(PhD) Thesis

Geothermal energy potentials in the agriculture of Northern Great Plain Region

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Introduction

The North Great Plain Region has favourable hydrothermal endowments, and the utilization of this source of energy in agriculture looks back on a history of several decades. Nevertheless, the volume of the sectoral use of geothermal energy is still far under the potentials. When compared to its natural endowments, the performance of the region and its agriculture is rather low. In the production costs, a considerable share is taken by the price paid for energies, and its reduction is viewed as a priority task.

Another hit issue is what a role geothermal energy can take in the changed political–economic environment within the ago-economy of the North Great Plain Region? How can it promote the improvement of the competitiveness of this highly significant, traditional sector of the region, the reduction of its production costs? What are the areas in the region that can be used for the exploration of geothermal energy and utilization in agro-economy? What is the current utilization rate of the existing geothermal assets, what a proportion can potentially be used for serving agricultural purposes? What experience business entities, organizations that operate thermal wells have, are there positive examples to follow? How do the stakeholders of agriculture relate to geothermal energy, how supported renewable energies are?

1. Explanation of the choice of the topic

One of the major problems of the world and Hungary is the need to satisfy a continuously increasing demand for energy, the mitigation of the environmental threats carried by fossil fuels, as well as the moderation of energy dependence.

In Hungary and the North Great Plain Region, agriculture is one of the dominant sectors of strategic significance, and its effective and cost-efficient operation has overall social implications. In spite of its outstanding significance, the sector has been in a difficult situation since the end of the 1980s, because the burdens that the sector is to shoulder have become more weighty, the former, efficient setup has been broken down, restructuring moves have been implemented in an ongoing, often inconsiderate manner, whereas developments have not been realized, the regulatory environment has been changing continuously, there has been a lack of funding (low lending supply) and the liberalized market has dictated a sharpening competition *(Juhász et al. 2006)*.

Agriculture is at the same time a key energy consumer, its costs and expenses are largely determined by the price paid for energies, which has been on a constant rise in the past twenty years.
A factor potentially increasing the efficiency of the agriculture of the basically disadvantaged North Great Plain Region is the broad-scaling, multi-phased and sustainable utilization of geothermal energy.

With respect to the existing capacities, the region has considerable, currently unutilized thermal water and geothermal energy reserves. From time to time, our broadening experience, the ever-changing economic and natural environment calls for the reassessment of the existing situation and the rearrangement of priorities in relation to the areas of utilization. With reliance on the available potentials and technologies, geothermal energy may contribute to the reduction of the volume of emitted pollutants and greenhouse gases, and the development of peripheral regions. The North Great Plain Region has outstanding potentials in the field of thermal waters and geothermal energy resources, yet their utilization rates– with respect to the available thermal well capacities – are low. This situation is due to the regulatory requirements imposed on the operators, the huge investment and maintenance costs, the general shortage of funding, the difficult situations of agriculture, industry and local governments.

My study is in search of a response to the question as to what extent the available and explorable thermal water and geothermal potentials can contribute to the more efficient operation of agro-economy in the North Great Plain Region.

2. Aim of the study

This study aims at proving that use of geothermal energy is a realistic alternative for agriculture activities in the North Great Plain Region in terms of the provision of heat to the technologies of the individual activities and the heating of the buildings. During the century-long history of the Hungarian utilization of thermal waters, traditional areas of utilization have been established in line with the local endowments, such as the greenhouse plan faming facilities of the South Great Plain Region, thermal water extraction in the Jászság Region to satisfy communal and animal farming water demands, or he basically balneological water utilization in Hajdú-Bihar County. The utilization technologies of thermal water and the carried heat have undergone significant development in the past two decades, and in consequence waters belonging to lower temperature ranges have become efficiently utilizable in areas where such use was unfeasible before. In addition to the multi-phased thermal water and geothermal energy utilization arranging users in the light of their respective heat demands, further opportunities are offered by the combined, mutually complementary and supporting application of renewable energy resources. The search for alternative options have been facilitated by the rise of energy prices, the broad-scaling dissemination of information in relation to the negative impacts of fossil energy carriers, the opening price gap between industrial and agricultural products, the need to improve cost-efficiency as driven y the intensifying competition in the sector.

3. My hypotheses

1. The North Great Plain Region has good geologic endowments, unutilized capacities in the field of geothermal energy utilization, particularly in the field of agriculture.
2. The distribution of thermal wells shows an uneven geographic setup, in alignment with the existing geologic endowments.
3. In view of their activities, most of the agricultural enterprises in the North Great Plain Region are suitable for the use of geothermal energy, which is also supported by their existing faculties.
4. The actual and intended application of renewable energy resources – principally geothermal energy – is strong among agricultural enterprises.
5. Legal and economic regulators tend to distort the use of endowments to a significant degree.
6. Those agricultural enterprises use or plan to use geothermal energy resources that have more thermal wells and effluent waters of higher temperature.
7. With the use of new geothermal technologies and procedures, businesses operating in areas of weaker endowments – even the smaller enterprises –could cut back their operating costs materially.

4. Structural units of the study

The first chapter of the study discusses the justification of the choice of the topic, the goal of the research, the hypotheses and the structure of the study alongside the explanation of the applied methods.

The second, third, fourth and fifth chapter of the study have been written to present and critically evaluate the associated domestic and international literature.

The second chapter gives a description of the natural geographic and social geographic description of the North Great Plain Region.

The third chapter presents the global situation of geothermal energy utilization, the methods of use applied in the individual countries and the milestones of the development of the domestic utilization of geothermal energy with special respect to agricultural applications.

The fourth chapter discusses the Hungarian and regional implications of the geothermal energy research, the geologic and hydrogeologic endowments of the northeastern region of the Great Plains, evolution of hydrothermal systems, their temperature, pressure, porosity, permeability and hydrochemical properties.

The fifth chapter reflects the regional and economic characteristics of Hungarian agriculture, the general, historic and geothermal energy utilization aspects of agriculture in the region. In Hungary, geothermal energy can be utilized in compliance with the domestic regulatory background. The relevant legislative acts and other regulations can be found on the basis of *Kurunczi, (2008),* and therefore these requirements did not need to be compiled separately. The regulatory references throughout this study are highlighted in the relevant research sections.

For the sixth chapter, I have conducted broad-scaling data collection in order to obtain information in relation to the thermal wells of the North Great Plain Region – including all the characteristic parameters of the wells – so that the existing thermal water and geothermal capacities could be assessed. When these data were processed, I mapped up the various ways of the utilization of the capacities of thermal waters, and determined their respective utilization rates. These data primarily originate from the databases of the county-based water management directorates, the Research Institute for Environmental Protection and Water Management, as well as personal data collection.

In the seventh chapter, a structured, questionnaire-based method was used in order to become familiarized with the attitudes of the agricultural actors of the North Great Plain Region to renewable energies, in particular geothermal energy. The questionnaires were sent to the enterprises in electronic and printed forms.

In the framework of the eighth chapter, case studies have been conducted among companies operating thermal wells, with the use of personal interviews. In this section of the study, I have been n search of positive models for the utilization of geothermal energy within the area of the region and its surroundings.

The ninth chapter presents the conclusions, recommendations drawn from the results of the research sections.

The tenth chapter is the summary of the study in English.

5. Applied research methods

The natural and social geographic description of the North Great Plain Region; global situation of geothermal energy utilization, methods of use followed in the individual countries; steps and agricultural applications of the domestic utilization of geothermal energy, the Hungarian and regional implications of the geothermal energy research, the geologic and hydrogeologic endowments of the northeastern region of the Great Plains, evolution of hydrothermal systems, their temperature, pressure, porosity, permeability and hydrochemical properties, as well as the regional and economic characteristics of Hungarian agriculture, the general, historic and geothermal energy utilization aspects of agriculture in the region have all been studied with reliance on and critical evaluation of the associated, domestic and international literature.

The parameters of thermal wells in the North Great Plain Region, the existing thermal water and geothermal capacities, the range of potential utilizations and the actual utilization rates have been described on the basis of detailed data collection, with the associated information coming from the databases of the regional water management directorates (FETIKÖVIZIG, TIKÖVIZIG, KÖTIKÖVIZIG) and Környezetvédelmi és Vízgazdálkodási Kutató Intézet Nonprofit Kft. (VITUKI), as well as personal data collection. For this data collection routine, I have relied on the thermal well cadastres, hydrogeologic diaries made available by the bodies of water management, regular data services from the operators of the wells, code number boards, operating measurements, thermal water data, as well as the production details of thermal wells. Any missing and current data have been provided by the operators of the wells upon telephone-based and personal inquiries. To present the outcomes of data processing and the results, I have made and edited maps.

A survey on the utilization of renewable energies among the stakeholders of agriculture in the North Great Plain Region was conducted with the use of a structured questionnaire-based method from February to May 2010. Queries were run with the EvaSys online software system and paper-based questionnaires. The particulars of the interviewed business entities – whose registered seats are located in the North Great Plain Region, have core activities associated with agriculture, and realize annual sales revenues over HUF 50 million – originated from the Cég-Kód-Tár 2009/1 database of the Central Statistical Office of Hungary. 27.3% of the 883 interviewed businesses responded. To process and present the results, I have prepared charts, tables and maps.

This study has been made with reliance on case studies and in-depth interviews made with the enterprises operating thermal wells; in this context, I paid personal visits to plants, conducted personal interviews with the representatives, owners of the enterprises contacted, and studied the operation of the geothermal system. The subjects of the interviews were selected from the FETIKÖVIZIG, TIKÖVIZIG and KÖTIKÖVIZIG databases, and then I met them on the basis of appointments agreed on the telephone and their willingness to respond. In terms of geographic location, the subjects of the interviews came from the North Great Plain region and the surrounding area, principally from the southern parts of the Great Plains.

For the preparation of this research and study, MS Excel, PPT, Evasys, Paint programs have been used, maps, charts and tables have been processed.

6. Results of the study and conclusions

The North Great Plain Region has favourable geothermal endowments, similarly to agriculture in the field of the utilization of energy resources, but the actual volume of use remains far under the potentials. Geothermal energy may have a key role in the reduction of the energy costs of the region's traditional sector– agriculture –, as well as the improvement of its performance.

6.1. Geothermal energy utilization in the world and Hungary, in the light of the associated literature

One of the most wide-spread of the global geothermal energy utilizations is represented by the generally available ground source heat pumps. They are followed by direct heat utilization, while for the generation of electric power areas featuring medium and high enthalpy are needed, and they basically follow active edges of continental plates. EGS systems, mostly under research and development with high investment and technologic demands, still have only pilot plants.

In the field of the utilization of geothermal endowments for electric power generation, today *Dickson*, *Fanelli* and *Bertani* have revealed 24 countries producing electricity from ground heat sources, with shares up to 15–22% from the electricity supply of the given countries, such as in the case of Costa Rica, El Salvador, Iceland, Kenya, the Philippines. In 2004, globally 8.9 GWe capacity produced 57 TWh power. From 1999 to 2004, the volume of global geothermal electricity production saw an annual growth rate of 3%; between 2005 and 2007, the installed capacity increased by 800 MWe. Recently, even geologically "quiet" areas, the like of Austria and Germany, have launched geothermal electric power generation operations. When a future outlook is concerned, *Bertani* claims that the minimally expected total capacity is 35–70 GWe, whereas its maximum is 140 GWe. The potential rises even higher if EGS systems are also taken into consideration; according to *Tester et al.* only the USA could commission a total capacity over 100 GWe, while *Paschen et al.* sees Germany to have the potential of 35 GWe. *(Dickson – Fanelli, 2003; Bertani, 2003, 2005, 2007; Tester et al. 2006; Paschen et al. 2003).*

Direct heat utilization is present in several fields of application: heating, industrial and agricultural uses, thermal water baths. In 2004, direct geothermal utilization was operated in 72 countries with a total capacity of 28 GWth and 270 TJ p.a. heat production. According to *Lund et al.*, so far reserves have been found in altogether 90 countries of the world. In view of the global distribution of direct utilization, 52% of ground heat is used for is used in the heat supply in buildings (of which 32% belongs to ground source heat pumps), 30% in baths, 8% in agriculture, 4% in industry and a similar 4% in fish breeding. *Rybach* claims that in the past decade the most apparent way of development in direct use has been the spread of ground source heat pumps. *Curtis et al.* have concluded their study by stating that in 2004 ground source heat pumps were responsible for 54.4% of the total capacity and 32% of heat generation in the world's direct geothermal heat utilization. The total capacity was then 15.4 GW, while the heat quantity came to be 87.5 TJ p.a. *(Lund, 1995, 2006; Lund et al. 2005; Rybach, 2005; Curtis et al. 2005).*

On a global scale, *Genter and Beardsmore* consider EGS systems to represent the most dynamically developed field whose potentials are unanimously highly esteemed. In spite of the fact that still there are several details to be clarified, Australia, Germany, France and Austria have already implemented pilot projects *(Genter, 2008; Beardsmore, 2007).*

Mádlné suggests that in the light of the international trends there seem to be two directions of development. The utilization of conventional, hydrothermal reserves with the use of geothermal power plants is foreseen to be spreading mostly in the developing countries, such as Indonesia and the Philippines. In addition, the propagation of ground source heat pumps is expected to commence in several countries where just very few such devices have been installed so far. EGS systems are likely to spread widely, at a quick pace. There are several countries where large-scale geothermal developments are being implemented, but none of the examined countries has such geothermal potentials as Hungary *(Mádlné, 2008)*.

A model ground for agricultural thermal water and geothermal energy utilization in Hungary is Szentesi Árpád-Agrár Zrt., where under the leadership of *Miklós Csikai, Ákos Zentai* and *Gál János Nagy* the complex and multi-phased utilization of the technology looks back on a history of a few decades. Since the 1950s, Szentes has been the key area for the development of the broadest range of utilization, and thus served as a model for several agricultural geothermal investments in the country. Beside the use of geothermal energy, a substantial role is attributed to the co-generation of energies from renewable sources, with a focus on energy saving, the improvement of energy efficiency, which requires continuous developments *(Csikai, 2008; Zentai, 2010).*

The development of domestic agricultural thermal water utilization, the current level of thermal water use in agriculture have been made feasible by the establishment of firm hydrogeologic foundations, the regular assessment of the conditions of water reserve management, associated with the name of *Árpád Lorberer*. The importance of the direct utilization of thermal waters in agriculture and its key role in Hungary have been stressed by *Miklós Árpási*. He has suggested that comprehensive legislation should be put in place to consider both the economic and environmental aspects. According to *Popovszki* and *Árpási*, in the field of the heating of greenhouses with thermal water – in spite of the economic disadvantages – Hungary is in the front ranks of the world. In the light of our surveys, in 2006 206 thermal wells were used for agricultural heat utilization in Hungary. When looking at the successful greenhouse utilization of low-temperature thermal waters and the technological solution of reinjection into the Pannonian sandstone layers, *Zoltán György* has taken a leading role, as he first proved the real potentials of these solutions in as pilot project at the horticultural site of Fülöpjakab. *János Szanyi* and *Mihály Kurunczi* have attributed outstanding significance to the maximum exploitation of the various temperature ranges of geothermal energy and the interrelated establishment of different fields of use *(Lorberer, 2003; Árpási, 2004; Popovszki, 1998; György, 2006; Szanyi – Kurunczi, 2007).*

6.2 Geothermal endowments in Hungary and the North Great Plain Region

Thesis 1: The North Great Plain Region has favourable endowments in the field of geothermal energy utilization and agriculture; in 2011, 31% of the available thermal wells, i.e. 96 thermal wells were out of use.

In Hungary, geothermal energy is a renewable source of energy having been used for long, while its current spread is allowed by technological development to an ever-broadening extent. The North Great Plain Region is rich in sources. As a result of the crust structure, its geothermal gradient is larger than the average, i.e. the geothermal heat flow is in fact the double of the continental average, and one and a half times larger than the global average. In more than 70% of the area of the country, minimum 30°C thermal water can be explored, and therefore the geothermal potential is remarkable. The favourable hydrothermal endowments of the region are the result of the geologic-hydrogeologic evolution of the Carpathian Basin. The accumulation of deposits starting in the Mesozoic Era has given rise to extensive water- and heat-containing rock bodies, forming the basis of our geothermal natural treasures. To the south of Lake Balaton and the Central Hungarian fault lines, there lie high-temperature areas that are the most favourable for the exploitation of geothermal energy. The energy-carrying thermal water rises from the neogenic and carbonate-containing reservoirs. The porosity and permeability properties of the formations holding thermal water are favourable, the rate of the heat flow and infiltration is high in certain areas of the Pannonian Basin, while it tends to be low in other parts. The hydrochemical characteristics of the fossil and refilling water bodies reflect considerable differences, their mineral contents are rather diverse. The energies of the Hungarian thermal waters featuring low enthalpies are primarily suitable for heat pump utilization and direct heat supply. Electric power generation calls for at least 120°C water. In the country, sufficient volumes of water at such a temperature can be found only at larger depths and kin water reserves of limited expanse. Today, no EGS-type geothermal power plant units are operated in Hungary *(Royden et.al. 1983; Royden – Dövényi, 1988; Lenkey, 1999; Liebe, 2001*; Lorberer, 2004; *Mádlné, 2008; Horváth, 2007; Tóth – Almási, 2001; Árpási et al. 1997; Árpási – Szabó, 1999; Dövényi et al. 2002; Horváth – Dövényi, 1991 Dövényi et al. 2001; Mádlné, 2008*; *Ádám, 2006; Ádám, 2008/a; Komlós, 2005; Komlós, 2008/b Rybach – Kohl, 2004; Gudmundsson, 1988; Lemale – Jaudin, 1998 Rosça, 2007; Dövényi et al. 2005; Martonné, 1995; Molnár, 1984).*

6.3 Regional and sectoral description of agriculture in the North Great Plain Region

In terms of agricultural production, the North Great Plain Region has favourable endowments. In the second largest agricultural region of Hungary, the significance of the sector tends to be over the average. With respect to the natural endowments, production experience and market opportunities, this traditional sector performs well behind its potentials on the national and regional level alike. From among the branches of cultivation, the most significant share is taken by plough lands. In the past twenty years, animal farming has gradually lost its significance, yet remaining a key sector on the national level. The proportion of forest areas is well under the national average, and shows uneven distribution regionally. In the industry of the region, the traditional focus is on food processing, the production of beverages and tobacco processing; food industry is dominated by small and medium-sized plants, the spatial distribution of light industry sectors is well-balanced. In agriculture, thermal water is used basically for the heating of greenhouses, irrigation, soil heating, crop drying, as well as the heating of animal farming facilities. Concerning food processing and the light industry, typical fields of utilization are the manufacturing of beers, edible oils and sugar, the dairy and meat industry, as well as tobacco fermentation. Due to its site endowments, this economic sector is in a very good position not only in terms of the utilization of geothermal energy, but also the exploitation of all the other renewable energy resources that are available in Hungary (*Romány, 2003/a; Nagy et al. 2000; Nagyné, 2008/a; Nagy – Kovács, 1999; Hajdú, 1999; Barna, 1999*; *Nagy, 2003; Lorberer, 2004; Barbier és Fanelli, 1977; Popovski, 1998; Árpási, 2004; Bobok – Tóth, 2010; Árpási, 2004.*; *Lindal, 1973).*

6.4 Thermal water and geothermal capacity available in the North Great Plain Region

Thesis 2: The geographic locations of thermal wells are well-aligned with the given geologic endowments. More than half of the wells are concentrated in JNSZ County, showing better geothermal potentials.

Since 1915, the North Great Plain Region has witnessed the construction of 312 thermal wells to serve broad-scaling purposes from use in bathing facilities via agricultural, industrial objectives to communal water supply. The largest user in the region is balneology running 34 percent of the wells, followed by communal water use with 26 percent, agriculture with 21 percent and industry with 10 percent. In addition to agricultural and bathing use, as well as monitoring and medicinal applications, there have been just a few examples for various combined utilization of geothermal energy in the region. By 2011, due to changes in the economic landscape, the support provided by the government and the transformation of public administration 30 percent of these thermal wells went out of use, were closed or stopped. The weights of utilization have shifted, the structure of use has been somewhat altered. By 2011, balneology remained the largest user with 22 percent, followed by communal water supply with 17 percent and then agricultural utilization with 14 percent. Although these sectors could preserve their ranks, but similarly to the average of the region the number of wells in use dropped by nearly 30 percent. A positive change has been that the utilization of geothermal energy being inherent in thermal waters has become an increasingly popular way of alternative energy use, though its application is almost exclusively characteristics of bathing complexes. On the average, the largest fallback was suffered by industrial thermal water use, up to 50 percent on a regional scale. The region still has just a few examples for medicinal and various multi-phased methods of utilization *(Figure 1–2).*

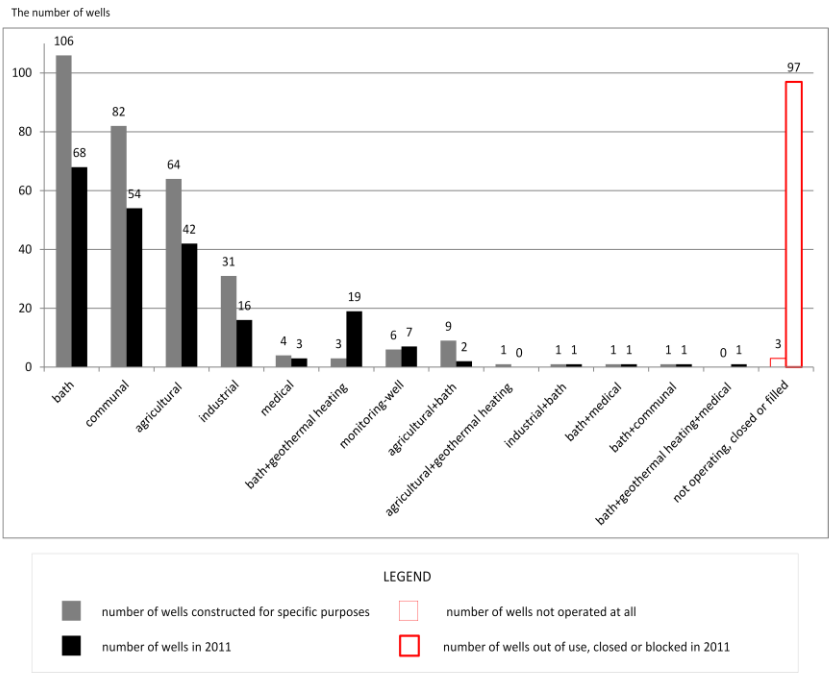


Figure 1: Sectoral distribution of the thermal wells in the North Great Plain Region, as well as its changes from their construction until 2011

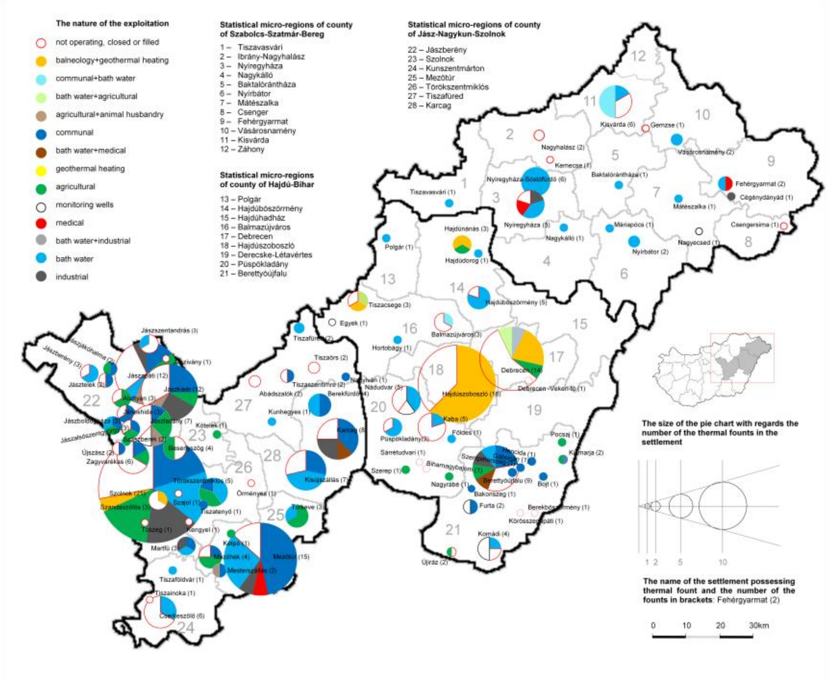


Figure 2: Structure of the utilization of the thermal wells in the North Great Plain Region, in 2011

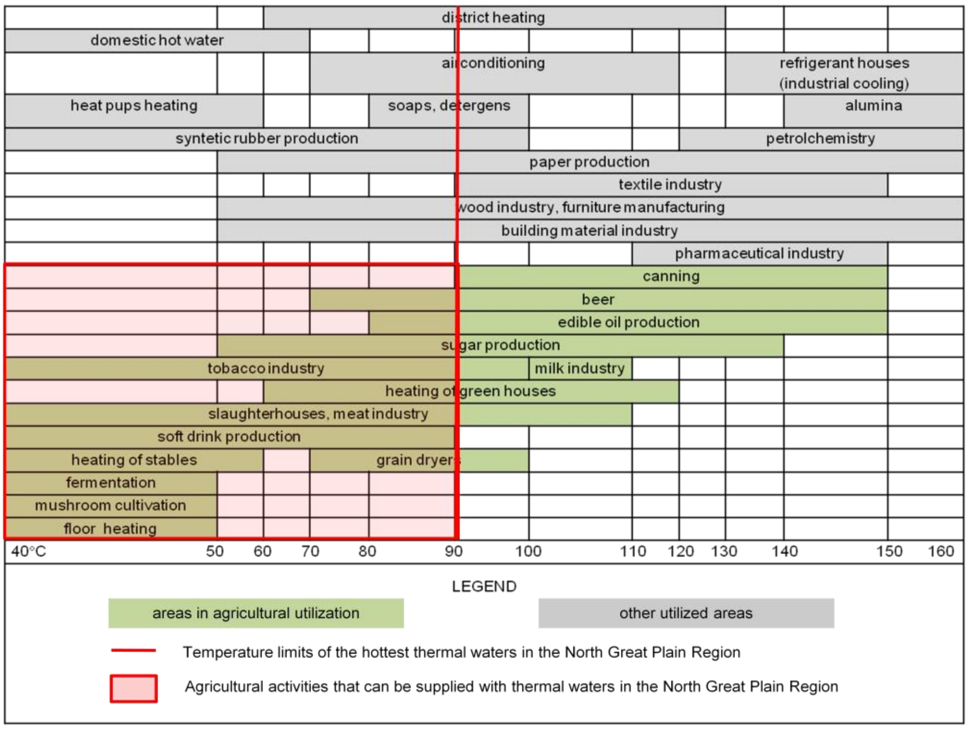
In the counties of the region, the various economic sectors have different weights in thermal water utilization. In the area of Szabolcs-Szatmár-Bereg County, the most significant way of utilization is use in bathing establishments, followed by drinking water supply, reflecting the weak local endowments. Energy-type utilization has potentials primarily in agriculture: heat supply in stables and other buildings. In Hajdú-Bihar County, its use is almost fully subordinated to bathing utilization. The exploited temperatures have considerable geothermal capacity reserves. The large number of thermal wells in Jász-Nagykun-Szolnok County – due to the favourable endowments of the area, i.e. good aquifer complexes – makes communal water use dominant, yet these wells serve the ends of reserve water supply, and have significant roles only in certain areas. Therefore, most of the operating wells satisfy the demands of agriculture and baths. The level of combined utilization is rather low in the county, whereas this area and the bathing towns of Hajdúság can boast of the highest level of thermal water utilization for heating *(Lorberer, 2004, 2003, 2009).*

6.5 Application of geothermal energy by agricultural enterprises

Thesis 3: In view of their activities and endowments, most of the agricultural enterprises are suitable for the utilization of geothermal energy in the North Great Plain Region.

In summary of the results of the questionnaire-based survey made among the business entities that are involved in agricultural activities in the North Great Plain Region, it can be claimed that business entities of agricultural operating profile in the North Great Plain Region perform 37 types of core economic activities and 50 complementary activities. Concerning the **core activities** of the region's businesses, there are 24 activities where geothermal energy as a way of direct heat supply can be used. They represent 65% of the optional core activities, and are pursued by 43% of the enterprises, i.e. altogether 87 businesses s core activities. On the basis of the utilization fields in the Lindal diagram, the direct heat energy of thermal water can be used for 21 different activities, representing 57% of the core activities. Such operations are performed by 73 enterprises of the region, i.e. 36% of the businesses *(Table 1)*. The enterprises pursue 50 of the 76 **complementary activities**. 28 of these complementary activities are potential grounds for the utilization of geothermal energy in the form of primary heat use. It corresponds to 52% of the activities, pursued by 201 entities in the region. With respect to the utilization areas of the Lindal diagram, the heat energy of thermal waters can be used for 23 different activities, representing 46% of the complementary activities. These operations are performed by 190 business entities in the region *(Table 1) (Lindal, 1973)*.

Table 1: Areas of the direct utilization of thermal heat, particularly in the North Great Plain Region



Source: on the basis of Lindal, 1973

59% of the business entities have one, 21% have two and 9% have three business sites. Only 1% of the enterprises have four business sites, 3% of the entities operate at 5 business sites, and finally 7% of the enterprises have more than five business sites. In total, the number of the business sites of the respondents was 455.

All of the **economic operations performed at these business sites** are able to utilize thermal water and geothermal energy. The business entities involved in agriculture use most of their business sites for animal breeding, plant farming, warehousing and crop drying, food processing, as well as logistic and other purposes. 705 of the 721 business sites of the respondents hosted some of the above purposes of utilization. Only one of the agricultural sites is used for the renewable energy production.

Thesis 4.a: The level of the utilization of renewable energies is low among agricultural enterprises (14%). There is no agricultural enterprise to use the existing thermal wells for energy production, and such use is not planned in the future, either.

In view of the current use of geothermal energy and other renewable energy resources by the business entities, it can be claimed that approx. 14% of the 186 respondents, i.e. 26 businesses rely on renewable energy resources for supplying their activities with energy in full or part. Most of them use biomass, wood pellets, biobriquettes, hay bales, biogas and biodiesel. The underlying reason is that the base materials needed for the production of these energy carriers are available in the region, can be produced in the course of the agricultural activities or are regularly generated as by-products. Six of the seven enterprises concerned uses biomass for heat generation, and one entity produces electric power. 14 businesses burn wooden pellets, bio briquettes and hay bales solely for heat generation. There is one entity producing biogas, and using the resulting energy carrier for electric power generation, while another company produces biodiesel as a form of fuels. Beside the green energy resources offered by secondary agricultural raw materials, the respondents use only solar energy. One of the three businesses relies on the power of the sun for electric power generation, whereas the other two for heat production and heating. None of the agricultural entities of the North Great Plain Region uses geothermal energy (neither from thermal water barrels, nor with the use of heat pumps), bioethanol, wind power and hydropower to cover their energy demands *(Figure 3)*.

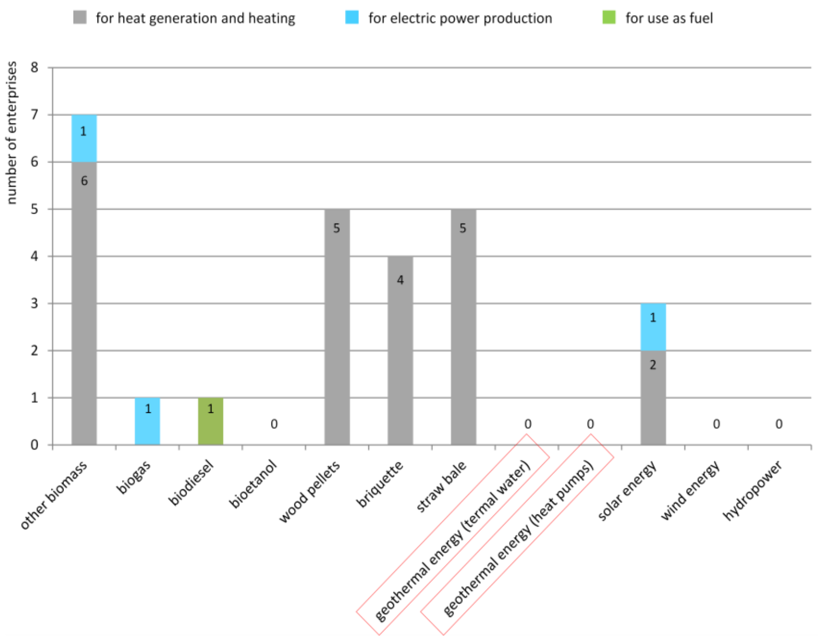


Figure 3: Mutual ratios of the renewable energy resources used by the business entities, as well as their distribution among the purposes of use

Regarding the future implementation of renewable energy investments, the application of renewable energy resources, as well as plans for the extension of operated capacities, 27.8% of the business entities foresee the use of alternative energy carriers, while the remaining 72.8% do not contemplate such projects *(Figure 4)*. 117 of these enterprises plan to use renewable energy carriers. The majority of the businesses, altogether 44 entities foresee to use solar energy, 23 for heat generation and 11 for

electric power production. 15 respondents wish to use energy from biomass, and 15 other respondents would apply hay bales. 14 of the ones intending to utilize biomass would opt for heat generation, while another enterprise intends to produce electric power out of the biomass. Hay bales are expected to be used for solely heat generation. 12 businesses plan to use wind power for electric power generation, and 11 entities want to produce biodiesel to make fuel. Biobriquette is foreseen to be used by two enterprises for electric power production, and six other for heat generation. Most of the business entities intending to produce biogas, i.e. give companies want to generate electric power in the future, one company would generate heat generation, while another plans to produce fuel. Four respondents plan to apply geothermal energy – where thermal water is the heat-carrying medium – in the future to cover their own energy demands, all for heat generation and heating, corresponding to the typically low enthalpies of thermal waters in the region. For similar purposes, four enterprises plan to implement heat pump-type ground heat exploitation. Four business entities plan heat generation from wooden pellets, and three other enterprises want to cover their fuel demands from bioethanol.
If this comparison is assessed with respect to the purposes of use, it can be claimed that for 71 of the 117 enterprises the application of renewable energy resources has the objective to perform heat generation and heating, 31 business entities plan to generate electric power from alternative energy carriers, while 15 companies endeavour to make fuel *(Figure 4)*.

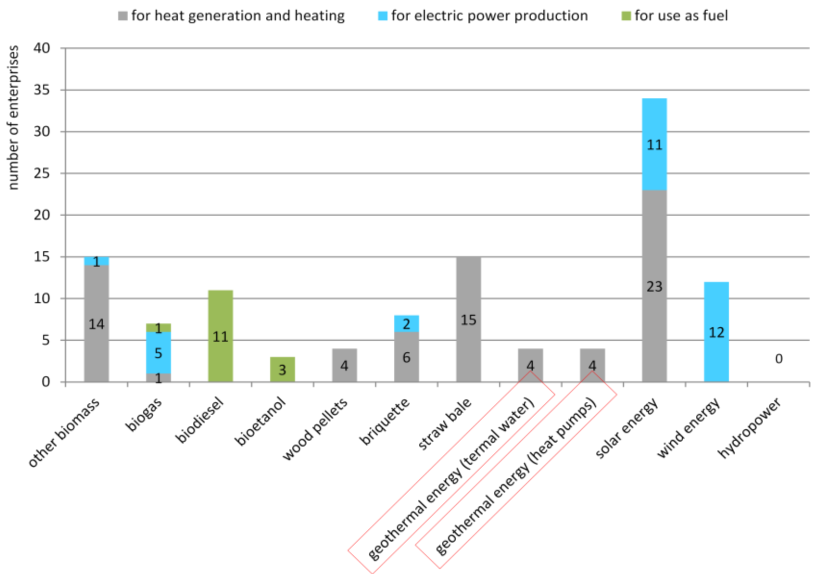


Figure 4: Number of those business entities involved in agriculture that plan to use renewable energy resources in the future

With regards to the volumes of these investments, it can be claimed that the agricultural enterprises planning to use renewable energy carriers want to install energy-producing facilities with a combined capacity of 14,454 MW in the decade of 2010–2020. 61% of the total capacity, i.e. 8771 KW is planned to be used for heat generation and heating, 26%, i.e. 3829 KW for electric power generation, 13%, i.e. 1853 KW for the production of fuel. With respect to the capacities to be installed, biomass is associated with the most outstanding capacity from the energy carriers in question with 6605 KW planned capacity, followed by the 3190 KW based on hay bales, as well as 1817 KW for solar energy. The other renewable energy carriers are presented in the plans of the enterprises with significantly smaller planned combined capacities. In view of the geothermal energy based on thermal water and ground heat, the planned level of total capacities for investment is 500 KW and 850 KW, respectively. From among secondary agricultural raw materials, the wooden pellet and biobriquette are both associated with 190 KW total capacities; for biogas and biodiesel, the plans are 500 KW and 300 KW, respectively.

The total capacity planned in relation to wind power is 312 KW among the agricultural enterprises of the region. None of the business entities wishes to use hydropower. Three companies indicated bioethanol, but with respect to the capacities to be installed they have not made any statement, and thus these two energy resources are accompanied by zero capacity.

Thesis 4.b: A fundamental obstacle to the exploitation of geothermal facilities is the lack of sufficient funding, as well as the absence of professional interests, innovating experts and knowledge of renewable energy utilization. These are the reasons for unexploited capacities and the failure to implement new investments.

Among those who discard the idea of applying renewable energy resources, the main underlying reason in 68% is the lack of necessary resources, 8.6% seemed to have doubts about the use of renewable energy resources, 9.9% had no knowledge in connection with the topic, 13.6% referred to other reasons beyond the offered options.

In order to enable business entities involved in agriculture to implement investments in renewable energies, for more than 60% of the period of return should be within five years, for 35% within ten years and for 3.2% within 15 years. The second most significant condition is the funding rate. One-third of the enterprises would launch their renewable energy projects with funding rates over 90%, 38.3 percent expect 70%, whereas 26.2% of the business consider a 50% funding rate to be acceptable. The results show that just very few enterprises contemplate the option to invest in alternative energies with funding rates of 30% (1.6% of the a respondents) or 10% (0.5% of the respondents). On the other hand, 160 agricultural enterprises would consider the potential replacement of fossil energy resources if any subsidy were provided for the implementation of investments in green energy. For a large number of enterprises (83 and 80, respectively), the improvement of the efficiency of the dissemination of information about renewable energy carriers, as well as the option of the authority takeover of energy not used for own purposes.

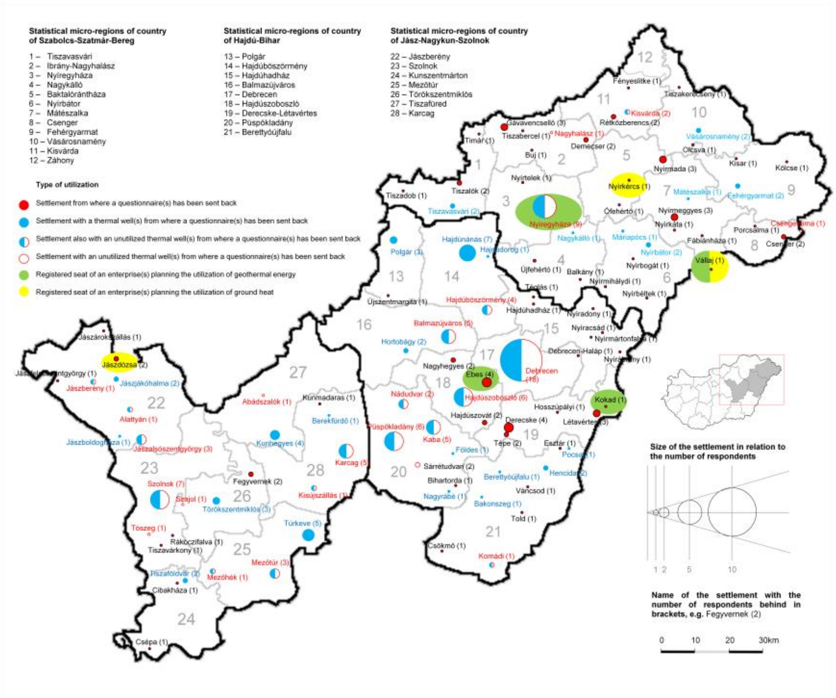


Figure 5: Geographic locations of enterprises planning to utilize geothermal energy and ground heat in the North Great Plain Region and further unutilized capacities

With respect to operating profitability, 74% of the enterprises closed the year of 2008 with profit, 10% were loss-making, while 8.2% were at the break even.

48 of the 106 settlements accommodating the registered seats of the business entities having responded to the questionnaires have thermal wells, yet currently none of the enterprises uses geothermal energy, and only four of them plan to do so in the future. In the North Great Plain Region, settlements accommodating the registered seats of the business entities altogether 201 thermal wells

have been constructed, and 56 of them are now out of use. These unutilized wells could be applied by the companies planning to rely on renewable energies.

6.6 Geothermal energy utilization in agricultural in the light of case studies

Thesis 5: Primarily, it is not the agricultural enterprises that have more thermal wells and waters of higher effluent temperatures that plan to use geothermal energy resources, but those with appropriate potentials on the agricultural markets and professionals featuring innovative and management-type attitudes.

In the light of the case studies, it can be claimed that business entities pursuing diverse agricultural activities in areas of outstanding geothermal endowments, and applying geothermal energies in all the fields of operations – as useable for production purposes – can achieve considerable cost savings, are more competitive and successful in their operations. These large agricultural plants did not break up after the change of the political regime, could preserve the volume of their operations, teams of experts and assets. Due to their sizes and lobbying powers, they can influence the markets, as well as the legislative framework of geothermal energy utilization.

Thesis 6: In 90% of the area of the North Great Plain Region, geothermal energy could be successfully used in agriculture. With the application of new technologies, even regions of less favourable endowments have the option to utilize geothermal energies and save energy in general.

Using geothermal energy to cover their energy demands, family-based agricultural enterprises, horticultural plants located in areas of good geothermal endowments have been able to cut their energy expenses by 60%, thereby becoming more competitive. Their investments having been implemented from grant funding or own resources have returned in 5–6 years.

Agricultural enterprises that are operated in areas of less favourable geothermal endowments, but able to exploit these weak potentials appropriately can achieve considerable energy savings, thus becoming more efficient and more competitive, even in sectors – negatively impacted by the relevant legal regulations – like tobacco industry.

Thesis 7: In the case of large animal farming plants, the regulatory environment channels available resources to biogas investments.

Large agricultural plants pursuing a broad range of agricultural activities in areas of favourable geothermal endowments, and have sizable livestock tend to expend their funds on the establishment of biogas plants in the light of the stringent regulatory requirements adopted in the footsteps of the directives of the European Union. This solution is in line with the requirements of agricultural operations that draw benefits from the extensive local use of biogas.

Those agricultural enterprises that are operated in areas of good geothermal endowments, and have their own thermal wells, but the business associations were dissolved after the change of the political regime, and continued their activities only in smaller volumes, in restructured forms fail to exploit the potentials of the existing thermal wells, neither do they construct new ones. The underlying reason is a serious lack of sufficient resources, resulting from the loss of most of the former agricultural fields and assets, teams of experts. Nowadays, these enterprises are striving for survival, and do not have resources for development.

The above statement (5) – smaller enterprises formed on the remaining assets of dissolved cooperatives and former companies of light industry experience a shortage of funding – is also true for agricultural enterprises operating in areas of weaker geothermal endowments. The available, but rather short financing options primarily serve compliance with the continuously changing regulatory requirements, operations and survival. Inmovative developments – change in the technological structure – cannot be implemented even with grant funding, or call for huge efforts and long-term commitments, the indebtedness of businesses. They are not able to finance geothermal developments of large investment demands, and on several occasions they are not in need of the heat energy supplied by the legacy thermal wells for their technological processes.

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