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Geothermal Use in Cities: Comparative Study from Four Different Countries

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Contents

Abbreviations

BHE	Borehole Heat Exchanger
GEP	Geothermal Energy Potential
NYS	New York State
GE	Geothermal Energy
GSHP	Ground Source Heat Pumps
DHS	District Heating System
RES	Renewable Energy Sources
EGS	Enhanced Geothermal System
GDH	Geothermal District Heating
GDHS	Geothermal District Heating System
GHG	Greenhouse Gas
ASHP	Air Source Heat Pump
SAP	Standard Assessment Procedure[1]
CO2	Carbon dioxide
EC	Ecological footprint
CF	Carbon footprint
MFT	Mean Fluid Temperature
USA	United States of America
HGE	Hydro-geothermal Energy[2]
HDR	Hot-Dry Rock
ORC	Organic Rankin Cycle
SC	Sustainable Communities
NGO	Non-Governmental Organization
TG	Thermal Gradient
FR	*Flow Rate of the Geothermal fluid*
et al.	*et alii*
i.e.	*id est (that is)*
e.g.	*exempli gratia (For the sake of example)*
sic	*sic erat scriptum* (thus was it written)
Sg.	Singular
CCHPP	Combined Cycle Heat and Power Production

1 Refers to an assessment procedure (originally from the UK), whereas buildings are compared between each other in terms of their energy performance, on the values from one to one hundred plus (zero energy house-values). The lower the values, the more is the house externally fuel dependent in its energy supply and the more GHG gas is being produced. On the contrary, the higher the values, the more energy-independent the building is. (http://www.buildenergy.co.uk/sap_calculations/what-are-sap-calculations/), accessed 18.02.2018

2 Refers to Geothermal energy contained in fluids, usually in warm or hot water. The other form of geothermal energy may be thermal heat coming directly from the ground, where there is no underground aquifer available

HDR	Hot Dry Rock
HRR	Hot Rock Reservoir
RCIL	Resource Center for Independent Living
GUP	General Urbanistic Plan
CoP	Coefficient of Performance[3]
GG	Geothermal Gradient[4]
GDP	Gross Domestic Product
WW2	World War Two
CS	Case Study
4GDH	4th Generation District Heating

[3] Usually refers to heat pumps and presents a ratio between cooling/heating and work that has been provided

[4] Also known as thermal gradient and refers to Earth soil´s thermal characteristics

1 Introduction: on cities, energy and the importance of their connection for the future

The text in chapters 1, 2 and 3 is part of publications of the author listed as [1]*,* [2]*,* [3]*and* [4]*in the reference list.*

"Urbanization today is the main driver of climate change, and various possibilities are offered to put a hold on this process or, at least, to make it less of a problem for the built and general environment. As recently mentioned in a study on cities by Wigginton et al [5], this process is happening at a rapid scale. It is affecting the environment silently but surely. What once used to be just a minor percentage of cities in comparison to rural habitats of humans, nowadays it has risen to more than a half of world's population living in them. Unfortunately, this urbanization costs us a lot. Earth surface is losing more and more its farmland and wildlands. This adds to climate change problem, which affects our environment as we speak. [223] Furthermore, this trend is going to continue in the future. The cities will continue to grow, and rural places will die off. Ecological footprint of cities will also grow[5]. More and more expectations on living standard of the global population lead to overburdening the environment outside the city boundaries and will eventually have to be re-thought. The global population have more and more expectations on living standards. This issue leads to the overburdened environment outside the city boundaries. As a matter of fact, it will eventually have to be re-thought for the sake of the cities and, more importantly, Earth and its natural cycles. There are positive aspects of this change, and the most important one is the opportunity to make cities more livable and to foster better sustainable future for generations that will live in urban environments. Achieving these sustainable urban environments can be made by using renewable and local resources, such as geothermal energy. [1]"

5 Under Ecological footprint we understand the level of impact humans have on the ecosystem of the Earth. Carbon footprint would be the level of carbon dioxide (CO2) and other greenhouse gas(GHG) emissions from an individual, organization or an event, expressed in CO2 equivalents. Raising ecological awareness of the individual is the calculation available at this following web site: https://www.footprintcalculator.org/

1.1. Cities´ relation to energy issues

"Building cities and their buildings, neighborhoods and infrastructures means a lot of open questions: how to use technology and how technology can be used in wider sustainable concept. The very distinction between (energy) technology and planning has not always been the same throughout history. During the Renaissance period, people were referred to as "uomo universale"[6], rather than just specialists in a field. This segregation of roles may have a direct connection to architecture and urbanism. It is not the goal of this contribution to question the importance of any methodological approaches mentioned above. The goals are to suggest the interconnection of data and use with user response and expert opinions. Rethinking the way of perceiving architecture and cities, not just as physical environment connected to infrastructure and its inhabitants, but rather as cities being one system of interactions (between each other), seems valuable nowadays. For example, geothermal utilization influences the environment, the environment in return influences the planning focus, the focus influences structures and structures the utilization. In general population, architecture was and still is thought to be an artistic profession, not capable of tackling the engineering issues to full extent. However, engineering is probably the only profession that accumulates knowledge within different fields and can be aware of the consequences, such as environmental outcome of planning and building houses, that other engineering branches do not necessarily have in their curricula. Its connection to all energy issues and geothermal use in cities, is therefore, important. Architects' analysis of cultural factors and thinking about architecture in everyday curriculum has created substantial number of theories that support the basics of serious systems 'thinking about cities.[7]

Many authors, such as Ivan Illich or André Gorz have mentioned the terms of political ecology as important aspects of the society we are living in [220][8]. Additionally, experiences from the past planning outcomes are valuable as they emphasize the need of the human kind to start reacting to what is happening with the cities- globalization, population growth, urban sprawl and economic and environmental changes and challenges. The real proof of this process are numerous catastrophic urban environments, lack of interest for the ecology of a city and most important- lack of understanding that any new technology and different modalities of its use can damage or make cities better for a long time. Finally, diversity and density of a city are re-examined, and low densities seriously questioned in this discourse,

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6 Leonardo Da Vinci was known to be a man of many different skills

7 System´s thinking of the "fourth wave" which is focused on unity, complexity & simplicity, cognition (more at: https://arizonawet.arizona.edu/resources/teacher-academies-school-water-audit-program-general-arizona- project-wet-aqua-stem-program, accessed 16.03.2018) The above-mentioned aspects are very similar to concepts of a city preferred by Jane Jacobs in her works on urban landscapes and mixed-use city neighborhoods. (Pušić, 2015) [213]

8 Gorz, 1982

especially by Jacobs [6][9]. Early in the late 19th and early 20th century Geddes and Giovannoni challenged urban planning's bias towards abstraction, physical form, design and organization over human needs, context and changing societal conditions that they felt ought to be shaping and influencing the evolution of cities and communities. They advocated for "not treating parts of the cities as museums," and instead recognized each city as a place with advantages, shortcomings, challenges and defects that ought to be continuously critically evaluated, changed and adapted to meet its changing needs, context and ideals, as argued by Rodwell. [7][10] Contemporary overview of planning with renewable energy considerations can help us get an insight into current trends in planning and its relation to geothermal energy, as shown in the next chapter. [1]"

1.2. Planning sustainable communities

In order to turn away from being a community of consuming and exploiting resources, each city should undergo two processes. The first one refers to cutting down on fossil fuel consummation needed for its services and infrastructure, including industry, housing, commercial and all human-associated activities. This means the city should rely on clean energy, such as geothermal. Secondly, the city should cut down on its energy consumption by measures of energy efficiency, changing consumer culture and investing in carbon sinks, i.e. green infrastructure which would serve to make cities more resilient, by absorbing Greenhouse Gasses (GHG). [8][11]

"The components of any sustainable community (SC) can be listed as follows: Energy, food, transportation, water, buildings, urban design, urban and economic development, governance and communication and waste. Research in energy as an important element of the sustainable city is on the rise worldwide. Especially, easily accessible energy that is affordable and locally available, possibly integrated into smart grids and which allows for high level of energy conservation, is important, according to Reber et al. [9][12]. Geothermal energy, available almost everywhere[13] can help communities to reach SC goals. After the preliminary results of an interview with urban planning experts in Iceland, geothermal energy (GE) does not seem to be integrated in planning at all. [10][14] What actions are necessary for geothermal utilization to be understood and implemented more in planning of cities and why

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9 Jacobs, 1961

10 Rodwell, 2007, 29-30

11 Kammen, Sunter, 2016

12 Reber et al., 2013

13 Shallow geothermal energy is available everywhere on Earth, because of the thermal accumulation in the underground

14 Iceland, Expert in urban planning, 2016

is this important, is the topic of the following research presented in the following chapters and case studies. [1]"

Current cities are largely dependent on fossil fuels. By using geothermal technology more extensively at the level of communities and cities, the levels of greenhouse gasses (GHG) such as CO2, NO2 and SO2 can be decreased [11][15], leading to healthier environment for the people. This can decrease the pressure on health and social system of the city or the State and, generally create the environment of energy balance, where energy production is localized and densified within an urban agglomeration. Together with environmentally friendly mechanisms in other areas of human life, such as transport, locally grown agriculture, mixed-use and densified cities, they can foster these goals and allow for SC to be a dominating principle in planning and renovating future cities.

1.3. Importance of planning geothermal energy in the regional context

"Geothermal energy utilization is one of the cleanest renewable energies on the Earth. It offers a way, how a city, building or sets of building can cut-down emissions caused by heating and cooling appliances which are mostly based on fossil fuel use and external energy sources, meaning the energy needed for their utilization is produced at another location and is being transported to the location of the building of where it is used.

Many cities worldwide, e.g. Reykjavik, Paris, a few smaller towns in Austria, Germany and Slovakia, etc., have adopted geothermal heating option within a district. Geothermal planning is an important tool for sustainable development as it can help stabilizing energy supply [12][16] and work in synergy with other renewable sources to enable transformations and urban revival of cities [9][17]. Lastly, it could help to develop a long-term strategy in urban planning. The possible implications of the effects of geothermal urban planning have not been vastly examined so far. [13]"

"This PhD research and work on the topic of geothermal in cities point to the importance of new initiative for more serious and permanent scientific research on the use of geothermal energy as a sustainable and local resource, contributing to the strategy of sustainable development of cities and rural-urban wholes. [4]" One especially needs to re-examine if sustainable *city* is the only option for the future of our planet or if there is something besides sustainability in planning, i.e. if there is any other option for approaching urban planning other than just following sustainable parameters as guidelines. If the answer is "yes", this can be suggested as one of the topics of future research in architecture." The sustainable city is in confrontation with the tendencies of a globalist city, which is energy inert city, consuming

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[15] GeoDH, 2017

[16] Ragnarsson, 2003

[17] Reber et al., 2013

external resources. It does not use local potentials for self-development or/and does not use these sources for the protection of the urban and architectural values and spaces. [4]“

2. Geothermal energy and its roots of utilization worldwide

"The geothermal energy resource results from the stored thermal energy in the earth's crust. It is considered as a renewable source, since its potential is large enough to cover needs of the human kind for centuries, without seriously endangering the environment, unlike fossil fuels´ exploitation. It is the clean energy and, together with solar, wind, water and biomass, it leads to substantial environmental benefits for the city. It is an important question how to approach geothermal energy planning in an urban environment. And how this can be integrated into sustainable communities 'urban planning strategies. [1]"

The level of use of geothermal energy throughout history corresponds to the level of social progression in society i.e. the willingness of society to accept and utilize locally available resources and society's technological level. There are particularities of GE´s use in the built environment which will be augmented more thoroughly.

Natural geothermal resources were present in various pre-historical sources and were documented in many legends and oral testimonies passed on to the next generations, especially in areas with active thermal springs and geysers. Yet, large Mediterranean civilizations, such as Hellenic[18] and Roman Empires, were the first who used geothermal energy systematically and became aware of the possibilities of such use.

2.1. Introduction to historical overview of geothermal utilization: pros and cons to technology appreciation of Ancient, Medieval, Pre- and Post- Industrial civilizations and their architectures

1.1.1 Use of geothermal in the Ancient Period

Geothermally heated baths found in Epidaurus, Kos and Acropolis (near Athens) are over 2000 years old. [14][19] Bathing culture was important for the Roman culture, succeeding the Hellenic one, and public baths (thermae) remained to be important carriers of public life even after the adoption of Christianity (starting with *Edict of Milan*) which later became the official religion of the Roman Empire. Even when public nudity may have been contested by Christian beliefs, hygiene and spa culture prevailed deep into the Christianity period of

[18] Delphi prophecy site was developed around thermal springs and carried an important role in Hellenic (Greek) culture. The devotion to mythology and well-being and magic, was involving phenomenon such as geysers, steam manifestations, which sometimes meant the acts of Gods and places of worship (Sørensen, 2010)

[19] Sørensen, 2010, 5

the Ancient Roman empire. [15][20] However, the use of GE for heating in buildings of ancient Roman empire was scarce as compared to overall potentials, because of complex set and interplay of *social*, *cultural* and *technological* reasons.

Truthfully, the Romans have perfected aqueducts in ancient times to that extent that some of them are still in use today in some towns. Floor and wall heating in Roman villas, public and private baths (*thermae*) and many other buildings are predecessors of contemporary building and infrastructure technologies which use low-grade energy heating. Despite having developed such systems, the use of geothermal energy for building heating was rather limited in Roman times. Hydro-geothermal energy was used in localities where water temperatures were close to 100 degrees (and above). Water was, then, transported by means of pipe system to a local bath which required water temperatures equal to the temperature of the human body (around 36 ° Celsius). This was achieved by mixing hot water with cold water. However, the technology of heat exchangers and heat pumps was unknown, as it was invented at the end of the 19th century, based on the writings and experiments of Joule and succeeding scientists, such as Thomson (Lord Kelvin) and finally Holden. [16, p. 20] It was therefore highly unlikely that Romans knew how to achieve district heating or how to warm up low temperature water. Even though there were many geothermal natural wells near Roman settlements in the Antique, the Romans were focused on supplying energy to their buildings and cities by using other fuels available as energy source and men labor for maintaining these systems. Additionally, their towns were much smaller than the cities and towns that we live in nowadays. In ancient Rome, even though modelled according to the ones around geothermal waters, the spas used *hypocausis*[21] systems and *praefurnium*, based on hard wood. A good example is Terme di Caracalla in Rome.

Hard fuel was used in spas because there was no geothermal fluid in vicinity which could justify geothermal utilization in buildings or heating systems. On the other hand, the Romans were masters of hydro design. Vitruvius mentioned sophisticated systems in his work *X books on architecture* but did not understand how heat flow exactly worked in buildings. [14][22] However, it seemed that his writings had not made a distinction between mechanical engineering and architecture, as most architects were engaged as engineers and vice versa, at that time. [17][23] [18][24] On the other hand, one might argue the fact that people of the Antique could have used the opportunity to integrate geothermal resource into their buildings and cities more, if they had known today´s principles of heat loss.

Despite this, Romans did have a connection to geothermal resources when building and advancing their towns technologically. Traces of Roman activities, building and

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20 Jeremić, Gojkić, 2012, 29

21 Hypocaustum Sg.

22 Sørensen, 2010, 3

23 Barber, 2012, 5

24 Toomer, 2018

infrastructures were confirmed around every archeological site near thermal springs in the Mediterranean. This showed that Romans built their cities around natural thermal waters. However, they did not use them for direct heating, but rather for balneology and wellness at Roman spas. Nevertheless, there were exceptions to this rule. In Pompeii, the dwellers used geothermal energy from Vesuvius volcano lava for heating up their homes in Ancient times. [19][25] A pipe distribution of hot water for domestic heating and use in spas was recorded there, as mentioned by Sørensen. [14][26]

Figure 1, Reconstruction of a Villa at Pompeii, Casa dei Vetii di Pompeii, most of city of Pompeii ´s architecture is preserved nowadays and it allows for models to other Roman architectures of similar purpose (see subchapter The origin of the city- important for re-thinking the city), which have been scattered all over the Roman Empire territory, source:https://upload.wikimedia.org/wikipedia/commons/thumb/1/1a/Ricostruzione_del_giardino, accessed 06.03.2018

Figure 2, Streets of Pompeii nowadays: these streets had piping which confirmed GE use. Here, trenches were used for hot water circulation, to supply households and Roman baths in Pompeii, according to [216], source: http://pbkphotos.co.uk/pompeii/, accessed 03.03.2018

Therefore, despite high technological levels of the civilization, most of ancient Roman heating systems did not include geothermal heat to great extent, especially where temperatures were less convenient, because of:

-lack of available know-how to use technology of heat pumps or heat exchangers, which is available nowadays

[25] Blodgett et al., 2014

[26] Sørensen, 2010, 5

-secured fossil fuels and wood reserves in the Roman Empire, being also larger at their time in the Roman territory, compared to now

-cheap and available slave labor which could heat up their furnaces with the above-mentioned fuel

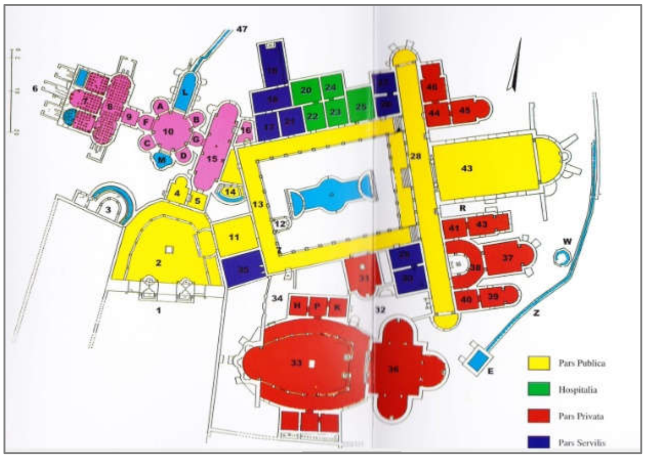

Figure 3, *Caldaria* and *iaconium* in the Villa de Casale, containing typical raised flooring for heating floors in hot baths. Had it been for geothermal hot waters in vicinity of the villa, Romans would have integrated it into the building´s heating system. http://himetop.wikidot.com/thermal-rooms-in-the-villa-romana-del-casale, accessed 05.03.2018

Figure 4, scheme of Villa Romana at Casale, near Piazza Armerina, Sicily, built between 300 and 400 A.D., contained Thermae (upper left part of the complex) and *aqueducts* which supplied the palace with cold water, which was then heated by hypocaust systems. This is one of the many examples where GE was lacking, however thermal bath found its use as integrative part of architectural design. Source: http://cannarella.com/wp-content/uploads/2017/01/villa_romano.pdf, accessed 24.01.2018

1.1.2 **Medieval use of geothermal**

The successor of Roman culture in Europe was the Byzantine civilization which continued the Antique Roman traditions (and lasted until 1453). Following this period, most of Medieval Europe´s culture and technology employed in cities was based on Roman and Greek experiences. In France, in *Chaudes Aigues* a medieval system of geothermal district heating dating back to 1330 AD was recorded in writings on the city. Here, an underlying aquifer was used in form of a natural spring with waters of 82 °C to supply the citizens of the town with hot water, who in return had to pay taxes for system´s maintenance to the community [20].[27] Nowadays, this heat sources are used for local tourism, balneology and cultural references. However, they are remnants of one of the oldest known GDHS in history on European territory.

Figure 5, The Par spring integrated in the urban tissue of the medieval city Chaudes Aigues, it started to be utilized by the dwellers in 1332 and the system had piping combining sewer system and delivering hot water to dweller houses. source: fr.wikipedia.org, accessed 06.03.2018

In terms of Eastern Europe, Ottoman Empire was considered a civilization of thermal baths.This was influenced by rich heritage of spas and geothermal wells in Asia Minor and Greece, assimilated by the Ottomans after the Middle Ages. For example, *Pergamon baths* of Greek origin had been built before the Ottomans came to rule in Asia Minor. They are located on today´s Turkish territory. Also, many spas in the Balkan countries, Greek, Macedonia, Aegean islands, as well as spas built in 16th and 17th century Budapest (Veli Bej, Rudas, Király et al.) testify of the rich thermal spa heritage of the Turks. [21][28] Additionally, the city of Bath in England was known to have been the city which name originated from its hot springs, which were utilized in the Antique and during the Middle ages and where, centuries later, famous Thermae of *Bath* were erected.

[27] European Geothermal Energy Council, 2007, 2

[28] Gyori, 2011

Figure 6, Veli Bej, Császár spa in Budapest, remaining Turkish dedications, source: http://visitbudapest.travel/activities/budapest-baths/csaszar-baths-veli-bej/, accessed 03.03.2018

But it was not only the ancient Mediterranean, European and American cities that were prone to using GE throughout history. The *cult* of geothermal water had evolved around spas in China 2000 years ago [14][29], and ancient *Maoris* in New Zeeland had known how to utilize hot springs for their needs [19][30]. Japanese culture, in form of the famous *Onsen* resorts, is known to have centered spa and other buildings around thermal manifestations for centuries. [22][31]

1.2 Contemporary use of geothermal

The come-back of spas did not happen until the end of the 19th century, when medical and heating purposes advocated geothermal use in many resorts and hotels in Europe, such as in *Gellért* Hotel swimming pool in Budapest, around 1900. [14][32] Also, the use of geothermal energy for electricity production happened in Italy at *Lardarello* where in 1904 P. Conti had performed a large-scale installation for power production in an experiment, which eventually lead to power plant being built her. The plant is still in use nowadays. The importance of this project for overall geothermal development was such, that it eventually influenced countries with known but untapped geothermal resources, to engage into exploring their own GE potentials for heat and power production options. Connection to cities and buildings was back then not as important as it may be today. The main triggers were the economic crisis and energy dependencies, which the post-industrial developing societies of Europe and US faced. A good example on the American continent is Boise, Idaho, where first modern

[29] Sørensen, 2010, 5

[30] Blodgett et al., 2014, 6

[31] Shortall, Kharrazi, 2017

[32] Sørensen, 2010, 7

district heating system in the world was built at the end of the 19th century and began operation in 1890 [23][33], using local geothermal hot springs and supplying the city of Idaho with heat. Some hundred years ago from then, geothermal district heating in the U.S. has hardly developed. Strangely enough, geothermal heat was part of the native Indian traditions in US territory for over a thousand years as medical and cooking tools [19].[34] In this way, American culture of the 19th century must have known of the importance of geothermal resources and decided to turn to District Heating System (DHS).

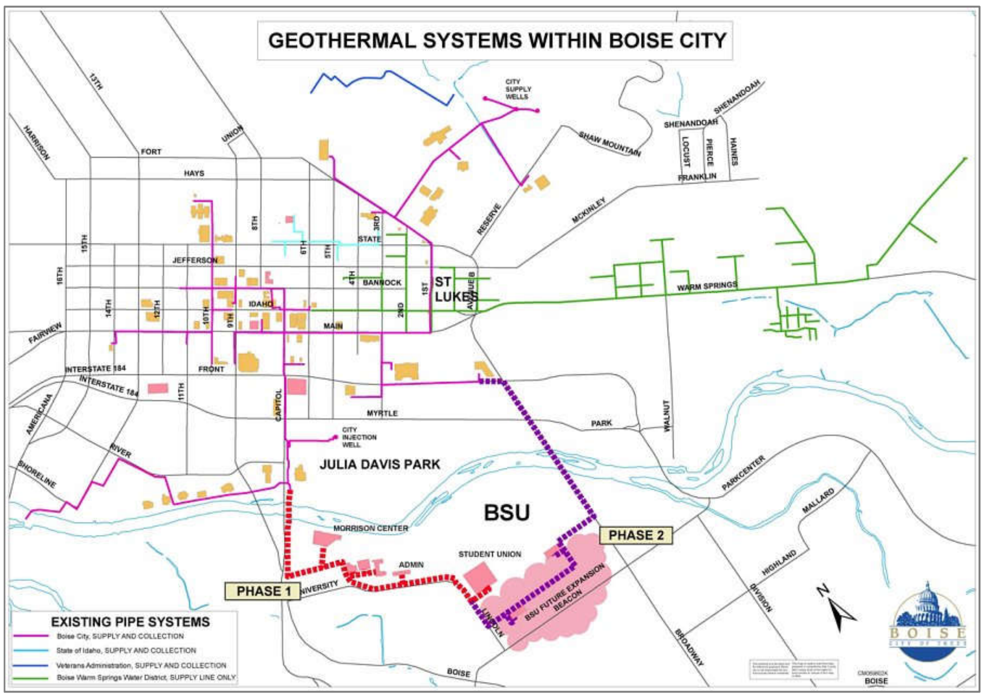

Figure 7, One of the first modern district heating systems in the world, Boise, Idaho, USA. Made in 1890s, it is still in use today (scheme shows the planned upgrades). Despite US being at the forefront in regards to Geothermal District Heating System (GDHS) back then, district heating has been neglected for most of the 20th century, and is limited almost exclusively to Western States, like Idaho, which are rich in geothermal manifestations, source: https://green.blogs.nytimes.com/2009/11/09/universities-turn-to-geothermal/, accessed 04.03.2018

[33] Rafferty, 1990

[34] Blodgett et al., 2014

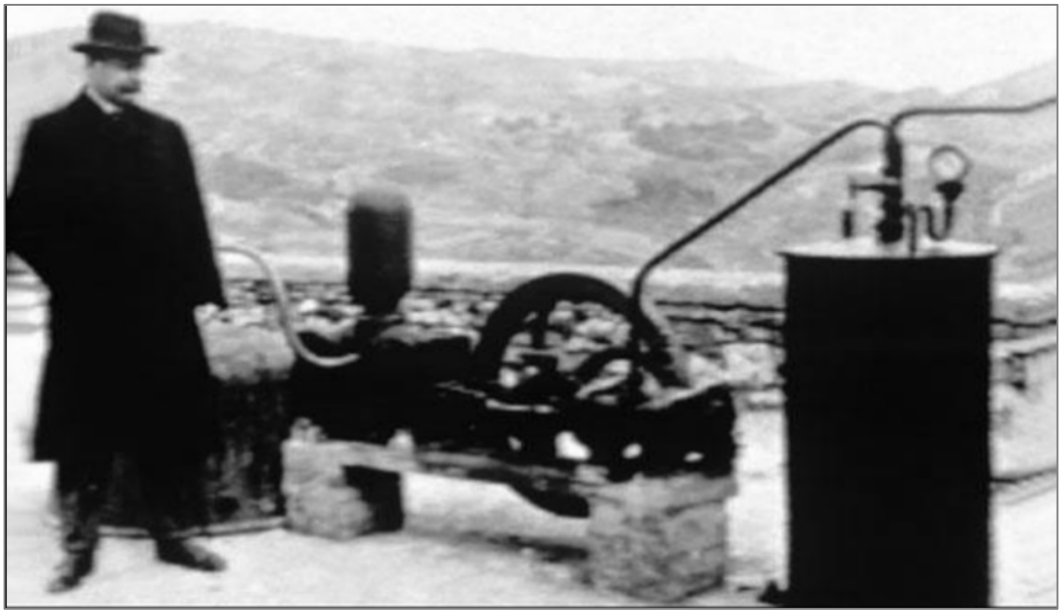

Figure 8, Larderello geothermal power plant with P. Conti shown next to the equipment, (at first, Lardarello firm used to extract boric acid, but later evolved into an energy productionfacility, using GE as power source), source: Geothermal heat organization, Report, 2014, http://www.geo-energy.org/reports/Geo101-Binder1.pdf, accessed 02.03.2018

The experience with GE used for heating throughout history influenced the installation of geothermal electricity production facilities later. For example, in Japan, especially after the *Fukoshima disaster,* GE is seen as an option for helping desperate communities that had been affected by the Earthquakes recently.[35]The use of GE for electricity production at Lardarello influenced other countries, such as Iceland, in the pursue of GE utilization both for energy production and district heating later in the 20th century.

At the turn of the 21st century, geothermal became a tool for combating energy poverty in least developed parts of the world. In terms of electricity production, this was suggested in Kenya. Strangely enough, although the whole geothermal energy development happened throughout history in the most developed parts of the World, the use of GE is becoming more important for re-development projects and as integrative tool for achieving sustainable development and relieving societies from the need of utilizing fossil fuels. This is especially true for underdeveloped communities, where countries like Iceland have been trying to export their know-how and advocate for GE use, based on their own experience with geothermal infrastructure and within UN projects [24]. [36]

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35 More on the effects of GE utilization for electricity and power production after the disaster at Fukushima can be found in Japan`s initiative to become an eco-friendly country, involving the tradition of GE utilization, see: (Ministry of Foreign Affairs of Japan, 2012) [224]

36 More on Kenya´s development with geothermal electricity can be found in a text at: https://www.nytimes.com/2018/02/23/business/geothermal-energy-grows-in-kenya.html (Amy Yee, 2018) [225]

1.2.1 The summary of history of geothermal use in buildings

In terms of Roman homes and villas that relied on men power and hard fuels for heating their *praefurnium* and *hypocausis* rather than on geothermal energy, little seems to have changed for the individual user or home owner. Despite technological advancements in district heating technology, the development of thought about geothermal energy as an excellent source of replacing fossil fuels and managing home heating and cooling, has been neglected for centuries of human development. It has mostly been considered as an opportunity that people recognize as an option but are hardly willing to engage in advocating its use in their own homes but rather into "the buildings and systems of the future", as argued by Rafferty [25][37].

Nowadays, there is a whole new technological dimension in contemporary society, as many technologies, including heat pumps, heat exchangers and DHS have evolved and their efficiency significantly updated. It seems that so little has changed in architecture and cities where we live in today, as the end consumer often does not care where energy comes from and planners often do not realize the relation between energy and planning of cities or buildings.

Figure 9, Presumably Roman octagonal villa in ancient Nis (Naissus), some 4 km from Mediana, heating systems of this villa was wall/floor heating with *praefurnium* (using hard fuel). It dates from

[37] Rafferty, 1992

the Golden era of Constantine and his sons (around 4th century AD), its function as a housing object or persons who have used it, has not been proven, according to Miric [26][38]

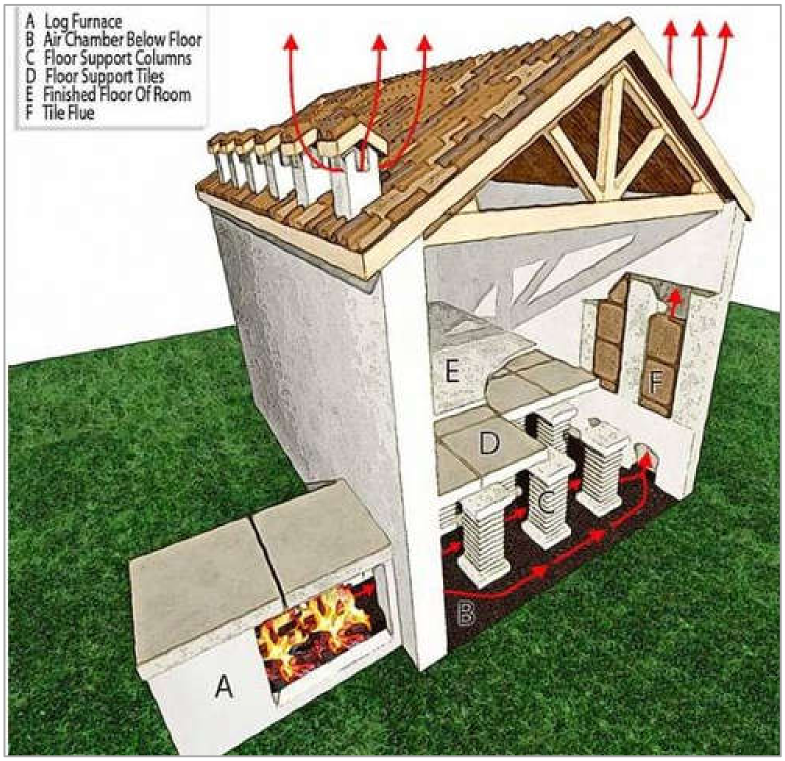


Figure 10, Typical furnace system, similarly to this, Romans have used *praefurnium* (pre-heating furnaces) and *hypocausis*, *tubuli* and *tegulae mammatae* (pointed clay elements inside walls, used for heat distribution) within floors or/and walls [15][39]; much of this technology has gained on attention recently and some of its components have been applied widely in modern heating of housing and public spaces, source: https://www.pinterest.com/pin/152840, accessed 26.10.2016

[38] Mirić, 2015, 142

[39] Jeremić, Gojkić, 2012, 32

2 Types of geothermal energy sources used for heating-direct use vs. heat pump technology

"Geothermal energy can be divided into two big categories: shallow and deep geothermal. Shallow geothermal energy (low enthalpy resources) refers to the fluid acquired from the depth of ground zero to 400 m in depth, as well as to its potentials in thermal energy that can be used for heating and cooling. Deep geothermal energy is usually at depths larger than that and at higher temperatures [1][40]." Usually, capacity of geothermal waters and its potentials in technical terms are evaluated by using temperature levels (in °C or °K) and flow rates (l/s or sometimes kg/s). These are both of equal importance for evaluating whether a fluid can be utilized for heating or electricity production over a period.

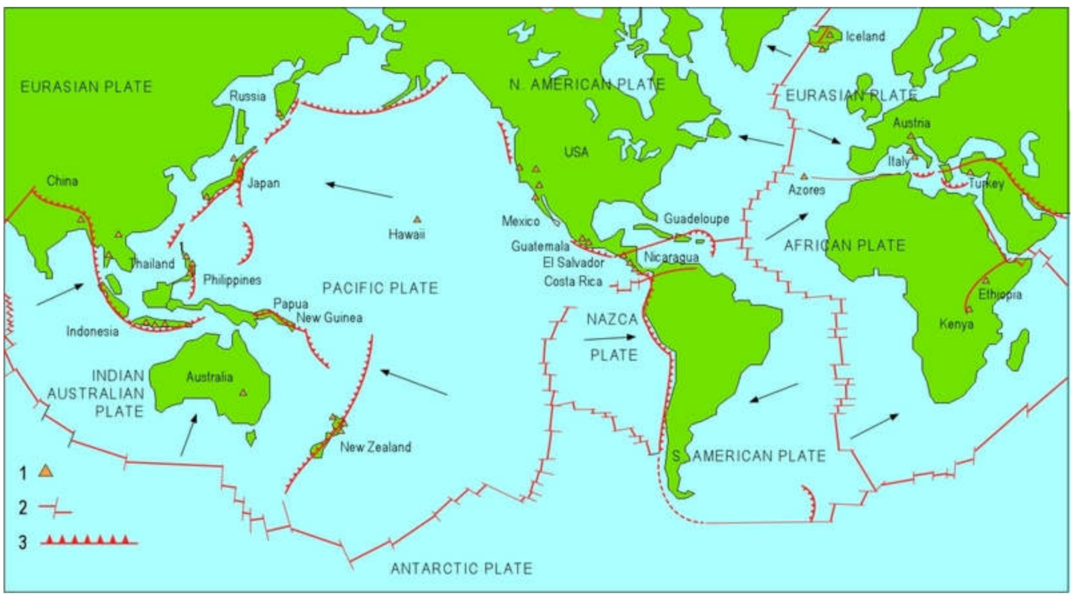


Figure 11, Tectonic plates of the Earth´s crust, the lines represent the plates 'boundaries, For example Iceland is between Eurasian and N. American plate, a volcanically active region, source: http://www.unionegeotermica.it/images/What_is_geothermal_en_html_2f5bdb15.jpg, accessed 04.03.2018.

"Depending on the characteristics of the soil and different factors, such as the amount of solar irradiation on the Earth´s surface, recent volcanic activities or high geothermal heat flow in the area, the city may be predetermined to use deep geothermal or shallow, or both. Very shallow geothermal systems to about 200m or less depth typically use heat pumps to enhance the thermal characteristics of the lower temperatures encountered. In deeper regions

[40] Jovanović, 2017, Ghent

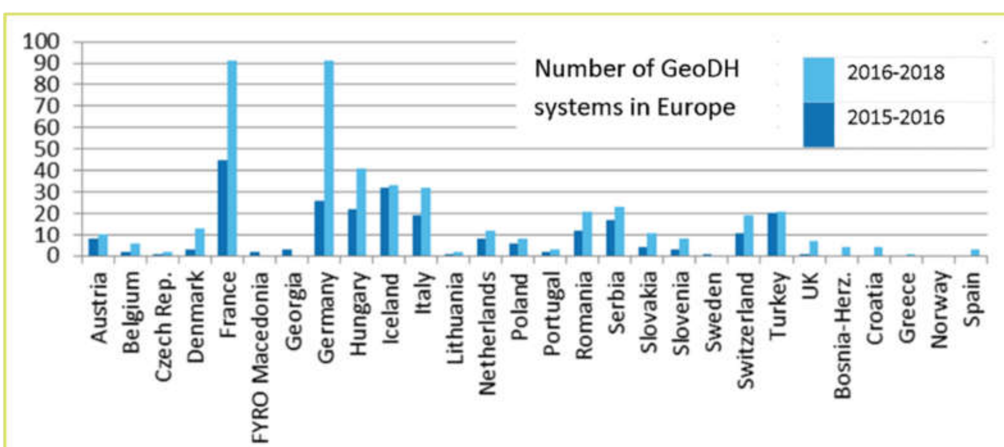
of the Earth´s crust, heated water or steam is sometimes found in hydrothermal rock formations that can be extracted and utilized directly in district heating systems. When rock temperatures are high enough to be useful but water is not naturally present, enhanced geothermal systems (EGS) technologies can be applied. Their use is in some cases necessary, if one aims at the high enthalpy[41] geothermal energy. It also may be contested since enhanced geothermal systems have the potential to induce seismicity. One example specifically seen as problematic in U.S. cities is *fracking*, used as a process for stimulating EGS reservoirs. This system is applied by making fractures in the rock at higher depths in the soil, that allow the artificial fluid to be heated and used for different purposes. The use of *fracking* as a tool and its real effects on the environment is contested. [1]"

Deep geothermal systems are usually "open loop" systems, which imply extraction from one place and injection of cooled fluid in another pipe, coming as used from district heating or cascade heating, to the other. This is also called "doublet", as there are two separate drillings (one for extraction, the other for re-injection of the fluid). (see Figure 13)

Current capacity of Geothermal District Heating System (GDHS)[42] in Europe (direct use) is estimated at 4400 MWTh with the annual production of 13 000 GWh on European level. There were 250 GDHS installed in Europe up to 2016, with some 200 currently being developed, mostly in central and Eastern Europe. [11][43]

Despite these facts, there are still constraints which limit the use of geothermal energy (GE) for heating, such as low level of incentives for GE and unfair position of it to other fuels, upon which whole cities and communities are largely dependent on.

Despite being one of the largest producers of electricity from geothermal energy, USA investments in GDHS have been contested due to cheap fossil fuels on the market. The installed capacity is relatively small as compared to overall potentials of GE here. However,



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41 High enthalpy- with higher temperatures (usually present with deep geothermal energy)

42 GDHS stands for a system of supply of hot water to a set of buildings within an area, which uses geothermal energy (geothermally heated fluid) as resource

43 European Geothermal Energy Council, 2017

there is great opportunity for developing GDHS in some regions of the USA in the future. [27]

Figure 12, Number of installed GDHS in Europe, source: http://geodh.eu/wp-content/uploads/2012/07/District-Heating-Project-in-Europe-2014-2018-EGEC-market-Report.png, accessed 05.03.2018

Figure 13, Geothermal system (doublet) in the Austrian town of Altheim, showing its main components, other than district heating piping, source: G. Pernecker, presentation of the project at the Calgary conference [28][44]

Figure 14, Installment of the Geothermal District heating piping in Iceland, source: www.verkis.is presentation by T. Johanesson, Cornell 2016, used by courtesy of the presenter[45]

Figure 15, Usual size of the piping within the geothermal system based on hot water, Iceland, www.verkis.is, presentation by T. Johanesson at Cornell, 2016

[44] Pernecker, 2010

[45] Johanesson, 2016

2.2. Use of geothermal energy for electricity production and the importance of geothermal cascades for energy use

When temperatures of geothermal resource are high enough, i.e. exceeding 150 degrees Celsius, one can engage into electricity production from geothermal. In some cases, lower fluid temperatures are used in so called Organic Rankine Cycle (ORC) or Kalina cycle to generate electricity. This complex mechanical process makes use of turbines which utilize pressurized vapor to produce electrical power. ORCs can also be used in combined heat and power systems to provide district heating. The importance of further improvement of such systems is lowering the cost of drilling and utilizing primarily natural resources, thus enhancing their level of utilization and more efficient use of energy. As many countries worldwide are not as lucky as geothermally potent countries (Iceland, New Zealand, Italy, The Philippines for once), they would have to utilize lower temperature fluids.

A cascade system of GE use is proven to be the most successful. Aside from being used for electricity production, geothermal energy can be used for heating (district heating system), as well as for agricultural, spa activities, aquaculture and aquaponics. Such systems have already been in use in Iceland, Europe and globally wherever GE is found within geothermally

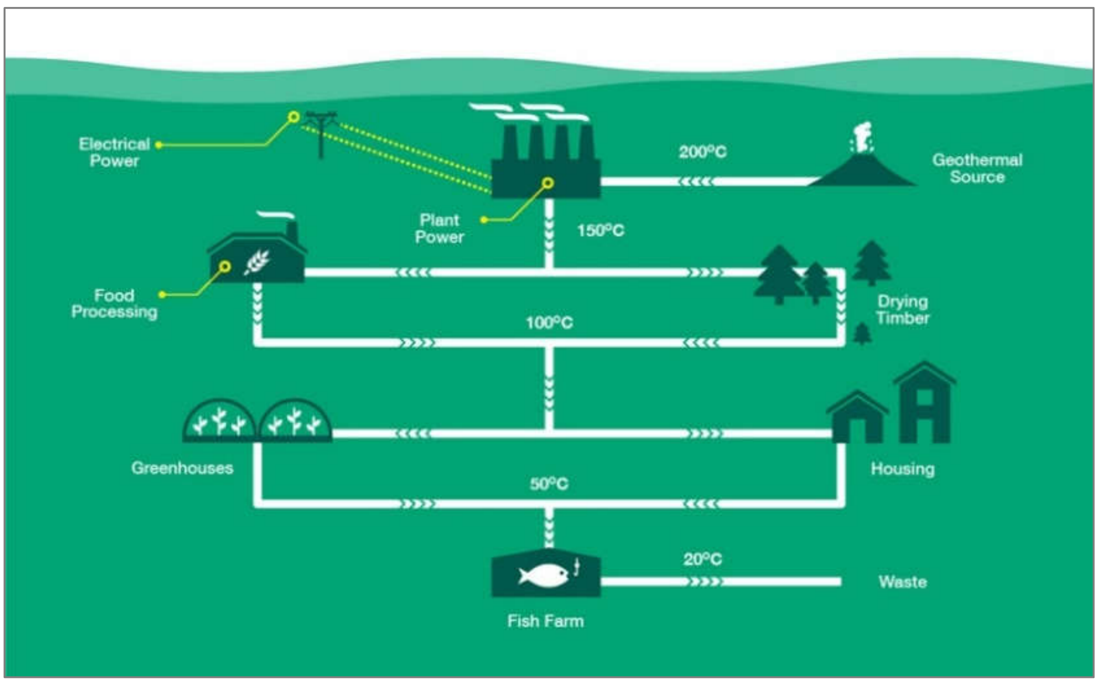

Figure 16, Use of GE within the cascade system, from electric power production (up) to fish farming (bottom end of the cycle), source: https://cdn.webvanta.com/000000/53/11/original/img/diagram_cascade_large.jpg, accessed 03.04.2018 potent zones[46] and are promising for countries which are yet to develop their geothermal potentials.

Figure 17, Geothermal distribution network in the small town of Heimaey in Iceland, district heating based on GE found in the preceding local lava eruption, clever method of attaining benefits from a disaster. Iceland isone of the most potent countries with GE, source: www.verkis.is, presentation by T. Johanesson, Cornell University, November 2016, courtesy of the presenter

2.1 Shallow geothermal energy and use of heat pump technology for extracting heat from the ground

Heat Pumps are divided into Air-source heat Pumps (ASHP) and Ground Source Heat Pumps (GSHP), based on heat extract carrier (air or ground or hot water). Geothermal energy employs GSHPs provided either from subsurface water or conductive heat from the ground itself.

GSHP utilize either through a vertical Borehole heat exchanger (BHE)[47], or through a horizontal ground loop system. The use of either of these is determined by the conditions at the site where GSHP system is being installed and the available space for drilling and putting the system into the ground. The choosing of the depth of drilling and therefore also the appropriate system also depends on the thermal gradient of the soil, usually around 1°C per every 100 meters of depth. This gradient varies, based on the location on Earth and can be significantly lower, in which case may be necessary to prolong the drilling depth, to achieve the substantial energy (heat) flow to the heat pump. Heat pump is an electrically driven device. It uses electric power as input and the fluid (usually water) temperature for the system to get output thermal energy needed for heating or cooling the space in a building. Its efficiency is determined by coefficient of performance (COP) and is being derived by

[46] Geothermally potent zones are centered around the continental plates breeches, and are considered to boost in geothermal energy of high enthalpies, available as such even at lower depths

[47] Sometimes referred to also as Downhole Heat exchanger (DHE)

dividing energy input with energy output. It is no less than 1 (otherwise it would not be plausible to use) and current state of the art heat pumps show efficiency as far as around.1:4. Heat pumps can only work with temperatures of water significantly lower than those employed by direct heat systems. They can use water in fluid state of almost any temperature, ranging from ±0 °C up to around 30 °C [16, p. 23][48], whereas for greater temperatures, heat exchanger is necessary. Heat exchanger is a simple installment unit which regulates heat in a heating system, providing it at an appropriate temperature level, which can then be used by the distribution system. For example, if the temperature of produced geothermally heated water exceeds the supply temperature of the district heating system, a heat exchanger can be used to produce fluid to supply the distribution system at the desired temperature, for example, with radiators operating between (60-90°C). This approach has found use in areas where there are steam sources with temperatures exceeding 100 °C degrees, like in Iceland, for example. The appearance of Heat Pump Technology via BHE is shown in the following figure, Fig. 18and that of *direct use* of heat within a District Heating System (DHS) in Figures 13-15.

Figure 18, upper part (left) and lower part (right) of the Bore Hole heat exchanger (BHE), together with the U-shaped pipe where groundwater circulates, they form the BHE. Source: https://upload.wikimedia.org/wikipedia/commons/2/24/Oberes_Ende_einer_Erdwärmesonde.jpg, accessed 04.03.2018

Heat pumps can be arranged in a centralized or decentralized manner. This means that the centralized arrangement of heat pumps must include two pipe-system and it means that the building owner should be able to either heat or cool with the system, but not both. As mentioned by Bloomquist, most of the building owners would choose heating over cooling, because it being more critical in most cases. [29][49]

[48] Šamšalović, 2009

[49] Bloomquist, 1999, 17

On the other hand, a ground loop system can be used if there is sufficient land area, thus eliminating the need for drilling shallow wells to create BHEs and associated costs. However, if only limited land area is available, BHEs are employed when there is enough space at the parcel next to the building itself. Naturally higher ground temperatures are to be expected at greater depths, which results in higher rates of heat transfer to the fluid in the BHE. Ground loops are buried at the depth of only a couple of meters in the ground and can be affected by temperature oscillations in the atmosphere to a significantly greater extent than BHE systems.

Many countries, such as Iceland, have abundance of geothermal heat and installed GDHS, and thus focus on exploring heat pump technology application which is able to supply the "*cold areas*[50]" with geothermal low-grade heat. Heat pump technology will probably play greater role in the future of GE utilization in the world as it represents the best way to utilize all of Earth´s energy present at a location and could be used anywhere.

Harvesting GE still has to be improved in terms of energy efficiency of heat transfer, utilization and infrastructure, and reduction of geothermal gases. Furthermore, it is necessary to minimize the sizes of the footprints, take care of the visual pollution of the environment by geothermal infrastructure and make earthquake risk considerations by enhanced geothermal utilizations. [30][51]

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[50] Cold areas are areas where there is no substantial hydro-geothermal potential an no higher enthalpies available

[51] Iceland geothermal cluster, 2015

3 Current state of research on geothermal energy´s use in cities

"Recently published study by Schiel et al. [31][52] has focused on geothermal energy´s connection to urban settings. The article examined shallow geothermal energy and its possible use for space heating and hot water in Ludwigsburg in Germany. The used methods implied calculation of heat demand of the city parts and heat extraction potentials. Additionally, the study calculated the extent to which the demand for energy was covered with geothermal on an individual object's scale, as well as benefits that such actions might bring to the environment. It also presented the Smart City Energy Platform[53] for each parcel within the city, showing geothermal boreholes at the parcel (mostly borehole heat exchangers were applied, with distances between boreholes and edges of parcel taken into consideration). This example showed how heat potentials could be determined and urban form of the settlement could be made accordingly by using simple methods of calculation and visualization of the results. The presented optimal urban forms were the ones with less density, such as a family housing, detached housing and low-rise structures that dominate the urban landscape. Shallow geothermal made more sense in a less dense urban setting for space heating and production of hot water, per study. In conclusion, the article emphasized that various stakeholders had to be analyzed in order to achieve a good project outcome when using this model or methodology. This is where qualitative research can find its use in the future research on geothermal use in urban environments. In respect to refurbishments, that most of the cities in Europe and the U.S. would have to undergo, parallel to the application of geothermal energy, a few innovative studies add to the knowledge database. Another study from 2014 by Mastrucci et al. [32][54] focused on the development of a tool for energy demand and supply calculations in the city of Rotterdam, with 300,000 dwellings. The greatest success of this study was that it developed a tool for energy analysis which was applicable to other cities. Another aspect was that the outcomes of the analysis of an urban setting gave grounds for decision making within the urban planning policies, especially in terms of urban heating networks and diffuse renewable energy utilization within the city parts. Local renewable sources were therefore supported at the policy and governing level when dealing with energy dependence issues. Some improved modeling of energy scenarios was suggested for the future applications in cities. This related to other cities worldwide as a possibility for their refurbishment models.

A manuscript on the importance of energy planning at a community level [33][55], explained why energy planning should go hand-in -hand with urban planning. It put emphasis on self-

[52] Schiel et al., 2016

[53] http://iguess.tudor.lu/, accessed 11.04.2018

[54] Mastrucci, 2014

[55] Petersen, 2016

sufficient heat and electric power supply of communities, with locally available renewable energy. It also emphasized that this transition toward energy efficient communities did not have to be costly and that it could be done by means of system*´s thinking*[56]. This article, however, put more focus on general renewable energy integrative approach with refurbishments. It did not go into much detail on geothermal potentials within the city as an incubator for city´s developments. It seems that case study methods and their conclusions are beneficial as they add to the knowledge on different energy potentials within different communities. It can help determine tools for approaches in cities. Additionally, they are beneficial as the results from different cities allow for a more comprehensive analysis. Forming models based on different settings and conditions is more viable in creating tools for rehabilitation of cities. However, the scientist is aiming at developing the so-called "magical tools" for refurbishments and redevelopments of cities and their neighborhoods. Too much emphasis is put on this, even though this universal tool does not seem to exist at all. Therefore, the focus in further chapters of this paper will be to show that each case study done in detail is far better than developing universal tools applicable to many cities. This points out the problem of city refurbishment from a perspective different to the current globally accepted trend: sustainability per se and even pushing sustainability into confined boundaries while not understanding the essence of each city and its experts 'opinions, historical development and even not dealing with the available statistical facts about energy use nor actual state and importance of buildings in a city and its neighborhoods. [6][57] [1]"

As for studies dealing with the differences between different countries in terms of GE utilization, a recent study by Shortall and Kharrazi [22][58] suggested the connection between cultural factors of Japan and Iceland as an input for geothermal utilization in cities and areas of the two countries. The findings suggest that there are overlapping factors that influence GE applications in cities, apart from just cultural particularities of each country which have been explained in the study, in detail. However, this study also suggests that cultural particularities do influence the application and diffusion of geothermal energy and other renewable energies in cities. The study emphasizes uniqueness of each of the two case studies and shows that cultural analysis preceding the techno-economic analysis of a geothermal system or project is of high importance for the success of the project. It also brings up the topic of more public involvement and understanding for GE utilization projects. Lack of knowledge among the Onsen[59] owners and the general public and low level at which it has been covered in campaigns for GE so far are obstacles to future development suggestions.

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56 Unlike typical district heating system which is detached from thinking electricity networks, demand and supply needs of buildings at different times and their own contribution to energy production, in a system

57 Jacobs, 1961

58 Shortall, Kharrazi, 2017

59 Onsen is a form of a Japanese hot spring resort. Onsen owners have been skeptical towards the state-wide plans for larger geothermal energy utilization to produce electricity lately and seen the plans as threats for business and the environment of the areas around the hot springs. On the other hand, as argued in previous

As for methodological approaches to examining energy issues by using social indicators in four different European countries, the study of Carrera and Mack [34][60] used the expert interview method by group Delphi approach and could deliver comprehensive results of the whole international sample on the renewable energy issues. These results can supplement the survey among general population on the feasibility projects in communities. Using phone interviews was a new approach to social research of energy technology issues so far and its role in developing array of new and important questions in the field deemed important [34] Therefore, it was a starting point in this research to apply similar methodological procedures in the research of both European and American case studies.

A very innovative approach to using geothermal energy for desalination processes was examined together with other renewable technologies, such as wind and solar, by Ali et al.. [35] These findings indicated that GE, compared to other RES, showed a continuous uninterrupted thermal energy characteristic, which was important for the future applications in many areas of development. Among these areas, GE´s relation to city and urban neighborhoods had not been substantially addressed so far.

However, the possibilities of heat pumps were acknowledged in a study by S. Miglani et al. [36] on supplying urban neighborhoods with constant flow of heat. This study showed that after long period of heat extraction from the ground, by using BHE technology, Geothermal Energy Potential (GEP)[61] seemed to decrease. The authors suggested that finding some way of supporting thermal balance of the ground, especially during summer season, would be of great importance for the future. Additionally, they suggested solar thermal as additional means to GE, apart from already known fossil fuels, such as gas and oil. The technical glitch to overcome in the future was to create such a technological system that would recharge the ground and at the same time, provide enough energy for heating of buildings within a study of an urban neighborhood which heat supply was based on shallow geothermal energy. The importance of this study is in the fact that it is one of the few published papers which deals with the topic of ***spatial*** constraints in the application of geothermal technology to a set of buildings to cover their cooling/heating demands. [36][62] It is therefore a step further in defining possible connection of urban planning to geothermal energy, especially shallow geothermal via BHE and GSHP technology. Finally, the study puts forward one basic question: how connecting between various energy sources and calculating their potentials, as well as connecting with their counterparts- buildings, can be further investigated as an advanced approach in the future.

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chapters on geothermal history, GE provides struggling communities in Japan with power securely, (Ministry of Foreign Affairs of Japan, 2012) [224]

[60] Carrera, Mack, 2010

[61] When a Borehole Heat Exchanger(BHE) maintains the value of Mean Fluid Temperature (MFT) above the certain given (assumed) threshold within heat pump operations, the heat demand required for this state is called the Geothermal Energy Potential (Miglani et al., 2018) [36]

[62] Miglani et al., 2018

On the other hand, there are many studies focusing on Deep geothermal energy and systems, especially EGS (Enhanced Geothermal System) that should enable larger quantities of heat to be extracted, using complicated procedures and technologies made available recently. In a study by T. J. Reber et al., [27][63] cost analysis of EGS for three states in the U.S. was made throughout different locations in New York State, showing geothermal potentials to be substantial even in areas of the U.S. where geothermal gradient (GG) considered to be quite low, like most of New York State. The study showed advanced state of thinking about tapping into geothermal heat of the ground at greater depths to be feasible and economically beneficial, in comparison to current fossil fuel usage costs. The only challenging costs are the costs of the drillings and EGS reservoirs 'completion, given that the existing distribution network in form of a district heating system and surface equipment are already present in some form, allow for simple transition to GDHS via a heat exchanger. The authors point out to the necessity for an aging community, in the northeast of U.S. especially, to become more focused on supplying its cities with clean energy and district heating as an option for the 21st century, to support resilience initiatives at the national level. The application of GDHS is thought to be the possible leader in these transitions in cities, despite its current states where GDHS application is sporadic and underappreciated in terms of the overall potentials in the country. The contribution of this thesis would also be to name some of the most important reasons which influence the expansion of geothermal systems for cities and which can serve as supportive arguments for its application in the future. For this, several case studies of different circumstances in geothermal potentials and socio-economic conditions existing within their communities will be explained further in the chapters on case studies.

In the U.K. there has been consideration of large-scale application of GSHP technology, which reached not only new buildings but also quite old Victorian buildings. A study of R. McMahon et al. [37][64] made a detailed thermal modeling procedure, showing the values of a Standard Assessment Procedure (SAP) for thermal modeling in the certification process in the UK to be less assertive of the real capabilities of GSHP in older buildings. The study induced confidence in using heat pumps in older buildings and emphasized the thermal modeling in combating SAP flaws. The study confirmed that the pay-back period of the investment in such a system in an old house in England was between five and seven years. The greatest assets in a project seemed to be the installer support, user behavior and expectations and long-term monitoring of the system after it had been completed. It also pointed out the problem of addressing mostly well-insulated and mostly new built houses, with floor (low -temperature heating) as appropriate for GSHP in literature on "success stories", however the greatest saving are to be expected in the buildings that are not attached

[63] Reber et al., 2014

[64] McMahon et al., 2018

to gas grids and which use oil for heating. [37][65] There are many old buildings both in Europe and in the USA, which are in need of refurbishments. Some of them are considered to be of greater value for architectural history and surely GSHP could be considered as one of the options to support their renovations and long-term sustainability within changing communities, such as declining cities, post-industrial cities, shrinking cities or even socially unstable cities[66], with strong segregation culture between neighborhoods and city´s urban, peripheral or even surrounding rural areas.

Lastly, new systems of the 4th Generation District Heating (4GDH) within the *smart grids* of gas, electricity and thermal grids, have been suggested in a study by Lund et al. [38][67] Special aspect of this system is creating as many as possible low energy buildings on the demand side of district heating supply chain. A GIS based model that advises on cities´ energy efficiency measures, determines efficient conversion technologies and RES utilization has been created by L. Girardin et al. [39][68] All of these studies aim at calculating centralized and decentralized options for heat supply and demand, thus emphasizing efficiency of urban area´s DHS and giving inputs that can affect urban planning.

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[65] McMahon et al., 2018

[66] The first case studies in this research are considered as good examples of this type of cities

[67] Lund et al., 2014

[68] Girardin et al., 2010

4 Motivation, aims, methods and sampling

"The topic of this dissertation was initiated due to the lack of interest for the topic in the academic urban planning environment and in its connection to practical implementation. Moreover, most of the research topics in architecture focus on different ways of approaching aesthetics, physical form or a specific problem in design. The socio-cultural context of technology is left far behind these topics. This aspect is rather important, because it is one of the biggest contributors to the evolution of architecture and should be studied with greater detail than it is the case now. Therefore, geothermal (as an "alien") has been put into focus of architecture to try and challenge its response to it and see what can a discourse in contemporary urban planning be made of, in terms of geothermal utilization and planning in cities. Finally, it is very hard to gain knowledge in an emerging field, such as geothermal utilization in cities and urban planning in a short time. Usually, technological achievements are happening too fast, for this knowledge to be consolidated and used. On the other hand, the expansion and further technological use of this knowledge is needed. [1]"

The purpose of this research is to address the problem of a more alleviated urban development of cities and their region in the context of renewable energies, especially geothermal energy. This has been achieved by connecting geothermal energy with demographic changes and conditions on energy market, and by referencing cases studies of "good practices" and their comparison to the ones less developed in terms of GE utilization.

The methodology is formulated around three most significant methods:

expert interviews,

historical analysis of the use of geothermal energy in cities,

comparative analysis of different case studies.

The following countries were chosen for the case studies: Iceland (having the most advanced system of geothermal district heating in the world), USA (having historically built the first GDHS in the 19th century, however with lacking geothermal advancements so far in cities), Serbia (being a post-communist country with fair geothermal district heating potentials that haven´t been used but promise a lot for the future) and Austria (Having installed GDHS on its territory and member of the EU, with cross-border cooperation programs on geothermal utilization, of importance to show good practice options and models for GE use for the rest).

The comparative analysis of these case studies was important to induce conclusions on the topic and to make certain generalizations that apply to GE´s utilization in cities, considering different shades of socio-economic situations and analyzing cultural factors. Finally, the analysis of city of Utica´s urban neighborhood certification tool helped to see ways in which geothermal energy could be advocated within an all-round integrative approach in urban planning. This method should be further applied to all other case studies, regardless of the level of geothermal energy utilization, as they touch the entire sphere of planning.

4.1 Expert interviews

"Experts were interviewed as part of the inquiry into the possibilities for urban planning strategies. This method gave the necessary insights to the problem of renewable energy use and helped to acquire the necessary information about the existing problems in this field from the specialists' points of view, who were engaged in the field of renewable energy or/and planning for more than ten years during their professional careers. [2]"

It was necessary to use a set of expert interviews with experts coming from different fields and put them into discourse of geothermal use in cites. Quantitative assessment in form of a wide survey among experts could deliver enough scientific material but no details. That is why a qualitative analysis, in terms of contemporary use of geothermal in cities with experts' interviews, was performed. Four case studies were selected and analyzed for the needs of this thesis- Utica, NY; Nis, Serbia; Altheim, Braunau/Simbach; Reykjavik, Iceland. While conducting expert interviews in Europe and in the U.S., a couple of experts coming from different fields were examined. Two of the interviews were made in the city of Utica, one with its urban and economic development expert, the second with an engineer working at the engineering department. A member of the academia was interviewed, to gather opinions on Utica and development of geothermal in the U.S. Finally, one of the samples was acquired by a workshop or by a special class with a geothermal expert. Couple of interviews included the firms that have installed geothermal as well. Contribution of the qualitative method like this is that it can supplement the quantifying methods usually used in planning (GIS, numbers, figures and statistical representations). [69] It was the case, that it also opened-up new questions for the researcher during the interview acquisition and allowed for a grounded-theory approach to be applied during the research.

[69] GIS is referred to as Geographical Information System, used in various representations of urban potentials of specific areas. One good example is Vienna, where the thermal maps are used to show geothermal potentials within environmental benefits. For more information see: https://www.wien.gv.at/flaechenwidmung/public/, accessed 19.03.2018

4.1.1 The process of obtaining interviews and its particularities

The experts are based in Iceland, Serbia, Austria and in the USA. A qualitative data acquisition and analysis approach was used, whereas the experts had at least ten-year experience in their field of expertise. The recommendation of the interviewee sample was collected by academic communities in Iceland, Austria and Serbia. On average, the interviews lasted for 40 minutes. The process of data analysis and citation was made anonymously. The verification of the interviewee adequacy and their references (professional papers, references and scientific contributions) were conducted by means of an Internet search at www.google.com. Also, at the end of each of the interviews, recommendations were given by the interviewees, on who they think can be the next interviewee that can address specific problems mentioned in more detail and with greater expertise. This method was also used by Shortall et al. [22][70] as a comparison tool in research on the role of geothermal energy in different case studies and showed to be helpful.

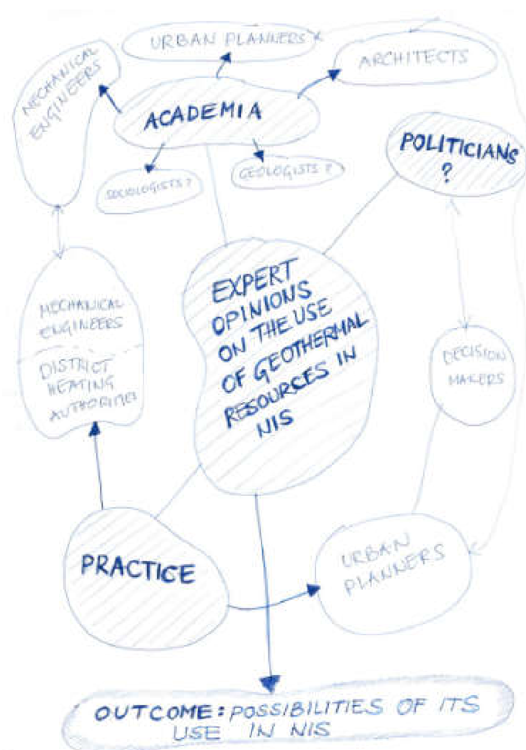

Figure 19, Introduction to the expert interview sample used via mind map, on the example of Nis. Sampling of experts within different fields: academia, architects, urban planners, mechanical engineers, geologists, district heating authorities, mechanical engineers, civil engineers, urban planners, politicians, decision makers, executives and geothermal experts. [2]

The particularity of this research is the number of case studies, shades of their geothermal potential and socio-economic structure. The examples are Austria, a rich European country with high Gross Domestic Product (GDP)[71] and being an energy conscientious society, Iceland with access to the resource, USA with high GDP, but with detested geothermal

[70] Shortall, Kharrazi, 2017, 107-108

[71] Gross Domestic Product are used as nominal values to help determine the economic capabilities of a country or region

heating options, sprawled cities consumer society, and Serbia, an Eastern Block European poorer country, with low GDP and medium level of sprawling and energy consciousness. There are, therefore, different shades of these case studies and each of them is in fact unique. It allows for conclusions about geothermal utilization to be more informed of the specific socio-economic circumstances than may have an influence on planning, policy, architectural design and advancing of geothermal energy as an energy source for cities and communities in the future.

By synthesis of opinions, comparative analysis and referencing, a collage of opinions is made, which contributes to science because it opens a new dimension of viewing of settlement planning in the context of energy inputs. On theoretical level, a theory of alleviated urban development has been scanned for its applicability in terms of geothermal energy and it has been suggested on the example of Nis, its region, urban planning and strategic development. *MaxQDA* was used for transcribing data. The samples used with specific case studies are illustrated below.

4.1.2 Problems associated with the research methodology/ the process of research methods´ validation by Institutional Review board (IRB) in the USA

"Unfortunately, not all the people asked were willing to participate. Especially, lack of interest to participate in any kind of communication was among politicians and surprisingly, among quite a few academic people from the sphere of urban planning. The experts who were willing to give their opinions, were challenged with the same questions on their expertise about the projects they were involved in, both urban planning or building/ district heating system where the use of geothermal energy or other forms of renewable energy was considered. The concept of stakeholders in the expert interviews can be seen on Figure 19. The questions started about general information about the project, dates, specific tasks of the interviewees within the project, responsibilities, problems and special aspects. Furthermore, the second part of the interviews focused on their opinion on the use of geothermal energy for heating and cooling. All the interviews were recorded and the answers were transcribed in their original languages (German, English and Serbian). [2]"

"In order to be able to start the expert interviews in the US and to ensure that the research was ethically correct, a review by Cornell University Institutional Review Board (IRB) was initiated and submitted. Cornell's IRB was informed about the research methods and materials planned to be used to ensure that they complied with ethical requirements regarding -human subjects. The process lasted almost one month, with e-mails and phone call exchange with the IRB committee. In the end, it was verified that the methods used, even though dealing with human participation as stated[72], were exempt and did not present the "real interaction with human subjects" in terms of Cornell ethical policies, so it was possible to move on to the next step: data collection, classification and data comparison between the new and previous case studies´ data (obtained earlier in Europe). [40][73]"

4.1.3 **Expert interview samples**

4.1.3.1 Sample in the USA

"The total number of acquired interviews in the USA (NYS) is 11 (some of which are listed in references [41] [42] [43] [44] [45] [46] [47] [48] [49][74]. One additional workshop result transcription on geothermal energy (lessons from Iceland) has been analyzed along with the expert interview sample, see reference [50][75]. Most of the interviewees were from NYS or US-based geothermal companies and research institutes with extensive experience in the field of GE (six out of eleven). Two members are tenured professors from academic institutions at Cornell University*, in the fields of geothermal energy and urban planning. One is an engineer from a facility dealing with energy distribution. Four interviews have been made with the engineers from the City Hall of Utica. Two interviews were made with the representatives of the companies that installed geothermal systems in their building retrofitting projects in Utica. One interviewee came from the neighboring city of Rome and spoke of the economic development of the region. The sample was rather diverse to try to answer as many questions as possible on the utilization of geothermal energy in Utica's neighborhoods and to relate it to its diverse architecture and its sustainability as goals of urban planning.

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72 IRB defines interaction with human subjects made at or by Cornell staff and students. They have to fulfil criteria of ethical conduct with humans. Even though this was not the case in the preliminary inquiry by the interviewer to the committee, it had to go through the process of validation, so that results could be used by Cornell University

73 Jovanović, 2017, KGH Proceedings

74 Expert in regional & economic development, 2016; Expert in business and industry, 2016; Expert in engineering, 2016; Expert in geothermal energy, 2016; Expert in geothermal heat pump, 2016; Expert in mechanical engineering, 2016; Expert in architecture, 2017, Expert from the engineering department, 2016

75 Cornell University guest speaker, 2016

Table 1, Expert interview sample in the USA- breakdown by profession

Expert interview type	*Architecture& urban planning*	*Geothermal energy (engineering)*	*Economic development*	*Public administration*	*Private companies*	*Special workshop on geothermal utilization*
Number of interviewees	1	6	2	1	1	1
Location	Cornell University	NYS, U.S., Cornell	City of Rome, NY	City of Utica	City of Utica	Cornell University
Dates of the sample MM/YY	12/2017	10/2016-12/2016	11/2016	11/2016	11/2016	11/01/16

In European case studies (including Iceland) the sample was somewhat different.

4.1.4 Sample in Europe

Table 2, Expert interview sample in Europe, breakdown by professional background

Expert interview type	*Architecture& urban planning*	*Geothermal energy (engineering)*	*Economic developm ent*	*Public administration*	*Private companies*	*Historians and experts on archeology*
Number of interviewees	2	1	-	1	1	1
Location	Reykjavik, Hveragherti, Iceland	Reykjavik, Iceland		Reykjavik, Iceland	Reykjavik, Iceland	Reykjavik, Iceland
Dates of the sample MM/YY	01/2016	12/2015	-	01/2016	01/2016	12/2015
Number of interviewees	-	2	-	1	1	-
Location	-	Altheim, Kirchdorf an der Krems, Austria	-	Altheim, Austria	Graz, Austria	-
Dates of the sample	-	08/2015	-	08/2015	09/2015	-
Number of interviewees	5	2	-	2	-	1

Location	Nis, Serbia	Nis, Serbia	-*	Nis, Serbia	-*[76]	Belgrade, Serbia
Dates of the sample MM/YY	10/2015	10/2015	-	-	-	04/2016

As to the expert interview sample, "the actual interviewees in Serbia were the professors from the Faculty of Civil Engineering and Architecture in Nis (3 experts), the Mechanical Engineering Faculty (1), the Technological faculty (1), the City's urban planning Institutions (2), and the district and local heating institutions (2 experts). …They were synthesized afterwards, to come to general conclusions on the level of awareness on the issue and to the specific opinions on the use of geothermal energy and especially its possible connection to the urban planning in Nis. [2]"The sample from Serbia also included a person from Belgrade, specializing in Antique architecture of Nis. The number of experts in architecture and engineering was predominant here (see Table 2). [51] [52] [53] [54][77]

In Iceland and in Austria, the sample included one academic professor with experience in geothermal practical applications [55][78], whereas all other interviewees were solely coming from private companies, clusters, public institutions or were working as freelancers in their fields [56] [57] [58] [10] [59] [60] [61] [62][79](see Table 2). The number of experts coming from the architectural/urban planning field was two, with both coming from Iceland. No planners were interviewed in Austria, due to the lack of interest to discuss the topic of geothermal energy.

4.1.5 The flow of the interviews and their further analysis

The analysis was performed both manually and with the use of *MaXQDA V.12* software, when available. The coding of different aspects of geothermal energy utilization was made and could be seen in Table 4. It also included other case studies in Europe, as a comparison

[76] Even though there was no official interview that took place, there was written and oral correspondence with the members of the economic and regional governmental bodies, and private companies, which indicated some aspects of GE in the future in the city

[77] Expert in geothermal energy utilization, 2015; Expert in urban planning, 2015; Expert in Antique civilizations, 2016; Expert from the district heating company, 2015

[78] Expert - geologist and geothermal expert, 2015

[79] Expert in geothermal projects, 2015; Expert in governmental institution, 2015; Expert- engineer working in industry, 2015; Expert in urban planning, 2016; Expert from the geothermal cluster, 2015; Expert-Architect and Town Planner, 2016; Expert coming from an engineering company, 2016, Expert from the geothermal company, 2016

of their results to the set of results acquired in the U.S.A. The interviews were conducted mostly in person and some by phone. [3]"

"The interviewees were asked the same questions in a semi-structured interview form. However, certain questions were left out whenever an expert showed interest in other aspects of GE or architecture, related to his or her own professional expertise. The first interview in Europe was made in August 2015. In terms of USA, the first interview was made in October 2016, after which each of the interviews was made based on the recommendation of the previous interviewee. This seemed necessary because, at the beginning of the research, the suggested methods, such as Delphi, could not provide results on the full scope of research questions pertaining to the way that geothermal energy and engineering technology connect to architecture and, more specifically, urban planning. [3]*"*

"As seen on Table 3, most of the interviewees in the interview set came from geothermal sector. Most of them were directly involved with geothermal installations and faced numerous challenges in the field of GE utilization. Most of the interviewees coming from this sector had experience predominantly with low enthalpy geothermal resources. A member of the academia had experience with deep geothermal resources as well. A sample was interpolated with one specific workshop result [50], with an expert who came from one of the largest district heating companies in the world. [3][80]"

Table 3, Expert interview sample in the overall sample in all case studies: breakdown by main professional profile of the interviewees

Expert interview type	*Architecture& urban planning*	*Geothermal energy (engineering)*	*Economic development*	*Public administration*	*Private companies*	*Historians and archeologists*
Number of interviewees	8	11	2	5	3	2
Location	Iceland, Serbia, USA	All case studies	USA only	Austria, USA, Iceland	Iceland, USA, Austria	USA, Serbia

There were 31 expert interviews in total in all countries. As seen on Table 3, the highest percentage of experts in the whole research sample came from the geothermal or engineering sector (11 experts), followed by architects and planners (8 experts) with all the rest (12 experts) of other professions, including public administration and private companies, regional and economic development and historians.

Based on the sample distribution, a comparison of opinions among architects and planners is possible between experts from three countries. In terms of engineers, the sample is

[80] Jovanović, 2017, KGH Proceedings

distributed among all case studies, at least with one expert. This allows for a good comparison results too. Distribution of opinions of experts working in public administration is fair among most countries as well. Comparison of historians from Iceland and Serbia is possible, based on the sample. However, economic development experts were solely USA- based [41][81] [63][82] [42][83] [64][84], that is why no conclusion for Europe is possible, based on the interviews only.

Table 4, List of the number of coded segments used for the analysis in *MaXQDA*; the first 20 interviews (corresponding to columns in the graphical presentation) were from Europe, the last ten from the USA. It can be determined that topics such as rural applications and urban history dominated the answers and codes in Europe, whereas policy matters and technological explanations occurred predominantly in the U.S. interview sample[85]

Code System																																
other technical explanations not connected	1		1					1																								3
differences europe to the us		1	1			1		2																								5
history of heating in the settlement		1				1		1	4																							7
urban history		1						3	13																							17
rural applications of geothermal										3	1									1												5
methodology of the phd									1																		1					2
possibilities of serbia for geothermal use		2	1		1				2	3	1			1	1	4	3	7		2	8	2	2	2	8	22	4	17	2	1	1	97
sollutions for the future	4	10	6	4	7	3	5	6	1	6	9		2	1	5	7	3	3	2	3	5		1		4	14	1	9	4	1	1	127
energy and architecture	2	1	7	1	1	4			2	6					4	5	4		1	1		1	1		4	6	7	2		1		61
technical explanation of geothermal system	1	8	3		1	1	1	2		3	6	1		2	2	2		8	1			7			2	5	2	8	2	5	10	83
architecture & construction industry			1			3			1	1				1		1			4						1	2	2			5		22
problems	4	5	6	3	3	2	3	5	2	9	6	3	1	2	2	5	1	3	2	1	2	2		3	1	7	6	8	2	8	1	108
reasons	5	4	10	5	5	5	4	2	8	6	4		5	4	4	4	1	3	3	1	3		1		5	1	3	2	8	19	5	130
specific tasks of urban planning	3	3	2		4	3	2	6	1	8	3		2	1		6	10			5	4		5								1	69
urban planning		7	9	4	8	3	2	7	9	7	8	2	2	1		8	9			2	11		7	1	4	5	5	13		4	1	139
History of use of geothermal energy in the :			1						5	1				2	3	1	2	6	1		1	1			1	4		3	2	20	5	59
connection: urban settlements and geother	2	1			2	1		1	8	3	2		2	1	4	1	12	1	2		2		3			5	2	1	4	10	4	74
positive example for the use of geothermal	1	6	4		1	1	1			3	1		1	2	6		2	4	1		4	1					1	2	4	5	2	53
dropbacks of the use of geothermal	1				1																											2
acceptance of the public	1	2	10	2	4	2	4	4		3			3		1		1	1	1				1	6	3	1	3	3	1	8	3	68
background	2	8	7	6	1	4	7	1	1		2	1	1	2	3		5	1	1	1	1		1		1		1	1	2	1	1	63
questions&recommendations	4	2	3	2	2	1	2		4	1	1									1							3					26
SUM	31	62	72	27	41	35	31	41	62	63	44	7	19	20	35	44	53	37	19	18	41	14	22	12	34	72	41	69	31	88	35	1220

4.2 Limitations of the methodology used for research results' discussion

Since the method of the interviews and research questions has evolved during the research, it is possible that the first data set from Austria is represented with less material, whereas in the latest ones, in the USA and Serbia, interviewees have tackled a larger array of topics[86].

[81] Expert in regional & economic development, 2016

[82] Expert in urban and economic development, 2016

[83] Expert in business and industry, 2016

[84] Expert in public administration, 2016

[85] Urban Planning in the USA (as a code) appeared 34 times within all the interviews, with one interviewer referring to the solutions for the future. Geothermal energy being new for most of the City Hall and Utica's population and administration, it is no wonder that only one interviewee declared interest in suggesting practical solutions for using GE in the future in planning. published in: (Jovanovic, 2017, KGH Proceedings) [3]

[86] This is due to the process of research development, whereas first case studies were Austria and Iceland

This is partly to be noted for Iceland as the second study, as the limited research time (two months) and few people living in the country may have contributed to relatively modest array of answers other than Icelandic experience with geothermal. Since USA was done in the latter part of the research with broadened expert interview sample and with larger country and longer research stay (six months), the number of interviewees was bigger and the quantity of the interviews material was greater. Therefore, in some segments of the results and discussion chapters, the answers and opinions attained from USA-based-experts in geothermal filled the blanks of GE utilization. In terms of Europe, some of these research topics were not covered in such detail as in the USA. Therefore, the comparison of many opinions was not possible across these countries. Also, in terms of historical analysis, European cities had ancient urban history, which was not comparable with that of USA which had existed for only a couple of centuries.

Drawback of the Case study selection is finally that it tackles the European (both Western and Easter Europe cities) and USA, belonging to Transatlantic area of countries[87]. Its implications may therefore prove not to be acceptable e.g. for Asian cities, and all other with different urban growth mechanisms and socio-political backgrounds, despite the technological and globally similar situations in cities. When compared to other case studies, Iceland has far greater GE potentials. That is why a plan comparison of its geothermal energy utilization, which could be applied to all other cities, is not possible. On the other hand, Utica´s case study relies on GSHP rather than direct use of geothermal. This is leveraged by adding lines on prospect for geothermal utilization both shallow and deep for each case study.

Finally, all countries have different socio-economic conditions and these particularities are the very things which make the overall sample valid to make a blunt representation what (all) aspects GE can be expected to touch in the urban planning realm of European and US cities.

4.2.1 Limitations of the expert interview sample for drawing conclusions and their applicability

As urban development in the examined cities and towns has been developing in one way or another, it is hard to answer if geothermal has influenced the expansion of the city or town or if it would have developed the same without its utilization. It also not possible to predict city´s development based on geothermal utilization in the future. This is because it is not possible to rule out the influence of other criteria within research and within expert interview

[87] Trans-Atlantic is referred to as USA and Europe, both Western Europe, Northern, Southern, South East Europe and broader all Eastern Europe

method, such as social economic or political factors, for their exact influence on the outcome.

Also, there is a different number of expert interviews acquired in each country. For example, the sample from Iceland comprises six interviews, but its structure, given the interviewee´s background, is heterogenic: planner, architect, cluster representative, geothermal historian and public and private companies' representatives. Even though small, it has allowed for a concentrated set of opinions in geothermal use, Iceland being a country with specific geothermal qualities, it is only natural that valuable material for comparison to another CS could be attained from these interviews.

Since Serbia is a country with less geothermal experience, the number of interviewees should have been greater in order to get as much as possible different opinions from all with geothermal associated fields of experts, to cover the CS´s prospects on geothermal use in cities. One possible limitation of choosing Niš as a case study in Serbia is that it is much smaller than the capital city of Belgrade or other larger cities such as Kragujevac, Novi Sad, Subotica, Čacak, all having different geothermal potentials. That is why general conclusions for cities in Serbia cannot be made based on Nis´s case study only. But, since socio-economic situation and historical analysis of SEE space is common for all Serbian cities, the approaches in advocating GE utilization in an array of different forms can be considered similar.

USA study is very similar to Serbian, since geothermal energy is mostly underutilized. However, as American cities belong to the Western communities, the generalization on the application modalities for geothermal in cities in Serbia and USA is made cautiously. Despite this, general approaches especially from USA to Serbia are deemed important, as the U.S case study city shares post-industrial heritage like Nis. Therefore, conclusions are possible to make.

A positive example of GE utilization is Austria which belongs to a set of countries of the West, like Iceland, with geothermal energy situation mostly advanced for the whole set of data. There are only four interviews. As GE is applied in smaller towns, some without urban planning offices, no substantial variety and number of interviewees could be obtained.

Another obstacle for comparing the results of interviews from different CS sets that could be problematic for generalizing conclusions is the fact that there are different professional background profiles in each country, years of experience and socio-economic context where the interviewee lives and some of these aspects might be omitted in the analysis.

Due to the vast amount of data from the interviews, it was not possible to have all statements covered in the results section. Therefore, some statements form experts explaining eventual solutions may be omitted in the results overview and may have been overlooked or underrepresented.

4.3 Work flow

The work flow of the research is synchronized with the chapters presented. Firstly, a historical analysis of each city within each Case study (CS) was elaborated, followed by the socio-economic discussion on the reasons which might influence geothermal utilization. An overview of the country-specific geothermal potentials was given, both in terms of shallow and deep geothermal potentials for GE utilization.

Some aspects were more important to address in each CS. Austria had a mutual cross border program to support GE utilization and the state-wide policies on green planning were important to put in context of the research on GE, as they could influence other cities in case studies. Icelandic advanced state of GE utilization seemed important for a broader elaboration of geothermal history of Reykjavik. Therefore, the morphology of energy utilization connected to neighborhoods development within Reykjavik was indicative for other cities within the analyzed case studies.

Even though the historic circumstances differ from city to city, a theory of architectural evolution in the aspect of technology for heating is present in all case studies. It has especially been evaluated in the part on Nis, since the archeological excavations from the Roman times give way to connecting geothermal energy utilization with Romans having founded the city like Nis near geothermal waters in the Antique. This aspect is important, since the Romans knew the benefits of wall and floor heating, being advanced systems of the past still in use today. These technologies are gaining on importance as contemporary utilization of heat pumps and geothermal energy in cities and their neighborhoods may be based on their broader applications in buildings in the future. With this aspect elaborated more thoroughly in Nis case study, attention is drawn to general attitude in the history of the Western society development towards energy and its use in buildings.

The US study is elaborated with the evaluation of the city of Utica for its general sustainability criteria, based on standardization, that GE is an integral part of. The purpose of this is to detect other important factors which go hand in hand with more extensive GE utilization in the future in cities, towns and their surroundings.

Secondly, expert interviews were made and their results shown within the text of each of the case studies, partly and finally in the results and discussion section, as a whole. The interview questions were the same in each of the countries, with some additional aspects in terms of the last two case studies of USA and Serbia. In the discussion and analysis of the interviews and within specific CS chapters, some expert interviews were given more attention than other, based on the quality of the information, relevance to the topic of urban planning and years of experience of the interviewee, when regarded as an important element for forming opinions for GE´s prospects for utilization.

Rather scarce deep GE potentials of NYS would imply deploying EGS systems for direct use of geothermal fluid. Due to this fact, GSHP can be more widely adopted as an option in the U.S. -case study. The European case studies, on the other hand, have more substantial deep geothermal energy options to begin or continue with, within city- wide applications of GE. As U.S.- case study implied a city in New York State(NYS) with decline in population numbers, social segregation, blight and urban sprawling, it was necessary to put it as the first case study, as to present the possibilities of GE to be part of a process for urban revival in cities in general.

5 CASE STUDY U.S.A. (NEW YORK STATE-CITY OF UTICA)

The following text if chapter 4 contains parts of the publications by author of the dissertation, listed as [1], [3]*and* [40]

5.1 Introduction to the planning circumstances of an American city

Post-industrial American cities are characterized by buildings and urban concepts that echo the once wealthy society that was developing quickly and which cities became crucial for socio-economic development of the whole American nation. There is certain similarity to European cities of similar sizes, as industrial revolution had its consequences on their urban planning and development for decades and sometimes centuries.

The only thing is that, in comparison to European cities, U.S. cities are largely car-dependent and are therefore more prone to urban sprawling. The segregation of the inner core from the rest of the city (suburbs are preferable places to live to downtown in most post-industrial NYS cities) has helped deteriorate the role of city cores in urban development, and their healthy morphologies. The inhabitants of city cores are turning away from the center, which loses its identity and is left out of development and city liveliness, with deteriorated buildings of the post-industrial age. It is with acceleration that this process tends to occur in American cities.

"How can urban planning, involving geothermal (GE) and other renewable energies, used as local resources, help to mitigate this problem? Here, a case study of an East Coast city of Utica, is presented. So far, the potentiality of geothermal energy has not been analyzed although it can contribute towards mitigating and solving of the city's development issues in the long run…The purpose of the following chapter is to point to the problem of architectural heritage in post-industrial cities, especially on the example of Utica, and to show how geothermal energy could be integrated into the planning of neighborhoods. Special emphasis is put on the role that urban planning can have in this process in the future. Utica is merely one of the key case studies on urban transformation in NYS that may set an example on how to deal with deteriorating cities and turn them into an advantage by using local resources such as geothermal, wind, solar and others. For the analysis, an expert interview sample has been selected, and will be described in the following chapters. [3][88]"

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[88] The sample selection was based on previous sample results gained in Europe

5.2 Geothermal development in the USA with focus on New York State (NYS)

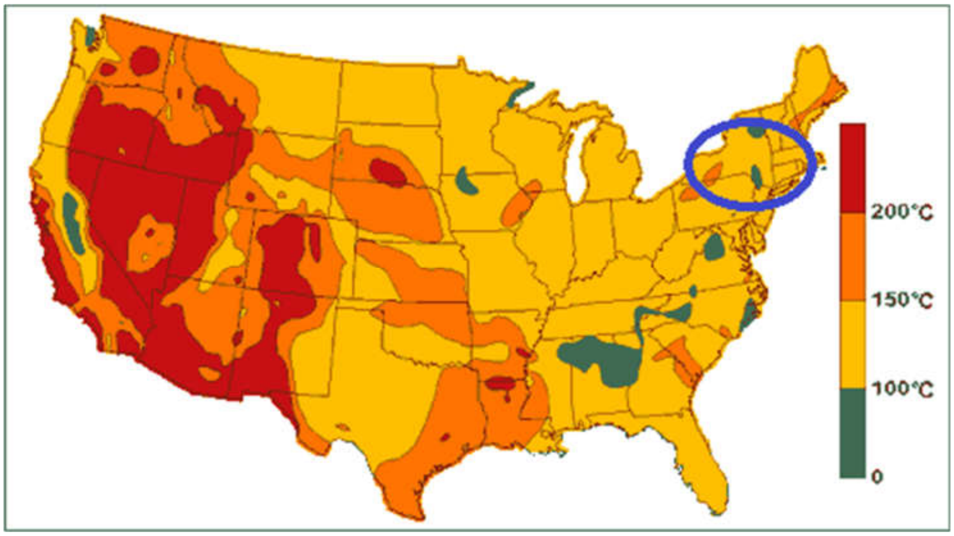

Figure 20, Geothermal potentials of USA that are to be expected in ***deeper drillings***. Western USA has abundance of deep geothermal resources, that are partly utilized today for electricity and district heating.[89] Northeastern U.S.A. (where Utica and NYS are located-circled) has more scarce resources for deep geothermal utilization, therefore heat pump technology is more viable as an option of using GE. source: U.S. department of Energy, source: https://d32ogoqmya1dw8.cloudfront.net/images/research_education/yellowstone/geothermalmap.gif, accessed 05.03. 2018

New York State (circled area in the Figure 20) does not have large potentials of natural geothermal aquifers containing hot water, in general. There are areas where there would be possible to use deep geothermal energy however EGS system would have to be employed for these purposes. There are some initiatives for thriving communities such as Ithaca (NYS) and New York City (NYC), especially in the frameworks of Cornell´s research and development, to engage into wider deep geothermal explorations in the state. However, both Ithaca and NYC are wealthier communities, where geothermal is easy to find customers willing to invest. In Utica, a city of decline and other facing problems, represents a playground for new ideas when it comes to GE utilization and other renewable energies 'utilization. The state in which Utica as a city is today bears resemblances to many major US post-industrial cities, which are facing renewal opportunities, especially at the turn of the new millennia. [90]Therefore, it was important in this research to dedicate time to understanding

89 U.S.A. is one of the World´s largest producer of electricity coming from geothermal resources (Western USA) and is one of five top nations which used geothermal fluid for direct use, with around 21, 074 GWh per year (Lund, Boyd, 2016) [84]. Despite this, DHS are uncommon thing in USA cities

90 For example, Cleveland in Ohio, being a post-industrial large city, recently joined an initiative made by U.S. department of Energy, named Better buildings Challenge, aimed at reduction of GHG emissions, energy conservation and responsible planning strategy adoption by 2030,

what drives the change in such communities, as their communities are the carriers of urban change in the US, in terms of energy transition in the future.

5.3 On the city of Utica´s urban morphology and urban planning

"Utica, NYS is a city of some 60,000 people in Upstate New York in the United States. It was first mentioned as a settlement of the early settlers coming from New England in the search for land and resources. [65][91] Its development as a large industrial city occurred throughout the 19th century, after the industrial revolution which allowed the expansion of industry and city growth and its urban population in most of the American cities. One of the greatest generators of development was the establishment of the Erie Canal.[92] [1]" "The growth of the city happened during this era of industrialization, when Utica set itself to be at the forefront of the so-called "Erie Canal", connecting the Eastern Atlantic shore of the U.S. with the Midwest. By constructing this channel, Mohawk and Hudson Rivers were joined together by Lake Erie, forming an advanced trajectory of commercial supply of material and other goods, whose flow was enabled throughout the U.S. This led to the expansion of the whole region, its cities and, finally, to the expansion of the U.S. to the unoccupied territories in the *Far West*. The significance of this canal for the region and the development of NYS and Utica is indubitable. Moreover, the local accumulation of goods, materials and railway intersections has led to much of its existing architecture being built. [3][93]"

Figure 21, Map showing New York State and rivers Hudson and Mohawk, along which the Erie canal was built, and which allowed Utica to prosper, south on the map is NYC and to the upper left Lake Erie, source: de.wikipedia.org, assessed on 23.08.2017

http://www.city.cleveland.oh.us/sites/default/files/forms_publications/Sust_Bldg_Policy_Cleveland-FINAL_April2013.pdf?id=3338, accessed 13.03.2018

91 White, 1998

92 Erie Canal construction had was completed in 1825, and these 580 km-long water canals once connected the Hudson River (East Coast) and Lake Erie (North of the U.S.) and was important factor for the past development of cities in NYS like Utica

93 Jovanović, 2017, KGH Proceedings

On state of the art of the buildings and their infrastructure in Utica from the 19th century, testifies this building of the hospital built in Greek revival style: "The building was one of the first designed with the modern conveniences of central heating and hot and cold running water on each floor. The hot water was pumped from the basement by a steam engine, while the cold water was supplied from storage tanks on the roof". [66][94]"

Figure 22, The Old Main of the NYS Psychiatric Hospital, a historic landmark of Utica, source: https://asylumnotes.files.wordpress.com/2011/04/img_6792.jpg, assessed 04.11.2017

"This expansion of Utica lasted to up after the WW2[95], when first signs of decline were noted, and Utica started facing years of steady fall. In comparison to nowadays[96], the city had some 100,000 people at the peak of its development in the first half of the 20th century. The decline in demographic statistics is not the only decline Utica was facing. Lack of jobs led to migration towards other cities, especially of the intellectuals. The population had no critical mass of intellectuals who would be employed and earn more money, adding to the number of significant tax payers and tax money that the municipality can count on. Poor population remained in the city core, whereas the remaining richer population moved towards the suburbs. [1]"

"An increasing number of people were losing their jobs due to the withdrawal of American factories from the area and the trend of de-industrialization that followed WW2. Being built for the population of some 100,000 people, Utica saw a major decline in numbers, coming down to around 60,000 people in 2014 [97]. Additionally, people lost their jobs in the industrial sector and turned to other cities and areas, where the promise of the need for a basic-skilled workforce persisted. Leaving the city budget emptier than ever, Uticans saw a major decline in public infrastructure funding. This also meant hardly any new investments, a rise in crime rates and Utica, with its deteriorating neighborhoods. soon became a dangerous place to live in. [3]"

94 Przybycien, 2004, 71

95 WW2 is referred to as the World War 2

96 Current population of Utica is around 60,000 people. Decline in population numbers was heavily influenced by industry job losses and migrations of population to other cities. The settlement of refugee population at the end of the 20th century in Utica gave birth to hope for its re-development, especially of the city core, as this population is diverse and is more prone to changes, in comparison to an average American city population that dislikes any change in their urban environment

97 According to data from 2014, available at: www.city-data.com, accessed 08.11.2017

"Decades of urban sprawl [98] and focusing on suburbs and Greenfield's as prime areas for development and settlement, by planners, developers and the culture itself, helped secure the abandonment of and the turning of attention and investment away from the inner city of Utica. In spite of its losses, Utica has endured and today is witnessing an upturn in its population as indicated by the last census where the city's population actually grew for the first time since the 1950's when its population began its downward trend. Growing numbers are a positive indicator that people are seeking for urban lifestyles and what a city has to offer. As a United Nations refugee resettlement city Utica has become known, it's the last 30 years, as a city accepting and supporting refugees escaping from war ravaged countries. New immigrant populations are on the rise in Utica due to influxes of people from Somalia, Bosnia, and other African and Latin American countries. The Mohawk Valley Resource Center for Refugees (MVRCR) is a significant agency and center of refugee resettlement in Utica and the neighborhoods and area around the center in downtown Utica, are seeing revitalization related to housing and small business development in particular. The population´s diversity is a contributing factor to changes, as the new immigrant populations are also seeking and taking advantage of the services and amenities urban life provides– education, transportation, jobs, housing, cultural and civic resources– as well as the communities and support systems–churches, religious and social groups– they desire and rely on to become integrated in the community. Affordable properties and access to social services are also providing new opportunities for immigrant populations. [40][99]"

Figure 23&Figure 24, Vacant parking lots in downtown Utica. These are the places where geothermal energy could be employed, within the process of urban regeneration. Cities in the U.S. are heavily dependent on car culture. Consequently, many empty parking lots appear in Utica, which could be put to better use. (sources: bing.com/maps), assessed 23.08.2017 [3][100]

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98 Urban sprawl refers to a phenomenon of cities spreading uncontrolled, consuming large land surfaces and by this process creating large commuting areas and inefficient and large infrastructure needs, that could otherwise have been stopped by careful planning, diverse neighborhoods with mixed-use and to some extent, densifications

99 Jovanović, 2017, Report

100 Jovanović, 2017, KGH Proceedings

"Furthermore, the urban revival potentials of the Utica are enormous, especially the potentials in energy reconstructions and use of architectural heritage buildings and sites. In the case of Utica, there were many parks from the period prior to WW2 with many different concepts defined by famous offices in the U.S. These park concepts are interesting since the city structure can be best seen within these pioneering solutions which are aimed at wellbeing and comfort of an individual and the whole community. The emphasis is put on urban connections, green infrastructure, recreation and integration of parks into city tissue. The benefits of parks on wellbeing has been examined in a recent study published in PLOS ONE [67],[101] where it was suggested that this relationship is important also for urban management and planning. Therefore, this element should be considered along with geothermal and other renewable energy utilization concepts in Utica, as in any city worldwide. This park situation and concepts from the past alone have a lot of potentials nowadays. New standards for sustainable redevelopment of neighborhood, such as LEED-ND, support green infrastructure in the auditing process. This in return enables a comparative approach in future planning and states what needs to be taken care of in the city. The integration of sustainable technologies within these processes of urban transformations, with addition of parks and more compact developments in the future, supports the idea of sustainability. This finally, adds to social stability and emphasizes the importance of the place and its urban amenities, and makes the city more livable and worth saving. [1] "

5.4 Ongoing urban revival of Utica- Sustainable communities (SC) project for Utica within R2G program

"The sustainable communities' project at Cornell University has been dealing with urban transformations of Utica for several years. [68][102] The project focused on solar, shallow geothermal energy utilization and possibilities for district heating system with shallow geothermal. It puts emphasis on the benefits of solar and geothermal use and some of district heating and it is a good presentation on how different parts of Utica can be imagined with geothermal district heating in the future. The project is valuable as it also examines the benefits of landscape architecture as an element of urban redevelopment and shows its possible connection to technology, in this case Ground Source Heat Pumps (GSHP). [1]"

"Finally, a key goal of the project was to develop a system model for feasible urban development of Utica. This was done by suggesting a representative, small-scale initial

[101] Larson et al., 2016, 14

[102] George et al., 2016

project in the city center, in the area that includes Stanley theater(Landmark), Baptist Church, vacant parking spaces around it and a couple of commercial objects and individual housing (one-family). This multi-purpose-block area (shown in Figure 21) was the subject of the analysis. The overall objective was to design (1) systems for solar and geothermal energy capture, (2) a district heating system, and (3) green infrastructure projects, that could be implemented to enhance the sustainable aspects, attractiveness of the inner city including its economy and serve as a model for re- development of the city´s core. [40]"

5.4.1 Conducting an LEED-ND Audit comparable to other standards in Europe

"Another aspect that was analyzed in the Utica project, was how LEED- Neighborhood Development (ND) [103], supports the idea of urban renewal. The emphasis was on:

> *-Smart Location and Linkage (SLL) and neighborhood pattern and design(NPD), both of which deal with: walkability, public transportation and other alternatives to car use, access to diverse services, spaces for recreation and community gardens etc.*
>
> *-Green infrastructure and Buildings (GIB). This includes upgrade of green infrastructure in Utica (parks, remediation of a huge number of vacant parking lots) and refurbishments of the deteriorated and unused buildings to save energy. It also includes the use of natural resources and energy, reduction of the urban island effect104 and storm-water runoff.*
>
> *-The social paradigm within LEED-ND is that sustainable communities and neighborhoods significantly contribute to the formation of sustainable cities and societies in general, because they have an inviting character, with public spaces, favorable modes of transit options, access to pedestrian and bicycle infrastructure and ease of move-in and out of their urban matrixes.*

An area of 19 ha in downtown Utica was chosen, because it is a representative downtown section of the city, that could be a catalyst for urban transformations in the city´s core. An increase in downtown activity demonstrates the capacity to build on the larger scale

[103] Standard developed by the U.S. Green Building Council and that is comparable with many European standards, such as BREEAM (UK). They all share similar strategies for addressing sustainable urban neighborhoods´ role as key factor in urban renewal of neighborhoods within cities

[104] Urban island effect is created around the cities when pollution contributes to the level of CO2 and where temperatures are measured that tend to be high in comparison to its suburbs. The so called "heat" island forms, that influences the city´s microclimate and livability by reducing quality of the living environment

projects and city´s planning rethinking, which the city needs. If done correctly, redevelopment should increase the LEED-ND score.

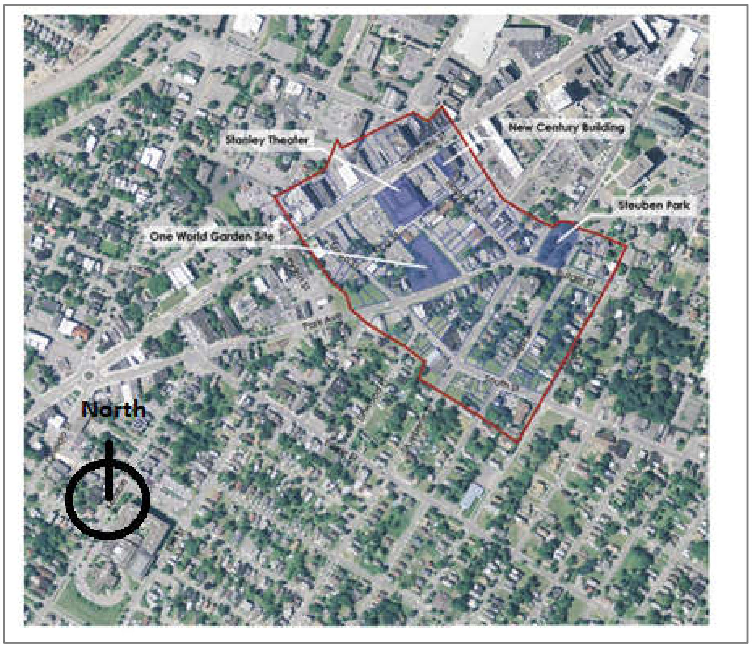

Figure 25, The location analyzed consisted of 19ha, source: Project report, Cornell University, 2016 [68][105]

It is important here to mention the way in which a LEED-ND project was audited. There are metrics in each of the categories mentioned above. They are summed up with specified weighting factors to give a final project score. Based on a predetermined point system, certified projects score ranged from 40-49, Silver projects from 50-59, Gold projects from 60-79 and Platinum from 80-106. The reason for using this evaluation system for Utica, is the standing point that redevelopments in the city can have larger impact and be targeted to specific aspects, if they can be compared to some preconditioned criteria. These criteria are given by LEED-ND in its concept and this methodology was used throughout the analysis. Several previous models of neighboring cities to Utica have been used to pre-assess the possibility of using LEED-ND in Utica, which proved to be adequate for this type of cities (post-industrial heritage Rust Belt cities in decline).[106] These earlier reports show that the urban cores of the neighboring cities show significant potential for improvements of urban life, sustainability and livability, even though they currently do not meet even the minimum scores required for LEED-ND certification. As a starting point of the study, Utica also lacked LEED-ND certification. Initially it was important to evaluate which aspects, and progressive measures would be most effective, to achieve a maximum possible number of points in the future.

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105 George et al., 2016

106 SALT (Syracuse Art Life and Technology) District in Syracuse, NY, neighboring city in NY to Utica, was precedent for the analysis. The project was done in 2008 (see http://www.saltdistrict.com/investments/creative-placemaking/, accessed 09.04.2018)

Figure 26, One of the many landmark buildings in Utica´s downtown was also part of the audit, The Stanley theater, constructed in 1928, designed by Architect Thomas Lamb, source: http://static.panoramio.com[107]

Figure 27, Tabernacle Baptist church, Utica (left), part of the analyzed area, source: https://upload.wikimedia.org/wikipedia/commons/2/2b/Tabernacle_Baptist_Church_Utica%2C_New_York_Jun_07.jpg, accessed 08.03.2018

Figure 28, New century building (right), scheduled for renovation into Green Century building within R2G program, now underused source: http://photos1.zillow.com/p_d/ISxfm7ouken0131000000000.jpg, R2G project building

According to the analysis, in the ***Smart Location and Linkage (SLL)*** category, project acquired 5 out of 28 points, on the basis of favorable terrain without slopes and floodplains, having low public transportation credits and no bicycling infrastructure, despite the proximity to services and shops. An opportunity for Infill development (housing and jobs proximity) was also noted as a way to contribute to achieving more LEED-ND credits in the future.

In the sub-category of ***neighborhood pattern and design (NPD)***, the points given were 12/41 possible. Notable was the presence of vacant lots and surface parking, even

[107] http://static.panoramio.com/photos/large/7282757.jpg, accessed 08.03.2018

though the area had good housing diversity and higher density in comparison to other parts of the city, and had access to services, parks and communal and local food production markets and shops. The *grey infrastructure*[108] can be improved, because even though pedestrian traffic is eased by sidewalks, car speeds are not regulated and signalization is often not adequate in the pedestrian street areas.

Bordering the area examined or within it, there are almost 5 ha of green recreational land, which contributes to the points given in the audit process. However, even though public recreational amenities within those parks exist, they are difficult to access by foot (poor roads, lack of sidewalks etc.). With 3200 sq. meters of food production dedicated space and vicinity of restaurants and the Farmer´s Market Utica, the area performs well. The FAR (Floor Area Ratio)[109] for non-residential buildings is 1,02. There are 56 residential buildings and 39 non-residential ones. There is a high diversity score in housing.

> *Parking is important to analyze and understand, as it forms the way neighborhood design is addressed properly. For example, more public spaces could be achieved with re-organization of the existing ones in Utica. Increased public areas make neighborhoods more attractive, and with well-articulated urban design qualities can go hand-in hand with the creation of safe environment for its inhabitants. This integrated feature is one of the prime postulates of LEED-ND auditing, mentioned and emphasized as a methodological approach by Cornell team´s Utica project report.* [68][110]*. Also, creating walkable streets adds to the overall quality in auditing requirements. Transit facilities, such as bus stops, serving different parts of the city, regularly and being located in the proximity of the analyzed area, play a significant role within auditing. Also, compact development or re-developments of the existing areas are worth mentioning as a possibility for the future. When possible, infills are one way of achieving compactness. Another approach is to reengineer or rebuild poor housing and/or commercial vacancies for habitation and in this sense, lead to more people living downtown and enjoying the proximity of services as well as walkable streets and different amenities. Because such densely populated areas of NY State cities are commonly found, this approach could again serve as a model for the state.*

Green infrastructure and building (GIB) principles used in the auditing process (LEED-ND), are of high importance for the aspect of urban analysis, which emphasizes renewable energy use. According to the report [68][111], only two points are achieved out of possible 28, in this category in Utica.

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108 Refers to roads, traffic, bicycle and pedestrian areas

109 Floor (to) area ratio is determined by dividing square footage (included are all floors of the building structure) with the square footage of the site where the building is situated. https://www.reference.com/math/calculate-floor-area-ratio-13c1cf1fd5fd1d39, accessed 07.03.2018

110 George et al., 2016

111 George et al., 2016

Green building certification is lagging considerably, as only few buildings in Utica have been certified by U.S. Green Building council. Possible room for improvement exists here, whereas 5 points could be acquired in the future, instead of zero at the moment. Energy efficiency is one of the following criteria that needs to be addressed in the future in Utica. Luckily, Utica has strong building infrastructure and lots of vacant buildings, that can be transformed into dwellings or offices and used to an extent, where there should be no need for unnecessary new construction. [40][112]"

> *"In the redesigned section of Utica presented, the total number of points given for all three major categories within LEED-ND audit, was 18, out of possible 98. As a result, there is still significant room for improvement. To achieve a more of sustainable neighborhood as measured by the LEED-ND, the area will require additional changes. This could be achieved by strengthening the fabric of Genesee Street (main artery of the neighborhood and one of the most important streets in the city, especially for walkability and pedestrian and biking traffic). Furthermore, retrofitting the NEW Century Building using an energy efficient design tool serves as a model for other refurbishments of heritage buildings in the city.*
>
> *Increasing service densities in the area and allowing for transport improvements can contribute to people re-settling in the mentioned area. Transformation of empty spaces and parking lots is necessary in order to improve grey infrastructure, provide more bike lanes, increase walkability and livability of the city core area. Finally, reclaiming large park areas (Park Avenue), landscape projects (One World Garden)[113] and connecting them to the existing neighborhood ideas, all support the above-mentioned measures and can and should go hand-in hand with them. Increasing safety of traffic and pedestrian movement within intersections is also important. In terms of social cohesion, providing different housing types (rental, municipal owned dwelling, privately owned housing) will create additional value.*

Figure 29, One World Garden, aimed at the mixed population of Utica, which would use the green space, project at Cornell University, R2G, 2016, source: [68], courtesy of R2G

[112] Jovanović, 2017, Report

[113] Project available at: http://www.rust2green.org/, accessed 09.04.2018

Figure 30, Green infrastructure´s integration into the project of areas ‘revitalization, source: Cornell University, R2G[114] [68][115]

In the area where sustainable design is being promoted, there has been a strong potential for using more RES. By coupling geothermal energy, district heating and solar energy resources in an integrated fashion, the potential for achieving energy independence is exploited. Additional value of the research is the development of tools and methodology to help in evaluating different scenarios for building retrofitting, while at the same time optimally locating and utilizing ground source, geothermal heat pump systems, district heating and solar panel technology. The results of the analysis could be applied in the future to other locations in Utica and in other cities in the state that need refurbishments and urban redevelopment, with minor adjustments of some parameters, such as solar irradiation, costs that may change during time, specific location climatic conditions etc. [68] [40]“

[114] Project available at: http://www.rust2green.org/, accessed 09.04.2018

[115] George et al., 2016

5.4.2 **Geothermal energy utilization in Utica- current situation**

"Geothermal utilization is neglected in the U.S. in terms of use for heating and cooling in cities. It is therefore challenging, to convince the consumer, private or public, to invest in a geothermal system, despite these benefits that exist. There are four confirmed utilization cases of GSHP in Utica. One of them is the law firm Hage and Hage[116], which was the first private company to invest in an old building in the city downtown, and the first to settle its businesses there. By making net zero energy building while doing the project, the company´s know-how was a success, in terms of advocacy for innovative technology and legal counselling which they offer on sustainable project. Another example is the Matt Brewery in Utica, which has made one of its storage buildings to a successful geothermal heat pump project in the old factory parcel. The third example is its use in the RCIL building in Utica, where an old Synagogue was transformed into a public Non-Governmental Organization (NGO) building for job seeking citizens, where geothermal system covers heat loads for administrative purposes and some common rooms (see Figure 31). [64][117]These initial steps were important for Utica, in terms of future geothermal energy utilization. [1]"

Figure 31a, 31b, Interior and exterior of the old Synagogue, now RCIL building. There were 39 geothermal wells dug into the parking lot of the buildings, during the refurbishment, source: A. Jovanović

[116] http://www.hagelaw.com/http://www.receptionhalls.com/media/NY/11889/homepic.jpg

[117] USA, Expert in public administration, 2016

Figure 31c and 31d, photos of the geothermal system (pipes with the fluid and radiators in the hallway)

Figure 32, Hage and Hage law firm, building which underwent refurbishment into energy efficient building using GE via GSHP, source: http://www.hagelaw.com/wp-content/uploads/sites/993/assets/banners/1438169980.jpg, accessed 08. 03.2018

Figure 33, Matt Brewery, which utilizes GE for cooling one of its warehouses. The reason for using GE was innovative nature of the enterprise, as well as an accident which required refurbishment. The company decided to use RES for this purpose, according to the interviewee [42][118], source: A. Jovanović

[118] USA, Expert in business and industry, 2016

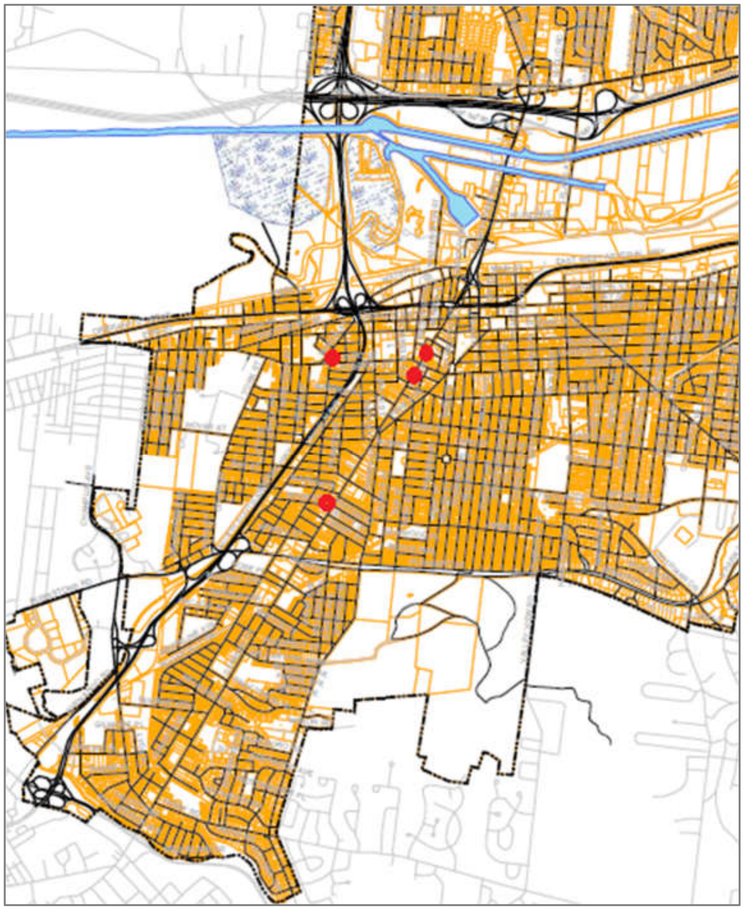

Figure 34, City of Utica, general map showing waterways, main arteries and current geothermal locations, Source: www.cityofutica.org, geothermal drillings 'locations by A. Jovanovic [1]

5.5 The results of the expert interviews

5.5.1 Sample and context description

There is a greater context of GE utilization which covers the State policies on geothermal, as well as city planning institutions' views on GE. These aspects are especially important as they allow for geothermal to be utilized at a scale larger than individual use in buildings. That is why the sample of US interviewees comprised of private engineering companies' representatives, public institutions´ engineers, and policy and economic experts. A DHS option has been discussed and analyzed, as well as other important renewable energy concepts, which can find its use in Utica, at a city or neighborhood level. Also, geothermal energy utilization´s connection to those options is important for the analysis and should be determined during the interviews.

It was very hard to convince other departments to give expert interviews on planning and sustainable options in Utica at the City Hall. The reason lies probably in the fact that there are few projects in the city and in the fact that planners and decision makers felt uncomfortable to be questioned about the topic. Fortunately, couple of interviewees were found, willing to share their views on city´s infrastructure, planning, policies, buildings and finally on geothermal projects in Utica. The greatest question which should be answered by this and similar researches is how people involved in planning can push the message of renewable energy use in the cities and what key stakeholders or strategies are possible at urban planning level. [1]"

"As seen from Table 1 in the chapter on methodology[119], most of the interviewees in the US interview set came from the geothermal sector. Most of them have been directly involved with geothermal installations and have seen the challenges of GE utilization. Most of the interviewees coming from this sector had experience predominantly with low enthalpy geothermal resources. A member of the academia had experience with deep geothermal resources as well. A sample was interpolated with one specific workshop result [50][120], with an expert who was coming from one of the largest district heating companies in the world. [3]"

5.5.2 Analysis of the results and discussion

"In an interview with an expert from the City Hall [63][121], the person mentioned that "people easily buy something if they can see it first". Having geothermal pilot projects in the city helps greatly. Unfortunately, deep geothermal was not something commonly seen in NYS[122], therefore it can be hard to try to advocate this in the current cultural setting in the city…The interviewee referred to several wind mills that are seen in Utica from the neighboring cities and areas and that people, despite their disbelief in them and what they can do, started eventually accepting them, although there are different controversies. Therefore, the initial geothermal projects in Utica made so far are important and future investments in public and housing utilization of geothermal. A master plan should be made by the city hall experts and externs. The greatest problem seems to be, how to convince people to think green and accept geothermal. Even among the suggested interviewees in the City Hall, certain dose of skepticism to giving opinions on geothermal was noticed, as only a few agreed to be part of the investigative approach presented in this paper. This is an obstacle, since they are disseminators of any innovative applications in the City of Utica. The above-mentioned term ***fracking*** is well known in the U.S. and has a negative connotation. However, shallow-geothermal applications are possible without this process.

[119] See chapter: Sample in the USA

[120] Cornell University guest speaker, 2016

[121] USA, Expert in urban and economic development, City Hall of Utica, 2016

[122] NYS is referred to as New York State, USA, where Utica is located

Probably the best way to overcome the "skepticism" in the future is to conduct workshops, invite lecturers and help disseminate the knowledge among the engineering and planning departments. Since Utica is member of the so-called Climate Smart Communities Pledge [69][123], it has committed itself in pursuing these goals. An important factor contributing to Utica´s development with renewable sources and sustainable planning is the younger entrepreneurial population, aimed at better business climate with local resources and climate change awareness. Understanding of Geothermal potentials and its utilizations in different commercial and housing sector can be supported by this growing population. There is a need for both qualitative and quantitative assessment of the geothermal energy. Based upon the research being done already with R2G program at Cornell University, a more thorough analysis of the urban planning process with GE utilization for the future seems to be possible. [68]

An important aspect of geothermal utilization for architecture and urbanism is its connection to density. In Utica, having mostly low-rise objects in its urban plan, except for a few public buildings form the second half of the 20th century, it was unclear, whether geothermal district heating applications can be thought of in the future. An expert in geothermal utilization was confronted with the question to see if urban density affects geothermal utilizations at all. The result within the special workshop [50] shows that economic use of geothermal is possible both with low and high densities, based on experiences of the expert´s firm which is engaged on GE utilization projects worldwide. Also, the expert pointed within his lecture that the utilization of geothermal is economically most acceptable with new built city areas (the "built from scratch" Chinese cities are good example of this) whereas installing geothermal district heating in poorly insulated buildings is challenging. [1]"

"Members of the engineering sector described challenges with low enthalpy (shallow) geothermal systems. The biggest issue would be how to convince the society to invest into geothermal installations more profoundly. Another issue is the financial plausibility of using geothermal energy at an urban planning level: the interviewees agreed that building a district heating system (DHS) makes no sense for certain city areas or suburbs, where using individual heating systems could save more money. Furthermore, in the U.S. district heating was developing completely on its own, meaning that it has less of a communal character than is the case in Europe. Surprisingly, the U.S. was the first country in the world to use geothermal district heating, in Boise, Idaho. There has been very little change in almost one hundred years in the advancements of geothermal DHS, according to interviewee, with engineering background. [44][124]

"The City of Utica was, for a long time, a city where renewable energy was not employed and was not considered for the future. Companies like Hage Law, Matt Brewery and NGOs

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[123] New York State, Department of Environmental Conservation, 2017

[124] USA, Expert in geothermal energy utilization, 2016

like RCIL, have been local pioneers for geothermal installations.[125] While interviewing the City Hall, the interviewees pointed out to an interesting problem in planning in Utica. They referred to the process as mostly reactive rather than proactive [49][126]. Mostly solving the arising issues is what is being done most of the time in City Hall departments. The proactive approach ceases to exist with the lack of resources (time, money and skilled professionals) needed for advocating large-scale urban transformations. This urban regenerative proactivity is what the City of Utica needs in the long run. One of the issues would be to deal with geothermal projects, integrating them into each and every city block and its scheduled renovations.

This would help Utica become a green city and a more vibrant community with a better infrastructure and greener technologies implemented for the future. It may also assist Utica in its urban planning issues, including connecting different city areas, such as parks, in one big whole, for example. To bring new life to older city parts and to try to secure a stable energy supply and local energy resource, instead of just using the fossil fuel-based heaters and hardly any centralized heating system in the city, except for the sanatorium or hospitals in Utica.

The interviewee coming from the economic and regional development sector pointed out the problem of setting a good example for the city's surrounding area. For example, the City of Rome had green initiatives that served the purpose of advocating other cities like Utica acquiring green projects afterwards. The interviewee was especially referring to the benefits for the city, the dwellers of projects set to have renewable energy utilization implemented at an early design stage [41][127]. This view is very optimistic nowadays, judging by the fact that most of the buildings built in the world today have little or no regard for local resources for heating, cooling or for any passive house techniques.

The most interesting answer came from interviewee from the sector of urban planning [48]. To get to the point where geothermal energy would be employed by the communities, there must be cultural circumstances that need to be considered in the U.S. as well as in other countries. The interviewee pointed out a global picture of energy consumption and progress, which many Asian and Latin American countries pursue and the very fine details in how the way a culture perceives energy can influence the way a new energy (such as GE) can be introduced into the cities of certain areas. There are issues beyond the understanding of planners or building constructors and architects, that influence the implementation of GE in

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[125] More on these companies that have installed geothermal heat pumps in Utica, can be found in the paper under reference [68] (George et al., 2016)

[126] USA, Expert from the Engineering department, City hall of Utica, 2016

[127] Expert in regional & economic development, 2016

communities, according to experts [45][128] [64][129] [63][130]. And these factors are in a large percentage of cases underestimated and given little weight in planning. The interviewee pointed out the problems of the stages of economic development a society is at, and stated that the level of understanding its citizens have for the technology is crucial for the success or failure of any new technology, including geothermal. There needs to be more focus on specific matters in planning such as how to deal with geothermal energy on a city level and to be proactive in these terms. Rather than attempting to address, even in fine detail, all of the existing regulations in planning of a city, where renewable energy integrations are usually set aside. A reference to geothermal energy being disregarded in city planning is the Serbian city of Nis, where, for decades GE utilization waits for the city government willing to pursue long-term goals in supplying even parts of the city with local geothermal resource. [3]"

5.6 Good practice examples of geothermal energy utilization for heating in the USA

New York State´s Cornell Tech Campus in New York City is a good example of the integration of geothermal energy systems via GSHP into urban planning, which Utica can learn from. In this project of urban planning revival of Roosevelt island, a former neglected part of New York, with good connections to the city by tramway, an energy conscious campus design was made, which is supposed with solar collectors on the roof, larger than the building´s plan, followed by green infrastructure, large water tanks underneath the campus collecting rainfall for irrigation and cooling and finally, use of geothermal energy. The campus's buildings produce as much energy as they consume. The project was part of the former mayor of NYS Michael Bloomberg who advocated for a design to be a technology, knowledge and diversity incubator for NYC´s economy, struggling against the effects of the recent financial crisis. [70][131]

Figure 35, Bloomberg center of Cornell Tech Campus in NYC, showing solar collector roof and part of its green design, integrated within the NYC timeline perfectly, source: https://www.bloomberg.org, accessed 06.03.2018

[128] Expert in geothermal heat pump technology, 2016

[129] Expert in public administration, 2016

[130] Expert in urban and economic development, 2016

[131] Bloomberg Philanthropies, 2018

The geothermal system of 80 wells dug 120 m into the ground (BHE), supports the whole concept of urban revival and offers the neighborhood with new identity, the city is striving for. [71][132] The connection of an open public space such as this campus 'design, to geothermal utilization is therefore important for future urban planning´s advancements in urban revitalizations.

Figure 36, Geothermal system within Cornell Tech Building of Bloomberg center, comprises system of heat pumps, regulators and exchangers that regulate the temperature of water coming from the depth of 120 m below the campus, source: https://www.nytimes.com/2017/05/29/,

accessed 06.03.2018

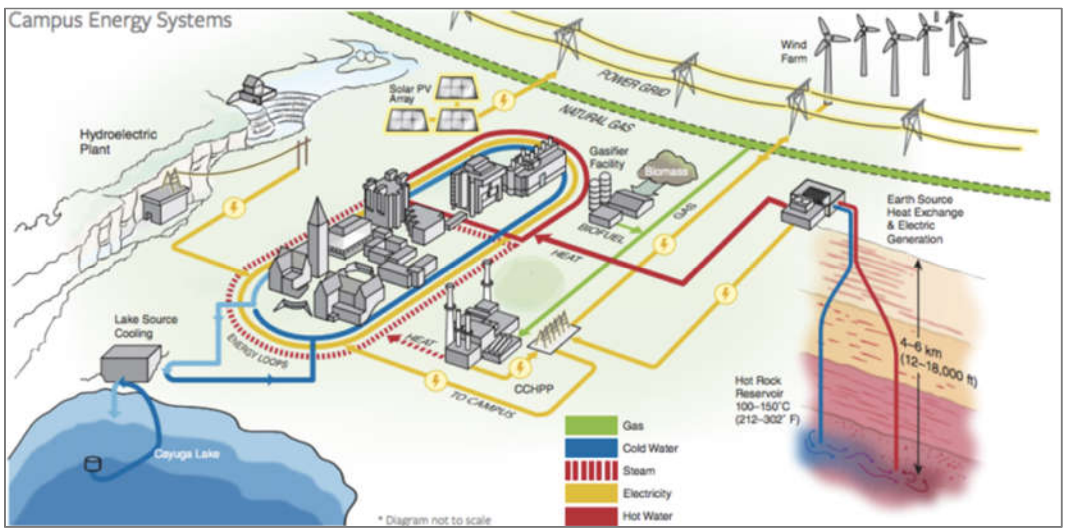

Figure 37, Campus -wide energy system proposal at Cornell University, Ithaca, project, Cornell University, NYS, 2016, The campus located in Ithaca, NY currently uses lake water-based central cooling system. Geothermal Hot Rock Reservoir (HRR) should supply the campus within a Combined Cycle Heat Power production (CCHPP) process. source: www.geothermalresourcescouncil.blogspot.com, accessed 13.11.2017

In the interviewee sample, there were experts who were for [47][133], [44][134] and the ones who were opposed to large scale district heating and cooling systems, and have potentiated using

[132] Cardwell, 2017

[133] Expert in mechanical engineering and district heating/cooling, 2016

[134] Expert in geothermal energy utilization, 2016

GSHP instead, whenever possible [46][135], [43][136]. For example, an expert coming from the geothermal sector criticized the current lake cooling method applied at Cornell´s main campus in Ithaca, because of the environmental issues that have arisen after its utilization (change of temperature of the lake, adding to problems with bio-diversity and plant and animal life and eco-systems. These experts pointed out to more chances for investing into GSHP technology and systems, rather than large cooling and heating projects, such as that currently installed at Cornell´s main campus (see Figure 37).

The possibilities of using geothermal energy and especially heat pumps in the USA, was emphasized also by an expert coming from Western USA, where geothermal resources are much warmer than in the Eastern US. The expert pointed out to the obstacle in applying GE more widely which lies in the business as usual models and decision makers lack of adequate profile to lead the change to renewable based cities and communities in the USA. [45][137]

The same expert referred to the Ball State University project where geothermal heat was extracted through a GSHP system and some 3600 boreholes found around the campus, which is supplying the campus with heat. This project was one of the most important projects in the USA in the GE utilization for larger communities and set of buildings. It also represents part of the initiatives for Green Campuses[138], where educational role of applying GE and other RES, is contributing to dissemination of knowledge on sustainable communities.

[135] Expert in geothermal heat pump technology, 2016

[136] Expert in engineering involved with geothermal and other systems, 2016

[137] Expert in geothermal heat pump technology, 2016

[138] More on the Green campus project can be found at : http://cms.bsu.edu/about/geothermal/greencampus and http://cms.bsu.edu/academics/centersandinstitutes/goc, accessed 13.03.2018

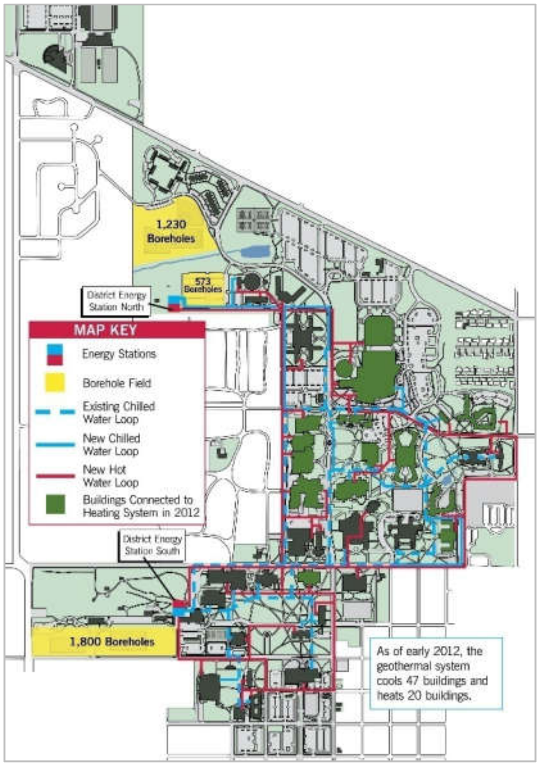

Figure 38, Ball State University, Indiana, USA, map of the geothermal heat pump system, applied in 2012, with 3600 boreholes, areas shown in yellow, source: http://cms.bsu.edu/-/media/www/departmentalcontent/geothermal/bsu-campus-piping-mapdec2011_large.jpg?la=en, accessed 13.03.2018

Figure 39, (down right) Ball State University drillings for GE extraction boreholes, source: https://fenleynicol.files.wordpress.com/2012/07/ball-state-geothermal-image-500x333.jpg, accessed 13.03.2018

Another aspect of importance of GE utilization in the NYS, according to expert interview [43][139] is the policy of incentives that NYS offers for installation of GSHP. This was declined by the Governor in 2016 and had huge impact on the number of installed units in NYS. Eventually, it has led to the decrease in GE´s application. This will indirectly affect the planned urban revival projects of communities such as Utica. Without the possibility of cost-effective application of GE and other forms of RES, the prospect of their promotion is significantly reduced. Therefore, the chances for using such technologies are reduced and neighborhoods can no longer attract the population to stay in the area, or make the area less blight and more livable.

[139] USA, Expert in engineering involved with geothermal and other systems, 2016

5.7 Discussion

„What can be done in the future is to make a quantitative assessment or a model of Utica´s urban development and to try to make geothermal a regular component in urban planning there. In other words, a local resource can play a greater role. How to do that is a big question mark. Based on the interviews, change of demographic numbers and more interest among young entrepreneurs in Utica for green architecture, can support geothermal utilization and can become a synergy with other initiatives leading to sustainability of the city, such as Microgrids, energy storage, urban parks etc. The use of geothermal in planning has less counter-arguments than positive ones in Utica and in the U.S. For once, because it is hardly used in planning at this moment. Secondly, this renewable source is considered an emerging technology that affects the environment and the city and therefore its context in architecture seems interesting for further theories and analysis, beyond Utica and it terms of regional planning in the U.S. [1]"

"The keys for a more profound geothermal utilization in Utica are:

> *Change in the population structure (the millennials) can contribute to the perception of GE in the future*
>
> *A lot can be done in terms of cultural studies, studies of behavioral patterns and achieving a more proactive way of thinking among planners and engineers. Some of the social indicators contributing to urban renewal developed for many other cities in the U.S., could be applied to Utica as well*
>
> *Cultural circumstances in GE utilization seem to play a far greater role in planning energy applications than the very engineering or architectural expertise and practice tends to acknowledge.*
>
> *There is a large gap between an optimistic all-round GE utilization in planning and current mostly reactive practice that still sees buildings as separate entities, where plumbing or piping should just be inserted. This also, unfortunately, applies to the cities themselves and their planning.*

Hopefully, Utica may live up to see the boost in its urban identity and sustainable and proactive planning in the years to come, including that with geothermal energy as an integrative part, quite opposite of how it is perceived today in the community, among its planners and in the City Hall. Luckily, majority of cities are still to learn how to comprehend renewable energy and local potentials, some of which have these in abundance too. Finally, urban planning can assist Utica to become a major NYS post-industrial city dealing with its urban future in time.

There is an offset between integrating geothermal energy within an engineering approach to supplying energy to the city and its neighborhoods, and the planning methods applied nowadays, which try as much as possible to assimilate new technology and attach it to the existing practice, but often lack the understanding of it and what it could do for planning. The problem lies in the very practice, or rather its potential to acquire new methodologies. For example, the City of Utica has been growing and declining for the last 200 years. Access to energy was never in question. This gave way to the city's reliance on fossil fuel, predominantly of external nature. The urban morphology of such a community was set to co-exist with external supplies and national grids which supplied the city. How would it be different, if the City of Utica had been planned, not only with external energy resources, but rather with geothermal heat pumps and other local resources as well? Would another energy crisis trigger the wave of "green thinking" in supplying the city with local energy? Would the architectural development of Utica have looked differently is yet to be answered. In the long run, energy needs to play a more significant role in urban planning. One of the ways to achieve this is through acquiring different approaches to harvesting local energy, retrofitting neighborhoods and making them more livable and above all, having long-term city planning goals, including local geothermal resource integration and cultural pattern analysis which could, with the aid of computer-based systems, help find ways for geothermal energy to get implemented and surpass the obstacles in the community and a fossil fuel-dependent culture of today' s Utica. [3]"

"The neighborhood´s identity plays an integral part in urban renewal ideas. Creating urban identity is important for improving as well as maintaining the city's character. Many cities throughout the world have adopted similar approaches to their redevelopment planning. Referring to them is important for understanding the benefits of development of these scenarios for Utica as well. [40][140]"

5.8 Conclusions

Geothermal energy utilization and urban revival (refurbishments) can and should go hand in hand. One of the greatest assets that GE can bring to American cities like Utica, is its possibility to help change its future urban structure. Cities in the USA are largely spread areas with external energy outputs. Consumer culture and spread or inefficient areas such as urban strip developments is based on these fuels. Once these fuels would seize to have value for them, most the American cities will be faced with upgrade to its local energy supply and led inefficient planning. As geothermal energy is still underused in the urban tissues of American cities, it can be a driver for change, securing jobs and renewable energy industry to take its

[140] Jovanovic, 2017, Report, 7-11

turn. Political hindrances and incentives on the State level and National level are needed for this to happen in the USA. In terms of urban planning, educating professionals and local governments to actively take part in geothermal and other renewables[141]' appreciation and integration in urban planning of refurbishment of areas, is necessary. In return, GE can help old valuable architecture to be preserved and assist the city in its wish to create urban identity of neighborhoods. Finally, local energy use (GE) and energy efficiency as postulates of urban planning in Utica can be a breaking ground for future endeavors of the city to combat sprawling, urban inefficiency, suppress car culture. This cycle allows even for urban tissues of Utica to densify, acquire identity and urban planning to take advantage of many parks Utica has, in building a community of prosperity in terms of urban space quality, prior to achieving any other kind of prosperity, social, economic, cultural, political.

Public buildings 'role in GE adoption more widely at a city´s and state´s levels, depends on the success of these pilot projects in the USA, because there is no better playground to test and disseminate ideas on sustainable resources than on a campus. There is a huge time gap between advanced systems used in buildings almost a century ago in Utica and today´s possibilities of technology such as geothermal. As shown on the example of Utica´s State hospital for mentally-ill, district heating was more common in public buildings. This and many other buildings in Utica, bare historical significance for the future of Utica´s sustainable building resource and urban planning. Their appreciation as historic and technological landmarks of the past can contribute largely to the understanding, why some principles in building have been abandoned for other, less sustainable. Given the large number of decision makers not being from the fields of engineering or architecture, this aspect should be further potentiated in the form of advertising and thorough historical analysis.

A thorough urban morphology analysis in a completely different setting is made in the following chapter on Europe. Being a city of rich urban and rural heritage, the City of Nis, just like Utica, has geothermal potentials for direct use of heat and bares historical references to GE utilization throughout history. Despite the aforementioned, there are numerous problems in terms of implementation of GE projects. These issues are thoroughly elaborated based on the results of the U.S.-case study and presented in this chapter.

[141] Renewables are referred to as RES

6 CASE STUDY NIS (REPUBLIC OF SERBIA)

This chapter contains part of the publications: [2], [4] *and* [13] *made by the author*

6.1 Introduction

"The Republic of Serbia is a country in South East of Europe (SEE) and is a country in transition, meaning that it is moving towards market economy and dealing with its politics and issues regarding spatial and urban planning [72][142]and realizing the need for its historical and local urban and rural heritage preservation, as a tool for sustainable projects. Although its history is somewhat different from other post-communist countries in Europe, it shares similar post-socialism heritage in urban planning with the *Eastern bloc* countries (referred to usually in general as Eastern Europe). This allows for a general cross-reference of the results of scientific studies and approaches in science from many countries in Europe. The purpose of this chapter is an in-depth analysis of Serbian city of Nis (in the South East of Serbia) and its geothermal potential for urban planning in transition to a more sustainable city with a locally harnessed geothermal resource as a tool of urban revival and regional cohesion.…For the analysis of these possibilities, the post-industrial situation of urban morphology in the city of Nis was explained and geothermal resources in the city of Nis were addressed by referencing literature sources and the inclusion of Geothermal Energy (GE) into General urbanistic plans (related to Serbian law on spatial planning as GUPs). The city´s past and current urban planning strategical decisions are analysed and criticized from the aspect of local sustainable planning. The chapter shows how the affirmation of sustainable and community-based urban planning of a city may be assisted by a more profound geothermal energy utilization. Additionally, a set of interview statements from several experts acquired in Serbia and abroad, within the scientific method of expert interview, is mentioned. Lastly, concrete physical location of the sources within the city and recommendations for further means of their integration in urban planning are given, proposing the next steps, in conclusion. [13]"

„The urban architecture in Nis is ideal as a foundation for analyzing sustainable planning strategies for the future development of South Eastern European cities. In its structure, this architecture represents a mixture of old vernacular, system-driven socialist architecture, and the post-modern contemporary [73].[143] Its complexity is rather uneasy to understand at first glance and it may even seem to be an unfortunate architecture in aesthetic terms. Managing diversity is a challenge for the contemporary urban planning. Having energy management as

[142] Maksin- Micić, 2008

[143] Ilić et al., 2011

an impulse for architectural development and urban planning seems to be the only possible method for redevelopment of the current situation on site. It seems though as if urban planning does not exist in Nis. However, upon further examination, it can be determined that the urban planning is not fulfilled where the strategies had already been made. This is where the problem lies; the plans are present, but are simply not implemented. This situation is similar in most cities and towns in southern Serbia.

Lying on geothermal reservoirs, Nis is an interesting place to be considered the incubator for testing strategies of urban development on mid-sized cities in Europe. By comparing the similar studies worldwide and by using expert interviews, the goal is to determine the current state of geothermal utilization and its connection to urban planning in Nis. These experts´interviews are an important mechanism for determining the measures needed to enhance planning and development strategies…Set of the interviews in Serbia collected so far still has to be further elaborated in the course of the whole research (comparison with the Austrian, Icelandic and U.S. case studies). The overall goal is to show on the example of different cities in different parts of the world, with different socio-economic and cultural backgrounds, if GE and its utilization can support urban planning and sustainable development. For example, in Iceland, "the present value of the estimated savings of space heating with geothermal instead of oil between 1914 and 2012 is estimated at 2300 billion ISK. or 200.000 euros per family of four person [74][144]."

Plans for sustainable redevelopments of many cities worldwide usually comprise utulization of geothermal potentials. The question is, if in Nis this can also be advocated and on what grounds? The following chapters on Nis aim also at determining the qualities in city´s history that seem to have been neglected and at suggesting further steps for re-thinking the city´s heritage and development. This especially refers to urban planning and energy planning.

[144] Orkustofnun, 2015

6.2 Renewable energy use in Serbia with focus on Nis

Current state regarding renewable energy sources in cities in Serbia is critical. The estimated potentials for utilization of renewable sources are rather high but are generally underused. Furthermore, the district heating infrastructures in major cities, such as Belgrade and Nis, are old and the systems still use coal, gas and bunker fuel (mazut). Use of geothermal in Nis is limited to a few balneological institutions and the real potential of this renewable source is lying untapped. On the other hand, it is considered as possible contributor to the economy of Nis, as argued by Stankovic et al. in their proposal for strategical development aspects of Nis [75][145], whereas focus was on European aspects and local resources [76][146].

On the other hand, city´s history of technology use and local resources ´utilizations testifies of on the potentials city once had and still has. Therefore, the purpose of this paper is to present previous urban planning strategies for Nis that defied green thinking and use of renewable energy. In particular, the aim of this chapter is to point to the possibility of enhancing the sustainable slot within the city. This specific case study of the city is important as Nis needs to and can achieve more utilization of local resources and create healthy environment and independent energy source for its own urban development. The applied investigation methods are based on the interviews with experts who are considered to be the stakeholders of urban planning development and individuals that can have impact on the use of renewable energy- geothermal in Nis's case, as one of the most promising local resources, besides biomass and solar.

If geothermal energy is to be used in Nis in the future, it can cut down on tax money, which can be used for other infrastructural interventions, such as parks and green infrastructure. This way, a healthier urban environment can be created. The following chapter has a scientific contribution as it points out the potentials of a city's development with GE. [2]"

[145] Stanković et al., 2004, 4

[146] Stanković et al., 2008, 46

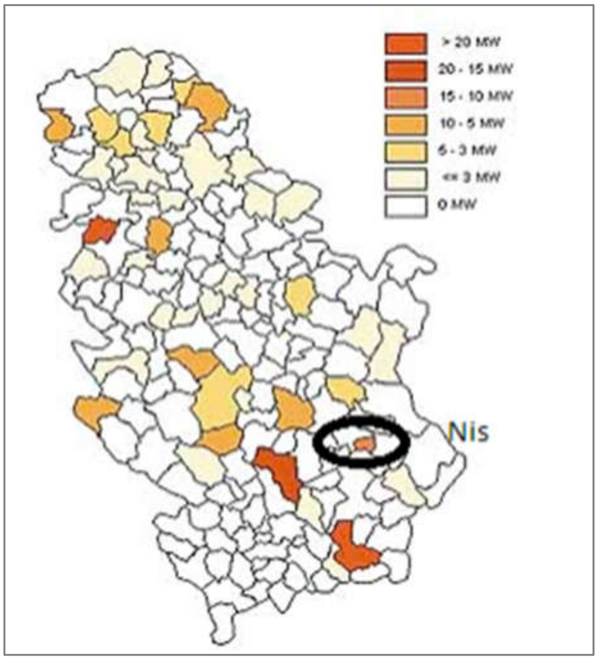

Figure 40, The actual available power from GE in Serbia. Nis area, with power between 10 and 15 MW, is circled. However, Nis area is not the most promising in Serbia for GE utilization for direct use, as are areas in *Vranjska, Lukovska* and *Kursumlijska Spa*, *Bogatic* and *Macva region*, which are areas with greatest potentials in Serbia. Despite this, thermal capacities of Nis region should not be underestimated as a resource in planning, Figure source: [77][147], adapted by the author

6.2.1 The possibility of energy as a driver for sustainable development of Nis region- comparison to worldwide models

"Serbia was not among the countries which were the initiators of creating geothermal atlas of Europe, despite having its geothermal potentials regarded as forthcoming. [78][148] [79][149] [80][150]'The geothermal atlas of Vojvodina (Northern Serbian province) has already been formed. [81][151]. Moreover, the zone of Nis, as well as of most of South East Serbia possesses the characteristics which allow for geothermal utilization at regional level (see Figure41). This is an asset if Serbia wants to cooperate with its neighbors and classify the resources in a joint venture. By locating these resources and mapping geothermal potentials, especially for achieving healthier nature environment, more extensive GE utilization can contribute to current rather chaotic urban-rural situation in the Balkans. [82][152] Especially, these resources can play a role in the surrounding of the city of Nis, as their utilization supports the local communities by investing in its energy infrastructure by using available and

[147] Fakultet zaštite na radu, 2014
[148] Hurter, Schellschmidt, 1999
[149] Milenić, Vranješ, 2011
[150] Andrić, 2015
[151] Institut za Hidrogeologiju, 2010
[152] Cekić, 2006

cheaper local resource instead of fossil fuels or involving wood consumption, leading to deforestation and eradication. [4][153]"

Even though this fact is often neglected, many landscapes have been diminished in the region of Southeastern Serbia in the last 150 years due to an extensive use of local wood and development of the country. This, in turn, may influence the flow rates of waters in the area, by diminishing them. [83][154] This would lead to less GE´s potentials available in the region. To conclude, the treatment of resources seems to be in a cyclic relation among its components.

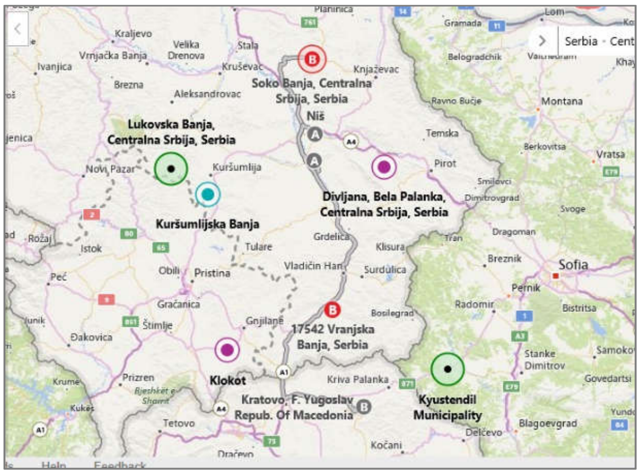

Figure 41, Balneological and other geothermal resources in Nis region and surrounding regions in Bulgaria, Macedonia and Kosovo, source: www.bing.com/maps, accessed 15.06.2017, adapted by Jovanovic, Cekic, 2017 [4]

6.2.2 Geothermal energy potentials and utilization in Serbian cities and in Nis

"Serbia has mostly low enthalpy geothermal potential that is being used mostly for balneology and tourism to a modest extent. [84][155] [85][156]However, in the recent decades, there has been an increase in geothermal utilization in Serbia, for agriculture and other organized uses. Based on the results from an interview with a geothermal expert based in Serbia, there is a great potential for Southern Serbia, where also Nis belongs to. They just haven´t found proper use yet [51][157]. In whole of Serbia, couple of most significant examples

[153] Jovanović, Cekić, 2017

[154] According to (Stanojević, 2005, 181, 200), free forest eradication and deforestation "began in 1936 when former prime minister Dragisa Cvetkovic of Yugoslavia passed out a law for giving access of forests to its voters from Nis region. Mostly used for heating, the woods have been massively torn down and some of them burnt. The wood used as fuel, supplied major cities in Serbia with heating option. The region of Suva Planina (near Nis) was specially affected by this process and has left the mountain hills without valuable forest assets. This proves how decisions from the past can have an effect for the whole areas and their developments. Data census from 1925 shows Nis region to have had twice as much sheep and goat numbers than the average number for the country. This all changed from 1926 onwards. [83]

[155] Lund, Boyd, 2016

[156] Arhus centar Subotica, 2012

[157] Serbia, Expert in geothermal energy utilization, 2015

of geothermal utilization can be found in Vranjska Spa [86][158], followed byDebrc, Kucura and Srbobran. [87]Recent geothermal utilization projects for towns include those at Bogatic [88][159]and Ljig. Nis is left behind in explorations on energy transition with renewable sources, although it is in greatest need of energy transition than ever and local government still does not realize the value of these examinations [89][160]. Some recent studies on energy efficiency which have suggested using geothermal for buildings have mostly been focused on the city of Belgrade. [90][161]. Despite these valuable suggestions, "*the use of geothermal for industry purposes or thermal energy gain is insignificant in terms of the overall redistribution of energy use in Serbia. In terms of energy balance of Serbia, the role of geothermal energy is underappreciated.* According to [87][162] i*t is not explored enough, at least not to the extent, when its role as energy source can be determined and position secured within the energy market*". The analysis of interviews with an expert in urban and economic development [63], an expert in geology and geothermal energy utilization [55]and an expert in GE utilization [51], showed the main problem to lie within:

-financing of geothermal projects, research and pilot studies

-lack of information about geothermal energy leading to the lack of finance for project initiation;

-cultural and socio-economic obstacles that sometimes play greater role in the utilization of geothermal sometimes than those of technical nature.

On the other hand, geothermal energy is one of the cleanest technologies and could significantly reduce the gases at an urban level, especially that of CO_2, N_2O, CH_4, HFC/PFC/ SF_6 emissions and other gases [87][163] [91][164]. This in turn, allows for a better living environment resulting in better health among the population and better and more liveable towns and cities.

The city of Nis has an issue of air pollution. Judging by the results of scientific public safety survey conducted recently [92][165]there are significant amounts of SO, CO, dust and other in the city of Nis. According to measurements available to Živkovic [93][166], an increase of CO_2 emissions is especially notable at the end of the heating season. In addition, a global increase

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158 Todorović, Ličina, 2011

159 Tulinius et al., 2012

160 Gajić, 2013

161 Vasović, Radulović, 2013, 39-45

162 Lazić et al.,2015, 1

163 Lazić et al., 2015

164 Malefeh, Sharp, 2016

165 Institut za Javno Zdravlje Niš, 2008

166 Živković et al., 2012

of CO2 emissions from year 1780 is estimated to be at the rate of about 31 %**.** And about 98 % of the CO2 emissions come from burning of fossil fuels. The rest comes from cement and calk production, uncontrolled forest eradication, burning of waste etc [87][167]. As for NOX, the biggest contributor to this pollution is traffic, followed by energy production. Based on the mentioned studies, some of these pollutants are present in Nis, despite the existence of clean energy utilization potentials.

The following part of this chapter focuses on the issue if geothermal energy as a local resource can help Nis have more sustainable urban development. A referral to the unutilized geothermal potentials of Nis will be given in the following chapters, to support the argument in planning of Nis in the future. Another argument for possible utilization of geothermal energy in Nis can be found in its historical use of spas (e. g. Spa of Nis) and heating systems dating back to Roman and Turkish times [4][168] [2][169] [94][170]. [13]"

"It was necessary to investigate this city and its possibilities to improve the ecological and sustainable objectives and at the same time, take care of its built structures and cultural heritage in the most democratic way, as a pluralist concept, where energy and city expansion go hand in hand. Historically analyzed, some of the decisions of urban planning strategical documents left the problems present today. Sustainable development means, per Brundland's report, that "humanity can make development sustainable to ensure that it meets the needs of the present without compromising the ability of future generations to meet their own needs [95]."[171] [2]"

Historic use of geothermal energy in the near-by spas could be also indicative for the urbanity of Nis and rural-urban development and was therefore examined within the set of expert interviews in Nis and this topic was given attention in the second part of the chapter.

6.2.3 Geothermal potentials in Nis and their relation to planning

"There are several natural warm water springs in the territory of the city of Nis. Mostly known are those in Niska Banja (Spa of Nis), just 11 km from the city urban core, with temperature of 38, 34 and 37 °C and flow rates of 40, 20 and 50 l/s, respectively [96][172]. The Spa of Nis had been known for centuries for its geothermal resources. The archaeological findings of Late Antique buildings have been located near the Spa centre. The existence and

[167] Lazić et al., 2015
[168] Jovanović, Cekić, 2017
[169] Jovanović, 2017, UIB IX
[170] Jovanović, 2014
[171] EC, 2004, 3
[172] Filipović, 2004, 261-267

utilization of geothermal source in the old bath, matching the historical location of the ancient bath in the Spa mentioned in literature, was documented by some archaeological excavations, mentioned by Stevanović [97][173]. There is a big layer of modern buildings, hotels, houses and other, which have been built on top of the archaeological findings. Some of them remain uncovered, for sure. Today's urbanity of the spa centre is very much due to the existence of the geothermal resources and the investments made by different governments in the country to make this small spa a place of leisure and balneology (see Fig. 43 within the next chapter for Map of the Spa). It is however, not decided to use geothermal sources for heating purposes other than a local hotel. Firstly, because the temperatures do not seem to be high enough (38 °C and around 29 °C, respectively) to be used as district heating resource. All buildings in the urban area of Niska Banja have individual heating, mostly based on wood, being the cheapest and most commonly found in the area. Individual ownership of housing, sticking to traditional resources and lack of interest in advanced technology in heating are the obstacles present here. Public hotel facilities where water is being used to some extent (via heat pumps) do not have interest in investing in a larger geothermal utilization system than it is now, as they do not seem to have any interest or lack funds. Furthermore, it seems that the political institutions do not have enough power to implement long-term projects and to invest in district heating with geothermal sources.

Another problem is the insulation of buildings and much needed renovation of buildings in the area. Even if geothermal district heating were applied, the waste of energy due to poor state of buildings would be inevitable. [13]"

[173] Stevanović, 1941, 1

6.3 Surrounding of Nis in terms of geothermal energy utilization in the past

6.3.1 Introduction-historical references

"The surrounding of Nis is known for the presence of geothermal phenomenon [98][174] [99][175] [100][176] as well as for it rich vernacular architecture [101][177]. It seems that none of these two have been taken seriously enough, especially not in terms of their importance for sustainable development of region and its settlements. [94] On the other hand, the whole towns, such as Niska Banja (Spa of Nis) and old town of Svrljig in vicinity of Nis, have been developed due to the existence of the stated natural resources.[178] The medieval town of Svrljig was established around the thermal locality of Banjica, a thermal well that has in the meantime lost its potentials and exists no more. [102][179] Truly, one portion of the geothermal resources has been used to some extent, for example in Banja Topilo, Kravljansko Topilo and Divljana. The regions of Niska Banja and Sokobanja (an hour drive from Nis to the north) belong to the group of thermal-mineral waters of Carphatian-balkanoids typeof mountain range. Their characteristics are temperatures of fluids between 25°C and 35 °C, with some over 35°C, but less than 45°C. [96]. [180]

The City of Nis is physically connected to Niska Banja (Spa of Nis) which is one of the city municipalities. The other localities with geothermal energy around Nis are less known and, at first glance, seem not to have substantial meaning for the city itself. However, their interconnection and dependence are undisputable. Niska Banja, Sokobanja, Spa of Topilo, Popsica village, Svrljig and Divljana do not have clear strategies of development which would enable their progressive expansion.

One must not overlook the idea that the development of urban wholes and rural-urban areas can go together with implementation of geothermal energy utilization strategies. This can be a trigger for more alleviated urban-rural development in areas which are facing a

[174] Kostić, Martinović, 1972

[175] Martinović, Kostić, 1975

[176] Martinović, Kostić, 1965

[177] Ilić et al., 2011

[178] Kostić, 1970; Stevanović, 1941

[179] Kostić, 1970

[180] More about the potentiality of waters (flow rates and other mineral composition characteristics) can be found in: (Filipović, 2004, 27)

serious problem of built environment dying-out and which have a lot of valuable built heritage from the past that needs revival for future generations. [181]

Historically speaking, these locations and their geothermal wells were used in distant past, though with primitive technologies, which greatly advanced in the meantime. Strangely, the *catchment* of geothermal wells in Niska Banja, which is still in use nowadays (for balneological and heating purposes for hotels) was done by the Romans. This is a proof that technology, such as geothermal, needs little knowledge to be applied in a community. Dealing with these and similar historical references about geothermal in this region serves as a reminder of the role of geothermal and has been suggested as a tool for backing-up the energy planning, and urban and spatial planning in the region.


Figure 42, Spa of Nis (left) Reykjavik (right) in the same period (first half of the 20th century). The Spa of Nis saw its development highlights between 1st and 2nd World war. At that time, infrastructure and transport linkages were built. Photo is showing the tramline that once existed between Nis center and Spa of Nis. In the meantime, it has been replaced by bus lines. During the reign of the Ottomans, hot waters in the spa of Nis were at disposal to the local population only during holidays, for body hygiene and washing of clothing. During the course of its history, spa of Nis had some rice crops production, due to warm waters available for agriculture. In Reykjavik, the waters were quite hot, so the accidents occurred leading to deaths, such as the case was in Laugardals site. Sources: http://www.zeleznice.in.rs/forum/download/file.php?id=4165 and http://lemurinn.is, assessed 19.06.2017, published in [4] (Jovanovic, Cekic, 2017)

Going hand-in-hand with the need of a multi-disciplinary approach in planning is another characteristic of the local places: historical significance of Niska Banja for Serbia and for the city of Nis, as well as natural climatic characteristics which prevail in Niska Banja and

[181] In its 2030 Agenda, UNESCO suggests that the role of culture through heritage preservation and creative actions should assist the sustainable development goals the world is striving for, more on http://whc.unesco.org/en/sustainabledevelopment, accessed 26.01.2018

are in the focus of scientific exploration. Furthermore, from Bela Palanka (the region of Pirot) throughout the Sicevo gorge there are signs of geothermal manifestations [96][182].

Sokobanja is located 62 km from Nis to the north and has historically significant geothermal resources within its urban territory. Here, as well as in Nis, only a minor part of geothermal potentials has been used, mostly for balneology. [103][183]

There was a significant connection between Roman architecture and geothermal localities in these regions of Serbia. Numerous archeological findings from the area testify about these connections. For example, an early Christianity tomb was discovered during the construction of hotel "Radon" in Niska Banja. Furthermore, the building underneath the old bath *(Staro kupatilo*) in Niska Banja dated from the era of Hadrian the Roman Emperor, who lived in the 1st century BC. [97][184]Urban development of this part of the Balkan Peninsula was, in some cases, connected with geothermal resources and bathing, which was the case in Kjustendil in Bulgaria, some 100 km southeast from Nis. [104][185]In Bulgaria, GE has been recognized, primarily by scientific community as an opportunity for intensifying balneology and tourism, as well as for preventing further pollution in the local communities and cutting down on the fossil fuel use. [105][186] This fact is of significance for Serbia as means of connection of different cross-border regions in terms of energy resources, which creates more possibilities for cooperation to prosper in the future there. [106]Additional back-up to these initiatives is made by data set, which testifies of the utilization of geothermal resources in the area dating to the period of Turkish rule, as the healing features of thermal waters were widely recognized in the Ottoman Empire. [21][187] For instance, the Spa of Nis, which was on the road leading from Nis to Sofia, was interesting for the Turks [97][188] [107][189] Other known spa used in the Ottoman period in Serbia were Vranjska spa, near today´s Vranje, a city south from Nis. It is interesting that this spa has almost the same thermal and structural characteristics as spa in Kjusten-dil in Bulgaria.[190]

[182] Filipović, 2004

[183] Milanović, 2005

[184] Stevanović, 1941

[185] Petrović, Filipović, 2013

[186] Bojadgieva, 2002, 35

[187] For example, Turkish conquest of Budapest led to the erecting of many buildings using thermal wells on its territory. Some of those spas are still in use and the Ottomans were the forefathers of geothermal utilization in Hungary

[188] In the Turkish yearbooks *(salnamas*) for 1883/1874 two Spas at the territory of the Spa of Nis were mentioned for their healing characteristics and richness in iron. However, not until the 20th century did one take this seriously (Stevanović, 1941)

[189] Kostić, 1978

[190] Temperatures of geothermal waters in *Kjusten-dil* (Bulgaria) are ranging between 71.5 and 74.8 °C (flow rates 33 l/s) [105] while in *Vranjska Spa* (Serbian town next to the border to Bulgaria) average temperature mounts to 85 ºC and with 46l/s flow rates. (Energetski portal, 2012) [218]

The Turks used Niska Banja as their bathing resort [108] and this was common practice of the Ottomans, who especially favored building *karavaj-sarajs* near thermal waters [109]. Also, the above-mentioned Spa of Sokobanja has its own *hammam* building in the center of the city. [110] [94]

> *Additionally, FYR Macedonia, the southern neighbor of Serbia, has a vast array of geothermal manifestations within its territory.* [111] *These sources are discovered in Kumanovo and Katlanovo Spa, followed by Banja Spa (Kocani), Kezovica, Kosovrasti, Debar, Negorci and Bansko. Roman spa building in Strumica testified of the importance of GE for the Romans who had settled in the Balkan regions in the Antique.* [112]
>
> *Moreover, Lukovska Banja, some 100 km south to Nis, near Kosovo region, is also located within the region of Southern Serbia. Also, Prolom Banja and Kursumlijska Banja are known for their rich geothermal resources, with various temperature ranges, flow rates and levels of mineralization. They have been used for heating-up hotels, medical facilities, pools etc.* [96] *Nevertheless, the potentials tend to be much larger than this, in the described region. Some studies conducted in Nis and adjoining Nis valley show that the utilization of existing enthalpies and flows of geothermal waters found in Southeastern Serbian spas can be used for upgrading water utilization level. Some older references that tackle this problem are to be found in the literature list under:* [99] [100] [98] [113].

The described historical references and their larger presence in society and media could contribute to the nurturing of a cultural identity of Nis as geothermal region and help building its continuity in time and history. Historical geothermal resources need to be determined and valued as possible contributors to local sustainable development. Unfortunately, these ties are not being addressed to great extent and have been neglected in planning and decision making at the level of the state in the described context.[191]

Creating geothermal regions is a known principle present in the region of Steiermark in Austria. The regions is known for the creation of many spas in the short time, and rapid spa development, balneology and tourism boom, which has enabled the region to be branded as geothermal success story. This may have similar tendencies and implications for Nis region as well. More on this region and scientific studies that have proven its benefits can be found in later chapters on Austrian case studies[192]. [4]*"*

"On the other hand, potentials of Spa of Topilo, sources at village of Kravlje/Popsica and Svrljig have been examined individually and so far, haven´t been associated with systematic utilization of geothermal within future spatial development of Nis region. Except from some mentioning in the current plans and the above-mentioned study, the context of its mentioning within environmental explanations clearly deals with the topic superficially,

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[192] For detailed description on how cultural identity of a region can be nurtured by GE utilization, see chapter: OTHER POSITIVE EXAMPLES OD GEOTHERMAL UTILIZATION IN AUSTRIA- Styrian case study in detail. For further reading also see: **http://www.oit.edu/docs/default-source/geoheat-center-documents/quarterly-bulletin/vol-26/26-2/26-2-art7.pdf?sfvrsn=4**

which is however some kind of a start. [114][193] Within the mentioned spatial plan, at the depths of 1000m, temperatures of 60°C are to be expected, whereas at depths of 2000 m, 90°C [115][194]. The document does not identify expected flow rates precisely and is therefore lagging on accuracy for any investment or drilling that may occur. However, if the temperatures are found, the spa of Nis and its buildings could be easily possible to connect to a system of GDHS. The same documents point to a non-satisfactory level of enthusiasm among the society as main obstacles to the idea of geothermal district heating, hand-in hand with financial problems associated with geological surveys and drillings, that would have to be done. Despite this, it says the only way to actually move from ground zero, is conducting geological examinations in the area. [114][195] Other documents dealing with urban planning strategies in the city of Nis are City of Nis development strategy from 2007[196] and Program of the development of Nis for 2017[197] and heat analysis strategy [219][198].

They also mention the potentials, with no details on how to achieve their proper exploitation. This is probably the next step in geothermal consideration on the level of the city. [4][199] On the other hand, district heating option, even with shallow geothermal sources seems like a good option, whenever the resource is available at a given rate, even with lower temperatures, since it covers the base loads, which are high and are covered normally by using fossil fuels. [13][200]

Figure 43, The map of Spa of Nis with the road Nis-Sofia (upper part), source: Nis: Plan Grada, official calendar, Direkcija za izgradnju Grada, 2014, for pictures of Spa`s architecture, see Fig. 44-46

193 Zavod za Urbanizam Nis -Sluzbeni Glasnik Grada Niša, 2017

194 Stanković et al., 2011

195 Zavod za Urbanizam Nis, 2017, 53

196 Mentioned in: Stanković et al., 2008 [76] and based on: Economic and environmental department, 2004 [75]

197 Available at http://www.ni.rs/, accessed 19.08.2017

198 Dag Henning, 2010

199 Jovanović, Cekić, 2017

200 Jovanović, 2017, KGH Proceedings

Figure 44, Remnants of the Spa of Nis´s rich architecture of the *Modern Movement*, one of the housing villas of the prosperity period of the Spa, now in decay, source: A. Jovanović

Figure 45, The New spa (Novo kupatilo) object, built in between World Wars (around 1932) in the Spa, commissioned by the King Aleksandar Karadjordjevic. Beneath it, there are remains of the Roman spa, now underwater [53], source: A. Jovanović

Figure 46, The Old bath (Turkish spa from the 17th century) in the Spa of Nis is actually the one built above the Roman catching (buried underneath the Old spa, at the depth of 2,5m); it is referred to as the main hydrothermal source well[201] of the Spa of Nis, source: A. Jovanović

[201] Glavno vrelo (in Serbian). The other wells are: Suva Banja, Školska česma, Banjica and Pasjača, see: http://www.serbia.com/visit-serbia/natural-beauties/spas/niska-banja/, accessed 12.04.2018

6.4 Urban morphology of Niš

6.4.1 The origin of the city- important for re-thinking the city

"The city of Nis, being at the crossroads throughout its history,originates from the pre-historic times.It was named after Scordischi, thought to be the original founders of the city (279 BC), and later renamed several times by the Romans (Naissus, Nisa (Byzantine), Navissos (Greek), Nish (Turkish), Niš (Serbian). [116] It has acquired many different influences, was part of many empires and for centuries has been a strong fortified centre in South Eastern Europe. Origins of many different tribes from the *Eneolithic*[202] period had been found in the archaeological excavations, including housing. [117][203]Its position on the route (Via Militaris in Roman Empire) and later regional Orient Express way contributed to its importance from the antique onwards. [13][204]"

"The most significant traces of these civilizations testify of the high cultural level of the domestic inhabitants in these parts. Most of those remains of archaeological nature can still be witnessed at the museum in Nis. The most significant part of this collection is most certainly the Roman period collection, with its rich findings in the city. The written proof of the existence of the city called Nais, Nisa or Naissus dates to Antiquity. Most significant period was the rule of the Constantine, as most of the Roman remains relate to the period of his rule. Nis was his birth place and became a strategical military center in the part of the empire called Mesia. Most of the city in the Roman times was still to be found in the outskirts of today´s Turkish fortress, whereas *Mediana* palace complex served the purpose of military and other officials' headquarters (and per some sources the emperors' as well) [116] [2]." At Mediana, *thermae* and adjoining spaces were heated by *hypocausis* technology and burning hard fuels, such as wood. Geothermal waters were available at 2km distance in Nis Spa and could have easily been transferred to the palaces at Mediana by Roman advanced aqueduct systems, which were available at the time. Instead, Romans preferred using local wood and men power rather than geothermal, because the traces of hard fuels around hypocausts were found at archeological excavations, suggesting extensive fuel burn. It is highly unlikely that Romans looked after the environment beyond their convenience, because geothermal waters were only at around 30 °C. When it comes to their heating systems and necessary temperatures

202 Also known as Chalcolithic, referring to pre-Bronze age, where it had not yet been discovered that adding tin to copper advanced the hardiness of bronze

203 D. Simonovic Ed., 1995, 41

204 Jovanović, 2017, Architecture and Urban Planning

needed to be developed to heat spas, the Romans obviously preferred to use other more suitable technology[205]. [53][206] Despite this, Romans utilized GE in buildings and were first to advocate its organized use in district heating.

"One of the preserved mosaics from the villa at Mediana is the one representing the River God, presented in the Figure 47. These representations give evidence of the once rich civilization, which had left behind important palaces, antique city walls within the today´s Turkish fortress, and dozens of artifacts like tombstones, villas with hypocaust heating systems etc. There are traces of the use of geothermal energy for heating Roman bathsin the region as mentioned already by Petrovic [118][207], whereas the information on geothermal use for heating Roman residential spaces still must be researched into. [2]"

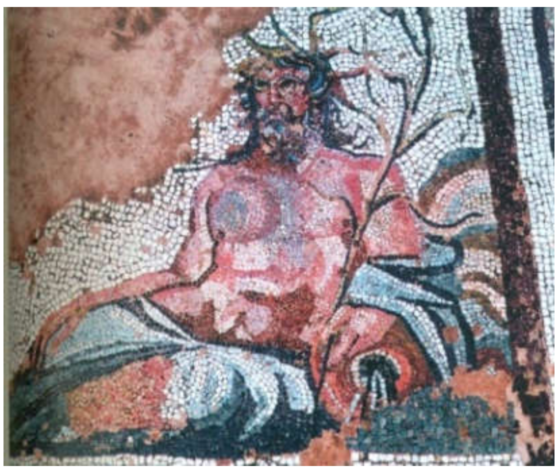

Figure 47(left), The Roman river god mosaic from the archaeological findings in Mediana Roman residential complex. Importance of water for the city was present even in the Antique, source: A.Jovanović, 2017, UIB IX [2]

Figure 48 (right), One of the examples of the Roman relation to GE in the Antique is archeological site Mediana close to Naissus. Villa at Mediana was near geothermal manifestations. The location of the Villa could have been determined by the presence of geothermal and vicinity of Via Militaris. There is not enough proof that GE was utilized at the site, source of the photo: cbma.projectkn.com, accessed 01.10.2015

[205] Sometimes, temperatures in Roman spas (Thermae) were such that they exceeded 250 degrees. Buildings were conceived as being cold and were built of stone and clay, with thick walls and needed hours to heat-up before they could be used

[206] Serbia, Expert in Antique civilizations, 2016

[207] Petrović, 1999

Figure 49, Remains of the private Terme of Mediana palace, the columns were part of the hypocaust system of floor heating, similarity to previously described *Villa de Casale* was that it had the same heating technology. Terme was next to the main peristyle villa. source: http://www.publishwall.si/medijana, accessed 05.03.2018

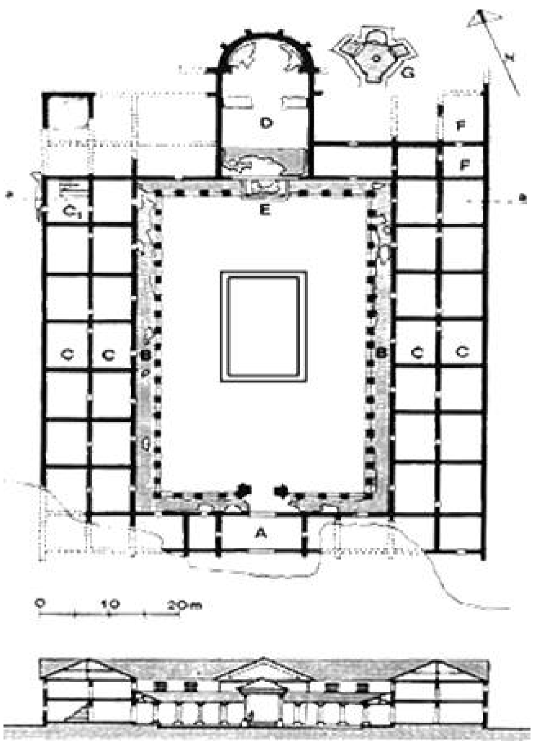

Figure 50 (left), Plan of the Villa with peristyle, located at Mediana complex in Nis, Serbia. The villa had an adjoining thermal bath to the north. The baths used *hypocausis* and *praefurnium* systems for heating. Geothermal sources were present at the distance of5.8 km from the palace, in today´s Spa of Nis. Even if GE was not used for heating, the allocation of the villa in vicinity to the GE resource in the Spa of Nis was highly probable[208], source: http://niskevesti.rs/11849-vila-sa-peristilom/, accessed 05.03.2018[209]

[208] As argued already in the chapter: Use of geothermal in the Ancient Period

[209] For more details on the appreciation of built cultural heritage in Serbian teritorry, see: (Kurtović-Folić, 2009; (Jeremić, Gojkić, 2012) and (Ilić et al., 2011)

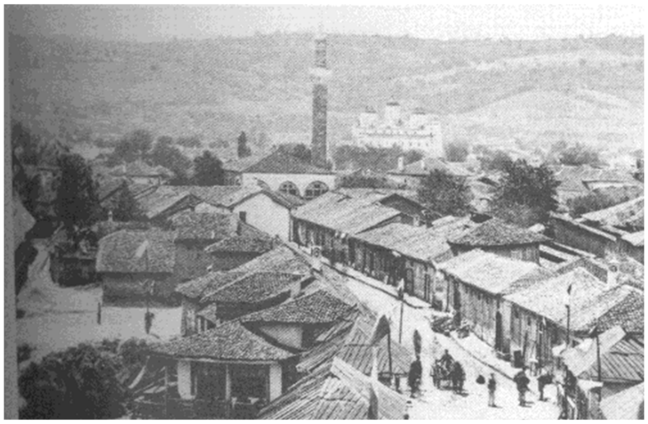

Figure 51, Photograph from 1879; Nis as oriental place, with mosques and vernacular Balkan architecture within the town core, unfortunately most of this architecture is gone nowadays, source: Milić, 1983 [119]

"Following the short medieval Slavic rule by Serbia and other Balkan states [116], Nis fell into Turkish hands and remained under the Ottomans with several interruptions during its history for almost 450 years. The city's structure was dominated by the oriental concept of a town (see Figure 52). This had influenced the urban sprawl around the Roman fortress to take its shape and become dominant appearance of the city on plans. [2]" As for Turkish baths (*hammam*), there were four buildings of this sort in Nis in the Ottoman period: Dumushoglijan Hammam (15th century, remains are within today´s Turkish fortress of Nis), Chukur hammam (15th century, was located in the Jewish quartier), Ero Hammam (in today´s Obrenoviceva St., demolished in 1924) and the Great Hammam (at the *Stambol* Gate, today´s Sindjelic Square, demolished in 1911). The first mentioned *hammam* was supplied by water from *Nisava* river, by means of clay pipes. Afterwards, the water was partially heated and supplied to the buildings with separate chambers made of stone and brick walls. As there was no geothermal well available in the vicinity, all hammams presumably used cold water from the river and had burning boilers in separate rooms to heat-up water. The used water was then returned to the river. [120][210] The Turkish bath (shown in Figure 46) was built in the 17th century, but it utilized GE from the hot waters of the Spa of Nis.

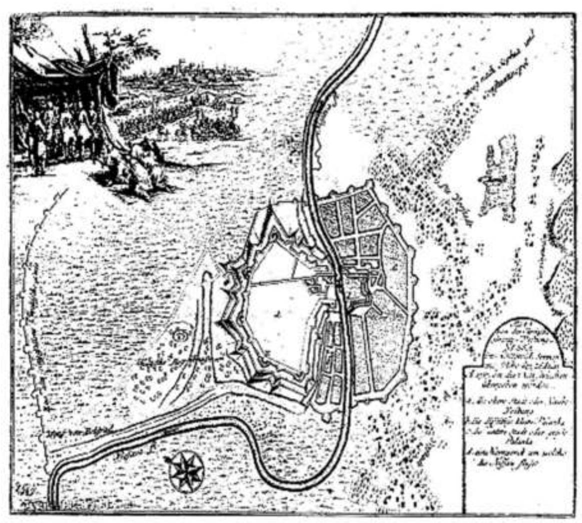

Figure 52, Austrian Plan of Nis, made before the liberation from the Turks, in 1737, showing Nis forming around the fortress, at least two of the hammams were integrated into the urban core at this time. source: Petrović, 1999, 78 [118]

[210] Andrejević, 1989, 104

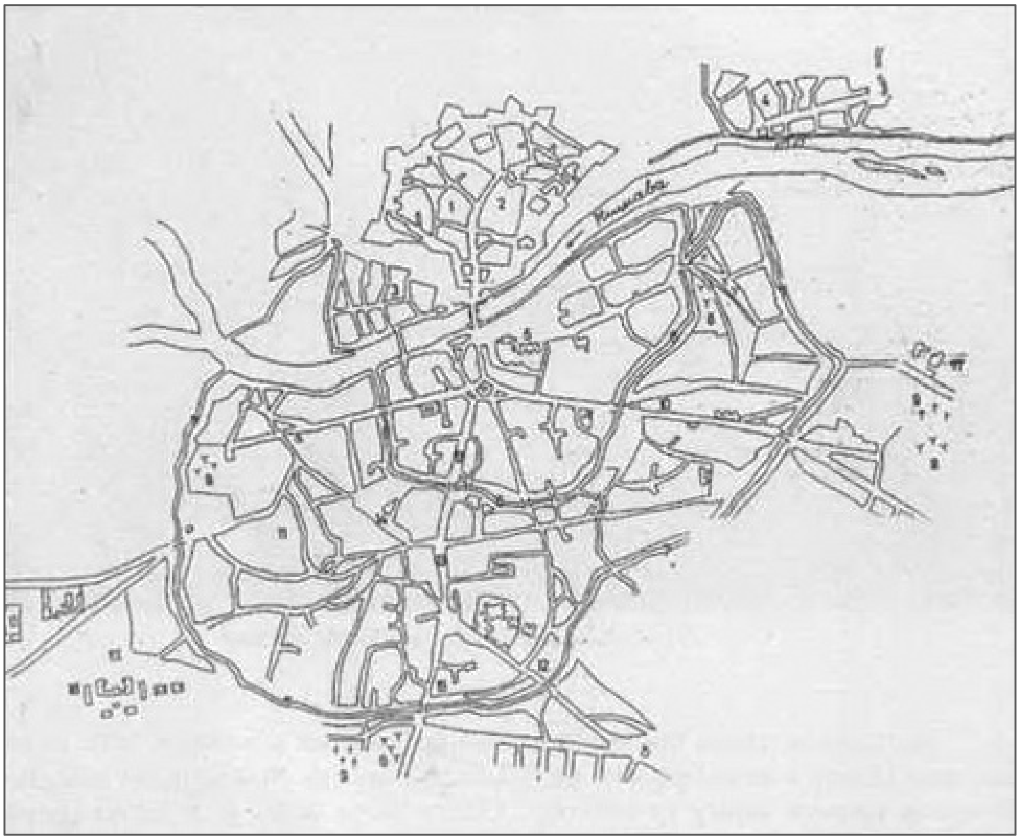

Figure 53, First regulation plan after the liberation from the Turks in 1878, laid foundations for the appearance of modern Nis´s urbanism in the 20th century, source: https://sr.wikipedia.org/sr-el/Винтеров_план_за_регулацију_Ниша#/media/File:Nis_1878.jpg,accessed 20.02.2018.

"After the liberation from the Turks in 1878, those involved in the urban planning of the Serbian cities began to look upon the European models of urban planning. Whether any of these characteristics were possible to use in the oriental center such as Nis was never questioned at that time. This process could be explained in terms of the historical circumstances, which saw a newly liberated land like Serbia dismissing Nis's oriental and conquered past, for the purpose of "pro-European" identity seeking. Figure 51 shows the photography of the Nis settlement and on Figure 53, the first plan after the liberation from the Turks in 1878 can be seen. The modernization and the technological turn of the 19th to 20th century opened new ideas which were to be replaced by new ones during the 20th century. What followed was many years of the prosperity with new public buildings in the academic style, modern style villas and various housing projects, among others. After the Second World War, Nis became part of new Yugoslav state network of cities and acquired new plans of urban planning strategies which saw a new industrial and regional center coming to life, with expanding socialist housing architecture, followed by rich industry expansion and substantial number of public buildings. Cancellation of some of the plans lead to the period when the city was developing on its own, and therefore was prone to the forming of the urban sprawl structure, as mentioned by Spasic and Nedeljkovic in [121][211]. [2]"

"Nis has secured its position as a strong transitional centre through its history and has finally become a centre of industry and education in the 20th century in Serbia. It was a strategically important industrial city of Serbia (and Yugoslavia) comprising electronics, machine industry as well as other primary industries. Unfortunately, Balkan wars at the end of the 20th century, the fall of the Iron Curtain and transitional changes made it one of the poorest of large Serbian cities. Unemployment in the industry, no investments, being away from the prosperous northern capital regions and the nearby cities gave way to a new transitional, "free-market"-based appearance of Nis and its urban design, which was not preferred by the citizens and its planners. Nis is known as the city of unfinished urbanization [2], meaning that most of urban planning strategies have not been fulfilled as scheduled and that a lot of city parts contain only fragments of urbanistic plans, that tackled the development of the whole city and its neighbourhoods. This also means uncontrolled urban development, more power to economic benefit of the investors and low capability of citizens in governing the urban expansion of their own city. [13][212]"

As the outcome, "Nis has a segregated city structure with the characteristics of a post-modern socialist industrial, educational and cultural center.Its evolution can best be described as a mixture of urban planning instruments' use and random urban sprawl. The urban sprawl form of a city reflects on the transport issues, such as the traffic problem, as more paths and time are needed to get from point a to point b within a city, as compared to more compact city structures (see Figure 54a, 54b and 54c for the effects of urban sprawling in Nis, especially in 1981, when major industrial facilities were built around suburban and semi-rural areas). These problems directly affect the environment and the pollution situation and offer no other alternative for rethinking the use of renewable energies wherever it may be possible to use them (transport, energy production, industry nonetheless public and housing sector such as buildings' operation). Excessive use of land and energy by the formation of the urban sprawl leads to inefficient use of resources which should be sustainably dealt with. An important aspect in cities is also the quality of life of the inhabitants of the city, as well as their right to a clean environment and public health, which can be solved by extensive use of geothermal within the city and in the region. [2]"

"On the other hand, the necessity for some sort of organized and planned approach to natural (geothermal) potentials 'utilization has proven to be necessary', as argued by Malefeh and Sharp. [91][213]In the case of Nis and its described semi-controlled 'free market' development, utilization of geothermal resources would also need to be informed by strategic decisions of planners and governing bodies, as the carriers of sustainable city development.

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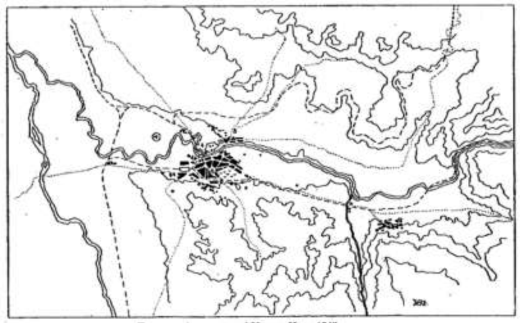
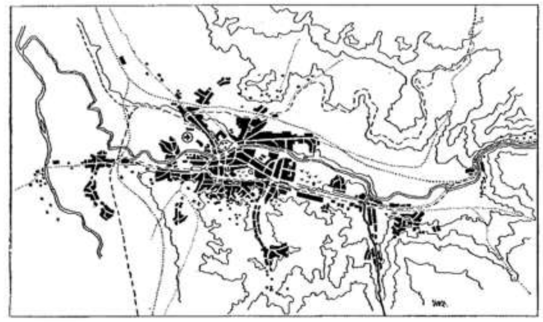
211 Spasić, Nedeljković, 2010

212 Jovanović, 2017, Architecture and Urban planning

213 Malefeh., Sharp, 2014, 1-11





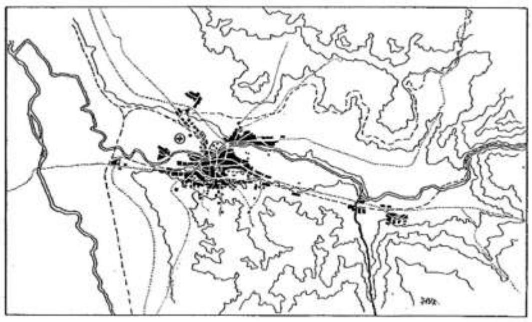


Figure 54a, Nis city plan from 1940 (upper left); Figure 54b, plan from 1960 (down left) and Figure 54c, plan from 1981(upper right), respectively, source: [217] [214]

6.5 URBAN PLANNING IN NIŠ

"Current urban planning instruments in Nis are suggested in the general urban planning document of Nis, GUP 2010-2025 [115]. Several other general urbanistic plans were developed before, but none of them considered opportunities arising by more extensive geothermal planning as an urban planning tool. With the declining role of urban planning, this is slowly going to change. During the amendment of GUP plan 1995-2010 (see Fig. 56), the urban planning authorities in Nis focused more on locating church facilities than on defining geothermal resources supply spots that could meet energy requirements of various city parts [4]. It seems that Nis, like many other cities worldwide, was growing depending on external energy supply for most of its infrastructure. At the dawn of the new energy crisis and arising policies of green movement, geothermal utilization in Nis seems like an option worth considering even if only as an option for a long-term city-energy-transition and despite its current unfavourable socio-political situation. In the next chapters, some arguments for and against geothermal prospects for Nis shall be given. [13]"

[214] Milić, 1986, 409-410

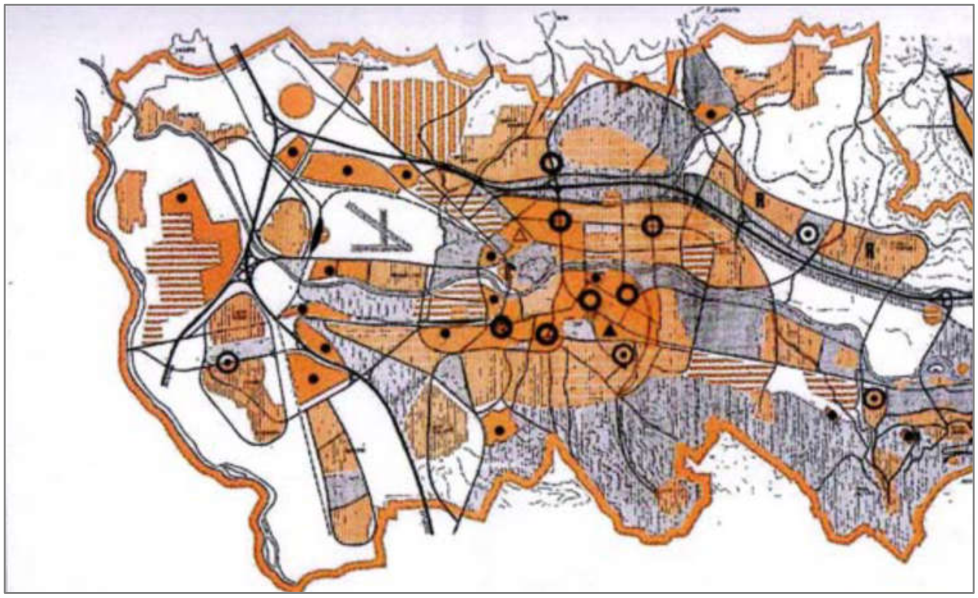


Figure 55, General urban plan of Nis from 1973. with emphasis on the physical expansion of the growing city. Despite the fact that geothermal energy was not considered as an asset in this plan, its value was that it succeeded the situation of Nis in the period 1961. to 1973. when the city had no urban plan. The previous plan by the architect Mitrović from 1953 was annulled in 1961, and therefore Nis was left without guidelines for many areas of planning, such as industrial locations, transport nodes and most importantly, housing market, which was being formed for new industries and jobs, booming in Nis in the 1960s and 1970s. source: JP Zavod za Urbanizam Nis, Urbana tradicija Nisa u planskim prikazima, 2009

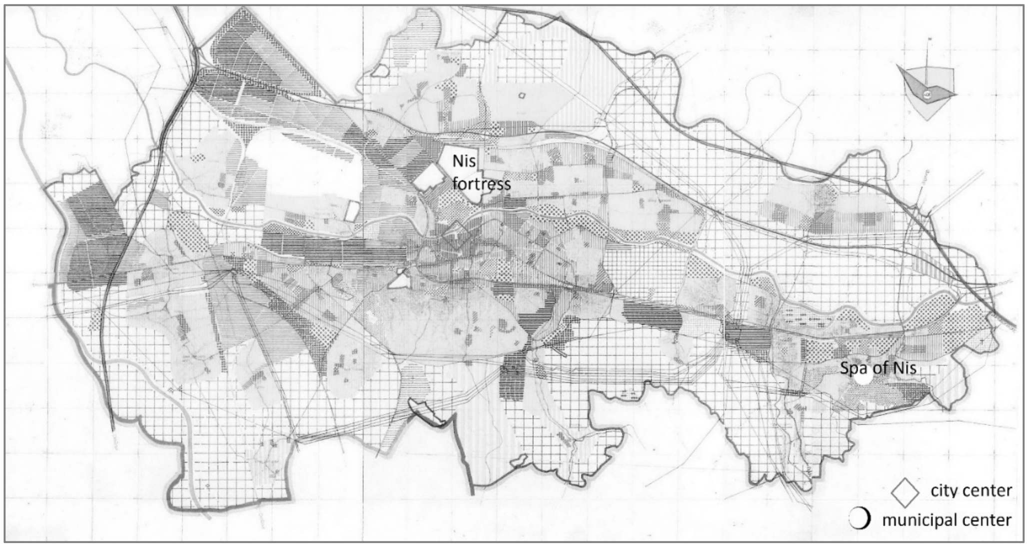


Fig. 56, General Urban Planning document (GUP) of Nis 1995–2010, focused on anything but utilization of geothermal resources, source: Zavod za Urbanizam, Niš, *kalendar,* 2011, additional graphical information by A. Jovanović [13]

Local Municipal Plan of Nis (GUP 1995- 2010), shown in Figure 56, valid until recently, was mostly defining strategic location for buildings, underestimating energy demand and supply possibilities of different city areas. If each of the changes to the plan was made with just one analysis of geothermal locations within the city, then the municipalities would already have something to base their development on.[215]

Figure 57, Urban neighbourhood of Nis Boulevard, modern Nis- idea of putting an end to a "housing boom "in the architecture of Nis by building collective housing,today´s view of the city, source:Jovanović, 2017, UIB IX [2]

[215] Authors of the plan: Javno preduzece Zavod za Urbanizam Nis, arch. Mihailo Medvedev et al. source: calendar ZURB NIS, 2015

6.5.1 Urban planning of Nis with reference to "green planning" and geothermal energy

Urban planning in Nis is made with disregards to its rich water and GE potentials. River front use has until recently been disputed in areas other than city center. Main urban and pedestrian trajectories in Nis are intercepted by car traffic arteries. Tramway lines, ones connecting Nis with Nis Spa have been disassembled and replaced by cars and busses after the 2nd WW. Nis also lack green infrastructure in newer city parts, which are developing rapidly. Large part of *Čair* park is made on former Turkish grounds of the city and covers city´s green infrastructure of the urban core. St. Sava (United Nations park), Sv. *Pantelejmon´s Church* and *St. Nikola´*s church parks are but a few, along with Nis spa center, that add to the quality of green infrastructure in Nis and they too need re-design.

Nis is also rich in heritage but lacks the use of sustainable technologies in protecting and preserving these localities. A chance for utilization of RES becomes more promising as a tool for improvements both urbanity of Nis and its buildings. On the city´s territory, there are 2 active springs in the city core (38 °C and 29°C) and some at the outskirts of the city territory (between 22 and 30°C) applicable to its development of planning (see Table 5 for details).

Table 5, Hydro geothermal resources in Nis area, with distance to central point of reference-urban core and fortress), source: [77][216]

Name of the place	T (°C)	Flow (l/s)	Distance from the city (km)
Niska Banja	35-40	100	11
Banja Topilo	30	10	20
Miljkovac	36	50	15
Ostrovica	22	10	25

„Today, the city of Nis has a combination of various vernacular and imported architectures, combined in a mixture of a functional, yet unfinished urbanization. Nis is the city of diversities: both urban sprawl and planning outcomes are evident today in today´s appearance of the city. General urban plan of Nis from 1973 is shown in the Figure 55. This document was the starting point for strategical decisions in Nis. Based on this, various other upgrades followed, however none of them followed the principle of the other and this is where the problem may be.

[216] Fakultet Zaštite na Radu, 2014, 50. Not all hydro-geothermal resources of Nis area have been included in this table. The additional locations for potential drillings and sites are mentioned in the parts on recommendations for planning with GE (end of chapter 6)

Current document, called the strategic plan of the city of Nis -sheet on the protection of the environment, GUP Grada Nisa, 2010-2025 [115][217], mentions some benefits of using renewable energy sources. Even though it still does not address the energy issues in detail, it points out to the problem in the text of the document. The only documents that considered GE as a RES, possible to use at a city level and its urban planning policies are the internal documents from the 80s, some of them pointing out to geological studies in the city area and benefits of using geothermal energy for Nis´s expansion and development, especially in the Eastern parts of the city, nearing Nis spa This document is an almost 30-year-old recommendation in terms of geothermal utilization. [113][218] [2]“

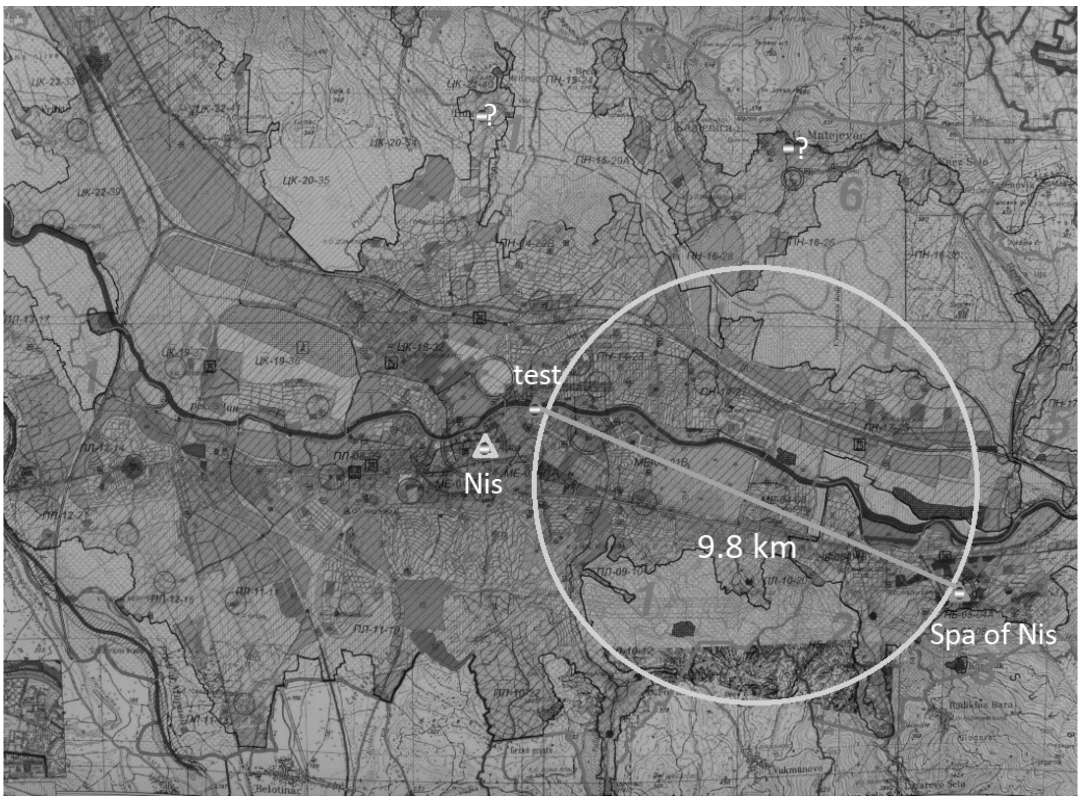


Figure 58, General Urban Planning document of Nis (GUP 2010–2025), source: [115], mentions geothermal energy as source of environmental protection very generally, according to the interviewer [52]. This official plan was modified with 3 triangles. Triangle (left): city centre, Triangle (centre-right): existing geothermal test drilling site, Triangle(right): potential untapped geothermal resources in Spa of Nis, (up): locations with question marks, other GE sources of possible value for city´s supply, author A. Jovanovic

217 Stanković et al., 2011

218 Perić et al., 1989, 11-18

6.5.2 Current Utilization of heating resources for buildings and district heating networks in Nis with urban analysis

Nis has a district heating network which covers large parts of the city. First traces of organized heat distribution in Nis were recorded in 1930. However, it was not until 1983 that the district heating company was formed, which emphasized that every newly developed are in Nis should be developed around DHS infrastructure.[219] The existing district heating network is based on coal, bunker fuel and gas. The capacities of the overall heat delivery in Nis are estimated to be at 254 MW. There are three main heat power facilities in Nis, each covering larger parts of a different municipality: Krivi Vir (128 KW of thermal capacity), Majakovski (14,3 MW) and Jug (60 MW of thermal capacity). There are several independent boiler substations, covering mainly public institutions or areas distant from the urban core: Somborska, Institut, Mokranjceva, Cair, Pantelej, Knjazevacka, Ardija, Ratko Jovic, Ledena Stena 1 and 2, and Pasi Poljana. [220] Large parts of the city are still not covered by DHS.

Due to the above stated, heat power plants and substations use fossil fuels for supplying buildings with energy, the city and its buildings have an enormous bill for district heating services. Adding to the problem, most of the buildings date from the period of the 1950´s to 1980´s; therefore, refurbishments involving energy efficiency measures are needed in order for heat energy not to be wasted.

In Figure 60, individual housing supply resources indicate that over 50 % of the heating fuel comes from wood and large percentage from electricity as heating resource (31%). On the other hand, Figure 61 shows that collective housing utilizes DHS which is fossil fuel based with 64%, electricity with around 36%. 2/3rds of electricity in Serbia comes from fossil fuel driven power plants, only 37% comes from hydro energy (considered as RES).

Figure 62 shows the overall distribution in schools. Although largest percentage is connected to DHS (around 36 %), individual facilities also use fossil fuels mazut and coal (together 45 % of the overall share), with 2/3 of 15% electricity share (10%), adding to almost 91% of all resources in Nis ´s public schools using fossil energy.

Based on these graphical representations, there are rooms for improvements in all types of buildings in Nis. Less dependence on fossil fuels can be achieved both in collective housing and public schools. On the other hand, attachment to DHS of individual housing in the future (preferable based on renewable sources) could add up to the overall distribution of RES in heating in Nis. Suggestions for a cleaner environment in Nis concern minimizing of

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[219] Nis has been developing spatially at its peak in the 1980s and 1990s, as most of the housing projects have been realized in this period. Shortly after the 2nd WW Nis began to develop further form the center core around t fortress. For example, *Krive Livade* was only a crop field and now it is the area around Nemanjica Boulevard, one of the second most important urban centers of the whole city

[220] According to the website of the DH company: http://www.nitoplana.rs/toplotni-izvori-cir.html, accessed 14.03.2018. The company does not advertise the investing in GE drillings on its website

fossil fuel use; density of heating networks and access to district heating to all parts of the city, regardless of the distance to the city core. This could serve the purpose of a **balanced urban development of all areas of the city.**

Figure 59, One of the urban nodes of the city around *Nemanjica Boulevard*, Park of the United Nations, with rich green infrastructure and commercial and municipal buildings located here, is surrounded by collective housing built in the 1980s and 1990s. Its design has contributed to more balanced urban development of Nis[221]. The presentation of GE (instead of currently used fossil fuel within DHS) in its vicinity could present Nis with green values as educational goals of the city´s urban planning, source: http://niskevesti.info/wp-content/uploads/2016/05/park.jpg, accessed 14.03.2018

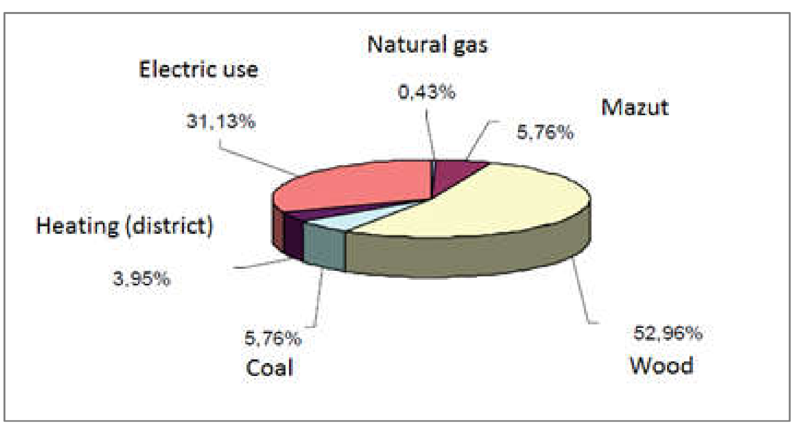

Figure 60, Overall distribution of heating sources in individual housing Nis; wood-based heating of individual households makes up most of the

[221] Until its creation as a city node-park in the late 1980s, the city center around the Fortress of Nis comprised the only spot of a once mainly *monocentric* urban development of Nis

heating load, source: [77][222][223]

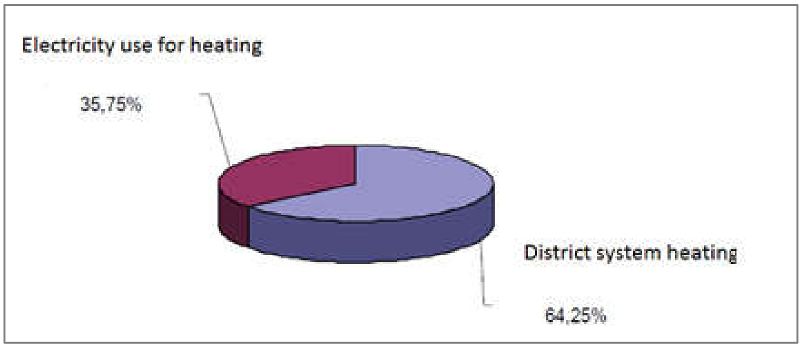

Figure 61, Overall distribution of heating sources in collective housing in Nis, large percentage of collective housing in Nis is covered with DHS. source: [77][224]

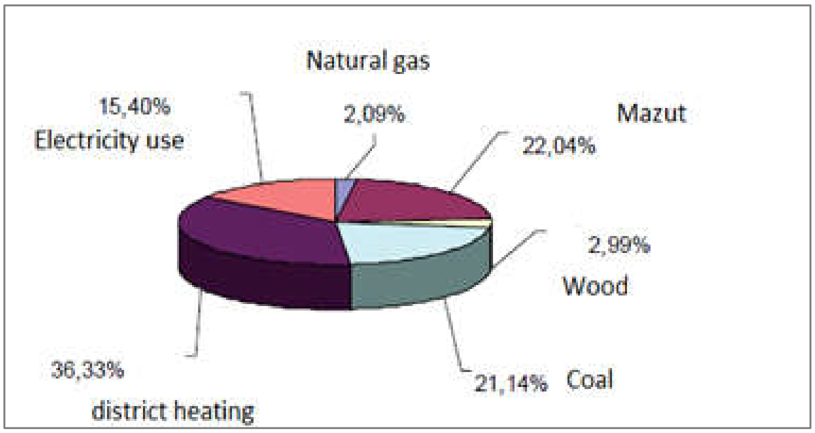

Figure 62, Overall distribution of heating sources in public elementary schools in Nis, DHS are present to great extent. source: [77][225]

6.5.3 On solutions for and obstacles of urban planning in Nis

As far as urban planning of the city of Nis is concerned, the documents giving analytical approaches to the problem of dying-out of the villages, have been at the center of attention lately. They point out to the problem of a more alleviated urban-rural development of Nis surrounding. Nevertheless, Nis and its adjoining area show tendency of urban sprawling, despite its city core being of more compact and densely populated urban forms, consisting of mixed-used areas (housing, industrial and commercial) and array of downtown activities. On the other hand, the situation is adapting to market economy in the city, which gives advantage to city cores for living, especially because of smaller transit distances and less

[222] Fakultet zaštite na radu, 2014, 96

[223] Wood is considered to be a renewable resource, even though it can be replenished only at a given rate. The individual households in Nis therefore show fair opportunity to affect the environment by them using more efficient technologies based on wood and biomass

[224] Fakultet zaštite na radu, 2014, 95

[225] Fakultet zaštite na radu, 2014, 58

commuting dependence there. This is an element typical of many European mid-sized cities, where the commuting is done by walking or biking to work. However, in the case of Nis, the surrounding rural areas melted with the city, thus making them the new suburbs. This resulted in a sprawling outcome. The first reason for this was the city wanted to expand its limits in search of new administrative zones which could be taxable for the needs of the city budget. The second reason was that the rural areas wished to be connected with the city, as the city offered them numerous amenities, especially in terms of employment. The role of the city has been contested lately due to economic crisis and lack of employment opportunities, however the boundaries of the cities and its neighborhoods remained unchanged. Urban planning is somewhat limited to capital gain, whether it is in public or private hands. Urban sprawling is only one of the few consequences of transitional process towards market economy. [72]

"…As for Serbia, it seems that both rural and urban environment are endangered in terms of at least one or more of these criteria. It looks as if development potentials have not been assessed and priorities have not been determined in urban planning. Even if they have, their execution is being contested. One good example is Nis, where geothermal studies have not been initiated for decades, despite the existence of scientific studies which suggest that this might be done for city fuel and heat supplies. The institutions dealing with this at the level of the City of Nis are *City Assembly* and *Secretary for Agricultural Development and Rural Development*. On the state level, official policy is trying to address the issue of dying-out of villages with rather vague media presence, involving testimonies of people coming back to rural places after having abandoned city life and its commodities, in the search of better life. [122][226] If this is one of the options, the question is which conditions these people have for their future to be secured in rural places, and especially, if energy security and energy plan are part of the urban revival.

On the other hand, the problem is in the small number of young people who are willing to be part of this. Based on the data of Statistical bureau of Serbia, majority of young people in Serbia aging from 18 to 30 are determined to leave the land or at least their current towns or villages, in the search for better life. [123] This can further intensify the problem Serbian cities are facing today, along with socio-economic conditions which are hard to sustain or improve growing population of the unemployed. A study about young people in Serbia and their intentions, by the same source, also suggested that investing funds into agriculture instead into the secondary sector*, more local product-oriented industry, can be achieved and this may be one of the key solutions for rural-urban cohesion. [124][227] Energy harvesting could help the communities to achieve this transition because it focuses on local potentials and their utilization, rather than "external", i.e. imported energy sources, the

[226] RTS, 2017

[227] Bubalo-Živković, Lukić, 2015

utilization of which usually means energy dependence and energy transport, often that of fossil fuels. [4]

Bubalo-Ćivković and Lukić expect that Serbia will have recovered from the currently existing economic crisis and turn to its further development by 2026. [124] It is therefore necessary to plan territories and settlements for the new conditions to come. Especially, one needs to focus on the problems of migrations and "dying-out" of the built environments in Serbia and, most importantly, the change in demographic structure of the Serbian society in which the elderly would prevail, especially in rural areas.

At first glance, it seems that at the beginning of the 21st century, one can mitigate the process of urbanization of cities and put an end to complete dying-out of rural environments in Serbia. However, this is not an easy task to accomplish. Nis is a good example of a mid-sized city with ongoing urban transformations, accompanied by area gentrifications, rural-urban migrations. [125][228] Densifying the suburbs of the city and acquiring rural land for further urban spreading and sprawling by the city itself seems inevitable. The induced concentration of citizens has negative impact on city´s ecology because of the commuting distances from rural and suburban places towards city commerce center, more fuel and energy and time used for transport and the level of motorization which induces the urban sprawl. [72][229] Finally, the population which moves from rural places and smaller towns is rapidly changing its cultural environment, as the rural landscape is replaced by the suburb or city culture. The conditions prevailing in this environment are completely different from the rural area. Sociologically speaking, one is thrown into a community, the values of which are completely different. For example, "cheap" flat-policy of most people in Nis draws the building investors into city centers, where the demand for housing is increased. However, overcrowded and unstable buildings, especially built after 1990s, do not constitute safe environment for people. With areas built so densely on the free market, parks and green infrastructure are deprived of their place in the city or rejected for profit of the prospective land. One should initiate a strategy which refers to these "free market" events. Such strategy would *involve advocating healthy environment, offering admittance to accessible housing, transport relations, green infrastructure and cheap energy and district heating options and microgrids. Geothermal district heating options should be applied whenever possible.*[230] [4] "Geothermal energy utilization is only one of the aspects, which together with urban revival tools can help the suffering communities in their search for re-development. [68][231] Regions surrounding Serbian cities such as Nis region, may benefit from a long-term urban-rural revival strategies involving geothermal energy, since local energy would be

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228 Dinić, 2015

229 Maksin-Micić, 2008

230 There are many cultural interpretations of contemporary Serbian rural life, describing dwellings of the rural and the eradication of the fireplaces in villages, replaced by city culture and contemporary life in cities, with no relation to the importance of a household in a more holistic sense

231 George et al., 2016

harnessed a and used for agriculture, aquaculture, aquaponics etc. [51] Picture of a dying-out of rural can be replaced by its reorganization, with changed energy-supply conditions in the areas of rural and semi-rural, for example. This is a bold step into facing reality which must be advocated at a State and regional level and is now hardly imaginable, due to economic situation and decline.

6.5.4 **What could be the connection between geothermal energy and urban planning in Nis**

Local economic development could be enhanced by using local natural resources. Geothermal energy could be used for heating of individual housing with renewable sources in low density areas (most of South East of Serbia is characterized by rural settlements of *spread village* morphologies), with very low population densities [126].[232] Also, investments in agricultural infrastructure can be supported by GE, because geothermal energy allows cultivation of crops which need soil and air heating in colder period of the year. By investing in this, the variety of agricultural products can be supported, and indirectly, survival of many small and medium-sized private companies can be assisted. Additionally, by investing in production capacities by using geothermal, local work force capacities would be employed and economic prosperity enhanced. This would result in achieving more acceptable life standards for local communities and more acceptable urban-rural cohesion of the region.

Another aspect of more profound geothermal energy utilization in rural places is contributing to the revival of built areas which are historically significant and which can enhance tourism and economic development. An important element which should be considered when making such strategies is the fact that Nis region has always been famous for its bathing culture using geothermal waters in spas and towns.

One crucial aspect of this paper is to explain and identify the influence of energy for a more efficient development of physical structures within urban and rural agglomerations, in terms of a more alleviated and balanced principle. Geothermal energy should be present much more in heating of housing, commercial and industrial buildings, followed by its utilization in agricultural structures, green house production processes and in tourism and spa sector. Moreover, GE may find its role in the revival of vernacular architecture, especially as a contributor to the existing spa heritage preservation and appreciation. The authenticity and originality of this cultural aspect of geothermal waters

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[232] As argued in: (Tehnička škola Čačak, 2013), the spread villages of the Serbian South are facing the tragic destiny, where the estate prices have been extremely low due to lack of population. On the other side, the landscapes of exactly these and similar villages have been advertised for beauty. For further reading on the importance of household preservation in rural places in Serbia, see text by M. Gorski in: (Vujović, 2013)

can be traced back to the rules and influences of Ottoman empire, Medieval state, Slavic culture, Austrian-Hungarian influence, Roman and Byzantine era. If this heritage can be researched on the example of Niš, it could serve as a model for re-development of many other cities and towns in the region.

6.5.5 Connecting energy with urb-architecture

There are initiatives in the EU which aim at addressing the problem of energy´s role in urbanism. [127][233] Serbia is indeed a stakeholder in treaties on sustainable rural development and cultural heritage preservation through sustainable development. [128] These concepts generally lack direct coordination between executive organs and there are rarely any master plans of settlements which would address the sustainable principles, advocating advanced and innovative approaches, initiated by governments or local communities' representatives. There is a need for a more rational exploitation of natural resources in space to allow for a more prosperous development of settlements of non-globalist types.

In terms of corridor Nis-Belgrade, one can notice certain smaller investments in infrastructural, production and energy capacities. However, at the beginning of the 21st century, towns and settlements have not developed strategically in the light of the current urban planning issues (demographic changes, local energy sources 'utilization, global, local financial trends etc.). This leads to the fact that the population of many towns moves to bigger cities and countries in search of better life. The infrastructure, or most of its parts dating back to the second half of the 20th century, cannot develop and be given a second chance because of the lack of means or interests to invest in strategic decisions on municipal level. If one would look at the long-term energy strategy with pay-back periods set accordingly to each project, this could allow for private investments. Only then would the young people want to stay in an environment like this and establish their business areas in these towns. This would be considered as a sustainable growth of a community, leading to more sustainable regional concepts and country´s spatial concepts of sustainability.

Opening new work places in the less developed municipalities would help mitigate the problems which have arose from the previously mentioned phenomena. Since only a smaller portion of the population is employed, this problem will occur sooner or later. Social sustainability of a city or settlement is manifested by its capability to allow for survival of its population by using measures and activities that address them. [129][234]. In terms of these problems, Serbia is facing the specific problems of energy supply, demand and intra-country-based migration policy. There seem not to be any mechanisms for stopping

[233] Nilsson, 2014

[234] Littig, Grieβler, 2005

migration from villages to cities, and from South to North. Primarily, it is considered this to be part of the "natural" flow of things in the society aimed at survival and growth. [235]

In case the heating source was electricity, butane gas or similar, the heating bill of an average Serbian household was RSD 20.000 (around EUR 170), and in case natural gas was used, the bills were RSD 8.150 (around EUR 68), according to Agency for Energetics of the Republic of Serbia [130][236].

The given price includes only price of energy acquisition. The price oscillates from these values based on the type of fuel, whether the heating system is newly installed or renewed.

According to the data given by RZS (Republic Statistics Bureau), the average salary in Nis was RSD 24.000 (around EUR 200). Monthly consumer basket for one family was RSD 19.100. [131]. Based on the empirical data obtained by the author, rent in 2016 in Nis was estimated to RSD 12.000 (EUR 100) for a one-bedroom apartment, and electricity charges from the electric company were estimated to be around RSD 3.500 (around EUR 30). Thus, a two-member family in Nis pays one-fifth of its monthly living expenses for heating. When one takes into account other expenses for energy supply, the share of energy is even greater. The sources of energy in *the District heating company* of Nis are being set by the market, with both domestic and imported sources. There has been an ongoing detachment of flats from the district heating net because of the very high prices for district heating in Nis. *These prices are not much different than in Belgrade or in other neighboring regions which use fossil fuels (mazut or gas). However, the economic situation is complex and salaries are too small to follow the energy market´s actual prices.* People often turn to electricity, which is generated by hydro energy (around 34%) and by thermal power plants which use coal from *Kolubara* coal mines. [237] There are even plans for an upgrade of these power plants to new, greater capacities, according to [132][238]. This would mean more tapping into fossil fuels consumption and no change in treating urb-ecology of the City of Nis and other cities in Serbia in the future.

This trend of un-ecological heating and fossil fuel exploitation and situation of people disconnecting themselves from the district heating due to high prices can be solved by long-

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235 The Government of Serbia, has recently taken initiatives for fighting against the drastic change in demographic structure with the aim of creating policies for families and supporting newborns. It has been an official governmental issue for the last six years only. Prior to that, there was no official policy advocating this. However, these policies can have an effect in a couple of decades. During that period, the population numbers and changes in rural-urban environmental structure of the land might already occur

236 Agencija Za Energetiku Republike Srbije, 2017

237 According to: http://www.elektroenergetika.info/istorijat2.htm, accessed 15.06.2017. Kolubara basin in Serbia is the country´s largest reserve of fossil fuels used for electricity production. Kolubara exploits lignite coal, which has low caloric values but burns slowly

238 Vujović (Вујовић), 2013

term planning in sustainable energy sources, one of which is certainly geothermal energy, followed by solar, wind, biomass and other. [4]"

6.6 The importance of GE of the level of planning cities and villages in Nis region

"Unlike today's sprawled car-culture cities which expand their limits uncontrollably, medieval and historic Serbian and European towns were compact structures. For example, for many centuries Nis was within the walls of the Nis Fortress where all city commerce, trade and public life were organized [118][239] [116][240] This principle is somewhat present in today's Serbian villages, which have additional communication with larger cities for commerce and cultural exchange, among other things. The dependence of smaller cities and towns to greater ones is getting more and more present in the global community. Nevertheless, there are local things that even the smallest communities may offer to bigger ones. For example, geothermal locations of Nis surroundings could be much more integrated into different regional and inner-city exchange policies. In Popsica, a village next to Nis, local people have made a thermal pool which attracts the local and city population during summer months. This is only a small project that the community itself has made. At the beginning of the 20th century, there was a similar situation in Reykjavik.[241]

When compared to European case studies, especially Iceland, Serbia is lagging when it comes to geothermal utilization of the present resources and capabilities. One might say, the lagging spans to one century of time. Moreover, the villages in the vicinity of Nis are decaying as there are no initiatives leading to changes in terms of tackling demographic issues in rural places, securing long-term policy, rationalizing energy supply and supporting local innovations. Additional problem is the lack of funding and/or inadequate dispersion of those funds. This is justified by the statement that the above stated is a natural process and that there is no needed to invest in a village, the population of which wants to move to the cities. By forming a long-term research goal at the academic level, we can try to address this problem and reverse urbanization of Serbian regions, such as those mentioned in the Nis region. One could look at the region of Vojvodina for valuable lessons on including geothermal into urban planning. In such cases, GE projects are integrated into local communities´ development plans. [133][242] However, this is primarily present in

239 Petrović, 1999

240 Milić, 1983

241 As comparison, the first installation of geothermal heating system in Reykjavik took place in a school pool, which has led to its further development. This has already been explained in the chapter on Iceland (see chapter: Geothermal development within urban morphology of Reykjavik)

242 Milenić, Vranješ, 2015

northern part of the country which is economically dynamic and geothermally potent, unlike the southern regions of Serbia. Nevertheless, Southern regions too have exceptional resources that need to be considered seriously.

Apart from geothermal and other renewable energy sources, SE (south east) Serbia has well preserved vernacular architecture. The importance of vernacular architecture has been widely recognized in Vojvodina region and numerous works have been published on the topic. [134][243] The next step is connecting the preservation of vernacular architecture with available local energy sources, which can be a valuable method for their preservation in the future. In Serbia, there were studies that tackled the problem of national vernacular architecture and planning [135][244]. The interregional cooperation on this problem, in the form of a joint project and collaboration between SE Serbia and Vojvodina, can be useful for both regions, especially for Nis region.

In terms of planning, it is necessary to engage local communities by investing into hydro-geothermal infrastructure. This way, one could influence the more alleviated development of the regions of Nis, Pirot and Zaječar and their towns and villages, already mentioned in the introduction. Indirectly, one could influence the urbanistic development of SE Serbia and trans-regional cooperation. The region needs more energy independence, especially as means to alleviate one more lagging behind, compared to the Northern state parts and even greater, to current European leading cities, in terms of energy efficiency initiatives and urban planning with renewable energy. [245]

In 2002, Serbia had population of around 7.500.000. The average age of the population was 42,7. [123][246] Everyone apparently produces negative emissions and pollutions to the environment by daily activities, consummation and transportation. The greenhouse gas emissions to the environment are not to be overlooked, especially those of CO2 and CO. For example, the emission of CO in Nis is quite high, especially in winter periods of the year, due to heating. [92][247] By the same sources, at one of the measuring places, the Spa of Nis, the average yearly concentration of CO has been above allowed values. This is alarming, as the spa is thought to be the healthy environment for treatments. Finally, it has geothermal resources used scarcely with temperatures of around 39^{o}C and flow rates of at least 10 l/s. Surely, one part of the spa could benefit from this and somewhat cut on the

[243] Simić, Mihajlov, 2016

[244] Mandrapa, 2017

[245] According to the data from the National Statistics Agency of Serbia, unemployment rates are far greater and wages are far smaller in the South of the country. (Republicki Zavod za Statistiku Srbije, 2015) [123] However, the energy prices for heating (especially district heating) are somewhat similar in all greater cities country-wide. Thus, one greater share of the total household expenses is given away for the heating expenses in Southern cities, such as Nis. This makes it additionally hard for the poorer communities such as Serbian South to prosper as they cannot gasp the rising prices of energy, to which they have no alternative at present

[246] Republicki Zavod za Statistiku Srbije, 2015

[247] Institut za Javno Zdravlje Niš, 2008

pollution produced by heating. Transportation is the next thing that should be drastically re-considered here, because it can contribute to cutting down pollution coming from fossil fuel exploitation. Currently, only Hotel Radon in the Spa of Nis uses geothermal for heating via heat pumps (2 out of 4 available), besides thermal bath and treatment buildings. [136][248] There seems not to be initiative to broaden this use, despite the presence of all capacities and historical fact that the Spa of Nis is on the route leading from Sofia to Nis. In the past, there was the han (*karavaj-saraj*) that used to take on the passengers from Europe on the route to the Orient. [137][249] Such places were certainly important for travelers and geothermal waters played an important role in the utilization and appreciation of such Turkish buildings.

Niska Banja (the Spa of Nis) does have tourist capacities [138][250] even though its capacities were built a long time ago (between two world wars and afterwards). The citizens of the Spa have no access to district heating or any centralized system for heat distribution. Strangely, the eastern parts of the City of Nis, where Niska Banja belongs, have been identified as potential parts for geothermal utilizations. [52][251] [113][252] [114][253] [115][254]. Moreover, there is a plan for pilot geothermal drillings in the city center, as means for supplying part of the heating energy to the existing district heating system of Nis, carried out by public enterprise for DH. [54][255] [87][256] However, there needs to be a broader thinking about utilizing geothermal energy beyond this single initiative, despite it being of essential value for this city. For example, the localities of Kravlje, Popsica and Svrljig have been mentioned and analyzed for geothermal potentials long time ago by [98] [99] [100] [102][257].Their connection to supplying of the area of the city of Nis with heat is of essential value, besides sources identified in Humska Banjica and Gornjomatejevacka banjica. [116]The municipality of the Spa of Nis still remains one of the most underdeveloped parts of the city, with semi-rural parts, so this aspect should play an important role in suggesting geothermal drillings in Nis. GE capacities should be directed towards creating an alternative to the citizens of the rural, endangered parts of dying-out villages found in the area near or surrounding the Municipality of Niska Banja. Backing up of these areas and urbanites is an approach favored in regional planning and has been proven to be successful in European experiences. [139][258]

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[248] Nis, Niska Banja, Expert- Technical officer, 2015
[249] Vasić, 2012, 20
[250] Direkcija za upravljanje i razvoj Niske Banje, 2013
[251] Nis, Expert in Urban planning, 2015
[252] Perić et al., 1989
[253] Zavod za Urbanizam, 2011
[254] Stanković et al., 2011
[255] Nis, Expert from the district heating company, 2015
[256] Lazić et al., 2015
[257] Kostić, Martinović, 1972; Martinović, Kostić, 1975; Martinović, Kostić, 1965; Kostić, 1970
[258] Honig, 2005

6.7 Development of RES potentials in Nis region- Recommendations for future activities

The City of Nis and the surrounding municipalities still do not consider introducing using RES as obligatory in their master plans. On the other hand, these can contribute to stopping of their dying-out, as with new technologies the needs for skilled workers would arise, which could allow for decent living for many who are seeking for better opportunities. For example, Nis region has no geothermal atlas or a solar atlas that deals with solar potentials in urban and rural settings of Nis area. They could contribute to locating potentials and possibilities for Nis at the level of an individual user that may consider building where energy supply conditions (with renewable energy utilization options) are more favorable within the city. This can determine the connection these sources may have to urban planning and change the policies or reactive planning to policies of proactive strategy. It can connect the idea of the change for individual and its connection for the collective planning-the city and its more alleviated development. [4]

"It is especially important to underline that the current states of geothermal utilization in Serbia is not as near to its whole potentials.

These potentials are not being seriously considered and they will have even greater meaning for the future of a more sustainable development of the region of SEE (Southeast Europe) in the decades yet to come. This is especially important in terms of regional cooperation on energy and urban and spatial planning, as well as for Serbian integration into EU. On the level of Nis region, it can make a contribution on different levels, and in the long term. Rural-urban cohesion can be supported which would result in de-urbanization and more alleviated development with less overburdening on the urban cores. This can happen as of 2026, when the country would show first signs of economic revival. It could be helpful in terms of supporting heating process, drying in industrial and agricultural sense, greenhouse production, followed by recreational tourism, aqua culture and aquaponics, as well as creating different geothermal clusters which can further support creating of networks and systems in geothermal utilization prospects for the society. A good example on the level of the local community´s government involvement in the procedure of making decisions related to geothermal utilization is shown in the study on the territory of Vojvodina in North of Serbia [133] . This model should be suggested for SE Serbia and Nis region, as it offers milestones which are region-specific and can assist in scientific explorations of geothermal energy.

With regards to expenses for heating of an average household, the current situation in Nis is largely dependent on Nis´s dependence on general energy market and current socio-economic situation in Serbia. They could be addressed by the use of GE at the city level.

[52][259] The sources could be integrated to the system of district heating [54][260], which has been partly suggested in the project pilot study in the central municipalities of Nis. [87][261] Niska Banja, on the other hand, should be seen as model for future re-development of the city with GE utilization at a community´s level, where urban planning is integrated. [52][262]

Secondly, local potential determination must be supported by the state, especially as a method of creating an updated climate in rural-semi rural and suburban places and networks ´creations, allowing for their survival and sustainability, if not prosperity as well.

Strong feeling of local identity and culture among population can be a milestone for this, as having this as an asset would introduce local energy harvesting as a job. The abundance of geothermal energy in places like Banja Topilo, Popsica, Kravlje, Divljana and other in neighboring regions like Sokobanja or Svrljig, in vicinity of Nis, can be valuable for the research of the region. They can serve as means of creating energy nets, combined energy facilities (for heat production and power production for example) and other already mentioned industrial and agricultural processes. The influence on the rural-urban landscape is easy to imagine, based on the opinions from experts from abroad [59][263] [140][264] and from Serbia [51][265] these expert opinions are supported by references from Iceland and Austria, about successful implementation of geothermal on the regional level. [141][266]

Moreover, by changing the activities one is doing today, for example from agricultural to energy harvesting, new skills among the population can be gained and the areas sustained. GE utilization and projects can be treated as some of the methods for re-development of urban and rural areas, not just as marginal issues in urban and spatial planning. For this, study on potentials for its utilization must be conducted, the financial support for test drillings obtained and all the necessary fund of the EU consulted. Agricultural and demographic support of the state, recently set as top priority by the government, can also encourage thinking on energy level. If other measures, such as birth policy or similar, are not giving results, then some other methods need to be reconsidered in the long-run. Eco-tourism of SE Serbia can be also supported by GE and other renewables 'utilization, especially in terms of saving the whole landscapes of built vernacular houses from deterioration by giving it a flair of new 21st century technology, such as geothermal.

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[259] Serbia, Expert in urban planning, 2015

[260] Serbia, Expert from the district heating company, 2015

[261] Lazić et al., 2015

[262] According to: Nis, Expert in urban planning, 2015

[263] Iceland, Expert from the geothermal cluster, 2015

[264] Austria, Expert - geologist and geothermal expert, 2015

[265] Serbia, Expert in geothermal energy utilization, 2015

[266] Goldbrunner, 2005

6.7.1 The problems of geothermal energy supply to buildings

However,, there are certain problems that one needs to take into consideration when designing geothermal wells and suggesting test drillings and projects with geothermal. In terms of Bečej in Vojvodina, one has to find proper energy demand carrier, a set of buildings which would need this amount of energy, before geothermal drillings could be made. This is done as to make sure there is sufficient energy demand as geothermal may prove to be uneconomical. This is of utmost importance, even greater than the technical conditions for doing drillings or equipment transport. There has to be the right combination of energy demand and energy supply in order for geothermal to be successful in a city or one of its parts. This may be an interesting element in the planning of Nis, as there are different parts of the city with different energy needs, i.e. dense areas in the city center and less dense parts of the suburbs and rural areas. However, the sources and potential sites for drilling are usually located in rural and suburban areas. This, however, can be a good signal for agricultural production. In Bečej case study, agricultural production is accounted for in the planning of areas with geothermal infrastructure. [142][267] Judging by potentials for agricultural development of Nis [114][268], the city could well benefit from similar approaches. However, one needs to go beyond the given schemes for geothermal development. Possibility of different energy combination within the city, synergy of many sources towards energy nets, needed for preserving city parts that are threatened by losing population to other more economically enhanced parts, should be analyzed. Low enthalpy energy sources used for individual user, that cannot afford upfront costs in investing into geothermal, may be used more economically in a network or array of heat pumps and district heating nets, within the concept of microgrids. These and similar approaches can contribute to fighting unfavorable demographic changes in Nis area, by allowing for energy savings and buildings made affordable to live in.

In terms of its potentials, geothermal manifestation in Nis region could have basic contribution to supplying heat to city areas, but also other cascade uses, especially balneology, agricultural enhancements etc. Electricity production seems unfavorable, because of low temperatures for these purposes in Nis region. Very high initial costs for drillings for such low-grade energy sources could be unfavorable. They are an obstacle even for companies which would like to invest in geothermal projects. [80][269] The community which is investing in geothermal shall have benefits in the long run. [59][270]

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[267] Petrović, 2005

[268] Zavod za Urbanizam Nis, 2011

[269] Andrić, 2015

[270] Iceland, Expert from the geothermal cluster, 2015

6.8 Discussion

"Based on the given brainstorming on the topic and by analyzing the expert interviews, the strategies for GE promotion in Nis in terms of urban planning are as follows:

-Instead of short term and instant reactive solutions, a long-term, multidimensional and interdisciplinary approach to geothermal energy utilization in Nis region is preferred and would give more results in the future of urban and spatial planning. By its careful considerations, the problem of a more balanced urban-rural economic development of areas and settlements can be expected. Consequentially, this could create the relief of urban cores and offer people an alternative for a healthier environment. This is in the focus of the population worldwide and will eventually be present in the minds of the Serbian population. The sources of pollution are heating and transport driven and are in relation to fossil fuel utilization in Nis region. By eliminating them, at least to some extent, the environmental goals may be achieved. Additionally, by using centralized geothermal systems and by further exploring possibilities for drillings for *high enthalpies*[271] in Nis and surrounding areas, especially in large urban centers such as Nis and similar cities, energy costs of households can be significantly reduced. Then, the city would have more funds to invest in green spaces, public infrastructure, safety and urban planning strategies. This is already happening in many countries of Europe and USA which have invested funds into revitalization explorations with local energy. In general, geothermal energy can contribute to the creation of a network of sustainable cities, using local resources and helping each other out. This is contrary to the current trend of a global, inert city, which is energy dependent and has no energy alternatives. Nis is one of those examples, but it has an opportunity to change, based on its abundance of natural geothermal resources and its rich history and culture, dating back to Pre-history and onwards, which is in need of better presentation and preservation methods.

Creating healthier environment should be considered an imperative in regional development of Nis. Recognizing GE potentials for utilization is not the same as concrete actions leading to its realization. This must be initiated at last. Connecting energy planning with spatial planning is a must, especially in Nis after 2026, in order to develop an area of an alleviated urban-rural development, supported by local energy use.

> *There is a strong need for sociological studies which would conduct serious scientific explorations with the aim of unveiling socially-dependent reasons for wasting energy and delivering a strategy for combating these and putting emphasis on the preservation of energy and sustainable governing of regional energy. Some of these results have already been recognized by the EU. Therefore, it*

[271] High enthalpies or high temperatures, usually referred to temperatures 150 °C and above

> *is possible to use them as guidelines until the expected economic revival in 2026 and eventual accession to the EU one day. By doing so, the region of Nis can be supported as infrastructure that is of use for the citizens. Some of these strategies must be very thoroughly and innovatively thought through, as they need to recognize the role of the Balkan mentality to executing or not-executing laws, decisions or strategies to the full extent. It can also be mentioned that the eventual energy market fluctuations and more expensive energy in the future in the region may be a trigger for analyzing more brave and advanced thinking about GE utilization in SE Serbia and in the rest of the country. Currently, those initiatives for such thinking seem to most of the people and experts in Serbia as "hard to reach" and not worth considering.*

Such thinking can be assisted by public and community´s initiatives for cleaner environment, sustainable utilization of resources, cultural continuation of using geothermal energy in Nis, and many more. By changing the current "consumer-culture" with a rising number of people in favor of "green" among general population, many mistakes made in the past, such as sprawling, could be affected. Comparing this situation with that of Reykjavik, the abundance of cheap energy does not necessarily mean knowing how to deal with it in planning of a city. This is a valuable lesson Nis has to try to evade once geothermal energy comes to the light of the day in Nis. Energy resource capacities 'relation to energy demand of an area of the city or village, needs to be addressed with utmost attention (such as drilling, production, transportation, waste waters, environmental aspects on one hand, and type of buildings, their expected lifetimes and "energy" densities on the other). In this sense, rural and semi-rural places would need to be somehow reorganized and used in order to avoid their further deteriorations. [4]" The role of cultural heritage preservation can be one of the methods to involve GE more firmly into local planning.

> "In terms of the mentioned potentials, GE manifestations in Nis region can have greater meaning for energy infrastructure that would be built and that would supply towns and villages with heat energy. Electricity production is hard to imagine, unless some investments into research for greater depth-test drillings is supported in the future. However, this should not be left out as an option. HDR method, even though contested in some countries, may be an option for Nis in the future, if environmental and seismic conditions for its explorations, among others, are met.
>
> Method of expert interview has allowed for receiving details about new arising issues in architecture and urbanism, such as geothermal energy and its connection to them. The method has proven to be compliant with further flow of research on geothermal, as the material on what is important for GE´s successful integration in urban planning, was scarce and no concrete research questions were known in advance. By the flow of the analysis, more such questions have

been derived from the interviews with experts than the usual quantitative analysis would assure. [4][272]"

One brighter aspect in Nis is the new wave of green thinking among the younger population, which enables changes into realizing the patterns of cities and how we conceive them. This fact is an opportunity to divert attention to a more locally-based society rather than globally induced one, at least in terms of energy consumption and living environment awareness, heading for improvements among the young.

> *"The considered historical connection of settlements and GE can serve as a back-up to creating cultural identity of the region through geothermal energy utilization continuity dating from the past development periods (Roman, Turkish, Slavic etc.). Local identity and cultural mind set change is necessary to explore in detail, in order to achieve this in Nis and Serbia.… The traditional way of presenting and conceiving cultural and architectural heritage should be changed. Sustaining rural-urban wholes needs integrative approach and understanding the ties that have not been thought of until now. It is a prerogative for any advancement in the urban planning with GE in Nis in the future."* [4][273]

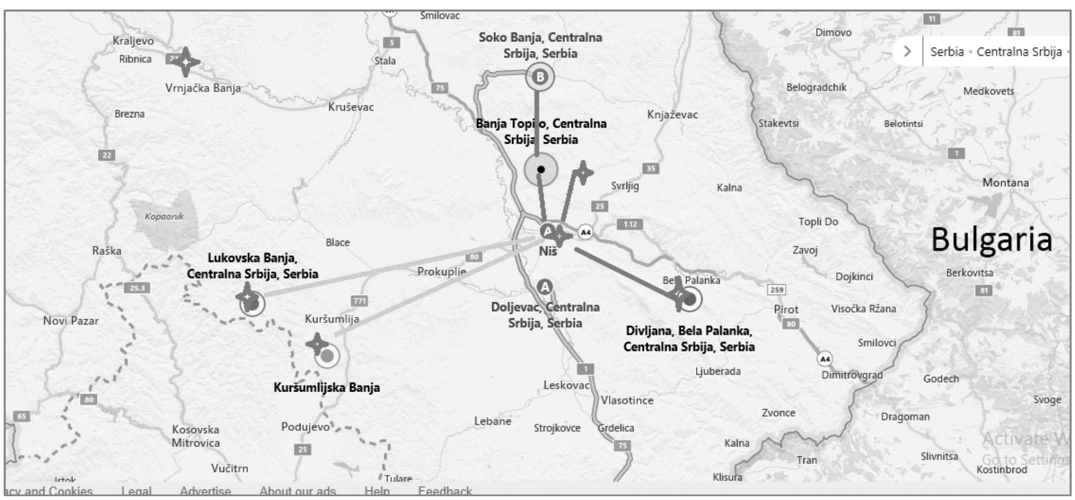

Figure 63, Regional map of geothermal resources, city of Nis being in the centre, surrounded by Banja Topilo, Sokobanja to the northeast, Popsica and Divljana thermal spring. Further away are Lukovska Spa, Kursumlija spa, Vrnjacka spa. In these locations, geothermal manifestations with low enthalpy have been spotted, in the range of 30–65 °C and with flowrates from 5 l/s (Topilo/Kravlje) to 60 l/s (Lukovska Spa), which can jointly be considered for supplying Nis with heat, making thermal network of towns in SE Serbia and connecting to other neighbouring regions. These resources are

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[272] Jovanović, Cekić, 2017, 15-27

[273] Jovanović, Cekić, 2017

most likely important for Nis in the future, figure source: A. Jovanovic, based on www.bing.com/maps

> *"One example of using low enthalpy geothermal energy is district heating in Paris, France. It has been in use since the 14th century when the initial system was installed. Some recent expansions of the system allowed for another 200,000 houses to be covered by this form of energy* [143]. *It contributes to the reduction of CO2 emissions in the metropolitan region of Paris and to better life quality of the urban environment in terms of pollution.*

There are at least two known geothermal localities outside the city, one in Miljkovac (Banja Topilo) and the other in Kravlje (Popšica), with some in the suburbs of Gornji Matejevac and Hum within the city limits, according to [116, p. 22]. The temperatures there are lower than current temperatures within the rural areas of the city region. They are used for small pools and some for spa (e.g. the spa of Topilo some 20 km from the city). Other resources are found in Sokobanja (62 km from Nis), Divljana, and further to the south, see Fig. 63.

Their vicinity to the city open a question: whether they could be used more and whether the capacities can support district heating at least in some parts of the city. Possibly DHS can be localized to a specific campus of buildings, resorts or residential complex as a pilot study for more geothermal use in Nis in the future. Currently, the city of Nis has a system of district heating, based on mazut and gas, approximately equally used in the share of fuels. As for electricity, it is subsidised by the state, therefore many areas use it for heating. It is being produced by burning coal and hydro energy, the first one contributing to greater extent in the share.

The city should have a broader planned set of initiatives such as green city project, that tackle the problem of careful and interconnected consideration of different elements of sustainability in the long run, as argued by Gaffron et al. [144][274].

Another important connection to planning is the fact that geothermal DHS and other GSHP installation initiatives are beneficial if they go hand in hand with refurbishments. According to the scientific reports on the state of buildings in Serbia, the built funds need refurbishments, as most of the buildings have been built before 1990, and some of them lack basic insulation and window installations that would satisfy the standards of energy efficiency [145][275]

There should be a good reason to invest in a city infrastructure in the long run and this is not easy to achieve. The reasons must be found in a feasibility study that would have to be developed. Theoretically, academia can help with information about the historic connection to geothermal sources and findings and on the role, it had in the past in this region, which

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[274] Gaffron et al., 2008

[275] Jovanović- Popović, Ignjatović, 2008, 31-38

should not be forgotten and neglected. Especially, if it initiates new solutions and thinking about the place where it is implemented and can bring financial benefits for the investors and environmental benefits to the citizens. Lastly, it can contribute to branding of the city and therefore to economic development and regional cooperation and planning. Regional planning is important for the role of cities in Europe, as it offers the combination of different resources and capabilities of the cities to develop the network of relations and utilization of the resources among them and to determine the models of their future expansion and cooperation. It also contributes to the polycentrism within the boundaries of the country, which in turn results in less dependence from the central regions, strengthens local initiatives to make further progress in green environment and projects of urban renewal, emphasis on the importance of introducing green infrastructure in the city and lastly, connecting rural-urban concept as part of the concept of sustainable regional development. [2][276] [13]"

6.8.1 Results of the interviews and their discussion in context of city of Nis`s development

"The results of the expert interviews in Nis indicate the lack of initiative and funding for the realization of the projects as the prime obstacles for general strategies of renewable energy use planning. Both interviewees from the engineering fields pointed out that geological studies would have to be made first in order to make a practical discourse on the problem. Since geothermal energy was the main topic on the interviews, the experts showed various knowledge levels in the field of this specific form of energy.

Generally, it is to be underlined that the information on this and other forms of renewable energies is well known matter to most of the experts in the field, since they are living in the region and because they belong to the city institutions, such as universities and companies. The combined use of several types of sources of renewable energy is a good concept in developing strategies for the city districts in the opinions presented during the interviews.

In the experts' opinion, the use and exploitation of geothermal energy in Serbia must be more intensive. Especially under the circumstances of oil-energy imbalance in the world, transitional process of Serbia towards market economy, rapid disadvantage of fossil and nuclear fuels and worsening ecology and increasing costs for the protection of the environment. The use of renewable energy in Nis can substantially contribute to its sustainable development. Most importantly, several pilot projects at the city of Nis level aim at determining the potential for the use of geothermal energy within the city and are very

[276] Jovanović, 2017, UIB IX

optimistic. The quality of the geothermal reservoirs is substantial to heat homes, especially in the eastern part of the city where the aquifer is located. In other parts of the city, the use of geothermal energy can be directed to agricultural usage, production of food and drying [51][277]. In terms of the city planning, this is most certainly a challenging issue- if the plans for different use of land are considered as important factors for achieving the *Eco-city* goals, as already implemented worldwide [144][278]. The determination of the capacities is the first methodological stance, followed by the concrete feasibility study of its use at the city level. Afterwards, energy shortage should be addressed. Experts see this as a specific challenge for the city development, especially in terms of the surface or the accumulation bodies for large amount of energy. Here, the experts pointed out the problem with various types of renewable energy storage.

On the city level, Nis has a special problem with exploitation of geothermal energy on larger scale, i.e. aside from the necessary capacities and the investment conditions. This is where the experts showed skepticism regarding the large-scale usage of this energy form. In conclusion, theoretical discourse was proven to be the only method for raising the question of large-scale energy use within the city strategic urban planning decisions.

The next step would be to consult experts in the field of urban planning at the city's urban planning institutions to get the complete picture of a rather complex problem. Nis still has a long way to go in terms of sustainable development. Being a mid-sized city in the heart of Europe which aims at attaining membership in the European institutions, it would be only natural to suggest that the described investigations should go hand in hand.

The results also show that the future educational and policy strategies towards renewable energy consideration could offer long-term benefits for the development of the city in terms of renewable energy use. The lack of financial funds for investment is a serious obstacle for the specified strategies to come to life in Nis, judging from the expert opinions' analysis. Therefore, a more thorough geological expertise is needed, as it could be a milestone for any renewable energy planning measures to take place in the future.

One might look up to the best practices around the world to see how beneficial the implementation of renewable energies can be on the local level. For example, even though there hasn´t been much use of geothermal energy in the bigger towns in Austria, such as Vienna, Graz or Linz, (since major cities are considered not to have enough potential for its use on a city level), well known upper Austrian geothermal reservoirs are being used substantially for district heating of towns like Altheim, Simbach or Braunau am Inn. In the major cities in Austria however, there are initiatives of using other forms of renewable energies and the so-called smart city projects, which might be interesting to compare and learn from in the case of urban planning with geothermal energy in Nis. A good example of

[277] Serbia, Expert in GE utilization, 2015

[278] Gaffron et al., 2008

how geothermal energy can be used to enhance the development of the region can be found in the Styrian basin in Austria [141]. This might be the model for the future development of the region of Nis and its surroundings. As for most convincing case study of the use of geothermal energy for space heating, one can look at Iceland, where the cities like Reykjavík, being of similar sizes to Nis, successfully utilizes geothermal and helps lowering the impact of fossil fuels on the urban environment. If this is not possible to do in Nis as the prime heat source like in Iceland, then it should be an important component in its urban regeneration concepts. [13]"

Secondly, cities 'complete domination in the human habitat will be part of our reality quite soon. The supplying of cities with energy and their survival will therefore be interlinked and determined by the utilization of local renewable sources because cities can become self-reliant in energy terms and less dependent on the market fluctuations of the global price of energy. [33][279] Until that moment, an examination of options for sustainable local growth is needed. Urban planning literature states that each community is to achieve the following in order to become sustainable: right of its dwellers to physiological needs, rights to food and water, energy supply security, etc. [146][280] One could easily measure the success of an urban environment based on these criteria which were presented more than half a century ago. Based on them, cities like Nis and many American and worldwide cities, have not been considered as successful yet, because their energy supply is primarily *external*.

"Due to different capacities and social-economic situation present in the Balkans, which is usually referred to as the poorest region of Europe along with Moldova and Ukraine, geothermal energy utilization is limited, despite technological capabilities and natural flow rates available. This is the result of high costs and lack of financial support of the communities. In addition, as far as the attitude towards energy efficiency is concerned, Serbian cities have more similarities to U.S. cities. In both countries, the consciousness about using local source for development is at beginner´s stage. For example, American cities show urban sprawling and strip development, with car culture which is prevailing in the urban scheme. On the other hand, the capital city of Iceland and other towns have been supplied by some form of GE utilization or systems for almost one century. The savings are enormous, measured from 1914. Until 2012, a four-member family has saved 200 000 EUR for using geothermal energy instead of fossil fuels such as coal, for example. [74][281]

The truth is that geothermal resources in Serbia are a lot different from Iceland in terms of temperatures, flow rates and drilling depths needed to get to the desired values for

[279] Petersen, 2016

[280] Slayton, Dewey, 1956

[281] Orkustofnun, 2015

economically suitable utilization. However, the resources are indeed present. A scientific study dating back to the end of 1980s, showed Nis to have potentials for geothermal utilization at its territory, as realistic, in terms of supplying parts of the city with heat and other uses within a "cascade" approach. [113][282] [4]" Unfortunately, as far as the author is informed, the city has made no initiatives in terms of infrastructure and drilling planning and feasibility studies, or any preparatory and investigational activities.

6.9 Implications of the results to a study on practical urban planning of the city´s area

"The city of Nis contains these favourable geological materials in the Eastern part of the city core and Nis Spa especially. In the latter, the natural phenomena of warm water exist for centuries. Here, the aquifer lies within the *karstificated* calk formations at depths of 500–700 m.

Karstification is the process of turning into Karst. Karts is an area of irregular limestone.

Currently, natural resources at the Spa of Nis are used for supplying a balneology hotel with warm water for treatments, as well as for three heat pumps that work using natural water temperatures. The experts of the Geology and Mining Faculty of the University of Belgrade have determined the capacities of 250 l/s at the temperatures of 40–50 °C. With this capacity, the hotel capacities of the spa can be doubled and a new water centre can be developed in the nearby auto corridor 10, connecting Sofia and Belgrade [87][283]. These geothermal reservoir capacities must be confirmed first. Because there can always occur unexpected phenomena and there is not a single drilling in practice that goes swiftly, without problems. This was confirmed in an interview with a geologist [55][284]and is likely to be expected in prospective drillings in Nis.

Additional set of data from the project report [87][221][285], mentions that the current capacities of the geothermal reservoirs in Nis Spa, are sufficient to make district heating of all hotels, hospitals, balneology institutions and to erect agricultural facilities for crop drying, winter fruit and vegetables. By this project report´s results, the capacities are sufficient for supplying heat to quantities of produce sufficient for export out of city and country limits. Especially, Eastern part of the city, surrounded by Nis spa, contains geothermal reservoirs

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282 Perić et al., 1989

283 Lazić et al., 2015, 36

284 Austria, Expert-geologist and geothermal expert, 2015

285 Lazić et al., 2015

sufficient for different uses, heating of housing buildings. In the rest of the Nis valley, geothermal reservoirs are favourable mostly for agricultural production and drying of herbs.

Finally, the study from 2010 initiated by JKP Toplana (Public District Heating Company Nis), wanted to address problem of high costs of district heating in Nis. Geothermal deep drilling at the depth of 1200m was suggested and elaboration of the project initiated in a study from 2014 [147][286] [87].Before that, a study proposing geothermal possibilities of Nis had been made [113][287].The official project was made and propositions for drillings and adjoining research activities were announced, supported by the *Ministry of technology of Serbia.* However**,** there would have to be more transparent public information on this on the websites of the heating company and the city, for further advancement of geothermal appreciation in Nis to be made possible. Also, the project proposal from 2015 suggests that the most favourable area of the city for underground waters utilization in Nis is north-eastern part. The exact location is from the hill Vinik (416m above Adriatic Sea level) and Baseva glava (328 m above sea level) [87][288].

The exploitation of the geothermal resources in elaborated within scientific projects which are predominantly in the regions of Northern Serbia and capital region of Belgrade [133]**.** There are initiatives taken to expand this use to other parts (central and southern Serbia), which do not seem to be enough, as other factors contribute to the lagging of the process of more geothermal utilization in the country, for example bad economic climate, lack of expertise and tax money, among other, which could be better addressed. Geothermal needs backup in Nis.

Like the situation in Nis, an interview with an expert from the City Hall in a post-industrial city of Utica in Northern USA, confirmed that after having done first initial geothermal project, it is easier for the community to accept and believe in the feasibility of renewable technology application in a city [63][289].

The Figure 64 outlines the necessary steps if geothermal utilization would be analysed for the benefit of the city and its **adjoining areas.**

[286] Petković, Radojević, 2010

[287] Perić et al., 1989

[288] Lazić et al., 2015

[289] USA, Expert in urban and economic development, 2016

6.10 Instead of conclusions: Urban planning and geothermal energy in Nis – the next steps to be taken

Figure 64, Phases that need to be done for Nis to get the most out of its geothermal energy utilization perspectives in the long-run, (left) showing actions and (right) showing the stakeholders and the challenge levels (by volume of the hexagon) for each corresponding phase on the left. The outcome of the basic initial phases allows for development and broader phases 'development. Probably the Spa of Nis would be one of the most suitable municipalities for a pilot study of a neighborhood. Figure developed by A. Jovanović[290]

One of the most important steps than needs to be taken now is to make a pilot study of a city neighbourhood and see if geothermal energy can be sufficient as heating source and to what extent it would be possible. If yes, one should focus more on it. If not, focus should include other renewable energies for long-term urban planning development, where geothermal sources can contribute. Secondly, by public activation, praising of geothermal and its importance for combating the decline of the city, alternatives could be suggested. This is the only way to find sources by the state and /or companies willing to invest money in test drillings for geothermal waters and confirming their accuracy of temperatures and flow rates available, being essential for the planning for geothermal utilization in Nis. Confirmation of geothermal reservoir capacities is the prerogative for seriously dealing with this local resource in the long-run in Nis. Should other forms of renewable energy be considered more fruitful for Nis (like solar), the confirmation of GE capacities is still to remain important, due to the broader regional picture in dealing with geothermal and energy networks in this part of Europe.

In Nis, the cases of geothermal utilization are very localized and specific for the places where the natural resources were known to have existed for a long time, like in the Spa of Nis. Only a portion of this energy coming from ground resources is tapped into and is currently used. Therefore, a more thorough case study on the state level is needed to evaluate the potentials of these spaces and their more efficient use of geothermal resources. In conclusion, there are substantial capacities for the utilization of geothermal water in Nis, with diverse capacities of the geothermal resources. This allows for endless possibilities and different implications for each part of the city and beyond.

One other aspect that is underappreciated is its (geothermal) connection to urban planning and especially to the development of neighbourhoods and urbanity where there would be the need for this in the future. Planning of cities with local resources will gain in interest, especially within the process of constant increase of urban territories in the whole country in the future, as part of the global trend of migrations from rural towards urban.

In this way, urbanism can play a role in the development of at least one part of the city in the future of urban planning in Nis.   By given expert opinions elaborated in this chapter,

[290] Jovanović, 2017, Architecture and Urban Planning

quite possibly geothermal utilization can play a role in the development of its surroundings, in the context of regional development and rural-urban cohesion as well. This is, however, an open question, how can this be advocated best?

Finally, more advanced geothermal utilization can affect the health and environmental issues the city and its inhabitants are facing, which arise by using fossil fuels for heating, such as natural gas and mazut. Parallel to this, by making neighbourhoods more pedestrian-accessible, less car dependent and designing buildings and blocks with passive house principles, some of the problems of Nis can be solved, even if just in the 'long-run'.

Urban planning situation in the city can benefit from GE utilization because it will include local resources in the early stages of further urban developments. Geothermal energy utilization and its effects on the city are a matter of long lasting interest. This way it can support future practical needs of the city, its engineers, planners and future dwellers. Beyond this, geothermal utilization can play a role in the development of its surroundings, in the context of local cooperation with other regions in SEE and rural-urban cohesion of the city and its surrounding villages.

It is easy for countries with strong economies to pursue transition to geothermally-based systems. For those which are not, the greatest challenge is to persuade the population to invest a great share of its tax money for geothermal drillings for cities and towns. Turning to historical references and praising the cultural awareness of GE is the greatest asset in the pursuit for greater energy independence of cities in the region of South East Europe, such as Nis. Once made, these pilot studies could be 'recycled' to offer development models for this part of Europe, in terms of renewable energy utilization as a planning tool. The next chapter is centred around one of the best case studies of GDHS in Europe.

7 AUSTRIAN CASE STUDIES

7.1 Geothermal use of district heating in Austria

7.1.1 Introduction

This chapter focuses on district heating supply of towns and cities in Austria, mainly because of extensive experience that Austrian towns have in terms of integration of geothermal fluid into a city´s DHS[291]. A considerable number of towns in Upper Austria, such as Simbach, Braunau am Inn, Ried im Innkreis, as well as Geinberg which is in the same geological basin, use GDHS for heat energy supply.

The region of Upper Austria borders Germany and its rich province of Bavaria on the Northwest, and Czech Republic on the Northeast. The central position in the European Union and cross-border connections with economically strong region of Bavaria have a strong impact on entrepreneurship character of majority of Upper Austria towns. In terms of geothermal use in the region, this fact cannot be neglected. However, there are other factors that contribute to the utilization of geothermal in this region. It is certainly upper Austria´s abundance of geothermal natural sources that has allowed for explorations to begin and the idea of district heating systems for its cities to be born. A historical connection of bath culture to the settlements is also one of the contributing factors. For example, these manifestations were present in the Upper Austrian towns of Altheim and Braunau /Simbach area before their district heating networks were developed.

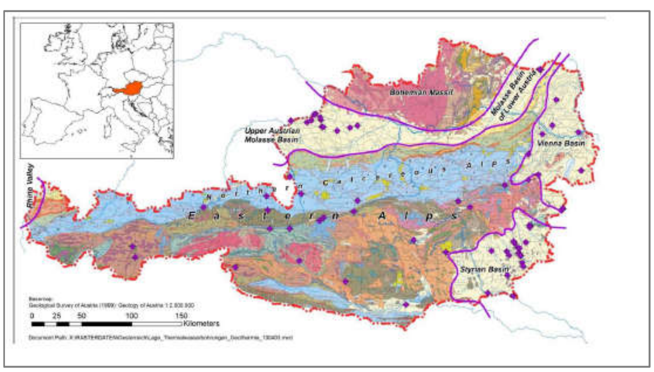

Figure 65, Map of Austria, showing different geological formations and regions, with geothermal applications for geothermal heat utilization (and some electrical use), source: Lectures, Geothermal energy WS 2014/2015, J. Goldbrunner, TU Graz[292]

There are several other zones with potential for geothermal exploitation in Austria. One of them is the Styrian basin, in the vicinity of Graz, with the so called "thermal ring" which allows geothermal use in spas and for other balneology purposes, which has not been proposed for cities with insufficient potential. For example, conditions for the exploitation

[291]DHS stands for District Heating System, GDHS for Geothermal District Heating System
[292]Goldbrunner, 2015

of geothermal waters for district heating in Graz are not favorable as the temperature of the fluid is not high enough to allow for economical exploitation of the source. [140]On the other hand, cities in upper Austria, such as Altheim, Simbach/Braunau and Geinberg, have done the test drillings which have shown potential for supplying the cities with geothermal heat for district purposes. Nowadays, all of these towns seem to be a success story and the reasons for the case studies being successful are going to be examined in this chapter and within the scope of the whole research. This is the best way to use case study method in order to compare it with other cities worldwide that want to invest in their green future with renewable source utilization. Additionally, it is important to connect one or several resources with the built structures in the city in order to supply the city buildings with geothermal. This was the case in upper Austrian towns of Altheim and Braunau am Inn at the beginning of the examination and the expert interviews. Some implications for larger cities within the topic were also examined, as shown in the interviews 'results and discussion chapter. (see chapter: Comparative analysis' results)

Both examined case studies, Altheim or Simbach/Braunau, demonstrated how smaller upper Austrian towns enjoyed the benefits of GE exploitation for district heating, how was this made possible and what may be the implications for urban planning of other cities. The aspects that have not been examined comprise the utilizations of heat pumps and shallow geothermal systems in the region these towns belong to. Austrian experience in GSHP installation is also ample.

7.2 CASE STUDY ALTHEIM

(a) History of Altheim

In the past, Altheim was inhabited by many civilizations, the remnants of which were connected to two Roman houses that are exhibited today in the *Ozhethaus*. [148] The origin of the name Altheim (Old home) seems to date back to the period between 6th and 8th century A.D. when the population, that was previously dislocated during population migration, returned to the old origin or old home (Altheim in German). The market town with this name was first mentioned in 903 A.D. The documented recognition of this status by Duke Wilhelm V. von Bayern took place on July 6th 1581, which was confirmed and documented once more in 1587. [149][293] This happened simultaneously with the official presentation of the coat of arms of the city. In 1849/1850, municipalities Stern and Weirading were added to St. Laurenz and in 1879 the schools of St. Laurenz and Altheim were united. It was in 1939 when the two settlements, Altheim and St. Laurenz, decided to form one mutual bigger community which consisted of 22 communities. In March 2003, Altheim was officially recognized as a town and was referred to as the City of Altheim, although the population was only around 5000. One of the reasons for this was the fact that the city had significant regional economic and cultural potential in those times. [149][294]

Altheim has a population of 4736, total surface area of 22,62 km² and is some 363 m above the Adriatic Sea level. It has three official cadastral areas: Altheim, Stern and Weirading. [149]

7.2.1 Geothermal use in Altheim-origins and current situation

The initial stage of development of geothermal in Altheim commenced in 1989, when the municipality of Altheim decided to use geothermal for heating purposes, mainly to reduce the emissions from fossil fuels. Since then, the town has seen numerous benefits from the decrease of CO_2 emissions and greenhouse gases. CO_2 has been reduced by 72%, NO_2 was reduced by 67%, SO_2 by 65% and CO by 58%. Town is saving around 2500 t of fossil fuels a year. [150][295] Around 650 individual users are connected to the district heating grid, which is around 40% of the town´s population. Flow rate is 46 l/s and temperature of the first drilling site is104°C. The length of the district heating system network is around 14,5 km. [150]. Another reinjection drilling has been made so that the water could be put back into

[293] Stadt Altheim, 2016

[294] Stadt Altheim, 2016

[295] Pernecker, Uhlig, 2002

the *Malmaquifer*[296]at the depth of 2,3 km. Eventually, an ORC process[297] was suggested as to make electricity from the process and the second drilling. This high temperature water is being cooled by the local brook called *Ache* and the outlet temperature is regulated as not to affect the existing environmental harmony. The initial reason for the location drilling in Altheim was the vicinity of local Bad Geinberg, which led to the assumption that there were geothermal resources which could be exploited for district heating. [57][298] The project was imagined as the future Bad Altheim. "We are happy to have had positive knowledge about the situation in Geinberg, as this led to the less risk of drilling for hot water in Altheim. " [56][299]

The whole area had a strong connection with geothermal use for spas in the past. Although there seems not to be a reference to the use of geothermal waters in the ancient civilizations on this territory, there are several balneology sites in Austria (Styria and upper Austria).When asked if these manifestations may influence the development of geothermal projects in their towns in Upper Austria, Deputy Major of the town of Altheim said that this knowledge of having geothermal waters in the area was available, just like the case of Geinberg, which had such resources due to the presence of spas. [57] [56]

Altheim has a combined heat and power plant which supplies the town with geothermal heat (GDHS). Additionally, energy is produced from ORC that the whole geothermal system and parts of the town use through the grid of Energie AG. Before the heat plant establishment, fossil fuels for heating and some wood were used as heating resources. [55][300] [56][301] 63% of the gross energy produces is given to the national grid and the rest is used for the functioning of the system (pumps and other elements). [150][302]The scheme of the complete geothermal concept of use in Altheim can be seen on Figures 68 and 71.

7.2.2 **Acceptance of the community and difficulties**

It was hard to convince the community to switch to geothermal at the initial stages of the project. The geothermal resource was implemented by the community itself and this was unique for all Austrian case studies of geothermal heat utilization. [140][303] The project´s main contractor was the municipality itself. The estimated budget for the first drilling for

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[296] "Malm" Aquifer refers to upper Jurassic origin of the aquifer, see: https://pangea.stanford.edu/ERE/db/GeoConf/papers/SGW/2016/Ueckert.pdf, accessed 28.03.2018

[297] ORC Process stands for Organic Rankin Cycle, where electricity is produced in combination with heat production, which allows for a better utilization and cost-effective use of the geothermal fluid, in case of geothermal production

[298] Austria, Expert in governmental institution, 2015

[299] Austria, Expert in geothermal projects, 2015

[300] Austria, Expert-geologist and geothermal expert, 2015

[301] Austria, Expert in geothermal projects, 2015

[302] Pernecker, Uhlig, 2002

[303] Austria, Expert-geologist and geothermal expert, 2015

geothermal was around USD 1,3 million. It was also supported by the EU programs on Non-nuclear energy initiatives as projects supporting local resources and contributing to the environment in terms of CO_2 emission reduction. [28][304] [56].

In terms of urban planning, the power station and the drilling itself were in the vicinity of the city hall in Altheim which is nowadays the central part of the town. Another aspect is that due to the vicinity of the city hall, fluorocarbon was used as fluid as it secured harmless utilization of geothermal in downtown area. [150][305] The scheme of the functioning of the GDHS can be seen on Figure 71. [151][306]

7.2.3 Urban planning and its connection to geothermal planning in Altheim

While talking about the future plans for Altheim´s expansion, Deputy Mayor mentioned that parts of Altheim would have access to GE. This was however taken as an individual expansion project that had no implications for broader energy planning of the town or the region even, according to the interview. [57][307] In a personal communication[308] with the urban planner of the area, it was confirmed that there was no connection between geothermal planning and urban planning, or to be more precise- urban planners had nothing to say about the use of geothermal for urban planning purposes. The space required for the installation of the heating plant was relatively small- some 70 m^3, whereas each drill hole required around 50 m^2 of space, with power house of 230 m^3 [150][309], which was of vital importance for the object in the town´s urban structure (see Figure 66 for the map and Figure 67 for aerial view of Altheim).

[304] Pernecker, 2010
[305] Pernecker, Uhlig, 2002
[306] MND, 2014
[307] Austria, Expert in governmental institution, 2015
[308] This communication included only e-mail correspondence
[309] Pernecker, Uhlig, 2002

Figure 66, urban layout of Altheim, position of the plan is shown as the green rectangle in the on the left of the photo, red (upper part) is the town´s main square and red (center of the photo) is the swimming pool, heated with geothermal from the plant, source: http://altheim.riskommunal.net/system/web/mapfinder.aspx?cmd=map&detailonr=222860348&menuonr=222860349, assessed 08.03.2017

Figure 67, Arial view of the town of Altheim, source: http://gotravelaz.com/wp-content/uploads/2016/01/Altheim.jpg, accessed 11.03.2016

Table 6, Thermal capacities of the outlet/inlet water in Altheim, source: Pernecker, 2010 [28], used by permission, accessed 06.04.2016

Data sheet ORC / nominal conditions (final design)

Thermal water inlet temperature	**106 °C**
Thermal water outlet temperature	**70 °C**
Thermal water flow rate	**81,7 kg/s**
Thermal capacity	**12.400 kW**
Cooling water flow rate	**340 kg/s**
Cooling water inlet temperature (mean)	**10 °C**
Cooling water out let temperature	**18 °C**
Electric net output	**1.000 kW**

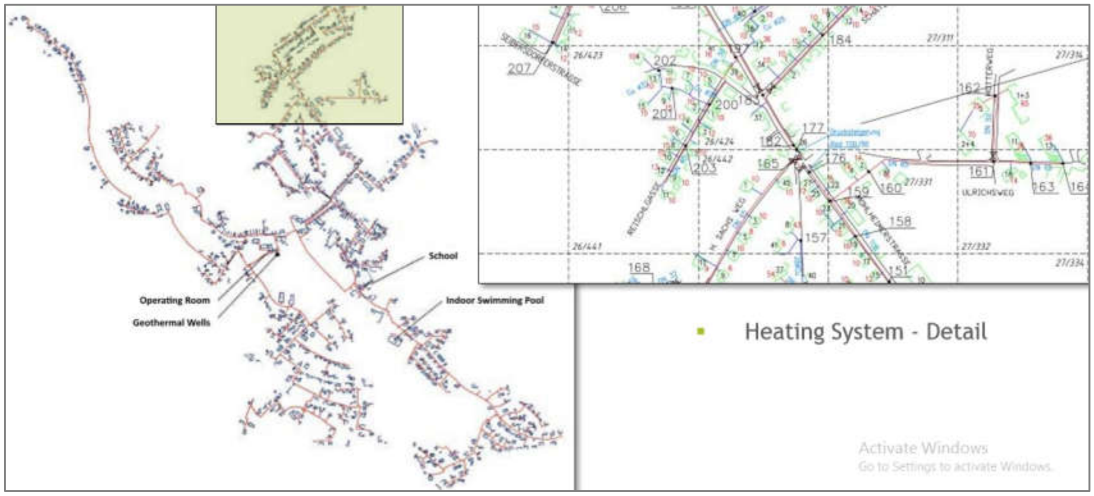

Figure 68, GDHS of Altheim, with a detail (upper right). As GE came only after most of the urban tissue had been created, it corresponded to the existing urban matrix of Altheim. source: http://www.fondazioneinternazionale.org/wp-content/uploads/2014/08/2014_Cociancig_Altheim_MND-Group_Hodonin-CZ.pdf, accessed 11.01.2016

Figure 69, small inlet (Ache brook), where the cooled geothermal used water is pumped back into the water system: it has to follow strict rules of environmental protection and has to be of certain temperature as not to endanger the ecosystem, source: A.Jovanovic, 2015

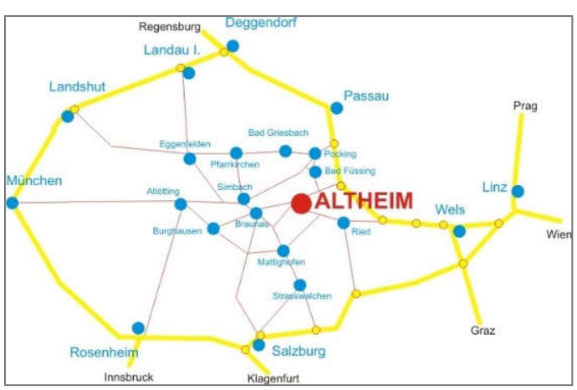

Figure 70, Position of Altheim in regard to main roads and other cities and towns in Upper Austria and Germany, source: http://www.modellbau-berger.at/images/altheimlage.jpg, accessed 11.03.2016

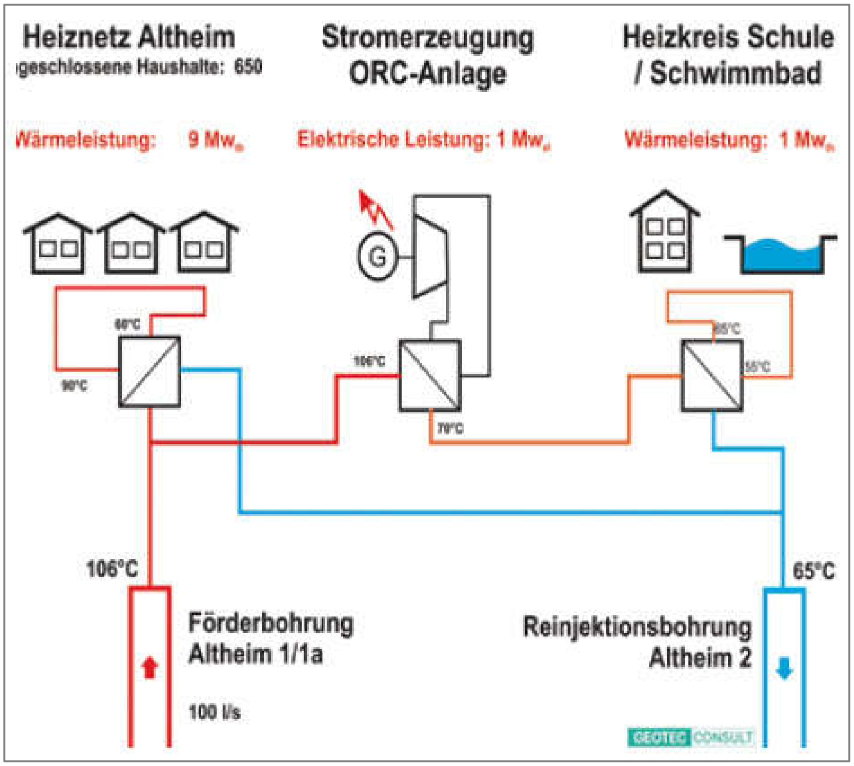

Figure 71, Functioning of GDHS and electric production with the ORC (Organic Rankin Cycle) machine, source: Pernecker, 2010 [28], used by permission, accessed 06.04.2014

7.3 CASE STUDY BRAUNAU/SIMBACH

7.3.1 Geothermal use in Simbach (Germany) and Braunau (Upper Austria)

7.3.1.1 History of Braunau/ Simbach

Simbach, a town in the south of Germany, has a population of 9,658 [152][310] It is located on the railroad connecting Munich, capital of Bavaria on the south of Germany and Vienna, capital of Austria on the East. This railroad was constructed in 1870/71 and since then, it has contributed to the town development. It is also known as one of the first places in the country where electricity network was applied (1894, two years before Nürnberg and three years before Munich). The place was first mentioned in 927 as *Sunninpach* in Salzburg´s documentation books. One of the most important moments in the history of the city was in 1646 when a count ship was established by the *Toerrings*. Then, in 1743 the city was destroyed in the war between Austria and Bavarian forces over the throne, after which the town belonged to the Austrian monarchy. [153] In 1951, it got its city status and in 1971 and 1972 it merged with parts of municipality of Kirchberg, Erstetten and Erlach, which now constitute its urban parts (see Figure 72 for the aerial view of urban core). [153]

Its good position attracts a lot of commerce and tourism from the other side of the river-twin city of Braunau, in Austria. The cities started collaborating on the project of the mutual GE district heating use and since then, there has been initiatives for mutual cooperation in a strategic urban development. The project was rewarded the Climate star award by the climate cluster in 2004. [153][311]The following chapters contain more information about the projects and their progress.

Figure 72, Appearance of Simbach nowadays, source: http://www.itcwebdesigns.com/tour_germany/simbach_am_inn01.jpg, accessed 11.03.2016

[310] Stadt Simbach am Inn, 2016

[311] Stadt Simbach am Inn, 2016, 4

Braunau has a population of 16, 716 as of 2016 [154][312] and, in terms of recent history, it is known as the birthplace of Adolf Hitler. It is a strong center of civic activities around the topic of freedom in the interpretation of contemporary history. [155][313] [156][314] Just like the house where Hitler was born, the city holds a valuable collection of heritage buildings in the city core. Its urban scheme is diverse with middle age buildings, such as the gothic church St. Stefan which serves as a symbol of prosperity and importance of Braunau, [157][315] followed by various baroque architectures in the area which is surrounded by various public institutions, industrial and residential objects.

Figure 73, Braunau, air photo, source: http://difundir.org/wp-content/uploads/2015/11/Braunau.jpg, accessed 27.11.2016

The city itself was built as a Bavarian fortress in the middle ages and has since then played an important role as the biggest city in the so-called *Inn Viertel,* area between Austria and Germany. [157] First documented mentioning of the settlement *Ransdorf (Ranshofen*), referring to today´s Braunau, was in 788, when Braunau went from a Duke´s territory into a palatinate of the king Karl (later to be known as Karl the Great). It was not until 1190 that the city called Braunau (Prounaw) was mentioned with its current name [158][316] and as a city in 1260, when Duke Heinrich 13th was talking about the city fortress that needed to be rebuilt and strengthened and the bridge across the river Inn to be constructed. [157] In 1276, Braunau got the civil right constitution, followed by free customs and salt trade privileges which were given in Braunau to support the fight against the Habsburgs' rising influence of Austria. There was a big fire in the city in 1380/81 which took down the bridge over the Inn river and a public building downtown. Between 1417 and 1492, most of the capital buildings in the city were erected, such as the milestone for St. Stephans cathedral, later with its spire

[312] Statistik Austria, 2016

[313] Stadt Braunau am Inn, 2016

[314] Fiederer, 2016

[315] City of Braunau, 2016

[316] Eitzlmayr, 1997

completion, along with Civil people´s hospital and leprosy chapel. [157] In 1620 the city was made a fortress and in 1672 the fortress was reconstructed under the Bavarian prince Ferdinand Maria who was under the French bastion influence. The decline of the fortress started in 1808 due to the change of the ruling party, i.e. Bavaria, Austria and France. In the upcoming years the city suffered a lot of damages and changes to its appearance. It was in 1816 that it finally belonged to the Austrians. As in the case of Simbach, the significant moment in the life of the city was the building of the railway in the period 1870-1873 and the building of the iron bridge in 1872. The iron bridge replaced the wooden bridge over the river Inn which had been destroyed by an ice jam. [157][317] In 1903, the erecting of the city hall was completed and the emperor Franz Joseph I personally opened the building [155][318]. During the first world war, Braunau served as the barracks for 15 000 wounded soldiers, mostly from the Trentino area. After a long period of economy stagnation and marching in of the Nazi Germany, Braunau received some 80000 displaced persons from the Balkan and east Europe and was liberated by the American troops in 1945. After the war, the economy of the city was recovered. A new car bridge over the Inn, which connected Braunau with Simbach, was built along with the power plant in Ranshofen, now part of Braunau. Many other public facilities were built- schools, public library and various industrial buildings, such as the aluminum factory, academy of trade and industrial district in 1981 in the south of the city. The population of Braunau has remained almost the same ever since. In 1992 the city faced employment crisis of AMAG (Austria Metall AG) which resulted in 2000 lost workplaces due to the migration of the work force towards Eastern European countries. [157] [158]

7.3.1.2 Historic bath in Braunau am Inn and its connection to the urban life in the city

The idea of having public baths came from the *Orient* and played a significant role in daily life of central European cities, including Braunau, in the period 13th to 16th century. The baths were places where people focused on body hygiene and treating less severe illnesses, as well as the centers of public life which implied public events, music, food and drink. [159][319]

There were three baths in Braunau in the middle ages. They were located next to each other, facing the city's creek. Vorderbad (Pre-bath, used by city dwellers), Mittelbad (Mid-bath, for the wealthy people), and Hinterbad (Back-bath, used for the ones stationed in the nearby public hospital). The only remaining building today is the *Vorderbad* and it lies directly on the *Stadtbach* (city´s creek). This warm bath was built in 1560. The same year, middle-age steam bath changed into a hot tub use. Around this year, the first written mentioning of the historic

[317] City of Braunau, 2016

[318] Stadt Braunau am Inn, 2016

[319] Tourismus Braunau, 2016

bath occurred (*Vorderbad*). This bath has been used for centuries ever since and served the public bath purposes, whereas the poorest people were allowed to use in for free, two times a year. The first owners were the members of *St. Catherine Brotherhood* (beer producers, corn dealers and other merchants from Braunau). In the following centuries, the bath was closed and re-opened several times due to plague, wars, etc. Additionally, the bath was renovated on several occasions with the addition of new built structures, floors etc. It also changed the owners, from surgeons and washers to private ownerships. The city of Braunau bought the building in 1992 and turned it into a museum in 2004, after extensive historical restorations by distinguished professors and their teams. [159][320]

From the 16th century onwards, a large coper boiler was used for water heating from the rear sides. In the antique times, non-medical cupping and bleeding practices were conducted in the baths. The traces of these, as well as many other artefacts, were found during archeological surveys in the 20th century, prior to restauration and turning the bath into a museum building (see Figure 74).

Figure 74, Vorderbad (part of the upgraded medieval bath) in Braunau, source: https://ask-enrico.com/images/oesterreich/braunau/braunau600x400/Malerwinkel-Vorderbad.jpg, accessed 28.03.2018

As wood was used for heating the baths, large quantity of wood had to be provided for this purpose. The bathhouse was located on the outskirts of the town, very close to wood supplies. In case of fire, the bath would be less threat to the adjacent buildings. There were many fireplaces, wooden structures, straw and wooden shingles and other inflammable materials and thus the location of the bath was of great importance.Drinking water was acquired from the wells in the city´s territory until the 16th century, when the piping system was established, using water from the city´s creek in two main pipelines. Due to the hydro power, the vicinity of the creek was inhabited by many businesses. The richest population lived in the vicinity, on the main square that exists today as an urban whole. The medieval

[320] Tourismus Braunau, 2016

town used the sower system only for dissolvable matters that ended in the creek and the solid waste was taken by containers outside the city. It was due to the public bath that some professions were present in the city. Many of the businesses´ names can be seen in the names of the streets where they operated their shops. This gave the city and its urbanity a distinctive character. [159][321]There is no evidence of the use of geothermal sources in the bathhouse or the city in these days. The natural thermal resources were probably unknown at the time in the city itself, although there were warm springs in Upper Austria and Bavaria that were known to have had warm water and that were used by the population for healing purposes. [159][322]

7.3.2 Geothermal use in Braunau/ Simbach

This project has been the first cross-border cooperation district heating plant. It supplies both towns with clean energy for heating and is made at the depth of 2 km. [160][323] The geothermal project in the Inn Valley (comprising both Simbach and Braunau) was initiated after having considered the climate protection, nature protection initiatives by both towns, that have also considered financial benefits this form of energy could bring. It is currently the largest project of geothermal district heating in central Europe and it is one of a kind, since it has opened new pathways to cross-border district heating development with GE.

The project took a long time to be realized. First studies were made in 1974, followed by Resolution for the supply of a hospital in Simbach, feasibility studies in the period 1989-1992, finalized with 1994 Resolution on a geothermal project and finally subventions granted from the EU in 1996. The first drillings took place 1999 and in 2001 there was an extensive drilling operation which allowed for experience in geothermal drilling to be obtained and used in other projects. Although it was planned to obtain connection of users in the amount of 20 MW, during the course of the development of the network, this was doubled and kept growing, with some network densifications and extensions in the years to come. [161] Nowadays, the whole project consists of various user types: public institutions, companies and housing that are connected to GDHS. Its connected load is 40 MW. [160][324] The project was completed in 2005.

Nowadays, Simbach/Braunau geothermal project comprises of 6,5-7 MW of geothermal performance [162][325] and its connected load equals to supplying around 6000 households with heat. Total investment is EUR 22 million and the length of the district heating network is 35 km in both towns. [160] The location of the power plant is in Simbach on the German

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[321] Tourismus Braunau, 2016

[322] Tourismus Braunau, 2016

[323] Energie AG Wärme, 2016

[324] Energie AG Wärme, 2016

[325] Brandstätter Energy and Environmental Technology, 2014

side, where the actual drillings were made. Geothermal heat is being distributed through a system of pipes underneath the river Inn to the neighboring Braunau to supply its customers with the district heating coming from Simbach´s GE source. The total extraction temperature is around 80° C and there are two wells, one for extraction (hot water), the other for reinjection (cold water). [160]

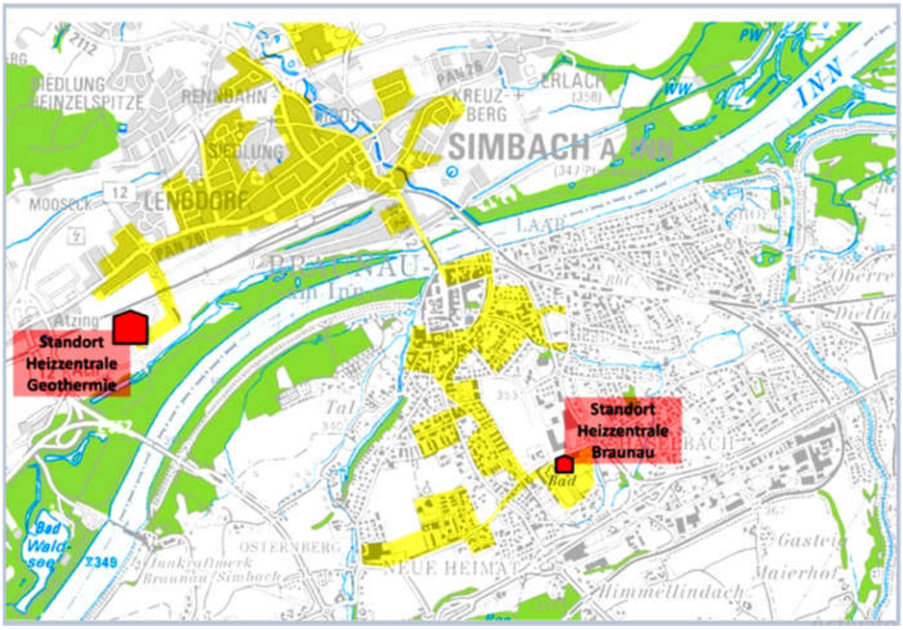

Figure 76, Map showing the areas covered with district geothermal heating (highlighted), upper part is Simbach (DE) and bottom Braunau (AT). The house symbol (left) represents the heating central unit where the extraction takes place, with additional reserve heating central (gas fired) in Braunau , shown in smaller central dot (right), source: http://www.geothermie-braunau-simbach.com/Das-Projekt/Das-Projekt/Das-Projekt-—-Europas-groesztes-laenderuebergreifendes-Geothermieprojekt.html, accessed 08.03.2017

Figure 75, Geothermal heat power plant Simbach-Braunau, located in the peripheral zone of the town of Simbach, source: A. Jovanovic, 15.08.2015

As far as managing of the geothermal resource is considered, there are two companies: GSB (responsible for water extraction) and GBS (water distribution)[326]. These companies are

[326] GSB Geothermics Simbach Braunau, GBS Geothermics Braunau Simbach

owned partially by the towns of Simbach/Braunau and the local energy distributors such as Energie AG(Austria) and E-On (Germany).

The total energy use for heating is divided between the cities (approximately 66% of heat load is used by Simbach and the other 34 % is used in Braunau). In Braunau, there is a mix of residential, commercial, public and industrial buildings. Housing buildings take 75 % of all buildings. It is important to say that housing building have 50 % share in the area of all building. [162]

Most important fact is that the total heat generation on the city of Braunau/Simbach is made with 67-72 % by geothermal resource, and 28-33 % by the natural gas for covering the high *peak demand*[327]. [163][328]

The heating central for GDHS is easily operated by personnel, takes very little space in the city core and looks like in the following figure (simplified version of the scheme of the heating central and its appearance): during the drillings for the boreholes, the intervention on the urban environment is minimal. Visually, the drillings were visible in terms of heights, but required little space surface for the completion. This was also the case in Altheim, as mentioned before. The methodology certainly helped pertaining the continuity of the urban environment functioning and processes, which was an additional argument in the acceptance of geothermal projects in the cities and even as shown in Braunau/Simbach and Altheim, within the walking distance of the historic centers that may be endangered by any kind of aggressive intrusion in their urban matrixes.

The project in Simbach and Braunau was initiated with the interest of the public in the region. There were many media reports of the signing of the first agreements. One of the most interesting aspects is that the project would not have been possible to achieve just for one city, but in the mutual project by both. [164][329]. Also, one of the interesting aspect was that the media was reporting about the benefits of the projects not only for the commercial and public, but also for household end users, which was considered important. The project was backed-up by the district gas company[330], which was of high importance for its realization. As there were other spas that used hot fluid for balneology in the vicinity (Geinberg and near Bavarian spas), it was decided to use water for purposes other than that, as it turned out for heating network. [165][331] Another important aspect was the politicians´ involvement. The media reports showed that the project was initiated by signing of the fourteen different

327 The highest heating demand within a year, usually in winter with very low outdoor temperatures

328 Bucher, 2015

329 OÖ. Landesnachrichten, 1996

330 OÖ Ferngas AG, upper Austrian district gas supplier, that was supporting the utilization of geothermal as part of the DH network. These and other factors contributed to the starting and realization of the project, despite the difficulties

331 Braunauer Rundschau, 1996

parties involved. It was noted that one of the political figures, Bruni Mayer, the county commissioner of the *Innkreis area*[332] said it was an honor to see the project starting during her mandate, and the making of two companies for the heat supply as a confirmation of her work. This suggested the commitment of the politicians involved and their will to overcome the usual short-time thinking the projects were faced with. [166]

In 1998, when the project started to make its way though, three major public facilities agreed to be supplied by geothermal district heating of the Simbach/Braunau Geothermie[333]. This important step was made by the hospitals in Braunau, Kreiskrankenhaus Rottal Inn, Marienhöhe Inntal-klinik. They decided to follow the examples of some public buildings in Simbach which had already been connected to geothermal.

Along with financial benefits of geothermal utilization, one of the hospital managers, Joseph Oswald from the company Kreiskrankenhaus GmbH, emphasized the benefits for the environment and making a healthier surrounding for the inhabitants of the city. [167][334] He also mentioned that the independence from any external resources was a valuable asset. [167] These reports were followed by the EU decision to co-finance the project with 40 million Shillings (EUR 3 million). All of this largely contributed to the urban expansion of the district heating network in Braunau.

There were various obstacles for the use of geothermal in its initial stages in cities. The project in Simbach/Braunau was initiated with a lot of difficulties. One of them was that the potentials of geothermal energy for district heating were overestimated at the pilot study. Then, there was the moment when the drillings at one municipality (Simbach or Braunau) influenced the capacity of the other municipality's supply with geothermal energy. This all had to be surpassed by measures that would allow for projects to be realized and be made financially viable. [58][335] Additionally, at the very beginning of the project, the costs of geothermal district heating were somewhat the same as the costs for heating a household with fossil fuels (gas). However, this was expected to be changed by introducing $C0_2$ taxation by the country, which actually occurred later during the course of the project and made the costs of geothermal installations more viable to apply in Braunau/ Simbach [168][336] As far as initial drilling and financing are concerned, there is a strong economic precondition when drilling for geothermal, since if the test project fails to give the expected results, this means a lot of money needs to be spent for nothing. [140]Apart from the funds by the states from the Austrian and German side, during the course of the project´s development the German

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[332] Innkreis area is an area covering the so-called circle around the river Inn in upper Austria and its towns

[333] Simbach Braunau Geothermie (Simbach Braunau Geothermal) is referred to in the text as the whole project between two cities that involved the founding of both companies involved, SBG and BSG, as explained earlier

[334] Wochenblatt, 1998

[335] Austria, Expert- engineer working un industry, 2015

[336] Wirtschaftsblatt, 1999

province of Bavaria gave a guarantee that it would cover the costs of drilling if something went wrong with the pilot project. [140]This, along with the accession of Austria to the EU and possibility to use these funds, was one of the predominant reasons for the project to be a success. This allowed for a more secure position even as the problems arose with the capacities, as mentioned in the interview with one of the experts. [58][337]

An interesting aspect is the use of inflected drill hole underneath the river. There are two different boreholes, the first is for extraction on the German side that sways underneath the Inn river and ends in an open hole at the depth of 1941,8 m. The second one is located only on the German side and is used for re-injection of the water to the aquifer at the depth of 1650m. [163][338] Additional positive aspect of the project was that the professional development team was international. [160][339]

7.3.3 **Planning and architecture in Braunau/ Simbach**

As for the built environment, there are more than a few important heritage buildings, built throughout centuries in Braunau and Simbach. For example, Simbach is home to quite a few Jugendstil residential and public buildings built in the first half of the 20th century, one of which is the old City hall (Rathaus), built in 1910. There are also several important churches in both towns, e.g. church in Simbach Christi Himmelfahrt is the best example of late Gothic sacral architecture in the region. [169][340].

Figure 77, a and b, today´s appearance of Braunau´s city core: historic buildings are part of the downtown´s urban structure and most of them are attached to the GDHS, source: A. Jovanovic, August 2015

[337] Austria, Expert- engineer working un industry, 2015

[338] Bucher, 2015

[339] Energie AG Wärme, 2016

[340] City of Simbach, 2017

There is a significant number of public buildings in the area, dating from the past centuries, such as hospitals, museums, etc. The towns have developed their unique urban morphologies for centuries. The bridge in the center of the town which connected two different entities was a cross-over for many years and symbol of connection within the area, i.e. commercial, trade, cultural and historical. A sculpture of the artist Domenik Deng[341] stands at the former borderline between Germany and Austria, i.e. between Simbach and Braunau.The GDHS helps the urban area of both cities and strengthens their urbanity which needs to be preserved (see Figure 79 for GDHS plan and Figures 77a, 77b and 78 for the urban setting of Braunau).

Figure 78, Aenus sculpture in Simbach, source: https://foursquare.com/v/aenus-auf-dem-huchen/517aaec5e4b027b15ae7e0aa?openPhotoId=517ab0ebe4b0c34969c02df7, accessed 21.11.2017

Building cultural heritage landscapes from both ends of the river can help the region develop more strategically and compete with the surrounding neighborhoods and counties of Upper Austria and southern Bavaria which share a strong touristic and heritage value. RES surrounding these heritages can be used for sustainable development and preserving urban structures for the generations to come. This is especially important for the towns that are dying-out or towns where population growth is unlikely to happen in the next period, as most of the European small and middle-sized cities will be facing this problem in the future.

341 The sculpture named *Aenus auf dem Huchen* was placed in 2004 on the place where once there was the border crossing, symbolizing new era in relations between once divided countries

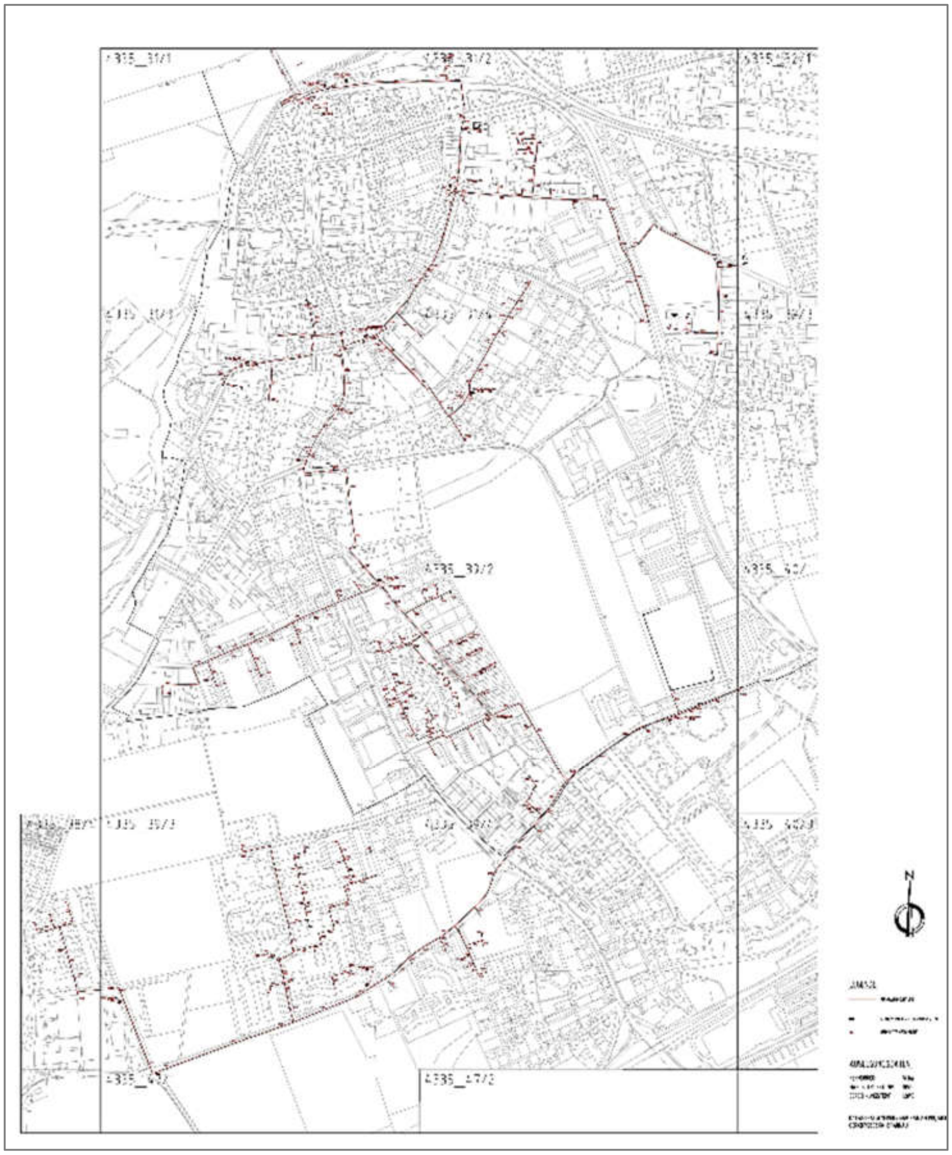

Figure 79, Part of the GDHS network in Braunau, also here as in Altheim, GE was integrated into the existing urban core, source: personal communication O.Bucher, project: Energie AG, GBS (Geothermie Braunau Simbach, Kremsmüller), accessed 20.12.2016

This is also the case of Altheim, where the core of the small town has a rich heritage and where geothermal option within the city is an advantage as compared to other towns that do not have this. The expert from the city hall in Altheim confirmed the advantage of GE utilization in Altheim being mostly of economical aspect and competitiveness of the town, however could not determine the scope of this advantage: "There is not an instrument to specify to what extent this influence can be quantified financially or in terms of development. We have not conducted a survey on this topic yet. [57][342]"

7.3.4 Conclusions on Braunau/ Simbach geothermal project

There were many benefits from geothermal project Simbach/ Braunau.

The first benefit was reflected in the fact that the rise in the number of building developments occurred after geothermal energy project had been realized. This led to **pertinence** of the existing jobs and secured new jobs. Secondly, new companies settled within the area. Thirdly, the city was less reliant on the use of external fossil fuel resources, such as gas. The local sources were put into play and this was the benefit on its own. Economically, the energy tax money that would otherwise have been payed externally, now remained in the city, which helped the budget both of the city and the region of upper Austria. Finally, the importance of the source was in the rise in the attractiveness of Simbach/ Braunau region for further investments and last, but not least, tourism and branding of the cities. The city saved yearly 16,000 tons of $C0_2$ by switching to geothermal in the two cities. This led to the considerable environmental benefits. [163][343]

The upgrade of geothermal system implied installation of a new extraction pump in 2014, that led to the extraction volume capacity to be enhanced to 90l/s. The investment was around EUR 0,5 million. The reason of the upgrade was that the old pump had been in service for almost 14 years constantly and it needed a replacement, which was also more efficient in the use of geothermal fluid. [163][344]

Due to the heavy rain fall and flooding that affected the area and prevented access to heating to several major parts of the city, the city management decided to make a reserve boiler at the end of the geothermal district heating network in Braunau. It was also supposed to cover the top heating demand in the coldest days, as extra amount of heat for the system could not be provided by using geothermal station in Simbach only. In this way, the city of Braunau could count on its own heat supply, regardless of geothermal district heating operation. This was especially significant in cases of flood which affected the transfer pipelines lines which were used for delivering heat to Braunau from Simbach. This secured the supply of the homes. Furthermore, this aspect seemed to be very important and was done after the natural disasters in Upper Austria endangered the supply chain and infrastructure and caused

[342] Austria, Expert in governmental institution, 2015

[343] Bucher, 2015

[344] Bucher, 2015

building damages in Simbach and Braunau. The emergency and peak demand station was done in 2015 at a cost of EUR 1,5 million. [170][345]

The cost of heating a one-family-house in Braunau is largely less than gas and wood pellet heating. The fact that the house has been renovated is an important factor for calculating the cost of heating supply. For example, State energy agency of Austria calculated the benefits of GDH346 use for 148 sq. meter house. [171] These findings confirmed, that for the poorly insulated houses, well insulated (renovated) and new houses, GDH proved to be the most effective form of heating with less costs. The other forms of heating, except from some forms of heat pumps and combined natural gas systems, proved to be much costlier solutions in the city, costing on average EUR 1600 to 1900 more per house on the annual level. In the meantime, the annual costs for GDH per household were between EUR 2600-4300. [172][347]

According to the city energy report [162][348], Braunau had a good distribution possibility in terms of energy due to densely-populated city core. Also, Braunau had access to the high voltage network and was in the vicinity of a local hydro power plant which was established in 1953. The attachment to gas network is 40 % on the territory, whereas some areas do not have the access to the network (around 4 % of the whole area). As for geothermal, some parts of the city are connected to district heating (central Braunau and Braunau Neustadt), while a substantial part of the territory has not been covered yet. It is important to say that some of the public buildings in Braunau (hospital and schools for example) have their gas boilers that are used to cover the need for additional heat, when the 80°C geothermal fluid is not enough for heating purposes. It is 1/3 of the whole heating energy that is supplied by natural gas boilers, a central one and some localized at certain buildings. [162][349]

Despite geothermal energy use for district heating in Braunau, a significant percentage of energy use is divided among other sources, such as natural gas, 63,2%, followed by electricity 31,3%, geothermal 2 %, and biogenic energy, liquid fuels and solar thermal 3,5%. Approximately 87% is used in commercial building, agriculture and industry, 10 % in residential and 3% in public buildings. The other interesting data for Braunau is that ¾ of the whole household annual energy is consumed for space heating (73%) and warm water supply 20%, and 9% for lighting and air-conditioning. Due to the temperature increase, it is necessary to cool the premises for 150 days a year and consequently, the figures are growing by 20 % per decade. This is probably going to influence the total energy use in Braunau in the years to come, as more energy would have to be used for cooling in hotter periods of the year. [162] It is substantial that the technology for supplying these needs is covered by

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[345] Geothermie Braunau Simbach, 2017

[346] GDH refers to Geothermal District Heating and GDHS to the Geothermal District Heating System, both meaning the same, depending on the context the phrases are used, for example system in terms of city´s GDH system

[347] Geothermie Braunau Simbach, 2016

[348] Brandstätter Energy and Environmental Technology, 2014

[349] Brandstätter Energy and Environmental Technology, 2014

renewable sources. This is where GE can be utilized with new perspectives for Braunau/Simbach.

7.4 Other positive examples of geothermal energy utilization in Austria- Styrian case study

A very positive example of geothermal energy use is in Bad Blumau, Styria, where geothermal energy is used in a combined process of power generation, heat supply for the hotel resorts accommodation and swimming pools. This is an exceptional example of the so-called ORC process. It has been considered a very successful illustration of the application of geothermal in the regional development since the whole region has benefited from its initial installation. The utilization of this form of energy resulted in more than 340 jobs in the hotel business and 170 in regional service sector. Moreover, the overnight stays in the region increased from around 2000 in 1995 to around 37, 000 guests in 2003, not taking into account the hotel itself. [141][350] Since this was not connected to a specific urban setting, its main principles would be taken into consideration. Moreover, further use of geothermal for combined use which implies a lot of savings from the energy efficiency approach can be expected.

There was a substantial help from the state in the investment for the drilling of the first boreholes, infrastructure change and upgrade, drinking water supply improvements, old villages´ revitalizations etc. Being a private project, the total investment of around US$, 60 million, out of which around US$, 20 million were subsidizes by the state and used for these purposed. [141]

Application of geothermal was visible in other locations in the region of Styria, Austria, such as Bad Waltersdorf, Bad Radkersburg and Loipersdorf. Bad Blumau and Bad Waltersdorf use geothermal for district heating (length 1,5 km each), installed capacity 7,3 and 2,3MW, respectively. Apart from balneology uses in all four places, Blumau has $C0_2$ production and energy power production, whereas Waltersdorf case study emphasizes additional greenhouse (vegetable production??). Flow rates in Blumau are 30l/s and 17l/s in Waltersdorf, in Bad Radkersburg and Loipersdorf are 0,8 and 0,6, respectively. [173][351]

The development of spas has had a positive influence on the region of south East Austria since 1977. Eight additional spas were built until 2004. in the so-called Styrian basin. Annually, around 3.5 million guests visit these locations in Austria [139] In terms of utilization efficiency, most successful of all of the spas is Bad Blumau which has combined several different uses in the projects. [141]

[350] Goldbrunner, 2005

[351] Goldbrunner, 2015

What one can see and learn from these examples in Styria, is that they supplied smaller places, such as spas, with district heating from geothermal. It was successful for the small-scale concepts and therefore these applications might seem possible for application on the neighborhood level in the cities and their structures. The question is: what challenges have to be faced in terms of the already existing infrastructure underneath the surface and above (meaning buildings) and what this has to do with geothermal utilization and concepts there?

7.4.1 On some unsuccessful geothermal projects in Austria- Case study of Aspern city in Vienna

Recently developed district Aspern Seestadt in the area of Vienna[352] metropolitan region is located on the corridor to Eastern border to Slovakia and its capital Bratislava, an hour drive away from the Austrian capital. This brownfield site was declared a construction site for a new part of the city of Vienna that should follow the policy of strengthening the regional development of the mentioned corridor and supporting the idea of cross-border cooperation and further economic development of the region. This was to be followed by persuasive urban planning in the area and use of its location and local resources to achieve a true success of the project.

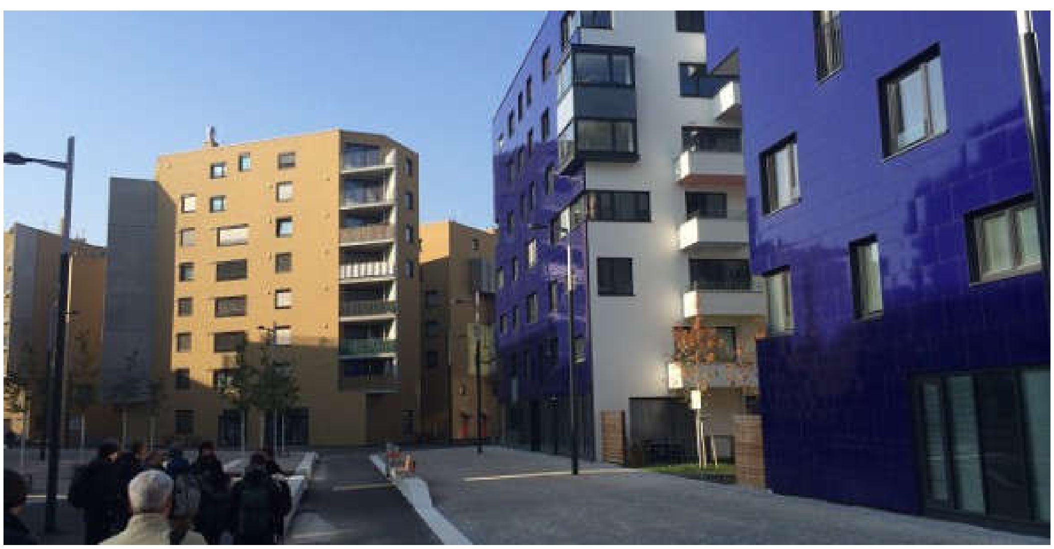

Figure 80, view of the buildings in recently built Aspern city, it will be heated with other resources, as no deep geothermal project was financially plausible and the drilling gave less than expected capacities, source: http://www.smartecocity.com/wp-content/upl, accessed 21.11.2017

[352] More information available on the website: http://www.aspern-seestadt.at/, accessed 28.12.2016

It all started as early as the first findings of hydrothermal resources in the area. Following some hydrocarbon extraction on the area of the airport Aspern in Vienna suburbs, findings made by the company OMV AG showed the presence of a geothermal reservoir at the depth of 3000m. This was the reason why test pilot project was initiated in 2005 to see whether these potentials were correctly estimated. If shown positive, they could be used for the supply of a yet to be developed part of the city of Vienna, called Seestadt Aspern. The study was intended to support the idea of renewable energy use in the new development of the neighborhood that should consist of mixed use high density areas, residential, industry, business and educational. The total used land area is 240 ha with the new population of around 20,000 people who would settle in the years to come and some 23,000 jobs that would be created once the project is finished. Although geothermal energy would not be able to cover all of the heating loads for the buildings and warm water, a substantial part of it would be used. The predicted temperature of the targeted aquifer should be between 110 and 150°C. Some previous studies have suggested that in the Eastern and Southeastern direction from the city, formations at 8000 m or even at 4000m can deliver temperatures ranging over 150°C and some suitable for electricity production. [174] [175][353]. This amount of hot water suitable for heating was not discovered within the drillings that followed up with the feasibility studies made in 2006 by the Economy development fund of Austria [176].[354] The newly developed city part had to be supplied with other forms of energy for its district heating, rather than geothermal coming from the deep reservoirs, since there was not enough economic potential to use what had been found rationally. [140][355] The project of Aspern was still developed to great extent, despite this catastrophic outcome of the drillings for deep geothermal resources. It is a mixed-use vibrant new neighborhood with a lot of urban spaces and has other qualities that may enhance and support urban life in the area. Although geothermal was not found, some initiatives from the city of Vienna´s Transform + Initiative and Transform FP7 EU -wide project supported the idea of rethinking the Aspern city project in terms of smart city initiatives. Some of the important components are the use of geothermal loops (shallow geothermal), heat-pump systems, synergy with local solar energy use, some biomass for base load instead of gas and other initiatives. Importantly, the report suggests the coordination of energy use, storage, user behavior and legal, legislative and policies for area planning, quantifications as necessary. It supports the idea of stepwise planning, especially in terms of energy supply. [177][356] The Aspern Seestadt concept supports sustainability, even though it cannot supply deep GE for district heating (see Figure 80 for urban setting representation of Aspern City). [178][357]

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[353] Straka, Schneider, 2007; Wessely, 2006

[354] Wiener Wirtschaftsförderungsfonds, 2006

[355] Austria, Expert - geologist and geothermal expert, 2015

[356] Mollay et al., 2016

[357] City of Vienna, 2016

"Proposed use in larger cities like Graz or Vienna has proven to be currently not possible either due to lacking geothermal potentials and/or due to failure to justify, for economic and technical reasons, projects on such a large scale. While larger scale projects are costlier and technically complex, bigger cities with higher and more densely settled populated areas, stand to benefit the most from the use of central heating and cooling. Such cities have high heating and cooling loads, for example, and could be covered by geothermal with high efficiency. …This is the aspect that would need to be further investigated in the planning of the cities. In smaller communities in Upper Austria, where the connection to the geothermal grid is possible and more economically viable, more people are willing to connect and when the community itself is willing to think consciously about its environment and long-term future plans. The same applies to large cities, like Vienna, where there is an additional advantage of being part of the larger scale structure. In this sense, different neighborhoods could benefit from each other's energy use patterns, by filling the holes in the energy supply and demand, where this is needed and giving away energy produced to the other neighborhoods within the city that need it. This means a lot of coordination and thinking in terms of the smart city projects, as shown in case studies about energy use in Vienna´s new development district [177][358]. [40][359] "

7.5 Additional material needed for understanding: introduction to energy planning in urban planning in larger cities

Another key example of good practice can be found in the Styrian Capital-Graz. Even though lacking geothermal, a "smart city" concept has been proposed for Graz offering a similar level of understanding of sustainable energy use as is the case in Vienna and the Upper Austrian towns of Altheim and Braunau/ Simbach. Graz's smart city concept employs smart grids and solar energy for producing electricity, for water heating and ground water use for covering basic loads for heat pumps within neighborhoods. Two projects are exceptionally notable: Smart City Graz and Reininghaus. The redevelopment of a formerly industrial brownfield site and its buildings into a mixed-use neighborhood with diverse energy supply sources and a network to integrate and support them, offers an example of employing new holistic urban planning strategies in Graz. Being the first initiative of its kind, this project demonstrates the potential for undertaking greater sustainable planning in the city. It also demonstrates that such innovative planning is possible in a city core that is largely comprised

358 Mollay et al., 2016

359 Jovanović, 2017

of older structures, is protected by UNESCO (as of 1999[360]) and is being stewarded by city planners who are adopting policies and approaches supportive of a city vision that will make Graz friendlier to its population.

Another distinguishing aspect of Graz is that it is home to a diverse population. It is a University city that welcomes many international students and where an estimated 40 000[361]students attending its universities reside. The total number of internationals constitutes around 10 %)[362] of the population. Graz's unique geographic position makes it a vibrant cultural crossroads and connection to South East Europe. With such a diverse and youthful population, there is conceivably the potential for greater acceptance of change and not only new populations, but also new environmental knowledge and ideas to direct, impact and benefit the city's future. Such internationalization goes hand-in-hand with the concepts of sustainable development initiatives and refurbishments, as seen later in the chapters on the American postindustrial cities. Making the city more accessible to different population categories, offering more advanced and diverse options for dwelling and for access and transportation in the city, increasing social equity and inclusion and finally, providing access to inexpensive and affordable local resources and energy, that is produced locally, contributes to these processes, as it could be identified from the case studies described in this PhD. There are quite a few things that need to be done as the next step. The investment in educational matters on green thinking, user interactions, serious studies and bold policy making for the next couple of decades have allowed for this to happen. Smart city initiatives seem to support the idea of local energy use and its even distribution within neighborhoods. This in return influences community-based urban planning, and is connected to balanced urban redevelopment, which any city in Europe transitioning from being industrially based to being a more serviced based economy, is striving for. All of this is for the sake of competitiveness with other cities in the region and country that have similar agendas and offer even more options when it comes to livability, chances of personal growth and security.

Another aspect of Austrian use of RES is connected to its determination to pursue green energy use in its cities. The example of Vienna city government that shows the actual distribution of geothermal resources (shallow ones in this case) within the city limits is just one of the current initiatives that supports this idea. [179][363] by using interactive map, the user of the parcel can be informed about the depth he would have to go and get the certain temperatures of the ground. This GIS-map offers the insight into the possible uses of ground water for geothermal purposes. The areas in Vienna are therefore divided into 4 classes

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360 For the process of UNESCO´s inscription of Graz´s historic center, see: http://whc.unesco.org/en/list/931, accessed 12.04.2018

361 University of Graz formed in 1585, has around 32,500 students, additional students are at TU Graz and KUG etc., http://www.uni-graz.at/de/die-universitaet/die-universitaet-graz/die-universitaet-im-portraet/

362 More on international aspects of higher education in Graz can be found at: http://www.uni-graz.at/de/die-universitaet/interdisziplinaeres/internationale-beziehungen/

363 Stadt Wien, 2016

(range from 1KW to 20KW of rated power output).[364]This information is integrated into the city´s public information system along with other information on different aspects of renewable energy use, recycling locations, green zones, protected areas etc. Available interactive map explaining the system can be found at: https://www.wien.gv.at/umweltgut/public[365].

7.5.1 Austrian contribution to the thinking of the environment and development of green movement

Without a doubt, Austria has significantly contributed to worldwide green thinking. The Austrian government extensively supports projects of passive design. Houses incorporating passive solar methods are frequently made in Austria and serve as pilot projects. Austria is well known for the project which involves a house that is built halfway into the ground, which enables the use of ground´s constant temperatures throughout the year. This house is designed to require minimum energy from external resources. In the Austrian province of Vorarlberg, there are incentives for buildings, based on passive standards, that can be applied for [180][366]. Special initiatives undertaken by the Ministry of Transport, Innovation and Technology (BMVIT) include competitions for the design of "houses of tomorrow" and the offering of funding for pursuing alternative design options for projects. [181][367]

Another good example of Austria's contributions regarding rethinking its energy consumption is its protocol of "reuse" of building materials, which is designed to encourage modular designs making strategic use of old materials and incorporating new materials that are environmentally least harmful. Transport, storage, material availability and low construction costs are all considered to be primary factors when developing new building designs, new building materials and new building components. In terms of new construction, emphasis is on the reuse of older extant building materials. Instead of discarding old building parts and treating them as garbage in landfills, Austria has created country-wide regulations that encourage these materials to be sourced and reused so they can have a second life in new construction [182][368]. Good examples of Austria's forward-thinking energy efforts are found in their entries to the Solar Decathlon, an annual worldwide competition where teams compete in designing and building an exemplar house with a zero-energy supply and demand

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[364] Thermal energy available from ground water with the rated power output, in the area of Vienna ranging from 1 kW-20 kW of available thermal power, divided into 4 categories of land´s capacities for geothermal applications

[365] Accessed 11.04.2018

[366] Pedersen et al., 2015

[367] Ministry of Transport, Innovation and Technology, 2017

[368] Austrian Energy Agency, 2016

system. Austria has made substantial contributions to the Solar Decathlon and was awarded top prizes for innovative house designs which satisfy the competition's criteria. Austrian entry at the Solar Decathlon has also emphasized the re-use of EU wooden pallets which have been characteristically used in shipping, crating and transport. These materials, which have often been discarded, are now considered to be reusable, easy to transport and readily available almost everywhere. By being reused as a building material, pallets contribute to carbon footprint reduction and their low cost makes them economically affordable and applicable in many places worldwide where there is often a scarcity of available materials with which to build. They have an important role to play in promoting ecological building construction and sustainable development [183][369]

Austria is also a country that maintains a connection to locally produced and made products. This seems to be supported by local governments and despite inner country migrations towards cities, this local initiative and protection of urban and rural landscapes is significantly present in the laws on planning, land use, resources and economic development. [184][370]

7.5.2 Urban morphology of the Austrian cities, social and other backgrounds of urban planning in Austria

Major cities in Austria, including Graz, Linz, Salzburg and Vienna, have interesting concepts revealed in their urban planning morphology. The urban form of Austria's cities has resulted from their historic development and the influences of the Austrian-Hungarian monarchy. Additionally, the particularities of locations, positions and other accumulated influences, across centuries, have played a role in their evolution. The concept of the continuous and uninterrupted row of facades lining the street is a notable characteristic of Austrian urban morphology. As there is no gap or space that is allowed to interrupt the façade flow, the street becomes walled and enclosed and behind the street wall, another space of private yards, accessed by moving through the house to its rear, is to be found. These rear and enclosed yards, with their own walls dividing them from their neighbors, are considered very private and important private social spaces. They are evidence of how Austria's culture of social hierarchy is visibly registered and maintained by spatial configuration and zoning of its urban fabric. An opinion shared by many contemporary sociologists involved in urban studies, is that social structure connects to the way urban space is conceived and configured. For example, in Austria, especially in larger cities such as Graz and Vienna, public life for urban populations has historically happened largely in the streets and parks. In contrast, private life has happened in the private yards found at the back of the houses. Such yards were accessed

[369] SchnetzerPils ZT, 2016

[370] Tischler, 2015

by guests only when the family living there invited and allowed others in. This formation of social ties and bonding that is still present in today´s Austrian culture most likely has its roots in the Austro-Hungarian Imperial era and *Gründerzeit* period (19th century). It is during these time periods that most of the urban form and construction of these cities developed and it was also when the largest percentage of the buildings in Graz were built as part of the prosperity period[371]. Urban development and building emphasized and followed principles which over time became well accepted and established reflections and frameworks of Austrian society that can still be perceived today. However, Austrian urbanity has undergone change and evolution as evidenced in the newer parts of these cities where the international style was adopted and where growth and expansion, beyond the historic core, was undertaken and was influenced by such global factors as industry, retail and transport. This is why the urbanization process has never stopped and has continued to take on new forms. Public space has remained one of the most important elements of Austrian cities. The parks, mostly built throughout the 19th and 20th century, served for the purpose of strong public life and continued to play a central role in urban life and culture. Today, more than ever, there is the need to make public parks and spaces more welcoming and accepting to growing and diversifying populations, as well as to expand and increase access to park space in dense urban areas where open space is often lacking. There are many strong initiatives underway in urban planning, through legislation or planning codes and through architectural competition culture. Such initiatives are encouraging and supporting green infrastructure development and integration and whenever possible, the use of renewable energy sources. If these are available at the locale, this element is considered especially welcome.[372]

7.6 Instead of conclusion: future of energy planning in Austria with regards to urban planning and more geothermal utilizations

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[371] Prosperity Period, or the *Gründerzeit* refers to the period of the 19th century until the economic crisis of 1873. In this period of time, Austrian-Hungarian empire was an established monarchy for centuries and where cultural, intellectual and economic capital allowed for prosperity, seen among many other aspects involved, also in the built structures, luxurious facades and urban modernizations from the previous centuries and the middle ages. One good example is Vienna´s center Ringstrasse and Graz´s city center and suburban luxurious areas with villas and other residential substantially decorated objects still to be seen today

[372] Many architectural competitions in Austria, especially in urban planning and master plan design, follow the green initiatives present at the country level and advocate the use of local resources and integration of green infrastructure, wherever possible, because they want to compensate for the old parts of the city having already been built and where room for additional parks and green areas cannot be found, due to spatial and heritage protection constraints. This all supports the green policies of the region and the city, that support C02 reductions and more livable communities in cities such as Graz, Vienna, Linz, Salzburg and many more

Energy concepts were largely unknown to Austrian cities during most of their planning history prior to the 20th century. There was, for example, a tradition of constructing continuous rows of houses with northern orientations. Today, extant housing of this type lack daylight source and are difficult to renovate and upgrade in order to achieve higher energy efficiency in terms of urban planning. Historic buildings and their urban block assemblages have kept a special status due to their age, endurance over many centuries, and location in the oldest city center or core. They are also often privately owned and used as residences, businesses and commercial properties. This urban typology is reflected in downtown urban core of Graz which remains, like many of its culturally important sister cities in Europe, historically intact and museum-like in character and form. There are several theories from the past, including those of Geddes and Giovannoni[373], that counter and challenge such wholesale historic preservation over time in cities like Graz. In the late 19th and early 20th century Geddes and Giovannoni challenged urban planning's' bias towards abstraction, physical form, design and organization over human needs, context and changing societal conditions that they felt ought to be shaping and influencing the evolution of cities and communities. They advocated for "not treating parts of the cities as museums," and instead recognizing each city as a particular place with advantages, shortcomings, challenges and defects that ought to be continuously critically evaluated, changed and adapted to meet its changing needs, context and ideals. While Geddes and Giovannoni´s prescient theories could be seen as being embodied in today's theories and practices of sustainable urbanism, it is in historic cities like Graz that sustainable development agendas are apt to clash with those of historic preservation and tourism.

Heritage protection concepts and initiatives figure prominently in the planning of contemporary historic districts like those mentioned above. Such approaches are less than likely to be reconsidered as they are strongly supported and reinforced by UNESCO's mandates and recommendations emphasizing the preserving of the urban whole and the allowance of only minor changes to it. In Graz, where the city core was declared a UNESCO heritage site in 1999, no interventions are allowable [185][374].

In 2010, Castle Eggenberg, laying outside the historic city, was added as the newest UNESCO designated heritage site. With that designation came the establishment of a buffer zone, running between downtown Graz and Castle Eggenberg, and occurring along the historic pathway or street known as the Annenstrasse. It is along the Annenstrasse corridor that the city core and castle were connected. The border mandates that this historic pathway remain undisturbed by further commercial developments [186][375]. The impact of this planning strategy will undoubtedly impact the city's future and the look and function of the Annenstrasse corridor over time. While it was once a country road from city to castle, the

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373 Rodwell, 2007

374 UNESCO, 1999

375 UNESCO, 2010

Annenstrasse, evolved and transformed across centuries as the industrial revolution and the city's expansion occurred. Today it is Graz's main commercial and civic conduit. UNESCO heritage designation in the core and along the Annenstrasse corridor stands to impact and, in some respect, deter Graz's adoption of sustainability[376]. That said, Graz has a lot of land adjoining these heritage areas that can be refurbished and reused and where sustainable urban planning concepts have the opportunity to be applied. Graz is well positioned to develop in a manner that ensures community-conscious urbanism and that contributes to environmental sustainability through the use of local resources and green infrastructure [187][377].

In contrast to Graz, the city of Vienna has its own concepts for sustainable redevelopment, which its governmental institutions articulate in their plans. In 2015, Mercer's 18th annual Quality of Living survey declared Vienna to be the city offering the highest quality of life in the world [188].[378] The city's urban development concept, known as Vienna 2025, calls for transportation innovations to increase mobility, housing condition improvements and increased emphasis on green infrastructure. These changes go hand-in-hand with Vienna's expected population increase over the next 25 years. The main framework of Vienna's smart city project was declared in 2014 by the city government and is expected to be implemented in phases. Living quality, resources and innovation are Vienna 2025's main goals and the plan will be regularly monitored and analyzed up to the year of 2050 when it is expected to reach its final year of validity [189][379]. The example of Vienna contributes to this analysis as it shows that large scale capital investments in geothermal energy need not be considered the only route to sustainability. In Vienna's case, local shallow geothermal energy sources are being utilized in combination with such other renewable energy sources as biomass and solar and all these alternative energy sources are contributing to the city's sustainable planning and development. Most importantly, the Vienna case demonstrates the importance of strategic urban planning and energy networks´ creation and shows that cities can have a promising future in terms of urban development. Sustainable treatment of local resources is crucial for local regional development and population distribution as is urban redevelopment that increases urban density and reduces urban sprawl and travel distances. Geothermal thermal networks are particularly important to develop in the near term and to plan for in the long term, as future growth and development takes place in cities [190].[380] Such planning can

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[376] Once declared by UNESCO as built heritage, cities do not enjoy the privileges of interventions within their protected environments, which has its good and bad sides. The innovative uses of renewable energies and explorations of it possible use and eventual benefits for the heritage sites, is not being supported as to allow swift progress or even minor challenges to the heritage. This is exactly in contradiction to the principles of sustainable development and theories supported by Geddes or Giovannoni on urban renewal and reasons for it (Rodwell, 2007) [7]

[377] Rainer et al., 2014

[378] Mercer, 2015

[379] Stadt Wien, 2016

[380] Gavriliuc, 2016

contribute to achieving the long-term goals set by the municipality's plans over the next decades.

All of this information on different initiatives within municipal planning is further supported by the idea of "city regions." In the European context, the cities of the future will develop not alone but in relation to each other. [191].[381]The model for European planning will be the forming of a region of cities.

Furthermore, European planning acts support the idea that goes over the border of each state. [192].[382] One good example of this development is Vienna, that is moving towards the city regions (Stadtregion) concept, by emphasizing expansion and development of its frontiers towards Bratislava (Slovakia), being very near and having its own metropolitan region. [184][383] This was not possible to do in the past, because of each state´s planning strategies. And still in the rest of Europe, this segregation in planning is still present, as almost there would be no EU.

The role that each city and its different sectors will play in city regions, and as related to renewable energy use and sustainable development, remains an open question. In terms of a new element (geothermal projects and energy savings and networks ´creations), city would have to accept the change in their urban planning policies, for the sake of energy, if nothing else.

A country which has been left out of the European planning agreements is Iceland. The country does not belong to the EU space but shares similar heritage and belongs to the Scandinavian cultural space. It is therefore rewarding to see, how a country within the European continent but still spatially excluded from it, conceived its utilization of GE in the past century and how it was able to employ or not employ the postulates of sustainability in its cities.

[381] Priebs, 2014

[382] Institute of International Sociology, 2017

[383] Tischler, 2015

8 CASE STUDY ICELAND (REYKJAVÌK)

8.1 Introduction to Iceland´s history, background and geothermal utilization

When one says Iceland, one usually thinks of is geothermal heat and boiling springs. The country came a long way from a fossil fuel dependent country to the global leader in the use of geothermal energy resources for district heating purposes. In 2014, roughly 85 % of primary energy sources came from local renewable energy sources and 66% came from geothermal. According to National Energy Authority of Iceland, 99 % of all houses in Iceland are heated by means of RES (either electricity coming from hydro or direct or cascade use of geothermal)[384]. However, GDHS was implemented in the entire Reykjavik just after the oil crisis in the 1970s. The savings in the country of Iceland are 3000 USD per capita annum, or 7% of the GDP. [193][385] On the other hand, Iceland is one of the top countries when it comes to energy consumption per capita in the world. [12][386] These figures seem to be overestimated, partly because the aluminum industry utilizes a lot of energy for the production and Iceland has a small population. There are many countries in the world whose industrial production relies on heavy fossil fuels´ use and Iceland seem to be way ahead in terms of renewable energy´s contribution.

The city of Reykjavik (Iceland) is a city with the largest known geothermal district heating in the world, operated by Reykjavik Energy [194].[387] Therefore, it has always been interesting to observe the development of the city where geothermal installation has been operating for a vast number of years. Reykjavik is a mid-sized European city that has evolved from a small harbor district. Its structure implies low urban density and various suburbs that have their own particularities in terms of urban morphology. Geothermal utilization and expansion have occurred simultaneously with the urban development. This chapter will focus on other factors that may have influenced the city's urban morphology, as well as on the influence that geothermal heat has had on the morphologies, especially to see why other factors have had a dominant role in Reykjavík´s development. The case of Reykjavik clearly proves that

[384] Cascade use of geothermal is here referred as to the geothermal heat coming from the use of geothermal fluid or steam for electricity production. Almost half of Reykjavik´s demand for heat was covered in this way. Another half came from direct use of boreholes within Reykjavik, which carry hot geothermal fluid to the heat exchangers in houses and commercial and public facilities in the city

[385] Verkis: Newsletter, 2015

[386] Ragnarsson, 2013

[387] Gunnlaugsson, 2013

access to the abundance of geothermal heat does not mean sustainability. It sometimes may lead to urban sprawl and transport issues[388].

Moreover, the increase in the use of renewable energy sources in Icelandic cities led to less CO_2 emissions that would have otherwise been emitted through fossil fuel use. This meant that the Icelandic cities, such as the capital of Reykjavik, were given a chance to develop to greener cities, or cities that offer healthier environment for the citizens. The citizens were then allowed to focus on other problems of the built environment that otherwise may have been neglected, if primary issues, such as clean air and energy dependence of the city and region, had been the primary development concerns.

Still, there are emissions of gasses, such as H_2S, partly due to extensive geothermal utilization. This represents a drop-back in terms of pollution which affects the population in terms of lung problems. Many environmental organizations are the greatest critiques of the large-scale geothermal projects which may affect the biodiversity of the island (see Figure 81 for presentation of major geothermal reservoirs, power plants and hydro-dams along with areas claimed to have been affected by large scale GE utilization in Iceland.

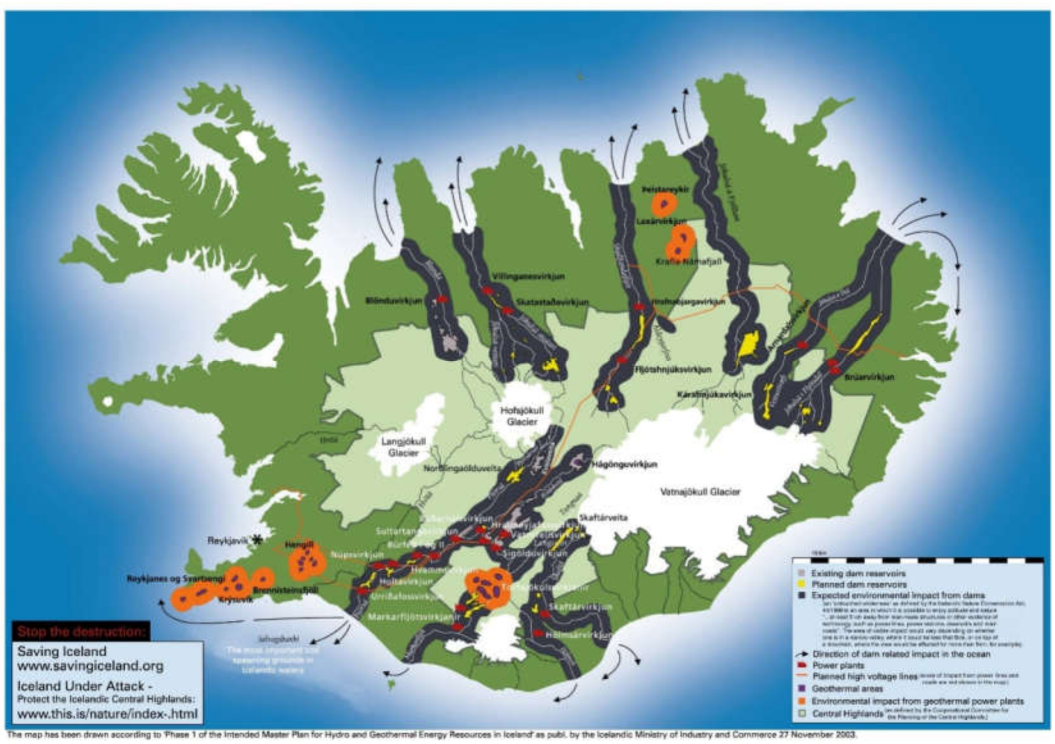

Figure 81, Map of Iceland showing places for dams and GE power plants, with environmentally endangered places in orange, Iceland´s equilibrium of biodiversity and balance is something that must be well calculated with when making geothermal project even at a small scale, such as single towns

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[388] As there is access to cheap energy, people do not care about saving it

or areas, source: https://mmillericeland.files.wordpress.com/2011/07/iceland-dam-and-geothermal-impact-map1.jpg, accessed 20.05.2017

It can be said that Reykjavík has witnessed an urban resilience[389] with RES utilization, especially geothermal heat for space heating from the local area. The term "urban resilience" is known in the urban planning literature and is becoming more important for cities reaching their goals towards climate change mitigation [195][390] There are probably other benefits of the use of geothermal in Reykjavik or in Iceland that could not be that easily qualified and seen in the city structure. Energy independence of the city of Reykjavik is an exceptional model for the use of local resources throughout the world. Would the city develop differently if it wasn't for a specific resource, such as geothermal? This is a complex question which cannot be answered by yes/no. However, the modalities of the city development, especially in terms of global race for energy sources, can be understood by comparing it to other cities and movements in urban planning, as well as some urban planning theories[391] that may have influenced its present-day appearance. It is also good to examine Reykjavík´s urban morphology, as Reykjavik was "growing from a small town, looking like a scattered array of farmer´s houses with gardens for livestock or growing vegetables and basic farmer´s needs, rather than a town, especially in the 19th century [196][392]".

Reykjavík is considered to be the Europe´s greenest city since most of its heat and electricity demand is covered by RES (geothermal and hydro), as is the case with most Icelandic towns, and because the pollution in Reykjavik has been considered low by the successful replacement of fossil fuels that otherwise would have been used for heating with geothermal energy. [74][393]

To fully understand the genesis of geothermal utilization and its connection to current planning issues in Iceland and in Reykjavik, one needs to go back to the history of Reykjavik´s urbanization, especially the 20thcentury urban development, where most of geothermal installations took place. The expansion of the happened in the 20th century, which was the

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389 Urban resilience usually refers to the term resilient city: "A city that is prepared to absorb and recover from any shock or stress while maintaining its essential functions, structures, and identity as well as adapting and thriving in the face of continual change. Building resilience requires identifying and assessing hazard risks, reducing vulnerability and exposure, and lastly, increasing resistance, adaptive capacity, and emergency preparedness. (ICLEI, 2017) [195]"

390 ICLEI, 2017

391 In his book on Planning in Iceland, (Valsson, 2003) [196] advocated the influence of urban planning theories in the first half of the 20th century on the development of Reykjavík, many of those were not implemented or taken seriously enough, such as proposals of Hannesson, which the author thought had to do with the tradition in the history of urban morphology of Iceland, to talk about urban planning in terms of aesthetics of buildings, monument disposition and other factors, not related to environmental issues, hygiene or quality of the space, such as Hannesson´s writings from 1916 had advocated (Hannesson, 1916) [202]

392 Valsson, 2003, 117

393 Orkustofnun, 2015

period of the expansion of geothermal use in Iceland as well. It is interesting to see Reykjavik´s response to geothermal district heating together with other factors that have obviously influenced Reykjavik´s appearance nowadays. Reykjavík, and the entire Iceland, represent an outstanding model for developing geothermal potentials and urbanization which could be used by many cities worldwide.

The re-silencing of the cities includes concerns about renewable energy as well, among the general understanding of it being "capability to prepare for, respond to, and recover from significant multi-hazard threats with minimum damage to public safety and health, the economy, and security" [197].[394] In these terms, Reykjavík seemed to be moving in the right way. However, the history of the city was not always like that due to the occurrence of urban sprawl[395] and natural or man-made disasters which constantly happened in Iceland. This gave way for rethinking the urban re-development of Reykjavik. The following chapter deals with Reykjavik´s urban morphology and where it is at present, i.e. what needs to be taken care of now, so that the city can enjoy even greater level of urban resilience than it has now. This is achieved mostly because of the use of renewable energy within the city. However, the following chapters will show that this is not always the case. Therefore, the purpose of the paper is not to determine the role of geothermal in Reykjavík but rather to see the shades and controversies[396] with urban planning development in the city. This analysis is of crucial importance for other cities and towns that do not share the same social, historic and urban background.

8.2 Urban development of Reykjavík

8.2.1 **Origins: from a typical Icelandic house (burstabær) to wooden and other types of houses**

Typical Icelandic old house is a turf house[397]. It was designed to withstand the conditions of harsh Icelandic climate. The house has good insulation, as at least two sides of the house were surrounded by earth and had an earth-molded roof.

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394 Willbanks, 2007

395 Urban sprawl refers to the phenomenon of uncontrolled spatial spreading of the city´s territory, usually leading to forming of satellite (housing) suburbs to the main city core, which is reserved for administration and cheaper living (not always the case)

396 Controversies in urban planning of Reykjavík are contained in the fact that although having geothermal energy source, there was not and seems still not to exists, an organized approach to try to integrate energy planning into strategic urban planning in the city, which is to be seen later in the analysis and results chapter of this thesis

397 Turf house and its forms are best known as the heritage of the *Norsk Era* in Iceland and could be explored at: http://www.hurstwic.org/history/articles/daily_living/text/Turf_Houses.htm, accessed 24.05.2017

How were geothermal waters used for this specific type of house, if any of them were used, was questionable. Additionally, the use of the waters for heating before geothermal revolution in the 20th century was highly contested. However, geothermal use in small ponds for balneological purposes at a microscale was evident. The rural history of Iceland should be thoroughly explored in order to obtain more details on the development of first settlements, which will be presented in the following chapters. Most likely, the rural level of thinking of the Icelanders did not allow them to consider GE use in a systematic way. This may have been possible in the areas of geothermal manifestations where urbanization was more common at that time and where urban settlements had a long history of existence, based on the technological experiences of the ancient civilizations, like for example that of the Romans in the European continent.[398] If the Icelanders were living in rural environments for most of their history prior to 20th century urbanization , mostly coming from Denmark, [196][399] , then they would probably think less in terms of an organized geothermal use in the past. On the other hand, the constant exploration spirit of the Icelanders and contact with other nations allowed them to hear about geothermal use for heating or power in the first place, like in the U.S. (Boise) or in Lardarello in Italy [198][400]. This occurred at the end of the 19th century.

Figure 83, Woman washing clothes in Laugardalur from 1902-1910, the starting of geothermal utilization in Reykjavik happened at this place, then at the outskirts of Reykjavík, source: http:// lemurinn.is, accessed 28.03.2018

Figure 82, A man coming from a turf house, this is how the old ways in Iceland looked like. Main commerce in those days was with wish, wool from sheep and a few other basic items. Source of the photograph: lemurinn.is, http://lemurinn.is/2012/10/04/otrulegar-ljos, accessed 28.03.2018

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398 Roman civilization built its cities as urban structures, with high sanitary standards and this civilization was aware of the water transfer through aqueducts. Large cities like Rome in the Antiquity were densely populated and required technological solutions to be applied to be able to function as survive as cities

399 Valsson, 2013, 96, 99

400 Iceland, Expert in geothermal history, 2016

Figure 84, Reykjavik´s old Harbor, first half of the 20th century photo, source http://lemurinn.is, accessed 28.03.2018

In terms of architectural development of an Icelandic house, turf house prevailed in the rural environments for centuries, especially because Iceland territory lacked wood and had to import almost all of it. With a lot of wood coming from abroad, the houses in Iceland started to be made of this material. Wool and other local materials were sold in exchange for materials which were not present in Iceland. The centers of commerce were the coastal towns. Nowadays, these towns are a testimony of the times of great merchants and their cultural influence on everyday life advancement in Iceland[401]. When we look at Reykjavík today, we see a lot of houses especially from the 19th century, as a testimony of the period when other materials (imported ones) have become more available in Iceland through trade with other countries overseas. This and the urban trends from abroad influenced the construction of houses and to some extent, the layout of the urban cores like the one in Reykjavik.

8.2.2 **Origins of the city of Reykjavík**

Early explorers, such as the first settler, thought to have been the Ingólfur, mentioned smoke coming out of the Earth, as mentioned in the book ***Íslendingabók***(meaning the History of the Icelanders): "There was a man of the North [Norway], Ingólfur, who is truly said to be the first leave it for Iceland, in the time when Haraldur the Fair-Haired was sixteen winters of age [...], he settled south in Reykjavík." [199][402] Per Ingólfur Arason, it was established in 874 AD and it was set as the first permanent settlement in Iceland, after several unsuccessful efforts by sail men to inhabit Iceland permanently. Its name means *Smoke cove* [200], and is

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[401] One good example of such a town in South of Iceland is *Eyrarbakki in Iceland*, with an old harbor town, merchant´s house and adjoining buildings. The role of merchants that use to sell imported goods such as wood from abroad (Denmark, Norway, Great Britain) in the exchange for local fishery products and wool, is more that evident. They were the centers of culture as well. For more information see: www.husid.com

[402] Þorgilsson, 2016

considered to come from the first settlers´ impression of a place where they have landed in today's Reykjavik area which looked like bay of smoke.

The country of natural beauties and a relatively big island (being second largest island in Europe and third largest in the Atlantic), [201][403], but small in population numbers, Iceland advanced from the fishery dominant country to a country that had its own parliament. The rise of the nation occurred from 980 AD to 1240 AD, when it was claimed as part of Norway kingdom. There are written sources (sagas) from the early history, prior to 1240, that testify of the glorious days of Old Nordic nation of Icelanders. [201] [199]. Centuries after, during the Danish rule, the parliament moved to Reykjavík. Back then, it was a strategic decision which would help Reykjavík strengthen its position as a leading city in Iceland and center of all development in Iceland.

It was in 1786 that the city was thought to have been founded. [200] The first urban compact forms derived from monastery structures which were formed in middle-age European towns, especially after the reformation. According to [196], the reformation in Iceland occurred later, which had its impact on the urban structures. On the other hand, Valsson said that farmers were independent and the households were not grouped in order to protect themselves. This was a very common practice in continental Europe, so the forms were more compact and grouped than in Iceland. Additionally, the settlements did not have chiefs, like it was the case with Europe. [196][404]

Prior to any urbanization in 20th century, Iceland was a land divided into several areas, all of which had regional centers of commerce and trade, which allowed these settlements to gain some form of structure, although this form was mostly like a set of individual farmlands surrounded by adjoining gardens, having no urban scheme. This was noticed in Reykjavik throughout the course of most of the 19th century, unlike the rest of Europe where a lot of 19th century cities had their urban structures clearly manifested. Iceland´s position, distance from the mainland and scarcity of population may have influenced the urbanization being late in Icelandic towns. This was the case with Reykjavík as well. It was not until the 19th century that Reykjavik became the capital and most important city in Iceland. And this was made by a political decision. [196]

The development of other towns in Iceland was very similar, with Reykjavik being at the forefront of it all.

[403] Böhme, 2002

[404] Valsson, 2013, 63-64

8.2.3 Further on urban morphology of Reykjavík

Reykjavik´s morphology has been quite simple until the 20th century growth. The center of the city, the old core, with some of the buildings as old as 200 years, has not significantly altered its appearance or scheme until nowadays (see Figure 85 below for appearance and Figure 97 for the plan in the chapter: Future of geothermal utilization and development).

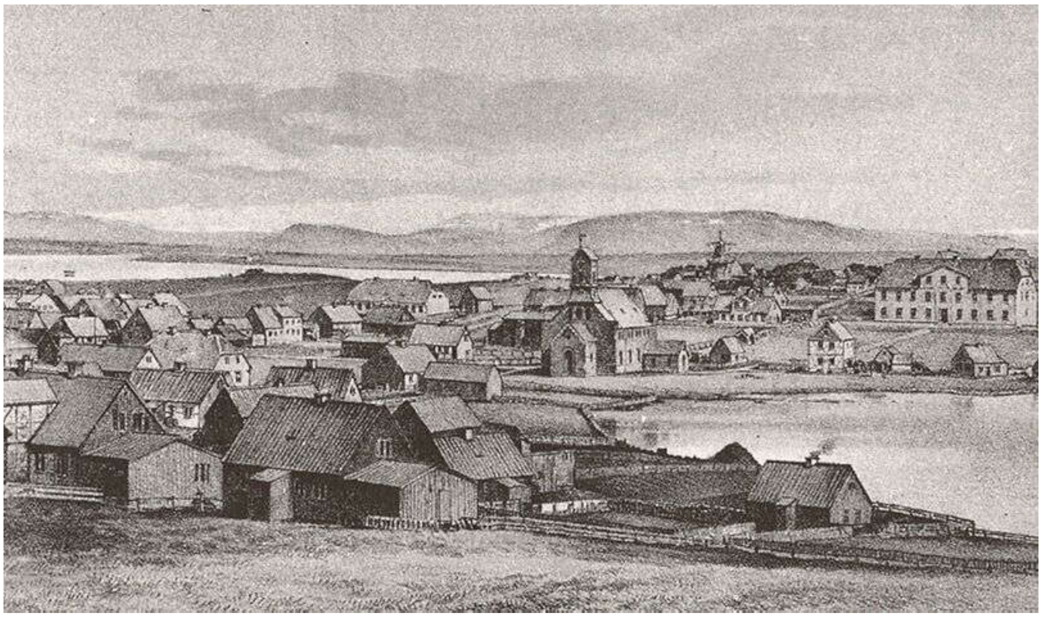

Figure 85, 19th century Reykjavik, now known as downtown Reykjavik, drawing. Source: http://www.northernlite.ca/19thcenturyiceland/gallery/images/gall-icel-19-05.jpg,.accessed 28.03.2018

The greatest importance for understanding the urbanization of Reykjavik and its rise as the capital of Iceland is probably the period of the Danish rule. The Danes, although considered "wretched rulers" by Icelanders who lived at the time, were also the ones who allowed for settlements like Reykjavik (back then being more a hamlet than a city) to develop into urban centers. The Danes believed that a country like Iceland needed restructuring and adjusting, especially because of natural disasters that occurred around the year 1800. This gave way for more advanced ideas on urban planning or organization of urban settlements, which the Icelanders opposed, as they lived a rural and declining way of life. One of the centers of the Danish rule was Reykjavík, whereas suburbs were inhabited by native population [196][405]. Despite this fact, the idea of independence started emerging among Icelanders who wanted to liberate their land from the Danish rule. Back then, Reykjavík was just one of the few towns that was a candidate for the capital city. It was mostly because of its position, at the shore and at the crossroads of different pathways, that gave way for its up rise as an urban whole, as well as political support from one of the most eminent Icelanders of that time- Jón

[405] Valsson, 2003, 112-113

Sigurdsson. Despite the Danish rule there, he pointed out several factors why Reykjavík should be set as the capital of the growing and independence-craving nation such as Iceland was at the time. [196][406]

Reykjavík was also facing a lot of problems with fires, so there was an obligatory document asking for distance between houses to be taken into consideration when making parts of the city and making new houses in downtown. [196][407] After being proclaimed the capital, the city experienced expansion and urbanization in the years to come. During the growing independence movements throughout Europe at that time, Iceland was gaining more strength to pursue its goals for becoming an independent state. This, however, did not fully happen until 1944, when the official independence recognition took place.

8.2.4 New planning ideas for Icelandic cities with G. Hannesson´s writings

With the rise of Icelandic idea of national uprising, especially in the 19th century, Iceland came closer to the ideas of European culture and politics. However, the particularities of the island remained one of the reasons why some of those ideas were not present in the urban morphology of Reykjavík. One of the good examples of this is the book of Guðmundur Hannesson from 1916 [202][408], where he mentioned planning under the "healthy environment" principles and these were back then common for the European thinking on city planning. He was also a student of Danish schools that have advocated these healthy city principles. Some of the most important thoughts from Hannesson´s thinking about cities and planning in Iceland can be described as follows:

In the layout of the city:

> *-Building semi-detached housing rather than detached one, especially because of the energy savings*
>
> *- Ventilation and hygiene principles in the urban planning schemes of streets*
>
> *-taking care of the visual environment of the city, by locating buildings at the street endings that may contribute to the harmony and attractiveness of the streets and street and building landscapes*
>
> *-using models of other successful residential schemes from abroad for the development of housing in Iceland.*

This was the first reference to a thoughtful planning in urbanism in Iceland, which was unfortunately not widely applied in Reykjavík, except for a smaller portion of blocks designed

[406] Valsson, 2003, 112, 115
[407] Valsson, 2003, 115
[408] Hannesson, 1916, 91-92

by the architect Guðjón Samúelsson who followed Hannesson´s urban design principles of ecological architecture and compact urban forms for Reykjavík´s urban development. Workers' stations at Hringbraut in Reykjavík is the name of this project that is very different to the urban blocks surrounding it, built before its coming of age.

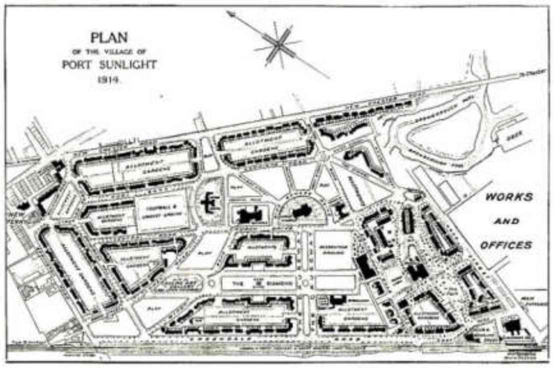

Figure 86, Port Sunlight in the UK (here shown is a map from 1914) was a concept mentioned in Hannesson´s book from 1916, as a good example for the redevelopment of Reykjavík that he was proposing. Unfortunately, much of his writing was ignored. Source:http://4.bp.blogspot.com, accessed 28.03.2018

Figure 87, Old workers´ buildings in Reykjavik (shown in this photo) are one of the examples where Hanesson´s ideas of compact and clean blocks he had promoted in his book were realized. The architect was Samúlsson, who continued to pursue the ideas in his further projects. The set of building has a heat boiler system using coal, which was used before GE came into city parts. Source: http://vatnsidnadur.net/2017/03/31/minjar-s, accessed 28.03.2018

Figure 88, Old turf house principles (burstabær), attached to each other to save energy, keep warm and lower the surfaces exposed to wind and cold

In his further projects, Samúelsson mixed the common international novelties in planning at those times about energy conscious planning (from 1930´s) and successfully implemented them to Icelandic traditional views on architecture and living.[409] He mixed the turf house appearance with that of energy savings and compactness.

Figure 89, Landbanki structure from the 1930s, this concept was suggested as the model for the future development of Icelandic housing. Unfortunately, not very much of these principles were adopted to great extent in Reykjavík. The idea of saving energy was present among other internationally recognized principles in planning at those times, advocated by Samúlesson in Reykjavík, source: (http://blog.pressan.is/eyglohardar/2015/12/30/gudjon-samuelsson-og-ibudir/, accessed 29.03.2018

There are other aspects of Hannesson´s book that tackle the problem of daylighting and sunlight and its importance to the urban layout of cities, that seems to have been underestimated in contemporary building development still nowadays and is unwillingly integrated by the architects in the urban design concepts, for some reason. [196][410] The reason

[409] Having in mind that before 20th century, typical Icelandic house was a turf house and that the imported wood and other materials lead to the construction of individual housing in Reykjavik very detached (because of lowering the risk of spreading of fires), urban scheme prior to Hannesson´and Samúelsson´s ideas and designs was very low-density blocks with detached housing. Abundance of energy after the WW2 lead to the understanding of detached housing as a preferred option, this time mixed with consumer culture present globally and that affected Iceland too

[410] Valsson, 2003, 121

for this can be the consumer culture that is founded on more space, more commodities, more amenities which sacrifices local resources and does not rely on the real situation. Architects face the consumer changes going in this direction and they cannot do anything, but to try to advocate the role of healthy planning and mitigation of some cardinal mistakes in urban layouts that lead to urban sprawling and a heritage that is to remain for generations to live with.

8.2.5 Urban neighborhoods of Reykjavik and situation with the settlements in the rest of Iceland

Nowadays, city of Reykjavik consists of many neighborhoods. It is a strong urban center and there is a tendency of migration towards the city from the rest of the country. This is explained by the fact that the rest of the country in the parliament in Reykjavík is over-represented and sometimes Reykjavík does not have access or authority to get engaged with the regional planning [201][411]. It is probably a situation very like most European capital city areas, whereas in Iceland this seems to be more noticeable, especially because four fifths of the land are inhabitable and only 25% of the territory is covered in green area. The authorities in Reykjavik have tried to suggest polycentric organization of the Icelandic network of towns, with towns like Akureyri, population of 15,396 (all following population numbers in 2000), Ísafjörður, (population of 4,225), Hornafjörður, (2,370) and Egilsstaðir, (population of 2,024), being proclaimed strategic towns in the urban system of Iceland, along with Reykjavík. Additional focus of this proposition made in the proceedings of the conference on Polycentrism in Iceland [203][412] was to focus on the further development of the capital region of Reykjavik. [201].[413]

The first urban plan of Reykjavik was proposed in 1921 and since then we can say the official urban planning seems to have started existing on paper. Heritage protection consciousness among the population throughout the 20th century was especially present. During the 1970s, the population reclaimed the urban wholes of Reykjavik, the appearance of which has remained up to today. After WW II, city infrastructure was expanded and the population number was increased, probably due to global baby boomers and intra-Icelandic migrations towards capital area. This resulted in the appearance of districts, suburbs and a range of highways and mostly car street boulevards which shape the silhouette of the city nowadays. Hand-in-hand with physical expansion, there was a rise in income and education, which

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[411] Böhme, 2002

[412] Ìslensk Storbórg, 2002

[413] Böhme, 2002

meant more low-density housing for the population and more roads and distances to surpass. Access to district heating, fueled by geothermal energy, also meant better living standard and better access to communal services in most parts of the city. Sometimes, it was a prestige to get the geothermal district heating inside of the houses or offices and some of the different institutions (like University of Iceland) [59][414]fought to become the next neighborhood with the privilege of being connected to the district heating.

It is not clear if Reykjavik would solve its current problems is it was built with more compactness and geothermal integration from the start. These experts are trying to address this issue in the Municipal Plan 2010-2030.

8.3 The context of planning and urban development in Reykjavik and Iceland

8.3.1 Current city Municipal plan and its implications for the urban planning strategies

As mentioned in Reykjavík Municipal Plan 2010-2030 [204], the plan sets out the position of future residential and employment areas, defines basic planning and design principles and encourages development of dynamic commercial activities in the city, being part of the capital region. Its propositions, especially the necessity for Capital region of Reykjavik to encourage a diverse supply of housing and housing options, are founded on studies and facts. For example, the population of Reykjavík is set to be 143,000 in 2030, which is 39 % of the total estimated population of Iceland in this year. Population growth in the capital region and the city of Reykjavík will imply new jobs, which will increase housing options that will accommodate the changing population. The plan estimates that this will affect the urban structure of Reykjavík as well. Numerous scenarios for the city are being developed. Some of them imply more responsibility to the sustainable development of the city than others and therefore are suggested as guiding principles in city´s urban planning in the future and its development in the years to come.

There are three existing scenarios in the suggested Municipal plan (MP) called: A, B C. Each is considering different densities for city parts. The first option implies more densification and merge of residential and commercial in mixed zones, seems more environmentally friendly and bears less segregation, in comparison to B and C that rely on the suburbs as centers of development of semi-segregated city parts and distinction of residential and commercial in the plan.

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[414] Iceland, Expert-geothermal cluster, 2016

The above-mentioned document mentions three aspects in the future thinking about the city of Reykjavík: City by the sea, Green city and City for People, as being important milestones for Reykjavik's development. This means densification of city structure, compactness and attractiveness of the city, followed by changes in travel behavior, preservation of open and green spaces, encouragement of sustainable lifestyles of citizens in different neighborhoods and reduction of pollution in the city limits. Finally, this is connected and leads to the third principle, meaning improvement of the quality of life of citizens in urban neighborhoods of Reykjavik and promotes advanced building design and arrangements of their adjoining (in-between) spaces. [204][415]

> *Further on, the municipal plan suggests that robust commercial areas should be formed, especially around the airport zone, and then connected to the two Universities and the hospital, as to offer a space for education, high-tech development and especially economically enhanced activities. It is all to be in the downtown area around the airport and there is an emphasis on connecting these entities with pathways and recreational areas. Also, harbor area re-development allows for mixed-use activities, which in turn allows for cutting on travel distances that would have been needed by further expansions of the suburbs and city´s growth horizontally.* [204][416] *Industry placement as well as other commercial activities, retail, services and administration, tourism and leisure play a significant role in the plan´s principles. Furthermore, there is an approach of minimization of the effects of greenhouse emissions until the year 2050. This will be achieved with more present public transportation by developing new (sustainable) energy supplies, planting and waste treatment (more recycling), optimistic values of 73% are suggested by this year in the total amount of CO2 emissions in the city of Reykjavík.* [204].

One of the most interesting aspects of the MP in the field of transport is its sustainable character. This means suggesting a center point in the map of the Reykjavik area from which it will be possible to travel to other parts of the city on foot 1,5km and 4 km by using a bicycle in 15 minutes' time. This allows for choosing these forms of sustainable transportation within the city limits and is a good start in the reduction of CO2 emissions within the city, apart from mixed-use neighborhoods and densification of the city center. Another goal is that by 2030 about 22 % of all travels within the city of Reykjavik will be made by pedestrian transport and 8% by cycling. This would mean a decrease in the number of cars transports within the city from the current 75% of all transport to a projected number of 58 %, [204] The goal is to put an end to the urban sprawl in Reykjavík, leading to less car use, less congestions and thus less roads. Along with greening spaces, this should make the city more attractive for living and supportive of the urban development of Reykjavík. If being made hand-in hand with building refurbishments, it can also mean more possible investments in other activities within the city. There is a good promotional plan to integrate the principles mentioned above into educational curricula for children and lastly, citizens'

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[415] City of Reykjavík, 2014

[416] City of Reykjavík, 2014

initiatives, already strongly present in Iceland, that support the conservation of the environment. [417]Quality of the built environment and public spaces is also addressed separately, along with heritage protection of the urban wholes and other aesthetical instruments in urban planning, street layouts and mono-activities within certain central city parts. [204]

Municipal plan emphasizes the importance of historic preservation of the urban core of Reykjavik. This should be achieved by building height regulations and zoning of the area that need to be preserved as an urban whole. In this sense, low-rise development of the past should be given advantage over high-rise, as this is relevant for the protection of the urban wholes. Hringbraut ring is a special historic district that corresponds to these principles. There is also a strong façade provision principle, which means that certain street appearances in the city are given special attention and fall under the criteria of the same function (for example- some streets are to have at least 50% of street front with the same mono-functions). [204] Strengthening of the city culture is also one of the important aspects of sustainability goals of the city, as the city core should be the center of cultural spirit of the city and offer room for the identification of the citizens with their city and social cohesion within the locale. Finally, the concept should encourage diverse activities within the city and enhance the role of the entrepreneurship and retail, as opposed to predominant and large shopping centers which have been built in different parts of the city in the last decades. There is a special emphasis on the development of the city neighborhoods in Reykjavik, whereas 8 of the 10 neighborhood plans 'preparations have already begun. There is also a strong environmental assessment strategy within the municipal plan, which includes the assessment of all the three predominant scenarios and their relation to various risks to the environment. As it can be seen on the plan diagram which is presented in the chapter on environmental protection, the actual municipal plan for Reykjavik has a very positive impact on transportation, air quality, greenhouse gas emissions, green space and energy production, and thus strongly supports development of the city urban core. Landscape and recreational areas seem to be uncertain in terms of the outcome in the future, as improvements are not clearly seen at this stage. There is also a notable negative effect on flora and fauna and the shoreline, which seems to be a significant drop-back in the plan. [204].[418]

[417] More about the understanding of the Icelandic green initiatives within their environment protection can be found in the source available at: http://www.ecoprocura.eu/reykjavik2009, assessed on 01. 06. 2017

[418] City of Reykjavík, 2014

8.3.2 A short reference to the recommendations on Planning from 1939- the setting of important urban planning strategies

Several statements from the Document obtained from the Town Planning Board of Iceland in 1939 are quoted below. It is one of the starting points in the analysis of today´s appearance of Reykjavík.

> *"Division of the town into districts according to various facts has until now been ill defined. Industry so far from being confined to fixed areas, has been established in many separate parts of the town, much to its detriment. …There are also University, the modern hospital, a large hotel, several business houses, elementary schools, and art gallery, library and archives, churches, swimming baths (heated by water from hot springs), various government buildings, the Parliament house, banks, etc. There is a plan for the making of a complete athletic ground with bathing beach beside a calm fjord (Skerjafjörður) on the outskirts of the town.* [205][419]*"*

The geothermal beach was made later during the course of time in the same area, called Nauthólsvík in Skerjafjörðurand is operational today. 420 This citation from 1939 document shows the importance of clear definition of priorities for the distant future of Reykjavik´s urban development in terms of urban planning.

> *"The town´s water supply is brought from a distance of a bout fifteen kilometers; and electricity from a power station on the River Sog which is seventy-three kilometers from Reykjavik.* [205][421]*sic"*

> *"To and from Hafnarfjörður, (which is eleven kilometers from Reykjavík, and has about four thousand inhabitants) there are regular services of ´buses similar to those plying within the town itself. These carry about half a million passengers annually. This is somewhat remarkable, since the figure is equivalent to that which would be reached if every Icelander journeyed four or five times annually between the two towns.* [205] *sic"*

The recommendation of the 1939 plan that Reykjavik and its districts should be built as spacious ones is very important for understanding of the planning outcomes of the city today. This recommendation of Town planning board of Iceland together with other factors, such as economic development, consumer culture after the WW II and cheap energy, are to be held responsible for the urban sprawl of today´s Reykjavík. An illustration of the recommendations is as follows:

> *"The aim of those responsible for present town-planning activities is to ensure that the town shall be built in spacious and bright districts, with adequate provision for open spaces, children´s playgrounds, definite*

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[419] The Town Planning board of Iceland, 1939

[420] More on the geothermal beach, located very near to the University of Reykjavik and within a walking distance to the center of the town, can be found at: https://travel.sygic.com/en/poi/nautholsvik-geothermal-beach-poi:11321, accessed 12.04.2018

[421] The Town Planning board of Iceland, 1939

industrial and commercial districts and so on. Of late years' efforts have been made to bring into operation a scheme ***where the entire town would be heated by the utilization of water from hot springs.*** *Borings in connection with this scheme have been made in an area of subterranean heat not far from the town. This project will undoubtedly provide many great and varied possibilities for Reykjavík, among other facilities for the better cultivation of gardens in the town.* [205] *sic"*

The extent to which the gardens have been considered is rather questionable, as energy has been primarily used for heating up homes.

"This will be a remarkable instance for the utilization of natural forces, something indeed unique throughout the world, for the hot water will be pumped **directly** into the town´s heating system. From the hygienic point of view the scheme is also of great importance to the town which, under the completed project, will become **smokeless**. [205] sic" [422]

Figure 90, a and b, Reykjavik prior to geothermal utilization, Importance of Reykjavík becoming smokeless is contained in the fact that most of the imported coal and other fuels were quite expensive and were pre-dominantly used as energy sources at the end of the 19th and in the first half of the 20th century (heating, industry and other purposes). This has created an atmosphere of a polluted city, compared to the photos nowadays that show a difference to the situation with transfer to renewable district heating source (90b, down left photo).

[422] Further on in the text it says: "Such a heating system had been in operation for several years in certain parts of the town and from it experience has been gained which will facilitate the adoption of the general scheme. It is expected that the entire undertaking will be complete in 1940." [205]

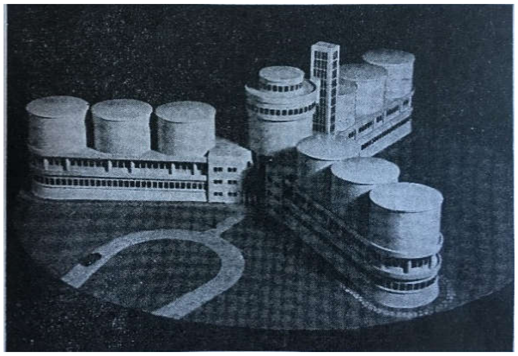


Figure 91a and 91 b, Project a geothermal accumulated heat station building competition´s winner, from 1939 Publication by the Town planning board of Iceland[423] (left). Much of this competition was not realized in the same manner. However, the idea of water tanks remained and Reykjavik saw development of a distinguished building in 1991 (to the right: the *Perlan* building today)

8.3.3 **Context of regional planning and Reykjavik**

Regarding the regional planning in Iceland, as the issue which is of importance for balanced development of other towns in Iceland, there are attempts to "weaken" the role that Reykjavik has as a dominant area of development. Proposals are made to make Akureyri the center of the north and east Iceland, as well as to make Ísafjörður and Egilsstaðir University centers. This supports the idea of polycentric development in the future. [201][424] However, it is noticeable that Reykjavik will continue to develop, especially as it will strengthen its role of green city. Regional economic development initiatives are more fruitful in Iceland, as it supports decisions and policies made by the government and connection between regional policy and public services, economic and industrial decisions. [201] These strategic regional development plans carry a lot of power of decision making. Unfortunately, these plans are not treating geothermal or hydro energy adequately. [201] Both resources are important for regional planning because the country and city´s supply with energy for heating, electricity consumption and industry (aluminum industry) development is highly dependent on these sources. [30][425] The issues around the use of RES are discussed in political circles but are left out of the regional development plans. [201][426]

[423] The Town Planning board of Iceland, 1939

[424] Böhme, 2002

[425] Iceland Geothermal, 2015

[426] Böhme, 2002

Master plans are good tools for observing the current situation in cities and managing their growth. [206][427] If managed as a whole, they can be held responsible for the implementation of energy planning and issues. A clever master plan takes into consideration various issues and confronts them with a specific vision. Whenever a local energy source is available, the plan is to suggest its utilization and examine its connection to other aspects of the city´s development. It also should be in compliance with spatial planning at the state level, which carries more weight, but is not as detailed to the specific community and its needs as the master plan. There are other factors, such as private ownership, which are barriers to the development of master plan that could substantially bring benefits for the community in the long run. [207][428]

As far as spatial planning is concerned on the state level, the concept is less present. Therefore, it is regional development that is supportive of decision making through infrastructure projects. This is however without a significant attempt for cross-sectoral thinking. Reykjavik´s development is strongly connected to rural-urban relation. Majority of parliament members come from rural places in Iceland, so the power of decision-making is not in the hands of predominant capital region. Therefore, decision making in terms of spatial planning and development is rather difficult, as there is disproportional representation of the capital city in the total political power, and this may be the reason for weakening of the spatial development and planning in Iceland. [201][429] There is a need for exchange of experience with European and international experts in the field of spatial and urban planning, as well as for more powerful national and regional decision-making processes, and cooperation from which Island could benefit in terms of a balanced urban and urban-rural development. Many of these case studies are to be found in Europe and all over the world, but they are to be carefully studied, as not all of their implications may be applicable to Iceland. However, such case studies can offer certain relevant issues on regional planning and rural-urban development that Iceland seems not to have covered in the long run. Reference to some of these studies will be made during the dissertation, as a comparison to what effects a strong national or regional planning policy may have on the development of the areas surrounding urban centers.

Regional planning in Iceland is relatively new term. [201] Iceland´s first urban settlements were thought to have emerged around the settlement of Althing, Thingvellir, now part of the national park in Iceland, where in the middle ages, Icelandic parliament used to covenant important laws for the whole Iceland [208].[430] It was an open-air structure and is still not excavated enough to see the exact urban form it had in those days, for some reasons

[427] Hameed, Nadeem, 2008

[428] Zancanella, 2014

[429] Böhme, 2002

[430] UNESCO, 2016, on Iceland

mentioned in urban planning literature on Iceland. [196][431] The most important fact to understanding the genesis of Icelandic urbanization is that Iceland is a large island with relatively small population. At the turn of the 19th to 20th century, Reykjavik had a population of around 6000, i.e. 8 % of Iceland´s population. Internal Migration towards larger cities was among one of the factors that made Reykjavik larger, having the approximate population of 111,000 (around 170,000 with adjoining suburbs and city-related region) or 62% of the total Iceland population of around 282 000 in 2002. [201][432] One of the important things to mention is that not always has Reykjavik been the most important or largest city in Iceland. It was mostly in the twentieth century that the towns have developed in Iceland. [201] This is especially important if we want to understand the situation with geothermal development in Iceland for heating purposes, because since its introduction in Iceland in 1907, Reykjavík has been developing rapidly as a city. Therefore, it is possible to comprehend the introduction of geothermal almost simultaneously with urban re-development of a city. This is the case with many cities in the world which are in the process of re-developing, as we shall analyze in the chapters on post-industrial cities in Europe and USA. Using the present infrastructure, street and side-walk infrastructure, water and sewage systems, commercial activities, housing, parks and recreational use emphasis within the city, allows the cities to be put in the category of identity-established and attractive communities. [209][433]

Pollution in Reykjavík is relatively small, especially after vast usage of geothermal district heating. However, there is considerable smog from cars and spiked tires, which is especially notable in Reykjavik in winter. H2S coming from geothermal utilization is also one of the pollutants present in Reykjavik.

Greatest pollutant in the city seems to be the car [10][434], as low density of the city and somewhat existent urban sprawl and commuting seems to be the cause of pollution in the city. In the chapter *City by the Sea*of the*Municipal Plan of Reykjavik* [204][435], Reykjavik planning authorities try to make the city more attractive by proposing further densification of the city and more compactness of its form. The chapters of this thesis which deal with results and analysis shall present the ways the city deals with various problems today. During the expert interview [10][436], the expert mentioned the theory on compact form in city planning given by Hannesson, which was published prior to any planning decisions being made in the 20th century. These theoretical principles have not been taken into serious consideration during planning procedure until now. Unfortunately for the city of Reykjavík, the ideas of energy planning in architecture [202][437] were not explored in detail and were largely neglected for decades, despite the fact that they existed in the written form.

[431] Valsson, 2003, 121

[432] Böhme, 2002

[433] New Jersey Future: Working for Smart Growth, 2016

[434] Iceland, Expert in urban planning, 2016

[435] City of Reykjavík, 2014

[436] Iceland, Expert in urban planning, 2016

[437] Hannesson, 1916

8.4 Geothermal utilization in Iceland (past, present and future)

In the first years of the 20th century, geothermal energy was used in smaller portions. As for geothermal, more than a century had passed form the moment a farmer and an inventor named Stefán B. Jónsson started to utilize thermal water at his home Reykir in Mosfellssveit in 1908. Twenty years later there was a three-kilometer-long pipeline for warming-up the Austurbær - elementary school, ready to be used. From those moments, Reykjavik was developing with GE. [210][438]

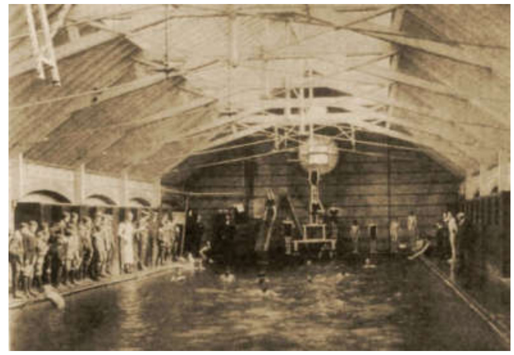
Before installing the first heating system in a school in downtown Reykjavík, warm water that was present here was used for washing clothes, as well as for other cleaning purposes. Some people believed in healing powers of warm waters and several priests were proclaimed saints after they had blessed warm water sources which cured the people. The strategic use of geothermal water came much later as Iceland and its capital were predominantly rurally formed. The habit of washing clothes led to the formation of the street Laugarvegur-meaning the "laundry road" in the center of Reykjavik.Unfortunately, this site was a disastrous place, where a lot of women lost their lives by accidental drowning into the pool of hot water. This and the fact that a lot of people, such as fishermen, did not know how to swim forced the Icelanders to think about using warm water for heating -up swimming pools and some public institutions. After having installed the first system in the school, it was the parents of the children who saw the advantages of its use and this fact may have provoked the use of GE in the future DHS, according to the expert in history. [198][439]

Figure 92 (left), Bath by Snorri, in this picture warden of the school in *Reykholt* examining the bath, some ideas for district heating have originated from the old uses for bathing, schools were apparently leading the way into district heating with geothermal in Reykjavik, sources: lemurinn.is, http://lemurinn.is/2012/10/04/otrulegar-ljosmyndir-af-islandi-eftir-hollenska-meistarann-willem-van-de-poll-1934/, accessed 20.05.2017

438 Orkuveita Reykjavíkur, 2015

439 Iceland, Expert in geothermal history, 2016

Figure 93 (right), Photograph of one of the first swimming pools in Reykjavik, source: http://www.yeovilhistory.info/images/swimming%20baths-interior.jpg, accessed 20.05.2017



8.4.1 Future of geothermal utilization and development in Iceland

Hydro power is still a major source of energy in Iceland (70 %), while geothermal share is only 30 %.[440]There will be a 50% increase in the use of the total GE in Iceland by 2050. [30][441] However, there seems not to be a strategical coherence of geothermal energy planning with the level of spatial planning. [201][442] There are indirect implications for the use of geothermal energy in a certain area. For example, many case studies throughout Iceland support this. Excellent example of combined heat and power plant is *Svartsengi* geothermal power plant which produces steam, potable hot water, brine, condensate, geothermal gas, brown water, lava filtered sea water. [30] The use of GE for heating purposes in Iceland makes 44 % of the total geothermal energy use. Another 42 % is used for electricity consumption, while 4% are used for fish farming, snow melting, swimming pools, and 2%, for greenhouse production processes´ and industry. [30] This was not always the case, especially before 1945, when the use of geothermal and hydro was still developing. There are a few illustrations that are showing this: [443]

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[440] Landsvirkjun is the national hydro energy company and they produce and sell electric power to the aluminum smelters and the ferro silicon plant in Iceland. These companies influence the electric consumption intensity in Iceland and are largely contributing to the geothermal to hydro ratio, despite the extensive geothermal utilization

[441] Iceland geothermal cluster, 2015

[442] Böhme, 2002

[443] One of them is by the National Energy Authority (Orkustofnun, 2015) [74], showing the amounts of primary energy use in Iceland and the way the share if geothermal and hydro was growing from 1940´s to nowadays situation, where hydro and geothermal especially take a big share in the whole energy consumption in Iceland. They are renewable energy sources in comparison to fossil fuels that had been used before that

Famous examples of the above stated are pictures of Reykjavik and its surroundings in the past (see Fig. 95 and 96).

Figure 94 (left), using piping for access to geothermal heat for washing clothes in Iceland, around 1930s, source: http://lemurinn.is/2013/01/30/folk-i-reykjavik-fyrir-hundrad-arum/ accessed 25.07.2017

Figure 95 (right), the swimming pools around Laugardalur ("Frá laugunum í Laugardal", in Icelandic), source: http://lemurinn.is/2013/01/30/folk-i-reykjavik-fyrir-hundrad-arum/, accessed 25.07. 2017

The territory of Iceland has over 600 active springs hotter than 20°C. There are 250 local spots with temperature up to 150 °C. Additionally, at least 20 known resource spots where temperatures exceed 250°C prevail at the depth of 1000 m. These areas are in direct contact with volcanic activities, whereas the first ones are only touching these zones. [30][444] Reykjavik uses both low enthalpy geothermal resources and high enthalpy ones for district heating supply and the total installed capacity is 1 GW in the city of Reykjavik. It is considered to be one of the most sophisticated systems of geothermal district heating networks in the world. [193][445] The starting point for any tourist who wants to understand the genesis of the geothermal energy use is probably Laugardalur. This place is a monument to the beginnings of the use of geothermal within Reykjavík. The hot springs are still visible in the city and it holds the information on the use of geothermal for washing clothing and other basic uses

[444] Iceland geothermal cluster, 2015

[445] Verkis: Newsletter, 2015

for households. The street leading to the center or the harbor area to this place was called Laugardalur (washing way), because the site had been used for the dwellers of Reykjavik (being small at a time) and predominantly in the area- today´s city core. It has become one of the main streets in Reykjavik today. [198][446]

Figure 96, Laugardalur washing of clothes in Reykjavik, source: http://www.nordic-aputsiaq.blogspot.com, accessed 24.05.2016

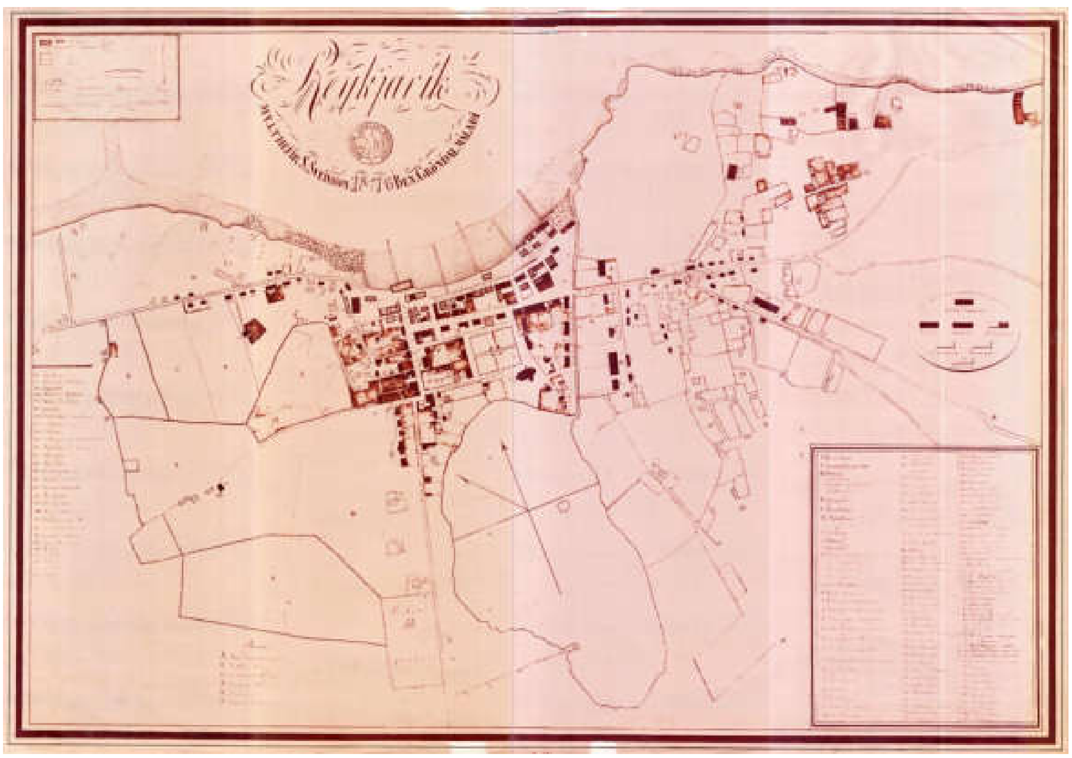

Figure 97, Map of Reykjavik from 1876, the street called laundry way could be noticed as the main artery in the urban form of Old Reykajvik, source: https://annsofiegremaud.files.wordpress.com/2014/01/rvk-map-gl.jpg, accessed 24.03.2018

50% of all geothermal energy in Reykjavik for district heating comes from the combined heat and power plants near the city and the other 50% come from the direct geothermal resources within the city. These two systems are not mixed because of different water characteristics

[446] Iceland, Expert in geothermal history, 2016

and various technical problems that may arise by doing so. Instead, the old parts of Reykjavik are connected to the system that uses wells from within the city and the rest of the newer districts is connected to the power plant heat. [62][447] The DHS of supply heat from the power plant uses a mixture of tap water and geothermal water from the ground. Therefore, there is a less direct contact between the user and the initial geothermal fluid. However, the old parts of Reykjavík use geothermal fluid coming from the ground more directly and therefore have sometimes chemicals such as Sulphur-dioxide that causes smell, which is the situation with the spas used in this area. Consequently, in the older parts of the city of Reykjavík the final users may occasionally witness side effects of direct geothermal in terms of excess heat and smells of accompanying geothermal water substances, like sulphur. [198][448] This is typical of most places in the world, where geothermal waters are used either for balneology or other commercial or heating purposes for households and different buildings. Good examples are the spas in central Europe, for example in Hungary, Slovenia and Serbia, where the culture of using geothermal waters dates from the Middle Ages and sometimes the Antique. These case studies should be elaborated within the special chapter on heritage of the local cultures and its connection to contemporary planning of cities and its urban developments. Heritage can play a significant role in the appreciation of cultural values, and its integration into urban planning and energy planning. This might not have been the case with the city of Reykjavik. Oil crises in the 1970s, as well as the future vision of the engineer major are considered to be the main drivers for the expansion of geothermal in Reykjavík, present today.

8.5 The integration of RES and green thinking into the municipal plan of Reykjavik

The expert interview with city of Reykjavik´s municipal planning authority does not mention integration of geothermal energy in the urban planning of Reykjavik even today. [10]This will be thoroughly explained in the chapter which deals with interview analysis. However, it would be good to take a look at the integration of green thinking at other levels that tackle the issues of sustainability within the above-mentioned plan.

Having in mind the data given in the previous subchapters of Reykjavik´s planning, there is high level of geothermal energy exploitation in Iceland, especially in Reykjavik capital region and the city. Almost every district in the city is connected to geothermal and the city benefits from the green resource as pollution levels are significantly less than before the utilization of

[447] Iceland, Expert from the geothermal company, 2016

[448] Iceland, Expert in geothermal history, 2016

geothermal. This has allowed the city to focus on other equally relevant problems of urban planning, such as transportation efficiency and putting an end to the urban sprawl within the city limits as an element of sustainable planning.

Although geothermal energy has a tremendous effect on the economy and other aspects, there seems not to be a high level of integration of GE on the level of urban planning or a strategy for regional planning that allows this to be done, except for economic development purpose and analysis. It seems that in this aspect, there is room for development and interdependency between energy and planning.

In addition, rural-urban relation is underestimated in planning, even though Reykjavik is dependent on its surrounding rural areas. The question is whether Reykjavik can afford to let its urban planning to the game of chance, without giving a chance to outer communities to develop their own potentials when it comes to self-sustainability, i.e. with other aspects of sustainable urban development, such as transport issues, green infrastructure, connectivity to the city, neighborhood planning and a more polycentric development in the country.

GE utilization will continue its growth in Reykjavik and the rest of Iceland. The way it is going to be exploited is affected by urban planning mechanisms, especially if a regional plan supports its polycentric use and allows access to the areas where the resources are scarce, but need connecting to district heating infrastructure. The importance of the following is to be determined: a central production and exploitation of geothermal with a more centralized management of resources and central policy, or a sustainable long-run plan which enables the determination of spatial plans and then integration of geothermal hot-spots (or supplying locally available forms of energy as an alternative). There is also an increased interest in geothermal pump exploitation in Iceland, which may allow this aspect to be further potentiated in the years to come. This is an exceptional opportunity for the rural areas to develop their own potentials and amortize the migration within the country towards the capital region, which is a current trend that tends to grow. Reykjavik would develop further, with or without migration; *the question is what else could be supported by good planning policies in Iceland which are relevant for sustainable development?*

8.6 Geothermal development within urban morphology of Reykjavik

From 1930s onwards, Reykjavik has been developing with geothermal energy use (see Figure 98 for details). This scheme shows that the main urban spatial expansion of Reykjavik has occurred simultaneously with geothermal district heating expansions. What started off as only few areas until 1938 and central part (1339-1944) grew to become a large expansion from 1962-1972.

Along with higher living standards and more commodities (such as district heating in homes) new areas in Hafnarfjörður, Kópavogur and Garðabær were connected to huge areas in the period 1973-1977. Having in mind that these areas were built mostly as low rise and detached houses, the density was low and the distances from the place of living to the city center became larger. This all seems to have contributed to the urban sprawl in Reykjavik today.

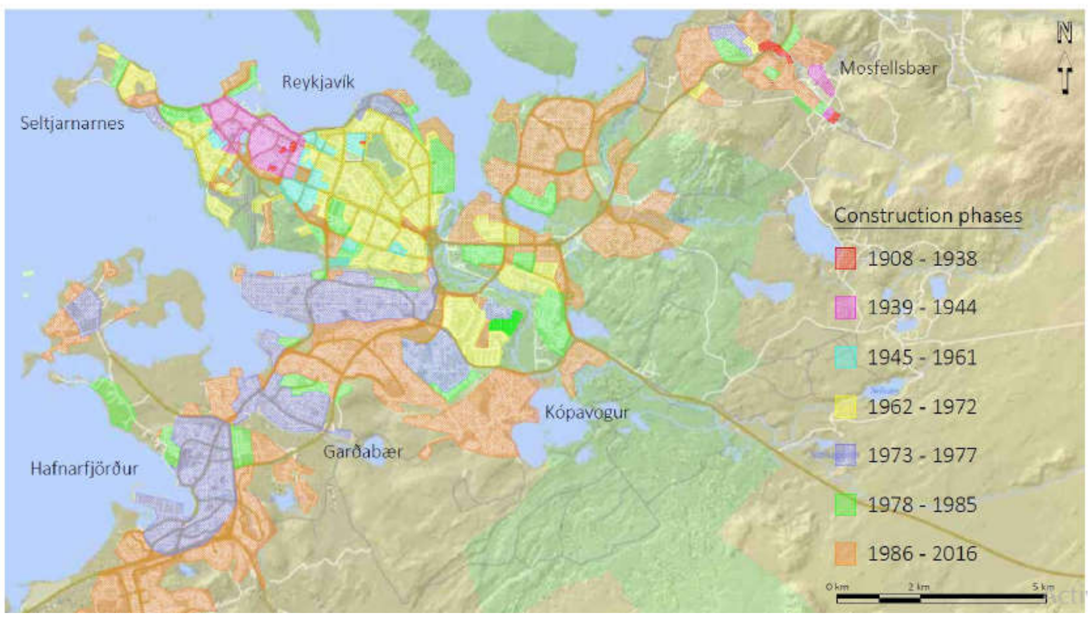

Figure 98, Reykjavík GDHS development by construction phases, the area covered by geothermal district heating was growing almost exponentially from 1939 onwards. Source: photos from the lecture given by Thorleikur Johanesson, on October 14th, 2016 at Cornell University [50][449]

8.7 Summary of the interview results on Reykjavik

Within the following pages, an overview of the results and outline of the most significant opinions within expert interview method and Icelandic sample will be presented.

[449] Cornell University guest speaker, 2016

According to the expert with background in engineering and promotion of GE [59][450], GE utilization is valuable for the community as a renewable energy´s supply for heating. It is not so valuable for a specific company that wants to gain money in a short time, as it is for the broader cause: communities and their resilience. To use renewable energy is quite important for them in the first place. Energy security is one of the main drivers to start utilizing geothermal energy. It is local energy which helps in greenhouse gas reduction. Compared to other RES, such as biomass, it is stable and always available at certain flow rates and through time. Although geothermal is quite expensive at the beginning, if one can captivate the resource, there is an obvious advantage of safe and cheap energy.

Long term perspective is quite valuable on a bigger community scale, than on a one-company interest scale. Therefore, GE is used whenever long-term goals in energy security of the community are aimed at. Its benefit is that it can help community to develop slowly but surely, as it relieves the community from the necessary burden of paying for energy, leaving the fossil fuels out of the game, and allowing for local resources to be employed. It is a stable resource with constant flow of power for the future. There are obstacles to using geothermal: there is no guarantee that the return of investment money into drilling and exploring reservoirs would be made possible, as there is a risk finding temperatures and flow rates which are satisfactory. In this sense, the investor of funding body may not be able to re-pay money in any way, for instance for the reservoirs´ explorations. The initial investment is rather high, but once completed, the one will be able to collect money from the investment in for the next 200 years. Technical issues of accessing geothermal and dealing with operational problems are less of a problem. As *there are ways to do almost everything,* it is the matter of (initial) costs. Technically, within the operational phase, it is important to keep the pressure high enough and not go below certain temperatures. Initial costs and operational costs of a district heating system and their relation are significant for geothermal project. [59]

The National Authority of Iceland is the company that oversees GE distribution in the country. When present in houses (buildings), hot water used for house heating is put into the sewer system. Some users use it to heat up the pavement (or their parking places) or hot tubs before sending it back to the sewer pipes. The company *Orkuveita* uses specialized computer software for the utilization of the whole system [62][451].

In terms of Reykjavik, one half of all heating energy comes from the sources within the city, while the other half comes from power plants near Reykjavik. Capacities inside Reykjavik were not sufficient to cover the loads for the expansion of the district heating network, i.e. for connecting the districts to the network in the past. That is why they had to invest in

[450] Iceland, Expert from the geothermal cluster, 2015

[451] Iceland, Expert from the geothermal company, 2016

supplying the system with additional sources, that is- heat resulting from the electricity production plant as residue heat.

The interviewee has seen the relation between energy and the development of towns in Iceland on the example of summer cottages. According to the interview, access to geothermal heating is preferred when building a summer cottage. Also, the sources of how water and their capacities affect the city planning. There is an open process in geothermal energy planning: the energy authority sends the plan of drillings for energy production and utilization to the City of Reykjavik´s Planning Department and it is up to them to review the process. No reference has been made as to whether there is an initiative from the planning department or its relation to growth, mitigation of urban sprawl or transport.

In case of other towns in Iceland, some of them belong to the so called "cold areas"[452]. These areas mostly use electricity for heating purposes. There is obviously a housing policy of Iceland that deals with unequal distribution of people. This policy means that some municipalities and their budgets and investments in infrastructure are subsidized by the State and it helps keep people living there, instead of migrating to the capital area.

Finally, a comparison is made to the situation in the USA, as to emphasize the main differences to ongoing projects in Europe or China. Here (USA) there is a huge potential for geothermal use for heating. However, there is a strong influence of the market that relies on fossil fuels and consumerism that apparently affects geothermal industry. For example, USA has the oldest geothermal district heating in the world in the town of Boise, Idaho. It is around 100 years old, comprises of 4 separate systems. Unfortunately, the systems have not been developed since then and this shows the negligence in terms of resource possibilities. As for Europe, district heating systems are communal networks[453]. In the USA, heating and electricity production was separated very early during the course of the history (end of the 19th century). This has contributed to the problem of successful advancements in the adoption of geothermal district heating for USA cities. Among others, important factors are consumerism and energy policy of the federal government. Geothermal district heating is also affected by the Law system in the USA. For example, there are problems with ownerships, lawsuits with land appropriation, etc. In terms of Enhanced geothermal system (EGS) in the USA, research is very advanced. Still, district heating is lagging.

Association of cities in Iceland has been appointed as referential body that may support the geothermal district heating´s relation to urban planning as an institution that supports decentralization and should be addressing equal urban development of Icelandic municipalities and cities and regions. [62][454]

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[452] Under *cold areas* in Iceland, one usually refers to the places where geothermal hot water is not available at the levels that would allow direct use for heating purposes, like in Reykjavik

[453] Communal networks are referred to as owned and operated by the local community, the city or city-owned companies

[454] Iceland, Expert from the geothermal company, 2016

Historically speaking, important reason for introducing geothermal in Iceland was energy security: plan B to have sufficient energy which would prevent the Icelanders from being dependent on geothermal energy as they were in the past. Nowadays, the emphasis is put on "green power". Therefore, it is strange that the first electric power in Iceland was gained by means of coal, but politically, the date (later in history) when the same was done with hydro was celebrated as the date of energy production beginning. Additionally, the reason for starting with geothermal at the turn of the 19th to 20th century is that Icelanders were looking for electrification options from a local source. Primarily, geothermal role was seen in the power, not heat sector. They had seen the *Lardarello* in Italy producing power and knew through the Icelanders living in the USA about district heating options in Boise (Idaho), so this historical relation was searched for a reason, according to the expert. This has also justified investment in renewable energy and hydro and is somewhat understandable, from the sphere of politics and consumer´s way of thinking. [198][455]

Reykjavik was growing extremely fast in the 20th century by developing its infrastructure, new schools, roads, public institutions and residential units. The expert said that geothermal energy was not developed to the extent which would enable connecting this infrastructure to ecological source. This originated in fear from energy dependence in case of war which would prevent Iceland from obtaining energy source that was imported prior to geothermal and hydro energy development. In terms of Reykjavik, some of important factors were the interest in swimming lessons and modern way of thinking of the Mayor. In the 1920s, swimming pools were quite primitive, but it just grew out to be a standard in Reykjavík. Additionally, Knud Ziemsen wanted to improve safety of women who washing clothes (Laugardals) so this probably contributed to the expansion of the district heating in Reykjavik, per expert [198][456]. Per same expert, main problems with geothermal and architecture are that architects do not like the pipes to be outside the wall: they like to hide it. However, if there is a problem with the pipe, you would have to tear-down the wall. This also refers to planning- nobody cares whether it can be integrated better.

Another problem the same expert emphasizes is that there is a political pressure for some cold areas in Iceland to get warm water, despite it being economically not as feasible like in Reykjavik. Reykjavik is close to the geothermal ridge (very active volcanic area that contains abundance of geothermal with high temperatures). This is however not the case with Icelandic towns in the east, where the temperature found by drilling are (only) around 45°C to 55°C. When asked if this still could not somehow be integrated into the district heating system, the expert said that it could still be quite dangerous to promise to people that they would benefit more from this system and transfer to it from electrical or other sources, because it turned out it was more expensive and not as convenient as thought to have been

[455] Iceland, Expert in geothermal history, 2016

[456] Iceland, Expert in geothermal history, 2016

in the first place. [198][457]***It is probably the matter of "being used" to abundance of heat and that this puts expectations very high so the lower capacities are underappreciated among public.***

The expert further mentioned the KRAFLA eruption[458] which resulted in a big political scandal in local drilling only two months after the eruption. The expert put an emphasis on the so called "spread culture of Iceland". As the farms were very isolated and urbanization started with the mechanization of fisheries, people wanted to live next to the places which would make their living easier. After mechanization had come to Iceland, people could reach to longer distances and needed a harbor. As the infrastructure was developed, numerous factories were built at the turn of the century. Moreover, the expert thought that there was not that much of a gap with erection of swimming pools, especially at the turn of the century´s Reykjavik. On larger scale, hot tubs were introduced on a larger scale in mid 1950s. Since then, hot tubs have been a cultural institution for Icelanders: so quickly from being cold into being so warm. The society had changed rapidly, almost "overnight". Additionally, expert thought people did not care if their buildings were being energy efficient or not, at least to the extent necessary. [198][459][460]

Orkuveita Reyjavikur[461] does not need to measure how much a consumer uses; they do not do that with the cold water, for example," if you want you can keep the water running, it would not go into the system´s spending calculations easily… Now the ice "on my pavement" is next on the agenda. For example, melting the ice on steep hills inside of Reykjavik could be the next thing in Iceland´s city development.[462] "

The interviewed architect and town planner says that contemporary Icelandic architecture is imported from German, British, American or Danish etc. which is typical for architecture advancement. [60][463] There is only one particularity: there are no bricks, no timber and other materials present in the architect's country of origin. If a house in Iceland is made with these materials, then it is imported.[464]

[457] Iceland, Expert in geothermal history, 2016

[458] Latest Krafla eruption happened in 1984, before that there was a considerable number of events, it contains considerable high temperature fields in the "caldera" ranging from around 290°C, source: http://earthice.hi.is/krafla_eruption_history

[459] Iceland, Expert in geothermal history, 2016

[460] Especially daylight and sunlight and therefore passive design and orientation are important for thermal comfort, besides heating and cooling infrastructure as argued in: (A. Jovanović et al., 2014, 158) [227]

[461] Orkuveita is an Icelandic name for the National Energy Authority of Iceland, consisting of two companies: ON power and Veitur – previous one runs the power plants and the latter provides the utilities. Both are owned by Reykjavik Energy (Orkuveita Reykjavikur)

[462] Iceland, Expert in geothermal history, 2016

[463] Iceland, Expert- Architect and Town Planner, 2016

[464] On the contrary, typical Icelandic house in the past, as explained before, was a turf house, covered with earth from many sides, roof, side walls for example

If hot springs are nearby the area where the house is being built, then a construction of a so called "Floating house" is advised. It also serves the purpose of ventilation, the so called "crawling space". Earthquakes should have influence on architecture, and in architect's opinion, even though earthquakes are present in Iceland; there is not enough emphasis on this matter. [465] The expert thinks the earthquakes do not have that significant impact on architecture as contemporary buildings in Iceland are not being torn down by earthquakes. Maybe if majority of the houses are turf houses, like in the past, they would be torn down. However, most of the buildings are constructed with solid materials, such as concrete.

As for geothermal utilization, the expert thinks cascade thinking in geothermal is good because water (energy) is not being wasted. One should have a larger pipe into his house for this cascade use, which the expert sees as a possible technical shortage.

However, the expert says that if one wants to save energy, one should research *glass houses, especially passive architecture principles, as they are cheap and effective. The expert says that active*[466] *sun systems are more expensive and take on too much surfaces on the roofs. The costs of such systems are still high, and the end users cannot still obtain them at a reasonable price.* The expert also thinks that the Asian R&D[467] market would make a breakthrough on the solar device market.[468] The topic of solar energy and its influence on architecture are constantly evolving, which is shown in several journal articles and a boo which deals with efficient structures of green houses and sunlight use.

The expert points out to the problems with Windmills as sources of renewable energy. However, geothermal is a good resource and if countries would develop ways to utilize it economically and politically, it would also be a break-through for them (meaning continental Europe, currently dependent on natural gas from the East). There is a substantial economic and political pressure on Western Europe to keep using the existing fossil fuels and related infrastructure, says the expert.

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[465] The expert further mentioned the house he had built with the "crawling space" between the ground and the bottom of the house, to prevent it from being damaged in an earthquake or other natural disasters by ground sources, in this case possibly geothermal as well

[466] Active solar systems are the ones which employ energy and are usually attained at a price, such as photovoltaic or solar collectors, they convert the sun´s energy into heat or electricity. On the contrary, passive systems rely on the natural physical phenomenon of heat transfer and, once installed (designed), do not employ processes of energy conversion, meaning replacement of technical gear for their maintenance is minimal to none. (Pucar, 2006) [226]

[467] R&D is referred to as Research and Development. Main contribution to this sector is expected to come from the Asian countries which are developing at a rapid speed in the following years (quotation needed). In the past leader of R&D were the U.S., especially in geothermal development and research. (Iceland, Expert from geothermal company, 2016) [62]

[468] The expert pointed out the great breakthroughs in science. For example: one breakthrough was the silicon chip in the radiators/ instead of big valves, which allowed for smaller radios and devices in the 20th century. The expert thinks this is also to be expected in the RES sectors (solar, for example). (Iceland, Expert-Architect and Town Planner, 2016)

On the other hand, there should be more focus on individual user and his possibilities (possible topic and focus of the research community, instead of big companies and big projects in energy sector) ought to be favored. Small, single family solutions, that can be multiplied million times, if needed, are the solution, whereas the expert sees the energy breakthrough in buildings and society in the years to come. For instance, the expert says that Iceland should make a national project which implies that everyone will use an electric car in 10 years' time. It ought to be a national project which will eliminate diesel and transform all cars into electric vehicles. In this way, instead of buying energy from abroad (e.g. diesel form Kuwait), local energy (hydro) should be used to the full extent. The essence of this suggestion is to focus on the individual user and single solutions, as well as on policy which would reduce the impact the companies have on the end consumer. In expert's words, they (the companies) only put down meters and expect a return of money from big projects and invested infrastructure. The companies think about the profit, not about the environment or individual user and her/his needs. If the society reacts now by stating the supporting the individual is substantial and crucial, the situation can be changed. [60][469]

In terms of the origins of geothermal use for heating in Iceland, the expert from an engineering company said that there had been some glass houses in Hveragherti[470], where the artists used to gather and use the energy available from the boreholes. This was at the beginning of the advanced geothermal utilization in the second half of the 20th century. The expert however is of the opinion, that these initial things may have influenced the urban morphology of places and maybe even more, their settlement´s growth, but later other factors, such as building of new power plant, i.e. Nesjavelir and Hellisheidi, have been responsible for the utilization of geothermal in Iceland. People nowadays commute from Hverigherti to Reykjavik, so this place has not significantly depended on geothermal resource, at least not in the past 20 years. [61][471] The expert further mentioned the fields within Reykjavik, prior to the building of the power plants mentioned above, where geothermal heat was directly utilized in the first half of the 20th century. The wells in the areas of Seltjarnarnes had a separate district heating and economic advantages, as GE was cheaper than in the rest of Reykjavik. Urban morphology of semi-peninsula Seltjarnarnes was

[469] Iceland, Expert-Architect and Town Planner, 2016

[470] Hveragerði is a small town very near to the power plant Hellisheiði in central Iceland, some 25 km to the north east of Reykjavik. It is known as the place where some drillings have been made to get steam for electricity production. However, this has never been realized, despite the quantity of hot water which became available by the drilling. It is still available from those drillings and people extensively use it, by attaching their houses to the boreholes of steam and hot water, via a heat exchanger, to heat their homes. The place was known as the exhibition and green house space, as the hot water was used for exotic botanical garden in the 20th century. It was also the settlement point of many artists from Reykjavik and other places, that found sanctuary here and could use spaces with abundance of free energy for heating (more information on Hveragerði is available at: http://hveragerdi.is/English/ , accessed 22.03.2018

[471] Iceland, Expert coming from a company for Geothermal, 2016

somewhat different than the rest of Reykjavik. However, this was not connected to geothermal, but to urban scheme made for the area as a whole.

The expert also pointed out the problem of peak loads in Reykjavik, which were supposed to be covered with old oil fueled boilers at temperatures of -15ºC. Nowadays, they are still available and can be used in cases of emergency, but this does not happen very often due to climate change in the city of Reykjavik [211][472]. It would probably be more necessary in continental Europe, as temperature extremes during winter are more present than in Reykjavik.

In terms of geothermal utilization and utilization of additional fuels to cover harsh winters, the abovementioned opinion has been compared to the opinions heard at a workshop at Cornell university [50]. The participants confirmed that both continental Europe and Northeastern USA would need much more energy to cover heating needs at temperatures below zero. It was pointed out that geothermal used for district heating had high investment costs in terms of boreholes and infrastructure, but low operational costs. Heat boiler costs were to be taken into consideration, as sometimes they would imply great share of the overall costs for operating district heating with geothermal as prime resource. As geothermal is so expensive at the initial stage, "we must introduce some other sources to cut down on production". The expert pointed out the optimization problems (taken from his experience from China) and said that it was easier to get the most out of geothermal heating systems for new buildings, as the optimization was still possible, whereas already built objects that lack building requirements, tended to increase costs. There is a proportional increase of costs in this manner and a back-up system seems necessary.

Heat peak load would be different in Serbia, Austria and in the USA as compared to Reykjavik. [50][473] Another interesting statement within the above-mentioned workshop referred to the fact that urban density did not affect the economy of geothermal district heating system that much. The expert used a graph which proved that investment and operational costs related to higher densities were not much less than the costs of supplying single family housing neighborhoods with GDHS. The piping and losses were not significantly reduced in low density areas, as one would presume. It would be interesting to see if the above stated is still relevant for the aspects of urban planning.

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[472] Einarsson, 2017

[473] The expert further stated the technical explanations of the possibilities of covering heat loads within the district heating systems, referring to the humid climate situation (at Cornell): pressure to put on the system, has discussed the separate system for heating/cooling at the University, focused on the centralized way of doing heating/cooling with geothermal and discussed basic pressure equations. (Cornell University guest speaker, 2016)

8.8 Discussion

"Based on the results of expert interviews in Iceland, one of the urbanists and architects mentioned the need for rational approach to energy on the global level, done at the level of an individual. "There would have to be some break through …for individuals, not for the community, because the research money for energy is going to big companies who are building big power stations... where they could put a meter on it and to sell it to people, the solution is for a normal person is that he can do something with the sun space, with a wind mill, whatever it is… and that is where we should be concentrating... because it means that 1 billion people can use it, but companies they lose money on it... so, the research money does not go to individual research but to big companies who just thinking so big, to provide electricity for the whole community, where they could put a meter on every house… to get the money back… they think how they can get more money back from it (for us). They are not thinking how to create the environment, which should be good for us, but only money. All companies do that…In this country (Iceland) we should have a national project: in ten years' time, everybody car is an electric car… We have plenty of electricity… it should take 20 years or so…we use our energy… and stop buying oil from Kuwait…or whatever it is… we have a chance to do it…why not do it?" [60][474] [4]"

Based on the previous chapter on the history of Reykjavik, which has come a long way from a small town with no political power and dependence (political and in terms of resources) on the countries abroad, to the city aiming at sustainable development in the future. Cars, car-related pollution and transportation issues which cause city sprawling represent the biggest problems in the city of Reykjavik. The city planning authority is trying to put emphasis on densification of the existing city areas, which is contrary to the urban planning politics from the first half of the 20th century. Another aspect of urban development is that the focus is on people staying in smaller towns, which is tackled by the government policy. Geothermal has been an important element in the urbanization of Reykjavik for more than a century (first utilization in Reykjavik happened in 1907and was succeeded by the efforts of an inventor). Public places, such as schools have had an enormous influence on the spread of the word of geothermal utilization benefits in Reykjavik.

The abundance of heat and power in Iceland makes the areas which do not have enough high geothermal potentials to be underestimated and less developed in terms of infrastructure. This situation also affects the level of consumerism in Iceland, where people do not need to care where the energy comes from, as long it is cheap and readily available.

Centralization of power supply affects the agglomerations build-up around the capital area and available infrastructure resources, leaving the less developed areas with only a few options, involving solutions which are more expensive and hard to advocate on the

[474] Iceland, Expert-Architect and Town Planner, 2016

communal level and are a challenge for the state as well, as they represent an additional burden to the budget.

8.9 In conclusion on Reykjavik and Iceland

Geothermal heating is backed-up by electricity production processes, as the combination of heat and power is in abundance and supplies Reykjavik with heat. There is however, only informative nature of urban planning and energy planning correspondence in Reykjavik.

Even though there are efforts to support decentralization, the population of Reykjavik is still growing and is estimated to reach its peak soon. There is a need for better coordination of these two spheres (planning and energy planning). For example, problems with villages and low energy zones within Iceland can be backed-up with geothermal initiatives, where a combination of various other resources that are local (maybe even low-enthalpy use via heat pumps) can be advocated. Reykjavik is "lucky" to be at the hotspot, not only because it is abundant with geothermal energy, but also because it politically belongs to the region of advanced trans-Atlantic countries (such as Scandinavian ones) where culture of green thinking is present for a longer time. However, urban planning is facing a struggle against city sprawling, consumer culture and increased demand for various amenities[475]. Geothermal energy and its technical problems will be solved, one way or another, but they need initiative from the communities, how they can be best coordinated with energy efficient planning.

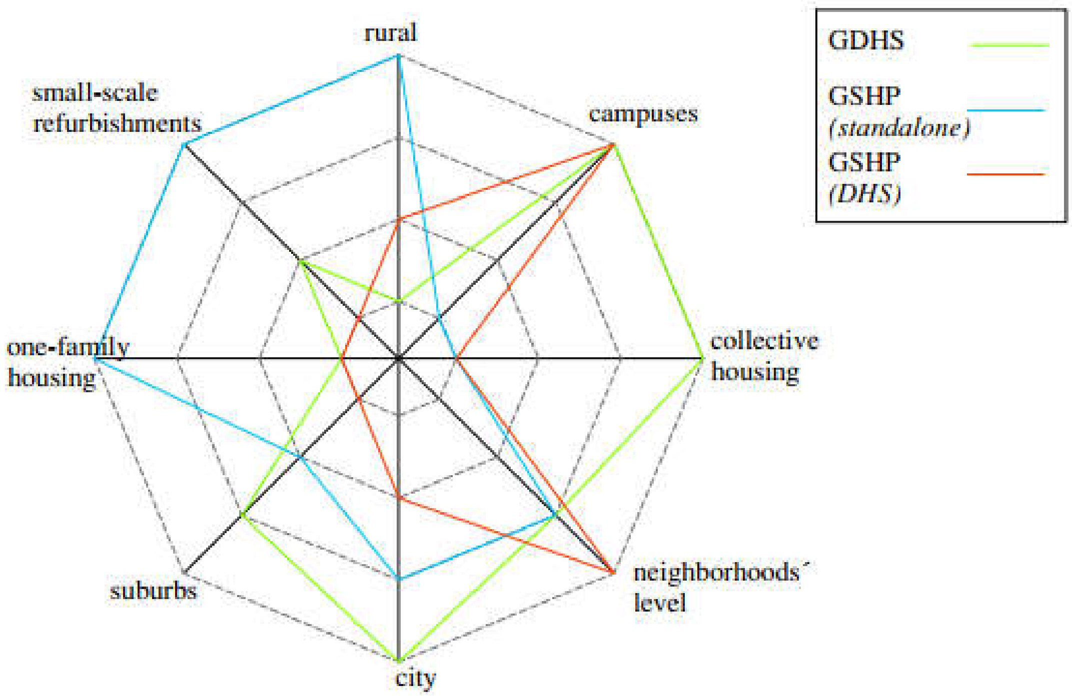
The results of the expert interviews from Reykjavik are very important to compare with other interviews in the whole dataset, as to see what the drivers for GE use can be, that could be applied to other case studied and which of these cannot be those, because of different circumstances. This is to be achieved by comparing different experts 'opinions on the same issues and this will be presented in the following chapter.

475 The situation is much worse in the USA where consumerism has reached its peak. The geothermal ideas there are still at the very beginnings, even though the potentials there for geothermal utilizations are huge

9 Comparative analysis' results

Based on the results of expert interviews, GSHP as DHS are employed well at campus typologies[476] and at the level of neighborhoods[477], whereas GSHPs as standalone have generally excellent applicability to small-scale refurbishments, one-family housing and rural buildings and wholes (see Fig.99). As for GDHS application, the importance lies within city-wide applications, suburban wholes and districts and collective housing. If small-scale refurbishments of urban wholes are with users with different energy demands, DHS is also to be re-examined as an option.

Figure 99 shows how GE utilization types relate to different levels and types of areas: urban, rural, suburban forms and wholes, such as the level of the city and types of housing. Ground source heat pumps (GSHP) were considered as one-time standalone installations (blue) and as coupled with other heat pumps in a district heating system(orange), whereas geothermal district heating system (GDHS) was the third option in the diagram (green). Based on this figure, neighborhood level planning shows possibilities for all three types of GE utilization[478].



476 Campus typologies include educational, industrial and military campuses with buildings of various heat demands, which allows for centralized shallow GE utilization

477 The level of neighborhoods is one step down from the level of whole-city planning, but connected to it

478 Highly supportive of neighborhood planning are ground source heat pumps as district heating systems. They are most promising of all GE utilization options analyzed for further research on their application. They coincide with the ideas of Jane Jacobs of a vibrant and diverse set of city functions, with various energy demands

Figure 99, Relation of different types of GE utilization types to different urban and rural forms and typical areas. Inner octagons are the lowest levels-4, the outer represent highest level of applicability of technology- level 1, source: A. Jovanovic

9.1 Connection between geothermal energy and urban morphology and urban planning

What is noticeable from all the interviews in Iceland is that the experts said they were still not able to see a clear or strong connection between geothermal energy and urban planning in the past or at present (four out of six). Even a person with historical background stated that the reason for GE utilization in Iceland was initially driven by drilling in the search of gold, not for utilizing geothermal fluids for attaching it to city parts or building new ones [198][479]. However, one person with engineering background saw its prime potential for the community and neighborhoods, rather than for companies and power production. [59][480] The interviewees involved with planning said that GE was not the cause of urban morphology in Iceland. [60] [10] One of those interviewees expressed the opinion about planning with GE by saying following:

” *But the decisions about planning- I am not sure they would have been so much different, because there are other factors that affect, rather than worries about energy and something else like that. But people today think quite different… both of those things (hot water and power generation) in terms of planning... does not affect that much our emphasis in planning, even though we have these resources- hot water and geothermal power and of course hydropower as well in Iceland, does not affect much how we plan the cities or towns in Iceland.* [10][481]**”** The expert in planning had no architectural background, but that of economy and geography. On the other hand, the other interviewee from Iceland with both urban planning and architectural background emphasized the *technological breakthroughs* as requisite to more sustainable built environment [60][482]. When being asked about GE relation to architecture, the interviewee saw no direct connection, but preferred to mention the possibilities for sustainable planning. The interviewee pointed to solar energy´s possibilities, passive house principles as most promising to solve the issues in energy supply in urban planning and architecture. This was in accordance with the first interviewee, who mentioned the works of Hannesson [202][483] on passive design in early 20th century Reykjavik. Both interviewees with

[479] Iceland, Expert in geothermal history, 2016
[480] Iceland, Expert from the geothermal cluster, 2015
[481] Iceland, Expert in urban planning, 2016
[482] Iceland, Expert- Architect and Town Planner, 2016
[483] Hannesson, 1916

background in planning referred to the potentials of solar energy for the future of sustainable planning of cities to being most potent.

The most promising technology refers to GE which does not depend on outside temperatures of the air and is the most stable component if properly treated within the cycle of extraction and re-injection. This is especially true in a combination of many different energy sources in the "energy mix" of smart grids and district heating and power grids. Such technologies are advancing as we speak. The 4th generation thermal grids are able to employ these different sources and make use of them more efficiently, should be better understood by planners and architects and engineers.

As for general population, there is a discrepancy between the latest research on the 4th generation DH technology (4GDH) use and prices of individual GSHP or geothermal drillings for the community or town to endeavor into GDHS installment. Once done, however, it is an ignition force to drive the community to sustainability both in terms of energy use and having indirect influence on physical planning by focusing on a more alleviated development of its resources. This again serves the purpose of combating the energy inert city of today and, indirectly fights sprawling caused by access to cheap transportation fuel and social segregation of neighborhoods.

9.2 Technical and social acceptance reasons to employ GE in cities

The expert from the architectural field based in the USA pointed out the importance of a multifaceted approach to renewable energy and cities [48][484]. The interviewee said that cultural circumstances of the utilization of solar, geothermal, wind power and any other RES form are highly dependent on socio-economic and cultural awareness and are dependent on the understanding of people and their leaders for the benefits of its applications. As this expert has had extensive experience abroad, his opinion refers to international projects both outside of and within the transatlantic region.

Based on the results of interview with Austrian expert in the field of engineering [58][485] there could be far greater value of GE in many mechanical processes used for *cooling* in the future, especially in larger cities. Another interviewee specializing in GE based in Austria confirmed the importance of GE for larger cities. [55][486] The expert had background in geology and vast experience in GE projects in Austria and Germany. The same interviewee saw major changes

[484] USA, Expert in architecture and urban planning, 2017

[485] Austria, Expert- engineer working un industry, 2015

[486] Austria, Expert-geologist and geothermal expert, 2015

in the settlements in Altheim and Braunau/Simbach over the years and confirmed that it was very hard to persuade the communities of these small towns to transfer to geothermal heat based on DHS. This expert confirmed that the initial change in thinking among people and public was of utmost importance for switching to GE in a town or a community. In larger cities, it is easier, as the density of energy demand is greater:

"Interviewer: So in the larger towns as for example Graz or Vienna this would be easier to accomplish (integration of GE)? Interviewee: Yes. It is easier. Of course, there we would have the supply structure completely different. There are big power plants that have big economic influence and they are the ones who do the geothermal projects. And there you could demand the attachment to the net by the individual users. [55][487]"

Regional and economic development expert from USA emphasized the Smart Grid projects in Utica as initial changes to more efficient energy supply of the city. The expert also confirmed the preceding statement that initial projects in RES and SC helped people to accept projects, such as geothermal energy utilization at a city or neighborhood level and opt for these solutions within their households. Also, companies that have installed GSHP in the USA and experts within the sample dealing with technology were in accordance with the statement from the expert based in Austria, that main obstacles to GE utilization in cities may be the resistance to change, or to be more precise, being used to consuming fossil fuels and not being able to see the ways how technologies such as GE contribute to the overall loosening up of the environmental burden created by humans. [43][488] [44][489] [45][490]

Majority of all public administration, regional development and economic experts, as well as private companies' CEOs (being 10 interviewees out of 31 in the overall sample) recognized the same opportunity for enhancing GE applications in cities within the population. "A significant number of interviewees (four out of ten) pointed to the changing situation with accepting "green technologies "among the general population. The new generations are more willing to accept changes in the way that they perceive their environment. This would help boost more geothermal utilizations in cities. Interviewees from companies based in Utica that used geothermal energy in their buildings said that geothermal energy had been beneficial for their refurbishment projects, offering an opportunity and setting an example for other home owners in Utica in the future. They also pointed out to the obstacles, referring to people not believing in something they could not see with their own eyes. This means that having one initial building project utilizing geothermal energy helps to achieve a domino

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[487] Austria, Expert-geologist and geothermal expert, 2015

[488] USA, Expert in engineering involved with geothermal, 2016

[489] USA, Expert in GE utilization, 2016

[490] USA, Expert in geothermal heat pump technology, 2016

effect, causing the building next door to be transformed as well, with the same or other RES and their combinations. [3]"

9.3 Importance of knowledge and experience of experts with pilot projects for understanding and advocating GE´s utilization

Serbian and American based urban planners within the sample were less knowledgeable about GE utilization than their Icelandic counterparts, due to the high level of presence of GE projects throughout time in Iceland. The interviewees from Serbia with planning and architectural background mostly referred to engineering departments of the faculty for answers. However, two out of five gave substantial opinion on GE utilization in the future in Serbia and in Nis, mentioning the known aquifers of GE fluids which are known to have been found in Nis and which have already been suggested for use in reports. Two of five suggested that Nis should engage into urban integration of the fluid on a city scale. Additionally, district heating company representative within the Serbian sample was optimistic about GE use in Nis. This expert had experience with the *test drilling* mentioned in the chapters on Nis (see Results of the interviews and their discussion in context of city`s development) and may have an insight into the capabilities much more than the other experts in the sample who lacked knowledge on city´s initiatives. [54][491] The interviewees with background in engineering and architecture were well informed about sustainability and in comparison to their Icelandic counterparts, showed very similar level of knowledge on advances in sustainable technology. Nevertheless, Serbian experts were more skeptical on large GE applications in Nis.

However, experts with background in engineering in Serbia were more cautious with the idea of supplying the city with geothermal heat, thinking it would be highly expensive solution and that technically the capacities lacked the necessary techno-economic preconditions for actual use. The most interesting was the answer of one of the experts with architectural background:

"*If the geothermal energy would be supplied to the city as you are implying in your question, then what would the power company do? People would lose their jobs there. I do not think it is a good idea. Maybe somewhere else but we are too poor for that.* [212][492]"

Even if one considers the fact that Serbia is the poorest of all analyzed countries and its experts lack expertise in GE and cannot be compared to Iceland or Austria for tax money, its architects and engineers have showed great level of knowledge on the theory of GE

[491] Serbia, Expert from the district heating company, 2015

[492] Serbia, Expert in architecture and energy efficiency, 2015

utilizations. The reason for not accepting GE as an option can be found in their professional indoctrination with views from the 20th century architectural education, focusing on aesthetics and spatial functionalities, rather than supplying buildings with heat or infrastructure.

9.4 Reasons for architects and planners not recognizing GE as a tool of urban planning more broadly

For example, parts on *Ancient Romans´* understanding of architecture testify of the system of thinking in architectural theory adopted throughout Middle ages, New Era all up to the Modern Movement, and up to today, where separation of professions leads to "not being able to see the whole picture in the energy supply chain of buildings and cities". Even though U.S. cities lack initiatives for GE utilization for heating and DH in general, their views on GE as an option are slightly more positive than this is the case in Serbia. Moreover, Serbia has substantial expertise in DHS installed in all major cities and its experience should be valuable for rethinking different DH options in the future, including those with GE as DH source. In the USA, DHS are almost unknown or not common. However, its experts have showed more appreciation for GE, even if only within the sample, showing that with proper policies and political will and understanding for GE, American cities are more easily to adapt to the geothermal market than that of Serbia. Even though the experts from the USA are aware or directly involved with shallow GE utilization, almost all of them have acknowledged the advanced GDHS from Europe and are aware of its importance for those cities. [43] [45] [47] [63] [48] [44][493]U.S. cities still have stronger policies and tax money for expensive technologies such as GE, and may see more GSHP installed in their neighborhood than Serbian cities such as Nis do. Therefore, it is important to advocate the use of GSHP in all countries, especially in countries which do not have ongoing projects or practical applications. In such countries, general population, policy makers and executives must be involved in this process. Especially in cities with underused or abandoned architecture, such as the case was with the analyzed US city, GE technology will make most sense if sustainable development is on the agenda of the community. If not, it is harder to advocate for GE utilization in such communities.

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[493] USA, Expert in engineering involved with geothermal, 2016; USA, Expert in geothermal energy, 2016; USA, Expert in mechanical engineering, 2016; USA, Expert in geothermal heat pump, based in California, 2016; USA, Expert in geothermal heat pump, 2016; USA, Expert in urban and economic development, 2016

Urban morphologies that can easily accept GE are large educational campuses which need DHS for a set of connected buildings. [45][494] Being educational institutions, the distribution of knowledge on GE among its academic population carries weight for the future of GE systems in many cities and in many environments these academics will set their foot on. If accepted as a policy of development, this may be the first contact of geothermal with contemporary use in architectural design and urban planning, which can overcome the standard understanding present over millennia, that they *"have their separate ways",* as mentioned by the experts in the interviews [53][495] [44][496].

9.5 Discussion

In the USA, cities will continue their struggle with urban sprawling by employing concepts such as sustainable communities. Access to cheap fuels for transportation and build-up of the consumer culture is at its highest peak so far. Its sway from such planning with fossil fuels must be based on incentives which support GE and RES in general, at all levels: public, private and in all types of buildings: commercial (with large areas and opportunity to employ sustainable technologies), public (where Governments can directly be the investors into RES´s applications) and housing (both collective and individual). Since for example in Utica, majority of buildings was single family housing, the question of addressing them was as important as public, industrial or collective housing. In North American north-east where NYS and Utica are located, EGS systems for direct use of geothermal heat have coupled with those of GSHP and their networks are most promising. As rural settlements are not present in Utica area (only make couple of percent of the land´s total inhabited area of the region) focus should be on supplying DHS to the city and its neighborhoods, as carriers of urban growth and prosperity.

As for Serbia, its economic struggle and that of its cities disables the GE utilization in cities as GDHS applications. Like in the USA, Serbian CS of Nis would benefit from direct use and EGS exploration possibilities for cities and further GSHP networks' exploration for neighborhoods and utilization of natural springs near rural areas, making up to 45% of the land´s area at present. Conservation of architectural heritage from the past in rural areas can be seen as an opportunity to employ GE in Serbian territory. For this to happen, state-wide

[494] USA, Expert in geothermal heat pump, based in California, 2016

[495] Serbia, Expert in Antique civilizations, 2016

[496] USA, Expert in geothermal energy, 2016

incentives on GSHP, solar technology from RES and energy efficiency of vernacular architecture, focus on compact form´s preservation of existing places and governance of urban heritage wholes are needed. Campus buildings in Serbia are largely neglected urban forms (most cities in Serbia have dispersed University buildings all over the respective city[497]) in terms of RES utilization. Their planning, re-use of old industrial and military facilities to take on the use as educational campuses play an important role in the spreading of knowledge on geothermal energy among the general public, as argued in the interviews´ results. [45] Serbia has abundance of geothermal manifestation with connection to settlement genesis and it should make use of this heritage to advocate for GE´s utilization, despite economic situation and beyond it. Also, binary solutions, such as combined solar and geothermal plants are one of the solutions for central Serbia, according to the interviewee. [51][498] The climate change affecting Serbian cities is creating need for geothermal cooling and this aspect is not to be overlooked in designing GE systems and suggesting solutions for Serbian cities in the future.

Iceland´s policy on a mixed-use and dense city in its Municipal Plan 2030, coupled with GE advanced utilization for GDHS in Reykjavik and other cities is a good example of the way to address cities´ urban planning with RES and energy efficiency. Despite this, consumerism has reached its peak, just like in the USA or Serbia. The genesis of urban form of Reykjavik happened in the last 150 years, simultaneously with infrastructure development and access to cheap resources. Reykjavik must re-examine ideas of passive solar strategies more closely, as should all countries in the sample. The investigation of GSHP in Iceland is forthcoming and the level of de-centralization of the capital area surrounding Reykjavik inter-dependent on the incentives put forward for GSHP and localized energy use, instead of giving power to main power companies, already tapping into the deep geothermal areas and forcing centralization of the energy supply system. The good thing about these power plants is that they allow for waste heat to be used for district heating in Reykjavik and other cities and are disseminators of knowledge on GE utilization among general population and international organizations. Cooperation in GDHS projects has proven to have benefits for smaller communities such as Austrian cities of Braunau/Simbach and has allowed for build-up of an ecology-conscientious small community of Altheim, with people given alternatives and professional experience of public administration employees with GE at the highest level possible. Because of this and because of formation of cleaner city, GE should be favored whenever there is room to do so. This has become the prerequisite for Nis, if one wants to employ a long-term urban planning of new neighborhoods or revival of existing ones, with

497 As this was the case with American Campuses in Ball State University, GSHP or DH systems with GE can be models for many other educational institutions, both in Serbian cities of Nis, Belgrade, Novi Sad, Kragujevac and for many other campuses in the USA, that still haven´t recognized geothermal energy´s value as a local source for heating and cooling of its buildings

498 Serbia, Expert in geothermal energy utilization, 2015

geothermal energy applied in these processes, especially because there are potentials and historical references on GE use in the past in the territory. As a tool, geothermal energy might be in a position to leverage social segregation of the Serbian society by creating additional jobs in the RES industry and upgrading the potential planning/engineering field occupations.

It seems that in Austria, despite having advanced examples of GE utilization for direct use and within GDHS in towns in upper Austria, the general and political power still needs to accept the lessons learned from these successful projects. [55][499] This also applies to the American public [43][500] [44][501] In the USA, however, the value of GE´s utilization can be to fight urban sprawl. Therefore, this fight for incentives from the government, both state and federal, has become an imperative for American cities that will undergo step-by-step urban revival in the future. The role of RES and GE in social de-segregations of neighborhoods by creating livable cities, urban downtowns that offer safety, ecology and identity of the habitats, is likely imaginable.

As seen on Figure 100 some countries, like Iceland, are at the forefront in GDHS application in their cities, but they lag in terms of urban compactness of cities and GSHP use, in comparison to others, such as USA whose cities are struggling to achieve a push in utilizing GSHP and passive design in their cities to achieve SC standards in the future.

There's is a general lagging in innovative district heating grids, even among the countries that have been utilizing DHS for decades, such as Austria, Serbia or even Iceland. However, Iceland has been using cascade thermal energy, and qualifies in the category RES´ use in its infrastructure and energy system, as number one. What can be noticed from the diagram (Figure 100), is that the country must turn to other options such as passive design, solar component in buildings, to intensify the efficiency of its GE resources 'use and to promote more alleviated urban sustainability of its city cores and local smaller communities.

On the other hand, urban compactness in Austrian and Serbian cities and mixed-use of their neighborhoods is an asset from which American counterparts could learn valuable lessons and *vice versa*. Urban sprawling has affected Serbian and Austrian cities, especially in the post-industrial era, where many commuter distances have been created and rural land and villages has been aggregated by larger cities, adding to urban sprawl syndrome.

In the USA, despite the general attitude to use fossil fuels in buildings and especially as a heating source, initiatives to employ GSHP more profoundly and to tackle refurbishments with passive design and mixed use in cities are valuable tools to transform them to livable communities and to achieve less sprawl and strip developments in the future. Based on

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499 Austria, Expert - geologist and geothermal expert, 2015

500 USA, Expert in engineering involved with geothermal, 2016

501 USA, Expert in geothermal energy, 2016

interview results [43] [47] [46] [45][502], the opportunities for GSHP in the northern USA are larger than that of supplying whole cities with GDHS. However, the experts from Iceland with engineering background involved with deep geothermal projects, advocated and preferred this option for the future of cities [50][503] [61][504] and were dedicated to exploring EGS options. This probably has to do with the fact that in the USA where most of the experts advocating GSHP come from, DHS are not commonly used, and individual ownership prevails, whereas Iceland relies on European experiences and culture of using DHS as a reference.

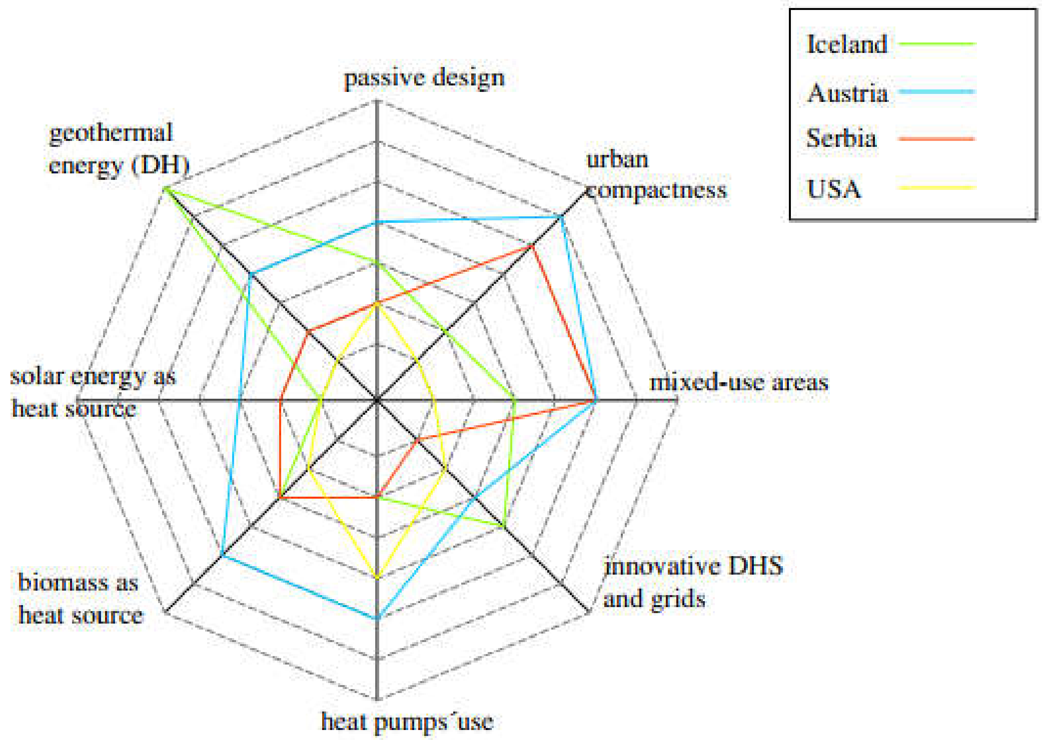

Figure 100, Comparison between countries analyzed by levels of utilization of different sustainability aspect employed in their cities (at center of the diagram values represent the lowest levels-0, outer octagons representing highest levels-8); Source: A. Jovanovic[505]

In general, cultural factors do seem to play a role in DHS appreciation. GDHS is more easily imaginable if it has been used in any form of district heat supply. On the other hand, it seems that where GE was historically used over the course of the history, the 20th century sudden

502 USA, Expert in engineering involved with geothermal, 2016; USA, Expert in geothermal energy, 2016; USA, Expert in mechanical engineering, 2016; USA, Expert in geothermal heat pump, based in California, 2016; USA, Expert in geothermal heat pump, 2016

503 Cornell University guest speaker, 2016

504 Iceland, Expert coming from an engineering company, 2016

505 Mixed-use neighborhoods advocated by Jacobs are currently not achieved by GDHS applications

growth of cities and industrialization has led to abandoning of buildings utilizing these resources and conceiving them as outdated (such as the case study of Nis and its Roman and Turkish architecture). The culture of public baths made use of GE wherever this was possible[506]. However, since this architecture has vanished due to changing communities in the 20th century, GE is once again being imported as "new goods" from countries with rich experience in GE use for DH[507] and forced into planning. It seems that there is no need for that, especially in countries which could rely on their historic use of GE as a local, readily available resource, used by local population and creating architectural identities for those communities and their neighborhoods, and culture for years and centuries.

[506] All countries in the sample had some sort of *public bath culture* present throughout their historical development

[507] Such as Iceland

10 In the end- further research topics

Unlike the situation in history of architectural development, where the idea of compact cities has been abandoned, especially in the 20th century with the invention of car and mass transportation, GE´s introduction into urban planning is significant for the re-examination of these principles, as any other locally available resource is.

Changing current approach in planning cities in direction of network creations of their power supply and heat supplies (such as 4GDH and Smart City projects) is important for the adoption of RES in cities. Now, it is the only method for advocating changes in cities which have suffered decrease in population and have faced post-industrial legacies. Architecture and planning of such cities are prone to further sprawling syndrome. Even though GE fits perfectly within the urban planning changes, such as SC approaches seen in the case study of Utica, more and more cities worldwide are facing urban growth where the role of geothermal energy is limited to a couple of demonstration projects and has no back-up from the urban planning departments of cities´ governments. Thus, a decentralization of urban areas, creating concepts of urban-rural landscapes, especially in the transitional countries such as Serbia, to serve as models of urban re-development, should not be excluded. There is a certain danger in focusing solely on sustainable cities and neglecting the prevail of rural or suburban culture in the years to come. In some societies, these cultures and subcultures are carriers of identity, heritage and habitat´s appreciation, sometimes more than that is the case in cities. Technology such as GE must be able to find a way to break through the end-consumer of such habitats too, if one wants to see global change in GHG emissions and if long-term sustainable approach wants to be addressed. For this, there needs to be a will of the governing bodies to employ change and thus create the options for the end-dweller to decide if he/she wants or doesn´t want this change to be his/her wish too. Finally, people need to realize the need to fight for their urban settings, including buildings and neighborhoods. If so, they could easily realize that by using GSHP in their homes, or by applying GDHS in their neighborhood, they can do something about it and contribute to the planet´s sustainability on a small scale.

Another important aspect are the buildings and their energy efficiency. Making sophisticated DHS and also GDHS in cities in the future, whether by using GSHP, EGS or direct use of geothermal fluid, such as the case is in CS in Iceland and Austria presented, there is large need to make these buildings energy efficient, for these systems to pay off. Investing into solar architecture and passive design at the level of urban planning is what GE industry needs to use as a backup to its technological breakthroughs. Lastly, there is a huge debate on the role of DHS and its efficiency in cities lately, according to the experts' opinions. Small scale solutions and abandoning the idea of inefficient systems or usual methodology for building infrastructure in cities is the key to profound GE utilization as well.

The value of GE for the cities is in the fact that it should be made available to the poorest populations of cities and different urban and rural neighborhoods. For this to happen, a technological breakthrough still needs to occur. The prices of Heat Pumps that could be installed almost everywhere on the Earth are still unimaginable for most of the population in cities, despite the decrease in pricing over the last years and decades. Moreover, the efficiency of GSHP has made an enormous breakthrough in efficiency (CoP) ever since it first appeared on the market. Because of this, incentives are more than ever needed globally for geothermal energy to be utilized for the benefit of communities. Unfortunately, the realization of GE projects is relying on decisions by political institutions and non-experts in engineering, who tend not to understand the essence of the technology or the need to keep on investing into R&D in the long run, beyond the 4-year mandates and beyond best case examples in cities. Also, there is a great governmental and private and public companies´ interest in continuing to use fossil fuels in power, transportation and for heating and cooling systems of cities, because the maintenance of such systems is easier, and skills needed for their functioning are already present, unlike for those of GE or other RES.

Lastly, cities are future habitats of mankind. Therefore, architectural research should be more dedicated to exploring different options for its sustainability in the long run. This seems of utmost importance now when the role of an architect has been misinterpreted in the society and connected to aesthetics, scenography and "special effects" of urban settings, urban design and interior giving visual pleasure to "pleasure-consuming society".

The clever approaches of the past civilizations, such as Roman technology and systems described in the first chapters of this thesis should be given attention in future architectural research on technology. A long-term planned use of GE in buildings and urban planning is important both for understanding of its capabilities and demonstrating its applicability to other cities.

As mentioned by Jacobs, Giovannoni, Geddes (and Rodwell), a diverse and dense city may be a model of planning which one should aspire to. Based on the results of the research discussed in previous chapters, turning to these types of cities, with neighborhood planning revivals, is a concept upon which GE´s more profound utilization will be possible to achieve in the future too. The value of centralized GSHP for mixed-use neighborhood planning is especially notable for further research on GE in cities. This could make cities less energy-inert and their neighborhoods spatially more equitable in terms of favorable urban identity.

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12 Description of figures

13 Description of tables

14 Abstract

The presented research was motivated by the question, whether the changes in energy supply technologies used for buildings, such as renewable energy sources (RES) and geothermal energy (GE), could have impact on the appearance of the buildings and urban settlement structure. The objective of the research was to acquire substantial knowledge on GE use in buildings, which would allow architects to re-think the role of a RES in design of cities. The above stated was carried out by means of expert interview model. The hypothesis in the paper was that current sporadic and unsystematic use of technology in cities could be addressed in a more profound way. The concrete examples chosen for cross comparison were different in terms of the types of GE potentials and levels of use (ground source heat pumps and geothermal district heating systems). The North American mid-sized city of Utica, NY, the Easter European city of Nis, Serbia, the capital of Iceland, Reykjavik and Austrian towns of Braunau/Simbach and Altheim, were compared. The analysis of the urban morphology of the case studies was elaborated.

The results of more advanced case studies showed that GE planning was of informative nature only, in terms of urban planning. The American and East European cities were less prone to using local GE source, as compared to the advanced cases studies, such as Austrian towns, which illustrated the presence of these projects. Research on cultural factors that could influence a single end-consumer to turn to GE is recommended for the future of GE utilization in cities. Changes in demography (millennial generation) can initiate a broader use of GE, as well as pilot projects, which demonstrate that GE *does* exist in a city.

In conclusion, GE´s utilization is supportive of the ongoing changes in cities and their planning, which involve proposals for thermal and power grids and solar architecture. One way of supporting GE utilization in cities is through investing in energy efficiency and turning to passive design in urban planning. This combination is especially important for many cities worldwide which are facing urban sprawl and transport issues. Finally, the dying out of many rural places in Eastern Europe could be mitigated by investing into GE infrastructure. This aspect of GE can help address a more alleviated urban development of urban and rural wholes. Finally, the value of centralized GSHP for mixed-use neighborhood planning is especially notable for further research on GE in cities.

Key words: urban planning, passive design, geothermal energy, district heating, ground source heat pumps, cities

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Dedicated to my family

Aleksandar Jovanovic, *DI*