applied sciences

MDPI

Article

Renewable Energy Sources in a Post-Socialist Transitional Environment: The Influence of Social Geographic Factors on Potential Utilization of Very Shallow Geothermal Energy within Heating Systems in Small Serbian Town of Ub

Nikola Jocić [1,*], Johannes Müller [1], Tea Požar [2] and David Bertermann [1]

1 GeoCentre of Northern Bavaria, Friedrich-Alexander-University Erlangen-Nuremberg, Schlossgarten 5, 91054 Erlangen, Germany; johannes.j.mueller@fau.de (J.M.); david.bertermann@fau.de (D.B.)
2 Institute of Geographical Research on Migration & Transition, Otto-Friedrich-University Bamberg, Am Kranen 1, 96047 Bamberg, Germany; tea.pozar@uni-bamberg.de
* Correspondence: nikola.jocic@fau.de; Tel.: +49-9131-85-23332

Received: 9 March 2020; Accepted: 7 April 2020; Published: 15 April 2020

Abstract: Energetic stability is a precondition for a regular functioning of society and economy. Actual climate change raised the awareness of population and policy makers about the importance of exploited energy sources. Renewable energy sources are revealed as the solution which should satisfy both needs—a need for energetic stability, as well as a need for producing 'clean' and 'sustainable' energy, and therefore reduce humans' influence on the climate change. Very shallow geothermal energy offers wide range for utilization, among others for heating and cooling living spaces. This article shows potentials of low temperature heating system networks in a small Serbian town of Ub. In addition to technical possibilities, this article combines geographical and social, as well as political and economic circumstances in the town of Ub, which emerge as a result of a complex (post-socialist) transitional vortex.

Keywords: renewable energy sources; very shallow geothermal potential (vSGP); low temperature district heating; post-socialist transitional environment

1. Introduction

This article focuses on the influence of social geographic factors on possible installation of renewable heating solutions in Serbia. Therefore, it takes in account legacies of post-socialist transitional society. Crucial point of interest is also air pollution which Serbia and neighbouring countries face every winter and which are largely caused by individual heating solutions powered by fossil fuels. Report of Serbian Environmental Protection Agency shows that small and individual heating solutions participate in emitting 57% of PM10 particles, as well as 75% of PM2.5 particles in Serbia [1]. Their replacement by renewable heating solutions would be an important step in reducing air pollution.

Thus, there are two layers that should be considered. First, most of Serbian households do not have district heating and are therefore suitable terrain for introducing new heating systems. Mainly, those households are located in smaller Serbian towns and rural areas. Second, socio-economic development of Serbia is heterogeneous. This article tends to present results for an average environment which can be representative for other Serbian towns, as well as for countries with similar socio-economic structure. These two stances revealed Ub as a representative case-study for this research. Ub is a town which does not have district heating system, but mostly various individual heating solutions. According to the socio-economic spatial differentiation of Serbia, Ub is a municipality placed around average [2]. Additionally, on the traditional regional inequality gradients in the Republic of Serbia (These gradients include the following directions: (I) north-south; (II) centre-periphery; (III) and urban areas with closer surroundings—rural areas [2] (p. 97)) the municipality of Ub, with its geographical location and structural characteristics, is placed between extreme values.

Ub is a small town in Serbia with population of around 6000. The entire Municipality of Ub which includes surrounding settlements has population of just over 29,000. While post-socialist geographical studies mostly address post-socialist capitals and major cities, this article tends to explore post-socialist trajectories in a small (semi-)peripheral town in a transitional environment. The example of Ub shows tendencies which should be applicable to other similar settings.

Accordingly, this article elaborates possible utilization of very shallow geothermal potentials in the field of space (and district) heating. In addition to scientific literature and statistical reports, websites and online reports are used as sources for the purpose of this article. Authors conducted a survey with 40 households in Ub concerning their opinion about actual heating status and potentials for geothermal heating. Such approach was necessary in order to get an actual overview of the situation. Soil analysis was provided by the *ThermoMap* Viewer (www.thermomap.eu) [3] which offered results presented in the article.

After a brief presentation of geothermal energy potentials, as well as district heating systems worldwide and in Serbia, this article focuses on the case-study of Ub. One specific test field in the town of Ub is selected to examine possibilities for utilization of (very) shallow geothermal energy in the terms of heat conductivity. Finally, there is a discussion about the advantages, but also about the limits that must be overcome in order to build and exploit such a system. Results are presented through three level analysis—technical, economic, as well as social and political limitations. Some general courses and patterns, valid for the most transitional cases, are extracted at the end.

2. Energetic Stability and Renewable Energy Sources

Adequate global energy consumption is one of the most important factors for achieving an adequate global average level of quality of life. However, this is not an easy goal to achieve, as the current global energy mix is 80% fossil fuel based [4]. Such massive dependence of fossil fuels rises issues which are not of newer date such as accessibility to fossil fuel and its uneven distribution, as well as altering the climate [5]. Fossil fuel is a negative solution for climate with respect to its greenhouse gases emission [6]. The extraction of fossil fuels is the biggest cause of climate change, which is furthermore not only an environmental issue, but also a social one [7]. Discussions regarding reducing CO_2 emissions and restraining climate change are of global significance, and one of the very important topics the society faces.

It is also crucial to keep stable energetic supply. Renewable energy sources (RES) are considered as a suitable alternative which minimizes environmental impacts and generates minimum secondary waste [8], as well as offers efficient solution for sustainable development [9].

Even though most of energy consumption in the world is provided by fossil fuels [10], part is still supplied from energy sources such as renewables and nuclear energy [11]. Nuclear energy is produced without CO_2 or methane emission, but is still not a sustainable energy source as it is not clear how to deal with the nuclear waste [12,13]. That leaves renewable energy sources as a choice for sustainable energy future [14]. Reports show that share of renewables in a global energy production is growing every year e.g., [15]. Renewable energy mix include solar, thermal, photovoltaic, bioenergy, hydro, tidal, wind, wave and geothermal energy [16,17].

As it is always clearer that humans and their actions are the primary cause of climate change (There is almost unanimous consensus regarding this topic among climate scientists. More than 97 percent of them understand that humans are the primary cause of climate change [18]), renewable energy sources permanently rise the attention of general public, policy makers, as well as scientific community. Renewable energy sources provide energy in different areas. One of their most valuable contribution is in electricity generation [19,20]. Technologies regarding storage and supply of electricity got in this way are constantly improving [21–23]. Furthermore, solutions including renewable energy and transportation are increasing [24]. Renewable energy solutions are also contributing in heating and cooling systems [25].

According to data of REN21 [15], participation of renewables in general global energy consumption was around 18%: 7.5% is covered by traditional biomass, while 10.6% is covered by modern renewables. Further division within modern renewables shows that 4.2% of total final energy consumption comes from biomass/solar/geothermal heat, 3.6% hydropower, 2% wind/solar/biomass/geothermal/ocean power and 1% comes from biofuels for transport. The rest is covered from fossil fuels (around 80%) and nuclear energy (around 2%). The share of renewables in total final energy consumption rose in period 2006–2016 for 2.3% (Traditional biomass did not increase its share, while modern renewables increased their share for 4.5%) [15] (p. 32). Renewable energy is mostly contributing in the sector of power consumption with at around a quarter of total power consumption. Renewables participated with around 10% in total energy used for heating and cooling, as well as with around 3% in the energy used for transport [15] (pp. 32–33).

3. Geothermal Energy and How Is It Used

Geothermal energy is the energy stored as heat in Earth's interior [26]. It can be used in various fields—electrification, space and district heating, space and district cooling, greenhouse heating, in aquaculture and in industry [27]. Geothermal energy for electricity generation has been produced commercially since 1913, and its utilization increased rapidly in the last decades [10]. The earliest known commercial use of geothermal energy through district heating system originates from 14th century in Chaudes-Aigues Cantal, France [28]. Geothermal energy supports agriculture around the world by greenhouse heating [29–31].

Geothermal energy can be captured from different depths and layers of the Earth. Normally, one can make a distinction between deep and shallow geothermal energy [32] (p. 38). Antics and Sanner [33] suggest a classification which comprises the following geothermal categories: geothermal power, deep geothermal resources (direct use) and shallow geothermal resources (mainly heat pumps). Shallow geothermal energy is energy acquired from sources on less than 400 m depth [34]. It is mostly captured from Earth's layers no deeper than 150 m, and definitely no deeper than 400 m. Layers deeper than 400 m belong to the category of deep geothermal energy [32] (p. 38). Shallow geothermal energy is a good alternative for fossil fuels in heating and cooling of buildings [35]. Very shallow geothermal potentials (up to 10 m deep) are gaining more attention in the last years (This layer can be further divided into three depth layers: first (0–3 m), second (3–6 m) and third (6–10 m) [36] (pp. 227–228)) [36]. In general, every soil is suitable for very shallow geothermal applications [3]. Several parameters, such as thermal conductivity of soil, water content, pore size distribution and bulk density, have crucial influence on efficiency of very shallow geothermal applications and create different local potentials related to the prevailing soil conditions [36,37].

Installed thermal power for direct geothermal utilization is growing every year at a compound rate (In the period 2005–2009 it grew at a rate of 11.4% annually) [38]. Most of geothermal power capacities in 2018 were located in the United States, Indonesia, Philippines, Turkey, New Zealand, Mexico, Italy and Iceland [15] (pp. 80–83). New capacities in 2018 are installed mostly in Turkey and Indonesia. United States and Iceland are countries which are following. Except Turkey, Italy and Iceland, European countries generally do not use geothermal energy for producing electric power. They use it mostly for heating systems, and shallow geothermal applications are the largest sector of geothermal energy use in Europe [39].

Geothermal heating can be used in two ways—as a direct heating, and as indirect heating and cooling via geothermal heat pumps [40] (p. 341). The direct use of geothermal energy refers to geothermal direct heating plants, geothermal heat in agriculture, geothermal heat in balneology, as well as geothermal heat in other and individual buildings. European countries exploiting most of geothermal direct use in 2018 were Iceland, Italy, Hungary, France and Germany [39].

Leading countries using geothermal heat pumps in 2004 were the United States, Sweden, Germany, Switzerland, Canada and Australia, respectively [40] (p. 345). Ground source heat pumps in Europe in 2018 were mostly installed in Sweden, Germany, France, Finland and Switzerland [39].

4. District Heating Systems

District heating systems are efficient and centralized systems for heating residential buildings. They are generally considered to be an ecologically efficient way of heating [41], and can be also operated by using geothermal sources [42]. "District Heating (DH) systems provide continuous heating through pipes from heat generators which are located away from individual apartment units" [43] (p. 73). In addition to district heating, there are also individual heating options [44].

District heating systems went through various forms [45]. As Lund et al. [46] wrote, there are four generations of district heating. The first generation (1880s–1930s) used steam as the heat carrier. The second generation (1930s–1970s) used pressurised hot water, while the third generation (since 1970s) still used pressurised water as the heat carrier, but often on temperatures below 100 °C. The fourth generation of district heating is characterized by low working temperature and a low heating loss, and aspire to connect to renewable energy resources [47].

The number of district heating systems, especially in Northern Europe, is raising since the beginning of the 21st century [48]. It is estimated that there are around 6000 of such systems in Europe, while those in Iceland are the most representative examples—they cover more than 50% of dwellings, and thanks to a geothermal source they have no CO_2 emissions [49]. Nevertheless, around 13% of EU27 heat market for buildings is covered by district heating systems [50].

Still, there are numerous barriers for spreading geothermal district heating systems. As the experiences from the United States showed, most prominent barriers are relatively affordable prices of gas and oil, as well as already developed electricity and fuel delivery infrastructure [51] (p. 804). Additionally, Thorsteinsson and Tester [51] (pp. 811–812) distinguish three groups of barriers for its development such as technical, economic and social/political feasibility.

5. Heating Systems and Renewable Energy Solutions in Serbia

After the fall of the Berlin wall, socialistic countries focused on political and economic transition. Part of transition included also the transition of the energy sector, which needed legislation, restructuring, liberalization and privatization, as well as investment [52]. Indeed, the transition in the energy sector did not contain different elements from those in other sectors. Compared to many other ex-socialist countries, transition in Serbia started later because of complex issues regarding territorial conflicts, civil war, economic embargo and political crisis. Even though transitional process started in 2000, there are still legacies originating from socialist era, as well as new-developed trends from transitional era, which strongly influence actual social, political and economic dynamics in Serbia [53,54].

The biggest part of energy consumption in Serbia goes to residential and commercial buildings with around 46%, and they are followed by industry and transport [55] (p. 36). Energy in buildings is mostly used for heating (around 62%), followed by energy spent for lighting and warm water [55] (p. 37).

Many post-socialist countries still rely on district heating systems operating on fuel oil and are built during socialist era [56]. Cities with a high population density are more favourable places for district heating because of lower distribution costs per household.

> "With higher number of heating consumers and a small object density, i.e., large number of apartments per object, district heating system is a better solution". [57] (p. 151)

It is also expected that post-socialist states reduce plant-level CO_2 emission during the transitional process [58]. Investing in RES can also be motivated by reducing citizens' energy bills [59].

Cost approach was not always considered in socialist states and their former planned economies [49] (p. 626). Most local heating plants in former Yugoslavia were fuelled by heavy oil and/or natural gas [60,61]. District heating systems are present in bigger Serbian cities, while individual heating solutions prevail in small towns [62]. District heating in Belgrade for instance [63] is in the phase of renovation and gains the importance again after the turbulent 1990s. Still, district heating systems, not only in Serbia, but in the whole region of Western Balkans, are based on using fossil fuels [64] (p. 30).

District heating in the Republic of Serbia is used in the bigger urban centres, and is supplied by heat produced by larger heating plants. This heating systems mostly uses coal, wood, oil fuels and gaseous fuels as primary energy source [65]. District heating plants were built in the socialist era, as a heating solution for growing cities. District heating systems are located in 55 cities, towns and municipalities in Serbia [66].

The situation in small Serbian cities is different because they are not dependent on huge heating systems. Their heating structure is very heterogeneous, but also more flexible than in residential complex of big cities. Smaller towns in Serbia, like Ub for instance, do not have such large heating plants, and they are not dependent on district heating systems. Therefore, smaller cities in Serbia are favourable areas for introduction and usage of renewable energy solutions.

According to data from 2002 [67], dominant energy source for space heating was coal. Around 36% of energy for space heating came from this source. Today natural gas is the most favourable fuel for domestic heating, while traditional fuels dominate in rural and low-income urban households [68]. Around 22% of occupied dwellings in Serbia are connected to district heating systems, around 21% use central heating, while around 57% are without district and central heating (see Figure 1). Đurić et al. [55] (p. 36) wrote that 26% of the households are connected to district heating systems, 30% use electricity for heating, 20% wood, 15% coal, while less than 6% use gas.

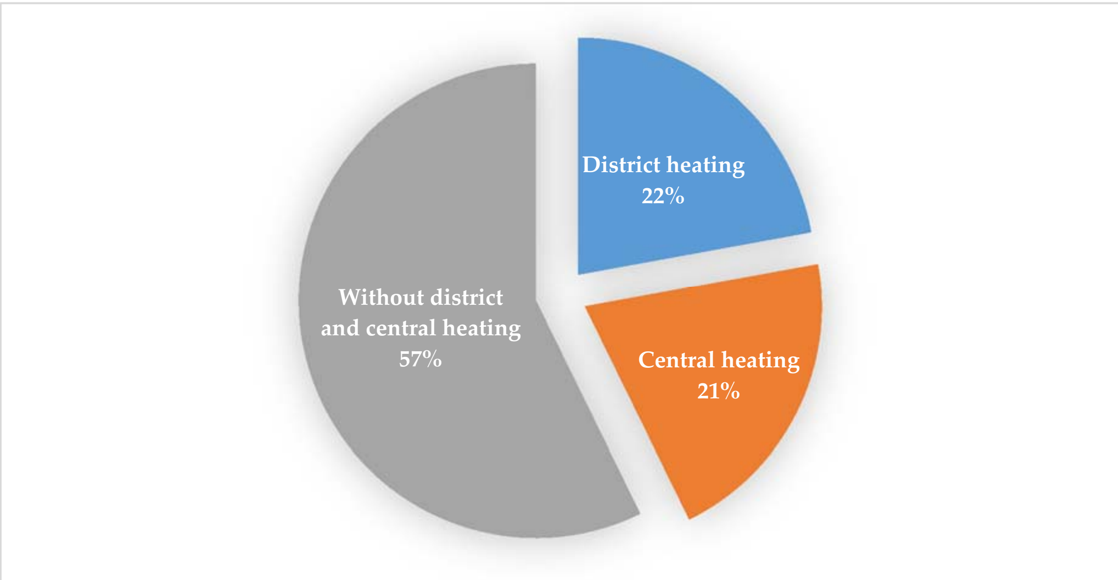

Figure 1. Occupied dwellings according to the type of heating in the Republic of Serbia. The graph is altered by rounding up the values [65] (p. 19).

Already at the beginning of 21st century it was clear that energy consumption in Serbia is outdated—including low energy efficiency, with high costs, as well as unfavourable influence on the environment and health [69]. Such findings are still applicable in this region [70]. Inadequate energetic efficiency of the most houses in Serbia should not be overlooked. Most of the houses have significant heat losses due to unsatisfactory walls, facades, doors and windows [71].

> “New energy use patterns and technologies need to be adopted if the economy is to grow and poverty is to be reduced”. [69] (p. 5)

Renewable energy solutions have been under discussion as potential solutions in Serbia for some time, but are not yet used in practice at a higher level. For example, in 2012 only 0.1% of

Serbian households had installed solar powered domestic hot water systems [72]. Solar energy development in Serbia dates back to 1970s, but its usage is still limited to not numerous locations [73]. Potentials of heating systems using geothermal water are not new in Serbia [74], and geothermal sources could replace significant amount of fossil fuel [75]. Many articles and researches concerning exploitation of geothermal energy in Serbia are oriented to hydro-thermal potentials [76–81]. In general, excluding hydro power (There are two big hydro power production complexes in Serbia [82]. One is located on the Danube (Hydro power plants Djerdap 1 and Djerdap 2), while the second is on the rivers Drina and Lim (Drinsko-Limske Hydro power plants)), the share of RES in total energy production in Serbia is less than 1% [68].

Average age of district heating infrastructure is over 25 years, and the system is based on fossil fuels. There are high heat losses as pipes with 25 years of age cannot have the newest insolation standards too. There are actual plans for reducing the share of liquid fuel and coal, and improving the role of RES [83].

6. Ub—Social Geographic and Energetic Overview

Ub is municipality and town in the central part of Serbia. It is located around 60 km south-western from Serbian Capital Belgrade (see Figure 2). Ub is part of the Kolubara District and is located around 30 km from the Kolubara District's administrative centre Valjevo. According to the census data from 2011, the municipality population was 29,101 [84] (p. 60). There were 9176 [85] (p. 98) households in the municipality, with 3.17 members in average.

According to the same census data, the urban settlement of Ub has a population of 6191 inhabitants [84] (p. 60). There were 2095 households [85] (p. 98), with 2.96 average members per household. In the urban settlement there were 2692 [85] (p. 99) dwellings in total. Only 2078 of them are occupied, while others were temporarily unoccupied, abandoned or used occasionally [86] (pp. 152–153). The average area of occupied dwelling is around 87 m^2.

More than half of the municipality's active workers have agriculture, forestry or fishing as their primary occupation [87] (p. 122). Other important activities for the local economy are mining, especially lignite mining, as well as manufacturing. According to the data on the official website of the municipality (www.opstinaub.org.rs), there are huge reserves of lignite in the municipality of Ub. Opening of the open-pit lignite mine is planned in the following years, and should be one of the biggest in Europe.

Available data show that in the municipality of Ub there are 2653 occupied dwellings with central heating, and 6466 occupied dwellings without district and central heating installations [65] (pp. 36–37). Vast majority of those dwellings use coal and wood for heating. Only energy raw material worth of mentioning beside coal and wood is electricity. Around 5% of dwellings get heating from that source. Other sources are used only by several households. More than 72% of dwellings in the urban settlement of Ub are located in the residential building with one dwelling, around 8% are located in the residential building with two dwellings, while around 20% are in the buildings with three or more dwellings (see Figure 3). More than 80% of all urban dwellings in Ub are located on the ground floor [88] (p. 444). A simple look to the facades in the town of Ub shows that many households use air conditioners for cooling and partly heating spaces.

Our survey with the inhabitants of Ub showed that around 73% of the households use wood and coal for heating. The rest use pellet and electricity. An average household in Ub spends around one third of yearly budget only for heating. Doors and windows are in average older than ten years, and it is made mostly of wood and PVC. Around half of the respondents are not satisfied with their insulation, around 40% are satisfied, while around 10% of them do not have insulation (e.g., Figure 4). Coal and wood heaters cause most of the air pollution in urban areas and are increasing health threats [91,92]. Their replacement by sustainable energy solutions should therefore be on the top of the priority lists.

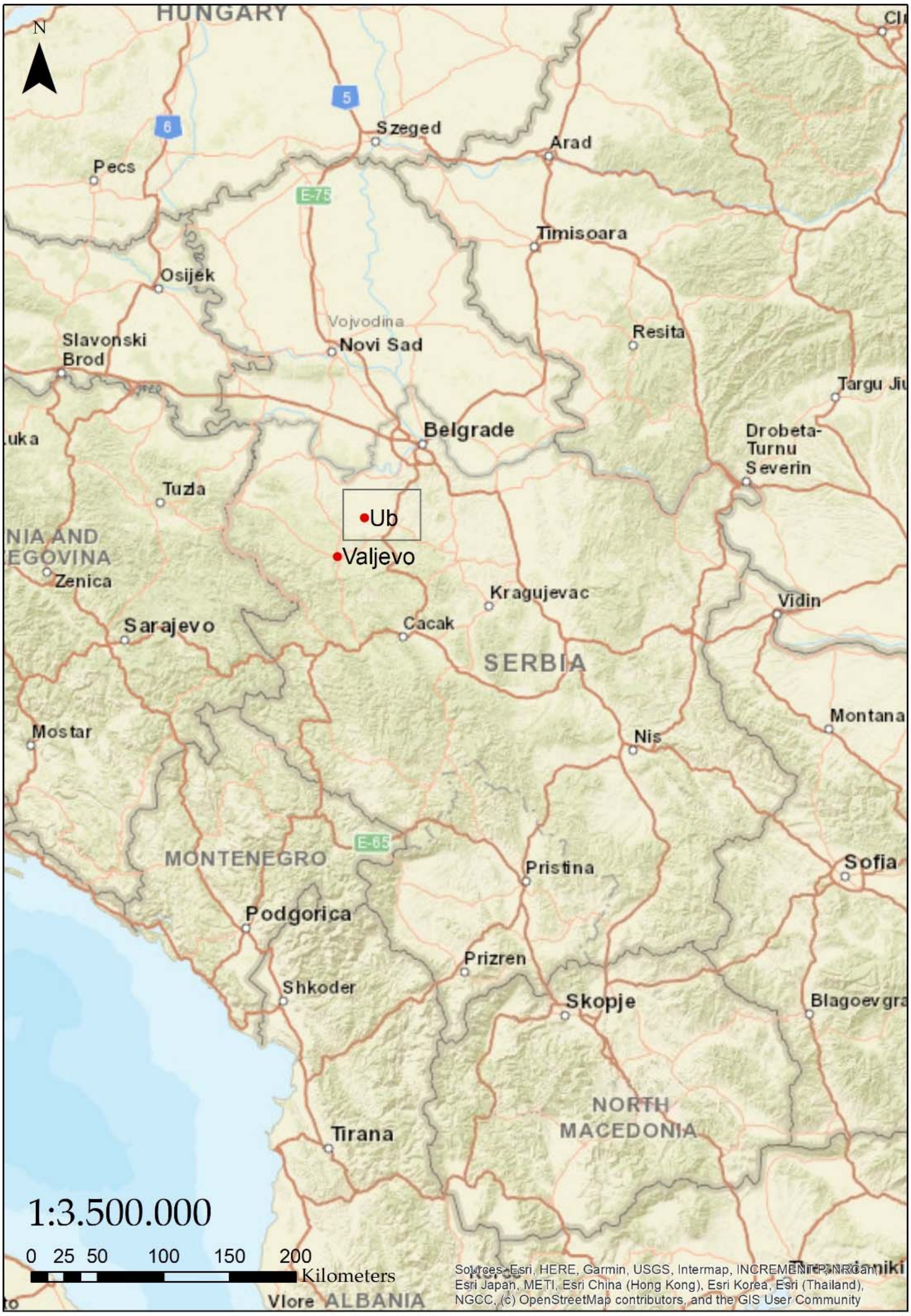

Figure 2. The location of Ub within the Republic of Serbia.

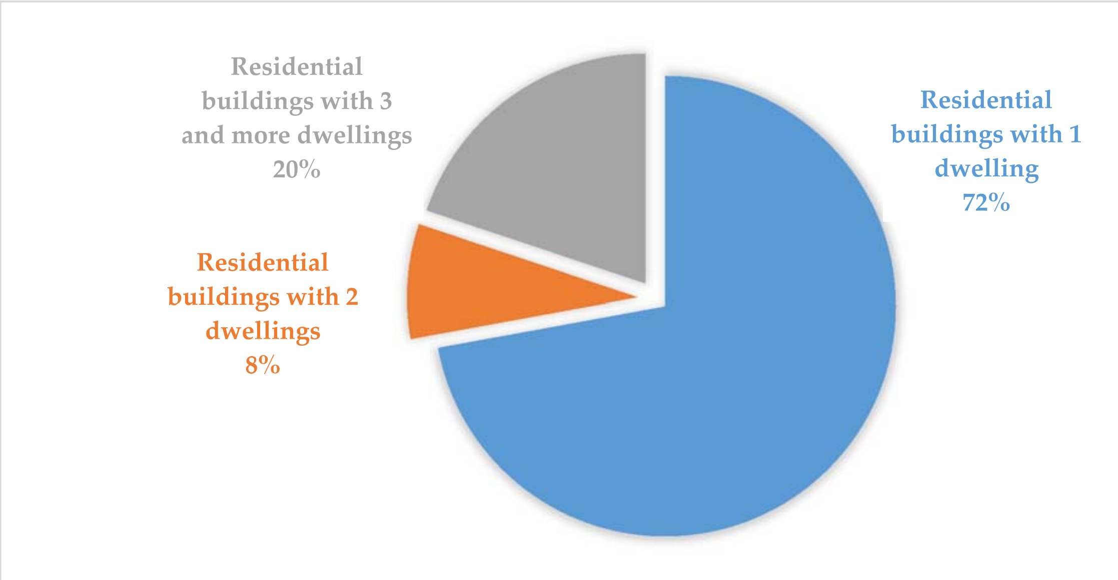

Figure 3. Dwellings by type of building in the urban settlement of Ub. The graph is altered by rounding up the values [88] (p. 234).The census data from 2011 show also sources of livelihood in Ub. Almost 40% of inhabitants of the urban settlement Ub are dependent persons, while around 35% of them have salary or other allowance based on work as primary source of livelihood, and around 18% has pension [89] (pp. 58–59). According to the date from the Statistical Office of the Republic of Serbia [90] average gross monthly salary in the Republic of Serbia in the December 2019 was 82,257 RSD (around 700 EUR), and in average 59,772 RSD net (around 508 EUR). Average monthly salaries in the municipality of Ub were on a lower level—74,182 RDS gross (around 631 EUR), and 53,687 RSD net (around 457 EUR).

Figure 4. Variety of house construction in Ub—old house in the first row and a new building behind them (source: own photo).

7. Very Shallow Geothermal Potentials of Ub

Geothermal based heating (and cooling) solutions require certain favourable characteristics of the soil. Very shallow geothermal systems for instance require favourable petrophysical parameters realized in thermal heat conductivity of the soil. In order to explore thermal heat conductivity in Ub, the soil was analysed by *ThermoMap* Viewer (Results presented in this part of the paper were obtained through *ThermoMap* Viewer and its option vSGP Report. *ThermoMap* Viewer is available at www.thermomap.eu). *ThermoMap* was a project funded by European Commission with the aim of mapping the very Shallow Geothermal Potentials (vSGP) in Europe [3]. It shows that the territory of the urban area of Ub splits almost equally in soil with 1.07 W/(mK) thermal conductivity, and soil with 1.21 W/(mK) thermal conductivity (These values are calculated by using Kersten formulas [93]) (see Figure 5).

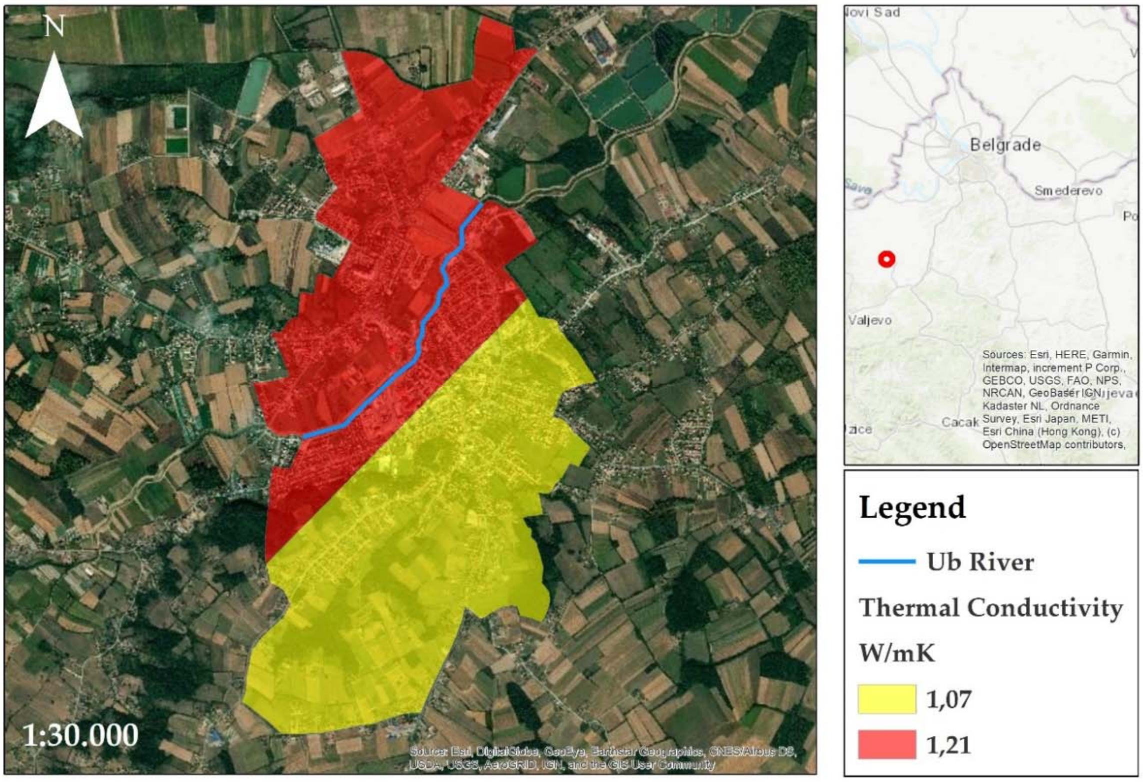

Figure 5. Very shallow geothermal potentials in the urban area of Ub (own map based on *ThermoMap*).

One area in the eastern part of the urban area of Ub is located, and chosen as a potential test field (see Figure 6). This test field is used for the purposes of this article to present an estimated model and show how very shallow geothermal potentials in Ub could be activated. This test field has around 26,000 m^2. It is surrounded by around 90 households, and located on the edge of the urban settlement. Most of the houses on the potential network consist of one or two households. It would make the planning process and eventual connection to the network less complicated, because of less parties involved in a process.

According to *ThermoMap*, a slope on the test field which is less than 15° is a favourable condition for very shallow geothermal system in a hydraulic point of view for e.g., horizontal collectors or special forms like heat baskets (see Figure 7).

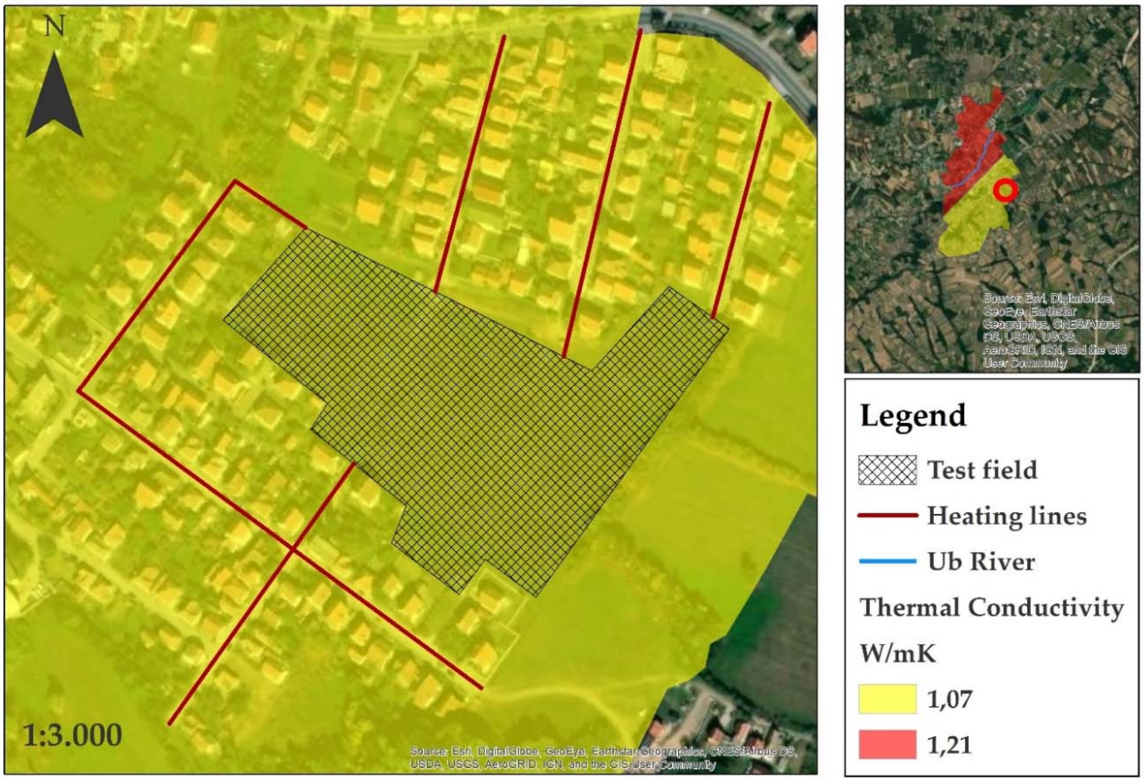

Figure 6. Potential test field in Ub and its surrounding (own map based on *ThermoMap*).

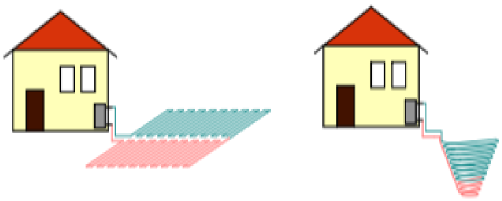

Figure 7. Horizontal collectors and heat baskets [94] (p. 240).

ThermoMap reveals also climatic conditions for the test field (see Table 1). Mean annual air temperature for the chosen site is 12.08 °C, while annual precipitation is 760 mm with maximal monthly precipitation in June. The nearest official meteorological station of the Serbian Hydrometeorological Service [95] shows similar results (see Table 1). Accordingly, climatic conditions of the selected area are favourable for utilization of vSGP—there are humid conditions.

Table 1. Climatic conditions—Ub and Valjevo.

Location	Mean Ann. Temp.	Ann. Precipitation
Ub (Test field) [1]	12.08 °C	760 mm
Valjevo (Meteorological station) [2]	11.40 °C	788 mm

[1] Climatic conditions for Ub (Test field) are taken from *ThermoMap* Viewer Report for the fitting location (Geographic coordinates: 44.45° latitude and 20.08° longitude). [2] Climatic conditions for Valjevo (Meteorological station) are official data of the Republic Hydrometeorological Service of Serbia in the period 1981–2010 (Geographic coordinates: 44.19° latitude and 19.55° longitude).

The following results from the *ThermoMap* Viewer Report for the Test field in Ub also show no limitations for the utilization of the vSGP. Dominant soil type according to the World Reference Base is Luvisol ("Luvisols have a higher clay content in the subsoil than in the topsoil, as a result of pedogenetic processes (especially clay migration) leading to an argic subsoil horizon. Luvisols have high-activity clays throughout the argic horizon and a high base saturation in the 50–100 cm depth" [96] (p. 165)).

This soil type should not have restrictions regarding the installation of (very) shallow geothermal systems. The dominant grain size distribution is medium according to the European Soil Data Centre (ESDAC) soil texture classification.

Thermal heat conductivity is defined essentially by texture, water content and bulk density of the soil [37]. *ThermoMap* predefines bulk density (relation between mass and volume) for selected area at 1.3 g/m^3. On the basis of humid conditions, a possible thermal conductivity value is 1.07 W/(mK). In general, these petrophysical parameters indicate that the possible test field is suitable for the utilisation of the very shallow geothermal potential in terms of heat conductivity.

It is assumed that average consumption of energy for heating in Serbia is 150 kWh/m^3. Estimation of the Energy Agency of the Republic of Serbia [97] shows that one household needs an energy of around 9000 kWh annually (For this analysis are taken following characteristics: 60 m^2 apartment—average insulation, 180 days of heating, 20 °C during 16 h per day in the whole apartment). If the potential test field in Ub (Figure 6) would be covered with horizontal collectors, it is assumed that it could receive around 1,300,000 kWh of energy annually (Here is estimated that horizontal collector provides 50 kWh/m^2 annually. This estimation is based on relevant literature [98,99], as well as our practical experience on various locations). Estimated annual energy heating consumption of 9000 kWh allows an assumption that this field could provide enough energy for heating (and cooling) around 140 households (The calculation is based on the following values: area covered by the test field (26,000 m^2), potential energy provided by the test field if it would be covered by a (very) shallow geothermal system (around 50 kWh/m^2 annually or around 1,300,000 kWh in total), as well as estimated annual energy consumption by household (9000 kWh)). Investment in the insulation and improving energetic efficiency of the houses would increase possible number of households in the system's network.

8. Discussion

Introducing of district heating systems could have three levels of possible limitations—technical, economic and social/political [51]. These three levels could be applied also on the involving of low temperature district heating and cooling networks. The analysis of the low temperature district heating potentials and their possible utilization in the town of Ub, allows that some general dynamics to be abstracted.

8.1. Technical Limitations

Technological solutions for utilizing very shallow geothermal potentials, and their involvement as heating and cooling system are already developed and installed [100]. These solutions are not territorially exclusive, and therefore could be also used in the example of Ub. Furthermore, very shallow geothermal systems like collectors or special forms like heat baskets a relatively simple and cheap to install and have usually less restrictions like vertical drillings (see Figure 8).

Natural geothermal potentials in Ub also support the installation of a very shallow geothermal system. In the case of the test field chosen for this article, it should be possible to eliminate technical restrictions. Additionally, Ub (and many other small post-socialist towns) does not have large district heating system inherited from socialist era. Correspondingly, Ub is not locked in a system which has to 'stay alive' like many major post-socialist cities are [102]. There is another advantage that cities like Ub have compared to larger urban centres: utilizing very shallow geothermal potentials free areas (fields) are necessary. Ub has many agricultural areas especially on the edges of the town, and they could be activated as a source for geothermal heating (and cooling) systems. These areas can be used for agriculture also after the installation of the heat exchanger, as examples from other similar projects proof [100]. Specifically, if heat exchangers are placed on the depth of 1.5–5m, they do not affect agricultural production on the fields where they are installed. Agricultural activities can be processed as it was before collectors are incorporated.

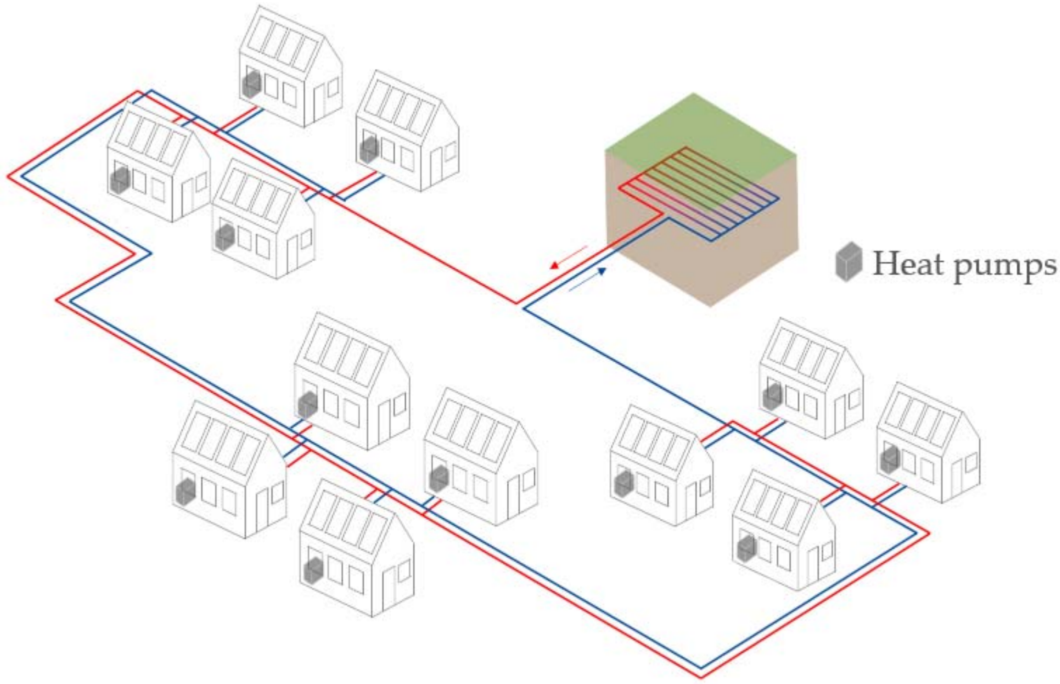

Figure 8. Low temperature district heating (very) shallow geothermal system with horizontal collectors and heat pumps [101] (p. 19).

8.2. Economic Limitations

Still, there are limitations which should be overcome in order to utilize very shallow geothermal potentials. The municipality of Ub, as well as its population, are not the wealthiest in the Republic of Serbia and therefore a public or private investment would be necessary. Furthermore, there must be organized maintenance of a potential heating network. Consequently, it makes funding possibilities and sources limited, at least on a local level. Therefore, economic limitations are coming to the fore. Building insulation is crucial factor for effective geothermal heating systems. As our survey showed, our respondents are not completely satisfied with the insulation quality of their houses and apartments. More than half of respondents are interested in renovating their wall insulation as well as doors and windows, and around 90% of them would welcome subsidies for that purpose.

Swedish experience showed what happens when fossil fuel got more expensive: district heating developed in urban areas, and heat pumps appeared as a solution in suburban and rural areas [103]. The Swedish state played a very important role in the development of district heating systems based on renewable sources by introducing high taxes on fossil fuels [103]. The question is if it could be a solution for Ub or Serbia in general. There are some limitations for such development. It is already mentioned that average net salaries in Serbia and Ub are just over 500 and 450 €, respectively. Those incomes are significantly lower than in Western countries (such as Sweden) where such policy brought a positive result. Rising energy prices in Serbia would mean significant upset for household's budget, and certainly would trigger social issues.

According to the data of Eurostat [104], prices of natural gas (including taxes) for household consumers in the first half of 2019 were almost twice so expensive in EU-28 than in Serbia. Serbian prices were still on the similar level of some EU members such as Romania and Hungary. Prices of electricity in Serbia compared to prices in EU-28 for the same period were on around three times lower level [105]. Coal is also playing an important role in Serbian energy balance. All energy prices are in responsibility of Serbian governments and government-owned companies [64] (pp. 69–70). Governmental subsides in this sector are instruments for keeping social peace and it is unlikely that such policy can be sustainable in the frames functioning in the EU [106].

District heating systems and heating prices in Serbia are in the jurisdiction of municipalities [64] (p. 69). That is a chance for local authorities to proactively act on the energy market. Community owned district heating systems can be also found in the United Kingdom for instance [107]. This is particularly true for smaller communities such as Ub, which do not yet have already built and inherited supply systems that they need to maintain in order to ensure continuity and ultimately social peace. A small low temperature district heating network could be also built as a result of private investment. It is hardly to be expected that low-income households, like most households in Ub, could invest in the development of such a system. There is a chance for local authorities to act. Numerous subsidies on a republic level in fossil fuels could be turned to local subsidies in renewable sources on a local level. If such local initiatives tend to become successful, there is still an important issue to be overwhelmed—the power of central political elites in Serbia which dispute (in most cases) local authorities to act without restriction and centralized control [108] (p. 93).

Low temperature district heating network needs heat pumps beside collectors and network grid. Geothermal heat pumps bring also economic benefits in the cases of low prices of electricity [40]. Compared to other European countries, that condition is fulfilled in Serbia.

Operators has to be aware that the district heating can be successfully deployed when the price is concurrent comparing to other heating possibilities [109]. Energy Agency of the Republic of Serbia [97] provided a price overview of heating depending of an energy source used for heating (This analysis assumes that needed energy for a heating season is 9000 kWh per apartment). The most affordable energy source is wood, followed by natural gas and low-quality coal, while the electricity is the most expensive energy source. Different economic analyses e.g., [40,110] show that heating using geothermal heat pumps is more cost efficient than other types of heating, especially if further heating seasons are taken in account, as well as rising price of wood, coal or oil.

8.3. Social and Political Limitations

In addition to economic, there are social limitations for low temperature district heating and cooling network development. The population of the town of Ub is not informed enough about developments in this sector, and such systems are not known to the majority of the population. Our survey showed that almost every respondent has positive opinion regarding geothermal heating systems, but they do not have enough knowledge about that topic. Our respondents are also not informed how those systems work, as well as how the systems could be installed. Local political leadership should be involved in resolving some of these problems. The precondition is that the local political elites are open and supportive regarding new energetic solutions. They should be involved in the developing populations' awareness to renewable solutions through for example workshops, education programs and public presentations. Different levels of power, including local and republic authorities, should develop regulations, as well as provide guaranties regarding new renewable energy source and systems (Similar proposals can be found by Millar, Burnside and Yu [109] regarding district heating in the United Kingdom).

9. Conclusions

The example of the town of Ub shows certain tendencies and conditions for successful implementation of low temperature district heating and cooling. Benefits of such development should be clear. This heating and cooling system provides ecologic and sustainable energy delivery. Therefore, such possible development could bring two crucial advantages for the town of Ub—first, de-carbonised energy source, and second, stabile energy supply. In this way, two of the most important goals for the future orientation of the energy sector would be achieved, thus defining how the energy debate should proceed in the future. It is also clear that such a development cannot be the result of individual efforts by any side involved in the process, but requires a joint effort by various stakeholders. The main role should be played by local authorities and local population, and the whole process should be based on their mutual partnership on achieving common goals.

Author Contributions: Conceptualization, investigation and writing, N.J.; investigation, T.P.; review and editing, J.M., D.B. and T.P.; funding acquisition, D.B. All authors have read and agreed to the published version of the manuscript.

Funding: The APC was funded by The University Library of Erlangen-Nuremberg and the University Administration's Department of Research Services and Research Development, as well as by ThermoMap EU Project (Grand agreement ID: 250446).

Conflicts of Interest: The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

References

1. Agencija za Zaštitu Životne Sredine. *Kvalitet Vazduha u Republici Srbiji 2018. Godine*; Ministarstvo Zaštite Životne Sredine: Belgrade, Serbia, 2019. Available online: http://www.sepa.gov.rs/download/izv/Vazduh2018_final.pdf (accessed on 12 November 2019).
2. Winkler, A. Measuring Regional Inequality: An Index of Socio-Economic Pressure for Serbia. *Collect. Pap. Fac. Geogr. Univ. Belgrade* **2012**, *60*, 81–102.
3. Bertermann, D.; Klug, H.; Morper-Busch, L. A pan-European planning basis for estimating the very shallow geothermal energy potentials. *Renew. Energy* **2015**, *75*, 335–347. [CrossRef]
4. Jess, A.; Kaiser, P.; Kern, C.; Unde, R.B.; von Olshausen, C. Considerations concerning the Energy Demand and Energy Mix for Global Welfare and Stable Ecosystems. *Chem. Ing. Tech.* **2011**, *83*, 1777–1791. [CrossRef]
5. Fulkerson, W.; Judkins, R.R.; Sanghvi, M.K. Energy from Fossil Fuels. *Sci. Am.* **1990**, *263*, 128–135. [CrossRef]
6. Ellabban, O.; Abu-Rub, H.; Blaabjerg, F. Renewable energy resources: Current status, future prospects and their enabling technology. *Renew. Sustain. Energy Rev.* **2014**, *39*, 748–764. [CrossRef]
7. Guerrero, D.G. The Limits of Capitalist Solutions to the Climate Crisis. In *The Climate Crisis: South African and Global Democratic Eco-Socialist Alternatives*; Satgar, V., Ed.; Wits University Press: Johannesburg, South Africa, 2018; pp. 30–46. [CrossRef]
8. Panwar, N.L.; Kaushik, S.C.; Kothari, S. Role of renewable energy sources in environmental protection: A review. *Renew. Sustain. Energy Rev.* **2011**, *15*, 1513–1524. [CrossRef]
9. Dincer, I. Renewable energy and sustainable development: A crucial review. *Renew. Sustain. Energy Rev.* **2000**, *4*, 157–175. [CrossRef]
10. Fridleifsson, I.B. Status of geothermal energy amongst the world's energy sources. *Geothermics* **2003**, *32*, 379–388. [CrossRef]
11. Starr, C.; Searl, M.F.; Alpert, S. Energy Sources: A Realistic Outlook. *Science* **1992**, *256*, 981–987. [CrossRef]
12. Carter, L.J. *Nuclear Imperatives and Public Trust: Dealing with Radioactive Waste*, 1st ed.; Resources for the Future: Washington, DC, USA, 1987.
13. Saling, J.H.; Fentiman, A.W. *Radioactive Waste Management*, 2nd ed.; Taylor & Francis: New York, NY, USA, 2001.
14. Goldemberg, J. The promise of clean energy. *Energy Policy* **2006**, *34*, 2185–2190. [CrossRef]
15. REN21. *Renewables 2019 Global Status Report*; REN21 Secretariat: Paris, France, 2019.
16. Johansson, T.B.; Kelly, H.; Reddy, A.; Williams, R.; Burnham, L. *Renewable Energy: Sources for Fuels and Electricity*; Island Press: Washington, DC, USA, 1993.
17. Boyle, G. *Renewable Energy*, 2nd ed.; Oxford University Press in Association with the Open University: Oxford, UK; New York, NY, USA, 2004.
18. Romm, J. One Fact about Climate Change That's Worth Repeating. Available online: https://thinkprogress.org/one-fact-about-climate-change-thats-worth-repeating-39ffa04bdf0e/ (accessed on 11 November 2019).
19. Haas, R.; Resch, G.; Panzer, C.; Busch, S.; Ragwitz, M.; Held, A. Efficiency and effectiveness of promotion systems for electricity generation from renewable energy sources—Lessons from EU countries. *Energy* **2011**, *36*, 2186–2193. [CrossRef]
20. Ahmad, S.; Tahar, R.M. Selection of renewable energy sources for sustainable development of electricity generation system using analytic hierarchy process: A case of Malaysia. *Renew. Energy* **2014**, *63*, 458–466. [CrossRef]
21. Kaldellis, J.K.; Zafirakis, D. Optimum energy storage techniques for the improvement of renewable energy sources-based electricity generation economic efficiency. *Energy* **2007**, *32*, 2295–2305. [CrossRef]

22. Denholm, P.; Ela, E.; Kirby, B.; Milligan, M. *Role of Energy Storage with Renewable Electricity Generation*; National Renewable Energy Laboratory: Golden, CO, USA, 2010. [CrossRef]
23. Sen, R.; Bhattacharyya, S.C. Off-grid electricity generation with renewable energy technologies in India: An application of HOMER. *Renew. Energy* **2014**, *62*, 388–398. [CrossRef]
24. Mathiesen, B.V.; Lund, H.; Connolly, D.; Wenzel, H.; Østergaard, P.A.; Möller, B.; Nielsen, S.; Ridjan, I.; Karnøe, P.; Sperling, K.; et al. Smart Energy Systems for coherent 100% renewable energy and transport solutions. *Appl. Energy* **2015**, *145*, 139–154. [CrossRef]
25. Cansino, J.M.; del Pablo-Romero, M.P.; Román, R.; Yñiguez, R. Promoting renewable energy sources for heating and cooling in EU-27 countries. *Energy Policy* **2011**, *39*, 3803–3812. [CrossRef]
26. Barbier, E. Geothermal energy technology and current status: An overview. *Renew. Sustain. Energy Rev.* **2002**, *6*, 3–65. [CrossRef]
27. Dickson, M.H.; Fanelli, M. *Geothermal Energy: Utilization and Technology*; Earthscan: Sterling, VA, USA, 2005.
28. Bloomquist, R.G. Geothermal space heating. *Geothermics* **2003**, *32*, 513–526. [CrossRef]
29. Adaro, J.A.; Galimberti, P.D.; Lema, A.I.; Fasulo, A.; Barral, J.R. Geothermal contribution to greenhouse heating. *Appl. Energy* **1999**, *64*, 241–249. [CrossRef]
30. Bakos, G.C.; Fidanidis, D.; Tsagas, N.F. Greenhouse heating using geothermal energy. *Geothermics* **1999**, *28*, 759–765. [CrossRef]
31. Lund, J.W.; Freeston, D.H. World-wide direct uses of geothermal energy 2000. *Geothermics* **2001**, *30*, 29–68. [CrossRef]
32. Stober, I.; Bucher, K. *Geothermie*; Springer: Berlin/Heidelberg, Germany, 2014.
33. Antics, M.; Sanner, B. Status of Geothermal Energy Use and Resources in Europe. In Proceedings of the European Geothermal Congress, Unterhaching, Germany, 30 May–1 June 2007.
34. Hähnlein, S.; Bayer, P.; Blum, P. International legal status of the use of shallow geothermal energy. *Renew. Sustain. Energy Rev.* **2010**, *14*, 2611–2625. [CrossRef]
35. Hähnlein, S.; Bayer, P.; Ferguson, G.; Blum, P. Sustainability and policy for the thermal use of shallow geothermal energy. *Energy Policy* **2013**, *59*, 914–925. [CrossRef]
36. Bertermann, D.; Klug, H.; Morper-Busch, L.; Bialas, C. Modelling vSGPs (very shallow geothermal potentials) in selected CSAs (case study areas). *Energy* **2014**, *71*, 226–244. [CrossRef]
37. Bertermann, D.; Müller, J.; Freitag, S.; Schwarz, H. Comparison between Measured and Calculated Thermal Conductivities within Different Grain Size Classes and Their Related Depth Ranges. *Soil Syst.* **2018**, *2*, 50. [CrossRef]
38. Lund, J.W.; Freeston, D.H.; Boyd, T.L. Direct utilization of geothermal energy 2010 worldwide review. *Geothermics* **2011**, *40*, 159–180. [CrossRef]
39. Sanner, B. Summary of EGC 2019 Country Update Reportson Geothermal Energy in Europe. In Proceedings of the European Geothermal Congress, Den Haag, The Netherlands, 11–14 June 2019.
40. Self, S.J.; Reddy, B.V.; Rosen, M.A. Geothermal heat pump systems: Status review and comparison with other heating options. *Appl. Energy* **2013**, *101*, 341–348. [CrossRef]
41. Köfinger, M.; Basciotti, D.; Schmidt, R.R.; Meissner, E.; Doczekal, C.; Giovannini, A. Low temperature district heating in Austria: Energetic, ecologic and economic comparison of four case studies. *Energy* **2016**, *110*, 95–104. [CrossRef]
42. Hepbasli, A. A review on energetic, exergetic and exergoeconomic aspects of geothermal district heating systems (GDHSs). *Energy Convers. Manag.* **2010**, *51*, 2041–2061. [CrossRef]
43. Yoon, T.; Ma, Y.; Rhodes, C. Individual Heating systems vs. District Heating systems: What will consumers pay for convenience? *Energy Policy* **2015**, *86*, 73–81. [CrossRef]
44. Münster, M.; Morthorst, P.E.; Larsen, H.V.; Bregnbæk, L.; Werling, J.; Lindboe, H.H.; Ravn, H. The role of district heating in the future Danish energy system. *Energy* **2012**, *48*, 47–55. [CrossRef]
45. Lake, A.; Rezaie, B.; Beyerlein, S. Review of district heating and cooling systems for a sustainable future. *Renew. Sustain. Energy Rev.* **2017**, *67*, 417–425. [CrossRef]
46. Lund, H.; Werner, S.; Wiltshire, R.; Svendsen, S.; Thorsen, J.E.; Hvelplund, F.; Mathiesen, B.V. 4th Generation District Heating (4GDH). *Energy* **2014**, *68*, 1–11. [CrossRef]
47. Lund, H.; Østergaard, P.A.; Chang, M.; Werner, S.; Svendsen, S.; Sorknæs, P.; Thorsen, J.E.; Hvelplund, F.; Mortensen, B.O.G.; Mathiesen, B.V.; et al. The status of 4th generation district heating: Research and results. *Energy* **2018**, *164*, 147–159. [CrossRef]

48. Torchio, M.F.; Genon, G.; Poggio, A.; Poggio, M. Merging of energy and environmental analyses for district heating systems. *Energy* **2009**, *34*, 220–227. [CrossRef]
49. Werner, S. International review of district heating and cooling. *Energy* **2017**, *137*, 617–631. [CrossRef]
50. Connolly, D.; Lund, H.; Mathiesen, B.V.; Werner, S.; Möller, B.; Persson, U.; Boermans, T.; Trier, D.; Østergaard, P.A.; Nielsen, S. Heat Roadmap Europe: Combining district heating with heat savings to decarbonise the EU energy system. *Energy Policy* **2014**, *65*, 475–489. [CrossRef]
51. Thorsteinsson, H.H.; Tester, J.W. Barriers and enablers to geothermal district heating system development in the United States. *Energy Policy* **2010**, *38*, 803–813. [CrossRef]
52. Mrkić Bosančić, M.; Gvero, P.; Ibrulj, J.; Husika, A.; Vasković, S. Komparacija sistema daljinskog grijanja gradova zemalja u tranziciji. *Mašinstvo* **2017**, *4*, 193–202.
53. Winkler, A. *Räumliche Differenzierung und Lokale Entwicklung: Divergente Transformationspfade am Beispiel Serbischer Kommunen*; University of Bamberg Press: Bamberg, Germany, 2015; ISBN 978-3-86309-318-1.
54. Jocić, N. *Creative Economy in a Post-Socialist Transitional Context: Spatial Distribution of Creative Activities and Their Interrelation with Urban Milieus in City Quarters of Belgrade*; University of Bamberg Press: Bamberg, Germany, 2019.
55. Đurić, S.; Krstić, M.; Jović, K. *Serbien und Montenegro. Energieeffizienz in Gebäuden. Zielmarktanalyse 2019 mit Profilen der Marktakteure*; Deutsch-Serbische Wirtschaftskammer (AHK Serbien): Belgrade, Serbia, 2019.
56. Lund, H.; Hvelplund, F.; Kass, I.; Dukalskis, E.; Blumberga, D. District heating and market economy in Latvia. *Energy* **1999**, *24*, 549–559. [CrossRef]
57. Brkić, D. Natural gas heating in Serbian settlements according to urbanity parameters. *Facta Univ. Ser. Archit. Civ. Eng.* **2008**, *6*, 139–153. [CrossRef]
58. Jorgenson, A.K.; Longhofer, W.; Grant, D.; Sie, A.; Giedraitis, V. The effects of economic and political integration on power plants' carbon emissions in the post-soviet transition nations. *Environ. Res. Lett.* **2017**, *12*, 044009. [CrossRef]
59. Mutani, G.; Vicentini, G. Buildings' energy consumption, energy savings potential and the availability of renewable energy sources in urban spaces. *J. Civ. Eng. Archit. Res.* **2015**, *2*, 1102–1115.
60. Grković, V. Optimizations for district heating of Belgrade from the Kolubara energy and industrial complex. *Energy* **1989**, *14*, 747–756. [CrossRef]
61. Dondur, N.; Cvetković, M. Economic appraisal of environmental effects: District heating project case study in Former Yugoslavia. *Proj. Apprais.* **1997**, *12*, 119–125. [CrossRef]
62. Vasiljević, P.; Savić, R. Rehabilitation of District Heating in Serbia. Available online: https://www.lsta.lt/files/seminarai/080911_Budapestas/Serbia1.pdf (accessed on 13 November 2019).
63. Osmanoski, T.; Valdevit, D.; Karličić, N. Gašenje individualnih kotlovskih postrojenja i povezivanje na toplovodnu mrežu sistema daljinskog grejanja. *Zb. Međunarodnog Kongr. Procesnoj Ind. Procesing* **2017**, *30*, 311–322. [CrossRef]
64. United Nations Development Programme (UNDP). *Fossil Fuel Subsidiesin the Western Balkans*; UNDP Regional Bureau for Europe and the Commonwealth of Independent States (RBEC): New York, NY, USA, 2011.
65. Republički Zavod za Statistiku Srbije. *Stanovi Prema Vrsti Energenata za Grejanje: Podaci po Opštinama i Gradovima = Dwellings by the Type of Raw Material Used for Heating: Data by Municipalities/Cities*; Republički Zavod za Statistiku Srbije: Belgrade, Serbia, 2013. Available online: https://publikacije.stat.gov.rs/G2013/Pdf/G20134023.pdf (accessed on 11 November 2019).
66. Stevanović, V.; Banjac, M. Energetska efikasnost daljinskog grejanja u Srbiji. *Zb. Međunarodnog Kongr. KGH* **2017**, *46*, 64–69.
67. Mariottini, F.; Georgiev, Z. The Challenges, Dynamics and Activities in the Building Sector and Its Energy Demand in the Republic of Serbia. D2.1 of WP2 from Entranze Project. 2013. Available online: https://www.researchgate.net/publication/314151872_The_Challenges_Dynamics_and_Activities_in_the_Building_Sector_and_its_Energy_Demand_in_Serbia_ENTRANZE_D21_of_WP2_from_Entranze_Project (accessed on 13 November 2019).
68. Brkić, D. Energy Situation in the Republic of Serbia. *Preprints* **2018**, 2018080279. Available online: https://doi.org/10.20944/preprints201808.0279.v1 (accessed on 14 November 2019).
69. United Nations Development Programme (UNDP). *Stuck in the Past—Energy, Environment and Poverty in Serbia and Montenegro*; United Nations Development Programme: Belgrade, Serbia, 2004.

70. Rehm Bogunović, D. Introduction: Still Stuck in the Past. Energy and Climate Change in South East Europe. *Perspect. Polit. Anal. Comment.* **2018**, 3–4. Available online: https://rs.boell.org/sites/default/files/perspectives_srb_2018.pdf (accessed on 13 November 2019).
71. Germany Trade & Invest. Serbiens Gebäude verbrauchen zu viel Energie. Available online: https://www.gtai.de/GTAI/Navigation/DE/Trade/Maerkte/suche,t=serbiens-gebaeude-verbrauchen-zu-viel-energie,did=2294950.html (accessed on 2 December 2019).
72. Stevanović, S.; Pucar, M. Financial measures Serbia should offer for solar water heating systems. *Energy Build.* **2012**, *54*, 519–526. [CrossRef]
73. Radivojević, A.; Pavlović, T.; Milosavljević, D.; Đorđević, A.; Pavlović, M.; Filipović, I.; Pantić, L.; Punišić, M. Influence of climate and air pollution on solar energy development in Serbia. *Therm. Sci.* **2015**, *19*, 311–322. [CrossRef]
74. Antonijević, D.; Komatina, M. Sustainable sub-geothermal heat pump heating in Serbia. *Renew. Sustain. Energy Rev.* **2011**, *15*, 3534–3538. [CrossRef]
75. Golušin, M.; Ivanović, O.M.; Bagarić, I.; Vranješ, S. Exploitation of geothermal energy as a priority of sustainable energetic development in Serbia. *Renew. Sustain. Energy Rev.* **2010**, *14*, 868–871. [CrossRef]
76. Kostić, M.; Jovanović Tončev, M.; Vukadinović, P. Iskorišćenost obnovljive geotermalne energije—Primer Vranjske banje. *Ecologica* **2014**, *21*, 587–591.
77. Andrić, N. Geothermal energy and its application opportunities in Serbia. *Tehnika* **2015**, *70*, 804–808. [CrossRef]
78. Dragović, N. Opravdanost upotrebe geotermalnih resursa u proizvodnim procesima i za zagrevanje objekata. *Zb. Međunarodnog Kongr. KGH* **2017**, *46*, 263–269.
79. Janković, Z. Economic and Energetic Effects of Geothermal Energy Usage in the Agribusiness Sector of the Vojvodina Region. Doctoral Dissertation, University Business Academy in Novi Sad, Novi Sad, Serbia, 2019. Available online: http://nardus.mpn.gov.rs/bitstream/handle/123456789/11562/Disertacija.pdf?sequence=1&isAllowed=y (accessed on 28 November 2019).
80. Nenković, M.; Pucar, M. Supstitucija tradicionalnih izvora energije korišćenjem geotermalnih izvora i energije biomase u banjama Srbije–teritorijalna rasprostranjenost i mogućnosti primene. *Zb. Međunarodnog Kongr. KGH* **2019**, *36*, 129–138.
81. Martinović, M.; Andrejević, S.; Saljnikov, A.; Komatina, M.; Rudonja, N.; Stevanović, Z. Hidrogeotermalni resursi i toplotne pumpe—toplifikaciona alternativa srbije. *Zbornik Međunarodnog Kongresa o KGH* **2019**, *39*, 314–320.
82. Eloektroprivreda Srbije. Hydro Power Plants. Available online: http://www.eps.rs/eng/Poslovanje-EE/Pages/Hidroelektrane.aspx (accessed on 2 December 2019).
83. Republic of Serbia, Ministry of Mining and Energy. *Energy Sector Development Strategy of the Republic of Serbia for the Period by 2025 with Projections by 2030*; Republic of Serbia, Ministry of Mining and Energy, Department for Strategic Planning in Energy Sector: Belgrade, Serbia, 2016.
84. Republički Zavod za Statistiku Srbije. *Uporedni Pregled Broja Stanovnika 1948, 1953, 1961, 1971, 1981, 1991, 2002. i 2011: Podaci po Naseljima = Comparative Overview of the Number of Population in 1948, 1953, 1961, 1971, 1981, 1991, 2002 and 2011: Data by Settlements*; Republički Zavod za Statistiku Srbije: Belgrade, Serbia, 2014. Available online: https://publikacije.stat.gov.rs/G2014/Pdf/G20144008.pdf (accessed on 12 November 2019).
85. Republički Zavod za Statistiku Srbije. *Uporedni Pregled Broja Domaćinstava 1948–2011. i Stanova 1971–2011. Podaci po Naseljima = Comparative Overview of the Number of Households in 1948–2011 and Dweilings in 1971–2011*; Republički Zavod za Statistiku Srbije: Belgrade, Serbia, 2014; ISBN 978-86-6161-110-0. Available online: https://publikacije.stat.gov.rs/G2014/Pdf/G20144009.pdf (accessed on 12 November 2019).
86. Republički Zavod za Statistiku Srbije. *Broj i Površina Stambenih Jedinica: Podaci po Naseljima = Number and the Floor Space of Housing Units: Data by Settlements*; Republički Zavod za Statistiku Srbije: Belgrade, Serbia, 2013. Available online: https://publikacije.stat.gov.rs/G2013/Pdf/G20134006.pdf (accessed on 12 November 2019).
87. Republički Zavod za Statistiku Srbije. *Delatnost: Podaci po Opštinama i Gradovima = Industry: Data by Municipality and Cities*; Republički Zavod za Statistiku Srbije: Belgrade, Serbia, 2014. Available online: https://publikacije.stat.gov.rs/G2014/Pdf/G20144002.pdf (accessed on 12 November 2019).

88. Republički Zavod za Statistiku Srbije. *Stanovi Prema Vrsti Zgrade: Podaci po Opštinama/Gradovima = Dwellings by the Type of Building: Data by Municipalities/Cities*; Republički Zavod za Statistiku Srbije: Belgrade, Serbia, 2013. Available online: https://publikacije.stat.gov.rs/G2013/Pdf/G20134018.pdf (accessed on 12 November 2019).
89. Republički Zavod za Statistiku Srbije. *Izvori Sredstava za Život: Podaci po Opštinama i Gradovima = Sources of Livelihood: Data by Municipality and Cities*; Republički Zavod za Statistiku Srbije: Belgrade, Serbia, 2014. Available online: https://publikacije.stat.gov.rs/G2014/Pdf/G20144004.pdf (accessed on 12 November 2019).
90. Statistical Office of the Republic of Serbia. Average Monthly Earnings by Municipality of Residence of Employees. Available online: https://data.stat.gov.rs/Home/Result/2403040103?languageCode=en-US&displayMode=table (accessed on 6 March 2020).
91. Robinson, D.L. Australian wood heaters currently increase global warming and health costs. *Atmos. Pollut. Res.* **2011**, *2*, 267–274. [CrossRef]
92. Mardones, C.; Sanhueza, L. Tradable permit system for PM2.5 emissions from residential and industrial sources. *J. Environ. Manag.* **2015**, *157*, 326–331. [CrossRef]
93. Kersten, M.S. *Thermal Properties of Soils*; University of Minnesota, Institute of Technology, Engineering Experiment Station: Minneapolis, MN, USA, 1949.
94. Buday, T.; Lázár, I.; Csákberényi-Nagy, G.; Bódi, E.; Tóth, T. Effect of the Solar Radiation on Underground Temperature Values and Heat Supply Around a Ground Coupled Heat Pump Based on Meteorological Data, Debrecen. In *Perspectives of Renewable Energyin the Danube Region*; Ortiz, W., Somogyvári, M., Varjú, V., Fodor, I., Lechtenböhmer, S., Eds.; Institute for Regional Studies, Centre for Economic and Regional Studies, Hungarian Academy of Sciences: Pécs, Hungary, 2015; pp. 239–250. Available online: https://www.researchgate.net/publication/279186182_Effect_of_the_Solar_Radiation_on_Underground_Temperature_Values_and_Heat_Supply_Around_a_Ground_Coupled_Heat_Pump_Based_on_Meteorological_Data_Debrecen (accessed on 30 March 2020).
95. Republic Hydrometeorological Service of Serbia. Valjevo-Srednje Mesečne, Godišnje i Ekstremne Vrednosti 1981–2010. Available online: http://www.hidmet.gov.rs/latin/meteorologija/stanica_sr.php?moss_id=13269 (accessed on 28 March 2020).
96. Food and Agriculture Organization of the United Nations. *World Reference Base for Soil Resources 2014: International Soil Classification System for Naming Soils and Creating Legends for Soil Maps*; Food and Agriculture Organization of the United Nations: Rome, Italy, 2014.
97. Energy Agency of the Republic of Serbia. Troškovi Energije za Grejanje Stambenog Prostora-Grejna Sezona 2018/19. Available online: https://www.aers.rs/Index.asp?l=1&a=541&id=245&tvid=1 (accessed on 28 November 2019).
98. Müller, U.; Waldeck, A. *Auswertungsmethoden im Bodenschutz: Dokumentation zur Methodenbank des Niedersächsischen Bodeninformationssystems (NIBIS)*; Landesamt für Bergbau, Energie und Geologie: Hannover, Germany, 2011.
99. Verein Deutscher Ingenieure. *Thermische Nutzung des Untergrunds-Erdgekoppelte Wärmepumpenanlagen (VDI 4640 Blatt 2)*; Verein Deutscher Ingenieure: Düsseldorf, Germany, 2019.
100. Bertermann, D.; Wienke, J.; Müller, J.; Böck, S.; Lach, G.; Steinhäuser, H. Oberflächennahste Geothermiesysteme als Quelle für kalte Nahwärmenetze. *BBR Leit. Brunnenbau Geotherm.* **2019**, *2019*, 62–65.
101. Dressel, T. Vergleich von Wärmeversorgungskonzepten für Wohn-Quartiere. Bachelor's Thesis, Hochschule Ansbach, Ansbach, Germany, 2018.
102. Bouzarovski, S.; Sýkora, L.; Matoušek, R. Locked-in post-socialism: Rolling path dependencies in Liberec's district heating system. *Eurasian Geogr. Econ.* **2016**, *57*, 624–642. [CrossRef]
103. Werner, S. District heating and cooling in Sweden. *Energy* **2017**, *126*, 419–429. [CrossRef]
104. Eurostat. Natural Gas Price Statistics. Available online: https://ec.europa.eu/eurostat/statistics-explained/index.php/Natural_gas_price_statistics (accessed on 28 November 2019).
105. Eurostat. Electricity Price Statistics. Available online: https://ec.europa.eu/eurostat/statistics-explained/index.php/Electricity_price_statistics (accessed on 28 November 2019).
106. Kopač, J. The Burden of Coal at the Doorstep of the Energy Union. Available online: https://www.euractiv.com/section/electricity/opinion/the-burden-of-coal-at-the-doorstep-of-the-energy-union/ (accessed on 28 November 2019).

107. Walker, G. What are the barriers and incentives for community-owned means of energy production and use? *Energy Policy* **2008**, *36*, 4401–4405. [CrossRef]
108. Petrović, M. Preconditions for new environmental governance in Serbia. *Sociologija* **2012**, *54*, 87–104. [CrossRef]
109. Millar, M.-A.; Burnside, N.; Yu, Z. District Heating Challenges for the UK. *Energies* **2019**, *12*, 310. [CrossRef]
110. Vulić, M.; Vujičin, K. Tehno-ekonomska analiza grejanja objekta toplotnom pumpom, u bivalentnom sistemu. *Zb. 4 Međunarodne Konf. Obnov. Izvorima Električne Energ.* **2016**, *4*, 407–411.