period of the return is expected within two years, compared with saves in fossil fuels costs. Ecological positive aspects are immeasurable.

Without water pumping	Temperature regime	Usable temperature (°C)	Thermal power (MWh)	Thermal equivalent (kWh/year)
Variant 1	85°C-20°C	60	25	$210x10^6$
Variant 2	85°C-65°C	20	7	$60x10^6$
With water pumping	**Temperature regime**	**Usable temperature (°C)**	**Thermal power (MWh)**	**Thermal equivalent (kWh/year)**
Variant 1	85°C-20°C	60	95	$840x10^6$
Variant 2	85°C-65°C	20	29	$255x10^6$

Table 14: Possible variants of energy production of five geothermal boreholes

D.5.4.1. Summary report on heat sector analysis

Annex 6. Romania national report

November 2017

Danube Transnational Programme
DARLINGe

D.5.4.1. Summary report on heat sector analysis
Annex 6. Romania national report

Authors: Anca Vîjdea, Albert Baltres, Cristina Fianu, Valentina Cetean with contributions from Terratechnik

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Executive summary

Romania has rich and varied resources of renewable energy like: biomass, hydropower, geothermal, wind, solar and photovoltaic energy. They are distributed in the entire territory of the country and they can be exploited on a wider scale as the performance-price ratio of technologies improves by maturing new generations of related equipments and facilities.

The geothermal resources are utilized only in some places in Romania, but there is a substantial potential of raising the utilizations of these sources in the next years. In some regions of the country, like Ilfov district and Bihor (regions with high geothermal potential), geothermal energy represents an economic option for heating and cooling, as well as a reduction of emissions.

The heat market in Romania remains stagnant, the competition is mainly among the technologies used in the production of thermal energy and less among the market participants. Thus, the thermal energy production and supply system is relatively closed, the transport and distribution of thermal energy are monopolized activities, carried out by zonal operators at regulated tariffs.

For increasing the competitiveness of the market in thermal energy, municipal networks of thermal energy will be resized – and if appropriate, zonally fragmented - and accessible, on a competitive basis for different sources of heat-agent, including solid biomass, biogas and geothermal energy.

1. Analysis of the energy sector in Romania

Due to the changes that take place worldwide and at European levels, as well as new objectives and policies imposed by the EU, the revision of the national energy strategy becomes essential in Romania. The report made by the Department of Energy describes the general framework for developing the national energy strategy for the period 2015-2035 and the perspectives for 2050, specifying also the following objectives:

- Security of energy supply and ensuring the social and economic development in the context of a future energy demand;
- Ensuring economic competitiveness by maintaining a bearable price to final consumers;
- Protection of the environment through the limitation of the effects of climate change.

Considering these principles Romania wishes to establish a diverse and balanced energy mix, using efficiently all sources of primary internal energy, as well as modern technologies that allow a long-term use of fossil fuels with low-emission of greenhouse-effect gases, and sources of renewable and nuclear energy.

In Romania the energy sector is represented mainly by hydrocarbons (crude oil, natural gas), coal, nuclear energy and renewable energy.
The investments in the energy field in Romania in recent years were in the following directions:

- Geological research for discovering new reserves of oil and gas,
- Development of national transportation system; interconnection of national transport systems with their counterparts of neighboring countries and increase the safety in operations of transportation;
- Improvement and development of distribution infrastructure;
- Development of the underground storage capacity for natural gas;
- Growth of the capacity of power generation from renewable sources and natural gas;
- Environment protection.

The policy framework for 2030 is based on the full implementation of the 20/20/20 targets including new targets, like maintaining the dynamism that underpins the development of renewable energy sources. In next years, Romania's energy strategy must be based on the following tasks: energy efficiency, efficient systems to support renewable energy, encouraging research and development, nuclear energy, hydrogen–based energy, natural gas as transition fuel, full integration into the internal energy market.

1.1. Sources

1.1.1. Hydrocarbons

Romania has an experience of more than 150 years in crude oil and 100 years in natural gas industry. The oil industry represents a strategic sector of the national economy and a support for other sectors. In 1977 the maximum production of 14.65 million tons of crude oil was reached, and in 1986 the maximum production of natural gas was 36.3 billion cubic meters. In 2013 the annual production decreased to 4.19 million tons of crude oil and 11.3 billion cubic meters of natural gas. At present there are 447 fields of crude oil and natural gas in operation in Romania.

1.1.1.1. Crude Oil

These reserves are limited, according to data from the National Agency for Mineral Resources (NAMR). In 2014 2020 million tons of geological resources and 60 million tons proved geological reserves were registered.

The majority (96%) of the resources and proved reserves identified so far are onshore, only 4% being in the area of the Black Sea shelf.

In spite of the decline of production of crude oil, Romania continues to remain the fourth country producing crude oil in the EU and the fifth in Europe (Table 1). In relation to the European production, the production in Romania represents approximately 2% of the production of Europe and 6% of EU production.

	2010	2011	2012
UM	thousands t	thousands t	thousands t
Norway	90584.5	84345.4	77825
UE28	89084.2	78319.7	70510.7
UK	59354.2	49758.4	43147.3
Denmark	12352.2	11125	10168.7
Italy	5145.6	5370	5490.8
Romania	4200	4075	3991

Table 1: Production of crude oil in the period 2010-2012. (Source: "The energy strategy of Romania", data provided by NAMR)

1.1.1.2. Natural gas

The natural gas sector in Romania is one of the most developed at the level of Central and Eastern Europe from the point of view of annual production, reserves and infrastructure. At national level, the consumption is covered from domestic production. On the national energy market, natural gas is significant as a primary resource with a share of about 31%, due to numerous factors:

- High availability of resources of natural gas;
- Reduced impact on the environment of natural gas, as compared to other fossil fuels;
- Existing infrastructure, extended throughout the territory of the country, for extraction, transport, storage and distribution of natural gas.

1.1.2. Coal

Based on the data provided by the National Agency for Mineral Resources, the status of coal resources is as follows (Table 2):

Resource type	Perimeters in operation	Perimeters out of concession	Total
Unit of measure	Mt	Mt	Mt
Pit coal	592	1614	2206
Lignite	986	11606	12592
Total	1578	13220	14798

Table 2 National coal resources. (Source: "The energy strategy of Romania", data provided by NAMR)

The coal basin of Jiu Valley concentrates most of pit coal deposits in Romania, the caloric power of these being 3650 kcal/kg. The pit coal deposits in the country are low-grade, being located in complex geo-mining conditions. Regarding the proved lignite reserves, they are situated in Oltenia mining basin, in the counties of Gorj, Mehedinti, and Vâlcea. The caloric power is between 1650 and 1950 kcal/kg, with an average value of 1800 kcal/kg. The reserves of lignite deposits in exploitation amount to over 400 million tonnes.

Up to present, coal has been treated as a resource exclusively for the national market, with no interest of integrating it into the international market. Also, in view of the low caloric power of the Romanian coal, as well as from the perspective of the high cost of production, the possibility of integration of the Romanian market of coal in the European market is reduced.

1.1.3. Uranium

In Romania, the uranium-bearing mineral resources are administered by the National Company of Uranium (NCU).

At present, the only active exploitation of uranium in Romania is in Suceava country, ensuring the production of uranium in two locations – Crucea and Botuşana, which have a history of exploitation of 26 years. In the future, NCU plans involve into a new occurrence in the Eastern Carpathian Mountains, the uranium deposit from Tulgheş – Grinţieş. In the future it is planned to construct a new capacity for ore processing and refining, with advanced technologies, which will ensure the increase of the recovery degree and the reduction of production costs.

The national resources of uranium and stocks of uranium technical concentrates in various stages of refining and stored at Feldioara Platform provide the necessary input for the nuclear fuels to be used at units 1 and 2 of Cernavodă Nuclear Power Plant.

1.1.4. Renewable energy resources

Theoretically, the renewable energy sources in Romania have a big potential, but their use is limited by technology, economic efficiency and restrictions imposed by the environment. Table 3 presents the energy potential of the renewable energy sources in Romania.

Renewable energy source	The annual energy potential	Energy saving equivalent		Application
Unit of Measure		Thousand toe	% of total	
Solar energy				
Heat	$60x10^6$ GJ	1433	9.74	Heat
Photovoltaic	1200 GWh	103	0.70	Electricity
Wind power	23000 GWh	1978	13.44	Electricity
Hydro power, of which:	40000 GWh	3440	23.37	Electricity
Under 10MW	6000 GWh	516	3.51	Heat
Biomass	$318x10^6$ GJ	7597	51.62	Heat
Solid biomass	$290x10^6$ GJ	6917	47.00	Heat
Biogas	$15x10^6$ GJ	353	2.40	Heat
Municipal waste	$14x10^6$ GJ	327	2.22	Heat
Geothermal energy	$7x10^6$ GJ	167	1.13	Heat
Total		**14718**		

Table 3: The energy potential of renewable energy sources in Romania. Source: adapted from the "Energy strategy of Romania"- ISPE, 2010)

At present, Romania can produce a surplus of electricity from renewable sources. At the same time, biofuels for transport recorded a deficit covered by imports. Currently there is no available data referring to the import/export of electricity from renewable sources, which can be certified by origin. At the beginning of 2014, the European Commission aimed to implement a competitive system on the territory of the EU regarding the production of electricity from renewable sources in order to develop regional markets, respectively, the single market for electricity.

Renewable energy can help the current energy needs in the country, a good example would be heating of disadvantaged areas, as the rural and so on. The actions that should be taken to promote renewable energy sources are: increasing the use of renewable energy sources for electricity and heat production by providing incentives in the stage of investment; promotion of specific mechanisms to support use of renewable energy resources.

1.2. Consumption

1.2.1. Electrical Energy

The electricity consumption in Romania registered significant fluctuations in the past two decades. After 1989, due to the fall in consumption in the industrial sector, the national consumption of electricity has been reduced significantly, stabilizing only after 2000.

The amount of electricity produced by the holders of energy dispatch units was 55.78 TWh in 2013, the total quantity of electricity supplied in the network was 51.70 TWh.

The structure of the electricity delivered in the period 2008-2013, based on the type of resources is shown in Figure 3.

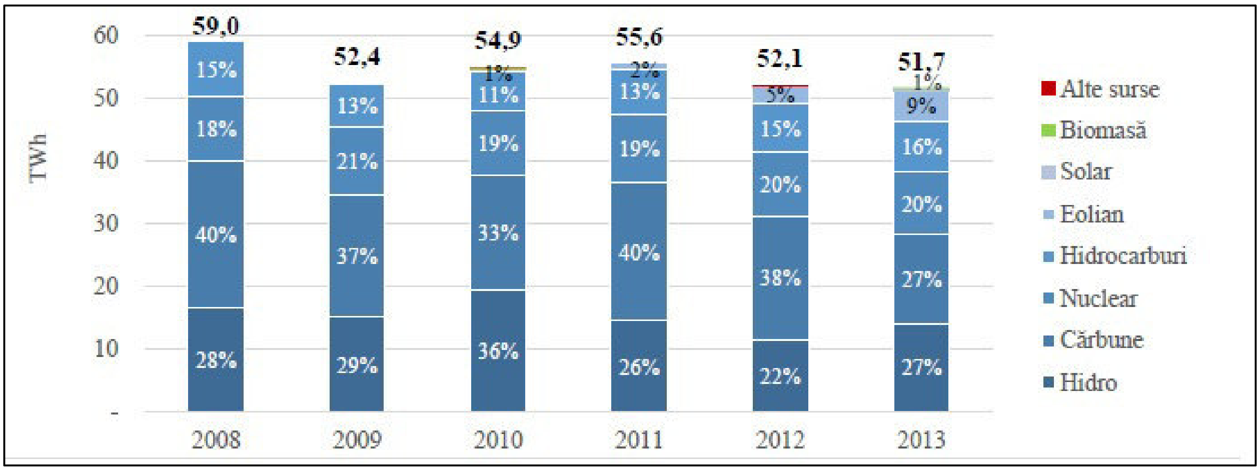

Figure 3: The structure of the electricity supplied in the period 2008-2013 by producers, based on type of resources (TWh) (Source: adapted from the "Energy strategy of Romania"- ISPE, 2010)

The resources of coal and hydro-power had a share of 57.4% in the production of electricity, while the nuclear production has 20.6%, the remaining quantities being covered from sources of natural gas, liquid fuels and other resources. It can be seen that while wind power mills increased their production capacity, their share in the production mix raised at approximately 9% of the total production in 2013.

In Romania, the national electricity system, which interconnects also with the energy systems of the neighboring countries is managed and operated by a national company “TRANSELECTRICA”, in which the Romanian state is major shareholder with a holding of 58.7%. The company is listed on the Bucharest Stock Exchange Market.

TRANSELECTRICA is a member of the European Network of Transport System Operators for Electricity (ENTSO-E), which has the purpose of promoting the integration of the electricity market within the EU, creating the market rules, and ensuring the security of electricity supply, based on network and market technical codes.

In 2013, the gross installed capacity of electricity production in Romania has exceeded 23 GW, while the net capacity of production has been approximately 18 GW, Romania occupying the first position in the Southeastern Europe as concerned the total installed capacity of electricity production.

Figure 4 presents the structure of the gross production capacity in Romania, between 2009 and 2013, in relation to the primary sources of energy.

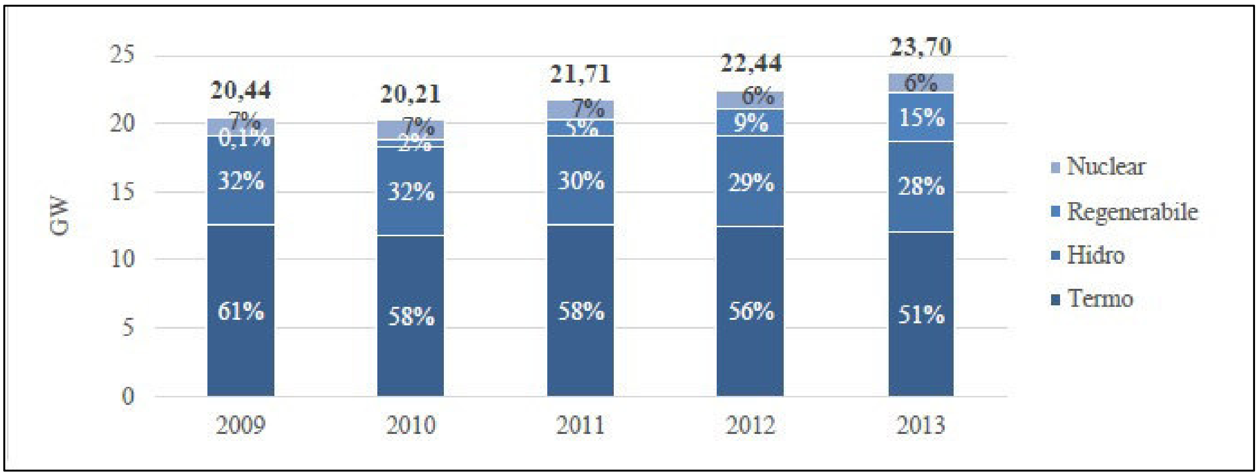

Figure 4: The evolution of gross production capacity, depending on the primary sources of energy in the period 2009-2013. (Source: "Energy strategy of Romania"- ISPE, 2010; Transelectrica Annual Report 2013)

Nevertheless, Romania is facing a series of great challenges regarding the electricity production capacities, because most of them have exceeded their life duration, are non-economic and pollutant. Approximately 30% of the production capacities exceeded 40 years of operation, and 25% of them have already been in use for 30 years. Approximately 15% of the production capacities have been put into service in the last 5 years. Thus, Romania should implement the new competitive operating energy capacities, using clean technologies in order to cover the eventual shortage of capacities, forecasted to appear after 2020-2025, in the context of lowering with 40% the greenhouse gas emissions at European level until 2030.

1.2.2. Thermal energy

The field of thermal energy, including also the centralized public thermal power supply service, holds a share of more than 50% in the energy consumption of Romania, having, moreover, the largest contribution in energy loss.

The centralized public thermal power supply service is carried out at the level of the territorial administrative units under the leadership, coordination and responsibility of the operators and the authorities of local public administration. Direct monitoring and control is ensured by the National Regulatory Authority for Services of Community Utilities (Autoritatea Națională de Reglementare pentru Serviciile Comunitare de Utilități Publice -ANRSC), with regulatory role in this sector. The purpose of the service is ensuring the required thermal energy for heating and preparation of hot water for the consumption by population, public institutions, economic operators and social-cultural objectives.

In Romania there are two models in the thermal energy chain at present (from production to the final consumption), namely:

- Centralized thermal power supply systems (SACET), represented by large heating systems, still in operation in large cities, which ensure the production, transport, distribution and supply of thermal energy to final consumers

- Decentralized systems of production and supply of thermal energy, which integrates two categories of consumers:
    - ➢ Consumers who don't have access to the centralized thermal energy supply, (represented by a significant share of the Romanian rural population, living in isolated localities or remotely from urban centers, where the heating systems have not been developed) are using mainly wood for producing thermal energy;
    - ➢ Consumers who disconnected from the centralized thermal power supply system (Figure 5) and consumers in cities and localities where centralized systems ceased activity, therefore they use various individual heating systems.

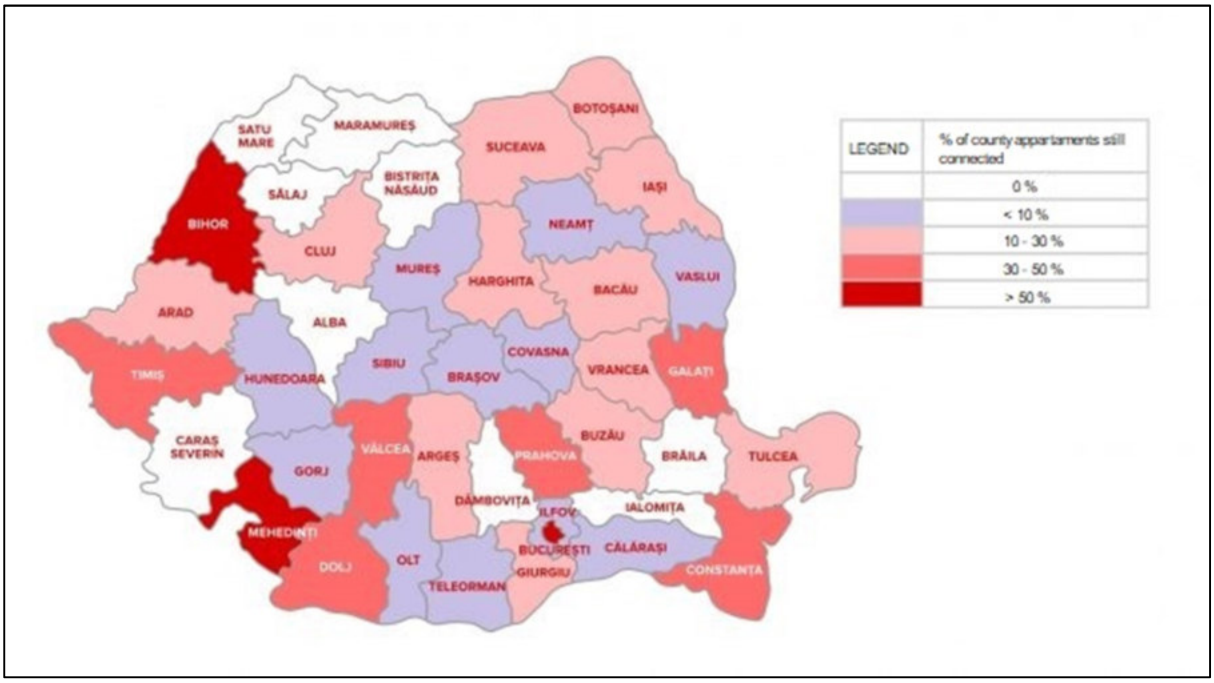

Figure 5: Distribution of Romania counties according to the percentage of appartments still connected to the centralized thermal power supply system. (Source: adapted from Stanici G., 2016 (data from National Regulatory Authority for Services of Community Utilities ANRSC - Autoritatea Națională de Reglementare pentru Serviciile Comunitare de Utilități Publice)

In the past few years, the consumption of thermal energy recorded a significant decline, with negative impact on the centralized system. The final consumption of thermal energy has dropped by about 21% in the period 2008-2013, to a value of 1415.67 thousand toe in 2013. The residential sector, which holds the largest share, more than 65% in the final consumption of thermal energy, has been reduced by 25% over the mentioned period.

The main factors which have influenced the evolution of the consumption of thermal energy, and their impact, are:

- Decrease in the number of industrial consumers and restructuring of the national economy, which led to a reduction in the industrial activity and therefore to a significant decrease of thermal energy demand in the industrial sector;

- Disconnecting of residential consumers from the centralized system of thermal energy, under the impact of high cost or low quality of services, in conjunction with the appearance of alternative systems of heating on the market;
- Increase of gas meters (more than 98% of consumers are metered, directly or indirectly), encouraging energy conservation and efficient thermal energy consumption;
- Increasing the price of thermal power because of the raising operating costs of inefficient equipment and costs of fuel;
- Shortening of the heating period, because of climate change, the months of winter being characterized by higher average temperatures (with 1.4 - 2.2°C) in recent years (2007-2013), than during the last 50 years;
- Decreasing of the population due to emigration (more than 2.3 million till 2013, after data of the National Institute of Statistics - INS).

Thermal energy production intended for consumption in the centralized system in Bucharest represents more than 40% of the total production of thermal energy at national level. The sources for producing thermal energy between 2008 and 2013 are shown in Table 4.

Energy resource	2008	2009	2010	2011	2012	2013
Unit of Measure	Thousand toe	Thousand toe	Thousand toe	Thousand toe	Thousand toe	Thousand toe
Coal	651.18	591.00	640.87	700.40	647.26	619.53
Biomass	27.46	28.90	44.96	74.51	67.33	63.31
Liquid hydrocarbons	189.60	238.57	258.93	288.41	194.55	179.83
Gaseous hydrocarbons	1692,89	1500.63	1490.17	1443.83	1367.72	1242.49
Other fuels	1.05	0.28	0.28	0.33	0.25	0.38
Unconventional sources	1.66	0.66	0.88	2.75	3.33	3.93
Total	2563.83	2360.03	2436.08	2510.21	2280.43	2109.48

Table 4: Share of resources used to produce thermal energy. (Source: "Energy strategy of Romania",ISPE, 2010; National Institute of Statistics – INS)

The thermal power supply infrastructure is belonging to public or private domain of the local public administration authority, or association of community development. At national level, there is a significant number of thermal power plants, and cogeneration and heat distribution networks operated by commercial companies which ensure the supply of thermal energy for heating and cooling of the administrative, commercial or residential buildings.

SACET consists of a unitary technological and functional assembly for the production, transport, distribution and supply of thermal energy in the territory of the towns, which includes:

- thermal or electric central heating system;
- transport networks;
- thermal stations;
- distribution networks;

- construction and auxiliary installations;
- connections up to the point of demarcation/separation of facilities;
- devices of measurement, control and automation.

Thermal power distributed by SACET is produced primarily in the thermal plants (CT), using hot water as heating agent (with higher temperature of 115ºC) or steam (pressure between 6 - 16 bar) and in the conventional and high efficiency electrical cogeneration power plants (CET).

Thermal networks mean all pipes, pumping facilities, other than those existing at the manufacturer, and auxiliary installations which provide transport and distribution of thermal energy in continuous mode, and controlled from producers to the thermal stations or users. According to the reporting of the operators at national level the lengths of the transmission and distribution network are approximately 2720 km, and 6944 km respectively.

Thermal energy market remains a local market, competition being at the level of the technologies used in the production of thermal energy and less between the participants in the market. The production and supply of thermal power is therefore a relatively closed system. Transport and distribution of thermal energy are activities that have monopoly character, being carried out by a regional operator, at regulated tariffs.

Thermal sector in Romania, namely that coming from renewable energy sources, is the most neglected due to several factors:

- worn-out and obsolete equipment;
- energy loss during transport (from the source to the end user);
- poor financial resources for operation maintenance, rehabilitation and modernization.

Currently, 57.9% housing (urban) are connected to the central heating system. The best centralized heating system (heat source-transport-distribution-end user), loses approximately 35% of the heat source until it reaches the end user, and the worst system loses 77%, both losses being incurred by the final consumer. These losses and distribution costs are lowering the quality services while users' energy bills are increasing. That is why in the last 5 years over 260000 families disconnected from the central heating systems (Figure 5). Considering these aspects above, Romania is in an early stage on the possibility of using renewable energy resources on heating purposes.

1.3. Geothermal energy in Romania

Geothermal energy in Romania has a relatively low potential, but could cover a considerable part of the energy demand for heating in some cities. Further studies are needed on the potential and economic competitiveness of this energy source.

In Romania, thermal springs are the only manifestation of geothermal resources in the areas as: Oradea, Felix, Herculane, Geoagiu, Călan, Căciulata, Mangalia.

The geothermal resources of Romania are low enthalpy ones (with temperature ranging from 40°C to 120°C). The main geothermal systems in Romania are located in sedimentary basins and fault zones at depths of 1-3 km, and they are used for heating spaces, spa treatments, and greenhouses.

The main geothermal resource is located in the porous permeable formations of the Upper Pannonian in the western part of the country (Satu Mare – Timisoara - Jimbolia). The aquifer is situated at the depth of 800 to 2400 m and the water temperature ranges between 50°C and 85°C (37 wells are currently exploited). Another geothermal source is in Oradea (Triassic limestones) at a depth of 2200-3000 m with a flow rate of 140 l/s and 70-105°C water temperature. North of Oradea is another geothermal reservoir (in Beius area) with temperature over 130°C, located at a depth of 2500 m.

In the Călimăneşti-Cozia area (Olt Valley) there is another reservoir in Senonian rocks at depths ranging between 2700 and 3250 m with water temperatures of 70 to 95°C.

North to Bucharest there is the Otopeni geothermal reservoir (Moesian Platform), at a depth of 2000 – 3000 m with water temperature of 58 to 84°C.

Romania's geothermal potential was revealed by drilling and experimental operations that began as early as 1964 and it is not confined in the western part of Romania. The rate of success of the geothermal wells drilled during 1995 - 2000 period at depths between 1500 - 3000 meters was 86% (in fact, only two wells were unproductive).

The main strategy regarding the increased use of geothermal resources in Romania should consider the following:

- Detailed research/exploration in the areas with most suitable conditions for extracting geothermal energy;
- Operating with the most effective methods in the most advantageous economic conditions;
- The development of technologies for the conversion of geothermal energy for direct use and/or production of electricity;
- Ensure the use of geothermal energy considering its possible environmental impacts, especially in terms of protecting groundwater drinking water resources;
- Regulation of sustainable use of geothermal energy;
- Granting investors the right to use geothermal energy in a given area.

1.3.1. Development of the geothermal sector in Romania

Romania has a significant geothermal potential in Europe. National exploitable reserves are about 167 Mtoe/year low enthalpy resources, from which currently about 30Mtoe/year is recovered.

EUROSTAT data revealed the primary energy production from geothermal energy in Romania (Figure. 6). The evolution of primary energy production from geothermal sources, in recent years shows a slightly growing trend. Figure 7 shows the primary energy production together with final consumers and other sectors which use energy from geothermal sources. It can be noted that during 2013-2015 the amount of energy sector "District heating plants" increased.

Romania has a significant potential of energy sources. For example, the amount of electricity produced from renewable energy sources in the total gross electricity consumption in 2010 was 19.65GWh. Concerning "renewables" (RES) Romania strives to implement new technologies to recover energy from natural sources, so renewable energy resources can be used both to generate electricity and for heat district sector.

The possibility of using geothermal energy is part of the development strategy of cities such as: Nădlac, Oradea, Beius, Sanmartin, Lovrin, Călimăneşti due to favorable conditions for the exploitation of geothermal resources.

Table 5 shows the evolution of heat consumption from renewable energy sources in Romania and the consumption target for year 2020.

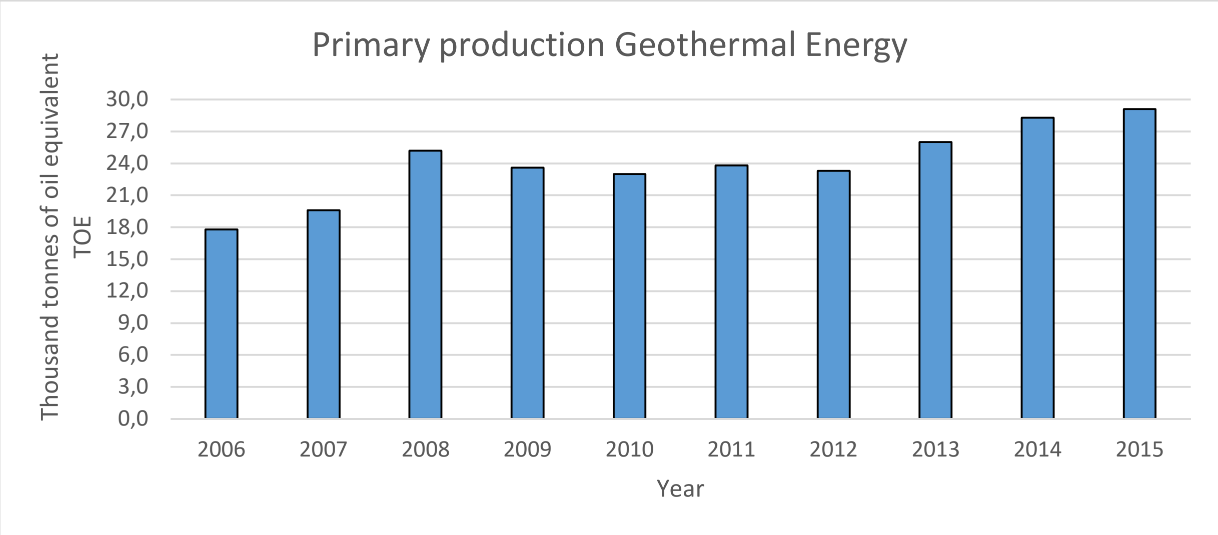

Figure 6: The evolution of primary energy production from geothermal sources

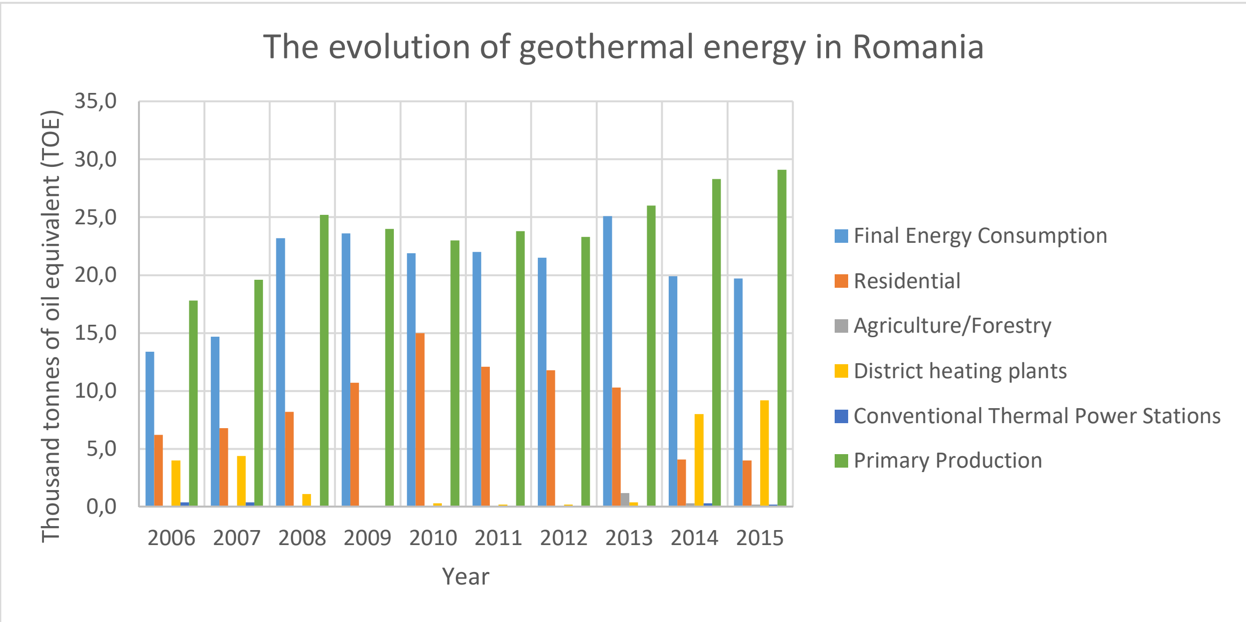

Figure 7: Primary energy production together with final consumption and other sectors which use energy from geothermal sources (Source: Eurostat data)

	2005	Average 2011-2012	Average 2013-2014	Average 2015-2016	Average 2017-2018	Target 2020
Biomass	3166	2882	2893	2954	3203	3876
Solar thermal	0	2	8	16.5	30	70
Geothermal	17	32.5	44	54.5	66	80
Heat pumps	0	1	2.5	4	7	12
Total RES	3183	2917	2947	3029	3305	4038
Gross heat	18779	16300	17010	17609	17890	18316
RES-E	16.94	17.89	17.32	17.2	18.47	22.04

Table 5: Contribution of RES to the heating and cooling consumption for Romania (ktoe) Source: NREAP-Ro, 2010

RES – total, heating and cooling energy
RES-E – share in gross final heating and cooling consumption

2. Analysis of the geothermal energy use and potential at regional level – W-ern part of Romania

The western part of Romania, part of the Pannonian Basin, is an area well known for geothermal reservoirs and is the study area of the DARLINGe project (Figure. 8).

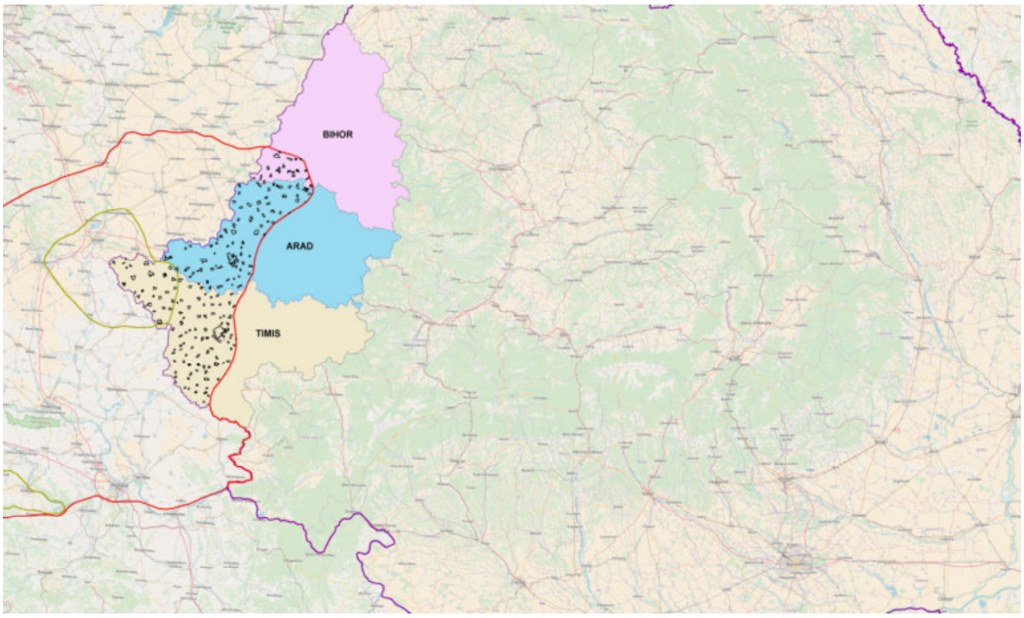

Figure 8: Study area of DARLINGe project in Romania, covering partly the counties of Bihor, Arad and Timisoara (background OpenStreets maps)

The cross-border pilot area (with light-green colour on Figure 8) of the DARLINGe project covers the westernmost part of Timis county, including the main municipalities, capitals of the counties (Arad, Timisoara), but not Oradea, the capital of Bihor, where there is another type of geothermal aquifer.

In the Romanian territory of the DARLINGe area systematic exploration and evaluation both for geothermal and oil and gas exploration have been initiated in the last 50 years. In the Western

Plain the geological formations contain aquifers with very different potentials and thermal properties. The heat flux value is around 85 MW/m^2, higher than in other areas.

The most important thermal aquifer of the Pannonian Basin is located at the base of the Upper Pannonian formations, as evidenced by wells drilled in the area. The water in this aquifer system is generally artesian due to high content of dissolved gases. The temperature of the geothermal waters is rather low: 30° - 90°C. For this reason they can be used in therapy, domestic hot water supply, etc.

1.2. Arad county

Arad county is one of the main gates of entry in Romania, being well connected to major European capitals (Budapest, Vienna, Bratislava). The use of the rich geothermal energy resources is happening currently in small spas, but also for district heating in Nădlac town.

According to the "National Action Plan for Renewable Energy", the western region was the first area that developed a regional innovation strategy for 2009-2013, including the task of eco-innovation, namely sustainable development and promotion of renewable energy sources. The Sustainable Energy Action Plan in Arad emphasizes the importance of promoting energy efficiency and rational use, including buildings and large energy consumers as well, the deployment of recovery of significant renewable energy resources available in Arad.

In Arad city the use of geothermal energy is limited, due to difficulties of geothermal water exploitation and to the low yield of available flow. It can be used in small scale applications, such as thermal pools, for example Grădina Termală Dorobanţi (near Curtici city), which extends over a surface of 1.5 ha and contains pools with thermal water recommended in the treatment since 1988 when the pools were opened to the public. Their water temperature is 36 – 40°C.

Region	ARAD county
Region headquater	Arad
Surface area [sq km]	3198.55
Number of habitants	343408
Population density [persons/sq km]	107
Number of cities (above 20000 habitants) with district heating system	1 (Arad) - 190114
Number of cities (above 20000 habitants) without district heating system	0
Number of towns (habitants: 5000-20000)	6 (Chișineu-Criș, Sîntana, Curtici, Nădlac, Pecica, Vladimirescu)
Number of rural settlements (habitants less than 5000)	77

Table 5: Demographic characteristics of Arad county in DARLINGe project area

In Arad county, 41% of its area, corresponding to 74% of the county population overlaps the DARLINGe project area. Table 5 and Figure 9 show the area, number of inhabitants, population density and number of settlements classified according to the number of inhabitants and type of heating system.

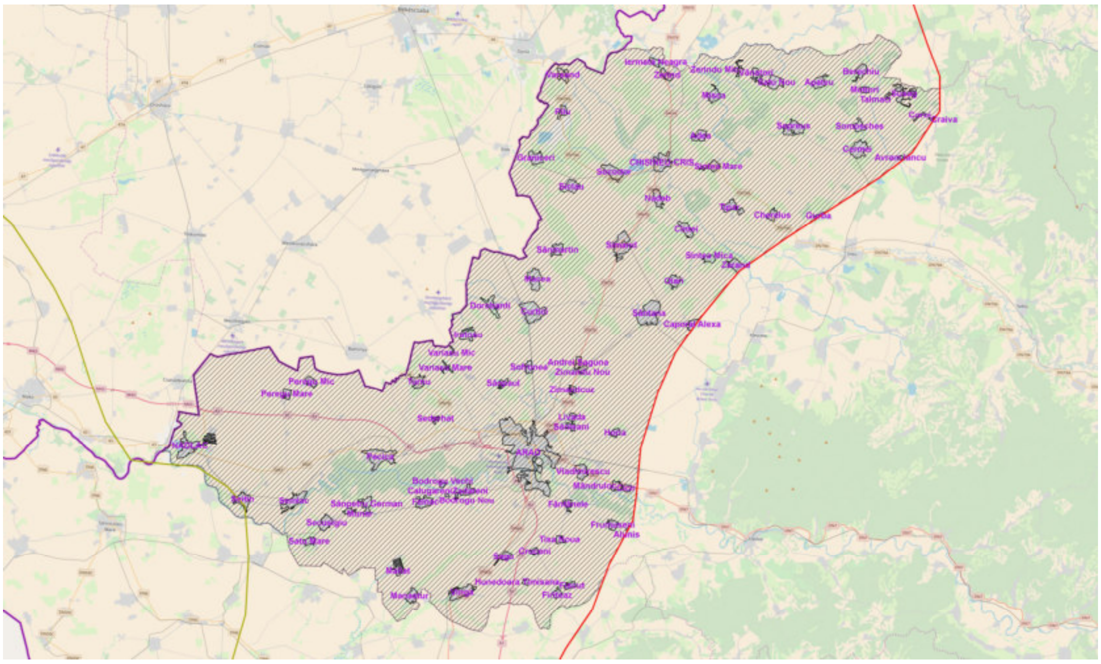

Figure 9: Study area of DARLINGe project in Romania, showing the localities in Arad county (background OpenStreets maps)

A detailed questionnaire was sent to the town halls in the project area. Unfortunately there was very little feedback. We learnt that for example in Curtici town there are 180 days/year of heating demand and 90 days/year of cooling demand. There is no central district heating system, the inhabitants are using mostly individual heating stations, with a capacity around 24 KW/station. The type of used energy is: gas, wood, electric energy. The provider of natural gas in the town is the company Gaz Vest S.A. and approximately 10% of houses are thermally insulated.

The situation for Nădlac town in the category 5000-20000 inhabitants is presented in Tables 6 and 7.

Energy characteristics	
Annual energy production (including import) kW/MW	2487.2 MW
– Fossil energy sources	
– Renewable energy sources • solar • eolian • hydro • geothermal	geothermal
Annual energy consumption (kW/MW)	
– by type of use • Heating/Cooling - district heating • Domestic hot water • Electrical power	Domestic hot water: 127.56 MW; Hot water for industrial and commercial units: 8.62 MW
– by sector type • Housing sector • Public and commercial buildings • Industry • Agriculture	Housing sector: 642.94 MW; Public and commercial buildings:1183.43 MW
Main electric power providers in the area	
Main heat providers in the area	S.C. APOTERM NADLAC S.A.
Main natural gas providers in the area	
Percent of flats/houses that are insulated	
Percent of flats/houses that are expected to be insulated in the next 10 years	
ECONOMIC ANALYSIS	
Price of heating (eurocent/KWh) for the different energy sources: – central heating – individual heating	
Annual number of days for heating demand	180
Annual number of days for cooling demand	

Table 6: Energy data for Nădlac town (based on the reply to the questionnaire)

District heating system (DH)	Yes/No	Yes
Flow temperature (in case of DH)	^0C	42-52
Total installed power (of heat power plant)	kW/MW	8.72 MW
Estimations of total installed power in individual systems	kW/MW	
Type of heat production (cogeneration, boiler)		
Energy source (*coal, hydro-electrical, natural gas, biomass, eolian energy etc.*)		geothermal
Annually sold heat to households	GJ	2314.45
Annually sold heat to industry	GJ	
Share of heat loss in the DH	%	27
Total flat (heated) area surface	m^2	
Flat (heated) area surface on DH	m^2	aprox 3200
Flat (heated) area surface out of DH	m^2	
Share of modern buildings in DH	%	
Share of modern buildings outside DH	%	
Estimated specific heat load per square meter (in average)	W/m^2	

Table 7: Detailed energy data for Nădlac town(based on the reply to the questionnaire)

For the county capital, the "Integrated Urban Development Strategy of Arad city for the period 2014-2030" includes a project proposal of 5.5 million EUR for developing the use of geothermal energy (Table 8):

Proposed Project Title	Solicitant, Potential Partners	Project Objectives	Estimated Value (Ron)	Estimated Value (Euro)	Estimated duration of the Project (months)	Funding sources
Use of geothermal energy to produce energy and hot water	Arad Municipality	Thermal water is an alternative of providing this resource to serve certain objectives of public administration	24750000	5500000	2018-2025	Local budgets, Other sources

Table 8: Renewable energy and modern technological solutions in providing utilities Source: "Integrated Urban Development Strategy of Arad city for the period 2014-2030"

1.3. Bihor county

In Bihor county, besides Oradea county capital (outside of DARLINGe project area), there are other localities with wells for geothermal waters, the most well-known being Salonta, Chiumeghiu, Cighid, Maghiras (Figure 10).

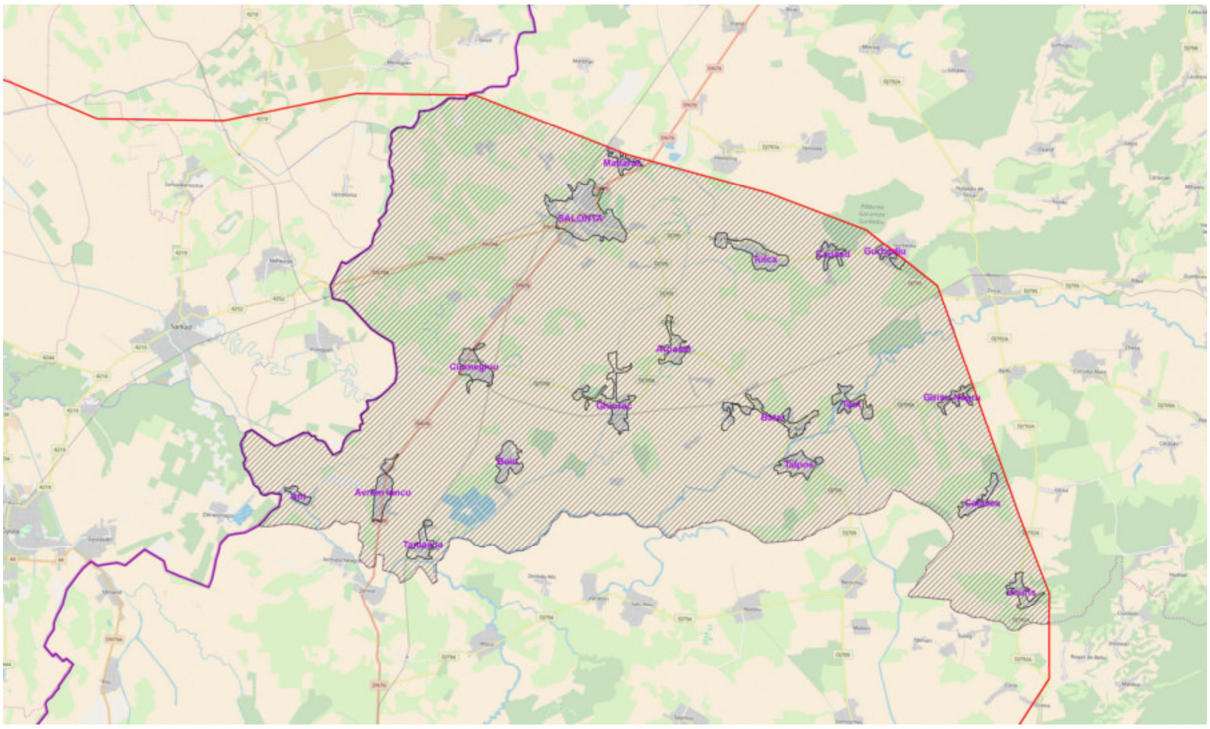

Figure 10: Study area of DARLINGe project in Romania, showing the localities in Bihor county (background OpenStreets maps)

In Bihor county, 8% of its area, corresponding to 7% of the county population overlaps with the DARLINGe project area. Table 9 contains the area, number of inhabitants, population density and number of settlements classified according to the number of inhabitants and type of heating system.

According to a special report regarding the approval of the local heating energy price practiced by the SC Termoficare Oradea SA, valid starting with 01.09.2014, the price of thermal energy on the local market is composed of:

- the producer price of the thermal energy;
- the transport tariff;
- the distribution tariff.

Regarding the current system of supply of heating energy in Oradea, there are three service operators:

- Transgex SA - producer of thermal energy from geothermal water;
- Electrocentrale Oradea SA - producer of heat in cogeneration;

- Termoficarea Oradea SA - Transporter and distributor of the heat produced in cogeneration.

The production prices and the transmission and distribution tariffs for heating energy, approved by the competent regulatory authorities and taken into account in the current price of heating, in national currency, are the following:

- 64.74 RON/Gcal, exclusive VAT for the production of thermal energy based on geothermal water for economic agents;
- 20.61 RON/Gcal, exclusive VAT for the transport of geothermal water thermal energy.

This sums up to 85.35 RON/Gcal, respectively to 105.83 RON/Gcal with VAT at the end-user in the capital of Bihor county, Oradea. Compared with studies made in 1987 by IGR, the price of heating using geothermal energy was comparable (100.96 ROL/Gcal in Oradea - the lowest price from all 7 geothermal systems of the country, the mean being around 118 ROL/Gcal). It should be mentioned that the value of ROL (Romanian Leu) in years 1970's and 1980's is approximately equal to the New Romanian Leu (RON) in last two years (2015-2017).

Region	BIHOR county
Region headquater	Oradea
Surface area [sq km]	631.87
Number of habitants	42094
Population density [persons/sq km]	67
Number of cities (above 20000 habitants) with district heating system	0
Number of cities (above 20000 habitants) without district heating system	1 (Salonta) – 20660 inhabitants
Number of towns (habitants: 5000-20000)	0
Number of rural settlements (habitants less than 5000	17

Table 9: Demographic characteristics of Bihor county in DARLINGe project area

1.4. Timis county

Timis county is privileged from the point of view of the position within the country, in terms of the geothermal energy potential. More than 50% of this county surface has a geothermal potential above 100°C, covering all areas of the West, including Timisoara (Figure 11). In the eastern part of Timisoara there are areas with temperatures ranging between 70 and 100 °C.

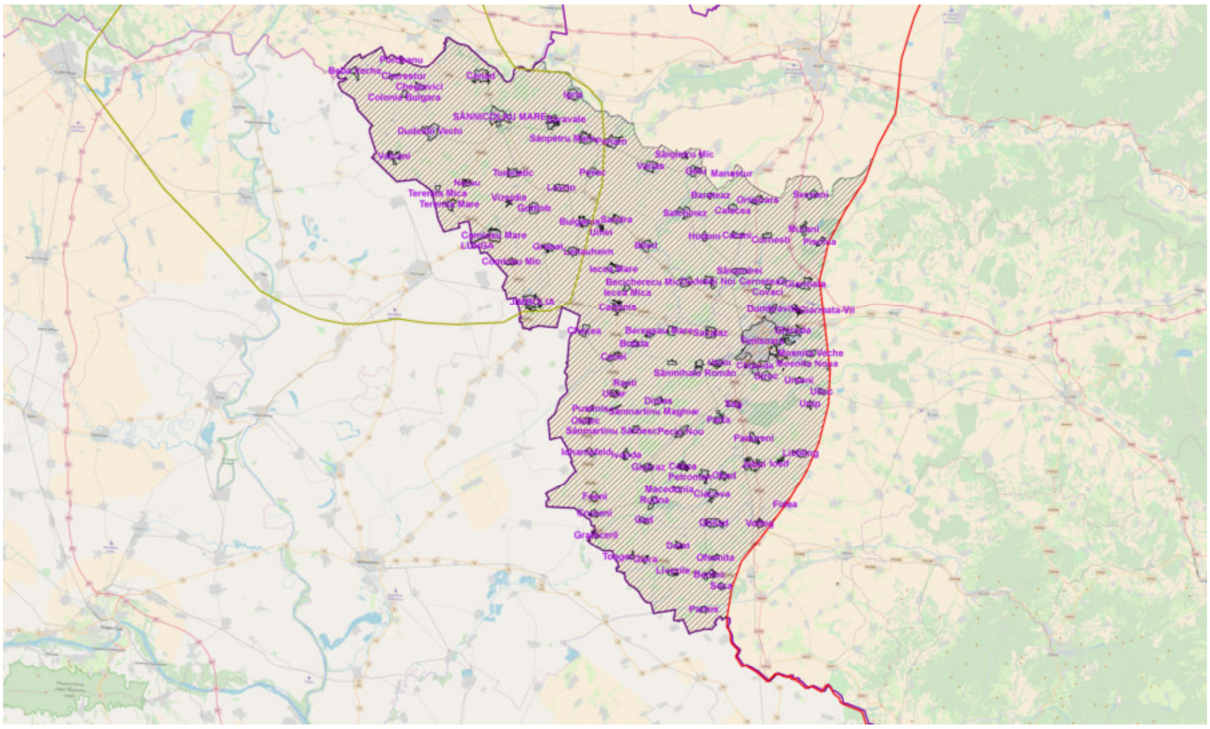

Figure 11: Study area of DARLINGe project in Romania, showing the localities in Timis county (background OpenStreets maps)

In Timiș county, 48% of its area, corresponding to 79% of the county population overlaps the DARLINGe project area. Table 10 contains the area, number of inhabitants, population density and number of settlements classified according to the number of inhabitants and type of heating system.

Region	TIMIȘ county
Region headquater	Timișoara
Surface area [sq km]	4180.7
Number of habitants	523461
Population density [persons/sq km]	125
Number of cities (above 20 000 habitants) with district heating system	1 (Timișoara) – 334115 inhabitants
Number of cities (above 20 000 habitants) without district heating system	0
Number of towns (habitants: 5000-20 000)	2 (Jimbolia, Sînnicolau Mare)
Number of rural settlements (habitants less than 5000	112

Table 10: Demographic characteristics of Timiș county in DARLINGe project area

In comparison with other renewable resources - such as wind or hydraulic power - the geothermal energy has the greatest potential for use and recovery in Timis county. The wind energy has in this area the disadvantage of low average speeds and high uncertainty. The hydraulic power has low capacities and potential, due to the fact that it is mainly a plain area.

A great advantage is the presence of geothermal resources on almost the entire surface of the county. This potential is permanently available, regardless of the presence of the sun or the period of the year. For this reason, it is possible to operate geothermal power plants for more than 8000 h/year (standard operating time for the plant 8760 h/year).

Due to the existing infrastructure and technical endowment, the municipalities and towns from the county can be privileged places for the development of geothermal energy applications.

A study on geothermal resources in Eastern Europe published in December 2001, contains the applications in Timis county, as shown Table 11.

Loction	Status	Temperature (^oC)
Berecsau Mic	Preliminary identification / reporting	77
Beregsau	Direct use-development	75
Calacea	Preliminary identification / reporting	-
Comloşu	Direct use-development	81-85
Grabat	Direct use-development	80-88
Jimbolia	Direct use-development	82-88
Lenauheim	Preliminary identification / reporting	82
Lovrin	Direct use-development	81-91
Periam	Direct use-development	58-80
Sânnicolau	Direct use-development	78-80
Saravale	Direct use-development	75-90
Teremia	Direct use-development	85-90
Timişoara	Direct use-development	31-60
Tomnatic	Direct use-development	80-84
Varias	Direct use-development	64

Table 11 Use of geothermal resources in Timiş county. (Source:"Suport la dezvoltarea unui concept durabil pentru valorificarea energiilor regenerabile din judeţul Timiş – Fraunhofer")

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