Geothermal Energy Utilisation Potential in Croatia

Field and Study Visits' Report

June

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Orkustofnun,
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Iceland

Energy Institute Hrvoje Požar
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INTRODUCTION

The Project Team

This project was a part of bilateral relations at a national level between the Donor States of the EEA Grants and Croatia. The project was ongoing from April 2016 to June 2017 and it was meant to promote the development of cooperation in geothermal energy between Iceland and Croatia.

The national focal point was the Croatian Ministry of Regional Development and EU Funds.

The Beneficiary/Applicant was the Energy Institute Hrvoje Požar (EIHP) and the person managing the project on the behalf of the EIHP was Danica Maljković with her team.

The Project Partner was the Icelandic National Energy Authority, and the person managing the project was Jón Ragnar Guðmundsson.

Geothermal resources and district heating experts were J. Rúnar Magnússon, from EFLA Consulting Engineers, and his team.

The Project Objectives

This project aim was to recognize and promote early stage development, strategy planning, capacity building, networking and awareness of geothermal utilisation to ensure increased possibility of geothermal utilisation for heating, energy security and quality of life in Croatia. It is meant to strengthen the cooperation with the partners and share opportunities to transfer knowledge on geothermal energy harnessing and prepare for a geothermal energy pilot project in Croatia.

The Project Tasks

In order to obtain the project objectives, the following tasks were established:

a. Study visit to Iceland of representatives of the Croatian party
b. Study visit to Croatia of representatives of the Icelandic party
c. Field and study visits' report
d. Final Conference and round table

a. Study Visit to Iceland of Representatives of the Croatian Party

Representatives of the Croatian party visited Iceland in April 2016 where they attended ESMAP III GGDP Roundtable on 25-26 April 2016, and the Iceland Geothermal Conference (IGC 2016) that took place on 26-29 April the same year. The Conference and round table enabled establishing contacts with relevant stakeholders in geothermal energy in order to provide opportunities for future cooperation and project developments. Selected geothermal locations were visited during the conference field trips enabling an insight into Icelandic geothermal developments.

During the visit meetings were held with representatives of Icelandic Ministry of Foreign Affairs, and National Energy Authority.

The following representatives from the Icelandic and Croatian project partners attended this meeting:

Icelandic party:

- Jonas Ketilsson, NEA, Senior Manager – Deputy Director General
- Baldur Petursson, NEA, Manager - International Projects/Public Relations
- Hafsteinn Helgason, EFLA, Director - Business Development

Croatian party:

- Danica Maljković, EIHP, Deputy Head of Department of Energy Management and Organization
- Sanja Živković PhD, EIHP, Senior Researcher and Specialist Geologist
- Rudolf van Hemert, EIHP, Legal Expert

Kristina Čelić, Head of department at Ministry of Economy appointed as a contact with Icelandic partners

Second meeting: During the visit meetings were held with representatives of Icelandic Ministry of Foreign Affairs, and National Energy Authority.

The following representatives from the Icelandic and Croatian project partners attended the study visit and meetings:

Icelandic party:

- Stefan Larus Stefansson, Ministry of Foreign Affairs, Ambassador - International Trade Negotiations
- Jonas Ketilsson, NEA, Senior Manager – Deputy Director General
- Baldur Petursson, NEA, Manager - International Projects/Public Relations

Croatian party:

- Danica Maljković, EIHP, Deputy Head of Department of Energy Management and Organization
- Sanja Živković PhD, EIHP, Senior Researcher and Specialist Geologist
- Rudolf van Hemert, EIHP, Legal Expert
- Kristina Čelić, Head of department at Ministry of Economy appointed as a contact with Icelandic partners

b. Study Visit to Croatia of Representatives of the Icelandic Party

The study visit took place on 6-10 November 2016 and was intended to assess geothermal potential in Croatia and to explore and evaluate feasible locations for a geothermal pilot project. Three different locations were visited and representatives from two other locations attended separated meetings with the Icelandic and Croatian parties in the EIHP headquarters. The names of the locations were:

- Karlovac (visit)
- Krapinske Toplice (meeting)
- Križevci (visit)
- Varaždinske Toplice (visit)
- Vukovar (meeting)

The following representatives from the Icelandic and Croatian project partners attended the study visit:

Icelandic party:

- Jón Ragnar Guðmundsson, NEA, Specialist – Engineering Management of District Heating
- J. Rúnar Magnússon, EFLA, Division Director – Mechanical & Geo Engineering
- Jill Robinson Haizlip, Geologica, Senior Resource Consultant
- Manon M. Stöver, Geologica, Reservoir Engineer

Croatian party:

- Danica Maljković, EIHP, Deputy Head of Department of Energy Management and Organization
- Sanja Živković PhD, EIHP, Senior Researcher and Specialist Geologist
- Rudolf van Hemert, EIHP, Legal Expert
- Karmen Stupin, EIHP, Head of Department of Energy Management and Organization
- Kristina Čelić, Head of Department at Ministry of Economy

c. Field and Study Visits' Report

The Report was built on information, observations and discussions assembled during field and study visits to Croatia and Iceland. Bilateral sharing of knowledge and expertise between the project partners via direct contacts during field and study visits, internet and phone talks was also a vital element in the elaboration of the report. The results are presented in form of pre-feasibility study of geothermal potential and uses in Croatia and pre-feasibility study of the selected location(s), in Croatia, with good potential for geothermal district heating. The report provides good understanding of the current state of geothermal in Croatia and shall be good basis for further development of its uses in Croatia.

d. Conference and Round Table

The conference objective was to present the main findings and outcomes of the study visits report, that is:

- Summary of geothermal energy utilisation potential in Croatia
- Summary of geothermal heating possibilities and benefits in selected locations.

It was held in Zagreb, Croatia, on 26 June 2017 and was attended by representatives of the Croatian and Icelandic partners and other important stakeholders. The meeting comprised ten presentations and was attended approx. 50 attendees.

After the Conference, a project meeting was held to finalize the conclusions of the project and coordinate finishing of the study.

Icelandic party:

- Jón Ragnar Guðmundsson, NEA, Specialist – Engineering Management of District Heating
- J. Rúnar Magnússon, EFLA, Division Director – Mechanical & Geo Engineering

Croatian party:

- Danica Maljković, EIHP, Deputy Head of Department of Energy Management and Organization

- Sanja Živković PhD, EIHP, Senior Researcher and Specialist Geologist
- Rudolf van Hemert, EIHP, Legal Expert
- Dražen Tumara, Junior Researcher

The Project Scope

The important scope of the project is a transfer of knowledge from the Icelandic partner to the Croatian partner. Geothermal energy has many uses with low emissions of greenhouse gases while at the same time it provides a solid basis for development of local industry and businesses. Therefore, key element of the project was to select a promising location for a geothermal pilot project achievable in the next period and to enable preparation of the project in both technological and administrative issues.

The Project Outcomes

A good cooperation between Croatian and Icelandic project partners were established which may result in more common activities on geothermal heating uses in Croatia with the implementation of proven solutions and technologies applied in Iceland. The project had a good impact on increased awareness of geothermal energy uses in Croatia with special focus on district heating and presenting it to relevant stakeholders and officials. The knowledge and experience of the Croatian geothermal heating sector will strengthen the position of the Icelandic partner in possible future international projects.

EXECUTIVE SUMMARY

Resource assessment

- **Križevci**

  Geothermal potential is confirmed with one exploration well near the city. It would be of great interest to evaluate the well capacity for supply of hot water for heating of the public buildings and the swimming pool in the immediate area that should be beneficial and feasible for Križevci community.

- **Varaždinske Toplice**

  This health, rehabilitation and spa centre also appears to have a good geothermal resource potential. There is obviously a long-term tradition for using the geothermal water for house heating, spa and swimming pools. The Varaždinske Toplice area overflows hot geothermal water and there are additional wells that could provide heating of the planned new extension of the hotel and other buildings.

- **Krapinske Toplice**

  There is a tradition of over 150 years of harnessing geothermal water for heating households, hotel/spa, and agriculture. Recently, a water park using geothermal fluid was constructed and opened. The confirmed geothermal area is giving 40°C hot water but further exploration, and drilled well found water with temperature of 56-60°C. This promising result should be an incentive for further evaluation of data and exploration.

- **Karlovac**

  The Karlovac area has at least two wells, Ka-2 and Ka-3, with a confirmed temperature over 140°C and 50 kg/s flow which indicates a good geothermal resource that can support a combined electrical generation unit (ORC) and a district heating system with 90°C water for heating or as a discharge from the power generation process. The geothermal area around wells is around 8-10 km from the city and is favourable for utilisation of the geothermal water for district heating system for house heating, hotel and spa systems, green houses, fish farming or other industries.

- **Vukovar**

  A geothermal potential has been confirmed with seven wells drilled near the city, with indication of water with temperatures ranging from 60-80°C. The temperature gradient of the wells varied from 33.5 – 43.3°C/km, highest gradient in Vu-4 and lowest in Vu-3. However, these wells were drilled decades ago for oil and gas exploration and their condition is unknown.

Main Recommendation

Karlovac

- The district heating system at Karlovac is heated with fossil fuel today but the available resource data indicate the possibility to use renewable geothermal water for heating instead of fossil fuel.
- Current district heating system at Karlovac is well past its lifetime, needs expensive refurbishments and lacks efficiency. Therefore, it is highly recommended that a new district heating system is installed.
- Karlovac needs to establish a working group that will focus on energy efficiency to save fossil fuel in the heat central with the future goal to change over from fossil fuel to renewable energy (geothermal hot water).
- The geothermal field is in nearby area and therefore feasible to establish a district heating system.

- The quality and amount of available geological data gathered in the course of drilling of the wells, as well as obtained data on geothermal water in the reservoir has put Karlovac in the most favourable position for further development.
- Conservative approach for utilisation of the geothermal resource at Karlovac with a relatively low risk is to build up the geothermal system in stages.
- Recommendations for the first stage of the utilisation of the geothermal resource is to establish the geothermal energy for district heating and connect it to Karlovac. Next stages, if the first stage is a success, is to expand the geothermal heating district system by drilling more wells and reinjection wells with connection pipelines to it. Production of electricity is a possibility, in the latter stages.

  Recommendations for the first stage is to divide it into two different phases as follows:

  - Recommendations for phase 1 is to do a test investigation of the geothermal area by re-enter either well Ka-2 or Ka-3 with a drilling rig to clean out the well before inserting a deep well pump.
  - Phase 2, if phase 1 is a success, will involve construction of the connection pipelines to the heat central in Karlovac.

  Recommendations for other stages are not included in this report as the success of the first stage decides whether it is feasible to continue with the expansion of the geothermal heating system.

Recommendations for Utilisation of Geothermal Resources in Croatia

The geothermal resources in Croatia should be examined in the light of the following criteria:

1. A policy based on professional and scientific assessment and conditions in Croatia.
2. Support Schemes for the geothermal development.
3. A properly structured policy system, is critical for success for each location.
   a. Priority 1 – Education capacity building, networking and awareness raising.
   b. Priority 2 – Evaluation of geothermal resources and district heating opportunities.
   c. Priority 3 – Promotion of geothermal district heating and power generation.
   d. Priority 4 – Development of framework conditions.
   e. Priority 5 – International cooperation based on geothermal and financial expertise.

Additional Framework Recommendations

Following recommendations are highlighted for Croatia:

1. Simplify the administrative procedures to create market conditions to facilitate development.
2. Develop innovative financial models for geothermal district heating, including a risk insurance scheme and intensive use of structural funds.
3. Establish a level playing field, by liberalizing the gas price and taxing greenhouse gas emissions in the heat sector appropriately.
4. Train technicians and decision makers from regional and local authorities in order to provide the technical background necessary to approve and support projects.
5. Increase the awareness of regional and local decision makers on geothermal potential and its advantages.
6. Modernize the district heating system.
7. Improve the role of independent regulators.
8. Improve the role of district heating companies.
9. Additional elements of public authorities.
10. Harmonization with EU Law.
11. What can international financing institutions do to help?
12. Access to international geothermal expertise, markets and services.

Other Recommendations

Križevci

- It is recommended to plan a long term well test and evaluate the feasibility of drilling a new reinjection well for the return water from the possible district heating system.

Varaždinske Toplice

- It is recommended to map all available wells connected to the health and rehabilitation centre and evaluate the energy efficiency for the Varaždinske Toplice hotel and spa.
- It is recommended that a geoscientific study of the geothermal resource potential in the area will be performed.

Krapinske Toplice

- It is recommended to perform a geologic and hydrogeological study of the geothermal resource potential in the area.

Vukovar

- Few years ago, Vukovar established a newly refurbished district heating system and heat centrals using fossil fuel. Vukovar could be a good example for exchanging fossil heating by using geothermal water from the existing wells in the area and the heat centres could be used as backup in the first years of operation.
- It is recommended to perform a geoscientific evaluation of the warm water aquifer and an engineering evaluation of the existing wells including pressure temperature surveys and flow testing if possible in order to evaluate the geothermal potential of the aquifers discovered by the wells and the geothermal capacity of the existing wells.

I. GEOTHERMAL ENERGY IN CROATIA

Geographically, Croatia is located at the crossroads of Central Europe, the Balkans, and the Mediterranean. It is a country with high diversity according to the geographical features - from the Adriatic Sea coast over high mountains of the Dinaric Alps to large river planes in the Pannonian basin. Geographical distinctions of the northern and southern part of Croatia are a direct result of geological features of the country.

Croatia is basically situated in two main regional geological provinces: Pannonian basin to the north, and Dinarides to the south (Figure I.1.).

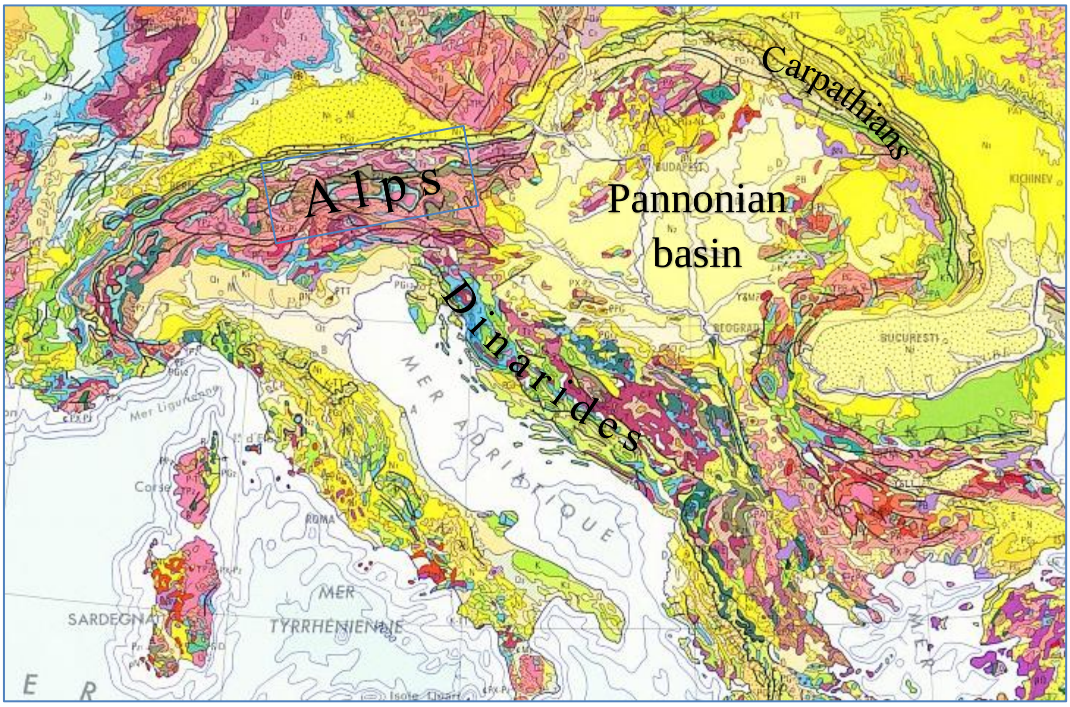

Figure I.1. Geological map of the SE Europe
Source: Geological map of the world

High geothermal potential of Croatia in the Pannonian basin area is indicated by numerous spas with temperatures ranging between 17°C and 65°C. Even though in the Dinarides area geological conditions are less favourable, there are the Istria spa - Livade (with water temperature of mainly 28°C) and more subthermal events along the Adriatic coast.

The use of geothermal waters hadn't changed much and it is still mostly used for spas, medical therapy and recreation. Since the end of the 19th and in the beginning of the 20th century in the northern part of Croatia a number of spas were developed. Today there are 18 spas in Croatia, of which 17 are located in the north, and only one in the southwest of the country.

1. Geology of the Pannonian Basin System

The Pannonian Basin System (PBS) is surrounded by the Alps, Carpathians and Dinarides, (Figure I.1). The formation of the PBS started in the early Miocene due to the continental collision and subduction of the European plate under the African (Apulian) plate. Subduction caused thermal perturbation of the upper mantle, resulting in attenuation and extension of the crust and the formation of a backarc-type basin (Pavelić, 2001). The first phase of basin development was characterized by tectonic thinning of the crust and isostatic subsidence (synrift), while the second phase was marked by cessation of rifting and subsidence caused by cooling of the lithosphere (post-rift). The synrift phase lasted until the middle

Miocene (middle Badenian), and resulted in the formation of elongated half-grabens characterized by large sediment thicknesses strongly influenced by tectonics and gradually increasing volcanism. Towards the end of the synrift phase sinistral strike-slip faulting took place, transverse to oblique to the master faults, which disintegrated the longitudinal structures contemporaneously with volcanic activity. The depositional environments gradually changed from alluvial and lacustrine to marine. The syn- to postrift boundary was characterized by significant erosion of the uplift fault block footwalls. The post-rift phase extended from the middle Miocene (middle Badenian) to the latest Miocene (end of the Pontian). Tectonic influence drastically decreased, volcanism ceased, and subsidence of the basin was controlled predominantly by cooling of the lithosphere. Marine connections gradually decreased, resulting in a transition from marine to brackish, 'caspi-brackish' and finally fluvial-marsh environments. By the end of the Miocene the basin was finally infilled. The basin evolution was additionally complicated by an alternation of phases of extension and compression.

Within the area of the Pannonian Basin, Cenozoic sediments, following a major hiatus, overlie deformed pre-Tertiary basement. Sedimentation was controlled largely by tectonic and eustatic processes. As the Pannonian crustal fragment subsequently overrode the European plate, the elevated Pannonian lithosphere underwent active back-arc extension and attenuation, producing a compound system of Neogene rift basins characterized by initial synrift sedimentation overlain by a generally thick blanket of relatively undeformed postrift sediments (Horváth and Royden, 1981; Royden and Horváth, 1988). The pre-Tertiary basement of the Pannonian Basin system consists of a complex of igneous, metamorphic, and sedimentary rocks of Precambrian, Paleozoic, and Mesozoic age that have been strongly folded and faulted.

Croatian part of the Pannonian Basin, known as the North Croatian basin, mostly belongs to the Tisza block (Figure 1.1), and represents a marginal part of the basin thus featuring smaller sediment thickness. North Croatian Basin is characterized by an WNW-ESE-trending sub-basin along the northern margin of the basin known as the Drava Depression (Figure 1.2).

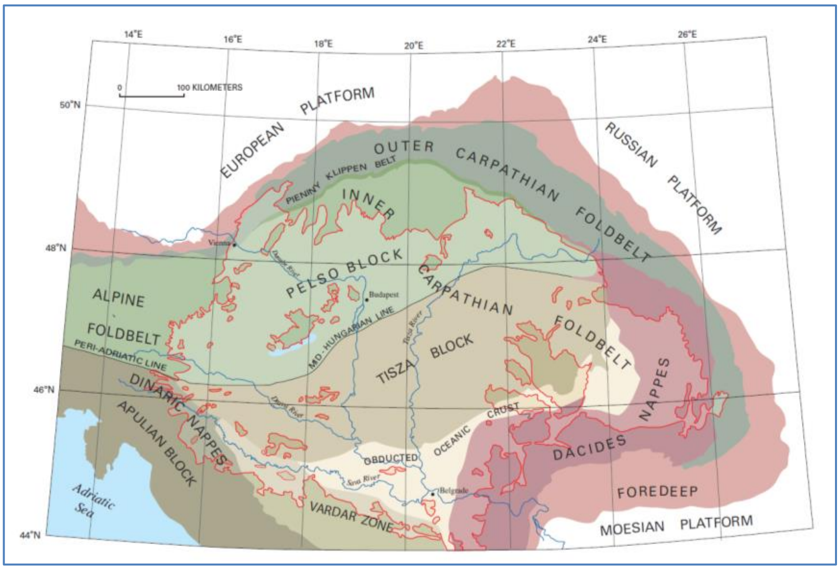

Figure 1.1. Generalized map of major structural elements of Alpine-Carpathian orogen.
Areasoverlain by Pannonian Basin Cenozoic rocks are shown in lighter shade within red outline.

Source: Dolton, G.L., 2006

Figure 1.2. Location map of the depressions in the North Croatian Basin

Source: Malvić and Saftić, 2008

The maximum depth to the pre-Miocene substratum in the Drava Depression is about 6,500 m. In the Sava depression along the southern margin of the North Croatian Basin, the maximum depth to the pre-Miocene deposits is 4,000 m, in the Bjelovar depression reaches 2,600 m, and in the Slavonija - Srijem depression 3,500 m.

The pre-Miocene rocks of the Tisza terrane are characterized by Precambrian and Paleozoic metamorphic and igneous rocks. Upper Paleozoic and Mesozoic sedimentary rocks, including *Hauptdolomit*, and *Dachstein Limestone* present source rocks and reservoirs for oil and gas but also for geothermal waters. The basement blocks were assembled during the Paleogene by extrusion from the west along strike-slip faults and were mainly subjected to sub-aerial erosion during the Maastrichtian-Paleocene. During the Cretaceous compressive deformations were common in the basin, caused by the closure of the Tethys Ocean. During the Paleogene and early Neogene, the Pannonian crustal blocks (Pelso and Tisza) were high-standing, and sedimentation was restricted to the adjoining Carpathian foredeep where flysch sediments were deposited.

Synrift sedimentation was initiated with a rapid transgression in Eggenburgian time (early Miocene) with a massive influx of terrigenous sediments derived from faulted and uplifted blocks into marginal sub-basins of the Pannonian system. Synrift sediments, although dominantly terrigenous, included marls, algal limestones, evaporites, non-marine clastics, and coals. In Ottnangian time (early Miocene), a widespread volcanoclastic sequence was deposited in the west and south, largely rhyolite tuff and ignimbrites, accompanied by andesite intrusions. In the southernmost Pannonian Basin system, shallow-marine breccia and conglomerates, marls, and sands were deposited on volcanics (including andesites, dacites, and pyroclastics), especially bordering the Dinarides. The synrift phase is generally terminated by a regional unconformity in Sarmatian time (middle Miocene), except in deep basinal areas where deposition appears to have been continuous. In sub-basins of the southwest, coarse-grained fluvial sediments and variegated shales are overlain by transitional and shallow-marine conglomerates, sandstones, marls, and limestones. Badenian (middle Miocene) rocks represent a widespread transgression in which open-marine and nearshore rocks surrounded many small, emergent basement blocks. Basal deposits are conglomerates along the margins of the basin system but are usually sandstones in the central Pannonian area. Sedimentation was affected by differential subsidence, resulting in considerable local variation in facies. Marls and clays were deposited in open-marine areas, including hemipelagic sequences, while limestones of littoral and shallow-water origin were deposited in shelf-margin reef complexes and shallow, offshore banks. Brackish-water lagoonal sediments, including lignites, also accumulated along basin margins. An increase in subsidence produced a late Badenian marine transgression, causing these beds to rest unconformably on lower Badenian beds in marginal sub-basins of the system. Sedimentation was widespread and typically marked by an argillaceous marl sequence containing upwardly increasing reef intercalations. Shales and marls occupied basinal settings, and limestone facies of littoral and shallow-water origin were deposited along local shelf margins in reef complexes and in offshore banks.

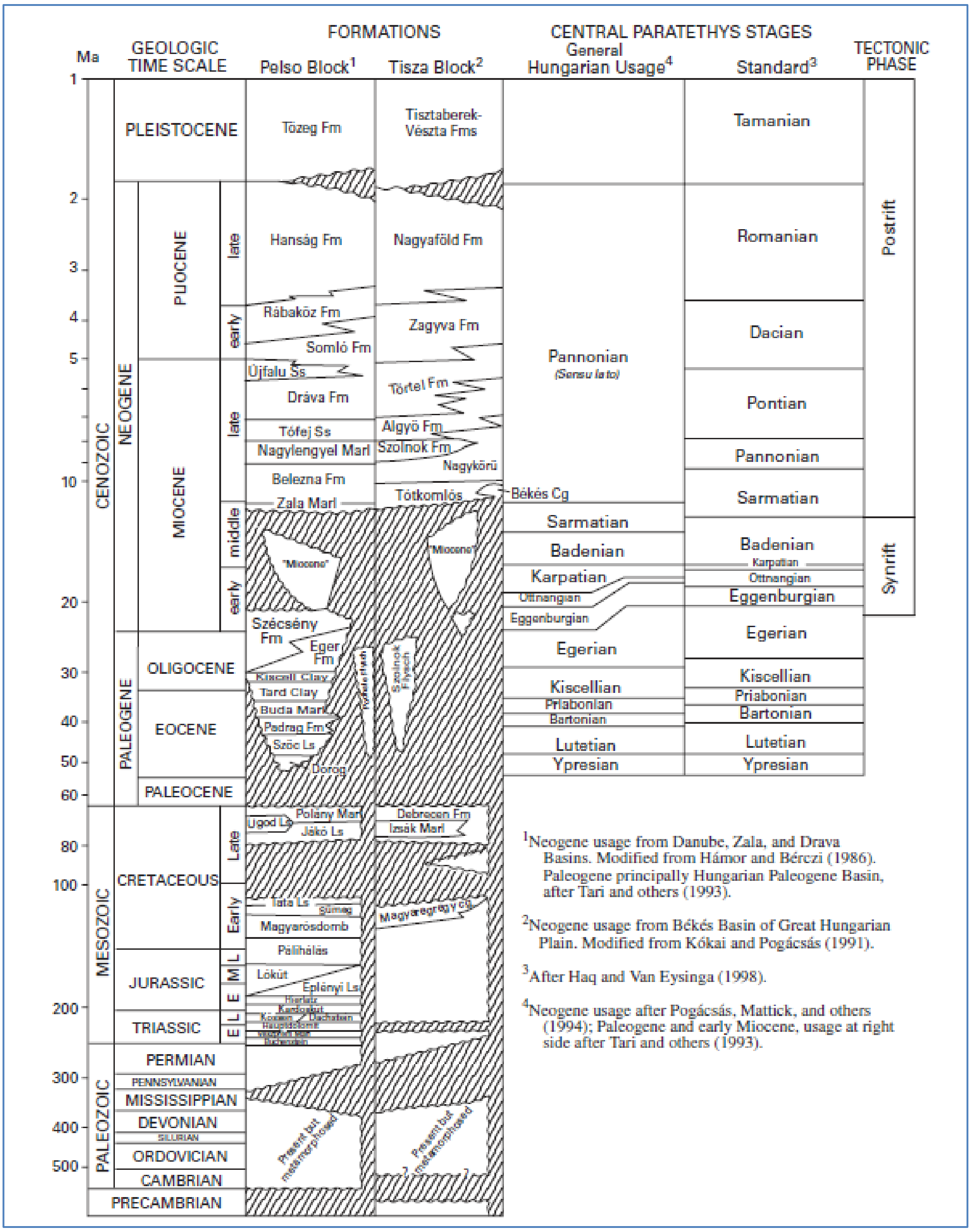

Figure 1.3. Generalized stratigraphic columns of Pannonian Basin showing selected formations. *Volcanic rocks are not presented.*

Source: Dolton, G.L., 2006

Postrift sedimentation was rapid and dominated by relaxation, thermal subsidence, and differential downwarping. The postrift sequence, that followed in middle to late Miocene time (late Sarmatian and early Pannonian), is marked by regression recording the isolation of the Pannonian Basin from the Tethys Sea and the evolution of a large lake. During this time, deposition changed from marine conditions to lake, fluvial, and marsh conditions. The lithic sequence is made up primarily of a varied mix of fine- and coarse-grained clastic rocks and subordinate, locally important, coals. The style of sedimentation within individual basins is influenced by proximity of the basin to active thrusts of the bounding Dinarides. The base of the Pannonian sequence is commonly marked by transgressive sandstones and conglomerates, particularly around margins of the system and uplifted blocks. This is succeeded by generally marly sediments deposited in deep brackish-water basins, followed by a mixed clastic sequence of sand, silt, clay, and marl, including occasional turbidites in basin axial areas. The upper Pannonian sequence shows a more variable composition, especially in uppermost parts where paludal, fluvial, and lacustrine interbeds become increasingly common. By the late Neogene, sediments had buried most of high blocks and expanded to encompass the present Pannonian Basin. Sediments are largely undeformed and unfaulted except for compaction features over basement highs and deformation associated with late strike-slip faults. They generally rest with regional unconformity on synrift rocks or on pre-Tertiary basement, as in much of the central Pannonian system, but locally appear to rest conformably on synrift sediments in several basinal areas. The final phase began at the end of the Pliocene, with the formation of the strong transgressive regime. Marginal faults of the basin are transferred into reverse faults with common occurrence of positive flower structures and associated anticlinal forms. Succeeding Quaternary sediments are characterized by highly variable paludal, fluvial, and delta-plain deposits.

2. Geothermal Features in Croatia

Position of Croatia in two main regional geological provinces – Pannonian basin to the north, and Dinarides to the south (Figure I.1) – has a direct influence on the geothermal potential of both areas. The Dinarides are a 200-300 km wide southwest vergent foreland fold and thrust belt extending in a northwest-southeast direction along the eastern side of the Adriatic Sea. The Dinarides were formed as a result of a convergent movements of the African plate towards Euroasian plate causing subduction of continental crust and deepening of the Moho discontinuity (Figure 2.1). Pannonian basin is the result of the same movements of African plate. Its formation started in the early Miocene and subduction caused thermal perturbation in the crust and formation of a back-arc type basin. The first phase of basin development was characterized by tectonic thinning of the crust and isostatic subsidence. Thus, due to their very different geological setting and origin, they vary significantly in terms of geothermal conditions. Namely, continental crust thickness in the Dinaric area ranges between 35 and 40 km, whereas in the Pannonian basin area it amounts to 25-30 km (Figure 2.1) influencing directly heat flow density (Figure 2.3) as one of the main parameters of geothermal potential.

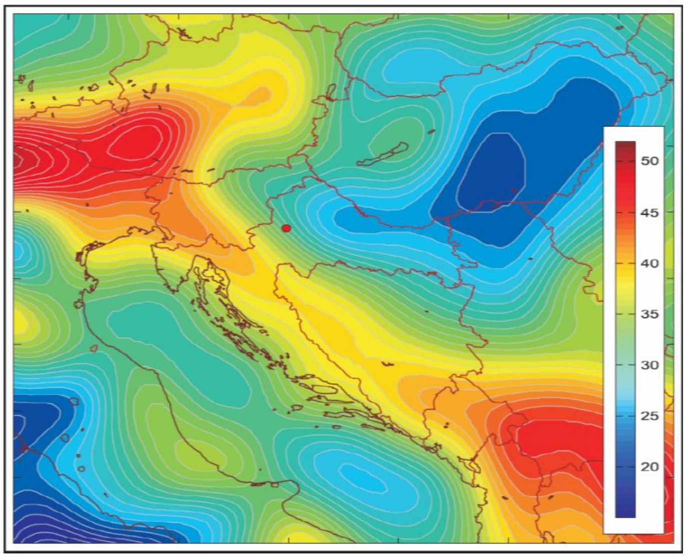

Figure 2.1. Map of Moho discontinuity depths in SE Europe

Source: Grad et al., 2009.

Accordingly, we could divide Croatia into two geothermal regions: Pannonian basin area and the Dinarides (Figure 2.2). Pannonian basin area has a significant geothermal potential where the temperature gradient is commonly higher than 0.04°C/m and in places reaches values of more than 0.07°C/m (Figure 2.2). The terrestrial heat-flow density is also high, ranging from 60 to over 100 mW/m^2 (Figure 2.3). On the other hand, in the Dinarides area the temperature gradient ranges between 0.01 and 0.03°C/m and the terrestrial heat-flow density between 20 and 60 mW/m^2 (Figure 2.3).

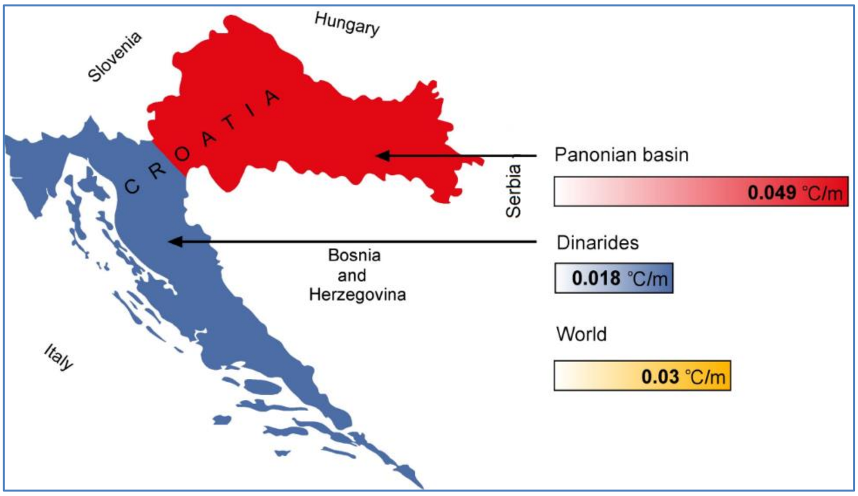

Figure 2.2. Geothermal regions of Croatia
Source: GEON, EIHP, 1998.

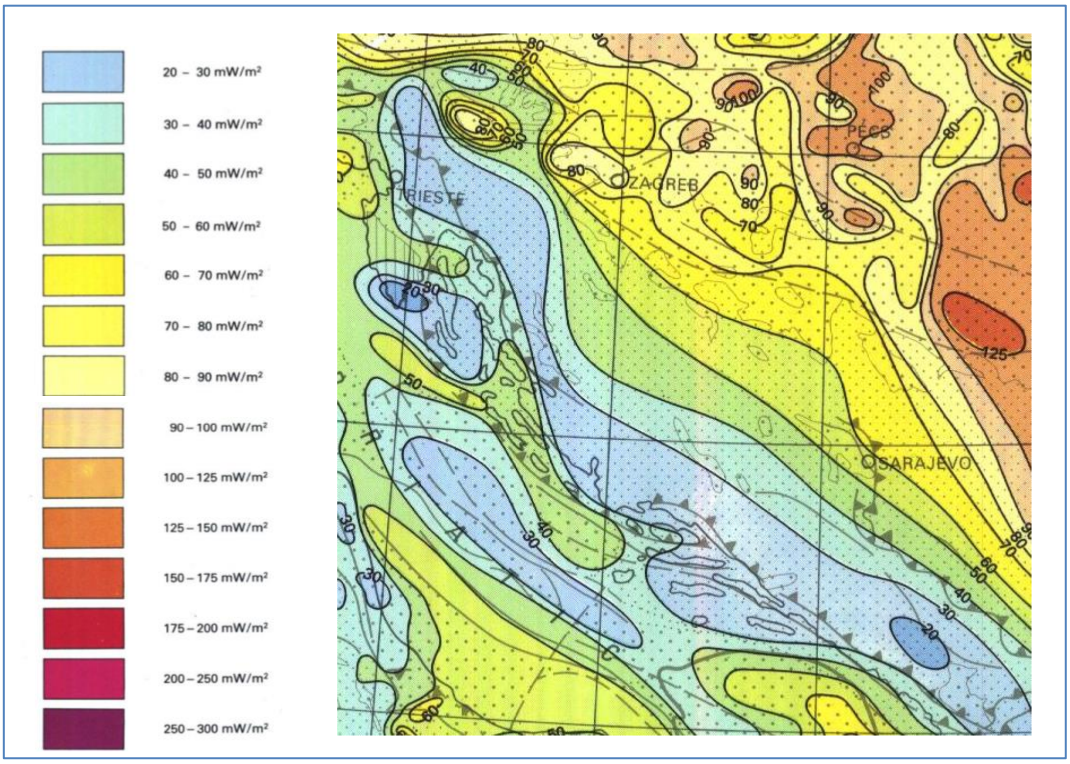

Figure 2.3. Terrestrial heat flow density in Croatia
Source: Geothermal Atlas of Europe

The geothermal potential of the Pannonian basin area is marked with 30 natural springs of thermal water mostly in the western part of Croatia, many of which have been known since the Roman times. They exhibit temperatures up to 65°C and have often been developed with new boreholes in order to reach waters with higher temperatures or increase flow rates. However, waters with higher water temperatures were found in the course of oil and gas research taken in the Pannonian basin area in the second part of the 20th century. In that time, more than 4,000 deep wells were drilled and nearly fifty oil and gas fields and five geothermal fields were put in production.

3. Geothermal Fields in Croatia

Even though a number of promising geothermal sites were discovered during oil and gas research (Figure 3.1) only five of them were developed to geothermal fields. Of these, three are operational with more or less efficiency, and two are in development.

Figure 3.1. Geothermal locations in Croatia
Source: GEON, EIHP, 1998.

3.1. Geothermal Field Zagreb

The field is located at the south-western entrance to Zagreb. It was discovered in 1977 after hydrodynamic tests in negative oil well Stupnik-1, which was drilled in 1964. The field covers an area of about 54 km^2 and its use was assumed in two phases. So far, a total of 14 wells were drilled, and the cost of their development and equipment amounted to about 12.8 MEUR. The reservoir is in dolomite and limestone rocks of Triassic age at depths of 881-1,374 m. The measured average water temperature in the well Mla-1 was 75°C, and the measured pressure was 104 bars. In the deeper interval temperature of 82°C was measured. The salinity of the water ranges from 0.2 to 2.3 g NaCl/l and the analysis of the chemical composition of water indicates it is suitable for balneological use.

Geothermal energy on the geothermal field is currently used in two technological systems:

- Technological system "Mladost" with 3 wells: production well Mla-3, production - injection well Mla-2, injection Mla-1. Geothermal water is used for heating of swimming pool and associated facilities at sports-recreation centre Mladost,
- Technological system at unfinished object of University hospital Zagreb with 4 wells: production wells KBNZ-1B and KBNZ-1A, and injection wells KBNZ-3α and KBNZ-2A, where geothermal water is used for individual space heating.

The degree of utilisation of heat energy at geothermal field Zagreb is less than 2%: only 0.34 MW$_t$, of the total power output of 17.7 MW$_t$. Utilisation temperature is 20°C with a flow rate of 77 kg/s and temperature of 75°C at the wellhead.

3.2. Geothermal Field Bizovac

Reservoir of thermal mineral water Bizovac was found in 1967 during oil and gas exploration in the Drava depression. Another well drilled in the same year led to discovery of greater amounts of hyperthermal water and few more wells were drilled in the following years. The water is drawn from the interval at depth between 1,761 and 1,841 meters. Thermal water is accumulated in fractured base rock gneiss and in breccia probably of Miocene age. These reservoir rocks are overlain by thick sediments of Upper Miocene, Pliocene and Quaternary age. The water temperature at the wellhead is 96.8°C, with mineralization of 25.29 g/l. Studies to determine possibilities of exploitation of water for commercial purposes were conducted during 1970's. Test results showed that water supply is limited to 1.4 kg/s in the well Biz-4 but cold water injected into well Biz-2 increased the capacity of the borehole Biz-4 to 3.3 kg/s. The well Slavonka-1 (Sla-1) is 1,667 m deep, with the water temperature of 75°C at the mouth with a yield of 3.17 kg/s. Water from this well has very favourable properties for spa therapy which was the foundation of the development of the Bizovac Spa. Except for therapeutic application, water is also used for energy purposes in space heating lowering the temperature to 43°C, with recovery of separated gas. Geothermal field Bizovac comprises reservoirs Terme and A_3+A_4. Balance reserves of deposit Terme amounts to 3.17 kg/s, with a thermal power of 0.4 MW_t. For deposit A_3+A_4 balance reserves amount to 3.05 kg/s with thermal power 0.4 MW_t. Today, the geothermal water is produced via two production wells and one injection well, but current production is 5.5 kg/s. Reservoir A_3+A_4 is regionally developed and there is a possibility of expansion.

3.3. Geothermal Field Ivanić

Geothermal water reservoir Ivanić was discovered near the traditionally oil producing area at depth of 1,300 m. Water temperature at the wellhead is 60°C with a characteristic oily smell and is characterized as oily water with total mineralization of 15,035.2 mg/l. As such oily waters are known to be beneficial in treating different skin conditions and other health issues at the location was built Special hospital for skin and rheumatic diseases.

3.4. Geothermal Field Kutnjak-Lunjkovec

Geothermal reservoir Kutnjak-Lunjkovec was discovered during oil and gas research in the NW part of the Drava depression. Geothermal reservoir is formed in highly porous 117 m thick fractured carbonates of Triassic age at depth of 2,000 m. The thermal water contains 5 g/l of dissolved salts and 4.5 m^3/m^3 of dissolved gases (mainly CO_2 and methane). The projected average discharge in the field is 80 kg/s per each of the three wells, with the wellhead pressure of 3-5 bars, and the wellhead temperature of 125-140°C.

At the geothermal field Kutnjak-Lunjkovec expected production will include electric power generation (up to 10 MW_e in two phases), and direct heat utilisation in drying of agricultural products, individual space and district heating, bathing and other purposes (up to 125 MW_t). As there is no natural water inflow to the reservoir, used (cooled) geothermal water must be injected back into the reservoir. Geothermal water has balneological properties suitable for health prevention and post-traumatic rehabilitation.

3.5. Geothermal Field Velika Ciglena

Geothermal reservoir Velika Ciglena is made of a thick complex of carbonate rocks of Mesozoic age. So far, four deep wells reaching 2,526 to 4,790 m were built. The water temperature is 172°C and flow rate of 83 kg/s. Water contains a lot of dissolved gas (30 m^3/m^3) comprising 99.5% CO_2, and about 59 ppm H_2S. Study on reserves was confirmed in 2007, but the amount of water in the reservoir is about 167 million m^3. Optimization of the production of geothermal fluid are shown for the production and injection couple of two wells, VC-1a as a production, and VC-1 as an injection well. From these two wells, it is possible to produce 115 kg/s with wellhead pressure 20-25 bars and wellhead temperature of 165-170°C.

Construction of a geothermal power plant started recently and will use the largest ORC turbine in Europe, with electrical output of up to 16 MW. The power plant is expected to become operational during 2017. In second phase of the project is foreseen construction of a heating plant and 8 ha of greenhouses which should use the two remaining wells.

4. Overview of Current Geothermal Utilisation in Croatia

Geothermal energy is in the Republic of Croatia manly used in 18 spas and recreation centres for bathing and swimming and for different kinds of medical therapy treatments. Along with water use in pools there are several locations where thermal water is also used for individual space heating and greenhouses (Table 4.1). There is no electricity production from geothermal energy by now even though efforts are made in this direction.

In 23 locations with a developed direct use of geothermal energy from which a total direct heat capacity is placed slightly above 75 MW_t (Kolbah et al., 2016). Annual utilisation of thermal energy from all geothermal localities, calculated on the basis of the average capacity factor of 0.27, could reach nearly 650 TJ/yr.

Table 4.1.Utilisation of thermal waters in Croatia
Source: EIHP

<table>
<tr><th>Utilisation</th><th>Location</th><th>Utilisation</th><th>Location</th></tr>
<tr><td rowspan="2">Balneology</td><td rowspan="2">Bizovac Spa
Daruvar Spa
Naftalan Spa
Terme Jezerčica Spa
Krapinske Toplice Spa
Lešće Spa
Lipik Spa
Istarske toplice Spa
Stubičke Toplice Spa
Sv. Martin Spa
Topusko Spa
Tuhelj Spa
Varaždinske Toplice Spa
Velika Spa
Sutinske toplice Spa
Sveta Jana
Samobor Spa - Šmidhen
Zelina Spa</td><td>Greenhouses</td><td>Sv. Nedjelja
Bošnjaci
Krapinske Toplice</td></tr>
<tr><td>Individual space heating</td><td>Zagreb – University Hospital
Zagreb – Mladost
Zagreb – Lučko
Bizovac Spa
Krapinske Toplice Spa
Lipik Spa
Stubičke toplice Spa
Topusko Spa
Varaždinske toplice Spa</td></tr>
</table>

5. Overview of Projects under Development

In the last few years several domestic and international companies increased their activities regarding geothermal energy in Croatia. Most of activities have been directed to power generation especially at and around already existing production licenses at Lunjkovec-Kutnjak and Velika Ciglena geothermal fields. Hereto, ten new exploration licenses were approved (Figure 3.5.1) at: Draškovec, Prelog, Kotoriba, Legrad-1, Mali Bukovec, Ferdinandovac-1, Slatina, Babina Greda for electricity generation (

Table 3.5.1) and Bošnjaci - sjever and Sveta Nedelja in Zagreb area for direct use (Table 3.5.2).

Table 3.5.1. List of geothermal projects licenced for power generation
Source: EIHP

Locality	**Power Plant Name / Type**	**Expected Capacity Installed (MW_e)**	**License type**	**Holder of license**
Draškovec	Draškovec	3.1	Exploration license	AAT Geothermae d.o.o. (von Düring Group)
Prelog	Prelog	-	Exploration license	HOT ROCK ENERGY d.o.o.
Kotoriba	Kotoriba	5	Exploration license	MB Geothermal d.o.o. (BLT ENERJİ ELEKTRİK ENERJİSİ TOPTAN SATIŞ SANAYİ VE TİCARET ANONİM ŞİRKETİ, Turkey)
Legrad	Legrad-1	5	Exploration license	MB Geothermal d.o.o. (BLT ENERJİ ELEKTRİK ENERJİSİ TOPTAN SATIŞ SANAYİ VE TİCARET ANONİM ŞİRKETİ, Turkey)
Mali Bukovec	Mali Bukovec	5	Exploration license	*Republic of Croatia
Ferdinandovac	Ferdinandovac-1	5	Exploration license	MB Geothermal d.o.o. (BLT ENERJİ ELEKTRİK ENERJİSİ TOPTAN SATIŞ SANAYİ VE TİCARET ANONİM ŞİRKETİ, Turkey)
Slatina	Slatina	-	Exploration license	Dravacel d.o.o.
Babina Greda	Babina Greda	1	Exploration license	*Republic of Croatia
Lunjkovec-Kutnjak	Kutnjak	2.5	Production license	MB Geothermal d.o.o. (BLT ENERJİ ELEKTRİK ENERJİSİ TOPTAN SATIŞ SANAYİ VE TİCARET ANONİM ŞİRKETİ, Turkey)
Velika Ciglena	Marija 1	10	Production license	GEOEN d.o.o. and MB Geothermal d.o.o. (BLT ENERJİ ELEKTRİK ENERJİSİ TOPTAN SATIŞ SANAYİ VE TİCARET ANONİM ŞİRKETİ, Turkey)

Table 3.5.2. List of geothermal projects licenced for direct use
Source: EIHP. Based on data from the Ministry of Environmental Protection and Energy.

Locality	**Purpose**	**Expected Capacity Installed (MW_e)**	**License type**	**Holder of license**
Bošnjaci - sjever	Greenhouses	3.1	Exploration license	AAT Geothermae d.o.o. (von Düring Group)
Sveta Nedelja	Greenhouses	-	Exploration license	HOT ROCK ENERGY d.o.o.

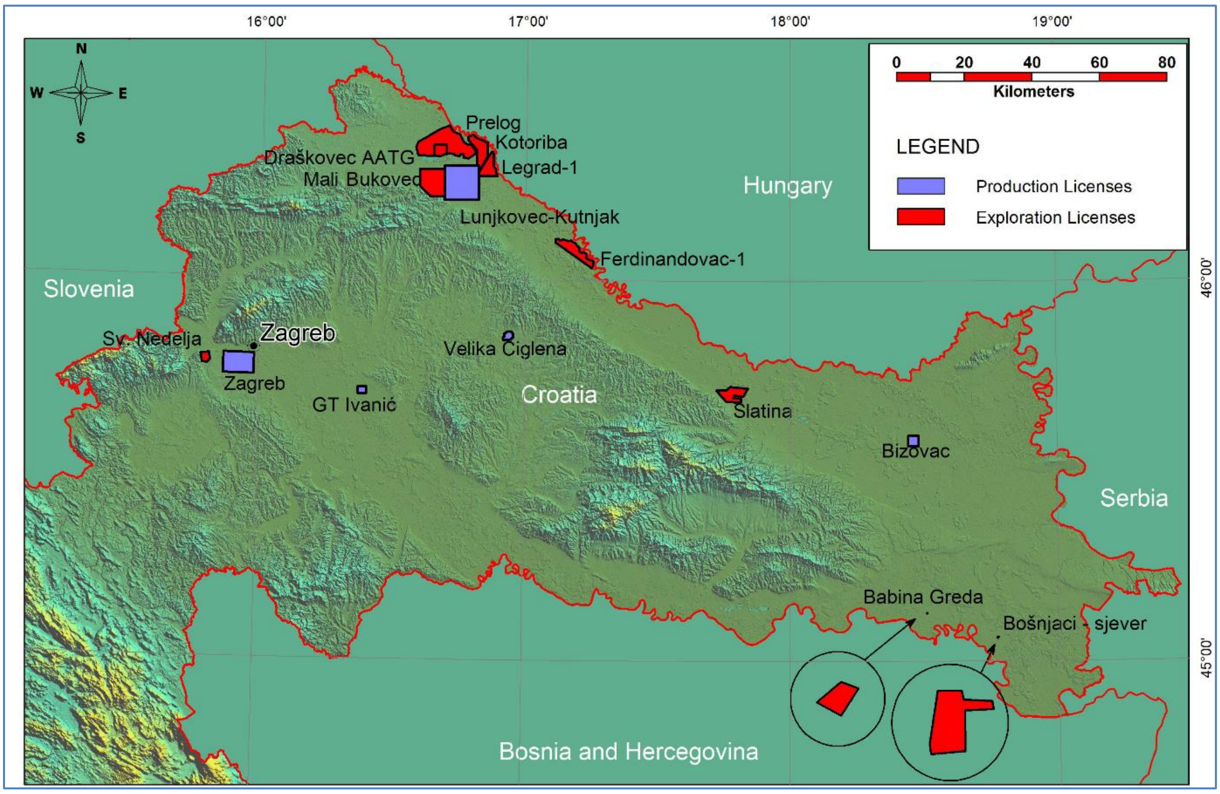

Figure 3.5.1. Location of geothermal exploration and production licenses issued in Croatia
Source: Kolbah et al., 2015

5.1. Direct Use Projects - Greenhouses

Utilisation of geothermal energy for direct heat has started to grow recently which is noticeable by growing number of exploration licenses: Bošnjaci sjever (Bos-1) and Sveta Nedelja (N-1). Even though capacities (3 MW_t at Bos-1; and 4 MW_t at N-1) and annual production are not significant they can be assumed as icebreaking projects which will hopefully be followed by many others. These two projects tend to transfer from exploration to a production phase, as during several years of testing their performances have shown geological, technological, economical, and environmental viability.

5.2. Power Generation Projects

Recently investors from Turkey have expressed their interest for building several geothermal power plants, and have already taken over three of existing exploration and two of existing production licenses at Kotoriba, Legrad-1, Ferdinandovac-1, Lunjkovec-Kutnjak and Velika Ciglena, all located in the NW of Croatia. Kotoriba, Legrad-1, and Mali Bukovec exploration fields are assigned based on results from adjacent Kutnjak-Lunjkovec geothermal production field with highly explored and elaborated wells Lunjkovec-1, Kutnjak-1 and Legrad-1. In all wells were found aquifers at depths between 1,700 and 3,000 m built of carbonate breccia with water temperatures 120-150°C. The whole area is having similar geological and hydrodynamic characteristics with an outstanding geothermal potential similar to the geothermal field Kutnjak – Lunjkovec. The area of Ferdinandovac municipality is characterized by exceptionally high geothermal gradient often over 0.055°C/m, reaching in places over 0.065°C/m. Temperature of thermal water is over 160°C. Geothermal well Ferdinandovac-1 has reached the aquifer with thermal water with a temperature of 125°C at depth of 2,223.5 m. Reservoir is found in Mesozoic and Miocene carbonate rocks with high porosity and permeability and excellent hydrodynamic features. Expected flow rate is 30 kg/s with temperature of 150°C.

The well Draškovec-1 was drilled to a depth of 4,200 m. The aquifer of geothermal water was found in the Miocene (Pontian) sandstones between 1,827 to 1,878 m. Flow rate to the surface is about 8 kg/s, and with the additional pumping approximately 25 kg/s. The temperature at the bottom of the borehole is 113°C, while at the wellhead between 70-77°C. Draškovec geothermal exploration area is operated by the AATG where the aquifer gas dissolved in the geothermal water, is used for electricity production.

6. Overview of Potential Geothermal Projects in Croatia

Table 6.1. List of locations in Croatia with potentials for geothermal usage

Source: EIHP

No.	Location	Resource Natural well, borehole	Temp.	Flow	Status Idea / Project / EL / PL / Concession	Proposed use
1	*Karlovac*	Boreholes Ka-2; Ka-3	140°C	50 kg/s	A. Project; B. Idea	A. Electricity generation; B. Upgrade of existing district heating system
2	*Vukovar*	Boreholes Vu-1-7	43-82	n.a.	A. Idea	A. Upgrade of existing district heating system
3	*Osijek*	Boreholes Biz-2; Biz-4	96.8°C	1.4 kg/s	A. Production license Bizovačke toplice in use B. Idea	A. Spa; Spa facilities heating B. Upgrade of existing district heating system
4	*Vinkovci*	Boreholes	n.a.	n.a.	A. Idea	A. Upgrade of existing district heating
5	*Križevci*	Borehole Kža-1	68°C	4 kg/s	A. Project	A. Local district heating
6	*Virovitica*	Borehole	-	-	A. Idea/Project	A. Local district heating; Direct use
7	*Bjelovar*	Boreholes VC-1 injection well; VC1T Production well	172°C	83 kg/s (7,200 m^3/day)	A. Production license Velika Ciglena	A. Electricity generation; possibility of new (local) district heating and direct use
8	*Legrad*	Boreholes Lun-1; Kt-1; Kt-2	140°C	53 kg/s	A. Production license Lunjkovec-Kutnjak	A. Electricity generation; possibility of new (local) district heating and direct use
9	*Varaždinske Toplice*	Natural well, borehole	57.6°C	35 kg/s	A. In use B. Project	A. Rehabilitation centre B. New spa
10	*Krapinske toplice*	Natural well, borehole	45°C	110 kg/s	A. In use B. Idea	A. Rehabilitation centre B. Direct use
11	*Lipik*	Natural well, borehole	58.2-63°C	6.8 kg/s	A. In use B. Project	A. Rehabilitation centre B. New spa
12	*Sisak*	Natural well, borehole DB-5, Sisak-1, Siter-1	65°C	151 kg/s	A. In use B. Idea	A. Rehabilitation centre B. Direct use
13	*Topusko*	Natural well, boreholes TEB-1; TEB-3, TEB-4	65°C	151 kg/s	A. In use B. Idea	A. Central heat station, spa B. Direct use
14	*Kloštar Podravski*	Natural well, borehole	n.a.	n.a.	A. Idea	A. Direct use
15	*Zagreb*	Boreholes KBZN-1B; KBNZ-1A	82°C	77 kg/s	A. Production license, In use B. Project	A. Individual space heating B. Direct use

6.1. Possible District Heating Projects

6.1.1. Karlovac

Karlovac is a city in the central Croatia, at the crossing from the Pannonian Basin towards Dinarides. Three boreholes were drilled about 8 km to the NE of Karlovac to the final depth of 3,500 m and 4,100 m, respectively. Perspective formation with water temperature of 140°C was reached 1,900 to 3,523 m in well Ka-3. The interval between 3,200 and 4,150 m in well Ka-2 was assumed as the injection interval for the cooled water. The third well Ka-1 didn't reach the carbonate aquifer.

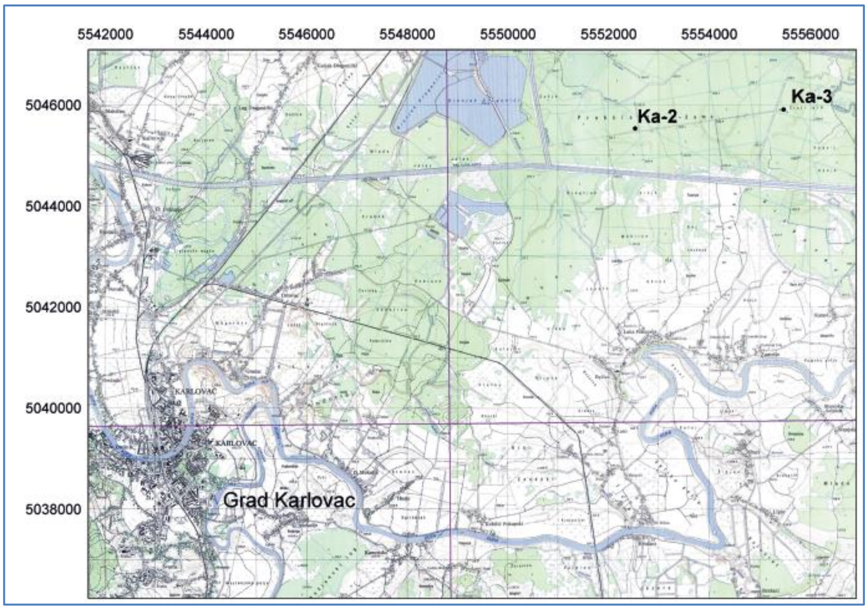

Figure 6.1.1.1. Situation map of the City of Karlovac
Source: Kurevija et al., 2010

Well Ka-3 was tested for the flow (20-50 m^3/h), salinity (0.99 g NaCl/l) and borehole temperature (87-94°C). As the main go for the drilling was oil exploration, the well was closed with cement barriers. The further tests were conducted in 2001 as a part of liquidation of the well.

From geological point of view, we can distinguish two different sediment formations of various geothermal potential (Kurevija et al., 2010). Clastic formation is built by sandstones, marls and silt. Water salinity in these deposits ranges from 17.5 to 21 g NaCl/l, indicating salt water. Although the water temperature of this formation reaches of up to 138°C, its geothermal potential is not large due to poor yields. Beneath clastic formation is a carbonate formation saturated with the water whit salinity less than 1 g NaCl/dm^3, with measured water temperature of 140°C in the reservoir. The large thickness and spread of the highly-fractured carbonates are indicating its high geothermal potential.

The carbonate formation reached by wells represents a far northern edge of the big Mesozoic carbonate platform which existed from the Permian to the end of the Cretaceous. The formations differ significantly in wells Ka-2 and Ka-3, which indicates they originated in very different environments. Borehole Ka-2 is located in the deepest part of Karlovac Basin, where the thickness of the Tertiary clastic sediments amounts to 3,000 m. The carbonates are rising toward well Ka-3 where Tertiary sediments are 1,567 m thick. In the well Ka-3 the reservoir temperature was estimated based on geothermal gradient to 133°C. Based on the well logging, showing porosity between 5% and 8%, bearing in mind secondary porosity of carbonates it can be concluded that this formation represents an excellent aquifer suitable for geothermal harnessing.

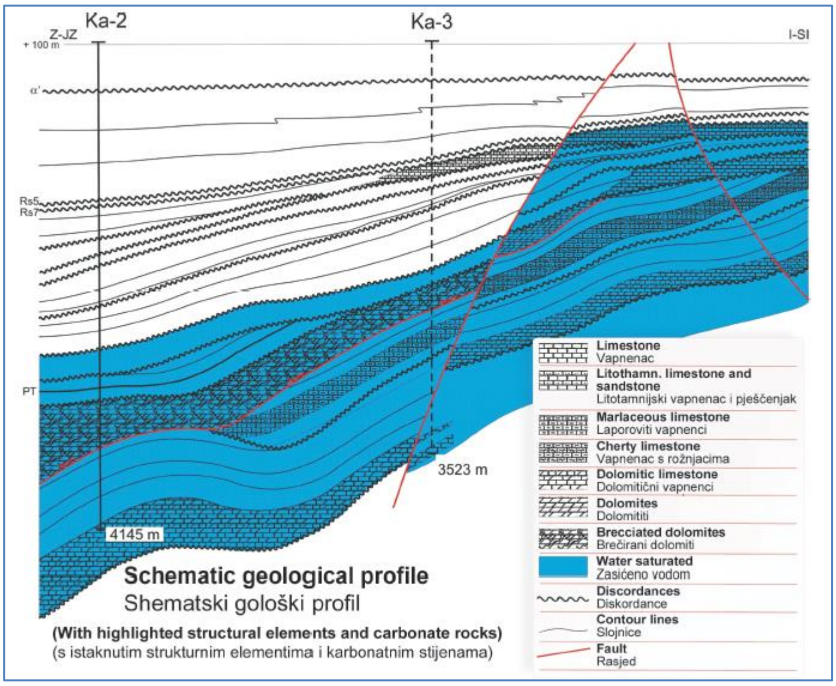

Figure 6.1.1.2. Schematic geological profile in the area of the City of Karlovac

Source: Kurevija et al., 2010

The wells are located in forest area under the direction of governmental company Hrvatske šume (Croatian Forests). The wells themselves are not in concession of any company, but equipment of the wells is owned by INA. At the location of these two wells a Turkish company MB Holding has filed request for exploration license. Also in the vicinity of this area another company has filed a request for another exploration license. Both licenses filed aim at electricity generation.

In case of district heating for Karlovac, there is an idea for new drillings closer to the City, as carbonate formation is much closer to the surface there, though the expected temperatures are lower but should be high enough for district heating.

Tender for exploration permits in the Karlovac area is currently being prepared.

6.1.2. Vukovar

Vukovar lies in high geothermal potential area of the Pannonian basin. Regional indicators support and high probability for finding a geothermal reservoir that could be used in Vukovar to support existing district heating system and for other projects. District heating system supplies about 3,600 households, comprising 3 closed systems, one independent system and two central thermal stations with modern infrastructure.

In the late 1950's during oil exploration several deep exploration wells were drilled in 4 km radius of Vukovar. Well-logging indicated geothermal gradients and indicated perspective intervals for finding geothermal water (

Table 6.1.2.1).

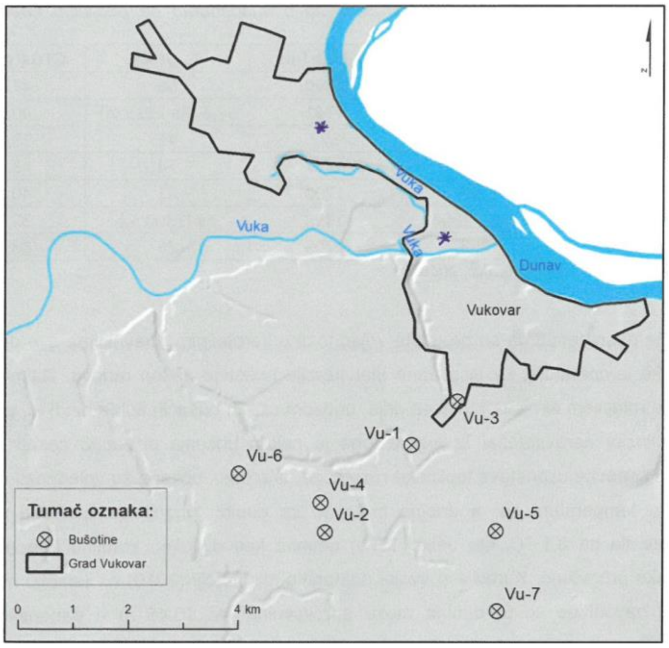

Figure 6.1.2.1. Location of deep wells in the vicinity of Vukovar
Source: Borović and Urumović, 2016

Table 6.1.2.1. Geothermal gradients and perspective intervals in wells near Vukovar
Source: Borović and Urumović, 2016

Well	**Depth** *(m)*	T_{max} *(°C)*	**Geothermal gradient** *(°C/km)*	**Perspective intervals** *(m)*
Vu-1	1,290	66	41.4	805-870; 1,103-1,285
Vu-2	1,741	57.6 (at 1,115 m)	40.4	1,100-1,160
Vu-3	877	42	33.5	820-880
Vu-4	1,421	74	43.3	1,080-1,130; 1,365-1,406
Vu-5	1,703	82	40.8	1,330-1,700
Vu-6	1,398	59 (at 1,330 m)	35.7	1,045-1,065
Vu-7	1,705	78	38.5	1,170-1,250

Geothermal waters were tested from well Vu-1 indicating sodium-chloride type water of low alkalinity (pH 7.8) (

Table 6.1.2.2). The combination of cations is referring to mature waters (Borović and Urumović, 2016).

Table 6.1.2.2. Chemical composition of waters from the well Vu-1
Source: Borović and Urumović, 2016

Well - Sample	Sampling interval	Na^+ and K^+	Ca^{2+} and Mg^{2+}	HCO_3^-	Cl^-	SO_4^{2-}	Salinity	pH
	(m)	*(mg/l)*					*(g/l NaCl)*	
Vu-1 - 1	1,052-1,065	8,864	3.01	9.50	81.50	0.45	4.90	7.8
Vu-1 - 2	1,087-1,105	103.95	1.56	9.54	93.40	2.57	5.50	7.8

About 15-20 km to the south of Vukovar several of exploration drills reached aquifers with water temperatures between 40°C and 130°C but they were not properly tested or even not tested at all.

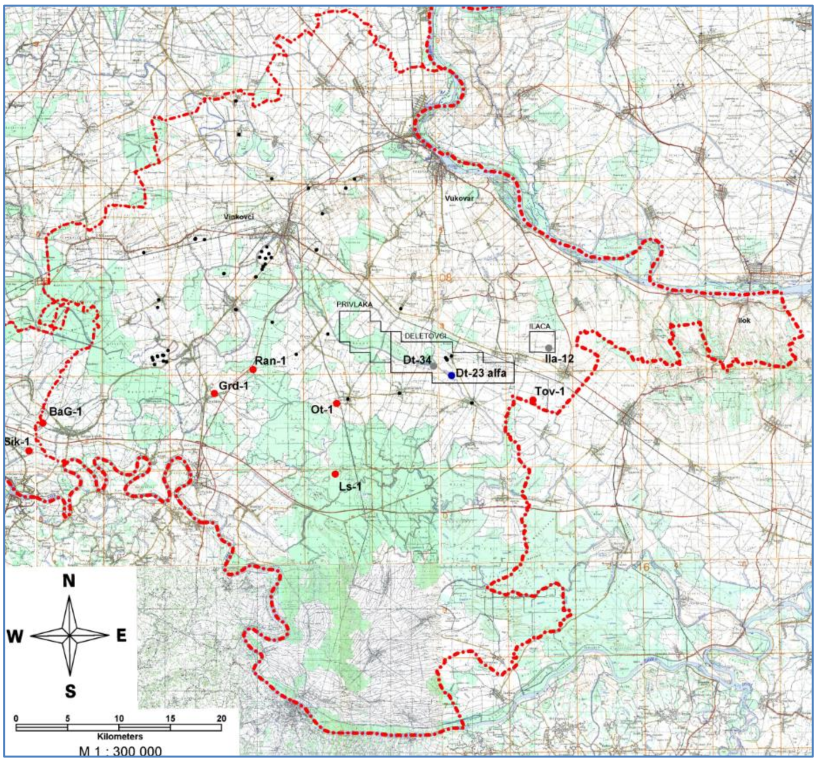

Figure 6.1.2.2. Deep wells in the Vukovar-Srijem County
Source: Getliher and Cazin, 2009

Table 6.1.2.3. Data on wells in Vukovar-Srijem County

Source: Getliher and Cazin, 2009

Location	Well	Depth of tested interval *(m)*	Capacity *(kg/s)*	Temp. *(°C)*	Possible purpose	State of the well	Remark
Ilača	Ila-12	764-773	0.11	43	-	Liquidated	Problems with access sand
Đeletovci	Đt-23α	450-453	0.31	40.2	High quality technologic al water	Liquidated	Small amounts of sand
	Đt-31	1,063-1,069	0.72	71	Geothermal	Oil production	-
	Đt-35	1,044-1,053	1.28			Measuring	
Babina Greda	BaG-1	1,571-1,585	1.75	110		Preserved	
		1,767-2,266	13.61	121			
Tovarnik	Tov-1	102-540	Not tested	-	High quality technologic al water	Liquidated	Well-logging data
		1,021-1,052	2.28	-	Geothermal		
Otok	Ot-1	2,635	Not tested	130		Liquidated, not restored	
Lešić	Lš-1	1,063-1,275		70			
Gradište	Grd-1	1,450-1,500		60			
Ranisavlje	Ran-1	2,965-3,000		130			
		3,063-3,078					

Regional potential is emphasized in Babina Greda, about 50 km to the SW, where testing was conducted in a 3,802 m deep well showing water with temperature of 110°C and with flow of 1.75 kg/s in the interval 1,571-1,585 m and of 121°C with flow of 13.67 kg/s in the interval 1,767-2,266 m. At the location was planned a geothermal power plant of 1.1 MW_e, greenhouses and recreational centre. The town of Babina Greda is also interested in development of district heating system.

6.1.3. Osijek

About 20 km to the west of Osijek is previously described Geothermal field Bizovac with popular Bizovac Spa. During oil and gas exploration in the second half of 20th century, a number of well were drilled in the region, some of which discovered hydro-thermal reservoirs. Due to geological properties of the region, there is a fair chance of finding hydro-thermal reservoirs in the vicinity of the City. At least ten deep wells were drilled within 15 km from Osijek, and several of them were positive to geothermal water with temperatures up to 100°C or higher. The available data about analyses done on wells should be examined, and possibly exploratory work should be carried out or repeated where needed to assess the potential reservoir. Also, given the state of wells new drills might be required.

6.1.4. Vinkovci

During oil exploration period, more than ten wells were drilled close to Vinkovci, 3 to 19 km away from the City. High geothermal potential is indicated by thermal water found in several exploration wells, but also by previously mentioned Babina Greda site. The find of an aquifer close to the City might contribute to upgrade of the existing district heating system.

6.2. Possible Local District Heating Projects

6.2.1. Križevci

An oil exploration well has reached geothermal aquifer in the very centre of the Town of Križevci. Testing was conducted in two phases: in the late 80's, and in 2008. In the first phase, geothermal fluid was found at depth of 1,496 m having water temperature of 65°C and flow of 4 kg/s. In the second phase at 1,052 m was found water with temperature of 83.9°C at the reservoir pressure of 103 bars.

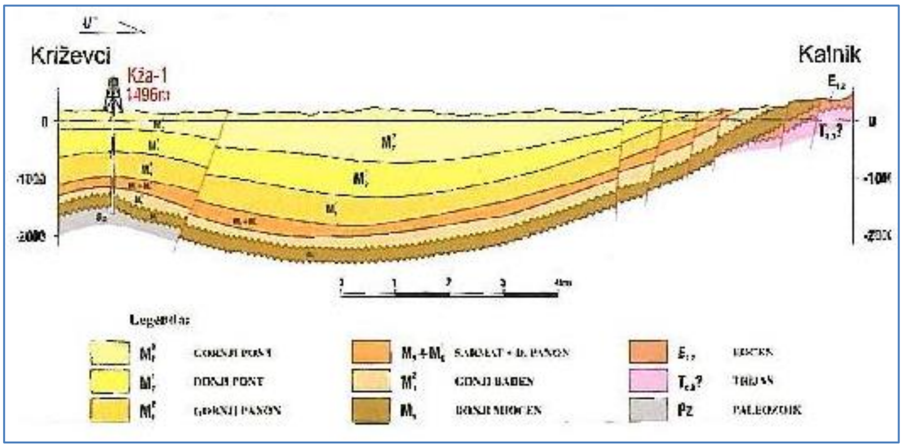

Figure 6.2.1.1. Geological profile of the Križevci area

Source: Šimunić (ed.), 2008

In the very vicinity of the well are three schools, gymnasium and a public pool. There are also greenhouses as part of the agriculture department of the High school and College of agriculture.

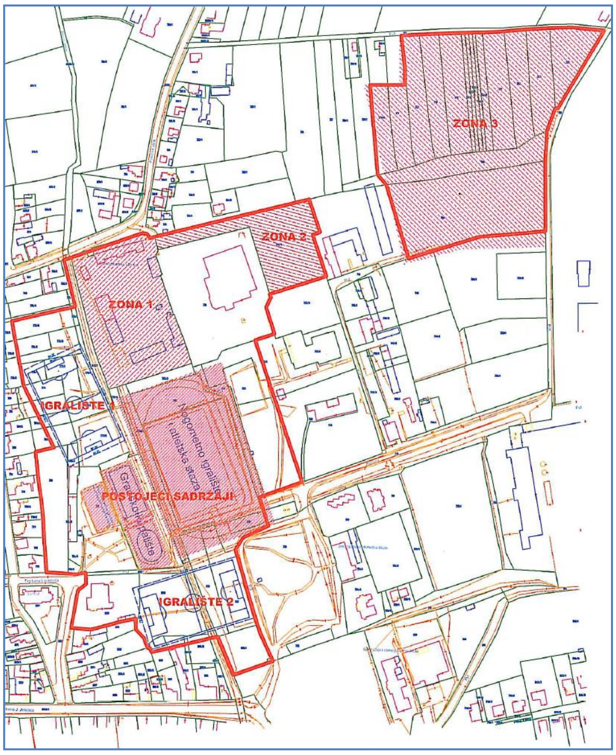

Figure 6.2.1.2. Map of Križevci with potential objects for geothermal energy use

Source: Šimunić (ed.), 2008

The idea to construct a district heating system that would provide heat for space heating of these objects needs to take into account drilling of an injection well. Preliminary study of geothermal energy use was made by EFLA in the summer of 2009, and was followed by conceptual idea for one-year study of the well made by HEP ESCO and Factus. A feasibility study of geothermal potential use has been done by the Energy Institute Hrvoje Požar in 2012.

The conclusions of these studies are:

- The geothermal well could produce 300-400 m^3/day (3.5-4.6 kg/s) for many years,
- The well Kža-1 was estimated between 750 and 1,000 kW,
- Utilisation of the geothermal well is feasible for district heating of the public buildings, and heating of nearby swimming pool.

6.2.2. Virovitica

Virovitica situated is close to high geothermal potential area of geothermal field Velika Ciglena. Local geothermal potential of the City analysed in the recent study that included four potential consuming locations within the City limits:

1. Industrial Zone West I,
2. Sport and recreation zone Vojarna,
3. Industrial Zone Southeast III,
4. Geothermal field Virovitica.

Specialized interpretation of available data indicated a number of potential reservoirs in sandstones with expected temperatures between 60°C and 75°C+ from the depths of 800-1,700 m. Capacities are expected at 1,000-3,000 m^3/day with help of centrifugal deep well pumps. Potential reservoirs in carbonate rocks with secondary porosity could provide high capacity reservoirs with water temperatures higher than 140°C even suitable for power generation. Determination of such reservoirs should be carried out using an abandoned well close to Virovitica. However, confirmation of size of the reservoir, its characteristics and reserves, as well as the quality of the water, its temperature and energy is to make a new exploration well. It is definitely justified due to high interest of customers for geothermal energy and certain consumers in four industrial zones.

6.2.3. Bjelovar

Bjelovar lies in the area of high geothermal potential. Only eight kilometres from the City is located geothermal field Velika Ciglena with highest geothermal water temperatures recorded in Croatia, up to 170°C. Geothermal exploration licence is issued to company GEOEN for the geothermal locality with two wells prepared for production, and two others for injection. In Velika Ciglena the geothermal power plant is in development. Business zone is being developed with anticipated new geothermal power plant, greenhouses, vegetable drying facilities, refrigerators, recreation park with swimming pool, district heating of Bjelovar etc.

In the centre of Bjelovar close to swimming pool is an indication of shallow geothermal reservoir with expected temperatures of 30°C. In Veliko Korenovo village, 3 km away from Bjelovar is a natural thermal outlet (ca. 5 kg/s) of water with 30°C. After carrying out basic geological research, the well was drilled for the harnessing of the technical water for a farm in Veliko Korenovo.

6.2.4. Legrad/Koprivnica

Koprivnica and Legrad are situated in the vicinity of geothermal field Lunkovec-Kutnjak. The whole area lies on a large geothermal potential recorded in wells Lun-1; Kt-1; Kt-2 with water temperatures of 140°C, and capacity of 53 kg/s. The geothermal water contains 4.5 m^3 of gas dissolved in 1 m^3 of water - mostly CO_2 and some methane. The exploration licence was issued to MB Geothermal company for both geothermal fields. There are plans for building geothermal power plant. The excess heat possible uses include building of district heating system for the nearby cities or business zones.

6.3. Possible Spa and Individual Heating Projects

6.3.1. Varaždinske Toplice

The natural thermal spring Klokot in Varaždinske Toplice had been used since the 1st century as spa. The water temperature is 57.6°C and has a high mineralization and high sulphur content. Capacity of the well is 35 kg/s. Three more colder sub-thermal springs (24-25°C) were registered to the west, up to 1,100 m from the Klokot. In the early 60's 55 m deep well B-1 was drilled next to Klokot, having highest flow of thermal water from depth between 20 and 26 m at the contact of tuff and dolomites which are in the base. Well B-2 was drilled up to 66.5 m but even though in the course of drilling some of thermal water was recorded it didn't reach the wellhead. About 13 m to the south-east of well B-1 was drilled another well, B-3. T well was drilled to 34.5 m depth and discovered thermal water of 57.5°C. At the same time, well B-4 was drilled finding water of 56°C at 15 m depth.

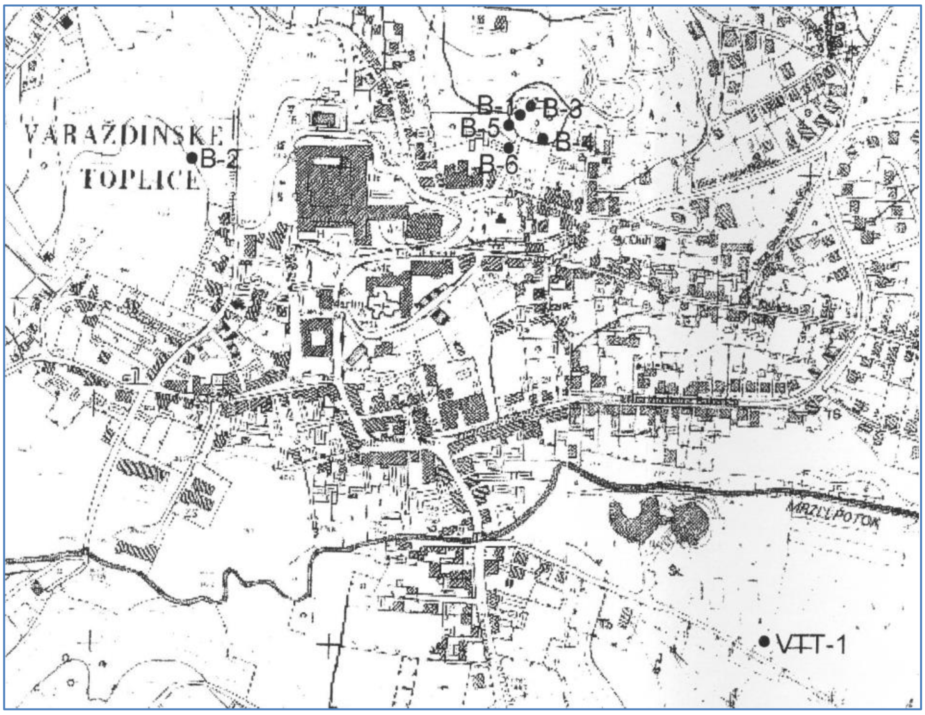

Figure 6.3.1.1. Situation map of Varaždinske Toplice

Source: Final report on works conducted at rehabilitation of geothermal water well in Special hospital for medical rehabilitation Varaždinske Toplice, Crosco, Naftni servisi, 2006

In the late 80's, geothermal exploratory well VTT-1 was drilled to depth of 605.04 m next to primary school, 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 small amounts, up to 1 kg/s.

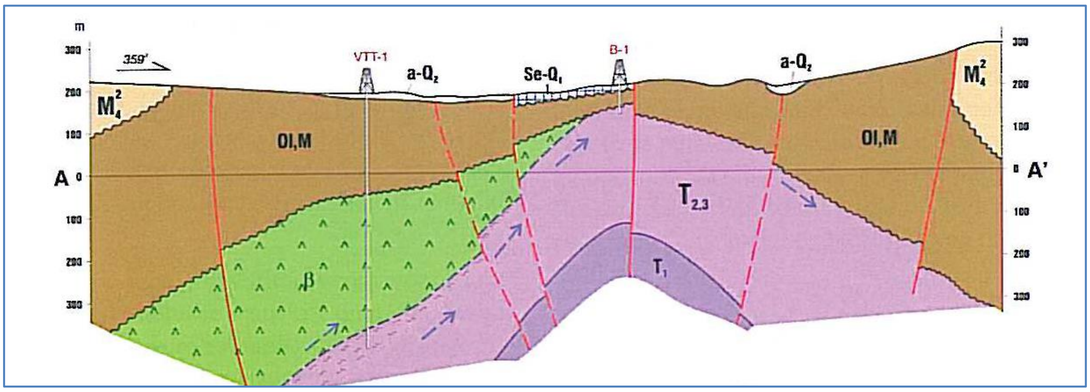

Figure 6.3.1.2. Geological profile of Varaždinske Toplice area
Source: Šimunić (ed.), 2008

In the late 90's the four old wells were investigated in order to determine the state of wells and water pipelines as well as sewage pipelines for recovery works. The temperature in B-1 was 58-59°C with capacity of 22 kg/s. Well B-3 was recorded to be buried up to 17 m, having water temperature of 57°C at the wellhead and 58°C at the bottom. Well B-4 was not in use, but after rehabilitation of the well thermal water overflew with temperature of 54°C. Average capacity of this well is 6.7 kg/s. Capacity of all three wells (B-1 + B-3 + B-4) was measured to 27.7 kg/s. Certain recommendations were given at the end of report considering lowering of pipelines and wellhead of B-1, cleaning od sediments that fill the boreholes in all three wells etc.

As wells are located in archaeological site of old Roman Spa the idea of new project in 2000 was to drill a new well for supply of thermal water to the Special hospital for medical rehabilitation. New well, B-5, was drilled close to B-1 to 35 m having temperatures up to 46.9°C with capacity about 20 kg/s. Few days later, another exploration-production well was drilled to depth of 49 m. Capacity of the well was estimated after airlifting to 25 kg/s with temperature of the water at 38.5°C.

The first pumping test was conducted at the well B-6 in 2006. Pumping at 15 kg/s proved mutual influence between B-6 and B-1 (and probably also B-3 and B-5 which could not have been measured). The difficulties during testing arose due to use of thermal water for hospital's needs. In the later phase of testing pump was drowned to 10.45 m enabling increase of capacity to 25 kg/s. Testing with pumping 20-22 kg/s influenced temperature of the water which decreased to 35.9°C, but the testing was terminated because the water level dropped beneath the deepest pump position possible according to diameter of column in the well. At the time of testing the temperature at the well B-1 remained 59.6°C.

Geothermal water is used in for Special hospital for rehabilitation balneology and space heating, and there is a need to rehabilitate the existing system and improve its efficiency.

There is an interest for widen uses of geothermal water to individual or district heating, heating of swimming pools and greenhouses in accordance to the capacity of the well.

There is also an idea of building a commercial spa in the vicinity of the town centre, for which a project already exists.

6.3.2. Krapinske Toplice

Three stronger and few weaker natural springs of thermal water were situated near the spring in town of Krapinske Toplice. The water temperature was 40°C, and it's rich in hydrogen sulphide. At the end of 18th century fist pool was built, and in 1862 the first hotel. In the mid-1980's additional tests were conducted and a new well was drilled to a depth of 861 m with capacity of 30 kg/s and temperature to 45°C. Pumping test of water from the well showed no change of the capacity of nearby springs indicating that thermal water is coming from different layers. Even though water discovered in deeper layers had higher temperatures, 56-60°C, until today there was no attempt to use this warmer water.

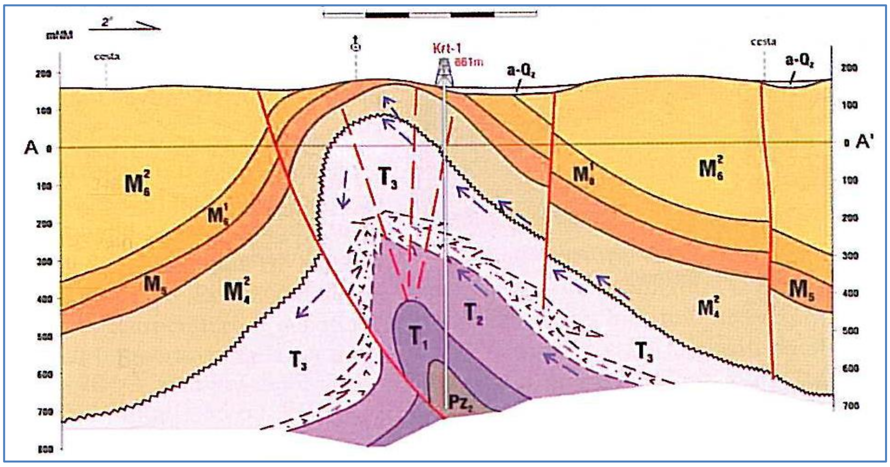

Figure 6.3.2.3. Schematic geological profile in the area of Krapinske Toplice
Source: Šimunić (ed.), 2008

Today, Krapinske Toplice are developed into an important health-tourism centre.

The water is now used in:

- the Special hospital for medical rehabilitation Krapinske Toplice which uses geothermal water for the heat pump but also uses water in therapeutic treatments,
- Clinic Magdalena next to Special hospital also uses geothermal water for space heating,
- New aquapark *Aquae vivae* which extends to 18,000 m^2 of closed space is heated exclusively to geothermal water heating,
- Thermal water is used in water supply distribution system connecting 271 households.

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.

Development strategy of Krapinske Toplice municipality anticipates increase of efficiency use of geothermal potential in Krapinske Toplice in use of geothermal water for heating of public buildings which are in a few hundred-meter radius from the main well. There is a project of rehabilitation of heating system in hotel Toplice due to outdated equipment. Project exist for building a new tourist resort with 100 beds with anticipated use of geothermal water.

The holders of exploitation licence are Special hospital for medical rehabilitation Krapinske Toplice and company Samek Ltd. Part of the licence is transferred to company Aquae vivae Ltd. which is the owner of the Aqaupark.

Project database of Zagorje development agency includes a project proposal about use of geothermal water in Krapinske Toplice as an energy source.

6.3.3. Lipik

At the area of Lipik are present several natural thermal springs that had been developed since the late 19th century when first well was drilled to the depth of 235 m. The well reached water with temperature of 58-63°C with the flow of 12-16 kg/s that satisfied the needs of Lipik Spa until mid-20th century. In the 1960's, six more wells were drilled, of which two increased spring flows leading to bottling of water for drinking. To meet the needs of bottling factory two more wells were drilled in 1972 (B-7 to depth of 214 m and B-8 to depth of 379 m). The geothermal water is used in Special hospital for medical rehabilitation for medical purposes and for space heating using heat pumps. The heating system is quite outdated and need to be renewed to be more efficient.

In the beginning of 90’s deep exploration well was drilled up to 720 m reaching thermal water in limestones with the temperature of 60°C, flow of 5 kg/s and constant occurrence of gas. The well is currently not in use and was meant to be the base for further development of rehabilitation and recreational tourism of the town.

6.3.4. Sisak

There are four thermal wells in the city area. Three of them are located in the very centre of the city, and fourth is located abbot 2-3 km away. The well DB-5 has been used until 1991 for Iodine rehabilitation centre Sisak, where specific composition of water rich in Iodine is used in rehabilitation and treatment of dermatological conditions. The capacity of the well is 4.6 kg/s with water temperature of 48-55°C. The well DB-3 is located in the Bok village, having capacity of 0.3 kg/s and water temperature of 53°C. The well SI-1 has capacity of 3.9 kg/s with pressure at the surface between five and six bars, and temperature of 48-55°C. The well SITER-1 is having capacity of 16 kg/s and water temperature of 51°C, with surface pressure of two bars.

The thermal water is not used except in the rehabilitation centre, but there are ideas for its use in heating of the swimming pool.

6.3.5. Topusko

Topusko lies about 50 km to the SW of Sisak. The city is famous from the Roman times for its thermo-mineral water. Today a rehabilitation centre is supplied with water from three shallow wells (150-248 m). The flow of all three wells is estimated to 151 kg/s, and the temperatures are about 64-68°C. The water is also used for space heating of the rehabilitation centre, several restaurants and 50 apartments.

6.4. Possible Direct Use Projects

6.4.1. Kloštar Podravski

The Kloštar Podravski town also lies in the very perspective geothermal area having a well drilled in the very vicinity of the town. There is an idea to put geothermal resource in use but there are no plans for now.

6.4.2. Zagreb

Recently, the licence for additional exploration at geothermal field Zagreb was issued to GPC Instrumentation Process d.o.o., Zagreb. Further development of the resource is not yet determined.

II. INFORMATION ON DISTRICT HEATING IN PROMISING LOCATIONS

7. Krapinske Toplice

Krapinske Toplice has used geothermal for over 150 years. There is a free flowing well in the area with 80 kg/s at 40°C, which is used for a health care centre where rehabilitation and treatment is the major activity. The Krapinske Toplice health care centre is well connected to a team of doctors and nurses for the rehabilitation treatment. The representatives from Krapinske Toplice indicated that they plan to build a new hotel and spa.

In Krapinske Toplice, there are three natural spa pools and the heat source is 80 kg/s of 39-41°C from free flowing, “artesian” geothermal wells. The health centre 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 kg/s at 32-33°C. The geothermal system for the greenhouses is a pumped system with an 800 m deep well for the hot water production and all of the geothermal water is reinjected in another geothermal well in the nearby area.

In the Krapinske area are currently 227 households that use about 500 m^3 of water per month and a waterpark which is supported by geothermal water at 41-55°C and flow rate of about 51 kg/s. The waterpark has around 120,000 visitors from April to end of each year. The geothermal water is from two wells one owned by Ina covering 23 kg/s and rest from spa centre. In the Krapinske area are around 1,500 households of which about 400 are around the health centre. There is an expected increase of 170 households in the next years.

The households use a $\Delta T = 30°C$ for heating the estimated area, around 25,000 m^2, and use about 2.5 TWh/year. The representatives, of the Krapinske Toplice, informed that they have a concession in the area for harnessing geothermal water and it expires in the year 2020.

8. Križevci

The officials of Križevci were interested in making a changeover to renewable energy as much as possible. Testing, made few years back, of an existing well gave a highest outflow of 390 m^3/day (4.5 kg/s) with a level reduction of 53 m and a temperature of 68°C. In light of these values it is assumed that the existing well can produce between 300 and 400 m^3/day of at least 68°C hot water for many years which means that it could support heating of at least 700 kW for housing in the nearby area.

Figure 8.1. Geothermal well in Križevci

Table 8.1. Heat and well flow requirement for heating of public buildings and swimming pool in Križevci

Source: EFLA

	Ljudevit Modec	Visoko gospodarsko uciliste	Ivana Zakmardija Dijankoveckog	Swimming pool (450 m^3)	Total
Area [m^2]	2,484	1,820	1,908	N/A	**6,212**
Heating Requirement [kW]	62	46	48	225	**381**
Eq. well flow [m^3/day]	28	21	22	103	**174**

According to Table 8.1, the existing well can support heating of the nearby housing and the swimming pool with only 50% of the capacity of the geothermal well. It is estimated that the geothermal well at Križevci can support additional heating of 300 kW, which is suitable for heating at least 35-45 buildings if a district heating system is established and connected to private homes in the area. It is recommended to plan a long term well test and evaluate the feasibility of drilling a new reinjection well for the return water from the possible district heating system.

The Križevci community has around 6,500 households and each household pays about 1,000 EUR a year for heating of each 100 m^2.

9. Varaždinske Toplice

The management of the Varaždinske Toplice introduced the activity and daily routine of the health centre where geothermal plays a major role in the health care of the visitors. Varaždinske Toplice owns an artesian well that is situated in a historical site in the nearby area of the spa and pool systems.

The hotel is around 44,000 m^2 and the spa system is around 30,000 m^2 where the buildings are heated with geothermal water from two active wells in the area. Varaždinske Toplice have drilled few wells for the existing hotel and spa with a possible extension of buildings in the near future. The additional wells are not connected to the heating system but they are estimated to have a capacity to flow 350 m^3/day, currently discharging into the "river". Existing geothermal wells that are connected to the heating system do not support the current heating requirements at the Varaždinske Toplice. The additional heating needed is gained from ground source heat pumps and a backup system of natural gas burners.

Figure 9.1. Geothermal drinking fountain

The hotel and spa community includes around 2,000 households that need to be heated at least seven months a year and there are around 26,000 guests that stay at the health centre each year. The Varaždinske Toplice management estimate that using natural gas for heating covers about 60% of the heating demand for the health centre and spa. The Varaždinske Toplice management informed that they are planning to build a 5-star service hotel for the next extension of the health and spa centre that will need additional pools and heating.

Figure 9.2. Artesian well in Varaždinske Toplice

The Varaždinske Toplice has utilised the natural resource for the health centre and extended the geothermal utilisation well. Considering the amount of free flowing geothermal water at reasonable temperature, the overall energy efficiency for the Varaždinske Toplice might be improved to increase utilisation of the existing geothermal water at 58°C and 35 kg/s free flow. The available geothermal energy from the free flowing geothermal water to the river is 3,600 kW, which could be utilised from 58°C down to 25-30°C for heating of the health centre, spa and pools.

It is considered likely that the geothermal water resource is able to support much more heating if the resource is managed correctly and the additional wells are connected to the heating system.

III. FEASIBILITY STUDY FOR GEOTHERMAL DISTRICT HEATING OF THE SELECTED LOCATIONS

10. Karlovac

10.1. District heating

Karlovac has good geothermal potential according to the available data from a few existing boreholes. The geothermal area around wells, Ka-2 and Ka-3, is around 8-10 km from the city and is favourable for utilisation of the geothermal water for district heating system for house heating, hotel and spa systems, green houses, fish farming or other industries. The existing data show that Ka-2 and Ka-3, drilled in 1983 and 1988, have measured temperatures up to 140°C and a possible flow of 50 kg/s. The temperature and flow indicates a good geothermal resource.

If the wells in the Karlovac geothermal field show a possible 50 kg/s flow at 140°C as expected then it is possible to use the 50 kg/s geothermal water to support at least 1,500 kW electrical production by cooling the geothermal water down to 80-90°C with a Binary system (Figure 10.1.1).

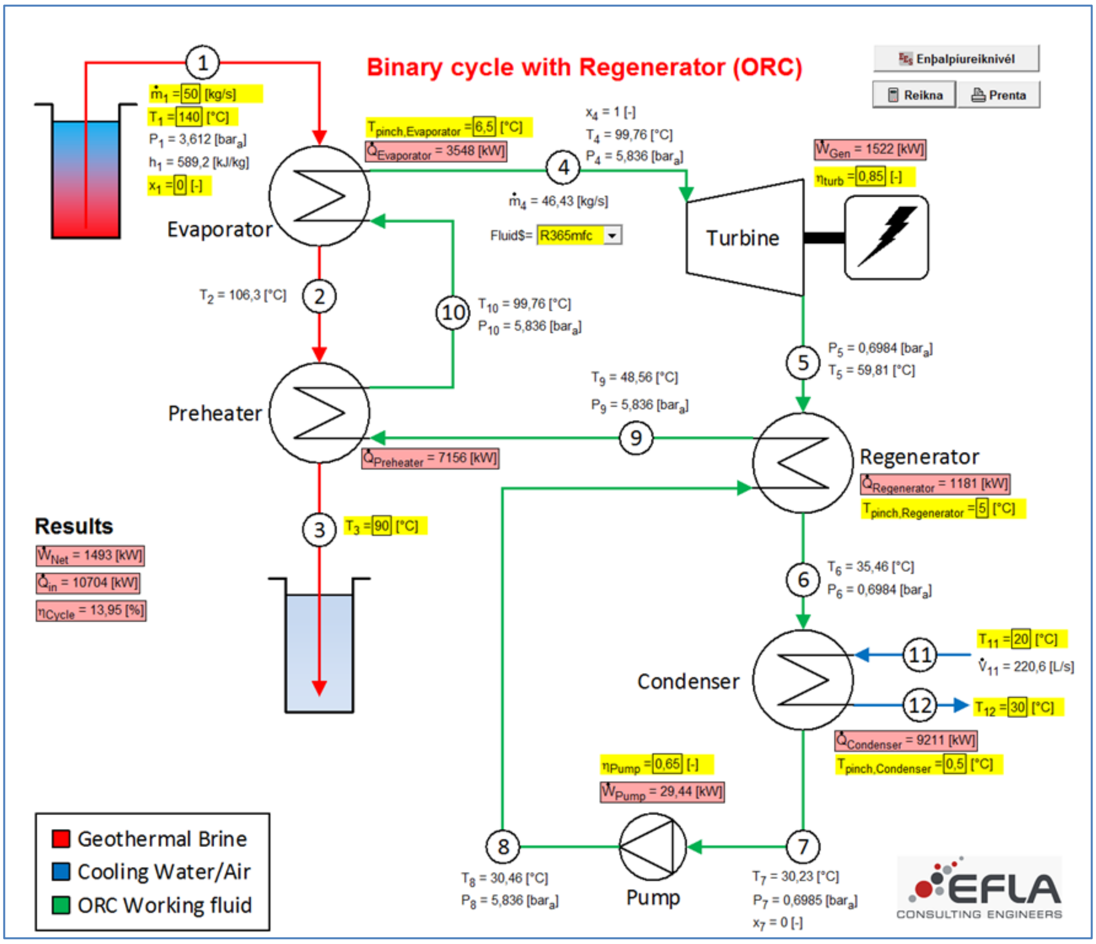

Figure 10.1.1. Process flow for binary cycle for electrical production
Source: EFLA

The return geothermal water from the ORC system can support at least 8,400 kW of 80°C thermal water delivered to the district heating system that can utilise the geothermal water down to 40°C.

The district heating company is running on a 40-year-old fossil fuel boilers that have recently been refurbished to use natural gas as the heat source for the district heating system. The district heating central is designed to cover about 50% of the heat demand for the population of 55,700 individuals in Karlovac. The district heating company has built up 3×13 MW boilers and at the time of the visit (7 November 2016) only one boiler was running and burning 1,217 kg/h of natural gas for the delivery of 12.9 MW to the district heating system.

The boilers are long past normal lifetime and the district heating company can expect a sudden shutdown or a major failure of the boilers main equipment or material. At the time of the visit, one boiler circulation was running at an outlet temperature of 118°C for the district heating system heat exchanger and the boiler return water was 100°C entering the boiler. The total flow pumped to the district heating system was 594 m^3/h and the boiler temperature, inlet/outlet, was only 18°C, resulting in an energy consumption of 12.6 MW used for the district heating system. The high temperature boiler outlet and the small temperature difference between inlet and outlet over the heat exchanger makes the boiler and the distribution system insufficient. The district heating system was running on a +55°C and the exhausting gas from the boiler was 151°C at the same time. There is a need to review the energy efficiency for the district heating company. It was losing over 15 m^3/h of water from the district heating system because of a leakage. That makes the system less efficient because of the constant need for preheating groundwater up to 60°C and inject it to the circulation system. The process of preheating of 15 m^3/h from 10°C up to a final return temperature of 55°C calls for 800 kW in thermal energy to cover the leakage. It should be of prime interest for the district heating company of Karlovac refurbish the leakage to save fossil fuel.

It is highly possible to use water from the existing geothermal wells in Karlovac (Ka-2 and Ka-3) to support at least 50% the district heating system or 21 MW of the total 39 MW, which is installed at the Karlovac heating central. By connecting the geothermal wells to the Karlovac district heating system, it is possible to save considerable amounts of fossil fuel (gas).

It is also clear that the city of Karlovac needs to establish a working group that will focus on energy efficiency to save fossil fuel in the heat central with the future goal to change over from fossil fuel to renewable energy (geothermal hot water).

10.2. Geothermal Reservoir

A map showing Karlovac area and the location of wells Ka-2 and Ka-3 is presented in Figure 6.1.1.1. Available data shows that Ka-2 and Ka-3 are sufficiently permeable to provide hot water at high enough rates for district heating. The available data for the deep exploration wells at the Karlovac geothermal area suggest a reservoir temperature of 140°C. However, the existing data shows that tests were performed mainly to find traces of oil in the area and well testing was not aimed at determining the maximum flow of geothermal water available from each well. Seismic data processing, focusing on wells Ka-1, Ka-2 and Ka-3, was also made and gives insight into the subsurface structure and its potentials.

10.3. Geothermal Utilisation Concept Design at Karlovac

Following is a description of possible geothermal utilisation concept for Karlovac and is based on very limited information. As the geothermal resource is at medium temperature, cogeneration process is possible, that is electricity and thermal heat production. A process flow for cogeneration is presented in Figure 10.3.1. This concept utilises the hot geothermal fluid for electricity production and the downstream brine from the electrical production is used to heat up water for the district heating system. It is also possible to utilise the downstream brine further for green house or other industries.

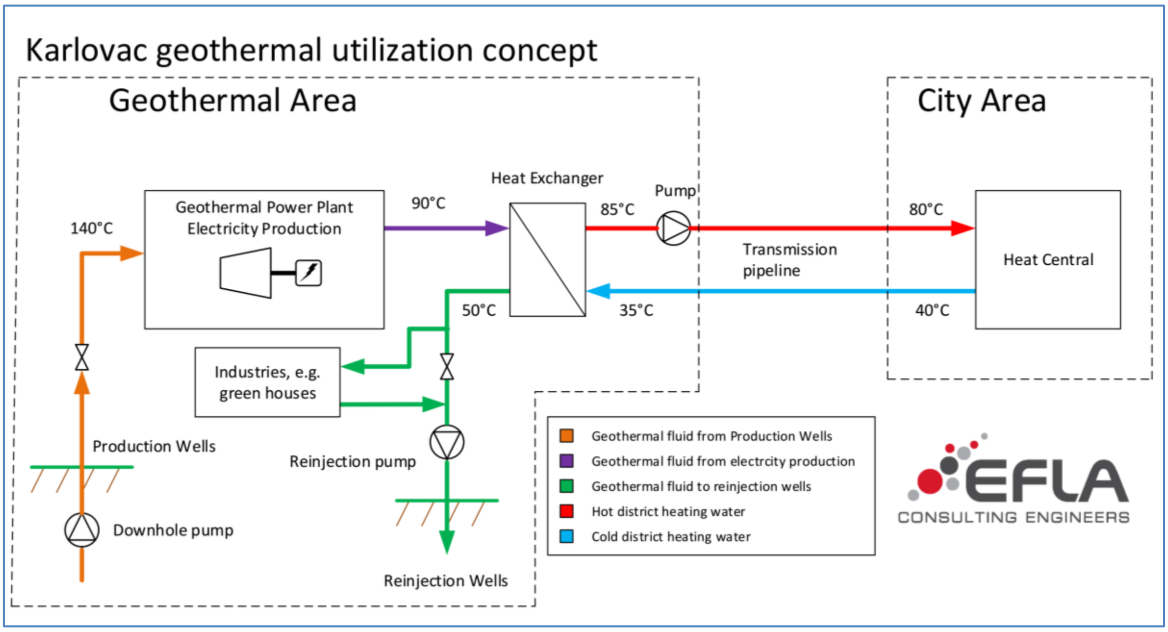

Figure 10.3.1. Karlovac geothermal cogeneration utilisation concept, more risk
Source: EFLA

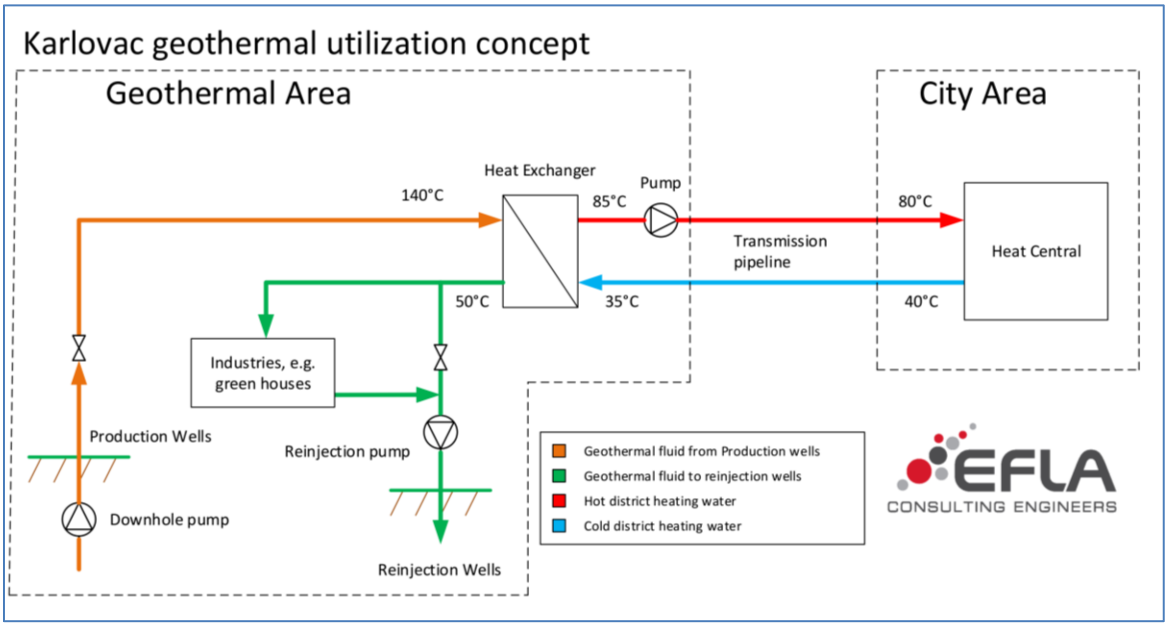

Figure 10.3.2. Karlovac geothermal heating concept, less risk
Source: EFLA

The cogeneration concept requires great deal of technical knowledge to manage the complexity of the electrical and district heating system. Bearing in mind that the use and knowledge of utilising geothermal energy in Croatia is in the early stages of know-how and therefore decided by the project group not to include cogeneration study into this report, it can be added to the system at later stages.

More conservative approach for utilisation of the geothermal resource at Karlovac with less risk is to build up the geothermal system in stages. As a phase 1 it is recommended to do a test investigation of the geothermal area before starting the actual construction of the geothermal district heating for Karlovac. It is viable to re-enter either well Ka-2 or Ka-3 with a drilling rig to clean out the well before inserting a deep well pump with a capacity of at least 50 kg/s, which can be used as a main production pump for Karlovac district heating system for the next phase of the project. If the outcome of the testing procedure shows a good reservoir that can support heating of Karlovac then phase 2 will be planned to construct the pipeline to Karlovac. A long-term study on the reactions of the geothermal resource after start-up of phase two will help to determine if the resource is capable of supporting the heating capacity in Karlovac in a sustainable matter. After a few years of at 50%-100% heating of Karlovac then it can be reviewed if it is feasible to install an electrical generation equipment as phase 3. A simple process flow diagram for the Karlovac geothermal heating concept is presented in Figure 10.3.2.

The existing heat central for Karlovac is rated at 40-50 MW thermal power. In the second phase of the geothermal heating utilisation concept for Karlovac we assume that 20 MW of thermal power supplied from the geothermal field to Karlovac heat central. It is assumed that an existing production well will be sufficient. The production well is installed with downhole pump with line shaft and a motor on surface. It is assumed that one reinjection wells are sufficient. This is depending on the assumption that Ka-1 or Ka-2 are/is usable as a reinjection well.

The district heating is only operated seven months of the year and assumed operation is 4000h. A new transmission pipeline needs to be built to connect the geothermal area to the heat central and length is estimated to be 8 km. Rough cost estimate is 4.75 MEUR for refurbishment of the existing well (Ka-2 or Ka-3) and a connection to the heat central.

Table 10.3.1. Cost estimate breakdown of the utilisation concept for Karlovac
Source: EFLA

Karlovac	**Amount**
Phase 1	
Refurbishment and testing	1,000,000 EUR
Phase 2	
Connection to heat central	3,750,000 EUR
Total	**4,750,000 EUR**

In table 10.3.2. is the levelized cost of thermal energy in Karlovac estimated in terms of refurbishing and testing at least two wells, connecting pipelines to and from the heating central at Karlovac and supplying 50% of the current heating capacity:

Table 2.3.2. Assumption and estimated levelized cost for 50% of the current heating capacity in Karlovac

Source: EFLA

Location	Karlovac	
Type	Geothermal	
Description	Heat production	
Items	Value	Unit
Thermal energy	80.0	GWh/year
Capacity factor	4,000	h/year
Total cost	**8.5**	**MEUR**
Lifetime	25	year
Interests	2.50%	per year
Cost of capital	5.43%	per year
Operation & Management	2.00%	per year
Cost of capital	0.46	MEUR/year
Operation & Management	0.17	MEUR/year
Total	0.63	MEUR/year
Capital cost	**0.006**	**EUR/kWh**
Operation & Management	**0.002**	**EUR/kWh**
Levelized cost	**0.008**	**EUR/kWh**

with expected accuracy range to be -50% up to +100% or 4,300,000 EUR up to 17,000,000 EUR. In Table 2.3.2. Assumption and estimated levelized cost for 50% of the current heating capacity in Karlovac is given the estimated price of thermal energy based on assumption defined in the table. Permitting and royalties fees are not taken into account. The range of the price of thermal energy would be 0.004-0.016 EUR/kWh with mean at 0.008 EUR/kWh.

The price of natural gas for is heating in 2016 was 0.0296 EUR/kWh according to Eurostat[1] and it is in the range presented above. This indicates that geothermal district heating could be competitive with natural gas heated district heating. Further foundation for design and costs need to be established before more conclusions are drawn. The above cost calculation is only for indication due to limited evaluation time and information.

11. Vukovar

11.1. District Heating

The Homeland war had a huge impact on the Vukovar area and it was necessary to renew a large part of the infrastructure, which included a new district heating system in 2005. The Vukovar area is mostly heated with natural gas and wood pallet heat centrals. It has a good district heating system where the outgoing temperature is around 97°C and the return water is 50°C from the users. The heating centrals in Vukovar are 22.7 MW, 15.6 MW and 2 x 2.8 MW. The Vukovar area has a well-

[1] http://ec.europa.eu/eurostat/data/database

developed centralized heating industry which is using about 15% of the total energy from the heating centrals.

11.2. Geothermal reservoir

In the Vukovar area are seven geothermal wells, drilled in 1957, where source of hot water was found. The geothermal system in Vukovar are two separate systems, one within 5 km away from the City and the other about 50 km away.

The area closer to Vukovar has measured temperature of the hot water in the range of 42 – 82°C (66°C, 58°C, 42°C, 74°C, 82°C, 59°C and 78°C). Wells Vu-2, Vu-5 and Vu-7 are around 1,700 m deep, Vu-4 and Vu-6 are close to 1,400 m, Vu-1 is nearly 1,300 m and Vu-3 is 877 m. The temperature gradient of the wells varied from 33.5 – 43.3°C/km, highest gradient in Vu-4 and lowest in Vu-3.

According to the representatives from Vukovar at the meeting with the project group, the INA gas production activity is within 30 km distance from the dense area and there is a known well about 50 km away from Vukovar which has 90°C of hot water and is not utilised because there is no reinjection well. The distant are with the higher temperature geothermal water is not included in the evaluation in this report. The representatives mentioned also an interest to build up green housing area and the tradition of using geothermal heat for the drying of timber and parquet factory.

The Vukovar area is of special interest because of the number of wells drilled and the available data showing the temperature measurements for the existing wells. There will be a need to confirm the temperatures at a measured flow from each well to estimate the energy potential in the area. The existing district heating system in Vukovar is relatively new and therefore most likely suitable for a connection to the geothermal wells.

11.3. Geothermal Utilisation Concept Design at Vukovar

Following is a description of possible geothermal utilisation concept for Vukovar and the focus is on the geothermal resource that is closer to the Vukovar city. The cost analysis is based on very limited information about the geothermal resource, flow and temperature of the individual wells. A process flow is presented in Figure 11.3.1. below showing a geothermal utilization for district heating only. This concept utilises the hot geothermal fluid for heating up water in heat exchangers in the heat central of Vukovar and from there the hot water is distributed in a closed circle loop. The used geothermal brine from the well field could be further utilised after the first stage cooling and used in e.g. green house or other industries.

Assumption about possible utilisation on the geothermal water in Vukovar area is based on limited information on the well fields and geothermal resource. In the near future, it is recommended to re-enter the existing wells and flow test them and review all exploration data to form a conceptual model for the Vukovar geothermal area. The available information on temperature show that a few wells in the range of 60-82°C are candidates for utilisation for agriculture and industrial area. The geothermal water below 60°C can be utilised for spa, swimming pools and health care.

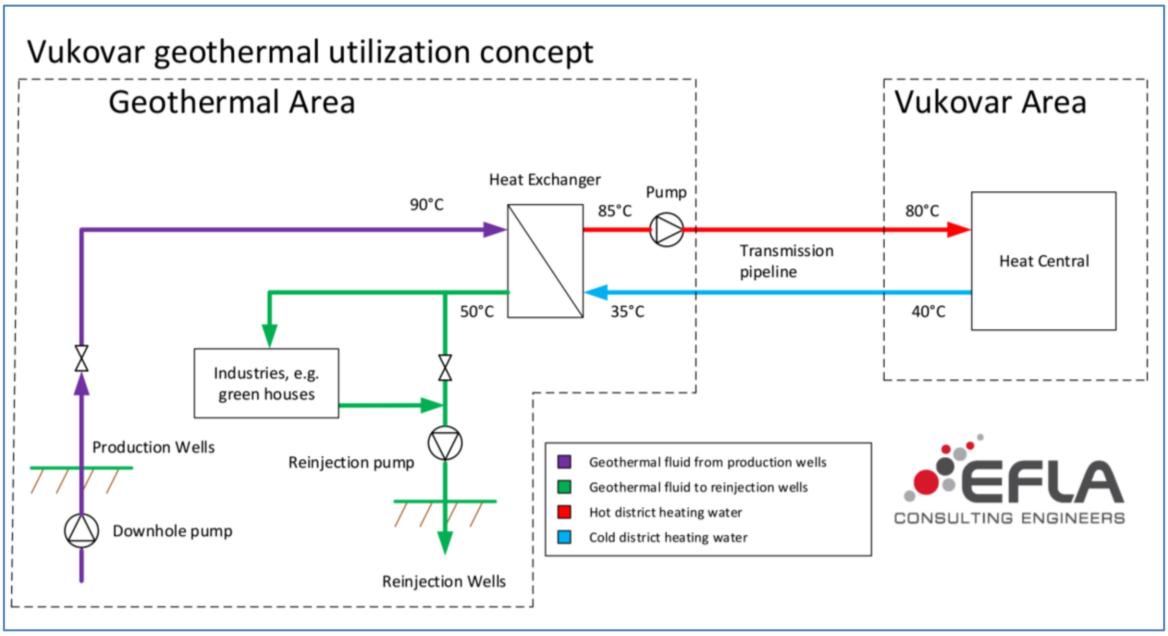

Figure 11.3.1. Vukovar geothermal heating utilisation concept
Source: EFLA

In the first phase gives promising results the next phase is to connect to the existing heat centrals in Vukovar. The district heating for Vukovar is rated 43.2 MW thermal. If it is assumed that a ΔT of 40°C can be achieved from the geothermal wells then Vukovar needs at least 265 kg/s of hot water available for the total changeover from fossil fuel to renewable energy but for the second phase it is recommended to supply 50% of the thermal power. For this purpose, Vukovar or a new established geothermal district heating company needs to plan exploration activity, establish a conceptual model and drill at least 3 successful production wells and two reinjection wells.

In this utilisation concept for Vukovar is assumed that each new production well will be able to produce at least 32 kg/s and the existing wells can be used for reinjection. The wells will most likely be installed with downhole pumps and it is not possible to make any assumptions about the water level in the well until it is tested. It is assumed that refurbishment of existing wells will be used as reinjection wells and will be sufficient for reinjection for the Vukovar geothermal field in phase 1. It is assumed that two of the existing geothermal production wells can be used in the first phase of the project. The first phase of the project is re-entering the wells with a drilling rig and flow test them to confirm flow and temperature from the production wells and the permeability of the reinjection wells.

In the second phase of the project it is recommended to drill a new production well and construct a new double pipe transmission pipeline to connect the geothermal area to the heat central in Vukovar. The length of the pipeline is estimated to be 5 km, 10 km in total for supply and return pipelines. Rough cost estimate for phase one and two is 12 MEUR for refurbishment of the existing wells and a connection to the heat central supporting supply hot water to replace fossil fuel 50%.

Table 11.3.1. Assumption and estimated levelized cost for 50% of the current heating capacity in Vukovar

Source: EFLA

Location	Vukovar	
Type	Geothermal	
Description	Heat production	
Items	Value	Unit
Thermal energy	88.0	GWh/year
Capacity factor	4,000	h/year
Total cost	**12.0**	**MEUR**
Lifetime	25	year
Interests	2.50%	per year
Cost of capital	5.43%	per year
Operation & Management	2.00%	per year
Cost of capital	0.65	MEUR/year
Operation & Management	0.24	MEUR/year
Total	0.89	MEUR/year
Capital cost	**0.007**	**EUR/kWh**
Operation & Management	**0.003**	**EUR/kWh**
Levelized cost	**0.010**	**EUR/kWh**

The expected accuracy range for early stage development set to -50% up to +100% which means that total cost can be in the range of 6,000,000 EUR and up to 24,000,000 EUR. In table 11.3.1 is given the estimated price of thermal energy based on assumption defined in the table. Permitting, royalties fees, etc. are not taken into account. The range of the price of energy would be 0.005-0.020 EUR kWh with mean at 0.010 EUR/kWh.

The price of natural gas for is heating in 2016 was 0.0296 EUR/kWh according to Eurostat[2].This indicates that geothermal district heating could be competitive with natural gas heated district heating. Further foundation for design and costs need to be established before more conclusions are drawn. The above cost calculation is only for indication due to limited evaluation time and information.

[2] http://ec.europa.eu/eurostat/data/database

IV. LEGAL FRAMEWORK OF GEOTHERMAL UTILISATION IN CROATIA

Geothermal waters belong to the mining resources or mineral resources of the Republic of Croatia and are described in the Mining Act (OG NN 56/13, 14/14) as „**geothermal waters”** that can be used for the accumulation of heat for energy purposes, geothermal waters that are used for medical, biological and recreational purposes are regulated by the Water Act (OG 153/09, 130/11, 56/13, 14/14).

The basic document for determining the management of mineral resources and for planning economic mining activities is the Mineral Resources Management Strategy.

Exploration of mineral resources, are, according to the Mining Act, work and research that have the goal to determine the possibility to store hydrocarbon and to permanently store gasses in geological structures and conditions for exploration. According to this Act exploration of mineral resources are not: geological prospecting of the terrain, geological, geochemical, geophysical, egologic and geomechanical research that is done for the exploration of minerals or production of complex geological maps, and research of the soil and exploration for scientific purposes etc.

Exploration of hydrocarbon, and mineral and geothermal waters when used for energy purposes, are according to this Act regarded as transport of hydrocarbon and mineral and geothermal waters as pipelines when they are technically linked with approved exploitation fields.

For the exploitation of mineral resources, a concession, or a concession for the exploitation of mineral resources is needed for the economic use of common good according to the Act on Concessions. Concessions for exploitation are given on the basis of a public procurement in a specific procedure that is done in the following phases:

a) Election procedure of the most economical viable bidder for the exploration of mineral resources for given an exploitation concession
b) Procedure for giving approval for exploration
c) Procedure for determining the exploitation field
d) Procedure for giving an exploitation concession

a) Election Procedure of the Most Economical Viable Bidder for the Exploration of Mineral Resources for Giving an Exploitation Concession

The competent administrative body for mining publicizes a public bidding for the election of the most economical viable bidder for the exploration of mineral resources for the purpose of giving an exploitation concession.

– if a decision is made that there is a need for determination of specific mineral resources reserves in a certain area or for the determination of their economical use, or for the determination of geological structures that are fit for hydrocarbon storage a permanent gas storage, and

– based on a **proposal done by a natural or legal person** that is registered for exploration and exploitation of mineral resources.

1. The ministry competent for the economy (the Ministry) will submit a proposal for giving a concession for exploration of mineral resources, based on this a public procurement that will be publicized.

2. A public procurement will be publicized on the basis of an evaluation of the Ministry for a need to determine specific mineral resources in a region or on the basis of a proposal submitted by a natural or legal person. The public procurement is publicized in the Official Gazette or the Official Gazette of the European Community at least 90 days before the deadline of a certain procurement for submitting offers.

In case the Republic of Croatia is the owner of the land parcels on which the exploration is planned, the Ministry is obliged to inform the **central administrative body that is competent for managing state property** (Central Administrative Office for Managing State Property).

The public procurement or the **submitted proposal** of a natural or legal person **must contain the following** according to the Mining Act:

1. the mineral resources that are to be researched,
2. topographical position, size and name of the exploration field,
3. program of all the exploration works listed by sort and size with the costs, and a detailed plan of works that have to be done in the first year of exploration,
4. the total amount of financial resources for the execution of the planned exploration works and the manner on how that will be secured,
5. an extract from the court or trade register that states that the person that submits the proposal is registered for exploration or exploitation of mineral resources,
6. geological or other documentation on the possibilities of existing mineral resources in the exploration field,
7. a spatial planning document that proves that the execution of mining activities is planned in the specific area.

3. The public procurement tender has to contain:

1. name or business name, PIN, address, telephone number, fax number and e-mail address of the tenderer, and extract from the competent register that proves that determines the registration for exploration and exploitation of mineral resources
2. 2.a list of personal, professional, technical and financial conditions that have to be fulfilled by the tenderer according to the public procurement notice, and the documents that prove the fulfilment of those conditions,
3. proof that there are no circumstances mentioned in art. 20 of the Mining Act,
4. information based on which the choice is made for the most economical offer according to the procurement criteria.

The offer has to be accompanied by:

1. program of all the exploration works listed by sort and size with the costs, made in accordance with the procurement documentation,
2. a detailed plan of works that have to be done in the first year of exploration,
3. deadline until when the exploration will be done,
4. the total amount of financial resources for the execution of the planned exploration works and the manner on how that will be secured,
5. deadline until when the exploitation of mineral resources will begin within the exploration field,
6. recovery plan for the exploration area,
7. tender guarantee,
8. offered concession fee,
9. other evidence that is important for the choice of the most economical bidder and that is mentioned in the procurement documentation,

4. The decision on the selection of the most economical bidder is made by the Ministry with consent of the ministry competent for regional development.

b) Procedure for Giving Approval for Exploration

5. The chosen bidder is obliged to inform the body competent for mining, before the decision on the selection of the most economical bidder, on the appointment of the manager that will be responsible for performing the mining activities, it also has to pay the costs of tendering and deliver a guarantee for the recovery costs of the exploration field.

6. The Decision on the approval of exploration of mineral resources is made for the purpose of giving an exploitation concession based on the final decision on the selection of the most economical bidder for a certain exploration field (certain coordinates that are bordered by a part of land and / or sea, which the body responsible for the mining industry after the tendering decision designated for exploration of mineral resources in order to award a concession for exploitation).

7. In order to start the exploration of mineral resources a simplified mining project is required for the exploration of mineral resources. If the competent institution for mining determines that, on the basis of the proposed scope and sort of mining works, the foreseen works are of that importance that they can only be done on the basis of a simple mining project.

Mining projects can only be made by a person registered for writing mining projects (Rulebook on the professional exercise of certain mining works, OG 09/00).

The team leader of the mining project (responsible designer) or team leader of the mining part of the project can be a qualified mining engineer or oil mining engineer with a specialization exam and with at least one year of work experience on exploration and exploitation works of mineral resources after passing the specialization exam (Rulebook on the professional exercise of certain mining works, OG 09/00).

8. Mining projects are to be examined by a professional committee for inspection of mining projects at the ministry competent for the economy according to the Rulebook on the Procedure of Inspection of Mining Projects (OG 140/99).

9. If it is necessary to build a mining object or facility for the exploration of mineral resources, the holder of the exploration right is obliged to **obtain a location permit**. A location permit is obtained according to the regulations regarding spatial planning. (Rulebook on Exploration of Mineral Resources, OG 125/98).

10. The holder of the license for exploration is obliged to appoint a responsible manager for the execution of the exploration works and inform the ministry competent for the economy every six months through a report on the executed mining works in the exploration field (Mining Act, art. 42).

The holder of the license is obliged to pay a fee for the exploration of mineral resources in the amount and manner specified in the Permit. The minimum annual fee for the exploration of mineral and geothermal waters is 3,000.00 HRK/ha (approx. 400 EUR/ha) of the drilling surface for the first year, 4,000.00 HRK/ha (approx. 535 EUR/ha) of the drilling surface for the second year 5,000.00 HRK/ha (approx. 670 EUR/ha) of the drilling surface for the third, fourth and fifth year (Regulation on Fees for Exploration of Mineral Resources, OG 40/2011).

11. The holder of the license for exploration is obliged to report the exploration works to the State Inspectorate, the ministry competent for the economy and the state administrative office, as well as all parties defined in the permit for exploration of mineral resources within a period of 15 days before start of the exploration works. For the exploration of geothermal waters, the holder of the permit has to report in the same period every start and ending of works on every drilling (Mining Act, art. 43).

During exploration, the holder is obliged to take safety measures in order to prevent dangerous situations for people or property, and to take work safety measures and sanitation (Mining Act, art. 44).

The holder of the permit has to submit a report to the ministry competent for the economy on the executed exploration works by February 15th for the past year and a program of works for the next year (Rulebook on Exploration of Mineral Resources, OG 125/98, art. 24).

At the end of the exploration a Final Report on Exploration has to be made (Rulebook on Exploration of Mineral Resources, OG 125/98), that has to contain:

- a detailed list of all executed works indicated on a map of a scale 1:5,000 or higher;
- characteristics of the findings of mineral resources and accompanying rocks;
- the quality of the usable mineral resources with chemical, physical and other features, and information on possible technological testing;

- information on the quantity of the collected mineral resources that are used for technological testing and definition of the conditions of the exploitation;
- the amount of the calculated reserves of mineral resources by classes and categories;
- the total amount of funds spent on research;
- a list of procedures and works undertaken for the purpose of rehabilitation of the potentially devastated terrain by research;
- a conclusion that makes clear the further steps and procedures regarding the executed exploration works.

The first calculation of mineral resources and geothermal water reserves are done in the exploration faze when on the exploration field the parameters are defined that are mentioned in the Rulebook on the Procedure for Determining Reserves (OG 48/92, 60/92). Re-calculation of the reserves is done during exploration:

- after realization of the research projects of article 147 point 2 to 5 of the mentioned Rulebook;
- during exploration or preparation of the exploitation fields and when the performed research works show a rather big difference in the reserve quantity, or when there is a need for a new categorization or classification of the reserves.

c) Procedure for Determining the Exploitation Field

A Decision on determining the exploitation field is made by the competent body for mining ex officio or on request of the authorized person of the exploitation field in line with the regulations of the Law.

12. Request for determining an exploitation field has to contain:

1. a decision on the appointment of the economically most viable offer for the exploration of mineral resources for giving an exploitation concession,
2. decision on the approval for exploration of mineral resources,
3. decision confirming the quantity and quality of mineral reserves,
4. conceptual mining project,
5. location permit,
6. a map of the requested exploitation field with marked coverage of confirmed balance sheet reserves of mineral resources, or a map of the requested exploitation field marked with the shape and size of geological structures suitable for storage and permanent disposal of hydrocarbon gases, in accordance with the conditions and limits of the location permit,
7. proof that there are no obstacles as stated in article 20 of the Mining Act.

13. The decision on determining the exploitation field is made by the body competent for mining.

Mineral resources can be exploited for the needs of laboratory research, technological experiments and for defining the exploitation conditions, within the quantities that are defined in the decision on approving the research of mineral resources and/or the decision on approving of additional exploratory works on the exploitation field. Mineral resources excavated or obtained by experimental exploitation of mineral resources are the property of the Republic of Croatia.

The exploitation of mineral resources is permitted only within the exploitation field specified in the concession agreement and within the limits of certain mining projects.

14. If reserves of mineral resources are identified before submitting a tender for the concession for exploitation of mineral resources, a <u>Study on mineral resources in the exploration area must be made and a decision on the determined quantity and quality of reserves of mineral resources</u> must be obtained (Mining Act, art. 17) according to the Rulebook on the Procedure for Determining and Verification of Mineral Resources Reserves (OG 140/99). Documentation on reserves may be made only by legal persons registered for the production of documents on reserves of mineral resources (Rulebook on the professional exercise of certain mining works, OG 09/00, art. 35, par. 1). Mining companies, or mining businesses that are registered for the exploitation of mineral resources can produce documentation on reserves of mineral resources and mining projects for their own purposes if they employ employees that fulfil the conditions for independent production of documentation on reserves of mineral resources (Rulebook on the professional exercise of certain mining works, OG 09/00).

15. According to the Environmental Protection Act (OG 80/13, 153/13, 78/15) before submitting a Request for Determining Environmental Impact a **Request for giving instructions on the content of an environmental impact study** is made.

16. An environmental impact study is an integral part of a Request for Determining Environmental Impact (Regulation on determination of environmental impact (OG 64/07, 67/09). The Request must contain the following:

1. Information about the submitter of the Request,
2. Information about the location and operation,
3. Information about the compatibility of the operation with the current spatial planning documentation
4. Information about the authorized person to perform the expert tasks regarding environmental protection – i.e. to make an environmental impact study
5. An Environmental Impact Study
6. Administrative fees

17. When the competent body establishes that the Request contains all required information, an expert advisory commission will be formed in order to perform the procedure for establishing the environmental impact of the operation (Regulation on determination of environmental impact, OG 64/07, 67/09), the competent body will also give an assessment according to the Regulation on determination of environmental impact (OG 64/07, 67/09). After acceptance of the Request the competent body will send the study to **public consultation**.

18. Obtaining a location permit for the exploitation field in accordance with the Building Act (OG 153/13).

19. Development of the main mining project for the exploitation of mineral resources according to the Mining Act and Rulebook on the professional exercise of certain mining works (OG 9/00).

20. Review of the mining project for exploitation of mineral resources by the expert commission for reviewing mining projects according to the Rulebook on the Procedure of Inspection of Mining Projects (OG 140/99).

d) Procedure for Giving an Exploitation Concession

Concessions are granted by the ministry competent for the economy after prior consent of the ministry competent for water management.

21. Request for a concession is done by a legal person performing mining activities that authorized for an exploitation field and that has been chosen as the most economical bidder.

The request has to contain:

1. Decision on the election of the most economical bidder according to the procedures of the Mining Act,
2. the decision on establishing an exploitation field,
3. the decision establishing the amount and quality of the mineral resources reserves or the decision establishing the manner, form, size and scope of the geological structures that are meant to be used for the storage of hydrocarbon and permanent disposal of gasses,
4. location permit,
5. main mining project and / or amendment to the mining project reviewed by the ministry competent for mining works,

6. written consent or confirmation on the main mining project by the administrative bodies that determine the conditions and limitations for executing the mining works,
7. proof of the right to use the land parcels within the exploitation field, in line with the pace of performing the mining works determined in the mining project for the period that is stated in the concession agreement for the exploitation of mineral resources,
8. map of the exploitation field with marked area of the determined mineral reserves or with the marked area of the geological structures that are suitable for storage of hydrocarbon and permanent disposal of gasses, as well as with land parcels with cadastral data and surfaces within the exploitation field,
9. proof that there are no limitations for obtaining a concession as stated in the Mining Act.

For a concession, it is necessary to:

10. obtain a legally valid location permit from the competent body for spatial planning,
11. obtain a declaration of the ministry competent for mining on the completion of inspection and the acceptance of the project solutions in the main mining project,
12. solve all property issues for the land parcels within the exploitation field.

22. Decision on granting a concession

23. Concession agreement for the exploitation of mineral reserves in an exploitation field with the obligation to pay a fee for the exploitation of mineral reserves.

Concessionaire are obliged to rationally use the mineral reserves fields in line with the concession for the exploitation of mineral reserves.

24. The concessionaire for the exploitation of mineral reserves is obliged to, at least 15 days before the start of performing mining works on the exploitation field, report the start of the mining works to all the subjects mentioned in the decision on granting the concession.

25. The request for a building permit is made by the investor. The request is accompanied by:

- three copies of the main project for building mining objects with a location permit,
- a map with marked borders of the exploitation field on which the land parcels are visible that are subject of the building permit,
- the concession for the exploitation of mineral reserves,
- proof that the right to build mining objects is obtained.

26. A building permit for the construction of mining objects is issued by the ministry competent for the economy.

27. The implementation project of construction of mining objects is a technical solution on the basis of the main project and has to be in line with the main construction project. The implantation project for the construction of mining objects, together with all amendments and changes according to the factual works has to be kept by the investor or his legal successor as long as the mining object exists.

28. Construction of mining objects. During construction, the contractor must have, according to the Ming Act:

- decision on registration on the court register or in the professional association,
- a document on the appointment of the main engineer on the construction site, or works manager,
- a document on the appointment of the main supervising engineer, or main supervising engineer
- building permit for the construction of mining objects with the main project,
- the implementation project for the construction of mining objects,
- construction diary,
- proof on the quality of the preformed works and usability of installed products and equipment,

- other documentation, permits in accordance with special regulations and that the contractor must have on site.

Mining objects can be used or put into function after the ministry competent for mining issues a usage permit.

29. Request for a usage permit is made by the investor. The request is accompanied by:

- a building permit for the construction of mining objects,
- information on the participants in the construction of the mining objects,
- a written declaration of the contractor on the performed works and conditions of maintenance of the mining objects,
- a list of proof of quality of the performed works and the usability of the installed products and equipment,
- a recapitulation of the reviewed and technical documentation,
- a final report of the supervising engineer on the construction of the mining objects,
- final design of the construction.

30. Within 30 days after receiving the request for a usage permits, the competent ministry is obliged to perform a technical inspection of the mining objects.

31. The usage permit is issued by the ministry within 30 days after the performed technical inspection, and is delivered to the regional cadastre office with the goal of evidencing mining objects.

32. **Investors to whom is issued a usage permit for mining** objects is obliged to, within 15 days after entry into function of the mining objects, give notice to the State Inspectorate and all subjects that are mentioned in the usage permit, that the usage permit has begun to be consumed.

33. Exploitation

The authorized holder of the approval for exploration of mineral resources and concessionaires for exploitation of mineral resources are obliged to possess:

- a location map of the exploration fields, or of the exploitation field for mineral resources,
- an extract of the cadaster with the marked boundaries of the exploration fields, or of the exploitation field for mineral resources,
- a geological map of the exploration fields, or of the exploitation field and its characteristical geological sections.

Concessionaires for the exploitation of mineral reserves are obliged to, at least once a year, with the status of the mining works on 31st of December, draw a map of the situation of the exploitation field for mineral resources.

The holder of the approval for the exploration of mineral resources and concessionaires for the exploitation of mineral resources are obliged to keep measuring records on all executed measurements that are done according to regulations regarding business records. Measurements records can be kept in electronical form.

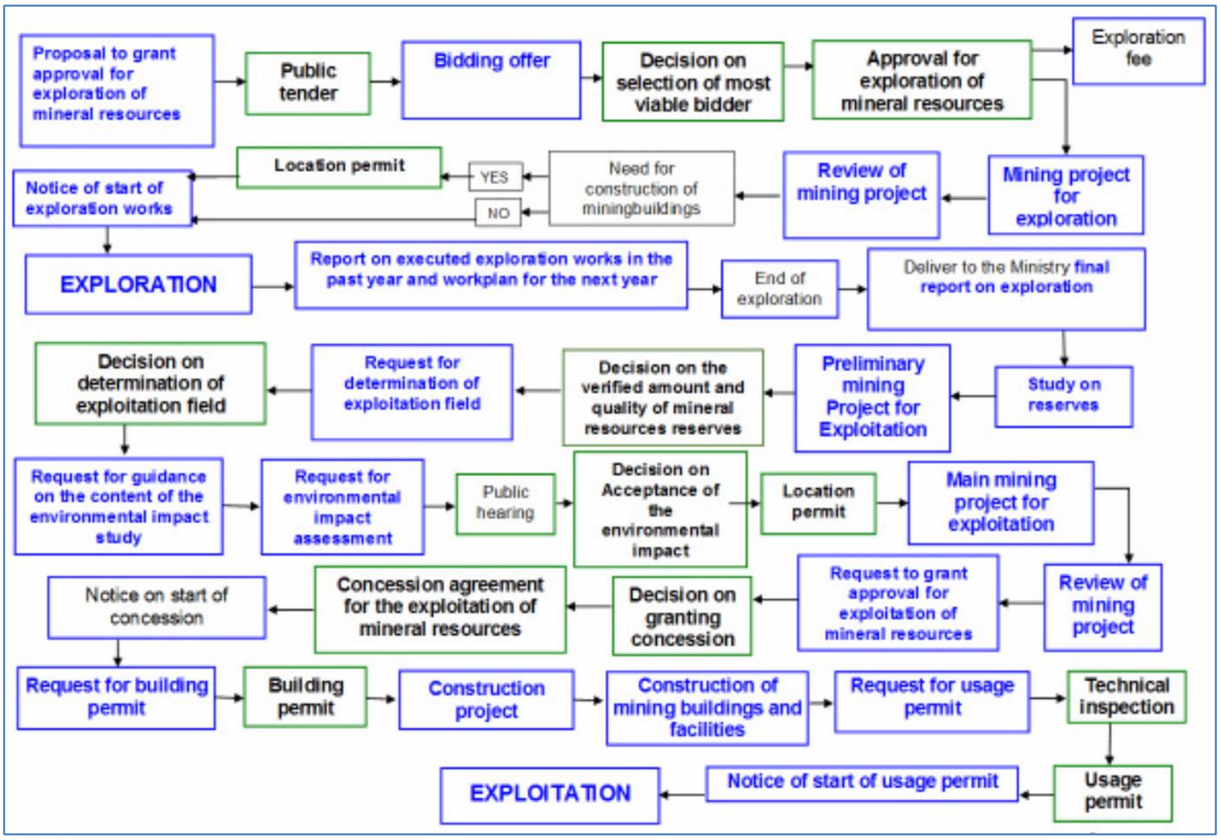

Figure IV.1. The process of acquiring an exploitation license
Source: EIHP

12. OVERVIEW OF THERMAL ENERGY REGULATIONS

12.1. OVERVIEW OF THERMAL ENERGY LEGAL FRAMEWORK

This apprehensive overview gives an insight in the regulatory framework of thermal energy use for heating and cooling in the Republic of Croatia. It contains a summary of the most important legal primary and secondary acts and regulations regarding thermal energy.

12.2. LEGAL FRAMEWORK OF DISTRICT HEATING IN THE REPUBLIC OF CROATIA

12.2.1. Energy Development Strategy of the Republic of Croatia (OG no. 130/2009)

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.

12.2.2. Energy Act (OG no. 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.

The Act is systemized in 12 chapters.

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 no. 127/14) and the Act on Renewable Energy Sources and Cogeneration (OG no. 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 no. 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.

12.2.3. Act on the thermal energy market (OG no. 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.

12.2.4. The Act on Renewable Energy Sources and Cogeneration (OG no. 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.

V. Energy in Croatia

From the publication Energy in Croatia (Energy Institute Hrvoje Požar, 2016) quoting:

In 2015, the total primary energy supply in Croatia decreased by 0.9 percent compared to the previous year. At the same time, gross domestic product increased by 1.6 percent, which resulted in a decrease in the total primary energy supply intensity by 2.5 percent. As compared to the average energy intensity in the European Union (EU 28), energy intensity in Croatia was 29.4 percent higher.

In 2015 the total primary energy production decreased by 6.7 percent compared to the previous year. Decrease is realized in usage of hydro power for 30.7 percent, 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 percent. Also, the production of the fuel wood and other types of biomass increased by 10.7 percent Production of crude oil is increased by 12.7 percent and of the natural gas by 1.8 percent. Also, the production of the heat from heat pumps increased by 20.3 percent. In 2015, energy self-supply amounted to 57.1 percent, which represents the decrease of 5.8 percent compared to the previous year.

Final energy consumption increased by 5.5 percent, whereas transport and distribution losses increased by 3.8 percent. All other energy needs decreased. Energy conversion losses decreased by 19.5 percent, whereas energy consumption for energy sector own use decreased by 6.5 percent. Non-energy use decreased by 1.9 percent. Compared to energy consumption in 2014, energy consumption in industry in 2015 decreased by 0.5 percent. Also, energy consumption in other sectors increased by 7.9 percent, whereas in the transport sector it increased by 4.5 percent.

In 2014, the share of renewables in the total energy consumption amounted to 31.4 percent (by applying the EIHP methodology), or 23.2 percent if the calculation is made by applying the EUROSTAT method. In 2014, the total electricity production in the Republic of Croatia amounted to 11,402 GWh, of which 67.3 percent was produced from renewable energy, including large hydro power plants. In this, large hydro power plants had a share of 57.7 percent, whereas 9.8 percent of electricity was produced from other renewable sources, such as small hydro power plants, wind energy, solar energy, biomass, biogas and photovoltaic. Electricity produced from renewable energy sources had a share of 42.2 percent in the gross electricity consumption in Croatia. In that, electricity produced in large hydro power plants had a share of 35.5 percent, whereas the electricity produced from other renewable sources had a share of 6.7 percent. During 2015 increased consumption of almost all energy forms and decreased only consumption of coal, coke, motor fuel and jet fuel. Decrease of consumption of motor fuel amounted to 0.2 percent and of jet fuel and petroleum 2.5 percent. Increase of total consumption of the fuel oil amounted 31.3 percent, extra light fuel oil 18.8 percent, and petroleum coke 10.3 percent. Also, the consumption of diesel fuel increased for 6.4 percent and liquefied gas for 0.8 percent. Share of biofuel in motor fuels in 2015 amounted round 1.2 percent.

Overall consumption of electricity in Croatia in 2015 amounted 1,819.4 GWh and was for 2.2 percent greater than in previous year. Consumption of natural gas increased for 3.1 percent, overall consumption of heat energy also increased for 8.8 percent, while increase of fuel wood and solid biomass amounted 14.4 percent. Increase of consumption of other renewable sources (solar, wind, geothermal, biogas, biofuel) amounted 7.4 percent.

In 2015, energy consumption efficiency in Croatia continued to improve as compared to the previous period. Energy efficiency expressed as energy efficiency progress index increased by 0.5 index points for all final energy consumers combined. The stated index was lower in the transport sector by 0.3 index point, whereas the industrial sector and households continued a positive trend of lowering the energy efficiency progress index by 0.3 index points in industry and 0.4 index points in households. In the period from 1995 till 2015, there was a positive trend of lowering the energy efficiency progress index by 20.1 percent for all final energy consumers combined. This positive trend was due to the all sectors, with the greatest contribution of industry, which improved its energy efficiency index by 32.8 percent. For households, this increase amounted 17.6 percent and for the transport 15.9 percent.

The emissions from fuel combustion have a dominant influence on the total CO_2 emissions. According to the preliminary results for the year 2015, the CO_2 emissions from the stationary and mobile energy sources amounted to 15.7 million tons, which is 4.7 percent more than the emission in the previous year and 21.6 percent less than the level of emission in the base year 1990. The increase of CO_2 emissions in 2015 is the result of a mild recovery of economic activities, but in the observed period from 2010 to 2015 there was a reduction in CO_2 emissions with an average annual decrease rate in the amount of 3.0 percent.

There is significant increase in 2015 in capacities for power generation, including great increase in RES capacities. Number of metering places in comparison to 2014 increased for 0.6 percent and selling of electricity increased for 3.7 percent. Price of electricity for households is slightly decreased (for 1.5 percent), while for the business sector decreased for 4 percent for the small customers, and increased for 2.2% for customers with annual consumption from 2 to 20 GWh.

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