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of the EU–supported project "Geothermal communities – demonstrating the cascaded use of geothermal energy for district heating with small scale RES integration and retrofitting measures"

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AUTHORS' PREFACE

Renewable energy resources (RES) have exceptional importance in the principles of sustainable development and energy management. Using the practically unlimited internal heat of the Earth, geothermal energy has one of the highest potentials among all renewables to meet these principles and related challenges. It should be pointed out that Central and Eastern European countries also have geothermal resources suitable for a wide range of applications, including a significant heating sector. However, to date they have either remained unexploited due to several reasons or their use has been carried out in an unsustainable manner; in some cases geothermal district heating projects lack the energy efficiency and sustainability components when, as often is the case, spent water is not reinjected back into the reservoirs but is instead released to surface waters.

The EU–supported project "Geothermal communities – demonstrating the cascaded use of geothermal energy for district heating with small scale RES integration and retrofitting measures", GEOCOM, carried out in 2010–2015 (*www.geothermalcommunities.eu*) was an initiative to promote the wider use of geothermal energy in sustainable and innovative ways.

The key activities and issues covered by the GEOCOM project were as follows:

- Pilot scale demonstration works on geothermal energy applications for heating in three different municipalities: Galanta (Slovakia), Montieri (Italy), and Mórahalom (Hungary). Geothermal uses were integrated with some other RES in order to outline ways of more efficient and more sustainable energy production. In some cases an additional focus was the trapping of methane from ground water for energy production. For all pilot installations the energy efficiency measures were applied by thermal retrofitting and optimisation. An efficient monitoring system was applied to the demonstration activities;
- Technological research on the integration, optimisation and applications of energy systems, to help the demonstration activities of the project become more efficient;
- Socio– economic research on the public perception and understanding of geothermal energy, other renewables and measures promoting the rational use of energy to ease the preparation of similar future projects;
- Transboundary issues on the exploitation of geothermal energy (based on the example of the geothermal reservoirs situated within the territories of Hungary and Serbia);
- Pro-active training and dissemination activities;
- Initiating and facilitating the networking of interested communities in the GEOCOM and other European countries by setting up the Mayors Geothermal Club.

The direct objective of the GEOCOM project was to demonstrate succesful, innovative and inspiring examples of the utilisation of geothermal energy for heat generation employing cutting-edge, environmentally sustainable and cost competitive technologies combined with innovative energy efficiency measures, integration with other renewable energy sources and retrofitting at three different pilot– sites (municipalities) listed above.
These pilot scale geothermal energy applications are given as examples of good practices in this Handbook. All three cases present intermediary phases between ongoing investments and planned future projects that will take into account the lessons learned from the pilot phases.
The key results achieved thanks to the GEOCOM works in pilot sites are highlighted below.

The key results achieved thanks to the GEOCOM works in pilot–sites

Galanta (Slovakia):

- Improvement of the existing geothermal district heating system
- Full reinjection study
- Thermal retrofitting and PV integration
- 1 239 kW_{th} heating capacity
- 440 t CO_2 emission reduction per year
- 16 500 m^2 retrofitted private and public place
- 8 kW_e PV installed

Montieri (Italy):

- Brand new geothermal district heating system
- Thermal retrofitting of historic architecture
- 6 164 kW_{th} new heating capacity
- 111 000 m^2 total heated volume
- Novel steam–two–phase fluid system
- 12 kW_e PV installed
- 29 m^2 solar thermal system

Mórahalom (Hungary):

- CHP utilization of waste gas trapped from geothermal water
- High–power heat pump heasting station
- More than 90% savings on heating costs
- 300 t CO_2 emission reduction per year
- 418 kW_{th} heat pump heating capacity
- More than 2 000 m^2 public building retrofitting

The GEOCOM partners hope that the good practice examples,and other project results will facilitate future geothermal investments and help create a better understanding and perception of such projects among investors, local and regional authorities, decision makers, the general public, and other stakeholders both in the countries covered by the project and in other European states.

Dedication:

The GEOCOM project was largely the initiative of Prof. Kiril Popowski (Macedonian Geothermal Association, MAGA) – outstanding scientist in the field of geothermal energy and great promoter of its wider use especially in Central and Eastern European states. The contributors to this Handbook and all GEOCOM partners dedicate this work to His memory in the hope that geothermal will play a more important role in the energy markets in these countries, also thanks to this project.

1 INTRODUCTION TO GEOTHERMAL ENERGY, STATE AND PROSPECTS OF ITS DEVELOPMENT IN THE GEOCOM COUNTRIES

(B. Kępińska, A. Kasztelewicz, L. Pająk, W. Bujakowski, B. Tomaszewska, G. Hołojuch – MEERI PAS)

1.1 Geothermal energy – definition and origin

According to the definition given in the Directive 2009/28/EC of the European Parliament and of the Council on the promotion of the use of energy from renewable sources, "geothermal energy is the energy stored in the form of heat beneath the surface of the solid Earth". In other words: geothermal energy is the natural heat contained within the Earth. Part of this enormous amount of heat (contained in water or steam transported to the surface) can be extracted and used for various purposes, i.e. to generate electricity, or directly for many applications.

In many countries geothermal energy resources (stored in steam, water and rock formations) are suitable for use for the purpose of extracting energy (production of electricity, heat and cold) as well as, among other uses, in tourism, balneotherapy and medicine. Such resources have appropriate reservoir and exploitation parameters and occur at depths that allow them to be exploited in an economically viable and technically feasible manner.

Geothermal steam reservoirs (temperatures above 150–200°C) occur in areas of contemporary or recent volcanic or tectonic activity, primarily related to the active edges of the lithospheric plates, or areas where they are passing under (subduction) or moving apart from (divergence) each other. The direct source of the heat is hot magma located in a shallow part of the Earth's crust (which escapes as lava during volcanic eruptions).

Geothermal water reservoirs (temperatures below 150°C) are much more widespread than steam reservoirs. The heat source is the natural heat flux of the Earth. They occur in many areas on all the continents, and are also known in many European countries.

Significant quantities of heat are also included in Hot Dry Rock formations (HDR) which do not contain water or steam but are characterized by temperatures above 150–200°C at depths of 3–4 km. Methods and technologies are currently under development that are designed to allow the capture of the heat accumulated in HDR structures and these are referred to as Enhanced Geothermal Systems or Engineered Geothermal Systems (EGS).

The heat contained near the surface of the Earth: in the ground, water and shallow lying parts of rock formations (several – a few hundred metres b.s.l.) can be extracted by heat pumps (GSHP), coupled with shallow holes or collectors (vertical or horizontal) receiving heat from the mentioned sources.

1.2 Geothermal energy applications and technologies

Geothermal energy can be used for electricity production, for commercial, industrial, or heating purposes, and for heating and cooling through heat pumps. Recreation and balneotherapy also represent important sectors for the use of both of geothermal heat and water. The applications of geothermal energy stored in water and steam are divided into the following groups (figure 1.2.1):

- electricity generation,
- direct uses,
- heat pumps ("shallow geothermal").

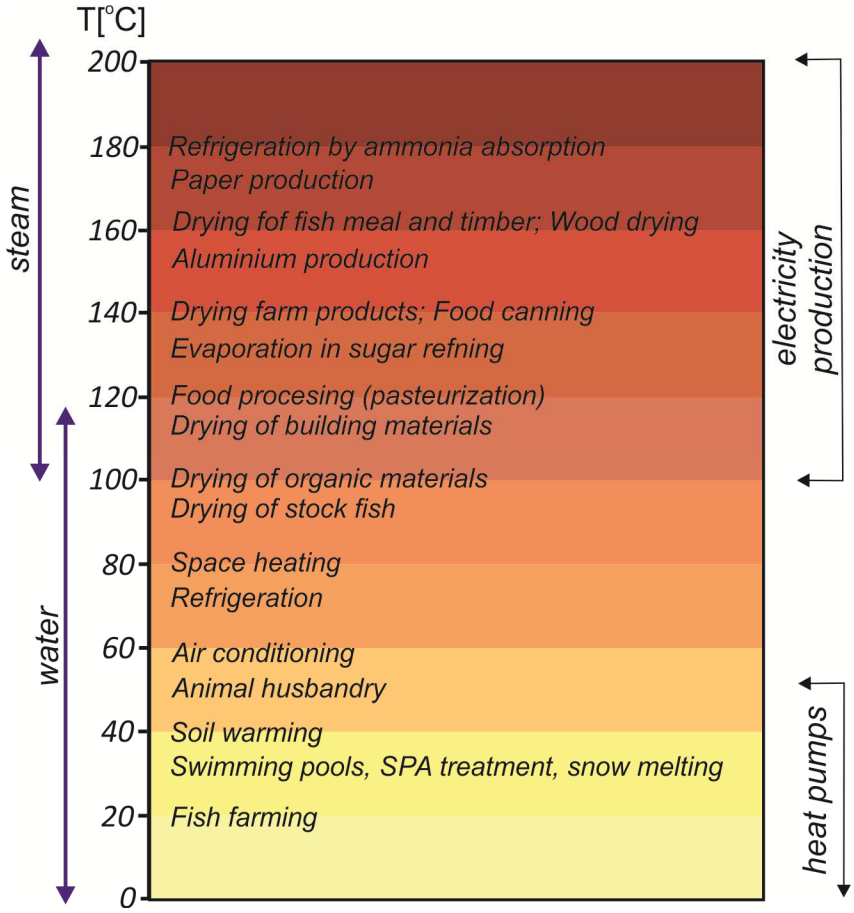

Figure 1.2.1. Main types of geothermal energy uses (modified from Lindal, 1973)

Electricity generation is based on applications using geothermal steam. In recent years growing attention has also been paid to so-called binary systems where geothermal water serves as a working fluid in the electricity generation process.

Power plants use steam produced from geothermal reservoirs to generate electricity. There are three geothermal power plant technologies being used to covert hydrothermal fluids to electricity – dry steam, flash steam and binary cycle. The type of conversion used (selected during development) depends on the state of the fluid (steam or water) and its temperature.

Dry steam plants use hydrothermal fluids that are primarily steam. The steam travels directly to a turbine, which drives a generator that produces electricity. The steam eliminates the need to burn fossil fuels to run the turbine (also eliminating the need to transport and store fuels). These plants only emit excess steam and very minor amounts of gases. Dry steam power plants systems were the first type of geothermal power generation plants built (first used in Lardarello in Italy in 1904).

Flash steam power plants are the most common and are appropriate for water dominated reservoirs and temperatures above 180°C. Fluid flows up through wells in the ground under its own pressure. As it flows upward, the pressure decreases and some of the hot water boils into steam. The steam is then separated from the water and used to power a turbine/generator. Any leftover water and condensed steam is injected back into the reservoir making this a sustainable resource.

Binary cycle power plants operate on water at lower temperatures of about 100–180°C. They are known also as Organic Rankine Cycle (ORC). In these plants, the heat is recovered from the geothermal fluid, via a heat exchanger, to vaporise a low bowling point organic fluid and drive an organic turbine. The water and the working fluid are kept separate during the whole process, so there are no emissions to the atmosphere.

Enhanced Geothermal Systems (EGS) technology is a new type of geothermal power technology that does not require natural convective hydrothermal resources. It is used in regions characterised by high temperatures but low permeability and lack of water in the rock formation (the-so-called Hot Dry Rock, HDR). Producing electricity from this naturally occurring hot, but relatively dry rock requires enhancing the potential reservoir by fracturing, pumping water into and out of the rock and directing hot water to a geothermal power plant. The first European EGS power plant system at Soultz–sous–Forets in the upper Rhine Graben is currently operating with two production wells, equipped with submersible pump sets, and one injection well, achieving all together a 35 L/s circulation rate and installed capacity of 1.5 MW_{el}. The temperature of the mixture of geothermal water and steam is 160°C.

Direct uses of geothermal resources cover a wide range of temperatures and a variety of purposes. The most common of these include heating, agriculture, balneotherapy and recreation as well as the drying of agricultural products, industrial processes etc. The different direct applications of geothermal energy vary according to temperature, as illustrated in figure 1.2.1. Direct use is typically associated with low–temperature geothermal resources (i.e. water temperatures less than 150°C), though some applications may require higher temperatures. Direct use of geothermal energy is one of the most versatile and common forms of use of geothermal energy.

Geothermal heat pumps extract heat from shallow ground and ground water to heat and cool buildings. They can be used almost anywhere in the world, they circulate water or other liquids through pipes buried in a continuous loop, either horizontally or vertically. Ground-coupled heat pumps are based on heat extracted from shallow ground or rock formations or shallow water horizons, ie. from:

- underground sources (cold, tepid or warm wells, abandoned mines, etc.) usually having a temperature of 10–30°C,
- surface sources (lakes, rivers, sea) with a temperature of 5–25°C,
- a field of borehole heat exchangers yielding water at a temperature of 0–15°C in heating mode.

Ground coupled heat pumps can deliver hot water at 40–60°C and as a result need to be combined with low temperature heating systems such as fan coils, floor heating and air handling units**.** They can also provide cooling during the summer period in warmer climates.

On a world scale geothermal energy has mainly been used for heating (central heating systems and domestic hot water systems, individual heat pumps), in recreation and balneotherapy, in agriculture (heating greenhouses, crop drying, growing in heated soil), in aquaculture (fish farming, etc.), in industrial processes (drying and pasteurisation, heating runways, the melting of snow and de-icing).
The methods of exploitation of geothermal water and energy reservoirs mainly depend on the depth of their occurrence. The main factor to consider is the need to maintain the reservoir's sustainable character or to run it in a sustainable way. Generally, the main methods for the exploitation of geothermal resources are as follows:

Exploitation of deep geothermal water aquifers (located at depths of 1–3 km) through drilling. Waters are extracted from the wells by pumping but sometimes the outflow has an artesian character. The water is exploited by:

- closed loop systems with production and reinjection wells: cooled geothermal water is reinjected into the geothermal reservoir after the recovery of a portion of the heat it contains (by heat exchangers or heat pumps),
- open loop systems where the cooled thermal water is discharged to a receiving surface or used for other purposes, for instance as drinking water (if it meets the applicable standards), or for filling swimming pools, after recovery of a portion of the heat it contains.

Exploitation of geothermal water arising from natural springs: this method is mainly used in order to use the waters for therapeutic and bathing purposes.

Exploitation of geothermal heat from the shallow subsurface part of the Earth's crust: heat contained in the ground, in water, and in shallow lying parts of the solid bedrock (several m – 100 m) is recovered using heat pumps configured with shallow holes or vertical/horizontal collectors designed to receive heat from such sources.

Enhanced Geothermal Systems (EGS): this technology relates to the recovery of heat from hot, compacted and "dry" rock masses (Hot Dry Rock), i.e. those rocks which do not have appropriate reservoir properties nor contain water themselves. Such rock masses occur at depths of less than 3–5 km. The relatively high temperatures (≥150°C) prevailing within them arise due to the depth and significant generation of heat by the radioactive elements present in the composition of certain minerals. Such massifs can act as dummy cavities, and the interstices created through drilling for water may be pumped. After being heated to a temperature of 100°C or higher, water is extracted to the surface and then utilised. Instead of injecting water, heat exchangers can be used for heat recovery. This method is, however, technically complicated and expensive.

1.3 Geothermal energy potential in the GEOCOM countries

Europe mainly possesses low–temperature geothermal resources (i.e. water and rock formation temperatures below 150°C). Geothermal aquifers are predominantly hosted by sedimentary formations, sometimes by volcanic and crystalline rocks. The reservoir parameters and exploitation characteristics mainly restrict their exploitation to direct uses. This is also the case in the GEOCOM countries.

Moreover – one should point out that some of them: Hungary, parts of Slovakia, Serbia, and Romania, are located within the Pannonian basin which contains one of the best such resources in Europe since it has very good reservoir parameters, a large extent of geothermal aquifers, as well as current and future interest and demand for their use. Poland and Slovakia have resource bases with very good potential which are also related to other geological structures – the basins of the Inner Carpathians. In Poland significant potential also occurs within the extensive Polish Lowlands.

High–temperature resources (water and geological formation temperatures above 150ºC) are also found in Italy (mainly in the Tuscany region). They have been successfully used both for power generation (and form the most significant area of geothermal electricity production in Europe) and directly. Italy belongs to the group of several European states possessing resources of geothermal steam, along with Iceland, Turkey, Greece, Portugal (Azores), and Spain (the Canary Islands).

It is worth noting that several of the main geothermal fields being exploited in Europe are located in the GEOCOM countries:

- in the Larderello region (Italy),
- in the Pannonian Basin (Hungary, Serbia, Slovakia, Romania /also some other countries/),
- in several sectors of the European Lowlands (Poland /also Germany/),
- in the Palaeogene systems of the Inner Carpathians (Poland, Slovakia).

The other main fields under exploitation in Europe are the Paris Basin, other Alpine and older structures of Southern Europe (Macedonia, Romania, Bulgaria, Greece, several other states), the Upper Rhein Graben, the Alpine Foredeep. Depending on the exploitation parameters (temperatures, water flow rates), the use of geothermal energy in the GEOCOM countries, (as in other states), can be realised both in systems based only on this energy source and also in conjunction with other energy carriers, both fossil and other renewable sources (so–called hybrid systems). These options open many opportunities for wide and efficient use of geothermal resources.

More detailed information on geothermal potential and resources in particular GEOCOM countries is given in other reports elaborated on frame of the GEOCOM project works (available at *www.geothermalcommunities.eu*).

1.4 State of geothermal energy uses in the GEOCOM countries

Geothermal energy has been exploited in 37 European countries (out of a world total of over 82 states; Lund & Boyd, 2015) for direct use, electricity generation or extraction by heat pumps. These states include seven countries forming part of the GEOCOM project, namely FYROM, Hungary, Italy, Poland, Romania, Serbia and Slovakia.

The principal direct uses are heating as well as bathing and balneotherapy. A significant share is also associated with agriculture (greenhouses, soil heating, polythene tunnels), some amount going to aquaculture, industrial processes, and sometimes for melting snow and ice from footways and roadways. In addition geothermal water is a resource used to extract carbon dioxide, edible salt and other chemicals. It is also used in cosmetics and in therapeutic, mineral or drinking water. According to data presented at the World Geothermal Congress 2015 (Lund & Boyd, 2015), the total installed thermal capacity from geothermal sources in Europe was 25 037.12 MW_{th} while heat production amounted to 220 419.17 TJ in 2013, i.e. 36% and 38% of the world total (table 1.4.1). Europe is one of the world leaders in direct use of geothermal energy and occupies second place ahead of Asia.

The total contribution of the seven GEOCOM countries to geothermal direct uses in Europe was ca. 2965.27 MW_{th} of installed thermal capacity and ca. 28 471.17 TJ of heat produced in 2013, i.e. 13% and 14% respectively (table 1.4.1). It is worth noting that two of these states – Italy and Hungary – had a significant share being among top European states in direct use (8th and 9th places) producing 11 065 TJ and 10 268.06 TJ of geothermal heat in 2013 (Lund & Boyd, 2015) respectively. The main types of use which dominate direct use both in Europe and in the GEOCOM countries are space heating (district and individual), heating greenhouses and poly tunnels, bathing and swimming /balneotherapy (table 1.4.2). These also give indications of the direction of likely future demand and prospects in this field. In many cases the utilities operate as integrated (hybrid) systems.

In a number of countries the development of uses of geothermal energy is based on hydrothermal resources exploited by wells up to 3–4 km deep. The energy of the Earth is also extracted by heat pumps, GSHP ("shallow geothermics") – a sector which has shown dynamic development in many countries. In 2013 these installations operated in 48 countries worldwide giving a total installed capacity of 49 898 MW_{th} and 325 028 TJ. Assuming 12 kW_{th} as a typical unit for a home, the equivalent number was ca. 4.16 million. Most installations are in North America, Europe and China.

Table 1.4.1. The GEOCOM countries: geothermal energy uses on general European background, 2013 (data source: Lund&Boyd 2015, and geothermal energy country update papers submitted for WGC2015)

Country	Direct uses		Power generation	
	Installed capacity [MW_{th}]	Heat production [TJ/a]	Installed capacity [MW_e]	Production [GWh/a]
Macedonia (FYROM)	46.68	601.11	-	-
Hungary	654.6	10 268.06	-	-
Italy	1 355.0	11 065	916	5 660
Poland	488.84	2 742.60	-	-
Romania	245.13	1 905.32	0.1	0.4
Serbia	115.64	1 802.48	-	-
Slovakia	132.2	2469.60	-	-
GEOCOM countries total (% of total Europe)	3 306.27 (13.20%)	30 854.17 (14%)	916.1 (42.95%)	5660.4 (38.19%)
Europe total	25 037.12	220 419.17	1640.8	11 147.8
World total	70 037.12	587 786.43	12 635	73 549

Table 1.4.2. The GEOCOM countries: specification of direct geothermal energy uses, 2013
(data sources: Lund&Boyd, 2015 and Geothermal energy country update papers submitted for WGC2015)

Country	Unit	Space heating	Heating greenhouses, foil tunnels	Aquacultures	Agricultural drying,	Industrial uses	Other	Bathing, swimming	Subtotal	Heat pumps	TOTAL (with heat pumps)
FYROM	MW_t	43.49	2.79	-	-	-	-	-	2.5	2.5	46.68
	TJ	524.97	61.14	-	-	-	-	-	586.11	15.0	601.11
Hungary	MW_t	186.58	271	6.0	25.0	19.0	2	352	863.58	42.0	905.58
	TJ	2026.31	3024.12	61.51	297.13	220.62	17	3712.0	9573.0	695.0	10 268.06
Italy	MW_t	157	69	122	-	18	-	421	787	257	1355
	TJ	1289	725	1927	-	108	-	3698	7747	1 500	11065
Poland	MW_t	87.2	-	-	-	0.3	1.00	10.34	98.84	>390	>488.84
	TJ	633	-	-	-	0.5	8.7	100.4	742.6	> 2000	>2742.6
Roma-nia	MW_t	107.94	15.69	4.78	6.32	3.75	-	66.65	205.13	40*	245.13
	TJ	823.45	80.49	9.5	12.7	6.84	-	492.34	1425.32	480	1905.32
Serbia	MW_t	32.899	12.85	1.653	0.967	-	3.947	52.238	104.554	11.09	115.644
	TJ	525.385	191.209	22.924	26.868	-	85.854	6861.759	1714.00	88.479	1802.48
Slovakia	MW_t	32.8	15.4	11.9		-	-	87.7	147.8	1.6	149.4
	TJ	565.2	224.7	271.0	-	-	-	1395.2	2456.1	13.5	2469.6

In Europe, in terms of total capacity and heat production, the leading in GSHPs are Sweden (5 600 MW_{th}, 51 320 TJ in 2013), Germany (2 590 MW_{th}, 16 200 TJ), Switzerland (1 702 MW_{th}, 10 997 TJ) and then Norway and France (Lund & Boyd, 2015). Compared with the leading countries, this sector of geothermal use is still in its initial stage of development in the GEOCOM countries; on the basis of data from the World Geothermal Congress 2015 one can conclude that significant investment is such technology is only found in Italy (568 MW_{th}, 3 318 TJ) and Poland (390 MW_{th}, 2000 TJ) whilst in the other five states geothermal heat pumps have so far only been used on a small scale (in the ranges of total 1.6 – 41 MW_{th} and 13.5 – 695 TJ in individual countries). Generally the GEOCOM states accounted for ca. 744 MW_{th} and 5 218 TJ of shallow geothermal use in 2013.

In several European countries geothermal energy use also includes electricity generation based on high–temperature steam: in Iceland, Italy, Portugal /Azores (Russia and Turkey were not taken into account since geothermal power stations are operating in the Asiatic parts of these countries). Moreover in Austria, France, Germany and Romania some 0.1–5.5 MW_e of binary installations for power production (in co–generation with heat) have been on–line for several years. These use ca. 97–160°C waters. In the case of Romania (the country covered by the GEOCOM project) a small 0.1 MW_e pilot installation was launched in 2012. In 2014, the installed capacity of geothermal power plants in Europe was 1 640.8 MW_e and electricity generation 11 147.8 GWh, i.e. 13% and 15.2% of world generation, respectively. Italy (a GEOCOM partner) is the European leader (before Iceland) in this technology with a significant contribution of 916 MW_e and 5560 GWh in 2015 and is also among the world's top countries (Bertani, 2015).

It is worth noting that the geothermal power plants that operate in the Larderello – Monte Amiata area meet ca. 40% of the electricity needs of the Tuscany region. In this area a variety of direct geothermal uses have also been developed (space heating, agriculture, bathing). It is also a region where Montieri, one of the GEOCOM pilot–sites, is located (and which is the subject of a detailed presentation later in this Handbook).

1.5 Current share of geothermal in energy structures and prognosed in national and European documents – the GEOCOM countries

According to the statistics, the average share of all renewable energy sources (RES) in gross final energy consumption in the 27 European Union countries in 2013 amounted to 15% (with a 20% target by 2020), with the dominant forms being biomass, wind and hydropower (eg. *http://europa.eu/rapid/press-release_IP-15-5180_en.htm; http://ec.europa.eu/eurostat/web/energy/data/shares*). In the GEOCOM countries this share was ca. 16% on average. In particular cases it ranged from 9.8% (Hungary, Slovakia) to 23.94% (Romania). However, geothermal only contributed a small share in the RES mix (FYROM, Poland, Romania, Serbia, Slovakia), more significant figures can be obtained from Italy and Hungary. From these figures it can be seen that the geothermal resources in the GEOCOM countries have been exploited at a scale much lower than (even conservative) possibilities so far. Note that geothermal bathing and swimming are not included in the country and European energy statistics.

The European countries are in the process of increasing the use of renewable energy sources following the provisions of the Directive 2009/28/EC of the European Parliament and of the Council. These provisions (indicating 20% as an average share of RES in final gross energy consumption in the EU–member states by 2020) were transposed into the National Renewable Energy Action Plans and national energy strategies. In general hydro, biomass and wind are treated as priorities while smaller contributions are envisaged for other RES, including geothermal; its officially forecast share will not exceed a few percent in most countries while locally and regionally it can reach a significant contribution in absolute terms and in a variety of fields.

For particular GEOCOM countries the share of RES in final gross energy consumption is projected to be in the range 14–27% in 2020. Taking into account the share of geothermal in final gross renewable energy consumption in 2020, it is projected to be 0.04–19.16%: the lowest share is forecasted for FYROM, the highest for Hungary.

It should be added that geothermal experts and communities have repeatedly called for a higher share of geothermal energy in the national energy strategies and national renewable energy action plans (NREAPs) for 2020 than was eventually included in official documents. This fact indicates that, unfortunately, geothermal energy is still undervalued by many decision makers and energy planners and that an increase in both knowledge and awareness is necessary.

1.6 Geothermal energy uses development prospects in the GEOCOM countries

It should be pointed out that despite these low official prognoses, geothermal energy, with its prospective resources, mature and credible technologies, proven positive effects of applications, numerous best-practice cases, increasing market and social demand can and will be successfully implemented on a much wider scale in many European countries. This refers in particular to those GEOCOM states possessing several of the best geothermal reservoirs in Europe such as eg. the Pannonian basin, the Inner Carpathian basin, the Larderello–Monte Amiata area, part of the extensive European Lowlands, etc.

The following should be recommended as the main types of wider geothermal uses:

- space heating (district, individual),
- agriculture (greenhouses, poly tunnels, soil heating),
- aquaculture (fish farming),
- drying,
- bathing and balneotherapy,
- heat pumps (for heating and cooling),
- cogeneration of electricity and heat.

As has been pointed out before, in many cases the optimal schemes for using geothermal enegy apply geothermal in integration / hybridisation with other energy sources (traditional or renewable ones) to increase the energy recovered, and their technological and economic effectiveness. What is more – geothermal can and may be implemented in integration with other energy sources (both traditional as well as other renewables) in hybrid systems, in some situations it can be applied to both heat and electricity production in co–generation systems.

Several examples of good practice demonstrating how geothermal energy can be successfully harnessed in various particular conditions in selected localities in the GEOCOM countries are presented in more detail in this handbook with the hope and intention that they will serve as an inspiration and encouragement to develop geothermal energy uses, including in integration with other sources of energy and its rational use, in many other localities and European countries.

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2 RATIONAL ENERGY USE IN GEOTHERMAL HEATING SECTOR

2.1 Introductory remarks

(T. Medgyes, B. Kóbor, J. Szanyi – University of Szeged)

The more widespread use of alternative energy sources has become a strategic objective in Central and Eastern Europe. The following factors and processes initiated the need to use RES systems:

- the drastically growing energy demand of the Earth's population,
- climat change caused by CO_2 and other emissions from combustion of fossil fuels and other greenhouse gases' emissions,
- the dependence of the import of gas.

The stimulation of the utilisation of renewable energy sources is a matter of paramount importance for mankind and economy in the long term. The recovery of fossil energy sources is becoming more and more complicated and expensive, the supply will not cover demand, and thus the total energy supply will not be sufficient. Therefore, the dissemination of alternative energy systems is one of the most important strategic tasks in the long term. This is particularly true for countries with outstanding indicators for one of the alternative energy sources. Renewable geothermal energy potential is one of the most significant alternative energy sources on Earth with a theoretical output of 5000 EJ/year (this is 75% of the total, extractable energy), thus a development worth USD 30 billion is forecast for the geothermal sector over the next 10 years. Geothermal energy is used for electric power production, direct heat recovery, and using heat pump systems to recover geothermal energy. The transformation of the tasks into local level projects fulfils the objectives much better than detailed descriptions of grand ideas. The best way forward is to design and implement urban energy rationalisation projects on the basis of a rational and long-term energy strategy prepared following consultations with local management. The two pillars of the strategy should be that the cheapest energy is unused energy, and local energy demand should be based on local energy bases. The suggested steps in the energy management programme are:

- thermal renovation of public institutions,
- improvement of the efficiency of heat supply (and lighting) systems,
- discovery and use of local renewable energy sources,
- switching to green sources for electricity generation.

As far as the different renewable energy sources are concerned, the methods used should be those with the best return on a cost-benefit basis resulting from economic analyses of the given field. External costs, reimbursement and prevention of environmental damage must be taken into account during the selection of the method. The region's geological and hydrogeological features and the parameters of the available heat market determine the technology applied.

Geothermal energy is close at hand and imposes a minimum threat to the environment, so it can be an optimum source of heat. The favoured method of its use should be a complex multistage application that enables the use of a larger quantity of heat from the geothermal water retrieved. However, geothermal energy is not always enough. The system is often dimensioned to allow supply to be topped up with other energy sources during peak demand on the coldest days. In these situations, ways to supply the missing amount of energy with other RES should be examined.

2.2 Conditions and requirements for efficient geothermal energy's gaining and uses, cooperation of geothermal installations with other energy carriers – hybrid systems

(L. Pająk, B. Kępińska, A. Kasztelewicz, W. Bujakowski, B. Tomaszewska, G. Hołojuch – MEERI PAS)

2.2.1 Generals

According to the scientific nomenclature (Cleveland and Morris 2006), a hybrid energy system combines two or more forms of energy or power to provide a particular energy service. This may include an energy storage component. An example of a hybrid system (according to the literature cited) would be a home powered by a combination of a diesel generator, wind power, and energy storage. Interestingly, scientific works that concern energy mostly discuss the idea of using hybrid systems in the context of electricity and in particular of combining conventional and renewable energy sources. On the other hand, relatively little work has been done on hybrid systems that meet the demand for thermal energy, at least in the context of the explicit classification of systems that combine different energy carriers in order to meet the customers' needs, while in accordance with the definition provided at the beginning, these can also be referred to as hybrid energy sources. Hybrid systems may produce both electricity and thermal energy. Moreover, the generation of electricity and heat is often integrated. Using technical nomenclature, it may be stated that these processes are combined, i.e. take place at the same time and in connection with each other.

In conventional coal– or gas–fuelled power plants, the production of electricity is preceded by the generation of high–temperature thermal energy. This energy is in turn converted into electricity by a system consisting of turbine and generator. After the generation of electricity, low-temperature thermal energy is still available which is often used for heating purposes. In the case of existing (older) heating systems, which were designed in an era when little emphasis was placed on aspects related to energy efficiency, particular attention was paid to reducing the diameter of the district heating distribution network which in turn required the use of high feed temperatures. As a result, the combined production of heat and electricity resulted in adecreased efficiency of electricity generation during the heating season. This was because high–temperature district heating systems used steam that was still sufficiently hot to be used in producing electricity. This steam (temperature of 130–150°C) could still be used to generate electricity, cooling it to ca. 60°C in doing so.

Geothermal power plants operate in a manner similar to conventional ones. If they are to interoperate with the existing large–scale district heating networks, their operating parameters must be adjusted to the operating parameters of the heat distribution network. Consequently, even given the high temperatures of the geothermal resources available, it is rarely the case in Europe that a geothermal power plant is able to feed the existing district heating networks. This is confirmed by the small number of locations in Europe where the temperature of geothermal resources is sufficiently high to enable this kind of interoperability (it is the case in e.g. Italy). Better conditions for the combined generation of heat and electricity are present when the (new or upgraded) heating system is adapted to the parameters of geothermal sources. In practice, the operating temperatures assumed when designing and constructing such systems are often much lower.

Apart from energy distribution issues, the operating parameters of the customers' heating installations are important as well. It should be remembered that the reduced operating temperature of the installation necessitates sufficiently large surfaces of the heating elements used.

The utilisation of hybrid energy sources may be a matter of choice or necessity depending on the parameters of the energy source, the customers' installations, and the distribution network connecting the source to the customers. Most renewable energy sources, including geothermal energy, are characterised by certain constraints on the resources available locally. In the case of geothermal energy, the flow and temperature of the geothermal fluid are limited. The amount of geothermal power available depends on both parameters and is described by the following formula:

$$P = V\,c\,\rho\,(t_1 - t_2) = V\,c\,\rho\Delta t \qquad (1)$$

where:

P – accessible power of geothermal well
V – flow rate of geothermal fluid
c – specific heat of geothermal fluid
ρ – geothermal fluid density
t_1 – fluid temperature at the inlet to the instalation of receiving energy
t_2 – temperature of geothermal fluid at the outlet of the instalation of receiving energy
Δt – the temperature difference of geothermal fluid between the temperature at the inlet and outlet of the instalation of receiving energy

The first constraint that implies the need for othersources in addition to geothermal energy is the incompatibility between the temperature required to feed heating systems and the temperature of the geothermal resources available. A second case in which a supporting source is required is the inadequate (insufficient) flow of geothermal fluid – according to formula (1), the geothermal power available is directly proportional to this flow. This situation is presented in figure 2.2.1.

Formula (1) leads to another important conclusion concerning the impact of the ability of the customer's installation to cool the geothermal fluid on the geothermal power available, and consequently on the need for peak energy sources. The ability to effectively (deliberately and in a manner that is justified in technical and economic terms) cool geothermal fluid, lowering its final temperature for a given flow, results in an increase in the geothermal power available and reduces the need for peak energy sources. The use of additional peak energy sources is not always required from the technical point of view. It may be the result of implementing a deliberate strategy whose purpose is usually to achieve the best economic effects of using hybrid energy sources.

The problem of optimising the use of hybrid energy sources is most readily explained by distinguishing the following categories of energy sources:

1. sources that characterise by high capital expenditure costs in the construction phase but low operating costs (resulting e.g. from the fact that they do not require energy carriers to drive them during operation or these energy carriers are widely available and cheap or free);
2. sources that are characterised by moderate to low capital expenditure costs but incur significant operating costs once they have been commissioned (these costs may result from the need to purchase expensive energy carriers to drive them).

The first category includes most renewable energy sources, and geothermal and solar energy are typical examples of group 1 sources. Group 2 is typical of conventional energy sources where capital expenditure is moderate while operating costs are fairly high. Simplifying somewhat, it may be claimed that the first group represents renewable energy sources, and the second one – conventional sources. In order for renewable sources to be competitive with conventional ones, the condition that the operating costs of RES are lower than those of conventional sources must be met.

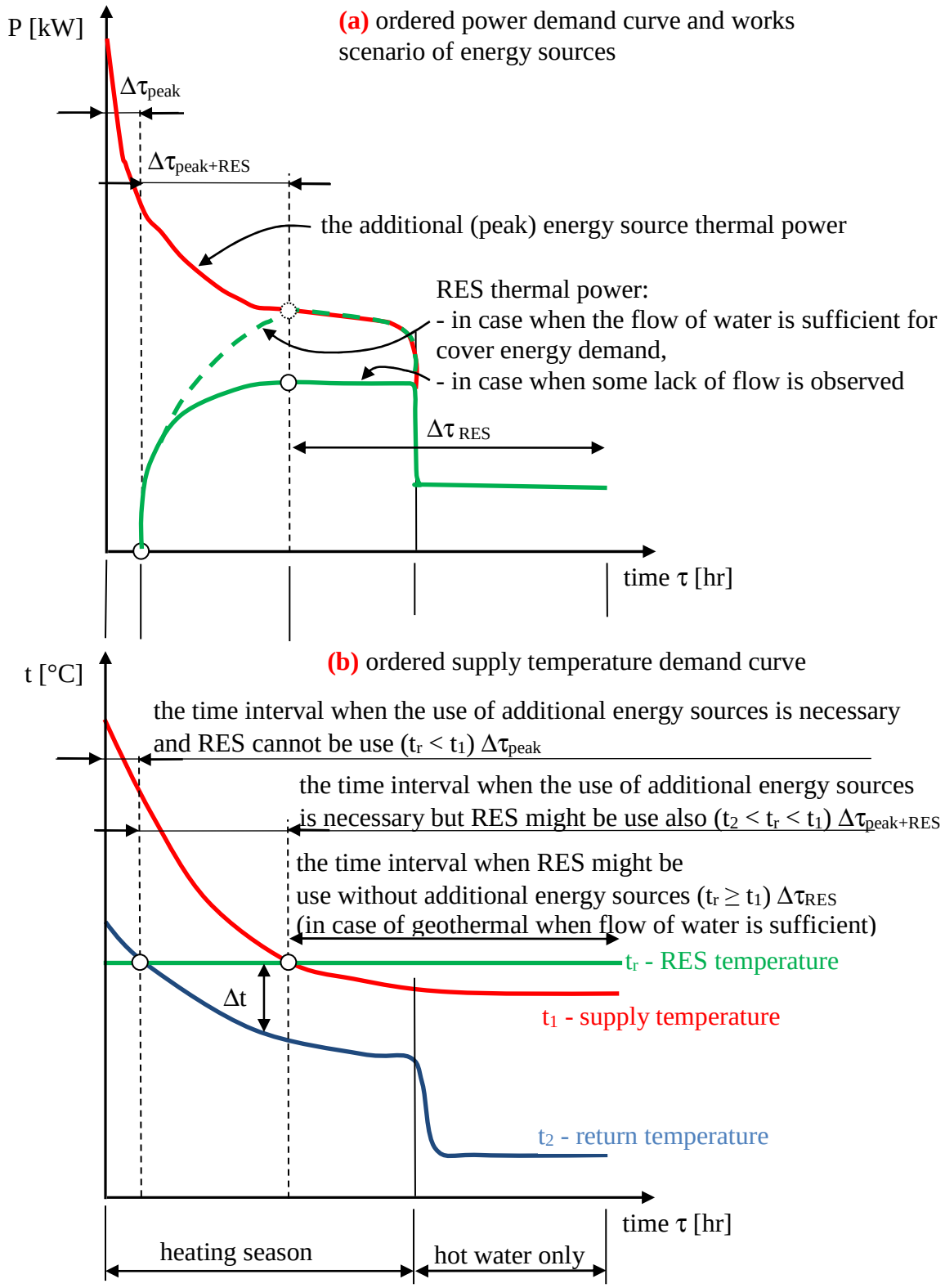

Figure 2.2.1. Determining the need to use supporting sources on the basis of: (a) the load duration curve and (b) temperature

The difference in operating costs can offset the increased capital investment cost and make renewable sources economically competitive with conventional sources. If the operating costs of renewable sources are not lower than those of conventional sources while renewable sources require higher capital expenditure, they cannot compete in economic terms. However, renewable sources usually do exhibit lower operating costs. The scale of economic benefits obtained depends on the difference in the unit cost of energy production and on the amount of energy generated from renewable sources. More precisely, the economic effect associated with the use of renewable energy sources increases as the difference in the level of capital expenditure decreases and at the same time both the difference in unit costs of energy production and the amount of energy generated from renewable sources increase. One measure of the beneficial economic effect of using renewable energy may be the simple payback period of the increased capital expenditure resulting from the use of renewable sources; this is expressed by the following formula:

$$\mathrm{SPBT} = \frac{E_{res} - E_{con}}{Q_{res}\left(c_{con} - c_{res}\right)} \left[\frac{€}{\frac{GJ}{yr}\,\frac{€}{GJ}} = yr \right] \tag{2}$$

where:

SPBT – the simple payback period of the increased capital expenditure resulting from the use of renewable energy sources

E_{res}, E_{con} – the projected capital expenditure related to the commissioning of the energy source

Q_{res} – the amount of energy generated by the conventional energy source

c_{con}, c_{res} – the unit costs of energy production for the conventional and renewable sources

The unit costs of energy production should include the cost of purchasing energy carriers (including additional carriers, e.g. the electricity to drive pumps), repair and maintenance costs, operating costs and the costs of purchasing supplies. It should be stressed that these are not total unit costs of energy production since they do not include the fixed cost component associated with plant depreciation. The deployment of the technology in question is justified in economic terms if the simple payback period of the increased capital expenditure (as compared to the conventional technology) is shorter than the technical life of the main elements of the energy source in question. Only in this case is the increased capital expenditure likely to be offset by the savings resulting from the difference in operating costs.

The simple payback period of the increased capital expenditure is inversely proportional to the amount of energy generated by the source. This conclusion can be framed as follows: if the source of energy is more expensive than the reference source in the investment phase but cheaper in the operational phase, the beneficial economic effect can be expected to increase together with the amount of energy produced by the source.

In most cases, the level of capital expenditure required to construct an energy source depends on the amount of power that we wish to generate. This relationship is typical of conventional energy sources – the greater the capacity installed, the higher is the capital expenditure to be expected. In the case of renewable energy sources, the relationship is not that obvious, however, and geothermal energy is a case in point. Here, the level of capital expenditure depends largely on the resources available – if we invest the same amount in two geothermal energy sources, we cannot always expect the same effect in terms of the power generated. However, in the light of the foregoing, irrespective of the type of the source and its characteristics, it may be claimed that if we invest a certain amount of money in a renewable energy source with a certain capacity, the initial expenditure will be repaid sooner

(compared to a conventional technology) if the operation of the source over time is more balanced, i.e. more energy is generated using the capacity installed. The impact of the balanced operation of the energy source on the amount of energy produced from the capacity installed presents figure 2.2.2, using the examples of two different uses of energy: heating residential buildings and producing domestic hot water. On the chart, heating power is shown as a function of time. In this coordinate system, the amount of energy produced corresponds to the area under the load duration curve, and this is expressed in mathematical terms in figure 2.2.2.

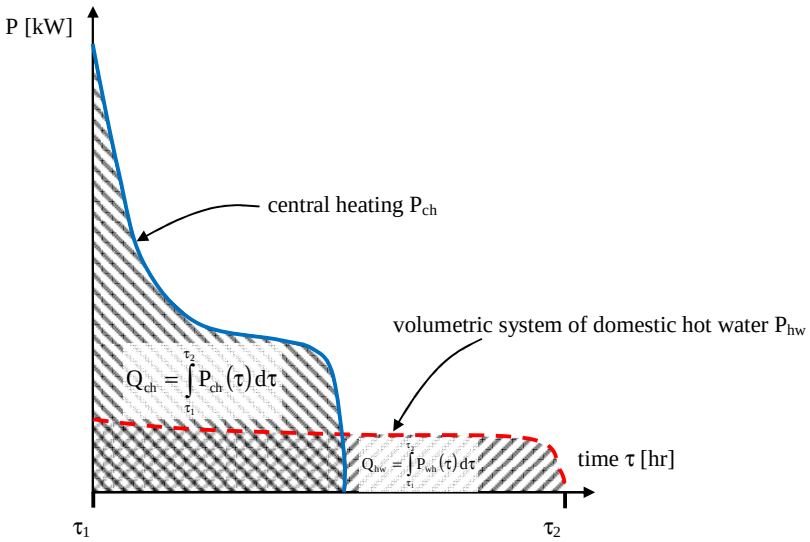

Figure 2.2.2. Comparison of the utilisation of installed capacity for two different types of heating needs

The load duration curve is often used in the heating industry. This curve is produced by ordering instantaneous power demand over the year in a decreasing order. It hasalready been used in the upper section of figure 2.2.1. The optimisation of the operation and design of hybrid sources is based on a certain proposition which can be formulated as follows: irrespective of the characteristics of the load demand curve, a certain power range can be distinguished for which the renewable energy source in question is preferable to the conventional source, and also a power range for which the use of the conventional source is preferable. In the above proposition, in line with the previous assumptions, the renewable source is synonymous to a source with high capital expenditure and low operating costs whereas the conventional source is characterised by low (or moderate) capital expenditure and high operating costs (related primarily to the purchase of energy carriers). The proposition applies in each case where the energy sources meet the above condition, i.e. they need not necessarily be renewable and conventional sources. In figure 2.2.3, the above proposition is presented graphically for a building that uses a source of energy for producing domestic hot water and for residential heating purposes. In the figure, the concept of the installed thermal capacity utilisation ratio is used, which is defined as the amount of thermal energy produced divided by the thermal capacity installed. The value of this ratio obviously depends on local climatic conditions since these affect the capacity installed and the amount of energy generated and consumed by the customer. For instance, the value of this ratio for Poland is ca. 7 (GJ/year)/kW_{th}, which means that each kW_{th} of installed capacity produces ca. 7 GJ of thermal energy per year.

However, figure 2.2.3 shows that it is possible to distinguish certain power ranges for which the value of this ratio may be much higher and also ranges for which it may be much smaller. Based on considerations concerning the cost-effectiveness criteria for the use of energy sources from individual

groups, it may be assumed that different sources will prove optimal in the corresponding power ranges. In almost every case analysed, the load demand curve can be broken down in order to isolate ranges in which capacity utilisation ratios are different; therefore it may be assumed that different sources will operate in an economically optimal manner in these ranges. This way of thinking about meeting load demand is the main idea behind the application of hybrid systems, and particularly of hybrid energy sources. The discussion above pertains to thermal energy but the same criteria apply to other forms of energy.

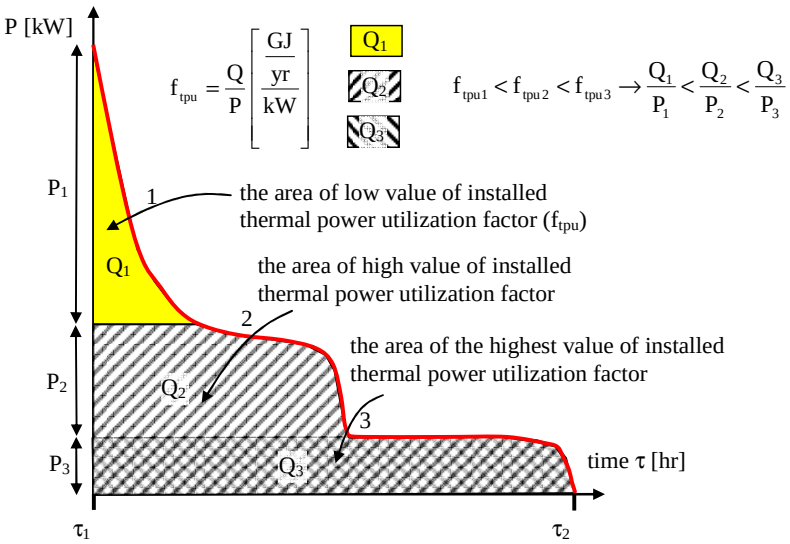

Figure 2.2.3. Breakdown of the load duration curve associated with space heating and the production of domestic hot water for a residential building into areas with different values of the capacity utilisation ratio

In conclusion, the use of hybrid energy sources may have two causes:

- it may be a matter of necessity where a single source of energy cannot meet the technical parameters required by the customer (usually due to insufficient capacity or temperature),
- it may be a matter of choice, and hybrid sources are usually used to achieve economic benefits, although they may also be used due to other criteria (environmental, limiting the consumption of certain energy carriers, etc.).

2.2.2 Cooperation of geothermal installations with other energy carriers – hybrid systems in case of the GEOCOM project works

Within the framework of the GEOCOM project, the idea of integrated production of energy in hybrid systems has been implemented on a fairly large scale. Additionally, the possibilities for the cascade utilisation of geothermal energy have also been highlighted taking into account its peculiar features and the impact of customer characteristics on energy efficiency. Before being connected to the network, most buildings covered by the project were upgraded in order to reduce their demand for thermal power and consequently energy – in each location (Montieri, Galanta and Mórahalom) where investment tasks were implemented under the GEOCOM project, the thermal efficiency of buildings was improved. In addition, the use of solar energy to produce heat and electricity was proposed. The use of solar energy is especially efficient in southern European countries and the use of the heat

generated by solar systems is also a good solution where connection to the district heating network is not cost–effective (for buildings far from the main hot water pipelines). The use of photovoltaic modules in local low–power applications is particularly cost–effective for building and street lighting and those were precisely the application areas proposed under the GEOCOM project. The use of combustible gas dissolved in geothermal water in Mórahalom is an interesting solution. Under the project, it was proposed to use this gas to drive the units used for the combined generation of power and heat. The individual investment tasks implemented under the project are described for the relevant pilot locations. In summary, it can be stated that they promote the idea of efficient integrated generation of various forms of energy in hybrid systems by:

- Adapting (improving) the thermal efficiency characteristics of buildings to reduce their power demand. The result was the ability to meet the needs of a larger group of customers using a single energy source.
  Locations: Mórahalom, Galanta, Montieri.
  Effect: energy efficiency increase;
- The combined production of different types of energy (heat and electricity).
  Locations: Mórahalom, Galanta, Montieri.
  Effect: combined generation of power and heat, using hybrid energy sources;
- Using hybrid energy sources.
  Locations: Mórahalom, Galanta, Montieri.
  Effect: using hybrid energy sources;
- Using renewable energy sources for residential heating and producing domestic hot water as well as meeting electricity demand to some degree (owing to the amount of power available, this concerns mostly lighting).
  Locations: Mórahalom, Galanta, Montieri.
  Effect: energy efficiency, using hybrid energy sources;
- Increasing the number of customers who use energy from renewable sources by improving the coverage of the district heating network and eliminating conventional energy sources.
  Locations: Mórahalom, Galanta, Montieri.
  Effect: energy efficiency increase;
- Using waste energy (using the energy of combustible gas dissolved in geothermal water.
  Location: Mórahalom.
  Effect: energy efficiency increase;
- Addressing the environmental impact of using geothermal energy resources through reducing the amount of water discharged by injecting it into the reservoir after its use. Location: Galanta.
  Effect: energy efficiency increase, reducing the impact on the environment.

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2.3 Integration of geothermal energy with other renewable energy sources – main possibilities in the GEOCOM countries

(Tamás Medgyes, Balázs Kóbor, Attila Csanádi, Emőke Egyed, János Szanyi, Elemér Pál–Molnár – University of Szeged)

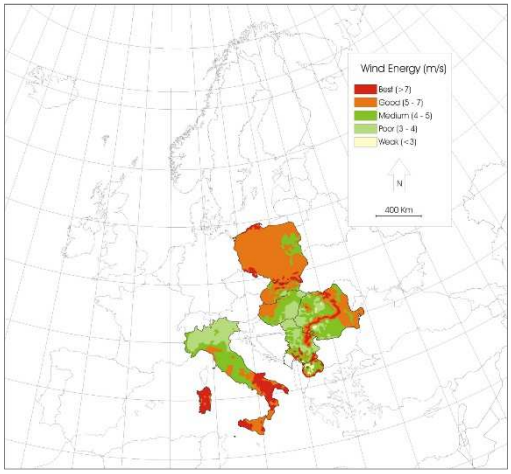
In a study carried out within the GEOCOM project the researchers of the University of Szeged analysed the integration potential of renewable energy sources in the countries covered by that project: Hungary, Italy, Macedonia, Poland, Romania, Serbia and Slovakia, using the GIS method. They created five categories for every source considered (ranks: best, good, average, below average, weak), and a union of these during the integration. The basic form of energy considered was geothermal, and the possibility of adding solar and wind as auxiliary energies was examined. While biomass is still the leading renewable source in CEE, none of the GEOCOM pilot sites uses this source hence biomass is not dealt with in this chapter. The prospective combinations of geothermal and other prospective renewable sources are presented in figures 2.3.1 – 2.3.3. and described below.

Geothermal energy and solar energy

Solar energy can be considered as an auxiliary energy for heat pumps. The addition of geothermal and solar heat flux maps results in a significant and useful map. According to this, the most favourable areas are Italy, especially the southern part, southeast Hungary, Serbia and Montenegro. In this case, the electricity for the operation of the heat pumps (for heating and cooling) could be generated with solar cells, and the primary water of the heat pump could be pre–warmed with solar collectors (in cold weather conditions), which would improve the efficiency of this pump. Moreover, solar collectors can provide support in the production of domestic hot water. When comparing temperature at a depth of 2 000 m and the solar flux the pattern is similar. In this case, the south–western part of Hungary is also a favourable region. The linking of these two sources can mainly be an advantage in the production of domestic hot water. The results are almost the same when comparing the temperature at a depth of 5 000 m and the solar energy flux. The same countries can be treated as favourable. In this case, the two sources should be linked if it is possible to install solar cells on a large area to provide the energy required for the extraction of geothermal fluid.

Geothermal energy and wind energy

The combination of geothermal energy and wind energy can be useful for covering the electricity demands of geothermal systems. First, let us take a look at shallow heat pump systems: for these systems, especially with pumps with capacities of several hundred kW_e or MW_e, one wind turbine could satisfy the electricity demand of one system. The map combining the maps for these two sources shows that the most favourable regions are the northern countries, especially Poland and southern Italy, and the western area along the sea. The mountain areas of Romania, Slovakia, Serbia and Montenegro, and the north–western part of Hungary have favourable features. The bufferability of the wind energy is a an important factor when considering its combination with geothermal features at great depths, since the extraction of geothermal water, both for heat and electricity production, requires a significant amount of pumping and reinjection energy. Buffer reservoirs, where it is possible to construct them, can allow the moderation of the biggest disadvantage of using wind energy, namely the unstable network load due to the dependence on temperature. On the basis of a 2 000 m depth, the most suitable areas are almost identical with the regions defined above. A comparison of geothermal features at a 5 000 m depth m and wind energy distribution shows a different pattern: mountains, specially the Carpathians, are not favourable regions.



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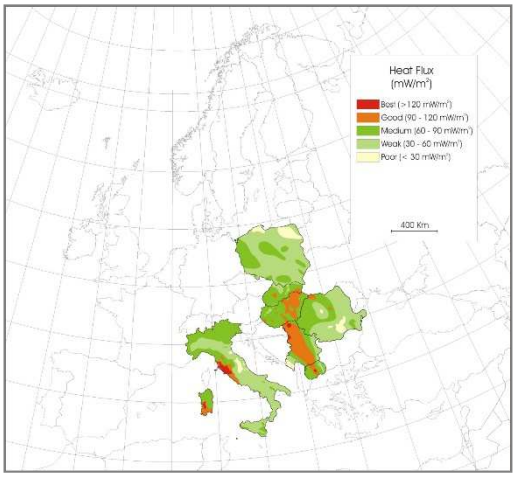

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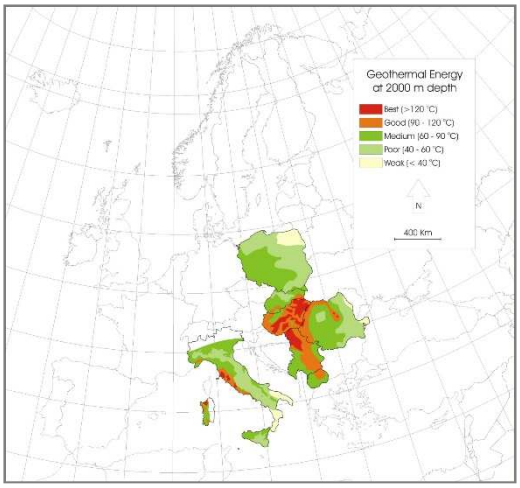

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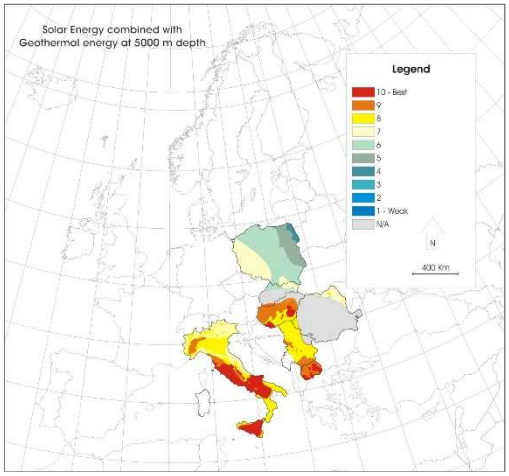
Figure 2.3.1. Exemplary maps of the potential of some renewable energy sources which were used for elaboration of maps of their prospective combinations (GIS method; figs. 2.3.2 – 2.3.3) – the GEOCOM countries:
a. wind energy,
b. geothermal heat flux,
c. geothermal energy (2 000 m depth)



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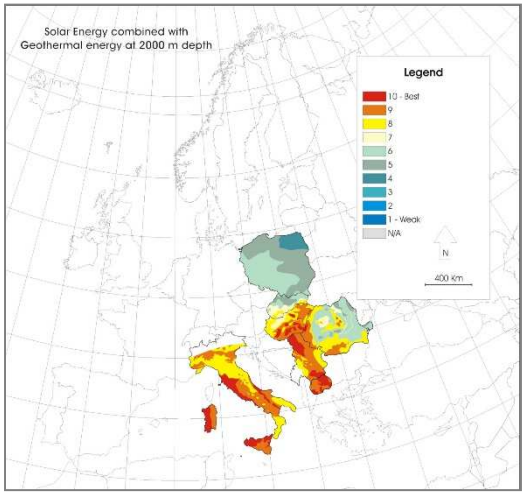

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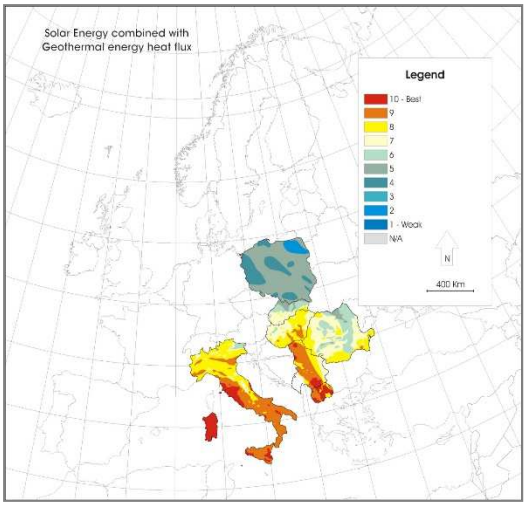

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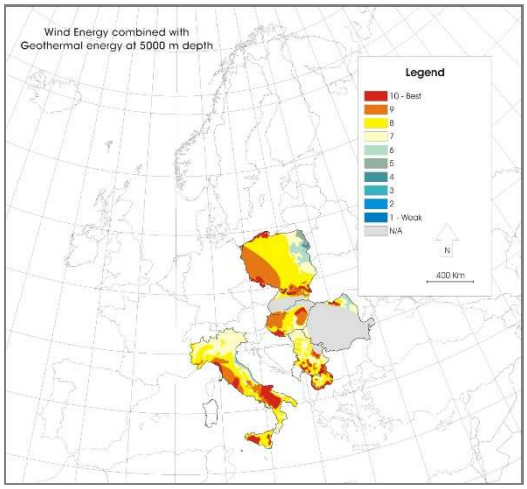
Figure 2.3.2. Maps of prospective combinations of solar energy and geothermal energy – the GEOCOM countries:
a. solar combined with geothermal (5 000 m depth),
b. solar combined with geothermal (2 000 m depth),
c. solar combined with geothermal heat flux



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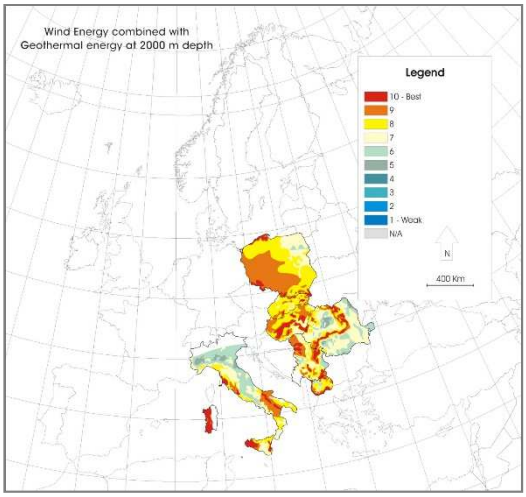

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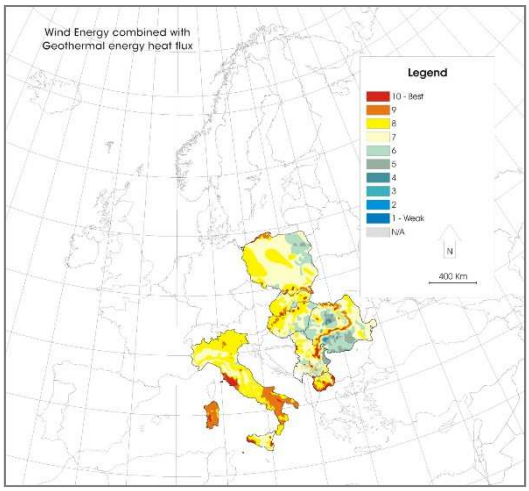

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Figure 2.3.3. Maps of prospective combinations of wind energy and geothermal energy – the GEOCOM countries:
a. wind combined with geothermal (5 000 m depth),
b. wind combined with geothermal (2 000 m depth),
c. wind combined with geothermal heat flux

3 BEST PRACTISES OF GEOTHERMAL USES IN INTEGRATION WITH OTHER RENEWABLE ENERGY SOURCES AND RATIONAL ENERGY USES' MEASURES – THE GEOCOM DEMONSTRATION SITES

3.1 Introduction

(B. Kępińska – PAS MEERI)

The chapter presents good practices of geothermal energy applications in integration with other renewable energy sources, thermal retrofitting, rational energy uses an other specific tools in three demonstration sites: municipalities of Galanta (Slovakia), Montieri (Italy) and (Hungary), as performed according to the objectives of the GEOCOM project.

The installations for the operation and geothermal energy uses in given localities were carried out in each case individually, in close liaison with the parameters and characteristics of available geothermal resources, the specifics of the heat demand, needed retrofitting works, existing surface infrastructure (or necessary for the implementation), the nature and value of architectural buildings and urban structures of particular municipalities.

This signaled diversity caused that each of the examples concerns some other existing realities and circumstances in which geothermal as well as other renewables and rational energy uses' measures were introduced. They are also representative of the various architectural structures, historically conditioned buildings and urban spaces often found in the GEOCOM and other countries in Europe:

- Original medieval building development of historical and artistic value and related requirements (like in Montieri),
- Building development typical for towns of Central and Eastern Europe from the nineteenth and early twentieth with relatively well preserved centers and newer parts (like in Morahalom),
- Multi-storey blocks of flats from the second half of the twentieth century typical for many towns in post–socialist countries (constructed from large concrete slabs) which require urgent refurbishments and thermal retrofitting, reduction of energy consumption and introduction of ecological energy sources (like in Galanta).

Each of the systems was equipped with proper metering and monitoring devices. In all cases the pilot investment works have resulted in a significant decrease in energy consumption and its costs. Importance was also given to inform residents and learn about their views on the introduction of geothermal, other RES and rational energy use measures to heating systems.

3.2 Galanta Municipality

(Marcela Mazsarova – Galanta Municipality, cooperation: Bysprav, Ltd., Galantaterm Ltd.)

3.2.1 The Galanta Municipality in a nutshell

Galanta is a town situated in the south-eastern part of the Slovak Republic. It lies on a lowland area lying approximately 50 km from the capital city, Bratislava. The distance from the capital city and its position approximately 50 km north of the boundaries of Hungary and Austria (figure 3.2.1) confirm the advantageous location of the town which is very suitable for investors and their business activities. Galanta has 16,500 citizens (density 466/km^2), an area of 396 ha and is one of the commercial and cultural centres of the region. As regards its local government administration, it is a district town belonging to the Trnava County. The town is divided into three regions: Galanta, Javorinka, Nebojsa. A bird–eye view of Galanta is shown on figure 3.2.2.

Galanta is surrounded by several rivers and smaller streams: the Váh, Malý Dunaj and Dudváh. The town has rich geothermal water resources.

Since Slovakia joined the European Union, many foreign companies have established themselves in Galanta and these have contributed to the general development of the town. Galanta is an important administrative and cultural centre serving the district of the same name. It is the seat of the bodies of state administration, and a centre of trade and services. An industrial park is situated along the railway line, which is an important railway junction with lines leading in four directions. The city hosts seven banks, a customs office and a Regional Development Agency. Foreign companies have successfully established themselves in the town over the years. The most important investor is Samsung (since 2002). The company has also built up a logistic and distributional centre for Central and Eastern Europe. This has resulted in the creation of a significant number of new jobs. The latest registered unemployment rate is 2.69% (equivalent to 230 unemployed persons in the city).

Visitors can find accommodation in the hotel and there are restaurants, pubs and cafes in the town. The Cultural Centre organises social and cultural events; there is a cinema, an amphitheatre, a town gallery, a museum of history and a library providing cultural programmes. Sports facilities include the sports' hall, the stadium, tennis courts, swimming pool, fitness centres and saunas. Close to the town there is also a recreation centre called Kaskády with excellent facilities for water sports and fishing on the Kráľová reservoir. In addition, there are three geothermal swimming pools near Galanta: in Diakovce, Horné Saliby and Vincov Les.

The town has a rich cultural and social life. Regularly repeated annual events are very successful and have a high attendance rate. The Galanta Summer Fair is held in August, it is enriched by cultural and sporting events as well as a beer festival.

Last but not least, Galanta is fortunate to have rich geothermal water resources. These have been tapped by several wells and used for its geothermal district heating system since the mid-1990s (the wells were drilled in the early 1980s but were not used until 1995). The system supplies several blocks of flats and a hospital. Geothermal resources were one of the main subjects of the GEOCOM demonstration works (described later in this chapter). The municipality has made efforts to extend the use of this green energy, which is widespread in the city, and to ensure that this energy will be available for future generations.

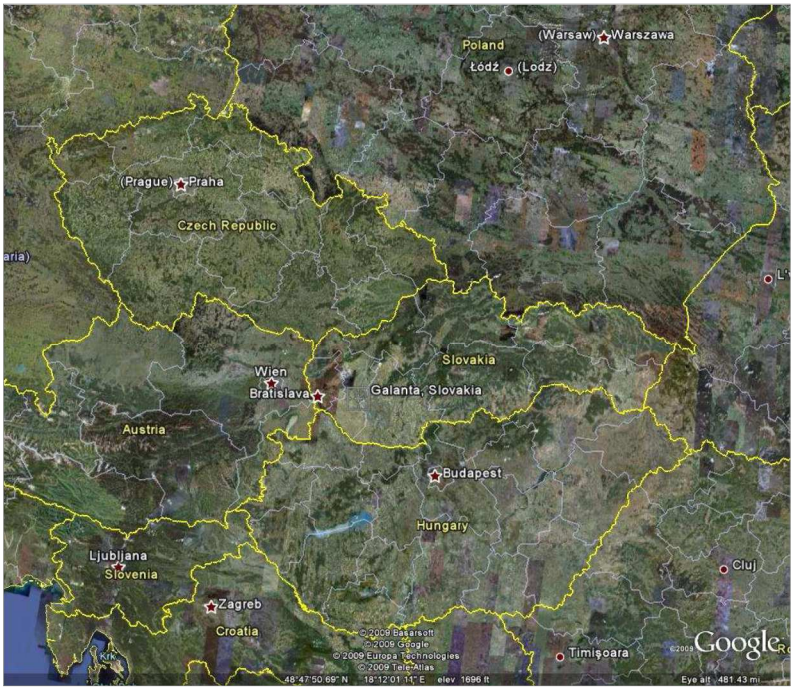

Figure 3.2.1. Location of the Galanta town
(image source: *https://www.google.sk/maps/@49.4528274,18.6699392,664280m/data=!3m1!1e3*)

Figure 3.2.2. Bird eye view of the Galanta town
(image source:
https://www.google.sk/maps/place/924+01+Galanta/@48.1875848,17.7062672,3703m/data=!3m1!1e3!4m2!3m1!1s0x476b6f6e0dc1f295:0x400f7d1c696eb20!6m1!1e1)

3.2.2 The geothermal district heating system

Activities related to the development of the use of geothermal energy

The energy supply for space heating and domestic hot water (DHW) in Galanta has been provided by the geothermal district heating system. It consists of three central hot water heating plants, heat exchangers and an appropriate distribution system. The system is based on natural gas and geothermal water as heat sources. The company Bysprav Ltd. (one of the GEOCOM partners) assures the production of heat and DHW via two central heating plants (K11 and K12) and one separate heating plant (K 16). The installed geothermal capacity of the system is 10 460 kW_{th} and the installed capacity of the gas heating plant is 13 100 kW_{th}.

The heating plant K11 was constructed for the district heating network in 1969. It used 5 solid fuel boilers (installed capacity 11.64 MW_{th}). In 1992 it was refurbished and the former solid fuel system was changed to one based on natural gas. This step decreased the plant's emissions to the environment and increased the efficiency of heat production. In 1996 the systems for production of hot water for heating and domestic warm water were changed. Since that year the DHW has been produced in three DHW boilers with 30 m^3 capacity.

The heating plant K12 was constructed in 1973 using four natural gas boilers with a nominal thermal capacity of 1.86 MW_{th}. In 2000 it was completely refurbished and four Viessmann boilers were installed with an overall capacity of 9.54 MW_{th}. In 2004 the second phase of the refurbishment was carriedout when the plant was connected with plant K16.

Two geothermal production wells (FGG-2 and FGG-3) have been working in the heating system to provide geothermal energy for district heating and domestic hot water production.

Geothermal well FGG-2 was drilled in 1983 as a part of a research programme implemented by the Geological Survey of Dionýz Štur (GUDŠ Geologický ustav Dionýza Štura).

A year later (in 1984) the geothermal well FGG-3 was drilled as part of a construction experiment. The geothermal water was intended to be used as a heat source for the blocks of flats in one of the residential districts of Galanta – Sever, for the hospital, health centre and for other public amenities.

However, due to alack of financial resources that plan was not implemented at that time. The fall of the socialist system created new conditions for private enterprise and made it possible to return to the project on a businessbasis. In 1995 the Galantaterm Ltd. Company was established. Its shareholders were the Municipality of Galanta, Slovenský plynarenský priemysel (Slovak Gas Industry), Orkuveita Reykjavikur (Reykjavik, Iceland), Slovgeoterm a.s. and Nordic Environment Finance Corporation Helsinki (which sold its business shares to the Municipality of Galanta in 2003).

After preparatory works the facilities for the geothermal water /energy uses were built in 1995 and 1996. In November 1996 Galantaterm Ltd. started the use of geothermal water for the production of heat and domestic hot water and their supply to the flats and public amenities located on the Galanta-Sever residential estate and to the hospital in Galanta.

The flats were equipped with heating elements/radiators for a 77/52°C circulation loop. After finishing the construction of the housing estate (blocks of flats) a central gas boiler plant was erected and put into operation to cover the demand for heat and domestic hot water of the whole residential district.

The operator of the gas boiler plant was the Galanta Municipal Housing Company. The gas boiler plant was equipped with 4 warm-water boilers with an installed capacity 4 x 2.65 MW_{th}, i.e. 10.60 MW_{th} in total.
Heat supply for the hospital was provided by a coal-fired heating plant equipped with 4 automatic medium-pressure water-tube steam boilers fuelled by lower-quality coal. Their total installed capacity was 4.44 MW_{th} (4x1.86 MW_{th}). There was also a reserve source – a 3.9 MW_{th} packaged gas boiler plant BK6. These generated medium-pressure steam (gauge pressure of 0.8 bar which provided heat for the radiators, ceiling heating, production of domestic hot water and industrial steam for the kitchen and laundry and the sterilization and air–conditioning systems.

The generation of heat and production of domestic hot water was performed in 3 heat exchanger stations (HXS): HXS 1 situated in the boiler house of the Hospital, HXS 2 in the health centre/polyclinic, and HXS 3 in the hostel attached to the Hospital.

To sum up – the basic parts of the energy system in Galanta are:

- Geothermal wells FGG-2 and FGG-3A – a primary source of heat,
- A geothermal heat exchanger station,
- A reserve heat source (gas-fuelled),
- The district heating network in the Galanta – Sever housing estate,
- The hospital's own heating system.

Their detailed description is as follows.

The structure of the geothermal energy system

Geothermal wells FGG-2 and FGG-3 – the primary source of heat

Geothermal water from the FGG-2 and FGG-3 wells (figures 3.2.3 and 3.2.4) serves as the primary heat source used in the energy system. Geothermal energy covers the heat demand of consumers until the average outside temperature falls to 2°C. When the temperature is lower than this a peak heat source (fuelled by gas) is put into operation to deliver the additional quantity of heat required. This source is also used as a reserve source should there be a failure in the supply from the wells.

Geothermal water is ptoduced by two wells by submersible pumps driven by electromotors equipped with a frequency speed–changing device. Their operation is controlled by a computer that ensures that only the exact quantity of geothermal water that is needed by the system at that moment is taken out of the wells. After degasification the geothermal water flows to the heat exchanger.

The characteristic parameters of deep wells FGG-2 and FGG-3 are given in table 3.2.1 while table 3.2.2 gives the physico-chemical characteristics of the geothermal water discharged. Table 3.2.3 shows the total heat production (from geothermal water and gas) produced by the heating systems operating in Galanta in recent years (2010–2014).

Table 3.2.1.Characteristic parameters of wells FGG-2 and FGG-3 – primary geothermal energy sources for district heating system in Galanta

Well name	FGG-2	FGG-3
Year of drilling	1982 – 1983	1984
Final depth	2101 m	2102 m
Open section	1706 –1932 m	1731–1999 m
Reservoir formation	Sandstone	Sandstone
Casing diameter	245 mm	245 mm
Water wellhead temperature	78°C	77°C
Natural water flow rate (artesian)	20 L/s	Cca 25 L/s
Recommended water production (from 1998)	15.8 L/s	18 L/s

Table 3.2.2. Chemical analyses of geothermal water discharged by wells FGG-2 and FGG-3 in Galanta. Year 2015 (source: Geological Survey of Sloval Republic. Geoanalytical Laboratory Spisska Nova Ves)

Date of analysis		03.03.2015	03.03.2015
Element	Unit	FGG-2	FGG-3
Cl^-	mg/L	406	838
SO_4^{2-}	mg/L	269	122
H_2S	mg/L	0.73	0.47
Al	mg/L	0.02	0.04
Fe	mg/L	0.035	0.052
K	mg/L	13.2	17.7
Na	mg/L	1 344	1 711
Ca^{2+}	mg/L	4.6	5.3
Mg	mg/L	1.03	1.31
SiO_2	mg/L	39	35.5
B	mg/L	13.4	14.7
pH	mg/L	7.31	7.3
HCO_3^-	mg/L	670	3 170
CO_2 tot.	mg/L	1 075	1 286
CO_2 free	mg/L	114	146
CO_2 agr.	mg/L	<1.1	<1.1
F^-	mg/L	2.6	1.9
TDS at 105°C	mg/L	3 566	4 456
TDS at 550°C	mg/L	3 408	4 322
Conductivity at 25°C	mS/m	454	599
Dissolved O_2	mg/L	0.5	0.46
NH_3^+	mg/L	7.26	9.82

Table 3.2.3. Total heat production (from geothermal water and gas) by heating systems in Galanta, 2010–2014

Year	Heat production [GJ]
2010	91 450
2011	77 819
2012	73 729
2013	73 672
2014	62 764

The heat production depends on the actual heat demand of consumers determined by the actual weather conditions. The decrease in production is attributed to climatic/weather conditions (warmer winters) and also to some other objective and production factors such as the consumers' efforts to reduce their heat consumption by carrying out different energy saving measures (owing to high heat prices), the refurbishment and external insulation of some residential buildings on the Sever housing estate and of the Patria Old People's Home, and the changing of the windows at the Gejza Dusík Elementary School. Also the Galantaterm Ltd. Company (operator of the heating systems) made several efforts to achieve the best possible operation of the heating system and energy efficiency.

The geothermal heat exchanger station

The geothermal heat exchanger station serves as the main unit for transferring the heat from the geothermal water to the secondary (heating) circuit of the local distribution system. Geothermal water pumped from the FGG-2 and FGG-3 wells is brought to the collector/accumulator in the heat exchanger station. Then it passes through the plate heat exchanger system and transfers thermal energy to the particular heat systems of the secondary circuit. The goal is to achieve maximal cooling of the geothermal water with a minimum flow rate from the wells.

In geothermal water applications one can distinguish two use periods:

- winter operation (heating period),
- summer operation.

Application of geothermal water in the winter (heating period):

A three–stage cascaded system is used when geothermal water is used for heating: Geothermal water gradually passes through 3 heat exchangers HX-1, HX-2 and HX-3 and transfers its heat to the particular heating systems connected to these heat exchangers. In the use of geothermal water for the production of domestic hot water, a two–step method is applied by which the geothermal water gradually passes through heat exchangers HX-4 and HX-5.

The geothermal heating system is divided into the following circuits (figure 3.2.3):

- A 90/70°C heating circuit – used for a classical radiator heating system in the Hospital and hostel, andalso used for the production of domestic hot water in the heat exchanger stations HXS-1, HXS-2 and HXS-3. The total heat output is 3 060 kW_{th}. Of this sum, 1 800 kW_{th} is supplied by geothermal energy from the heat exchanger HX-1. The system operates during the whole year and acts a control on the production / capacity of the boreholes during the summer period;

- A 72/52°C heating circuit – which provides the heating for the Sever housing estate. The total output is 6 500 kW_{th}, from which 4000 kW_{th} is supplied by geothermal water through the heat exchanger HX-2. The system operates during the heating period and also controls the output of the wells;
- A 52/42°C heating circuit: This is used for radiant ceiling heating in the hospital. The total output of the circuit is 2 740 kW_{th}, of which 2 300 kW_{th} is supplied by geothermal water through the heat exchanger HX-3;
- A district heating circuit for the production of domestic hot water (55°C) – which contributes to the combined supply of hot water for the Sever housing estate – preheating in the heat exchanger HX-4 with a capacity of 810 kW_{th}, additional heating by heat exchanger HX-5 with a capacity of 1 550 kW_{th} and accumulation in a heat storage tank of 10 000 L capacity. Geothermal energy is the exclusive source that is used for the production of domestic hot water.

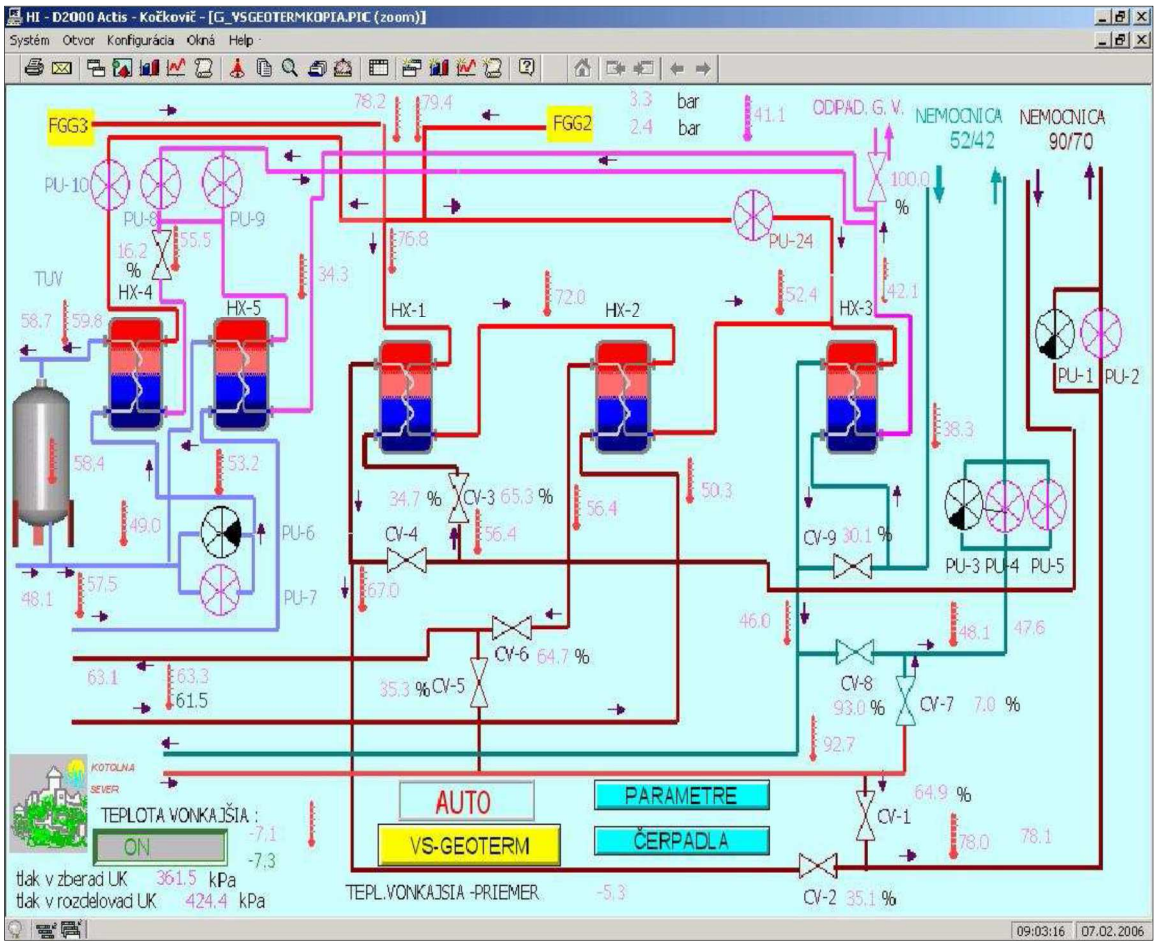

Figure 3.2.3. Sketch of geothermal heating system in Galanta – a screen shot

Words and abbreviations used in the sketch: *ODPAD G.V. – spent geothermal water, NEMOCNICA 52/54 – Hospital, heat gradient 52/54, NEMOCNICA 90/70 – Hospital, heat gradient 90/70, PU – Pump, TUV – Domestic hot water, HX – Heat exchanger, CV – Pneumatic valve, TEPLOTA VONKAJŠIA – Outside temperature,tlak v zberači UK – Pressure in the collector, tlak v rozdelovači – Pressure in the distributor, Teplotavonkajšia – priemer – Outside temperature –average, Čerpadlá – Pumps, VS Geotherm – geothermal heat exchanger station*

Application of geothermal water in the summer period:

In the summer period the energy production is focused on domestic hot water for the Sever housing estate and for the hospital:

- For the housing estate –a two–step method is applied with two heat exchangers,
- Heat exchanger HX-5 –pre-heats the cold tap water, heat exchanger HX-4 provides additional heating,
- Production of domestic hot water for the hospital – ensured by heat exchanger HX-1. In the summer period the flow of geothermal water is controlled to maintain a constant 60°C temperature in the 90/70°C heating circuit which is used for the preparation of domestic hot water in the heat exchanger stations HXS -1, HXS-2 and HXS-3. The gradients of temperature in the individual heating systems fuelled by geothermal heating is maintained down to an average outside temperature of 2°C.

With regard to the above–mentioned outside temperature, if the heat output from the heat exchanger is insufficient, hot water at 110°C (produced by the peak gas boiler plant) is admixed.

The flow rate of geothermal water from the wells and also the whole operation of the system is controlled by a computer. This guarantees that the essential parameters related to the temperature of the domestic hot water are observed and that the heating parameters determined from heating curves (equithermic regulation) for the different heat gradients are maintained.

Spent geothemal water is discharged by exhaust pipeline into the seepage drain of the Kraľova Hydroelectric Power Plant and after blending with the seepage water in the drain it flows into the river Vah.

The peak gas fired boiler plant – the reserve source of heat

Four gas-fuelled, warm-water boilers are installed in the boiler house (figure 3.2.4). Their capacity is 2 x 2 560 kW_{th} and 2 x 3 900 kW_{th} while the heat gradient is 110/70°C. The total installed capacity of the boiler plant is 13 100 kW_{th}. The gas boilers cover the missing output when the outdoor temperature goes down to 0°C – +2°C. Boilers start to operate gradually, the process is computer controlled. The peak boiler plant and heat exchangers are interconnected in order to provide heat at any operating state and under any conditions (e.g. failure of the wells).

Heating system of the Galanta – Sever housing estate

The buildings in the Sever housing estate are heated by a double-pipewarm-water heating system with bottom distribution and forced circulation with a 72/52°C temperature gradient in the heating system. The maximum demand for heating is 6500 kW_{th} and for production of domestic hot water is 2 360 kW_{th}. The heating water and the domestic hot water are distributed to the residential district through insulated warm-water pipes.

Heating system of the hospital

The hospital (figure 3.2.5) is supplied by the following systems:

- a double-pipe hot water heating system with bottom distribution and forced circulation of the water with temperature gradient 90/70°C and a heat demand of 1 540 kW_{th},
- a widesurface ceiling radiant heating system with forced circulation and a temperature gradient of 52/42°C and a heat demand of 2 740 kW_{th}, for the production of domestic hot water the heat demand is 1 520 kW_{th}.

Figure 3.2.4. The gas boilers in heating plant, Galanta (photo by M. Bartek)

Figure 3.2.5. Hospital in Galanta provided with heat, domestic warm water and some other needs by geothermal energy (photo by M. Bartek)

3.2.3 The GEOCOM demonstration works in Galanta

3.2.3.1 Scope of the works

The GEOCOM project's investment activities in Galanta were planned to be focused on the further use of geothermal energy by retrofitting measures, connection of new areas to the district heating system, integration of other RES and, last but not least, on the development of possible reinjection techniques. Four main groups of demonstration works were performed:

1. The retrofitting of dwellings and RES integration,
2. The retrofitting of the elementary school and RES integration,
3. The connecting of new areas to the geothermal district heating system,
4. Research into a reinjection borehole, project works and full documentation.

(The works in items 1–3 above dedicated to thermal retrofitting and the introduction of more geothermal energy into the district heating systems are described below).

The common goal was to achieve the sustainability and expansion of geothermal heating in the town of Galanta and to assure its sustainable development. This would also result in the streamlining and optimisation of the use ofgeothermal energy in integration with other renewable energy sources.

Three organisations, the GEOCOM partners, were responsible for managing the works: Bysprav, Municipality of Galanta and Galantaterm Ltd. (figure 3.2.6). Figure 3.2.7 shows the locations of the Concerto areas where the demonstration works of the GEOCOM project were done.

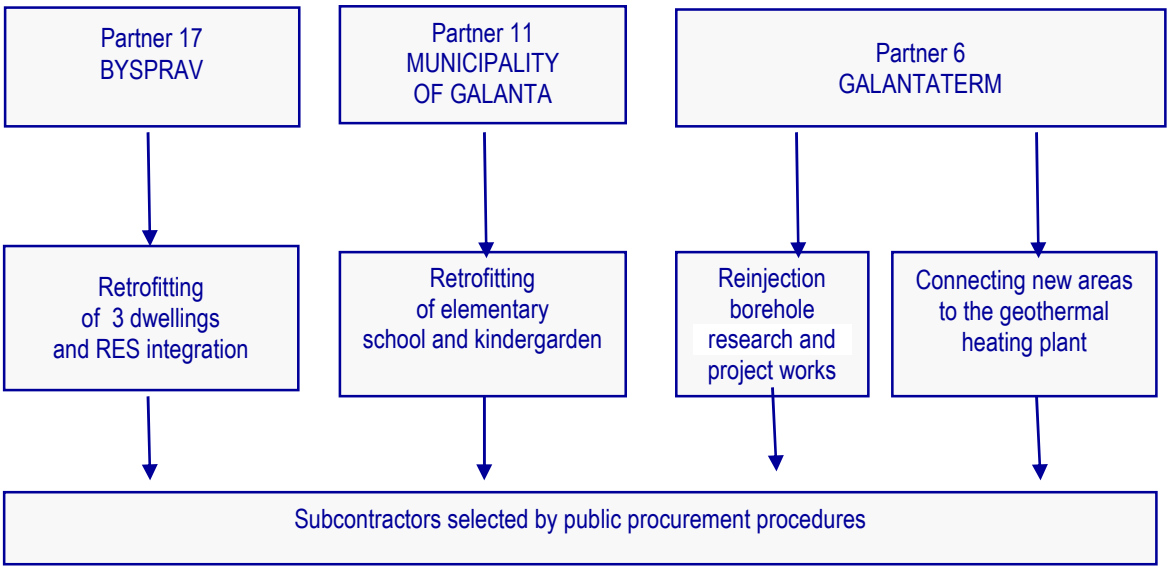

Figure 3.2.6. Division of demonstration works in Galanta among the GEOCOM partners and formal procedures of realisation

Figure 3.2.7. Galanta: Concerto areas where the GEOCOM project demonstration works were performed (map: *https://www.google.sk/maps/@48.1985503,17.7383409,3114m/data=!3m1!1e3*)

3.2.3.2 Retrofitting of dwellings and integration of RES

The thermal retrofitting works were carried out by Bysprav Ltd. – one of the GEOCOM project partners. The activities were divided into several parts. First of all, one of the main goals was implementing the retrofitting and energy efficiency measures. Inhabitants living in the area heated by geothermal energy were invited to an information seminar where they were given a presentation on the project and its aims.

There were three sets of project documentation produced, one for each of the multi-storey houses selected. The documentation included, among other information, accurate budget details.

A public procurement process was also part of the goals. That meant that a separate procurement process was undertaken for each selected multi-storey residential building which it was planned to retrofit. The overall budget, after the public procurement, was as follows:

- Česká Street 1437: a total of 220 916.19 EUR,
- Mierová Street 1436: a total of 226 375.01 EUR,
- Železničiarska Street 1432: a total of 218 715.01 EUR.

Another set of goals included system integration – integrating solar energy in the case of Galanta. The planned performance according to the project documentation was 2.16 kWp and the annual energy gain 2.4 kWh_e. The retrofitting works were successfully completed for each of the three multi-storey houses (figures 3.2.8 – 3.2.10).

Figure 3.2.8. A multi-storey house Mierová 1436 before thermal retrofitting works (photo by M. Bartek)

Figure 3.2.9. A multi-storey house Česká 1437 before thermal retrofitting works (photo by M. Bartek)

Figure 3.2.10. A multi-storey house Železničiarska 1432 before thermal retrofitting works (photo by M. Bartek)

The external walls of the multi-storey houses noted above are constructed of 300 mm aerated concrete boards on the facing. Furthermore, the shield is constructed of 150 mm reinforced concrete boards. The roof consists of 250 mm aerated concrete, 2x40 mm layers of basalt wool and 150 mm of concrete panel boards on the ceiling. The loggias are constructed of prefabricated reinforced panel boards. The doors and the windows in the common areas are not insulated, but constructed of single glazing with a steel frame.The thermally retrofitted features of the above-mentioned multi-storey residential blocks, which were the subjects of the GEOCOM activities related to retrofitting and energy efficiency measures, are shown on figures 3.2.11 – 3.2.13.

Figure 3.2.11. A multi-storey house Mierová 1436 during retrofitting works (photo by M. Bartek)

Figure 3.2.12. A multi-storey house Česká 1437 during retrofitting works (photo by M. Bartek)

Figure 3.2.13. A multi-storey house Železničiarska 1432 during retrofitting works (photo by M. Bartek)

Doors and windows in the common areas were replaced by double glazing with vacuum insulation of which the U-value is 1.1 W/(m^2·K), 5 cell plastic and aluminium frame. The façade insulation is constructed of 70 mm EPS polystyrene up to a height of 22.5 m and rock–wool above this height. The ceilings of the common areas were insulated with 70 mm EPS polystyrene. The ceiling of the cellars was insulated with 50 mm rock-wool. The roof insulation consisted of 100 mm XPS polystyrene, with roof foil and a geotextile separation layer on top. The insulation in the machinery room (situated above the roof) consisted of 40 mm XPS polystyrene, roof foil and a geotextile separation layer on top. Plinth insulation consisted of 30 mm XPS polystyrene. The loggias were insulated with 40 mm XPS polystyrene. Hydraulic adjustment was also carried out. The situation after carrying out the GEOCOM retrofitting works and introducing the energy efficiency measures is illustrated on figures 3.2.14 – 3.2.24.

Figure 3.2.14. A multi-storey house Česká 1437 after retrofitting works (photo by M. Bartek)

Figure 3.2.15. A multi-storey house Česká 1437 after retrofitting works (photo by M. Bartek)

Figure 3.2.16. A multi-storey house Česká 1437 after retrofitting works (photo by M. Bartek)

Figure 3.2.17. A multi-storey house Česká 1437 after retrofitting works (photo by M. Bartek)

Figure 3.2.18. A multi-storey house Mierová 1436 after retrofitting works (photo by M. Bartek)

Figure 3.2.19. A multi-storey house Mierová 1436 after retrofitting works (photo by M. Bartek)

Figure 3.2.20. A multi-storey house Mierová 1436 after retrofitting works (photo by M. Bartek)

Figure 3.2.21. A multi-storey house Železničiarska 1432 after retrofitting works (photo by M. Bartek)

Figure 3.3.22. A multi-storey house Železničiarska 1432 after retrofitting works (photo by M. Bartek)

Figure 3.3.23. A multi-storey house Železničiarska 1432 after retrofitting works (photo by M. Bartek)

Figure 3.3.24. A multi-storey house Železničiarska 1432 after retrofitting works (photo by M. Bartek)

Tables 3.2.4 and 3.2.5 give the energy performance evaluation of the three blocks of flats and a comparison of heat requirements as they were before the retrofitting works.

Table 3.2.4. The energy performance evaluation in three blocks of flats in Galanta before the GEOCOM retrofitting works and the introduction of energy efficiency measures

Construction element	U-value [W/(m²·K)]	
	Before retrofitting	Requirement according to Slovak technical standard 73 0540:2002
Ceiling of the cellar	1.11	0.75
Gable wall	0.69	0.46
Facing wall	0.77	0.46
Roof	0.37	0.30
Windows of the common spaces	3.00	2.00
Doors of the common spaces	6.00	2.00
Wall of the entrance	3.04	0.80

Table 3.2.5. Comparison of the heat requirements for the three blocks of flats in Galanta before the GEOCOM retrofitting works and the introduction of other energy efficiency measures

Multi-storey house	Heat requirement of the building [kWh_{th}/y]	Heat loss of the building [W/K]	Standarized heat requirement on m² [$kWh_{th}/(m^2 \cdot y)$]
Česká 1437	254 452.00	4 331.67	77.98
Mierová 1436	256 601.00	4 377.03	77.98
Železničiarska 1423	196 132.00	3 521.82	75.71

Table 3.2.6 gives an energy performance evaluation after the retrofitting and the application of other energy efficiency measures in three multi-storey houses. Table 3.2.7 gives a comparison of the heat requirements after the retrofitting works in these buildings.

Table 3.2.6. Energy performance evaluation after the retrofitting and application of other energy efficiency measures in three blocks of flats in Galanta

Construction element	U-value [W/(m²·K)]		
	Before retrofitting	After retrofitting (proposed condition)	Reduction [%]
Ceiling of the cellar	1.11	0.49	55.86
Gable wall	0.69	0.31	55.07
Facing wall	0.77	0.32	58.44
Roof	0.37	0.18	51.35
Windows of the common spaces	3.00	1.50	50.00
Doors of the common spaces	6.00	1.50	75.00
Wall of the entrance	3.04	0.69	77.30

Table 3.2.7. Comparison of the heat requirements for three blocks of flats in Galanta after the GEOCOM retrofitting works and the introduction of other energy efficiency measures

Multi-storey house	Heat requirement of the building [kWh_{th}/y]	Heat loss of the building [W/K]	Standardized heat requirement on m^2 [$kWh_{th}/(m^2 \cdot y)$]	Heat requirement savings due to retrofitting [kWh_{th}/y]	Heat requirement savings due to retrofitting [%]
Česká 1437	147 683.00	3 031.51	49.22	106 769.00	**41.96**
Mierová 1436	149 831.00	3 076.87	49.94	106 770.00	**41.60**
Železničiarska 1423	113 278.00	2 512.89	41.85	82 854.00	**42.24**

The diagram on figure 3.2.25 shows the results of retrofitting works by comparing the heat requirements of particular multi-storey residential blocks in Galanta before and after the retrofitting works carried out thanks to the GEOCOM project.

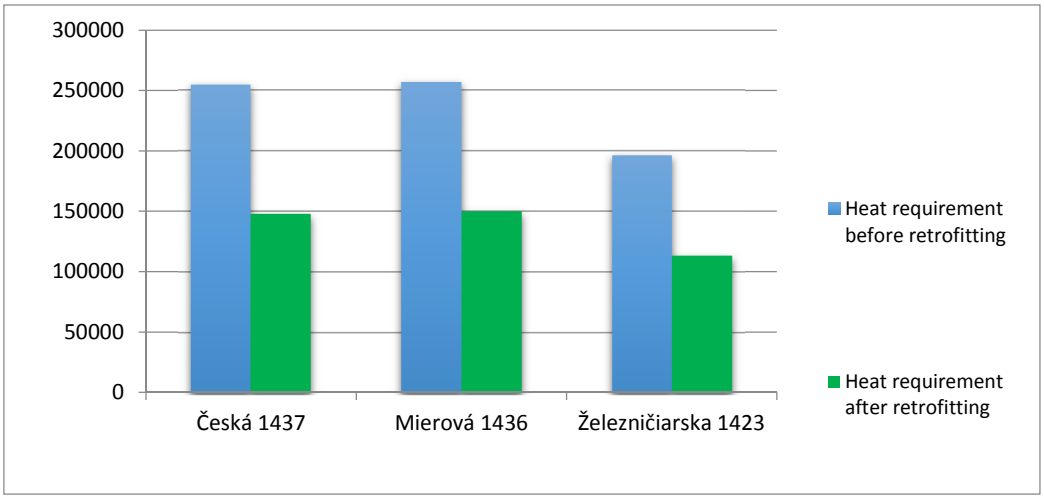

Figure 3.2.25. Comparison of heat requirements [kWh_{th}/y] in particular multi-storey houses in Galanta before and after retrofitting works done thanks to the GEOCOM project

The energy performance evaluation of each retrofitted multi-storey residential block gives a detailed overview of the constructional specification of the building.

This specifies the wall composition, its thickness, thermal conductivity, the U values of each type of wall and roof. An essential part of the evaluation is to compare the condition before the retrofitting with the planned condition after the suggested retrofitting elements and specifications.

This compares the composition of all of the wall and roof construction, where the thermal conductivity values are highlighted for every structural element (wall, plaster, insulation etc.). The crucial part for the GEOCOM project is the calculation of U-values for the condition before retrofitting with the suggested condition after applying the retrofitting elements. Each document notes the fact that all the constructional elements have unsatisfactory U-values in comparison with the Slovak national standards. It also calculates the heat loss and annual heat energy demand of each building before and after retrofitting.

This type of evaluation has been developed for each retrofitted multi-storey residential block. It gives us an important basic source of data for post-implementation monitoring of the GEOCOM retrofitting efficiency measures in Galanta.

To conclude and summarise the thermal retrofitting works and the implementation of energy efficiency measures for the three multi–storey residential blocks in Galanta described above, it is necessary to list the results of this project:

- the total heat requirements decreased by 296 393 kWh_{th}/y which is equivalent to 1067.01 GJ/y. This is larger than the annual heat requirement for a complete multi–storey residential block before retrofitting (!);
- recognisable savings were achieved. On the basis of the recent price of geothermal heating, it proved possible to save EUR 14 874.12 per year in the housing estate;
- the savings achieved per household were 3087.43 kWh_{th}/y, equivalent to a financial saving of EUR155.00 per year (the actual result will be determined from the audit of the building and from the project monitoring);

The photovoltaic power station installed as part of the works funded by GEOCOM is composed of 9 Magepowertec Plus 240 Wp photovoltaic panels. These are connected to a SB 2100TL – SMA inverter. This assures the conversion of direct current from the panels to single–phase alternating current at a voltage of 230 V / 50 Hz. Output from the inverter is connected to the distribution grid through security equipment and a meter for measuring the energy produced. The total output of the power station is 2.16 kW_e (measured at the clamps of the panels) and the maximum annual quantity of electricity produced (measured) at the clamps of the solar panels is 2.93 MWh_e.

Concerning the technology used and the equipment installed, all the three power plants located on the roofs of the residential buildings Železničiarska 1423, Mierová 1436, Česká 1437 are identical.

3.2.3.3 Thermal retrofitting of the elementary school, kindergarten and RES integration

The insulation works on the elementary school and the retrofitting of the kindergarten (CONCERTO area I) were carried out by the Municipality of Galanta. These buildings are heated by geothermal energy. The Municipality of Galanta decided to retrofit the elementary school instead of the care home for the elderly initially proposed because the school was in a worse condition, and no continuing reconstruction had previously been carried out. By choosing a school for thermal retrofitting, integrating other RES (solar energy) and by demonstrating the results, the GEOCOM project has an additional impacton public awareness and on the formulation of environmentally sound engineering and allows the project to focus on environmental education for future generations. The school children were “part” of the retrofitting and integration measures, thus they had first-hand experienceof both state-of-the-art RES applications via European projects. In the year 2015/2016 the school has 357 pupils on the roll and employs 41 staff. Figures 3.2.26 – 3.2.27 show the buildings of the elementary school and kindergarten before the retrofitting works.

Fig. 3.2.26. The building of elementary school in Galanta before the thermal retrofitting works (photo by M. Bartek)

Figure 3.2.27.The building of kindergarten in Galanta before the thermal retrofitting works (photo by M. Bartek)

The buildings were constructed of iron–concrete panel boards (without heat insulation), windows and doors were made of double window glazing with wooden frames and without insulation.

Due to defects and out of date construction techniques, the heating was very wasteful.

Insulation works included changing the windows and doors, which were in disrepair, and in addition (due to poor thermal insulation qualities) were dangerous to handle. The windows were of poor construction and affected by cracks in the wooden frame.
From the energy saving point of view, taking into account the technical conditions, the windows were the structures with the greatest impact in inducing the waste of energy during the heating of the building.

The technical specification of the windows and doors (retrofitting features) used was as follows:

- 6 cell plastic insulated frames with U_f = 1,1 $Wm^{-2}K^{-1}$,
- Insulated double glazing 4 – 16 – 4 mm with U_g = 1,1 $Wm^{-2}K^{-1}$,
- Overall U-value of the windows and doors: U_w = 1,3 $Wm^{-2}K^{-1}$.

Figures 3.2.28 – 3.2.29 show the buildings of the elementary school and kindergarten in Galanta after the retrofitting works.

Figure 3.2.28. The building of elementary school in Galanta after the thermal retrofitting works (photo by M. Bartek)

Figure 3.2.29. The building of kindergarten in Galanta after the thermal retrofitting works (photo by M. Bartek)

The school had high electricity consumption due to the need for continuous light during the day. The GEOCOM project included an element for the integration of renewable energy through the installation of photovoltaic panels with a performance of up to 5 kW_e (figure 3.2.30) with an annual energy gain of up to 5 300 kWh_e (calculated on the solar radiation in the Slovak Republic).

Figure 3.2.30. Photovoltaic plant on the roof of the elementary school (photo by M. Bartek)

3.2.3.4 Connecting new areas to the geothermal district heating network (New Concerto 2 area)

The GEOCOM project initially planned that the connection of the gas-fired heat production plant in Galanta to geothermal energy would beone of the main demonstration works. However, this was cancelled during the implementation of the project (for reasons given later in the text). Instead, the connection of new areas / buildings to the geothermal district heating system was carried out by Galantaterm Ltd.

It should be specially pointed out that this was possible due to the significant energy consumption savings in other buildings (the three multi-storey residential blocks described above) which were thermally retrofitted (through other GEOCOM works in Galanta).

The new buildings connected to the geothermal heating system as part of the GEOCOM works were as follows:

- 3 new blocks of flats (WEST housing estate),
- a senior citizens care home (Pohoda seniorov),
- the medical laboratories of HPL s.r.o.

The works were carried out in the Concerto areas (figure 3.2.7):

- Concerto 1: the area of Galantaterm Ltd. Energy centre where the geothermal heating system is in operation,
- Concerto II: the area of the (natural gas) heating plant intended to be connected to the geothermal system for the production of domestic hot water for other areas of Galanta. However, as described below, that plan was replaced by a new one – i.e. connecting some buildings in newly developed urban areas to the geothermal district heating system in the New Concerto II area.

As mentioned above, the original plan for the GEOCOM demonstration works in Galanta included, among other projects, the connection of the natural gas heating plant to the geothermal heating system (Concerto 2 Area).

Galantaterm Ltd. carried out the complete documentation needed for the building permission and or the evaluation of activities by the company. This included:

- comprehensive project documentation – the documentation specified a peak transferred power of 3 000 kW_{th} and a temperature gradient 70/50°C. The length of the connection would be 2 x 1 190 m and the total costs 966 120.50 EUR (due to the pipes being placed in an urban area and the costs of the machinery room needed to make the connection to the existing geothermal system);
- study of the economic aspects of the connection – the aim of the study was to review the economic benefits of the proposed connection. The connection would provide 5378 GJ of heat per year – resulting in a decrease of 185 286 m^3 per year in the Bysprav company's demand for natural gas. The connection would also provide a decrease of 8% in Galantaterm Ltd's electricity consumption.

However, the results from the calculations (made on the basis of the current price level) indicated that without an EU-contribution from the GEOCOM project, the return on the above investment would be 71 years. With the GEOCOM contribution this period would be 57 years. In order to achieve 15 years return it would be necessary to deliver 20 236 GJ of heat per year, i.e. four times higher than the planned capacity. For these reasons the original plan to connect the natural gas heating plant to the geothermal heating system (Concerto 2 area) was abandoned and replaced by a new target: the connection of newly developed urban areas to the geothermal district heating (as described below). Tables 3.2.8 – 3.2.10 give the annual heat consumption data of the new buildings connected to the geothermal district heating system thanks to the GEOCOM demonstration works (residential buildings, Medical laboratories, and a centre for the elderly; figures 3.2.31 – 3.2.33).

Table 3.2.8. Annual geothermal heat consumption of three residential buildings WEST in Galanta

Building	SO - 110	SO - 111	SO -112	Total
Number of flats	37	37	37	111
Annual energy consumption for district heating [GJ/y]	692.24	692.24	617.51	2 001.99
Annual energy consumption for heating up domestic hot water [GJ/y]	976.57	976.57	933.49	2 886.63
Total	1 668.81	1 668.81	1 551.00	4 888.62

Table 3.2.9. Annual geothermal heat demand and consumption of HPL s.r.o. (Medical Laboratories) building in Galanta

Building of HPL s.r.o. (Medical Laboratories)	[kW_{th}]	[GJ/y]
Annual energy for district heating	65	250
Annual energy for heating up domestic hot water	35	136
Total	100	386

Table 3.2.10. Annual geothermal heat demand and consumption of Pohoda seniorov (an elderly house)

Elderly building	[W_{th}]	[J/y]
Annual energy for district heating	200	870
Annual energy for heating up drinking water	275	1 000
Total	475	1 870

Figure 3.2.31. Residential buildings WEST located in the New Concerto 2 area supplied with geothermal heat (photo by M. Bartek)

Figure 3.2.32. Building of HPL s.r.o. (Medical Laboratories) supplied with geothermal heat (photo by M. Bartek)

Figure 3.2.33. Building of Pohoda seniorov (an elderly house) supplied with geothermal heat (photo by M. Bartek)

3.2.3.5 Ecological effect of introducing geothermal energy for district heating (New Concerto 2 area)

The estimated gas consumption for heating and hot water preparation in the-above-listed buildings in the New Concerto Area 2 (3 blocks with 111 flats), the medical laboratories and a centre for the elderly – if no geothermal energy were to be provided – was estimated at 236 969 m^3/y. The burning of such an amount of gas would generate 422 tons of CO_2 per year – so the emission of that amount of this hazardous gas was avoided thanks to the introduction of geothermal energy (table 3.2.11).

Table 3.2.11. Ecological effect thanks to geothermal district heating introduction for buildings in newly developed urban area (New Concerto 2 area) in Galanta

Estimated gas consumption for heating (if no geothermal would be provided)	236 969 m^3/y
Estimated quantity of CO_2 savings thanks to heat production from geothermal sources (instead of natural gas' burning)	442 tons/y

3.2.4 Some general remarks and lessons learnt from the Galanta best practice case

The retrofitting works, RES' integration and application of rational energy use measures for some buildings in Galanta (as part of the GEOCOM projects) resulted in the obtaining of a great deal of experience, and many benefits and lessons learnt. Some of them are presented below. They reflect the points of view and satisfaction obtained from the project as expressed by the inhabitants, experts and the Municipality.

Inhabitants' point of view

The major benefit in the minds of the inhabitants of the quarter whose houses were thermally retrofitted as part of the GEOCOM demonstration works was mainly the calculated energy savings. The inhabitants of Galanta were invited to an open discussion where it was clearly explained what materials would be used for the insulation of the external walls of the houses, what would be the ecological and environmental results and how these would be demonstrated in the energy savings.

It was explained in detail how the photovoltaic cells placed on the roofs of the buildings would work. Because the district heating and the water heating were supplied through the pre-existing and operating geothermal wells, the ecological aspect did not seem to play an important role for the inhabitants. On the other hand, the savings obtained from the energy needed to heat the apartments was also demonstrated to be an element of this aspect. Because the insulated houses use less energy for heating, the energy saved can be used for heating more buildings.
The photovoltaic installation installed on the roof of the primary school became an important part of the education programme, where pupils can learn in practice how solar energy can be used. The change of the school's windows offers pupils and personnel comfortable conditions and at the same time the town will save money which was previously used for building maintenance.

Experts' point of view

During the implementation of the works under the GEOCOM project, the Municipality of Galanta encountered many difficulties mainly connected with the complicated legislation in the Slovak Republic. The preparations for implementing the works included the acquisition of project documentation for the thermal insulation of the residential buildings, school and nursery school followed by the mounting of the photovoltaic cells on the roofs of the buildings. Many administrative procedures and permissions were also connected with that process.
The service providers were chosen by public tender to ensure that the individual projects were carried out in the most economic manner. The town selected buildings that were similar in their attributes so that the results achieved on the energy savings could be measured and compared.
Monitoring of the individual photovoltaic cells placed on the house roofs shows that the energy supplied achieves demonstrable savings. Otherwise the return on the investment is not cost-effective due to the administrative obstacles and national legislation.

The Galanta Mayor's point of view

The town of Galanta evaluated the thermal retrofitting works as very effective because the energy savings achieved on the individual properties can be used to heat other new buildings (i.e. in the newly developed WEST estate – New Concerto 2 area). The process of retrofitting the buildings went smoothly and without any unnecessary complications, so the inhabitants were not too much disturbed by these works. The change of the windows of the school and the nursery school was carried out during the holidays so that pupils could continue their learning programme in new and comfortable surroundings.

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3.3 Municipality of Montieri (Italy)

(Roberto Pagani, Valentina Marino – Politecnico di Torino, Department of Architecture and Design, Italy)

3.3.1 The historic village of Montieri and the GEOCOM project

The origin of Montieri is linked with the underground resources of its territory. Etrurian population in IV century b.C. was already exploiting silver and copper mines in the area. The name of Montieri appears for the first time in a document dated 973 a.C. Between XI and XV century Montieri was an important mining centre in the area. Nowadays Montieri preserves historical characteristics of traditional architecture of medieval time. During the centuries the urban structure became denser but, due to the presence of the hill, it didn't expand very much, preserving its original features. Table 3.3.1 outlines general figures about Montieri's population, geographical location and climate.

Table 3.3.1. General information about the Municipality of Montieri

Montieri in figures	
Population	1 216 inhabitants (01/01/2015)
Area	108.21 km^2
Urban density	11.24 inhabitants/km^2
Geographical location:	
Height above sea level	704 m (from 335 m to 1060 m)
North latitude	43°7' 55.56"
East longitude	11°1' 3.36"
Climate	
Climatic zone	E
Day–degrees	2 500
Seismic zone	3
Winter/summer peak temperature	-4°/+32°C
Winter/summer humidity	70% / 48%

The town centre is made up of narrow paved streets sided by two/three storey buildings terraced or isolated. Older buildings are made up of natural stone and brick masonry and wood horizontal load bearing structures with clay elements on floors and on roofs. Some very old buildings are recognisable among the urban texture because of stone masonry walls ("*filaretto*" natural stonework) and peculiar arches and openings. These buildings are listed by the local authority for cultural heritage and landscape as symbols of culture and history of Montieri. A very small urban expansion occurred in last centuries. Figure 3.3.1 shows current urban development of the village while figures 3.3.1 – 3.3.5 illustrate some typical buildings.

Figure 3.3.1. Bird eye view of the village of Montieri
(image source: *https://www.google.it/maps/@43.1313768,11.0181856,582m/data=!3m1!1e3*)

Figure 3.3.2 and 3.3.3. Typical residential buildings of Montieri made up of brick and stone masonry walls and clay tiles roofs (on the left). Casa Biageschi – a medieval tower of the outer city wall converted into a dwelling (on the right). Walls are made up of stone block masonry (photo by V. Marino)

Figure 3.3.4 and 3.3.5. On the left houses in Via Del Romito. On the right, building lines in via Matteotti (photo by V. Marino)

Before the construction of the geothermal district heating network the buildings of the village were served by a variety of fuel types: for residential energy needs these ranged from firewood (gathered from private sectors of wood that still are owned by the most of local population), to LPG and methane gas network (few dwellings connected), to the use of gas cylinders and fuel gas stoves. According to data collected by the municipality the main part of dwellings use wood burning stoves for heating and LPG and methane gas for cooking, hot water is mainly provided by methane gas or electric boilers. Public buildings instead were connected to both gas and LPG networks. Moreover according to the same data half of the private buildings are vacant or are holiday homes, and for the rest of buildings the combination of fuel use for different needs is hardly uniform.

The GEOCOM project had three main objectives for Montieri demo– site:

- realisation of a highly innovative geothermal district heating system by using high enthalpy fluid,
- thermal retrofitting of selected dwellings among the building estate of Montieri town centre with materials and methods in conformity with their historical value,
- RES integration: 8.5 kW_e of photovoltaic panels and 42.5 m^2 of solar collectors for sanitary hot water production.

A preliminary investigation highlighted the feasibility of a geothermal district heating network, exclusively devoted to the city of Montieri, with a total heated volume of 110 000 m^3 to be served by the system. The GEOCOM project covered the cost of buildings' connection to district heating network and, when necessary, the upgrading of the existing heating system of private homes.

Montieri also represented a challenging site for defining and testing a qualitative architectural integration of retrofitting measures on culturally–valuable buildings where the potential for intervention on building envelope is quite limited. Only materials and methods in conformity with the medieval city structure were considered acceptable. Retrofitting solutions were asked to reach an ambitious objective of reduction of current energy demand.

3.3.2 The geothermal resource

Near to Montieri, i.e. in geothermal area of Larderello, Travale and Radicondoli, there are two geothermal reservoirs: a shallow one and a deep one. Both are predominantly composed of steam but have different temperatures and pressures. The pressure in the shallow reservoir is about 10–30 bar at a depth of 1 000 m, whereas the pressure in the deep reservoir is 60-70 bar at a depth of 3 000–4 000 m. The top of the shallow reservoir is found at a depth of between 400 m and 1000 m with a temperature of 250°C in the more permeable areas. The top of the reservoir has an extensive system of faults that makes it extremely permeable and therefore uniformly productive.

The deep reservoir lies at a depth of between 2 500 m and 4 000 m. Its top is characterised by discontinuous permeable areas separated by rocks with low permeability that produce real barriers that enable the high temperature of the reservoir to be maintained and protect it from the permeable rocks above it that are able to absorb rainfall that may reduce the temperature. Exploration activities have found a homogeneous temperature at a depth of 3 000 m along a section of rock that crosses both the Larderello and Travale–Radicondoli fields demonstrating that the two geothermal areas are connected by a unique geothermal system at the level of the deep reservoir.

In some areas of the system the deep drilling activity has detected, according to the characteristics of the rocks surveyed, that the bottom of the reservoir is located where the temperature ranges between 350 and 700°C. Surveys have demonstrated that it is difficult to find permeable and potentially productive layers beyond the levels with a temperature in the region of 350°C. The geothermal system is about 400 km^2 in extent and has a volume of about 1 000 km^3. In the shallow reservoir superheated steam forms about 92-98% of the weight of the extracted fluid with a temperature in the range of 150–270°C and pressure range of 2– 18 bar. The non-condensing gas content is between 1 and 20% of the weight with average values of around 5%. The non-condensing gas is made up of CO_2 (96%), H_2S (1.7%), H_2 (0.1%), CH_4 (0.6%), N_2 (0.3%), NH_3(0.4%), H_3BO_3 (0.8%). There are other components in the extracted fluid in concentrations of the order of ppm including chloride, silica, sodium, iron and infinitesimal traces of mercury (Hg), argon (Ar) and neon (Ne).

Given the quality of the geothermal resource (whose main features are described in table 3.3.2), it has been used for electric power production in this area since the beginning of the 20th century. In the case of Montieri municipality, the district heating network is fed by a waste product of the steam extracted for power generation at the Montieri-4 well.

Table 3.3.2. Characteristics of the geothermal fluid discharged by Montieri-4 well

Minimum/ maximum pressure	15 bar / 20 bar
Minimum / maximum temperature	200°C / 215°C
Minimum / maximum flux of geothermal steam	50 t/hr / 60 t/hr

3.3.3 The geothermal district heating

This paragraph reports information on the project for the installation of a geothermal district heating network "*Realizzazione di un impianto di teleriscaldamento dell'abitato di Montieri*" contained in the two technical reports "*Relazione generale" and "Relazione Specialistica*". The project design was prepared and signed by Dr. Ing. Piero Ulivieri in September 2009. The authors acknowledge the assistance of the designer, Dr. Ing. Piero Ulivieri, and of the project manager, Dr. Alessandro Vichi, in providing support and references.

The Montieri demonstration site developed and constructed a brand new geothermal district-heating network that exploits the geothermal resource available within the territory of the municipality to provide heating in winter and domestic hot water throughout the year to properties, both public and private, in the historic town centre.

The innovative idea behind the project was the exploitation of that part of the steam extracted from the Montieri-4 well that is unsuitable for electricity production but appropriate for heating uses. The heat in the steam is initially transferred to superheated water and then to hot water to reach the required temperature for the district heating network (about 90°C). Table 3.3.3 highlights exchanges of heat between different fluids along the network, and related temperature variations.

Table 3.3.3. Exchange of heat and temperature variations of fluids between heat exchanger stations A and B and the geothermal district heating network in Montieri

	Direction	Fluid	Temperature
Heat exchanger station A final increase of water temperature: 50°C	IN	Steam	150°C
	OUT	Steam	100°C
	IN (from B – return circuit)	Water	80°C
	OUT	Super–heated water	130°C
Heat exchanger station B final increase of water temperature: 31°C	IN (from 2nd circuit – return)	Water	64°C

The geothermal district heating network is made up of the following elements:

- a first pipeline takes the steam to the heat exchanger station (indicated A on figure 3.3.6). Condensation fluid is conveyed directly into the same pipeline. Station A transfers heat from the steam to a first circuit of superheated water. This circuit is about 2*2200 m long. It takes superheated water to heat exchanger Station B (on figure 3.3.6) where heat is transferred to a second circuit. Inside Station A four heat exchangers (2 of 4 000 kW_{th} and 2 of 800 kW_{th}) are installed to transfer heat from steam to water. These two pairs of heat exchangers work in parallel: the first pair at 73% of nominal power, the second at 50%. In each pair one heat exchanger is the back-up of the other to guarantee service in case of malfunction;

- the main pipeline to the town commences at heat exchanger Station B. Here five branch circuits spread out to reach all the dwellings in the built-up area. Inside Station B, 2 heat exchangers of 4 000 kW_{th} are installed to transfer heat from the superheated water to hot water. These heat exchangers work in parallel at 78% of nominal power. Like in Station A, one heat exchanger is a back-up for the other.

Water in the first circuit, between Station A and Station B, is circulated by a group of pumps with a total power of 11 kW_e made up of 2 pumps and one reserve pump. A similar group of circulation pumps (11 kW_e) is placed in Station B to move water within the second circuit. The second circuit is about 5 100 m long overall. Schematic diagrams outlining the operation of the two heat exchanger stations A and B and the inflow and outflow of fluids to and from the steam resource and the geothermal district heating network, are shown in figure 3.3.6.

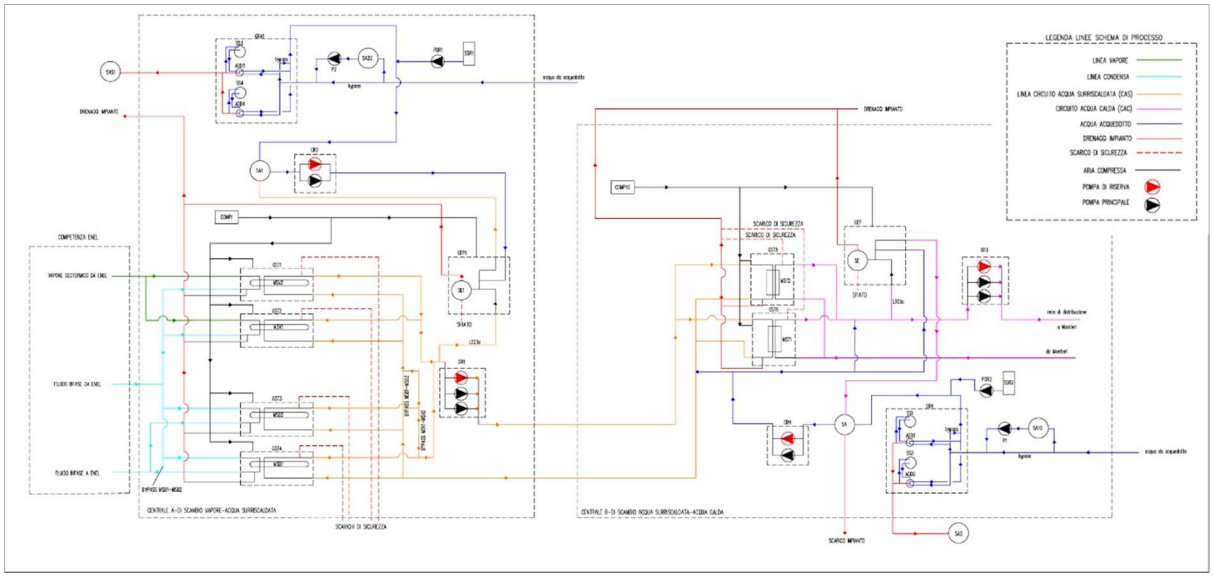

Figure 3.3.6. A schematic diagram of the plants inside the two heat exchanger stations A (on the left) and B (on the right) of the geothermal district heating network

(key: steam line; condensate steam line; superheated water circuit; hot water circuit; main water line; plant drainage; safety discharge; compressed air; reserve pump; main pump)

The path of the district heating network is highlighted in the maps (figures 3.3.7 and 3.3.8) that show the progress of construction yards during the year 2013. Figure 3.3.7 shows the progress of excavations and pipeline–laying between heat exchanger station A and B and between B and the very centre of Montieri. Figure 3.3.8 shows the progress of excavation yards inside the village. In order to leave access to residential buildings, no more than three streets were excavated at a time.

All circuits are totally sealed to prevent emissions of steam and water leakage into the environment. To prevent heat loss all pipes are insulated with polyurethane foam and covered with a HDPE casing. The network does not deplete the resource of clean water but always re-uses the same water within each circuit, and in consequence also saves residual energy.

Each dwelling is connected to the network by a flexible pipe (BRUGG type). When the final consumer is reached, a small heat exchanger provides hot water for space heating and DHW production.

The geothermal district-heating network is designed to serve 425 units of which 8 are public buildings. Table 3.3.4 highlights the design data used as a reference for scaling the plant.

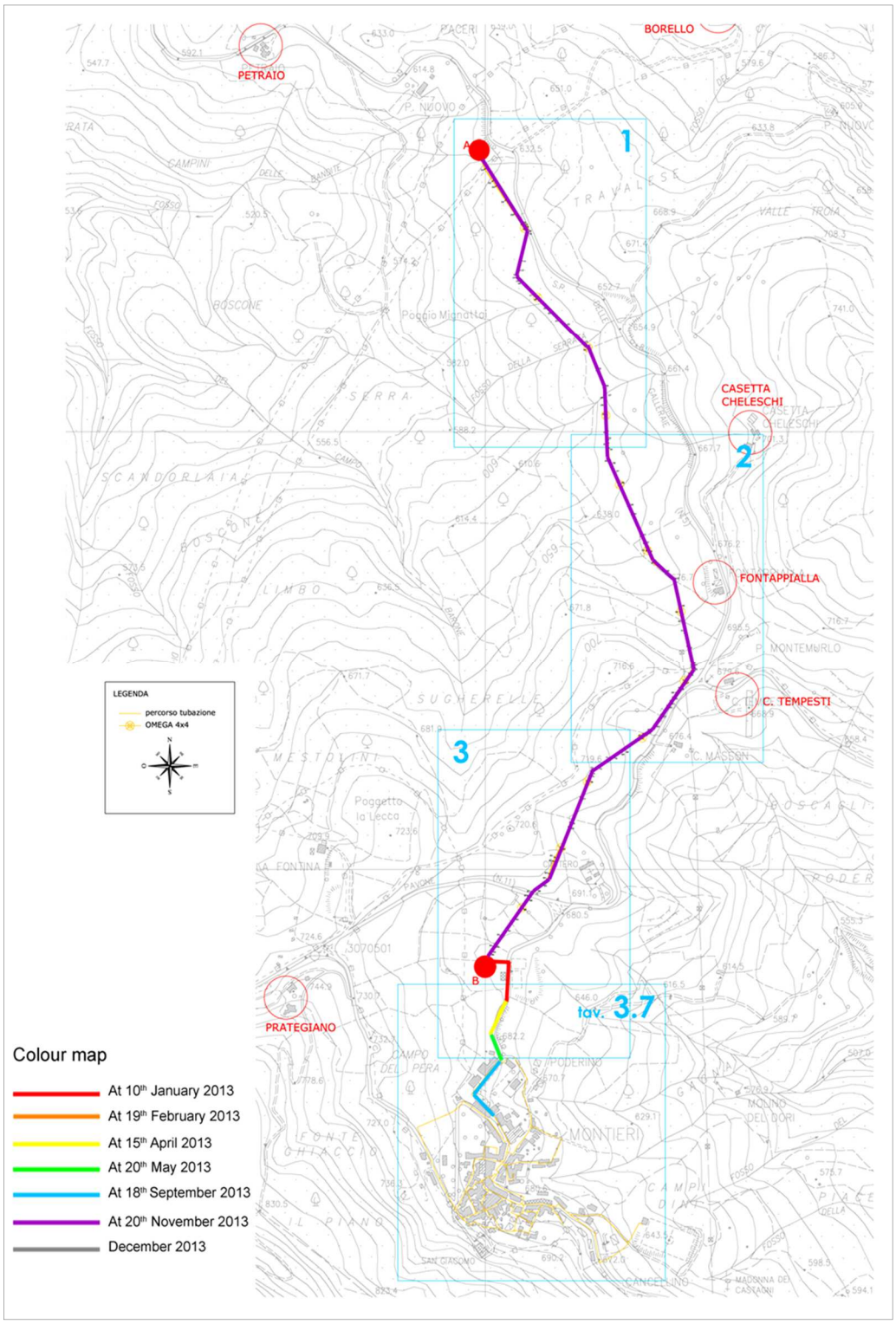

Figure 3.3.7. Montieri: development of the geothermal district heating network. From heat exchanger station A to heat exchanger station B

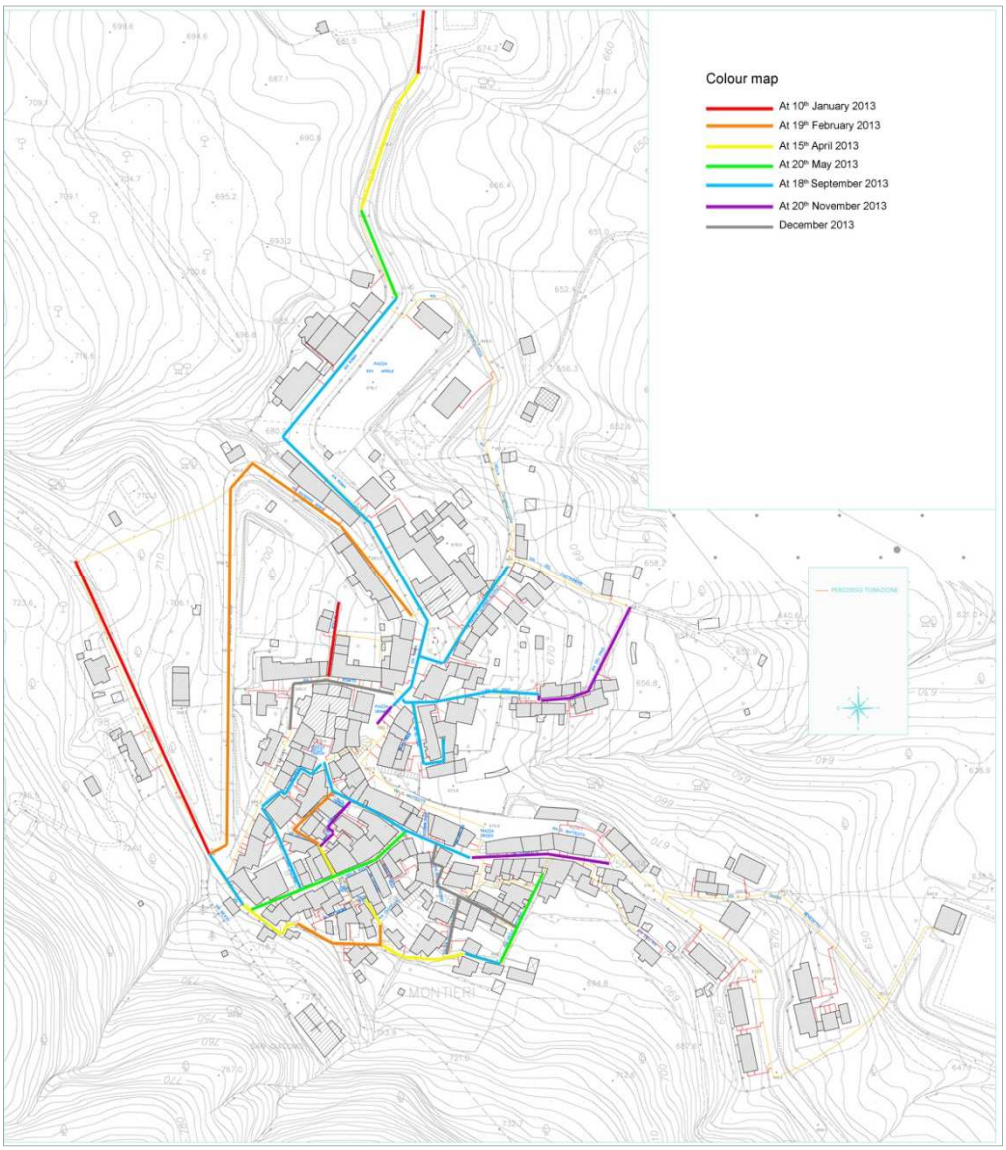

Figure 3.3.8. Development of the geothermal district heating network inside the historic village. Colours indicate several excavation phases

Table 3.3.4. Main features of the geothermal district heating in Montieri

Total heated volume	111372 m^3
Estimated average energy demand (space heating + DHW)	122.2 kWh_{th}/m^3y
Total annual energy demand	13 605 212.07 kWh_{th}/y
Total installed thermal capacity	6.164 MW_{th}

Construction work started in November 2012 and was concluded at the end of October 2014. In November 2014 about 200 units were connected to the district heating. The expected progress in connection rates is shown on table 3.3.5.

Table 3.3.5. Expected connection rates of users to the geothermal district heating network in Montieri

1st year	50%	213 units
2nd year	20%	85 units
3rd year	15%	64 units
4th year	10%	43 units
5th year	5%	21 units
Total	100%	425 units

Investment costs

About 80% of the final cost of the geothermal district heating network was represented by the construction costs. In order to finance the work, requests were made to a range of funds. These vary from European funds managed at regional level and local agreements for geothermal development as well as private financing from local utility companies. The breakdown of costs and funding is reported in table 3.3.6 as declared in the technical report presented by the project manager whose purpose is to define the final user tariff for geothermal district heating consumption ("*Proposta di gestone dell'impianto di teleriscaldamento alimentato da fonte geotermica a servizio del centro abitato di Montieri. Determinazione delle tariffe di vendita del calore*") approved in November 2014.

Table 3.3.6. Financial breakdown of costs and funding of geothermal district heating in Montieri

Cost breakdown for geothermal district heating network	
Geothermal district heating design and construction	4 503 137.72 EUR
Street works and other infrastructures	2 234 333.59 EUR
Total costs	6 737 471.31 EUR
Fund breakdown for geothermal district heating network and infrastructure	
Connection fee for individual units	367 822.22 EUR
European Regional Development Fund: POR–CREO 2007–2013	2 108 517.08 EUR
"General agreement on geothermal energy" managed by COSVIG	1 804 000.0 EUR
GEOCOM project	600 000 EUR
Bank loan	1 900 248.42 EUR
POT 2011–2012 (from Acquedotto del Fiora, the watermain company)	200 000 EUR

The last two figures in Table 3.3.6 only the cover costs of streetworks and utility infrastructure. This means that the unit cost paid by final users for the use of geothermal energy does not include the bank loan needed for this investment, resulting in a lower energy bill. In addition to the cost of construction, the operation and management of the geothermal district-heating network requires a series of activities and maintenance works that represent a constant expenditure for the municipality during the life span of the plant. Management costs cover a series of direct costs such as electricity, geothermal energy, internal staff, and external suppliers, which are given in table 3.3.7.

Table 3.3.7. Annual costs of the geothermal district heating system management

Annual costs of the geothermal district heating system management	
Direct management (internal staff)	5 000 EUR/y
External management	20 000 EUR/y
Electricity supply	35 000 EUR/y
Geothermal resource supply	0 EUR/y

The cost of the geothermal energy supply is negligible because national subsidies for the use of geothermal energy are equal to the cost of the resource, hence the municipality will pay only the V.A.T. on this cost.

Energy savings and environmental benefits

The integration of the geothermal district heating leads to important annual fossil energy and GHG savings, as shown in table 3.3.8.

Table 3.3.8. Environmental benefit of the geothermal district heating

Fossil energy saved (geothermal steam)	1 172.6 TOE/y
CO_2 saved	3 440 000 kg/y
NO_x	7 660 kg/y

In order to understand and compare the cost of the energy transition instigated by the introduction of the geothermal district-heating network in the town of Montieri, the equivalent cost per unit of CO_2 reduction was estimated.

An energy plant is considered to have a life span of 25 years and the total cost of the investment is considered paid off at the end of this period.

In order to detect the value of the measure in respect of the difference between the annual cost of the investment works and operation and the cost saving produced by the energy transition from fossil to geothermal energy resources, the funds received by the municipality for the implementation of the works are not taken into account in this calculation.

Given the variety of fuel types that were used in Montieri before the introduction of the district heating, it is assumed that the energy demand for both heating and domestic hot water was supplied by the oil and gas that used to be the most common fuels in the town, that is equal to EUR 0.133/kWh_{th}.

The agreed cost of thermal energy provided by the district heating is EUR 0.03/kWh_{th}, which represents a major reduction in costs for the final users.

The municipality receives national subsidies for the exploitation of renewable energy resources on the territory of the municipality (the so called "white certificates") that amount to EUR 25 400 annually. Taking into account these assumptions and figures, the data input for the CO_2 abatement costs are given in table 3.3.9.

Table 3.3.9. Annual cost, expenditure and saving related to the geothermal district heating

Annual cost of the investment (25 years)	269 498.85 EUR/y
Annual operation and management costs	60 000 EUR/y
Annual energy cost saving	220 607.445 EUR/y

The abatement cost of the geothermal district heating network in Montieri is calculated according to the following formula:

$$\frac{\text{(Annualized capital costs + annualized operation and maintenance costs) – (annual energy cost savings)}}{\text{annual } CO_2 \text{ emission savings}}$$

Following the calculation, the CO_2 abatement cost is EUR 31.6/ton CO_2, that is in a low range of costs compared with the simulation of costs needed for the implementation of systems for geothermal energy exploitation in the other countries involved in the project. This is mainly due to the fact that no drilling activity is included and the majority of the costs are for equipment and the civil engineering works. The opportunity to create a cascade system, in this case for the recovery of the heat from waste steam unsuitable for electricity production, represents a smart solution for cutting initial costs.

Cost savings for final users

In order to guarantee a fair cost for the management and control of the district heating network, to cover ordinary maintenance costs and, of course, the initial cost of the steam, the municipality set the unit cost of geothermal heat at EUR 0.03/kWh_{th}.

This unit cost is very competitive if compared to the current cost for other energy resources in the area as shown in table 3.3.10.

Table 3.3.10. Unit cost of fuel for domestic use (heating and domestic hot water)

Fuel	Unit cost [EUR/kWh_{th}]
Wood	0.035
Pellet	0.0625
LPG	0.195
Oilgas	0.133
Electricity	0.23

As a result of the survey of Montieri inhabitants it was found that the average annual costs paid for heating by the people living in the town ranges from EUR 500 to EUR 4500 per property. This is not only related to the fuel type but also to the low efficiency of individual heating stoves and boilers. The connection of dwellings to the district heating network by the installation of individual heat exchangers guarantees maximum efficiency in the exchange of heat between the network and the private heating systems.

Estimates of the average annual costs for heating and domestic hot water indicate that it is expected that the connection of dwellings to the district heating system will provide a significant reduction in this cost: the range of annual costs is expected to drop to an average of 400 – 1 200 EUR.

The geothermal district heating network was switched on for the first time at the beginning of the 2014-2015 heating season. However the system was still under test and few dwellings had already been connected. Moreover the management and control system only started to work in April and therefore only a few manual readings are available which are not sufficiently reliable to draw conclusions on the reduction of energy consumption and costs. The next heating season (2015-2016) will be critically important in assessing the accuracy of the estimates.

Monitoring system – management and data collection

The management, control and data reading systems in the district heating network are totally automated. Figure 3.3.9 shows a schematic diagram of the data collection and management service. Heat exchanger stations A and B have their own “programmable controller” (PLC) to manage all parameters of the network (e.g. temperature).

Dwellings and public users have their own monitoring systems mounted on each heat exchanger at unit level that transfer operation and consumption data to five data loggers located at strategic points along the pipeline in the town.

All monitoring devices are connected by reinforced optical fibre cables buried directly in the ground.

Monitoring and control of the main parameters, such as set point pressures and temperatures, can be performed either locally or remotely. The alarm system allows prompt intervention during breakdowns. The direct connection to the energy company in charge of management (ENEL) optimises synergies and data collection.

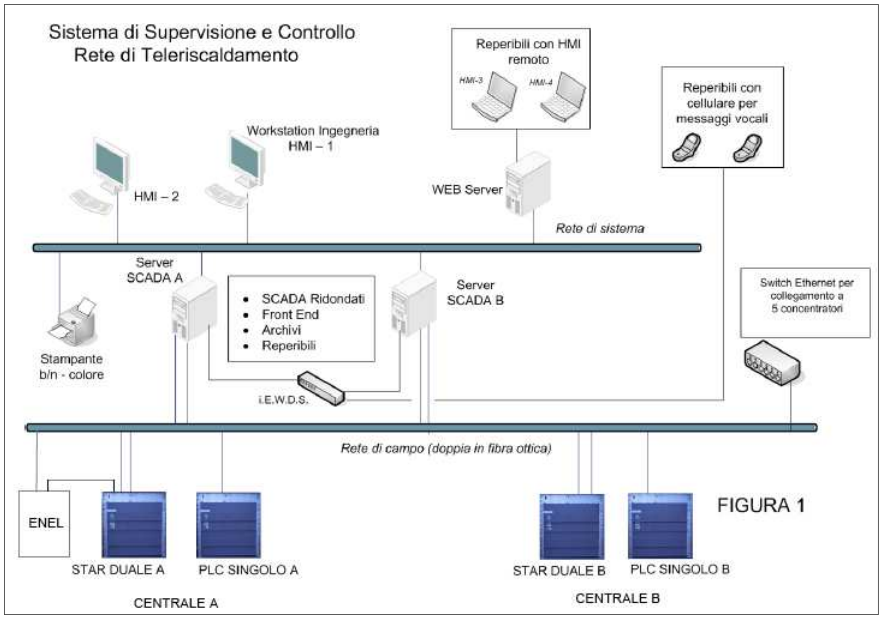

Figure 3.3.9. A scheme of the monitoring and control system for the geothermal district heating in Montieri

(key from top left to bottom right: Engineering workstation HMI-1; HMI-2; found by remote HMI, HMI-3 and HMI-4; Web server; found by mobile phones for vocal texts; printer b/w – colour; SCADA A server; redundant SCADA A, front end, archives, available; i.E.W.D.S.; SCADA B server; optical fibre field network; Ethernet switch for connection to the 5 concentrators; ENEL; double star A; single PLC A; station A; double star B; single PLC B; station B)]

3.3.4. Retrofitting activity in the Montieri demonstration site

The initial energy retrofit strategy proposed the implementation of a multi-level innovative approach in order to reduce the energy demand of dwellings by at least 40% (and reaching 100% fossil fuel free status) while meeting the constraints imposed by the culturally and architecturally valuable status of Montieri.

The target sample initially proposed as a demonstration area was 20% of the total number of dwellings in the town centre which would produce a significant impact on the town's energy balance. The strategy considered implementing solutions for the 425 dwellings on both the demand and supply sides. It planned to do this by combining retrofit measures for the building envelope with connection to the district heating network and the integration of other renewable energy resources. Very ambitious energy targets were set for the old buildings in Montieri.

There were various factors that presented challenges to the initial strategy as the project proceeded. As the building stock was owned by private citizens, the cost–effectiveness of the proposed measures influenced the penetration of the retrofit project as a whole. In fact, due to the presence of the brand new geothermal district heating system, with a very low cost for heat (0.03 EUR/kWh_{th}) anticipated, homeowners perceived the retrofit measures for the building envelope as not very cost–effective additional measures to reduce energy bills when compared to the district heating connection. Thus, most of them preferred to connect dwellings to the geothermal district heating network rather than improving the thermal efficiency of their buildings.

To improve the cost-effectiveness of building retrofitting measures to be integrated with the connection of dwellings to the district heating network and to guarantee the preservation of the cultural value of building facades and roofs in the historic centre, a new set of guidelines was defined for energy retrofit works on old buildings.

Table 3.3.11 summarises the performance requirements and minimum integration standards proposed for each retrofit measure.

Table 3.3.11. Energy retrofit measures chosen for implementation in the retrofit project

Retrofit measure	Performance of insulating material	Minimum thickness of insulation
Insulation of loft floor	λ ≤ 0.045 W/mK	12 cm
Roof insulation	λ ≤ 0.05 W/mK	8-10 cm
Internal insulation of walls	λ ≤ 0.045 W/mK	4 cm
External insulation of walls	λ ≤ 0.045 W/mK	5 cm
Thermal plaster	λ ≤ 0.09 W/mK	4 cm
First floor insulation	λ ≤ 0.05 W/mK	4-6, 8 cm
Groundfloor insulation	λ ≤ 0.045 W/mK	8 cm

Retrofit measure	Required performance
New window	1.8 W/m^{2}K

In addition to these new performance targets, the initial overall energy retrofit strategy was amended in order to allow a wider acceptance of the project among private homeowners. The following modifications were assumed:

- the target reduction in energy demand to be reached by the retrofit works was set at 30% of the initial energy consumption, and 100% fossil fuel free use for heating and domestic hot water was required,
- the area of application of the retrofit works was extended from just the town of Montieri to all the local community including three villages in the municipality, Boccheggiano, Gerfalco and Travale, also characterised by equivalent cultural and architectural heritage value,
- if there proved to be low penetration of retrofit measures on private buildings, the local administration committed to implementing a deep energy renovation on one or more public buildings in the Montieri municipality.

Implementation of the retrofitting strategy

Despite the efforts made by the municipality to promote energy retrofit measures, the retrofitting element resulted in a very low penetration. However two case studies of energy retrofit works were completed on private buildings which produced interesting results in terms of energy demand and CO_2 emissions reduction. Tables 3.3.12 and 3.3.14 summarise the main facts about the case studies while tables 3.3.13 and 3.3.15 highlight the resulting energy, cost, and CO_2 savings. Figures 3.3.10, 3.3.11 and 3.3.12 present some details of the retrofitted dwellings.

Table 3.3.12. Main facts of retrofitting works: dwelling 1– Via Verdi 41, Montieri

Building features	Building type	Residential
	Unit type Floor area Heated volume Initial energy performance	Private dwelling 596 m^2 331 m^2 705 $kWh_{th}/(m^2 \cdot y)$
Energy Retrofit measures	Retrofit measures	Roof insulation by internal false ceiling: 14 cm of EPS insulation λ=0.032 W/(m·K) Subsitution of 6 windows: - low-e double glazing with argon fill Ug=1.1 (W/(m^2·K) PCV frame Uw=1.6 – 1.7 W/(m^2·K) Connection to the district heating network
	Final energy performance	202 $kWh_{th}/(m^2 \cdot y)$
Costs	Declared cost of intervention (energy efficiency measures only)	6 915.8 EUR
	Eligible costs CONCERTO contribution	5 960 EUR 2 980 EUR

The energy retrofit measures were demonstrated to produce a significant improvement in the original energy performance. This fact is also reflected in the annual cost saving on the energy bill and in the reduction of CO_2 emissions. Originally the building was heated by an oil-gas burner and therefore the integrated action led to significant improvements in both the energy demand and CO_2 emissions of the building as given in table 3.3.13.

Figures 3.3.10, 3.3.11, 3.3.12. On the left the dwelling at the last floor of the building, in the center one of the new performing windows, on the right ceiling insulation (photo by P. Cialli)

Table 3.3.13. Effects of the energy retrofit measures on dwelling 1

Annual energy saving	29 979 $kW_{th}y$
Total reductiom of energy demand due to retrofitting	**71.27%**
Annual cost saving Annual CO_2 savings Total reduction of CO_2 emissions related to heating and domestic hot water	3 087.83 EUR/y 8 154.3 kg CO_2/y 100%

Assuming that the cost of the works was paid in one year, the equivalent CO_2 abatement cost is EUR 0.47/kg CO_2.

Table 3.3.14. Dwelling 2 – Via C. Grassini 4, Travale – Montieri

Buidlign features	Building type	Residential
	Unit type Floor area Heated volume Initial energy performance	Privare dwelling 170 m^2 722.0 m^3 252 kWh/m^2
Energy retrofit measures	Retrofit measures	Roof insulation 8 cm of EPS insulation λ=0.032 W/(m·K)
	Final energy performance	167 $kWh_{th}/(m^2 \cdot y)$
Costs	Declared cost of intervention (energy efficiency measures only)	2 0911 EUR
	Eligible costs CONCERTO contribution	17 000 EUR 8 500 EUR

Figures 3.3.13, 3.3.14, 3.3.15. On the left the building under refurbishment, in the centre and on the right – the insulation of the roof (photo by P. Cialli)

In this case the energy retrofit measures didn't involve the substitution of the heating and domestic hot water production system that already used a renewable energy resource, a biomass pellet stove. Table 3.3.15 expresses the results of the measure in terms of cost and energy savings whereas the reduction in CO_2 emissions is not remarkable in this context.

Table 3.3.15. Cost effectiveness of the retrofit measure on dwelling 2

Annual energy demand reduction	14 450 kWh_{th}/y
Total reduction of energy demand due to retrofit activity	33.6 %
Annual reduction of energy cost	903.125 EUR/y

Despite the limited success of the energy retrofit strategies introduced for private buildings, the results confirm that for the purpose of reducing CO_2 emissions, working on both the demand and supply sides at the same time leads to quite low abatement costs for kg CO_2 saved.

Both case studies demonstrate that there is a considerable annual energy saving on heating energy bills resulting from retrofitting the building envelope, in fact in the first case, where the energy saved exceeds 70%, the cost saving is greater than EUR 300, in the second case, where the energy savings are 33%, more than EUR 900 of yearly cost savings are expected.

The payback time of the energy retrofit works, taking into account the GEOCOM project's financial contributions, are respectively slightly more than 1 year for the first case study and 13 years for the second.

Indeed, the cost-effectiveness of retrofit measures depends on the combination of technologies chosen and the characteristics of the dwelling. As a general conclusion, it can be stated that when the implementation cost of the renewable resource is cheap, such as for the connection of dwellings to the district heating system, the whole operation of energy demand reduction and emission savings becomes more sustainable for the final user from the economic point of view.

Retrofitting strategy for public buildings

In order to compensate for the lack of involvement of private homeowners in the retrofit element of the project, the municipality decided to undertake retrofit works on a public building used by the whole community. The primary school in Boccheggiano was chosen; this school is used by about 50 people every year (both children and staff).

The School is a 1920–30s building constructed of load bearing brick masonry walls and horizontal structures of reinforced concrete. It underwent some renovation works in the past and nowadays needs to be refurbished in order to comply with seismic safety standards. The energy retrofit measures were combined with these planned works in order to produce a complete renovation from both the structural and energetic point of view. Table 3.3.16 describes the energy retrofit strategy and consequent expected reduction in energy demand and primary energy consumption and the CO_2 emissions saving.

Figures 3.3.16, 3.3.17 and 3.3.18 present an example of retrofitted buildings: the primary school in Boccheggiano.

Table 3.3.16. Retrofit strategy for the primary school in Boccheggiano

Buidlign features	Building type	Educational building
	Heated floor area	122 m^2
	Heated volume	5 330 m^2
	Initial primary energy demand for heating and domestic hot water	149 386 kWh_{th} 28 $kWh_{th}/(m^3 \cdot year)$
Energy retrofit measures	Energy retrofit measures	Looft floor insulation Uf = 0.23 $W/(m^2 \cdot K)$ External insulation of wall: Uw = 0.298 $W/(m^2 \cdot K)$ New windows: Uws = 1.6 $W/(m^2 \cdot K)$ New pellet heater for heating and domestic hot water
	Design energy demand	5 5504.97 kWh_{th}/y 10.59 $kWh_{th}/(m^3 \cdot year)$
Costs	Total cost of energy retrofit measures	127 806 EUR
	CONCERTO eligible costs (100 EUR/m^2)	122 000 EUR
	CONCERTO contribution (50 EUR/m^2)	61 000 EUR

In order to assess the economic feasibility of the intervention with respect to the environmental benefit, the CO_2 abatement cost associated with the retrofitting measure was calculated. It is assumed that the intervention is fully paid at the end of the first year. The effects of the retrofitting measures are summarised in table 3.3.17.

Figures 3.3.16, 3.3.17, 3.3.18. A example of retrofitted building: the primary school in Boccheggiano – external and internal views (photo by V. Marino)

Table 3.3.17. Energy and CO_2 savings related to the implementation of retrofitting measures in Montieri

Energy saved	96 614.43 kWh_{th}/y
CO_2 saved	33 549 kg CO_2/y
Primary energy saving	61.8 %
CO_2 saving	33.54 tonnes CO_2/y
GHG emission reduction (heating and domestic hot water)	100%
RES share increase	100%

The calculated CO_2 abatement cost is 3.24 EUR/kg CO_2 saved.

3.3.5 Renewable energy sources integration in Montieri

The area of RES integration that was initially proposed was the modernisation of the complete public lighting system in the town centre by a changeover to a solar–powered LED lighting system. It was planned to install a total of 8.5 kW_e of PV modules to provide the electricity for the street lighting. The initial electricity peak for the public lighting is 15 kW_e, from initial estimates a peak power of 8.5 kW_e PV would have been sufficient to cover the whole energy needs for such a public use.

This planned system would have reduced the energy demand by 35–50%, and its utilisation resulted in a 100% energy saving from the point of view of the system replaced.

The second area of RES Integration was the use of a total of 42.5 m^2 of thermal solar collectors. The reason for the limited amount of solar thermal results from the almost complete satisfaction of the community's thermal needs by the geothermal source.

The special architectural status of Montieri requires a special approach when it comes to RES integration measures. Traditional technologies of PV roof panels or solar collectors for DHW production are not feasible because, due to the cultural identity of the town, putting PV panels on the roof would seriously damage its medieval appearance.

Moreover, the analysis of solar conditions in the tight medieval urban structure indicated that the roof orientations are not favourable for a widespread use of integrated technologies in Montieri. Also, regarding domestic hot water production, a solar collector service would overlap with the geothermal district heating service and would result in it not being financially viable in those areas where district heating will be provided.

Solar photovoltaic array

A photovoltaic roof was installed on the building of heat exchanger A of the geothermal district heating system. Figure 3.3.19 shows the integration on the roof–top and the first energy production reading. In place of the originally planned 8.5 kW_e, the total power installed is 12 kW_e. The increase in the original capacity to be commissioned also represents a compensation measure for the limited success of the integration of solar thermal systems, as reported below.

The array covers the electricity demand of the pumps installed in heat exchanger A to operate the geothermal heating system. Its features are summarised on table 3.3.18.

According to the characteristics of the array and available solar radiation at the given location the expected energy production, CO_2 and TOE savings are given in table 3.3.19.

Figure 3.3.19. On the left: photovoltaic installation on the roof of heat exchanger station A.
On the right: data reading in the control room (photo by F. Mocca)

Table 3.3.18. Feature of the installed photovoltaic array

Power installed	12 kW_e
Area	83.12 m^2
Panel type **Nominal power**	S200 P50 (CENTROSOLAR) Polycrystalline Silicon 200 W_e
Number of PV panels	60
Inverter	1
Position	Orientation: South-west Azimuth: 40°, Tilt: 20°
Annual solar radiation on PV surface	5660.17 MJ/m^2

Table 3.3.19. Energy production environmental benefit and costs

Annual energy production	14 160.35 kWh_{th}
CO_2 saving	10 563.62 kg/y
Primary energy saving	2.65 TOE/y
Cost of delivery and installation	27 830 EUR
Occasional maintenance	3 600 EUR

The CO_2 abatement cost is calculated on the basis of the full cost of the installation and corresponds to EUR 2.97/kg CO_2. The payback time is expected to be around 10 years, after which time the investment will generate an income for the municipality.

Installation of solar thermal panels

The integration of solar thermal systems was promoted for those areas of the administrative territory that are too distant to be connected to the geothermal district heating network. This is due to two main reasons: first of all, the geothermal district heating network provides both heating in winter and domestic hot water and works all year round, secondly the town planning regulations currently in force prohibit the integration of solar panel systems (both PV and ST) within the historic town centre.

Hence, the municipality decided to publish a tender notice to allocate specific funds for financing the integration of solar thermal panels at building level on sites located outside the boundaries of the town centre. Priority was given to private tourist and production facilities such as hotels, restaurants, and farms in order to subsidise clean energy use. The tender, published on 20th November 2014, closed on 19th December 2014. Table 3.3.20 summarizes the eligible applications received. The expected cost and CO_2 saving related to the installation of solar thermal panels is expressed in table 3.3.21. The equivalent costs for CO_2 abatement show that the technology is very cost-effective in most of those cases where it substitutes for electricity demand. Figure 3.3.20 shows the installation of solar thermal panels on one of the buildings in Montieri.

Table 3.3.20. Features of the installed solar thermal collectors

No.	Building use	No.	m²	Tilt	Orien-tation	Storage	Substituted system	Estimated energy saving [kWh_{th}/y]
1.	Touristic	2	4.04	30°	South	300 lt	Electric boiler	7 235.6
2.	Commercial	2	4.6	18°	South	300 lt	Electric boiler	8 238.6
3.	Residential	1	2.09	43°	South	200 lt	Electric boiler	3 743.2
4.	Residential	2	5	35°	South	200 lt	Electric boiler	8 955
5.	Residential	2	5	45°	South	300 lt	Electric boiler	8 955
6.	Residential	2	5.1	15°	South east	300 lt	Electric boiler	9 134
7.	Residential	1	2.78	28°	South west	200 lt	Electric boiler	4 979
Total		12	28.61					51 240.4

Table 3.3.21. Financial and environmental benefits of the installation of solar thermal panels

No.	Cost saved [EUR/y]	CO_2 saved [kg CO_2/y]	CO_2 abatement equivalent cost [EUR/kg CO_2]
1.	1 664.18	3 787	1.45
2.	1 894.88	4 312	0.6
3.	860.94	1 959.2	0.42
4.	2 059.65	4 687	0.32
5.	2 059-65	1 746	3.57
6.	2 100.82	1 746	1.56
7.	1 145.17	4 780.7	0.53

Figure 3.3.20. The installation of solar thermal panels at Podere Butignano in Montieri (photo by Kiock Groels)

3.3.6 Social benefits for the local community related to the implementation of the GEOCOM project

Citizens who decided to connect to the district heating service are experiencing several types of benefit. Security of supply and an improved heating service are the main positive aspects related to the improved indoor comfort provided by the geothermal district heating. The reduction of energy costs and the shift from home delivery of fuel to a network service represents an advantage not only due to the annual financial saving but also due to the simplification and continuity of the energy supply.

The local administration overcame the technical and financial difficulties that arose during the construction phase and during the building works in the town. These were mainly related to the inconveniences to pedestrian and vehicular circulation resulting from the excavations and the management and financial issues which arose with the firms involved. The conclusion of works and the operation of the system contributed to creating consensus among the citizens regarding the action of the municipality at local level.

The ownership of the geothermal district heating plant managed by the municipality represents an opportunity to develop other secondary or tertiary activities that can take advantage of the low cost of heating and of incentives derived from the use of clean energy.

The project as a whole, with energy transition towards renewable energy resources coupled with demand side management, has already demonstrated its ability to improve the visibility of the municipality at national level. In fact Montieri has recently been given an award as one of the winners of Klimaenergy 2015, a national competition that assesses efforts to increase the share of clean energy in small municipalities.

3.3.7 Satisfaction with the results of the works, the public perception of geothermal energy and the RUE measures applied in Montieri

The construction of the geothermal district heating network was strongly promoted by the local political administration as leading innovation for the development of the municipality.

From the very beginning the citizens of the local community appreciated the introduction of the geothermal district heating because the exploitation of geothermal resource is well established in this part of Tuscany. In fact the presence of geothermal steam has always brought jobs and business opportunities for local residential facilities.

Moreover it can be stated that the presence of geothermal steam is part of the local identity, in fact it strongly characterises the area from the natural environment point of view (see for instance the natural park of “Le Biancane”) and locally there is a long tradition of its exploitation. During Roman times the area was famous for its thermal baths and the geothermal steam has been exploited for electricity production since the XIX century. This explains the positive attitude of the local community towards the exploitation of the geothermal resource.

The development of the district heating system represented a business opportunity for design and construction companies. The operational phase of the plant involves the work of a network control and management company.

The inhabitants’ point of view

The predicted economic benefit derived from the low cost of heating, reduction of the energy bill, and security of energy supply, were the two driving motivations for citizens resulting in the success of the construction of the geothermal district heating network.

The opportunity to overcome the problem of fuel delivery at the beginning of the season, which used to be the lot of the majority of citizens that owned oil/gas or wood burning stoves, as well as the increased indoor comfort derived from the continuous heating service and the significant control offered over heat distribution and temperature, are added values that convinced the local population to join the initiative.

The environmental benefit derived from the use of fossil free energy resources is not perceived as a priority because the quality of the air in the town has never been a problem due to the small number of people living there. Also, the higher level environmental issue of fossil energy use doesn’t represent a strong motivation at local level.

The fact that the construction of the district heating network didn’t include the drilling of a new borehole avoided concerns about the risk of water and soil contamination or vibration related problems that usually present the main sources of criticism among local environmental protection associations.

Because of the low penetration of the building retrofit strategy, only a small amount of business was stimulated among local construction firms and professionals. However it is expected that the studies

made for detecting appropriate energy retrofit measures, tailored to the characteristics of the local architecture, will be able to stimulate a new market for energy conscious building renovation activities.

The integration of solar renewable energy systems only addressed a part of the population directly. In fact funding for the integration of solar collectors for the production of domestic hot water was dedicated to residential, industrial/commercial or tourist facilities located outside the range of the district heating or in other settlements in the municipality.

The choice of installing photovoltaic panels on top of heat exchanger A's roof is consistent with the reduction of power demand of the plant, but weak in terms of the involvement of the local population and of sensitising the local population to the use of fossil free resources.

The solar measures are integrated with the geothermal district heating system and the other objectives of the project as part of a system for the whole municipality, but all the measures implemented were not directly integrated into the same case studies.

The experts' point of view

Taking part in the GEOCOM project not only represented added value due to the financial support received from the EU but was also an opportunity to set the baseline for a strategy for balancing the demand and supply of clean energy at local level through the implementation of customised measures which take account of the local identity of the place.

The local inhabitants experienced discomfort during the excavation works but tolerated it well, being aware of the future energy and cost savings to be derived from the connection of the individual dwellings to the district heating network. The start of the heating season confirmed the expectations of users who demonstrated general satisfaction with the energy transition.

Citizens perceived the objectives of the energy retrofit activity as overlapping with those of the connection to the geothermal district heating system. In fact, having the opportunity to exploit such a low cost energy source for heating and DHW discouraged the integration of energy saving technologies on the building envelope, the design and installation of which would have required a further economic contribution from the building owners. Moreover the fact that GEOCOM funding couldn't be combined with national incentives for retrofitting works further discouraged private owners making individual applications for retrofit measures to the building stock.

The construction of the geothermal district heating system took two years. These types of long-term civil engineering works imply continuous commitment by the administration and citizens to face the technical and logistical difficulties that may arise. Usually there are two main types of difficulty to face: financial-administrative and technical.

To the first category belong issues related to the management of the process that may arise during the pre-design, tender and construction phases. In fact several legal and financial constraints must be met: legal permissions, supervision of companies that cooperate in the construction work, lack of funding and the necessity to combine together different type of financial resources.

The main technical difficulty was linked to the location of the district heating pipes in the narrow streets of the historic town centre. This included taking care of the civil works linked to the construction of the district heating system and all the interference that may arise from the excavation works: structural damage to building foundations, the temporary blocking of entrance doors, the modification of the existing building envelopes and building systems to place equipment linked to geothermal district heating (e.g. pipes).

Moreover during the excavation works great attention had to be given to the existing utility infrastructure, such as water mains, the sewage system, and other energy networks that were renovated at the same time, thus improving the general urban services of the town.

Some positive returns are expected: a new liveability in the town in winter time will hopefully enhance the occupation of vacant/holiday homes over the whole year. Moreover the presence of the district heating is expected to be an incentive to the development of new agricultural production and craft activities able to stimulate the local economy.

The Lord Mayor's point of view

The municipality of Montieri paved the path towards the implementation of best practice in energy matters. The GEOCOM project has had a twin effect on the municipality: on one hand it has sensitively increased the citizen's awareness of energy issues by an information campaign and by introducing a systemic view of concerted action taking place simultaneously on both the demand and supply sides. On the other hand it involved the town in a network of geothermal municipalities that provides the opportunity to share best practice and experience on geothermal energy use, and this must be kept alive because it can lead to cross country cooperation on renewable energy matters.
In addition to the–above–presented aspects of social benefits for the Montieri community and individual beneficiaries of the GEOCOM works, some other issues which were investigated for Montieri in the framework of the separate socio–economic research based on quantitave methods are discussed in chapter 4.

3.3.8 General conclusions and lesson learnt from the case study

Geothermal district heating

The presence of the geothermal resource on the territory of the municipality represents an incomparable benefit for local communities, despite its exploitation sometimes raising criticism on environmental grounds. This is not the case with the demonstration site in Montieri, where the construction of the district heating network was well accepted by the local population from the early stages of the process.

Nevertheless, this geothermal district heating network, being quite a large infrastructure project to build from scratch and implying the presence of a long–term construction site within the confines of the narrow streets of the medieval town, meant that citizens experienced discomfort and had to put up with blocked streets, boardwalks for access to their homes, dust and noise. The experience taught us that in order to face the daily practical difficulties of citizens it is of primary importance to develop a good sense of commitment in the local administration and local population in order to provide mutual support in facing the technical and logistical issues.

The main difficulties faced by the local administration during the whole process of design and construction of the district heating system are of an administrative, financial and technical nature.

The first type of issue was related to the complexity and duration of the process from the pre-design phase, through tender, to construction. There are several legal constraints that must be faced at the beginning of the process, such as legal permissions for land expropriation and for the installation of the equipment. The publication of the international tender and the management of the assessment of proposals and financial offers, as well as the appointment of the successful company, require a high standard of expertise among the technical and administrative staff because the scale of the works implies a great deal of interest and money involved, and thus a complex process of decision-making.

Accurate controls on companies that cooperate in the construction works were also needed in order to avoid illegalities. Unexpected issues such as the reduction of the expected public funding occurred in Montieri and required the ability to combine new and different types of financial resources and to involve new stakeholders during the process.

In order to face these issues in a proper way, it is necessary to construct a team made up of technical, legal and administration experts who are able to cooperate in decision-making and to use their skills to find appropriate solutions for unexpected difficulties.

The main technical issue was linked to the location of the district heating system. The source of geothermal steam is located far from the final distribution network and with an altitude difference of about 200 m.

Within the historic town the main technical difficulty was the need to excavate deep into the narrow streets of the medieval road layout. There was a danger of threatening the structural stability of buildings causing damage to old masonry. In order to install individual heat exchangers at building level, the excavation of niches was planned in existing street-facing building walls to allow external access to the equipment for maintenance purposes. This work required special care, above all in older buildings.

However, the excavation phase on the streets was also useful for checking and upgrading the existing utility infrastructure, such as water mains, the sewage system and other energy grids.

The finishing works also required great care. The streets were totally re-paved and attention had to be paid to the choice of local stone for paving tiles, functional for pedestrian use on steep streets in all year round weather conditions (snow, rain) with an appearance and layout appropriate to the historic value of the medieval town. Several checks were done with the local heritage preservation authorities in order to find the desired solution.

A skilled technical team and lots of dedication were the two most important features for achieving good results in the implementation of the activities. The experience of the demonstration site of Montieri taught us that the pre-design and design phases are critically important for anticipating as many as possible of the technical difficulties that are linked to the characteristics of the construction site and to the size of the works. For unexpected issues it is instead a fundamental requirement to have strong technical expertise and synergy between the different companies working together and between them and the administration. When this cooperation comes to an end, even normal stages of work become incredibly difficult to continue.

Energy retrofitting activities

The implementation of the retrofitting strategy in the demonstration site of Montieri has taught us that actions on the building envelope must be evaluated and designed together with the planning of the district heating network and the related connections to individual dwellings. In fact, the benefits related to the integration of the demand side and supply side elements must be well coordinated in order to maximise the cost-efficiency of the total project.

Separating the two design phases (for the building envelope and plant integration) can lead to some implementation problems: on the one hand, there is the risk of starting an out-out choice phenomenon, where the financial convenience of the substitution of the heating system and the connection to a very convenient geothermal district heating network overrides all other environmental or energy conscious decisions on design choices on the demand side. This is what happened in the

Montieri demonstration site where the retrofitting strategy was planned separately from the design of the district heating network and it was also proposed and managed separately from the implementation of the dwelling connections to the network, resulting in a very low penetration of demand side actions.

On the other hand, implementing deep energy retrofit actions on a wide scale after the geothermal district heating has been designed and installed may reduce the viability of the investment on the district heating network at the town level, impeding a true integration of technological solutions on the demand and supply side.

Planning supply side solutions at a town scale, such as a new district heating system, while taking into account the opportunity to reduce building energy demand by the implementation of retrofit measures represents an optimum solution to reduce the waste of energy resources and to implement more cost effective projects, above all in the case of a district heating network fuelled by a mixture of energy resources, both renewable and fossil.

A second lesson learnt is the importance of subsidies for building retrofitting works when the proposed measures involve private housing stock. Since homeowners generally implement energy efficiency measures when they have already planned general building maintenance works, it is essential to investigate the possibility of overlapping several streams of funding to finance effective actions. In fact, the opportunity of receiving substantial help in the realisation of works enhances the design of whole building retrofit solutions and not just the implementation of single measures on building components (for instance window replacement).

In the demonstration site in Montieri, difficulties arose because project funding was not sufficient for an individual inhabitant to finance deep energy retrofit solutions and the measures were not compatible with national funding for the energy refurbishment of buildings. Another issue was that the distribution of properties inside each building is very complicated and it was almost impossible to find an agreement between all the inhabitants to design retrofit works at building level. The result was that each dwelling asked for funding as a single unit, not as part of a coordinated building retrofit project. If private homeowners are involved on the front line in the implementation of an important task in the project, such as demand side actions, the financial conditions for the proper implementation of the project objectives must be thoroughly investigated from the beginning of the process in order to facilitate the acceptance of the general strategy and boost the implementation of the plan.

Finally, but most importantly, the implementation of the retrofitting strategy in this peculiar demonstration site of Montieri, a small historic town in the heart of Tuscany, must take into account from the very beginning the quality of the retrofit measures proposed by the project. As it is necessary to respect of the details of old buildings such as stone masonry, window profiles, roof edges, wall and roof finishes, original and local building materials, the study of suitable energy retrofit measure becomes fundamental, as well as a compromise between energy performance targets and the architectural quality of building measures in order to preserve the cultural identity of the place.

Solar renewable energy systems

The third objective of the project, for Montieri demonstration site, consisted in the integration of other renewable resources of solar type. Two main aspects needed to be taken into account in this peculiar site: the potential overlapping of renewable energy resources with the service offered by the geothermal district heating and the valuable aesthetic character of the historical location.

The first aspect is related to the overlapping of functions between solar thermal collectors and geothermal district-heating, that was designed to provide either winter heating or domestic hot water

all year long. Photovoltaic installation did not overlap in functions with district heating, but the reduced solar exposition of the village during the year, Montieri laying on the north-eastern flank of the hill, impede a high efficacy of the photovoltaic system, dissuading from investments in this sense.

The second aspect is related to the visual impact that the integration of solar panels (either photovoltaic or solar thermal ones) have on the historic character of the place. The local urban regulation prevent from the installation of these systems on roof tops or façades in order to maintain intact the aesthetic of the place.

Taking into account these main restrictions, the administration decided to install these systems out of the perimeter of the historic town and of the district heating network path. Lesson learnt from the case study is to consciously planning the integration of several type of renewable resources in order to implement cost–effective actions and to respect the character of the place.

Sometimes, re–thinking strategies and involving a wider area or the whole community may result in a lower integration of different resources at individual level but on a more coordinated action at territorial one. Moreover, the involvement of the community by the publication of tenders for the installation of solar systems in the whole territory already had some positive effects in starting new policies for distributing subsidies for carbon free transition of local touristic and productive realities.

3.3.9 Implementing a demonstration project at community scale

As a very general conclusion, it can be stated that it was very challenging to implement the Geothermal Communities project in the Montieri demonstration site. The main reason is that such a small community was actively involved in a European dimension where it had to report about actions undertaken locally and to cooperate with partners of other countries not always directly involved in practical implementation works. At the beginning this change of scale represented a difficulty (language barriers, the overlapping of local and European duties) but afterwards was seen as an opportunity to enlarge the outreach of knowledge and cooperation on geothermal matters. This culminated in optimistic involvement of the Geothermal Mayors club of not only Montieri, but also of other municipalities in the area that have their own geothermal resources in their territories.

A very important lesson learnt from the municipality's involvement in the project is the need to have the whole community participating in the project from the early stages. This should not be limited to a communication and information campaign for citizens, but it should entail active discussion with local stakeholders (citizens, investors, companies..) to assess their interest in the project objectives and to express the potential exigencies and expectations that they may have from the project. The progressive involvement of the local community is likely to guarantee a wider acceptance of proposed strategies and a greater effort in the implementation of actions. Moreover, a final remark is necessary on the motivation pushing local citizens in their active participation in the project. Reading the results of the questionnaires on the public perception and understanding of RUE measures circulated to the local population in the demonstration sites it is clear that very few of the local population interviewed were concerned about environmental issues. A very small number of respondents considered the effect of, and the energy transition towards, renewable resources to be a relevant issue as regards reducing emissions and the waste of energy and the preservation of resources. The reduction of individual costs and improvement of heating services were instead identified as the leading reasons for accepting all the discomfort and difficulties faced during the development of the project.

Working on an awareness campaign on energy consumption and the environmental impact of individual behaviour before starting the project, with the help of monitoring activity to show real energy consumption data, would definitely have led to a more active participation in the project.

In fact it is believed that a higher consciousness of individual consumption habits and the shortage of resources would help people to focus more on energy and environmental issues and to drive their investments towards actions able to improve not only living standards, but also the quality of life and the preservation of common non-renewable resources for future generations.

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- Arch. Paolo Cialli for figures and pictures related to the retrofitting works on private buildings,
- Mr Massimo Morganti and Mr. Kiock Groels for pictures related to the photovoltaic array and solar thermal panel installations respectively.

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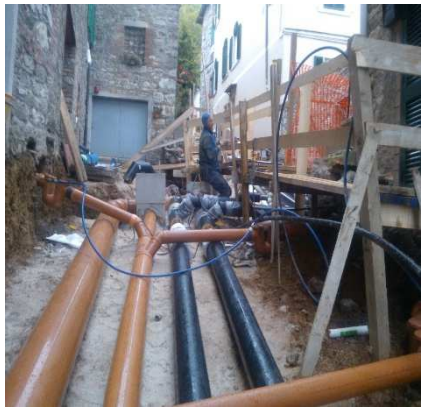
The GEOCOM project: geothermal district heating construction works in Montieri Photographic survey

(photos by Studio Tecnico Associato INGEO)

Geothermal heat exchanger station A:
from beginning of construction to technological installations

Excavation works in some typical streets and squares in Montieri



Piazza Papocchi and Via delle Fonderie

3.4 Mórahalom Municipality (Hungary)

(Jozsef Pastor – Municipality of Mórahalom, Istvan Pari – Geonardo Ltd., Tamás Medgyes, Balázs Kóbor, János Szanyi – University of Szeged)

3.4.1 The integrated system of Mórahalom – general background and assumptions

Mórahalom is a small town (population 5 800) situated in the south of Hungary on the border with Serbia. It used to be listed among the 50 most disadvantaged communities in Hungary, but the investments of the past decade – upon some of which the current GEOCOM project was also built – launched it into the top 10 most dynamically developing settlements. The installation of the geothermal district heating system can be considered the most influential of them all and that with the greatest impact, and it also presented a solid foundation to the local GEOCOM components that will be discussed in great detail below.

Building on the results of the past 10 years the primary objective of the town's leadership remains to continue to improve local competitiveness and boost tourism on a regional level by means of a series of innovative measures.

The first time the local municipality started to consider becoming involved in the exploitation of the local renewable energy resources dates back to 2007, and this idea derived from a number of reasons. The building stock owned by the municipality presented a series of significantly outdated technologies that were either inappropriately sized for their functions, or operated with very low efficiency. The resulting very high running costs proved to be unsustainable in the long run, thus alternative solutions had to be investigated to eliminate these pressing issues. For example the energy audit (upon which these conclusions were based) revealed that 87% of the municipality's energy use is based on natural gas and this translates into 59% of all municipal costs on an annual basis. Based on market analysis, it could not have been excluded that in a short while these costs might reach up to 70%.

The other reason that drove the decision-making process towards a greener solution is the local availability of high quality renewable energy resources. It is common knowledge that the South Great Plain Region of Hungary (where is situated) excels in having considerable renewable energy potential. On one hand, the local geology favours initiatives that are designed to harness geothermal energy (figure 3.4.1), on the other its geographical setting means that it has one of the highest values of sunshine hours per year in Hungary, giving it the opportunity for solar-related infrastructure developments.

Mórahalom (figure 3.4.2), just like other settlements in the region, has been using geothermal water for decades in its famous thermal baths. Geothermal water produced by the wells supplying the baths has a history of being used for heating the premises of the baths for many years now, and this dates back long before 2010, when the GEOCOM project started.

The drastic changes in natural gas prices, the social subsidy structure, the finite natural gas reserves, the service anomalies, and Europe's dependence have highlighted the importance of alternative energy sources. In the case of Mórahalom, geothermal energy is in place, is not import-dependent, and is managed by the local government.

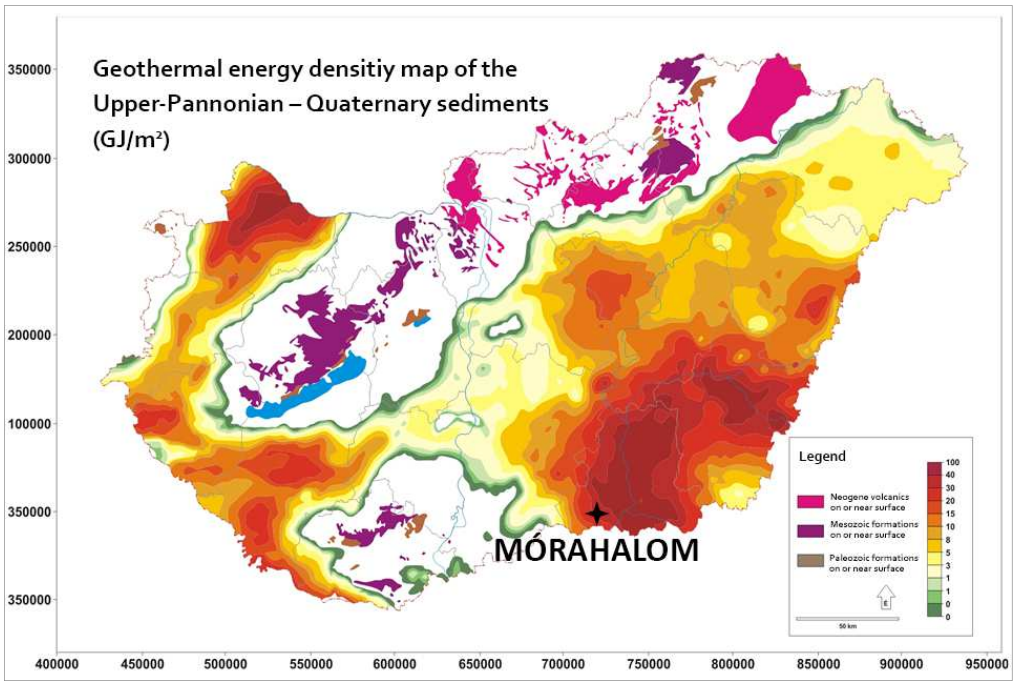


Figure 3.4.1. Location of Mórahalom on the map of geothermal energy density in the Upper Pannonian – Quaternary sediments in Hungary (map source: *https://sciart.eu/hu/2010-12-05-1212/1/hazai-geotermikus-energiavagyon-geologiai-problemai*)

Figure 3.4.2. Town centre of Mórahalom in 2014 (source: *https://hu.wikipedia.org/wiki/F%C3%A1jl:M%C3%B3rahalom_v%C3%A1rosk%C3%B6zpont.jpg*)

3.4.2 Initial activities oriented to introduction of geothermal and integrated energy system to Mórahalom – pre-GEOCOM actions in 2002–2010

The following pages discuss in chronological order the list of decisions and actions that were carried out in Mórahalom to initiate its renewable energy utilisation plan. These actions laid the foundations and provided a solid foundation for all GEOCOM-related activities that were carried out in the later phases, after 2010.

In 2002 the town leadership had grant assistance to examine the heating systems of its public buildings, but finally it decided in favour of tourism developments due to the "manageable" energy expenses, the moderate investment support and its own resources. The analysis of the potential replacement of natural gas – which was the sole type of energy used at that time – was a major aspect of the audit proposals which was justified by the anomalies of natural gas supply, the drastic increase in the purchase price, the harmful environmental effects, and the good geothermal features of the region. The local government authorities decided, as a continuation phase and based on reliable data, suggestions, and ideas from the audit, to carry out a feasibility study on the establishment of a geothermal public utility system in Mórahalom.

The pre–feasibility study, the construction plans prepared according to the version chosen in the study, and the preliminary environmental impact assessment made and authorised according to the plans, were finalised in October 2007 with INTERREG IIIA HUROSCG assistance. The project's objective, beyond the making of a feasibility study and plans for the current project, was for new production and reinjection wells to serve as sampling and measuring points for the first Hungarian-Serbian cross–border geothermal water resource and production monitoring system. Mórahalom's partners during the making of the pre–feasibility study, planning and elaboration of that transnational geothermal water resource monitoring were the experts of the Department of Mineralogy, Petrology and Geochemistry of the University of Szeged (USZ), the South Great Plain Regional Office of the Hungarian Geological Service, and the Geothermal Innovation and Coordination Foundation.

The project proposal was submitted to, and was given grant assistance from, the KEOP 4.1.0 (Structural Funds) call for applications. The main principles underlying the proposal and plans for implementation were as follows:

Geothermal water with good overall quality and specifically of medicinal standard with a temperature of approx. 70°C could be produced from a 1 300 – 1 400 m deep well located in the northern part of the town. An optional innovative feature of the proposal was that the geothermal water extracted – after utilisation of its heat – could be used in the increasing number of pools at the local thermal bath (spa), and then would be returned back into the aquifer through a reinjection well, which would be drilled on a brownfield investment site, the new industrial park (until such time as the water is classified as medicinal water according to the relevant regulations, the total quantity of used water should be reinjected). The most important of the local government's public buildings from the point of view of the heat market were connected through a 2.8-km-long insulated underground pipeline network. In another innovative feature of the project, heat pumps would supply heating to new buildings which only received a low-temperature fluid from the primary thermal circle.

The construction and operation of a geothermal cascade system at Mórahalom (fig. 3.4.3) were the expected results of the project activities; the proportion of renewable energy in the energy use by public institutions would increase from 0% to 80% resulting in savings in the use of fossil energy resources (natural gas) of 14 441 GJ per year both at the project and national economy levels.

A heat capacity of 2 620 kW_{th} was planned to be installed in the geothermal system at a very favourable market price of 165 thousand HUF/kW_{th} (523.81 EUR/kW_{th}).

Throughout the system's expected 25-year lifetime, it was expected that it would offset the burning ofan annual average of 481 907 m^3 of natural gas; the annual emission of pollutants from energy use would be reduced by 866 t of CO_2, 318 kg of NO_x and 605 kg of CO. The system should reduce CO_2 emissions at a specific cost of HUF 16 636.46/t (EUR 55.45).

The total gross investment costs of the project were HUF 526 000 thousand (1 669 840 EUR), 50% of which (HUF 263 000 i.e. 834 920 EUR) was to be provided by EU grant aid from the KEOP call for tenders. The net operating costs of the system, without amortisation, were HUF 19 200 thousand (60 952 EUR). As a result of this investment the local public utility system (run by the municipality) would become largely independent from the supply and price formation anomalies of imported gas. The operating wells of the geothermal system – designed with previous INTERREG funding – would be part of the Hungarian–Serbian water reservoir protection monitoring system, and would serve as a training site for the geothermal technicians and engineers at the University of Szeged.

With the development of a geothermal supply to the public utility system and the development of the new town centre, the expected reduction in the emissions of pollutants was 70 – 80% (roughly 1054 TOE). The system providing cheap heating would not only be the factor promoting the installation of the spa, but also that for the new "Colosseum" hotel as well. Therefore it would promote the competitiveness of the service sector based on regional tourism, and create new jobs in the operation of the system. The secondary target group of the project was the group of students in University of Szeged studying geology, geography, or participating at training sessions in the fields of regional development and training to become geothermal technicians.

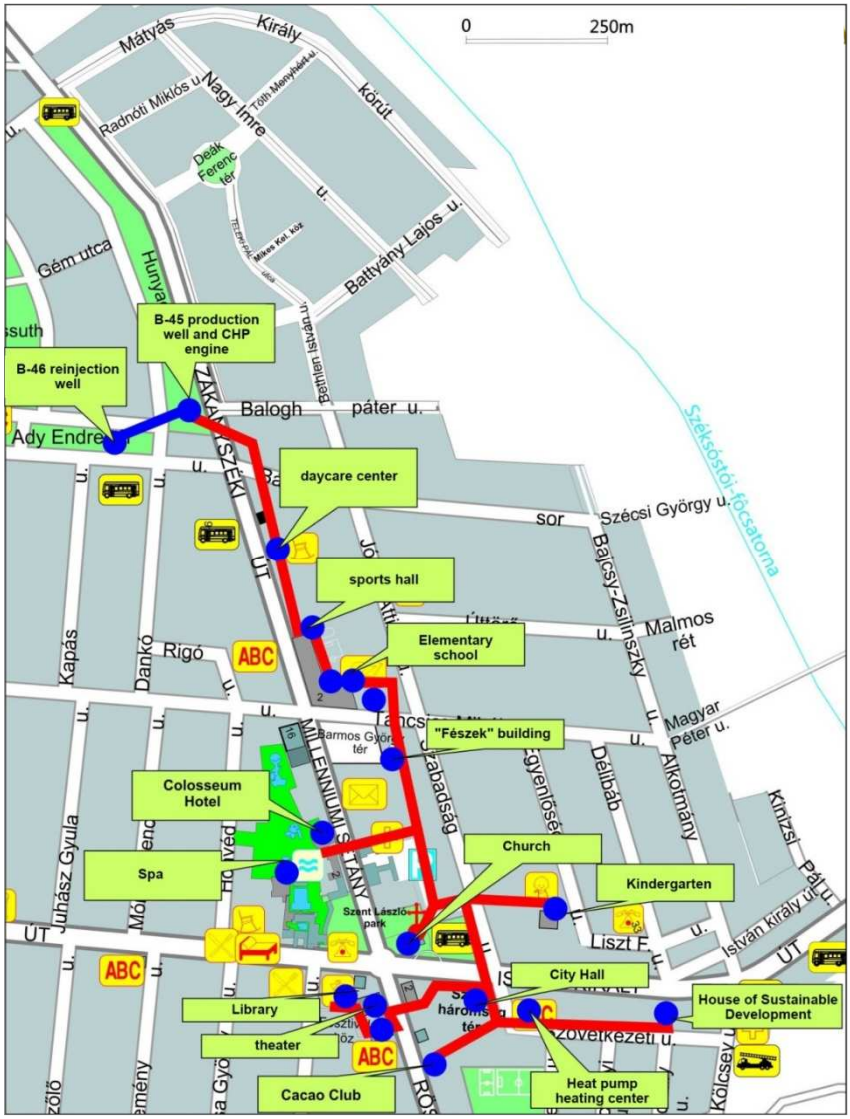


Figure 3.4.3. The geothermal cascade system in Mórahalom (source: Municipality of Mórahalom)

As the result of the project described above, and according to its objective of promoting geothermal development, an energy performance appraisal was made of the buildings in the town of Mórahalom, a feasibility study was made, and a successful application for assistance was made in order to build its geothermal heating system. After long planning and a lengthy decision making process the actual delivery of the above described actions took place over the course of 2009–2010. This included the drilling of the production (B-45) and reinjection wells (B-46) doublet at Hunyadi-liget. Parallel with this work, a distribution pipeline linked to the wells was also constructed with an overall length of 2.8 km and running N–S connecting the production and reinjection wells with the the city centre by a closed loop. The pipeline was designed in such a manner as to reach all of the municipality-owned public institutions and other public buildings (e.g. a church) that were connected to the district heating system. By the end of 2010 geothermal heating replaced natural gas at all of the buildings thus connected.

3.4.3 The GEOCOM project activities 2010–2015 in brief

In 2010–2015 a new set of actions was implemented complementary to the already commissioned geothermal district system. These took place within the framework of the GEOCOM project at Mórahalom, aiming to improve the overall efficiency of the district heating system and to demonstrate the many positive effects of a well designed integrated approach to energy management, its efficiency and more rational use:

- Utilisation of the waste gas content associated with the geothermal water from the B-40 and B-45 wells for CHP for the St. Erzsébet Spa and the Geothermal Cascade System of Mórahalom respectively,
- Integration of solar thermal collector systems in the existing geothermal heating and DHW production systems in the following buildings: Móra Ferenc Cultural Centre and Elementary School; Móra Ferenc Cultural Centre Sportshall; kindergarten and day–care centre complex,
- Energy modernisation of the geothermally heated buildings: heat insulation and replacement of doors and windows and thermal retrofitting: Móra Ferenc Cultural Centre and Elementary School; Móra Ferenc Cultural Centre Sportshall; kindergarten and day-care centre complex,
- Utilisation of the residual heat in the geothermal water using heat pumps: new high power heat pump heating stations to be installed in the new town centre and the Thermal Residential Park,
- Installation an energy saving (LED) public lighting system in combination with a photovoltaic system: photovoltaic micro power plant on top of the market hall and LED public lighting system throughout the new town centre.

In line with FP7 financial rules, the demonstration components of GEOCOM, including all the activities in Mórahalom, received 50% grant aid funding towards the costs incurred excluding V.A.T. (as a result of Research and Technological Innovation Fund call for tender). On this basis the municipality had to bear as its own contribution the remaining 50% of the costs, the VAT and the fluctuations deriving from the exchange rates. In order to reduce the total costs to the municipality there was an application submitted for one of the Government's fiscal aid programs, called *EU_BONUS_12*. The amount received through this channel was enough to cover all the VAT related expenses previously charged to the project.

A detailed energy audit was first carried out of the buildings to be retrofitted and a public lighting system together with an overall estimation of energy consumption of all the buildings within the Concerto area but not directly affected by project activities. Figure 3.4.4 shows the individual project components of the GEOCOM project implemented throughout the municipality.

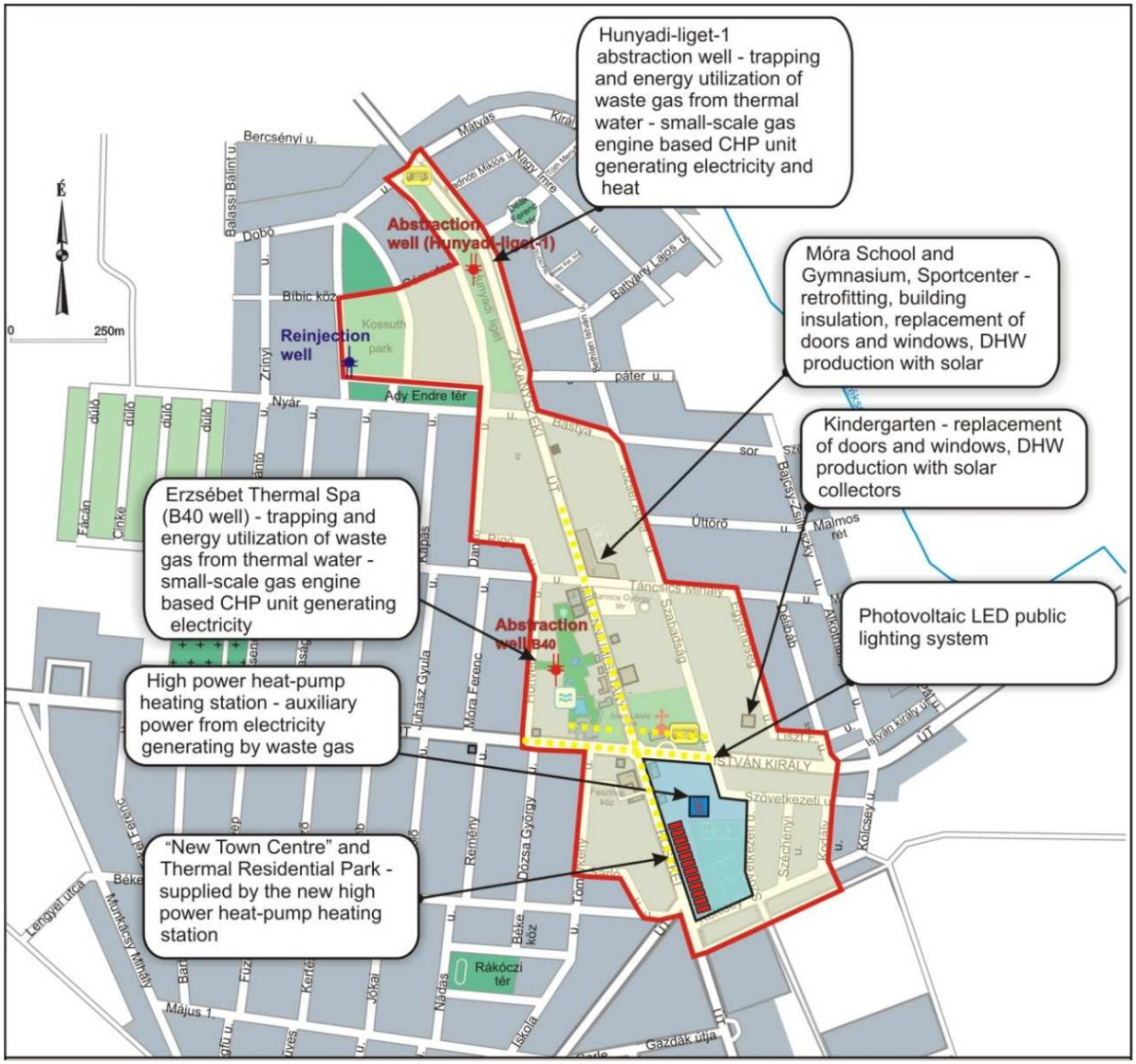


Figure 3.4.4. Map showing the elements of the integrated energy system established in Mórahalom within the framework of the GEOCOM project works (the CONCERTO Area). This represents the operational area of the geothermal cascade system

As a major part of the RES integration a small gas-engine CHP was installed on the B-45 production well at the Hunyadi-liget site. The power produced not only covers the needs of the abstraction pump but it also supplies the high power heat-pump heating station of the "New Town Centre" with auxiliary electric power (60 kW_e). Furthermore the thermal output of the CHP engine is used to heat up the geothermal water produced by about 2–4°C, which ultimately makes up for the total thermal losses over the full length of the distribution pipeline.

According to the gas sample analyses and technical feasibility studies prior the project, 2–2.5 kW_e electric energy and 6–7 kW_{th} geothermal energy can be produced in the co-generation (CHP) unit from 1 m^3 of trapped gas (87% methane). Parallel to this development, a similar CHP unit was constructed on the B-40 well which also generates electric current that supplies the Erzsebet Thermal Spa. In addition, the heat generated (90 – 120°C) is used for domestic hot water (DHW) production and heating of the Spa. The thermal value of the waste gas is an average of 8.48 kWh_{th}/Nm^3, the usable

electric power is 35 kW_e and the usable thermal power is 70 kW_{th}, with a total combined efficiency of 86.74%.

The modernisation of the complete public lighting system of the town centre (Szent Laszlo Park, Millenneum Alley, Central Bus Station, and the public transportation stops in the Concerto Area) also took place with a changeover to a solar–powered LED lighting system. The previous lighting system for these public areas used 36 W_e strip lights (consumption: 42 W_e/piece), and by 70 W_e sodium lamps (consumption: 90 W_e/piece). They were replaced by 10–12 W_e and 30 W_e LED lighting units, with consumptions of 15 W_e and 38 W_e respectively, while their power supply is provided by newly installed photovoltaic cells.

The establishment of the heat pump powered heat supply station for the supply of energy to the new town centre and the Thermal Residential Park was carried out in 2011–2012 to produce a thermal power of 450 kW_{th} in a heat pump system with an average efficiency of 4.5–5 COP (*coefficient of performance*). Despite the fact that the necessary infrastructure is in place, there are a number of reasons why the heat-pump has not been used at its maximum capacity. On one hand the mild winters of the past few years since commissioning were not cold enough to demonstrate the limits of the geothermal district heating system (below –5°C) at which the heat pump is supposed to kick in to back up the geothermal loop.

On the other hand, due to a number of reasons that delayed the delivery of the Thermal Residential Park (a major contributor to the heat market of the affected district), at the moment the heat market is not big and dense enough to make the heat pump system worth operating at full capacity. The total heated floor space of the "Thermal Residential Park" will consist of 12 of 12 apartment buildings (431 m^2 heated floor area each), and will be constructed in two stages in the near future.

In order to increase the efficiency of the energy infrastructure developments, the insulation of walls, and replacement of doors and windows was carried out at the Móra ÁMK (elementary school – cultural centre complex) as well as at the kindergarten and day–care centre. This was expected to produce a reduction in heat demand of 12–21%.

Finally, in order to guarantee the multiplier effect of the activities carried out in the Concerto area an on-line, real-time energy measurement and monitoring system was installed which is accessible to professionals (including those participating in on–site practical training sessions at the University of Szeged) and the general public (partially described in chapter 3.5).

The above-listed investment works performed within the framework of the GEOCOM project at Mórahalom are presented in more details below.

3.4.4 Geothermal systems development in Mórahalom

Three separate geothermal systems are in operation in the Mórahalom administrative area which are primarily used for heating purposes. The first is the geothermal system of the local St. Erzsébet spa, the second is the local geothermal cascade system (detailed above), and the last is an island-like geothermal district heating system for a few buildings of a demonstration complex on rural lifestyle located at the edge of town, and which was funded by an EEA – Norway Grants.

It is now commonly known that the Southern part of the Great Plain Region of Hungary excels in having considerable renewable energy potential. On one hand, the local geology favours initiatives that are intended to harness geothermal energy, on the other hand, its geographical setting means

that it has some of the highest values of sunshine hours per year in Hungary, thus giving it the opportunity to benefit from solar–related infrastructure development.

The geothermal systems in Mórahalom – as with most of the other geothermal systems in Hungary – are directry related to the results of the extensive hydrocarbon research campaigns that were undertaken in the 1960s and 1970s all over the country. These research activities revealed most of the reservoirs that ultimately yielded geothermal fluids rather than hydrocarbons. For example the first well in Mórahalom, upon which the local spa was established, was initially planned to be an exploration well for scientists seeking information on the local geological conditions.

The drilling principles and the applied technology for drilling geothermal wells are very similar to those for hydrocarbon well operations, however there are a few differences between the two types of wells, primarily in their structure, more specifically in their method of completion. Geothermal wells are completed by installing so called Johnson filters to allow the geothermal fluid to enter the well from the formation. This approach is in contrast with the petroleum industry where perforation is the most commonly used well completion method. Also the start and end diameters of these two types of wells show some fundamental differences.

The first geothermal well (B-13) was drilled in 1960, reached a depth of 660 metres, and was used for the spa in Mórahalom. The geothermal well continues to provide the pools with fresh geothermal water through a filler–unloader system up to this day.

There was a long gap after this initial success in the utilisation of the local geothermal resources. The very first well (B-40) which specifically targeted the geothermal reservoirs was finished in 2004 on the premises of the Szt. Erzsébet Thermal Spa. It's total depth is 1 270.6 meters. The primary purpose of this well was to provide the spa building, the local health centre and the old town hall with heating. Once it returned from the heating loop, the partially heat-depleted water was used to temper the temperature of the pools and to provide a fresh input for the pools by introducing a filler-unloader system.

This action was followed by an even more recent drilling job, again targeting geothermal reservoirs. This well (B-45) was finished in 2008 and reached 1 260 metres b.g.l. This well is currently working as the production well for the geothermal cascade system of Mórahalom. In order to be in line with Hungarian regulations and to meet the requirements of the relevant KEOP–4.1.0–2007 tender there was also a need to drill an injection well. B-46 reached a depth of 900 metres and was commissioned in 2009. A geothermal heating system linked to this system was completed in September of 2010. This installation provides the second geothermal system in the town.

The third geothermal-based district heating system in the town is based on a doublet system which was also completed in 2010. The production well (K-43) is 1 255 metres deep and the reinjection well (K-44) went down to 940 metres b.g.l. in a similar manner to its counterpart at Hunyadi-liget. The heating system also includes the necessary pipeline and engineering components on the surface.

The very last instalment of the geothermal wells of Mórahalom is the B-49 well which was drilled in 2011 on the premises of the Spa and is 660 m deep. It's sole function is to supply the spa with fresh geothermal water, thus there is no energy utilisation from this supply which only serves recreational (balneotherapeutic) purposes. Table 3.4.1 gives main data on the wells that supply geothermal water to different facilities in Mórahalom.

Table 3.4.1. Inventory of the wells related to the geothermal facilities in Mórahalom

Well name	Well location	Well depth [m]	Water production [L/min]	Water wellhead temperature [°C]	Solution Gas-Water Ratio [L/m³]	Well drilling year
B-13 geothermal well	Thermal pansion	660	340	38	362	1960
B-40 geothermal well	Thermal Spa	1 270.6	475	68	544	2004
B-45 geothermal well	Hunyadi liget	1 260	1 000	63.4	524	2008
B-46 injection well	Ady square	900	650	48.2		2009
B-49 geothermal well	Tömörkény street 3	660	700	38.4	89	2011
K-43 geothermal well	Szent János area	1 250	1 000	64.9	238	2010
K-44 injection well	Szent János area	940	750	45.8		2010

3.4.5 Gas utilisation systems associated with the geothermal wells

The presence of gas in underground waters is a general phenomenon found in the basin sediments of the Great Plain, the most common types of gases being carbon dioxide, nitrogen, hydrogen sulphide and radon. With the reduction of pressure in the water during the production of geothermal water from the wells, the gas dissolved in the water is released at “bubble point” and the density of the water column is reduced. The gas bubbles released help propel the water to the surface, thus the gases dissolved in the water have a positive impact from the production point of view. Upon reaching “bubble point” pressure, more and more gases are released from the rising gaseous artesian water. As a consequence, the density of the medium filling the well section gradually decreases. Beside the increasing amount of gases released, part of the gas content still remains in dissolved form. The ratio of gas dissolved in the water and that released, and also the comparability of various test results, is influenced by the water recovery and gas separation methods. The pumping method used in the well can also have a significant impact on gas content released, hence tests must be carried out at well inspections in which the expected amount of operational water recovery is applied.

As mentioned above, a significant proportion of the proved geothermal resources in the area of the Great Plain feature accompanying gas that surfaces with the geothermal water produced. This also contains a usable amount of methane. Similar high methane content geothermal water and accompanying gas sources have been described in the region of Mórahalom and Hajdúszoboszló. Both towns started to take advantage of this resource, however there are some differences in the utilisation practices at these two locations.

Firstly, in Hajdúszoboszló the geothermal water contains gas of high value, so there we can talk about gas wells with geothermal water. The amount of associated gas is significantly higher than the amount of geothermal water, the gas – water ratio higher than 1000 L/m^3. The geothermal wells are far from the spa, the site where it is used, so the produced and separated gas needs to be prepared to a suitable standard to be transported in the pipes.

The gas with water, dust and water droplets may cause blockages in the pipeline at some temperature and pressure conditions. In all circumstances it is essential for this to be avoided when transporting the gas. Additionally the utilisation technology does not permit water to be present in the gas.

Consequently the gas has to be cool and dry having passed through a gas drier compressor installation.

After drying, the water-free gas reaches the separator (as happens in the gas industry and the oil industry). Another alternative if there are no opportunities to dry the gas with the above-mentioned system is to use a glycol drier. However this is not an appropriate solution for utilisation in the spa and it is not the best choice for the environment and from the point of view of the economics of the process. Gas hydrates are naturally occurring, crystalline, ice–like substances composed of gas molecules (methane, ethane, propane, etc.) held in a cage–like ice structure. (clathrate). Hydrates are a concentrated form of natural gas compared with the compressed gas, which is flammable but less concentrated than liquefied natural gas.

The prepared gas needs to be compressed to be transported to the utilisation site. However as far as the geothermal wells in Mórahalom are concerned this is not an option for two reasons.

Firstly the associated amount of gas is significantly lower so in this case we can talk about geothermal water with gas. In addition the amount of associated gas produced with the geothermal water is also lower than in Hajdúszoboszló.

Secondly the production wells are very close to the utilisation sites, so there is no need to transport the gas for long distances. The associated gas utilisation equipment and instruments do not require the same preparation process. At the selection of utilisation technology the associated gas benefits from storage are also taken into account and the end of the energy utilisation process has to be positive. In other words, the amount of energy invested in the process should be much smaller than the energy produced by the process.

What does this really mean? If we used the gas in another location, and if we produce the gas in a similar manner to Hajdúszoboszló, the necessary energy could reach or exceed the energy which is obtained during the production process. In this way all the benefit obtained from using the energy from the gas would be lost.

From our geothermal wells the geothermal water has to be pumped because the water level is lower than the ground level. We use a submersible pump for this. During the production process the gas in the well partly separates from the geothermal water, so one part of the gas recovered we produce from the pipeline, the other part of the gas we produce from the geothermal water. The LVS type of degasser, which is installed in the drill borehole, was not suitable for this because it did not allow the gas in the closed system to separate from the geothermal water. Therefore there was a new gas separation technology developed which had to be deployed between the well and the storage tank, but for a safety margin the LVS degasser also operated due to the geothermal applications.

With regard to the geothermal water containing iron and manganese compounds, and also to the LVS degasser mix, the geothermal water contains oxygen so the iron and the manganese is oxidized, which also separates from the water and this we can separate in zeolite filled tanks. After this process the geothermal water will be appropriate for use in the spa.

Utilisation of the gas associated with the geothermal wells

On the basis of a detailed examination regarding the gas content in the B-40 geothermal well, which was undertaken at the St. Erzsébet Thermal Spa in 2008, the accompanying gas content is as follows:

Geothermal production well B-40 (Thermal Spa):

Well depth:	1 270 m
Water production:	30 m^3/h with submersible pump
Water wellhead temperature:	69° C
Gas content (composition, constitution):	CH_4 83.8%, CO_2 9.3%, N_2O 6.9%
Submersible pump frequency:	48.7 Hz
Separator fluid output /gas free/ water flow:	25 m^3/h, 417 L/min
Separator gas output, separated gas flow:	9.73 Nm^3/h, hydrocarbon content 7.63 Nm^3/h
Casing gas output flow:	3.87 Nm^3/h, hydrocarbon content 3.63 Nm^3/h
Total gas output:	13.6 Nm^3/h, hydrocarbon content 11.26 Nm^3/h
Total gas-water ratio:	544 L/Nm^3
Total methane-water ratio:	450.4 L/m^3

The following results were obtained in the laboratory in connection with the above measurements:

	a) Separated gas	**b) Casing gas**
C1:	76.117 mol%	91.140 mol%
C2:	1.944	2.304
C3:	0.238	0.273
I - C4:	0.024	0.020
N – C4:	0.029	0.018
I – C5:	0.009	0.002
N – C5:	0.008	0.002
C6:	0.009	0.003
C7:	0.013	0.007
C8+:	0.009	0.007
CO_2:	7.785	2.084
N_2:	13.815	4.140
Total:	100.000	100.000
Heat-value:	27.417 MJ/Nm^3	32.178 MJ/Nm^3

The heat value of the mixed gas: (9.73 : 13.6) x 27.417 + (3.87 : 13.6) x 32.178 = **28.772 MJ/Nm^3**

The average gross gas energy content produced at the B-40 site: 8 kWh / Nm^3 x 13.6 Nm^3/h = **108.8 kW**

The gas engine has 40% and the generator has 90% efficiency, producing 36% efficiency regarding the electrical performance. This result is **108.8 x 0.36 = 39.168 kW_e.** Thus the maximum available power is 40 kW_e, which means that electricity can be produced using the gas from the B-40 well (figure 3.4.5, figure 3.4.6).

Figure 3.4.5. The CHP gas-engine at the B-40 production well; a small-scale power plant (photo by J. Pasztor)

B-40 small-scale gas engine CHP power plant

NRG MINI P30 SP NG type CHP unit technical specifications:

CHP type:	NRG MINI P30 SP NG
Motor type:	NRG 30 G4LTi (Perkins 1004 G)
	4 cycle, lined 4 cylinder motor
Electricity output:	30.3 kW_e,
Thermal output:	60.61 kW_{th},
Total energy output:	90.91 kW
Generator:	Mecc – Alte Eco 32 – 3S/4 0.4 kV, 50Hz
Electrical efficiency:	30.3%,
Thermal efficiency:	60.61%,
Total efficiency:	90.91%
Gas requirements:	10.5 Nm^3/h, 25 – 50 mbar
Emissions:	N_2O 490 mg/Nm^3, CO_2 640 mg/Nm^3, CH 140 mg/Nm^3
Cooling water temperature:	70/90°C
Exhaust gas noise level @ 1m):	75dB(A)
Engine noise level (@1m):	75dB(A)

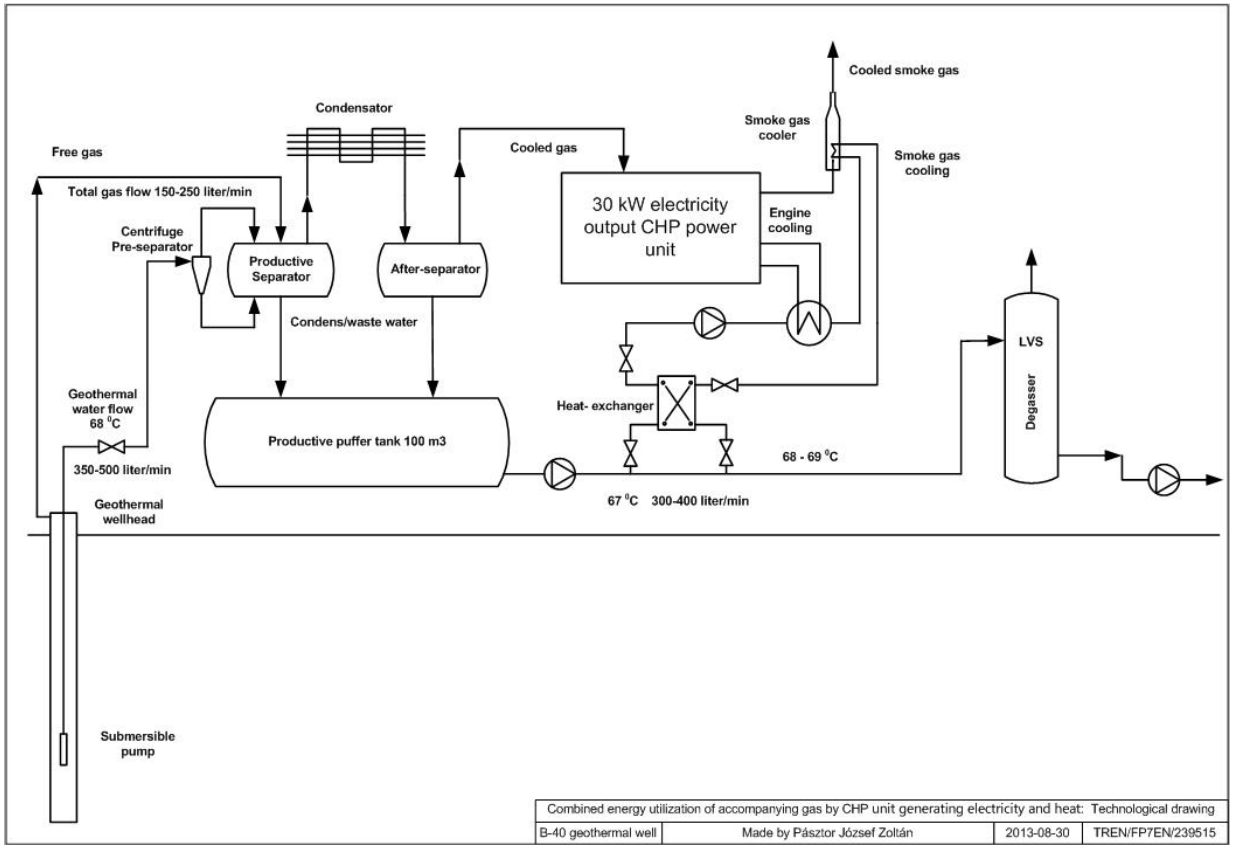


Figure 3.4.6. A schematic diagram of the system of gas separation equipment with the CHP engine at its centre for the B-40 well site (by J. Pasztor, Municipality of Mórahalom)

NRG 30 G4L gas motor technical data:

Manufacturing data:

Method of operation:	4 cycle, spark ignition motor, without turbo, suction-motor
Rotation angle as seen from the fly-wheel:	anti-clockwise
Cylinder arrangement:	lined
Cylinder number:	4
Bore:	100 mm
Stroke:	127 mm
Total stroke volume:	3.99 L
Mechanical capacity:	35 kW_e
Compression rate:	12 Epsi-lon

Normal reference terms/conditions:

Air pressure:	1000 *mbar
Air temperature:	25°C
Relative vapour capacity:	30%

* or rather 100 m above mean sea level

Builded datas:

Operation method:	4 cycle, sparkle ignition motor, without turbo, suction-motor
Rotation angle from the fly-wheel angle seeing:	inverse clock hand action angle
Cylinder arrange:	lined
Cylinder number:	4
Borehole:	100 mm
Stroke:	127 mm
Total stroke volume:	3.99l
Mechanical capacity:	35 kW_e
Compression rate:	12 Epsi-lon

Normal reference terms/conditions:

Air pressure:	1000* mbar
Air temperature:	25°C
Relative vapour capacity:	30%

*or rather above the avarage sea level 100 m

Gas consumption

The basic fuel is natural gas with 98% methane and with the following parameters:

Minimum methane number:	80
Heat-value:	34 MJ/m^3
Minimum gas pressure:	2 kPa
Pressure alteration:	< 10%

The quantity of gas consumed is estimated from billing:

Gas temperature:	15°C
Absolute gas pressure:	101.325 kPa

For the data regarding gas consumption, the valid tolerance is ± 5% at 100% performance and the tolerance is ± 8% at 75% or at 50% performance.

Dangerous substances emissions

The cogeneration units are the same with the following emission values:

NO_X:	500 mg/Nm^3
CO:	650 mg/Nm^3
Other hydrocarbons without methane C_xH_y:	150 mg/Nm^3

The emissions without methane value is relevant if the current consumption is higher than 3 kg/hour.

A detailed examination of the gas content in the B-45 well supplying the Geothermal Cascade System of Mórahalom was carried out in 2011 and gave the following results:

Geothermal production well B-45 (Hunyadi Liget T-1):

Drilling year:	2008
Well depth:	1 260 m
Filtration depth:	between 1 079.5m and 1 232.5 m
Total fluid recovery capacity:	1500 L/min.
Geothermal water capacity:	55.2 m^3/h with submersible pump (920 Ls/min), 132 m^3/h with compressor
Water wellhead temperature:	62.1° C
Dissolved gas-water ratio:	664.7 L/m^3
Total gas capacity:	608 L/min
Gas content (composition, constitution):	CH_4 83.8%, CO_2 9.3%, NO_2 6.9%
Water demand:	winter 60 m^3/h, summer 15 m^3/h

The Geo–Log Ltd. group, an enterprise specialising in measurement, made an examination of the chemical compounds in the gas from that well on the basis of the KHVM (Ministry of Transportation, Telecommunication and Water) 12/1997 (VIII.29.) regulation and obtained the following results:

Field test date:	21th July 2011
Location of the separator connection:	on the submersible pump pressure line
Separation method, duration:	electrical circuit, flow, 2 hours, the separated gas is also connected to the separator
Test hole:	behind the separator
Water recovery:	with submersible pump
Gas separation:	
Water production:	790 L/min
Gas production:	444 L/min
Water temperature:	63.0°C
Gas temperature:	47.7°C
Air pressure:	1003 hPa
Separated gas-water ratio:	508 L/m^3
Separated methane-water ratio:	446 L/m^3
Dissolved gas-water ratio: 15.6 litres/m^3	
Dissolved methane-water ratio:	9.4 L/m^3
Total gas-water ratio:	**524 L/m^3**
Total methane-water ratio:	**455 L/m^3**

Based on the 12/1997 (VIII.29) KHVM regulation, water with this methane content is in the “C” scale. The methane output is 359.4 L/min with 790 L/min water flow.

Figure 3.4.7. B-45 gas-engine CHP small-scale power plant in Hunyadi liget grove

Figure 3.4.8. B-45 gas-engine CHP small-scale power plant with turbo cooler

Figure 3.4.9–3.4.10. B-45 gas-engine CHP small-scale small power plant (left), the gas-engine in the container (right) (figs. 3.4.7 -3.4.10 by J. Pasztor)

B-45 Small-scale gas engine CHP power plant

NRG MINI P50 SP NG type CHP unit technical data/specifications:

CHP type:	NRG MINI SP50 NG
Motor type:	NRG 50 G4LTi (Perkins 1004 G) 4 cycle, lined 4 cylinder motor with turbo charger
Electricity output:	50 kW_e
Thermal output:	66 kW_{th}
Generator:	Mecc–Alte Eco 32–1L/4 0.4 kV, 50Hz
Electrical efficiency:	34%
Thermal efficiency:	50%
Total efficiency:	84%
Gas requirements:	13.9 Nm^3/h, 25–50mbar
Emissions:	NO_2 490 mg/Nm^3, CO_2 640 mg/Nm^3, CH 140 mg/Nm^3
Cooling water temperature:	70/90°C
Exhaust gas noise level (@1m):	75dB(A)
Engine noise level (@1m):	75dB(A)
Energy requirements:	132 kW_e

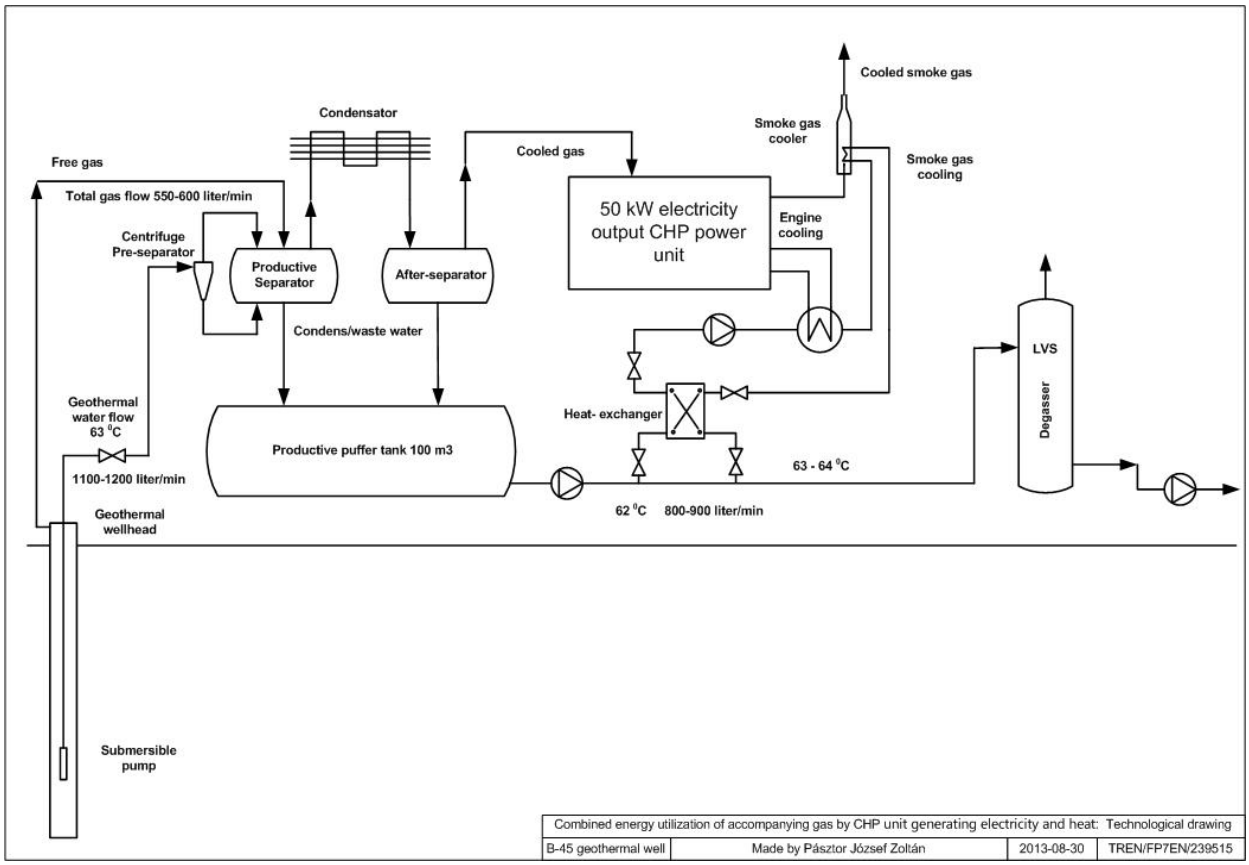


Figure 3.4.11. Schematic diagram of the system of gas separation and utilisation at the B-45 production well. Please note that the system is identical to the B-40 site but the volumes produced are significantly larger, and the power and heat output also differ from the B-40 site (by J. Pasztor, Municipality of Mórahalom)

A NRG 50 G4L TI gas engine technical data:

Manufacturing data:

Method of operation:	4 cycle, spark ignition motor, with turbo
Rotation angle as seen from the fly-wheel:	anti-clockwise lined
Cylinder arrangement:	4
Cylinder number:	100 mm
Bore:	127 mm
Stroke:	127 mm
Total stroke volume:	3.99 L
Mechanical capacity:	50 kW
Compression rate:	12 Epsi-lon

Normal reference terms/conditions:

Air pressure:	1000[1] mbar
Air temperature:	25°C
Relative vapour capacity:	30%

[1] or rather above the average sea level 100 m

Operational datas:

Nominal engine speed/revs:	1 500 revs/min
Average piston speed at engine normal speed/revs:	6.35 m/s
Lubricating oil operational pressure:	3 – 4 bar
Lubricating oil minimum pressure[1]:	2 bar
Cooling water output temperature with the engine on full load:	90°C
Lubricating oil consumption (average value with engine on full load)[1]:	0.2 g/kWh

[1] the lubricating oil minimum pressure depends on the motor oil: temperature and the motor temperature and is between 2 and 4 bar

Gas consumption

The basic fuel is natural gas with 98% methane and with the following parameters:

Minimum methane number:	80
Heat-value:	34 MJ/m^3
Minimum gas pressure:	2 kPa
Pressure alteration:	< 10%

The quantity of gas consumed is estimated from billing:

Gas temperature:	15°C
Absolute gas pressure:	101.325 kPa

For the data regarding the gas consumption the valid tolerance is ± 5% at 100% performance and the tolerance is ± 8% at 75% or at 50% performance.

Dangerous substance emissions

The cogeneration units are the same with the following emission values:

NO_X:	500 mg/Nm^3
CO:	650 mg/Nm^3
Other hydrocarbons without methane C_xH_y:	150 mg/Nm^3

The emissions without the methane value is relevant if the current consumption is higher than 3 kg/hour.

Geothermal Public Utility System co-funded by the Nordic – EEA grants

Following implementation of the geothermal production well, due to increasing production, a gradual increase has been experienced in the gas content in the water produced. The 90 L/m^3 initial gas content had become 160 L/m^3 when last measured. On the basis of logged data, the gas content is around 200–250 L/m^3, which must be verified by continuous gas measurement and gas content monitoring. By the time the Szent János area is populated, it could exceed 250–300 L/m^3. Thus, the use of the associated gas was recommended in an approx. 20–30 kW$_e$ small scale gas engine CHP power station. The power produced can be entirely used for the operation of the machinery equipment of the thermal well, thus significantly reducing the cost of geothermal energy production. Furthermore, the heat produced by the gas engine could be utilised for further heating of the thermal water, similarly to the Hunyadi liget and Spa systems.

3.4.6 Integration of the solar collector systems into the existing geothermal heating and domestic hot water production system

Shortly after the Geothermal Cascade System was launched in Mórahalom there was a need to reduce the use of natural gas to the bare minimum for domestic hot water (DHW) production. The school and kindergarten did not manage to get fully independent from natural gas due to their kitchen services running year round. The kitchens need 50–55°C water but the temperature of the geothermal water on its own is not sufficient for this so the system needed preheating which was carried out by natural gas boilers.

This was the primary set-up that initiated the idea of introducing solar-thermal collectors to the building engineering configurations. The solar collector systems primarily provide the hot water needs after the heating season is over. In the transitional periods (October and April) the solar system operates in conjunction with the geothermal system and this is how DHW is produced at both locations.

Figure 3.4.12 shows a sketch of the operation of the combined system with solar collectors for hot water provided at one of the installation locations. Pictures of solar-thermal collectors on the rooftops of the local elementary school and kindergarten are shown on figure 3.4.13.

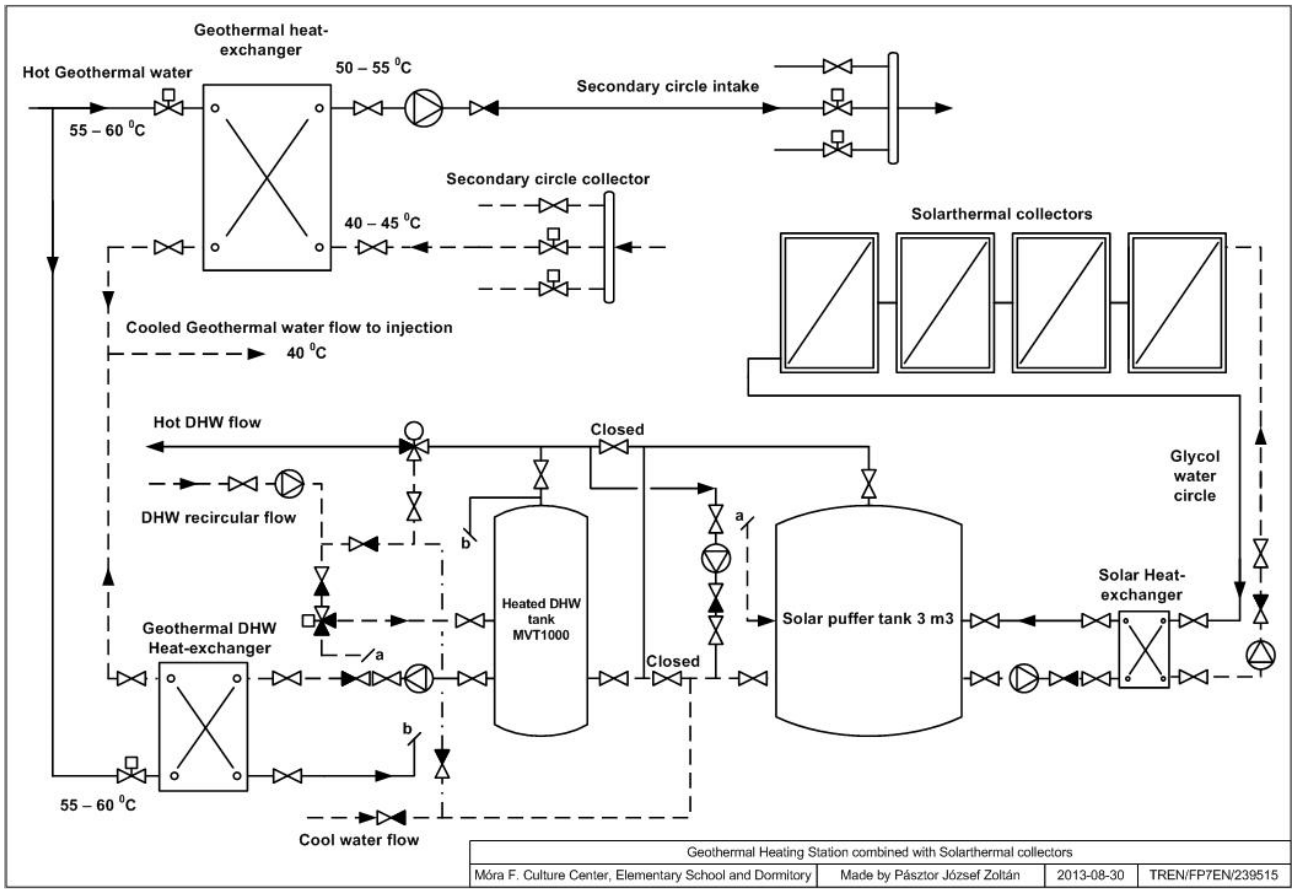


Figure 3.4.12. A schematic diagram of the system for integration of the solar collector systems into the geothermal heating and production system provided (by J. Pasztor, Municipality of Mórahalom)

Figure 3.4.13. Solar-thermal collectors on the rooftops of the local elementary school (left) and kindergarten (right) (photo by J. Pasztor)

3.4.7 Energy modernisation of the geothermally heated buildings – heat insulation and changing the doors and windows

When the Geothermal Cascade System of Mórahalom was in the planning and implementation phase a year before GEOCOM was launched, it was clear that the project will not comply with the criteria of modern energy saving systems because the KEOP – 4.1.-2007 call for tenders did not cover work on building engineering modernisation. For this reason the Municipality wanted to find an alternative source of funding to be able to save the energy that was dissipated through the poorly insulated walls, doors and windows. The demonstration actions met this desire perfectly. Partly using the project funding and the municipality's own resources (as the owner of these buildings), the radiators were converted to be able to utilise geothermal energy. In addition, all the doors and windows were replaced at the target buildings and a standard facade insulation was installed for the school, kindergarten and sports hall. As a result the heat demand of the buildings has been reduced and this has allowed the system to be extended farther into the town since less energy was used at the retrofitted structures than before.

Unfortunately there are no reliable figures available about the amount of heat used at the buildings since it is only the amount of natural gas consumption that is monitored at these buildings by in depth analysis of the monthly utility bill. Since the municipality owns both the geothermal system AND most of the public buildings that are connected to the cascade system, it is essentially putting money from its left pocket to its right pocket. The project consortium has never presented the actual heat figures used at the affected buildings, we could monitor progress only by keeping track of the dramatic reduction in the amount of natural gas utilised in these buildings. Even though it will not give you a very clear picture, the following before-after figures might indicate the effectiveness of a standard retrofitting action including thermal insulation and the replacement of the doors and windows.

In 2011 – before any of the above mentioned retrofitting actions were implemented – at the elementary school the total natural gas use was around 18,800 m^3/year. Two years later when the very last element of the retrofitting was completed, the same figure was in the range of 8 700 m^3/year.

For the kindergarten these figures are ~10 000 m^3/year natural gas used before the retrofitting, and about 900 m^3/year used after the actions were completed.

3.4.8 The extraction of waste heat from used geothermal water by a high power heat pump station installed in the new town centre and Thermal Residential Park

Mórahalom, as a result of its excellent setting, is able to provide most of its public buildings with geothermal district heating from local wells. Via a series of individual heat exchangers at each of the buildings served the geothermal water at 62°C as initially produced is cooled down to 40°C by the end of the cascade system. At this stage the 40°C water still contains a considerable amount of energy which has not already been recovered, but was sent to be re-injected.

A heat-pump heating station was planned and delivered (figure 3.4.14) within the GEOCOM project and this can utilise the significant residual energy content of the spent geothermal water (cooling it from 40°C to a minimum of 20°C) to produce over 600 kW_{th} thermal energy with an average COP = 4.5–5.0 prior it being re-injected.

This additional energy (418 kW_{th}) can easily be used on site for the development plans include some higher profile buildings to be erected in the near future in the immediate vicinity of the new heat pump station in addition to the recently completed Town Hall and Market Hall, thus creating a sufficiently

dense heat market for such an investment. At the moment no such coupled geothermal water – heat pump system with similar efficiency operates either in Hungary or elsewhere in Central–Eastern Europe.

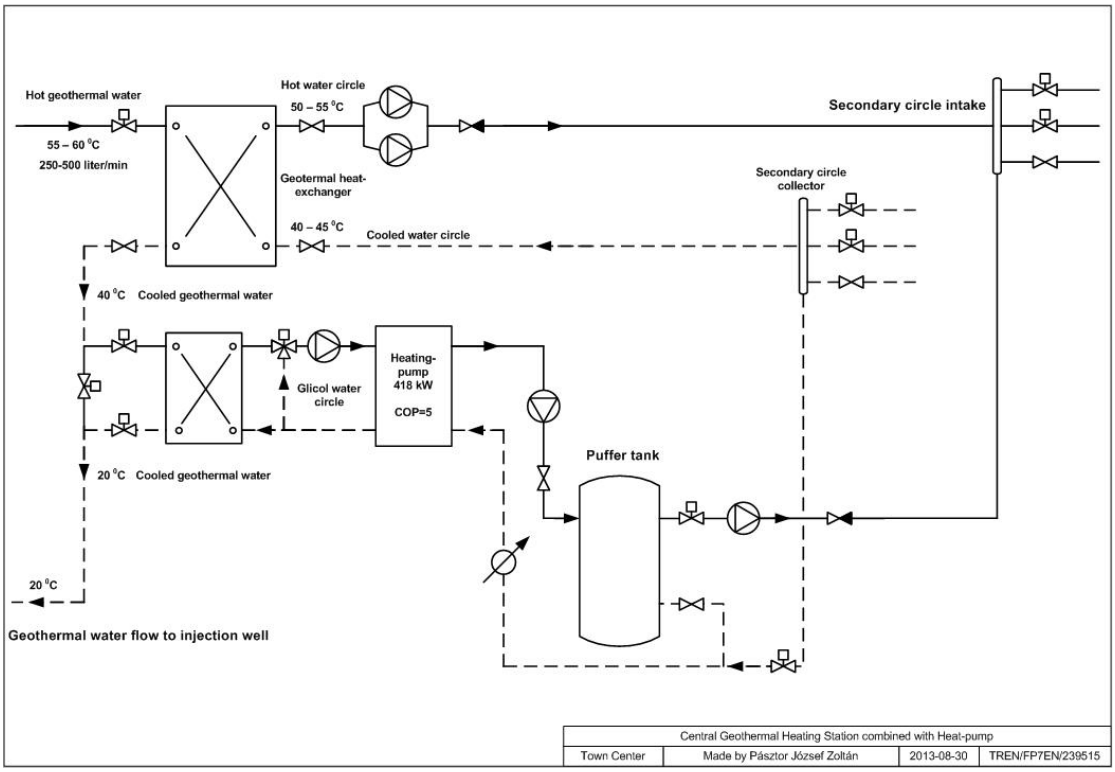


Figure 3.4.14. A schematic diagram of the heat-pump heating station (by J. Pasztor, Municipality of Mórahalom)

The quantity of geothermal water (200–250 L/min) reaching the primary heat exchanger is self-regulating, making the system capable of adjusting the thermal output to meet the reduced need during the transitional periods (early spring, late fall). Since no power is required to operate the primary heat exchanger, heat energy produced in this way has priority over the heat pump application which has some electrical power demand (approx. 90 kW_e). If the outside temperature drops below a certain value (– 5°C) this basic system alone can no longer provide sufficient thermal output and needs to be backed up by the heat pumps. At this point a technical challenge had to be overcome related to the minimum flow rate the heat pumps require for seamless operation, which is 15 m^3/h. This means that an automatic system activates whenever the heat pumps are turned on to provide a sufficient flow (15 m^3/h or more) of geothermal water to keep them running. Due to its mineral composition the geothermal fluid received cannot be directed straight to the heat pumps, but the installation of an intermediary heat exchanger was needed to protect the main condenser from scaling. In this separate and closed loop a dedicated pump circulating a 20% mixture of mono-ethylene-glycol and water ensures the heat transfer to the main condenser. In order to secure a continuous supply of hot water there was a 3000 Litre buffer tank installed on the output side of the system to hold the heated medium at 52°C (max 55°C). The closer this heat is to the maximum, the lower the COP of the system will be.

In the summer period the heat energy is used solely for domestic hot water (DHW) production since low enthalpy systems (less than 90°C) – similar to the one in Mórahalom – cannot be employed economically for cooling purposes. DHW production, however, has proved to be a sound and economic utilisation of geothermal water in the summer as the reduced heat demand yields higher water

temperatures in the whole system. During the summer DHW needs are met with the use of 20–200 kW_{th} DHW-dedicated heat exchangers in all the facilities, institutions and connection points that are linked to the geothermal loop.

3.4.9 Energy saving (LED type) public lighting system combined with photovoltaic system

For years the Local Government of Mórahalom has been looking for opportunities to modernise the public lighting system of the town by installing energy saving lamps and to expand the public lighting system to areas which were previously not covered by this service. However appropriate KEOP project funds had not been found for the energy saving public lighting system to be installed, so the project was realised as an innovative development forming part of the GEOCOM project works.

Technical details

Photovoltaic building integrated power plant:

Photovoltaic solar cells installed on the roof of the new town centre:
40Yingli Solar 240 W polycrystalline solar panels on top of the new market hall in the town (figure 3.4.15) 1 pc of Fronius IG Plus 12 V-3 (10000 W) inverter.
Total photovoltaic capacity: 10 kW_e

LED public lighting system:

Photovoltaic LED public lighting system installed in the town centre (figure 3.4.16):
50 LED lamps on 35 lampposts, 4 autonomous solar powered LED public lighting lampposts
Total electricity input: 2.95 kW_e

Installation area:

Town Centre (traffic roundabout, Szegedi Road), Szentharomsag Square, Tömbbelső Road and car parking, Szövetkezeti Street, Bus and Coach Station roofs, 4 bus stops.

Results, comparison

The solar collector of HMKE type produced 11.249 kWh electricity in 2014. This value of this electricity was 386 628 HUF (Hungarian forints). The LEDs' electricity consumption was 12.021 kWh in 2014 (460 044 HUF). In total the solar collectors produced 93.58 % of energy demand of the LED type public lighting system.

From a financial point of view the solar collectors produced 84.04% of the value of the demand of the LED type public lighting system.

Figure 3.4.15. The New Market Hall in the town centre hosts a PV installation that supplies the LED public lighting system with the necessary electricity (photo by J. Pasztor)

Figure 3.4.16. Various types of the LED public lighting fixtures in Mórahalom (photo by J. Pasztor)

3.4.10 Payback period of the GEOCOM project investment works in Mórahalom

The payback period of the GEOCOM project investment works in Mórahalom is summarised below.

Simple payback period

Based on current data the Municipality has realised net savings of 24 073 224 HUF (76 423 EUR) so far, with a yearly net 1 887 840 HUF (5 993 EUR) operating cost. We have realised total net savings of 22 185 384 HUF (70 430 EUR).

Basis on the above, the payback period is 10.881 years, if one doesn't count amortisation costs.

Payback period with amortisation

The yearly amortisation cost is 3 665 893 HUF (11 638 EUR). Taking this into account, the real gross savings are 18 519 491 HUF (58 792 EUR). In this sense the payback period is 13.035 years.

As the further calculations below will demonstrate, it is worth seeking potential additional national funding sources that may further reduce the payback periods initially calculated. In Mórahalom's case the Municipality applied for a scheme (EU-BONUS12) proposed by the Hungarian Government, that was designed to support the municipality's own costs (invested in the GEOCOM actions). The successful application for this scheme and the grant received reduced the overall payback period by more than 2 years.

Simple payback period: GEOCOM+EU-Bonus

Based on the data previously cited, the Municipality has realised gross savings of 24 073 224 HUF (76 423 EUR) so far, with yearly net operating costs of 1 887 840 HUF (5 993 EUR). Therefore they realised net savings totalling 22 185 384 HUF (70 430 EUR).
Therefore the payback period is reduced to 8.16 years if no account is taken of amortisation costs.

Payback period with amortisation: as given above, annual amortisation costs are 3 665 893 HUF (11 638 EUR) and the real net savings are 18 519 491 HUF (58 792 EUR). Calculated in this manner, the payback period changes to 9.776 years.

3.4.11 The importance of the GEOCOM project works for Mórahalom Municipality – general remarks and recommendations

One of the most significant aspects of the GEOCOM project was that it was focused on small communities rather than large cities. In the case of Mórahalom this approach helped the partners involve the whole community (5 800 citizens) in the process and helped the community to experience first hand the benefits that such a comprehensive development scenario could deliver to the community. Having involved the local schools and kindergarten in the retrofitting programme not only improved the indoor conditions for the pupils and teachers, but it also demonstrated the programme's strengths to the parents who visited the facilities on a daily basis.

The Municipality, as the owner of these public buildings, benefited enormously from these actions. Since the geothermal district heating system is also operated and maintained by the Municipality, it is obvious that the costs related to these elements remain in the same pool thus eliminating a risk factor from the equation, namely the natural gas requirements. Compared to natural gas costs of the GEOCOM target buildings in the base year of 2009, the Municipality spends an average of only 7% of the base line quantity for natural gas on an annual basis at these buildings. This leaves a significant amount of resources at the Municipality's disposal to be used for the benefit of the community.

But it was not only the Municipality itself that has benefited from the GEOCOM actions. Local enterprises and businesses were involved in the delivery of the various stages of the project. Insulation works, replacement of doors and windows, installation of solar panels, the LED public lighting system and the maintenance service of the engineering components have been, and are still, deployed by local and regional providers. It is evident that the project components triggered a great number of contracts that managed to boost the local economy.

Obviously if you really scratch the surface you may find a few items that could have been done differently or would be delivered in a different manner had the project started all over again now. At the moment it seems likely that the heat pump installation in the centre will not be running at full capacity for a few more years. One of the reasons is that the winters in the recent past were simply

not cold enough, and the geothermal cascade system managed to keep up with the mild winters and provide the required amount of heat. The other reason is that the residential buildings initially planned that were supposed to form the heat market for the heat pump station are not yet in place. On the other hand the heat pump station has to be maintained on a regular basis and occassionally needs to be run to remain fully functional. These unrequired runs cost money and they will burden the Municipality's otherwise impressive balance until it can start selling heat for the future tenants of the planned buildings.

The GEOCOM project components were only a small fraction of the integrated approach in which Mórahalom has been conducting its ever growing programme to be independent from fossil fuels. This commitment did not come about overnight and it took a while before the first actions were ready to be implemented. The most important factor was to recognise the local community's vulnerability to fossil fuels. This was followed by searching for those potential solutions that could lead out of this dependency.

Mórahalom's geological setting is extremely fortunate for the harnessing of geothermal heat, but this was not evident to the decision makers. There was a lot of research and consultation done before the main framework of this currently ongoing plan was drafted.

Since 2011, when the Cascade system (funded by the Structural Funds) became fully operational, major savings were realised on the heating costs at all the municipally run public buildings. These savings were then channelled in a structured manner to other types of development.

The implementation of the geothermal district heating system not only helped to achieve a cleaner and more citizen friendly environment in the area, but also induced industry and tourism to interest themselves in the area resulting in a boom in the local economy.

Mórahalom is a perfect example of what can be achieved by careful planning and with constant dedication towards these goals. The current mayor has been in office for the past 20+years, so continuity could also be counted as a factor for success.

Acknowledgments:

The authors would like to thank Mr. Csaba Csonka (Municipality of Mórahalom) for the valuable help during preparation of the text of this Chapter.

References

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https://sciart.eu/hu/2010-12-05-1212/1/hazai-geotermikus-energiavagyon-geologiai-problemai

3.5. Online monitoring system of energy measures and installations in the GEOCOM pilot–sites

(Miloš Staštík, Bohuš Bohovic, Juraj Suja, Milan Hán, Roman Svoboda – Slovak Innovation and Energy Agency)

3.5.1 Introduction

An online monitoring system was installed in all three demonstration sites of the GEOCOM project: Galanta, Montieri, Mórahalom. Among its main objectives was to encourage the owners and residents of the buildings covered by the project works (introduction of geothermal and solar energy, thermal retrofitting) to monitor and control their energy consumption as well as to manage it in a rational and cost-eff ective way. It was dedicated to providing the general public with a demonstration of the success or potential failure of individual measures or the GEOCOM works.
The monitoring system also provides valuable information for building owners to:

- review and/or to improve the performance of energy systems,
- review and/or to improve the energy performance of buildings,
- review simultaneous computer calculations (data base processing) that can signal any defect or failure in the system, help system control, and provide early warning of a need for maintenance,
- compare the systems operating in three GEOCOM demonstration sites.

The online monitoring system was prepared by the Slovak Innovation Energy Agency (SIEA) team (the GEOCOM partner). It is designed to permit automatic and manual data input at any frequency. The application is also ready to show the research results in graphic and table forms and may also be a tool for dissemination of the GEOCOM project deliverables that may be inserted into the application and shown on the GEOCOM website (*www.geothermalcommunities.eu*).

The achievement of energy savings depends on the quality of information provided by the building owners at the time of project preparation. After implementation of the measures the project manager evaluates the savings achieved. For this reason the online monitoring system is an important part of the pilot project.

3.5.2 General description of the online monitoring system

The online monitoring system was developed for and implemented in all three demonstration sites of the GEOCOM project. It covers the installations and buildings completed as part of the GEOCOM works which include geothermal and solar energy works, as well as thermally-retrofitted buildings.

The **Galanta** partners (i.e. Municipality of Galanta, Galantaterm Ltd., Bysprav) input the data manually at specific regular periods for the individual variables. For each of the partners the SIEA team set up a login and password to allow them to enter data onto the database itself. Therefore the partners are now responsible for inputting agreed variables onto the database on a monthly and yearly basis. On the graphs the application automatically calculates and displays the quantity of:

- electricity produced by the photovoltaic panels installed thanks to GEOCOM,
- heat and electricity consumption of the GEOCOM buildings monitored,
- heat consumption based on a calculation of day-degrees and a comparison of this data over the GEOCOM period.

The energy inputs are monitored at the level of the buildings and block entrances. It means that only one meetering of the the energy flows is on the whole building, and it is on the boarder between pipe owned by the energy supplier and the block of flats (so only one counter is installed). The calculations and comparisons are for the buildings as a whole. The balance of energy produced from renewable sources is monitored directly from the counters on the RES equipment.

The **Mórahálom** partner inputs the data manually with agreed variables on a monthly and yearly basis. The SIEA activated a login and password to allow the Mórahalom partner to enter data directly onto the database. Therefore the partner is now responsible for feeding the database with agreed variables on a monthly and yearly basis. The application automatically calculates and displays the following on the graphs:

- the electricity produced by the photovoltaic panels and heat produced by solar thermal collectors installed as a result of GEOCOM,
- the heat and electricity consumption of the GEOCOM buildings and installations monitored,
- the actual savings from invoices,
- a calculation of the heat consumption based on degree-days and its comparison within the GEOCOM period.

The energy inputs are monitored at the level of the building entrances and the calculations and comparisons are for the buildings as a whole. The balance of energy produced from RES is monitored directly from the counters on the RES equipment.

The **Montieri** partner inputs the data manually with agreed variables on a monthly and yearly basis. The SIEA activated login and password allow Montieri to enter data directly onto the database. Therefore the partners are now responsible for entering agreed variables directly onto the database on a monthly and yearly basis. The application automatically calculates and displays the following data on the graphs:

- the electricity produced by the photovoltaic panels installed as a result of GEOCOM,
- the heat consumption of the new GEOCOM installations – geothermal energy consumers,
- the savings of fossil fuels and environmental impact.

The energy flows are monitored at the level of the type of buildings (separately for private residences and other installations). The calculations and comparisons are for the section of buildings as a whole. The balance of energy produced from RES is monitored directly from the counters on the RES equipment.

The link to connect to the graphs from the online application running at the webpage is as follows:

www.asphere.sk/siea/pages/public/DataView.aspx?VID=code

Through this link it is possible to call up any of the graphs and display them on the GEOCOM website.

An example of the codes from the Galanta demo-site:

GACSETI, GASCDD, GASDHW, GASELP, GASCCOEF, GASHE, GACDD, GACELP, GACPES, GACHGEA, GACES, GACMSETI, GACHMS, GACHM

An example of the codes from the Mórahálom demo-site:

MOCHPEP – Mórahalom CHP electricityproduced
MOCHPHP – Mórahalom CHP heatproduced

An example of the codes from the Montieri demo-site:

MODD – Montieridaydegrees
MOHOUS – Geothermalheatcosumed by households
MOOCHEAT – Geothermalheatconsumed by othercustomers

The minimum size of display space required to display the graphs on screen is 582 px x 345 px.

The online monitoring application runs at *https://www.asphere.sk/siea* and the description of the system is presented as follows:

- design presentation layer,
- entity relational diagram,
- physical architecture,
- back–end system setup,
- back–end for data entry and collection of the data from demonstration sites,
- graphs and measured data including its description.

3.5.3 How the monitoring system works – case study of Galanta

The design of screens intended for data presentation to the general public is based on a graphic presentation that is easily understandable by readers (figure 3.5.1). A strong emphasis was therefore given to the use of graphs to display data from demonstration sites. Breakdown by the type/form of energy, the energy costs, and the savings in euro as well as the various natural conditions by which the demonstration sites are distinguished from each other were taken into consideration in the calculation.

The right part of the screen given on figure 3.5.1 shows a graph for a user selected value. It is possible to choose the required graph from a drop-down menu. The left window (figure 3.5.2) displays a map with the geothermal energy potential on the demonstration sites. The map enables a comparison to be made of the three demonstration sites representing the ideal natural conditions in Montieri, Mórahalom, and in Galanta. The map also indicates the localities with less potential for geothermal energy development.

By moving the cursor around on the graph it is possible to display a numerical value that represents a column of the graph (as shown on figure 3.5.3). For example – the number of degree-days for the Primary School in Galanta in 2013 was 3388.4 Graden (day–degrees). In general, all the graphs showing annual data are displayed in such a type of a bar.

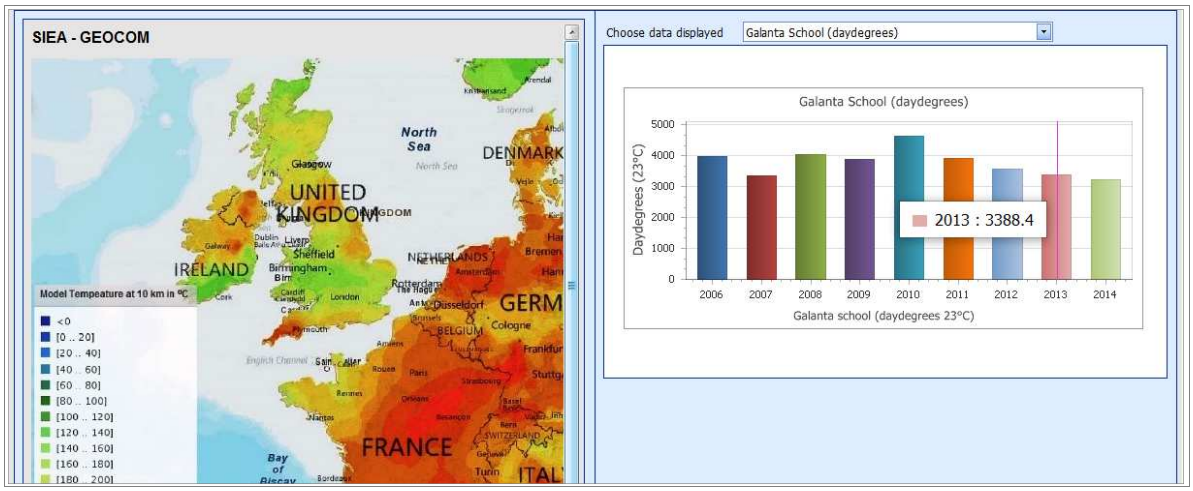


Figure 3.5.1. Design of the main web–page of the GEOCOM online monitoring system for the general public

Figure 3.5.2. The potential of geothermal energy at a depth of 10 km – map which may appear in the left window of the screen shown on figure 3.5.1

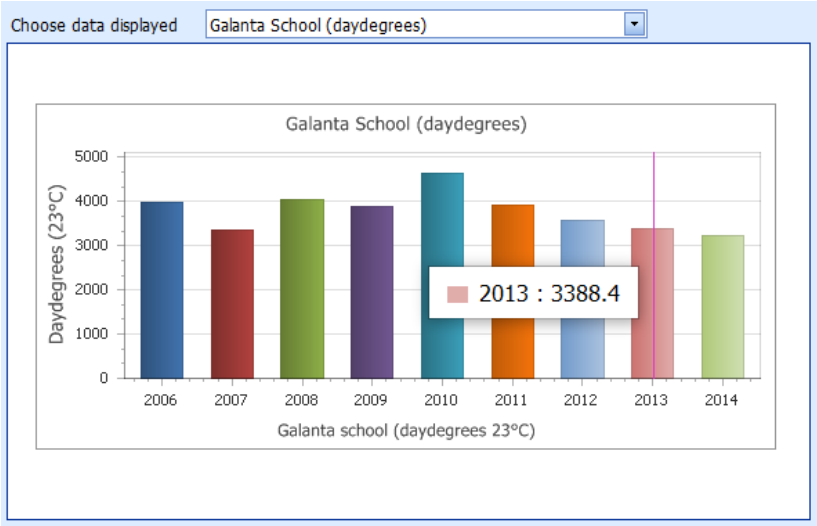


Figure 3.5.3. Degree-days for the demonstration site in Galanta, calculated individually for the school buildings to temperatures of 23°C

Graphs showing monthly data, if available, are displayed in the same type of a bars used for displaying monthly values as shown on figure 3.5.4. At the top of the graph it is possible to select the year. Similarly, in this type of graph it is possible to display the numerical value by placing the cursor in the position of the required month (figure 3.5.5). This feature is available on all the graphs. The heat consumption and heat production figures are displayed in kWh. The system allows one to enter the heat figures in GJ.

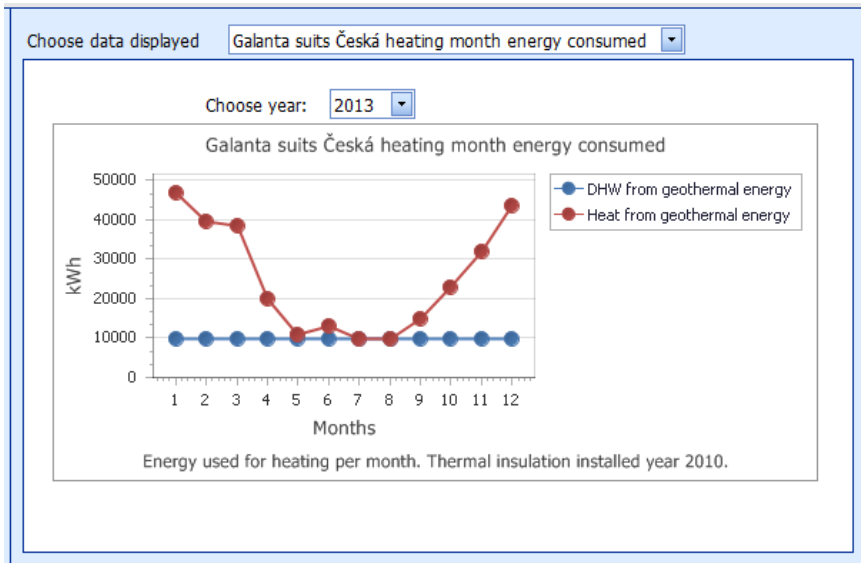


Figure 3.5.4. The graph shows the monthly values: the supply of geothermal heat for a block of flats in 2013. Building on Česká street, Galanta

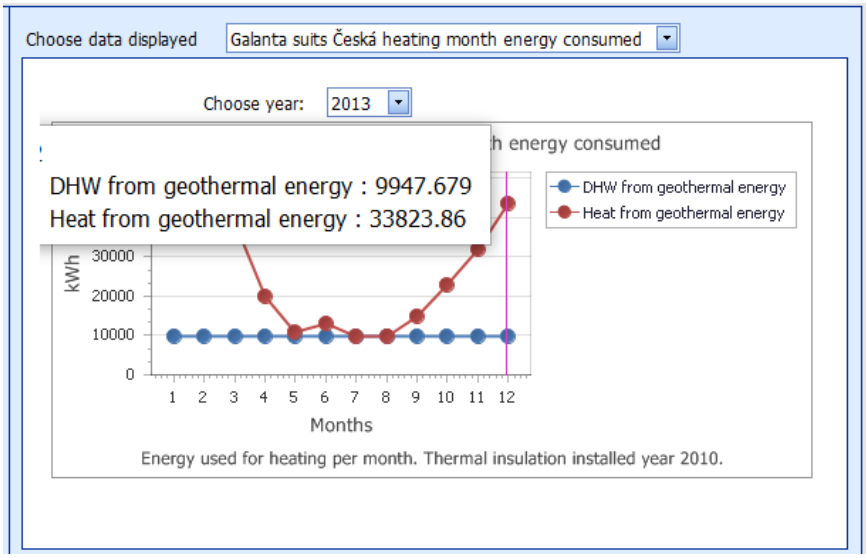


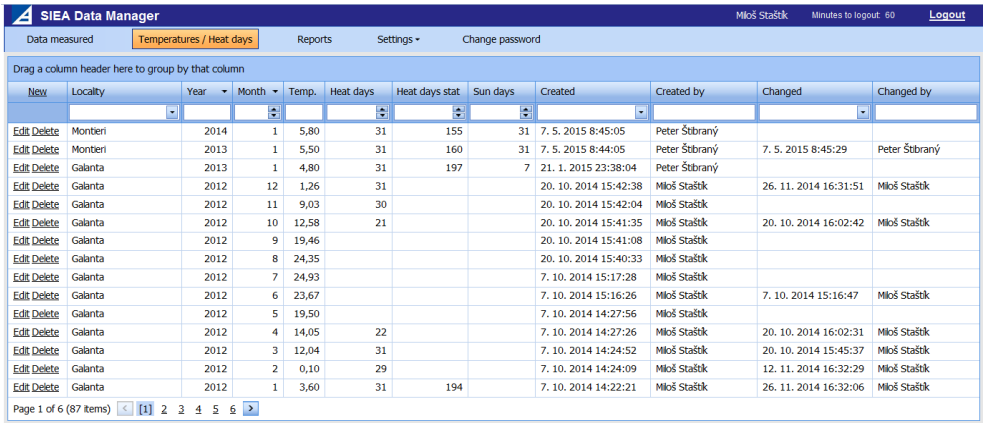
Figure 3.5.5. Display of the measured value by placing the cursor on the required month

3.5.4 The description of entering the data into the online monitoring application/database

This section presents the functionalities and possibilities of entering the data into the online monitoring application/database as well as typify the procedure of data processing including its displaying on the screen (as illustrated by the set of exemplary screen-shots on figures 3.5.6 – 3.5.11, diagram (figure 3.5.12) and tables 3.5.1 – 3.5.2).

Auxiliary data collection

Form used for manual editing of data within all demonstration sites (figure 3.5.6).



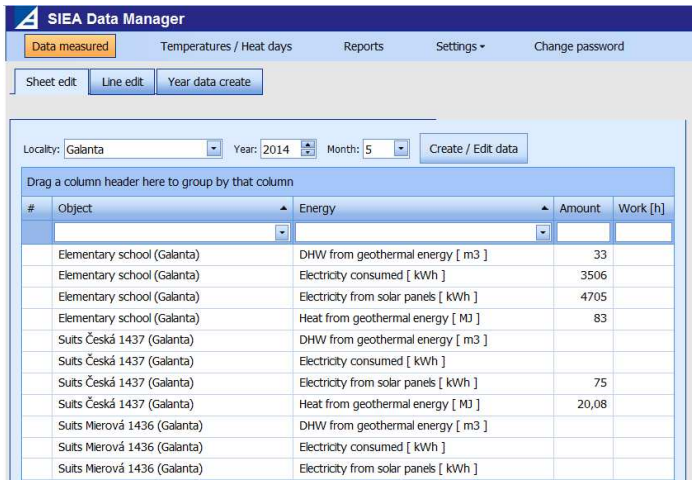
New	Locality	Year	Month	Temp.	Heat days	Heat days stat	Sun days	Created	Created by	Changed	Changed by
Edit Delete	Montieri	2014	1	5,80	31	155	31	7. 5. 2015 8:45:05	Peter Štbraný		
Edit Delete	Montieri	2013	1	5,50	31	160	31	7. 5. 2015 8:44:05	Peter Štbraný	7. 5. 2015 8:45:29	Peter Štbraný
Edit Delete	Galanta	2013	1	4,80	31	197	7	21. 1. 2015 23:38:04	Peter Štbraný		
Edit Delete	Galanta	2012	12	1,26	31			20. 10. 2014 15:42:38	Miloš Staštk	26. 11. 2014 16:31:51	Miloš Staštk
Edit Delete	Galanta	2012	11	9,03	30			20. 10. 2014 15:42:04	Miloš Staštk		
Edit Delete	Galanta	2012	10	12,58	21			20. 10. 2014 15:41:35	Miloš Staštk	20. 10. 2014 16:02:42	Miloš Staštk
Edit Delete	Galanta	2012	9	19,46				20. 10. 2014 15:41:08	Miloš Staštk		
Edit Delete	Galanta	2012	8	24,35				20. 10. 2014 15:40:33	Miloš Staštk		
Edit Delete	Galanta	2012	7	24,93				7. 10. 2014 15:17:28	Miloš Staštk		
Edit Delete	Galanta	2012	6	23,67				7. 10. 2014 15:16:26	Miloš Staštk	7. 10. 2014 15:16:47	Miloš Staštk
Edit Delete	Galanta	2012	5	19,50				7. 10. 2014 14:27:56	Miloš Staštk		
Edit Delete	Galanta	2012	4	14,05	22			7. 10. 2014 14:27:26	Miloš Staštk	20. 10. 2014 16:02:31	Miloš Staštk
Edit Delete	Galanta	2012	3	12,04	31			7. 10. 2014 14:24:52	Miloš Staštk	20. 10. 2014 15:45:37	Miloš Staštk
Edit Delete	Galanta	2012	2	0,10	29			7. 10. 2014 14:24:09	Miloš Staštk	12. 11. 2014 16:32:29	Miloš Staštk
Edit Delete	Galanta	2012	1	3,60	31	194		7. 10. 2014 14:22:21	Miloš Staštk	26. 11. 2014 16:32:06	Miloš Staštk

Page 1 of 6 (87 items) [1] 2 3 4 5 6

Figure 3.5.6. Average temperature and degree-days for every locality and time period (year/month)

Data measured collection

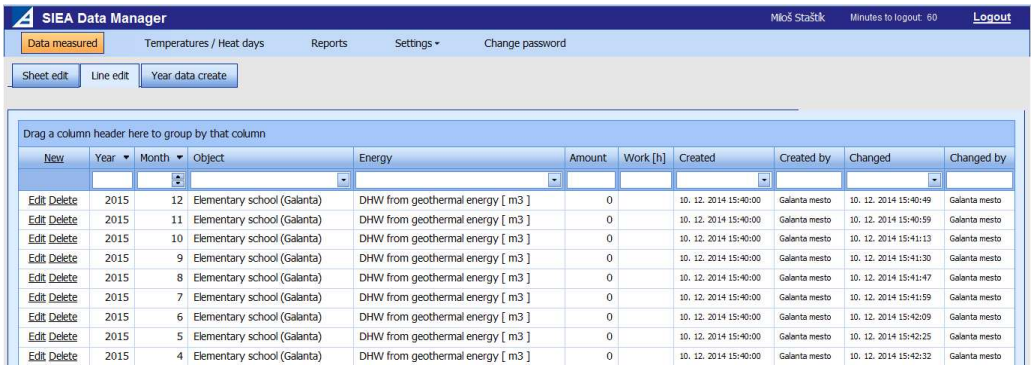
Batch data collection – form used for manual editing of all the data measured within one building/locality (figure 3.5.7).



#	Object	Energy	Amount	Work [h]
	Elementary school (Galanta)	DHW from geothermal energy [m3]	33	
	Elementary school (Galanta)	Electricity consumed [kWh]	3506	
	Elementary school (Galanta)	Electricity from solar panels [kWh]	4705	
	Elementary school (Galanta)	Heat from geothermal energy [MJ]	83	
	Suits Česká 1437 (Galanta)	DHW from geothermal energy [m3]		
	Suits Česká 1437 (Galanta)	Electricity consumed [kWh]		
	Suits Česká 1437 (Galanta)	Electricity from solar panels [kWh]	75	
	Suits Česká 1437 (Galanta)	Heat from geothermal energy [MJ]	20,08	
	Suits Mierová 1436 (Galanta)	DHW from geothermal energy [m3]		
	Suits Mierová 1436 (Galanta)	Electricity consumed [kWh]		
	Suits Mierová 1436 (Galanta)	Electricity from solar panels [kWh]		

Figure 3.5.7. Data measured for every point and energy type measured – batch edit

Single data collection – form suitable for editing single value of measured data (figure 3.5.8).



New	Year	Month	Object	Energy	Amount	Work [h]	Created	Created by	Changed	Changed by
Edit Delete	2015	12	Elementary school (Galanta)	DHW from geothermal energy [m3]	0		10. 12. 2014 15:40:00	Galanta mesto	10. 12. 2014 15:40:49	Galanta mesto
Edit Delete	2015	11	Elementary school (Galanta)	DHW from geothermal energy [m3]	0		10. 12. 2014 15:40:00	Galanta mesto	10. 12. 2014 15:40:59	Galanta mesto
Edit Delete	2015	10	Elementary school (Galanta)	DHW from geothermal energy [m3]	0		10. 12. 2014 15:40:00	Galanta mesto	10. 12. 2014 15:41:13	Galanta mesto
Edit Delete	2015	9	Elementary school (Galanta)	DHW from geothermal energy [m3]	0		10. 12. 2014 15:40:00	Galanta mesto	10. 12. 2014 15:41:30	Galanta mesto
Edit Delete	2015	8	Elementary school (Galanta)	DHW from geothermal energy [m3]	0		10. 12. 2014 15:40:00	Galanta mesto	10. 12. 2014 15:41:47	Galanta mesto
Edit Delete	2015	7	Elementary school (Galanta)	DHW from geothermal energy [m3]	0		10. 12. 2014 15:40:00	Galanta mesto	10. 12. 2014 15:41:59	Galanta mesto
Edit Delete	2015	6	Elementary school (Galanta)	DHW from geothermal energy [m3]	0		10. 12. 2014 15:40:00	Galanta mesto	10. 12. 2014 15:42:09	Galanta mesto
Edit Delete	2015	5	Elementary school (Galanta)	DHW from geothermal energy [m3]	0		10. 12. 2014 15:40:00	Galanta mesto	10. 12. 2014 15:42:25	Galanta mesto
Edit Delete	2015	4	Elementary school (Galanta)	DHW from geothermal energy [m3]	0		10. 12. 2014 15:40:00	Galanta mesto	10. 12. 2014 15:42:32	Galanta mesto

Figure 3.5.8. Data measured for every point measured and energy type – line edit

Batch data creation – form for batch generation for data measured within one location (figure 3.5.9). Data thus generated can be edited using the sheet edit form (batch data collection) and single data collection.

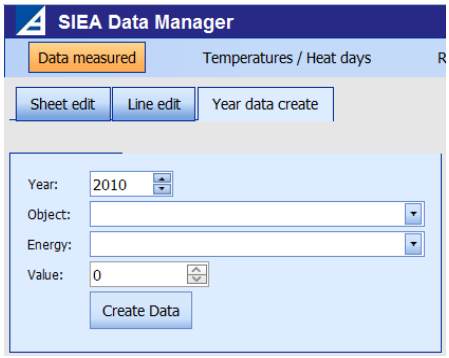


Figure 3.5.9. Batch generating null data for every point measured and energy type

Application architecture

- The presentation layer (main page) is dedicated to users who are not logged in and indicates the set of diagrams available (figure 3.5.10).

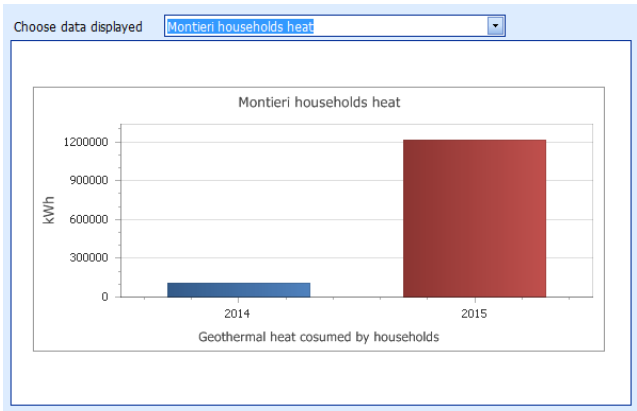
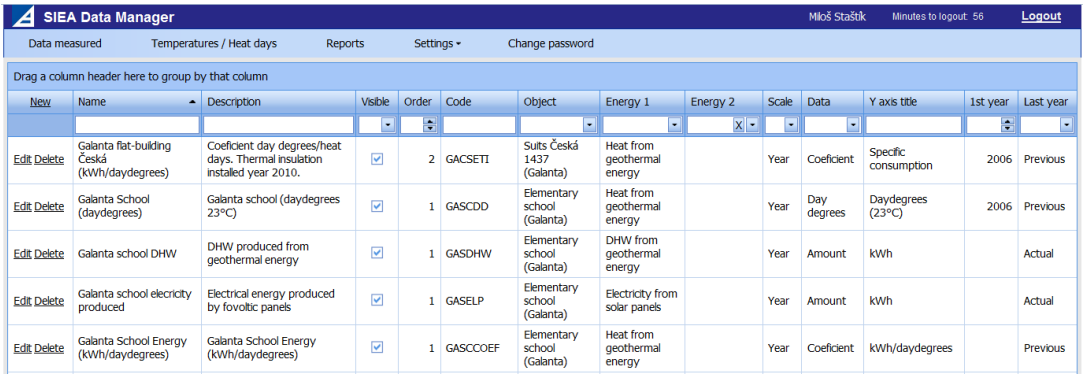


Figure 3.5.10. The diagram example showed on the main page

- System settings
  - Users – user and roles assigned management
  - Master data – master data management (localities, energy types, measuring points)
  - Graph settings – form to create and manage diagrams and graphs shown on the main page



New	Name	Description	Visible	Order	Code	Object	Energy 1	Energy 2	Scale	Data	Y axis title	1st year	Last year
Edit Delete	Galanta flat-building Česká (kWh/daydegrees)	Coeficient day degrees/heat days. Thermal insulation installed year 2010.	☑	2	GACSETI	Suits Česká 1437 (Galanta)	Heat from geothermal energy		Year	Coeficient	Specific consumption	2006	Previous
Edit Delete	Galanta School (daydegrees)	Galanta school (daydegrees 23°C)	☑	1	GASCDD	Elementary school (Galanta)	Heat from geothermal energy		Year	Day degrees	Daydegrees (23°C)	2006	Previous
Edit Delete	Galanta school DHW	DHW produced from geothermal energy	☑	1	GASDHW	Elementary school (Galanta)	DHW from geothermal energy		Year	Amount	kWh		Actual
Edit Delete	Galanta school elecricity produced	Electrical energy produced by fovoltic panels	☑	1	GASELP	Elementary school (Galanta)	Electricity from solar panels		Year	Amount	kWh		Actual
Edit Delete	Galanta School Energy (kWh/daydegrees)	Galanta School Energy (kWh/daydegrees)	☑	1	GASCCOEF	Elementary school (Galanta)	Heat from geothermal energy		Year	Coeficient	kWh/daydegrees		Previous

Figure 3.5.11. Form used for creating/setting of the diagrams

Entity Relational Diagram

The diagram below (figure 3.5.12) shows entities (tables with primary and foreign keys) and relations between them as implemented in the relational database.

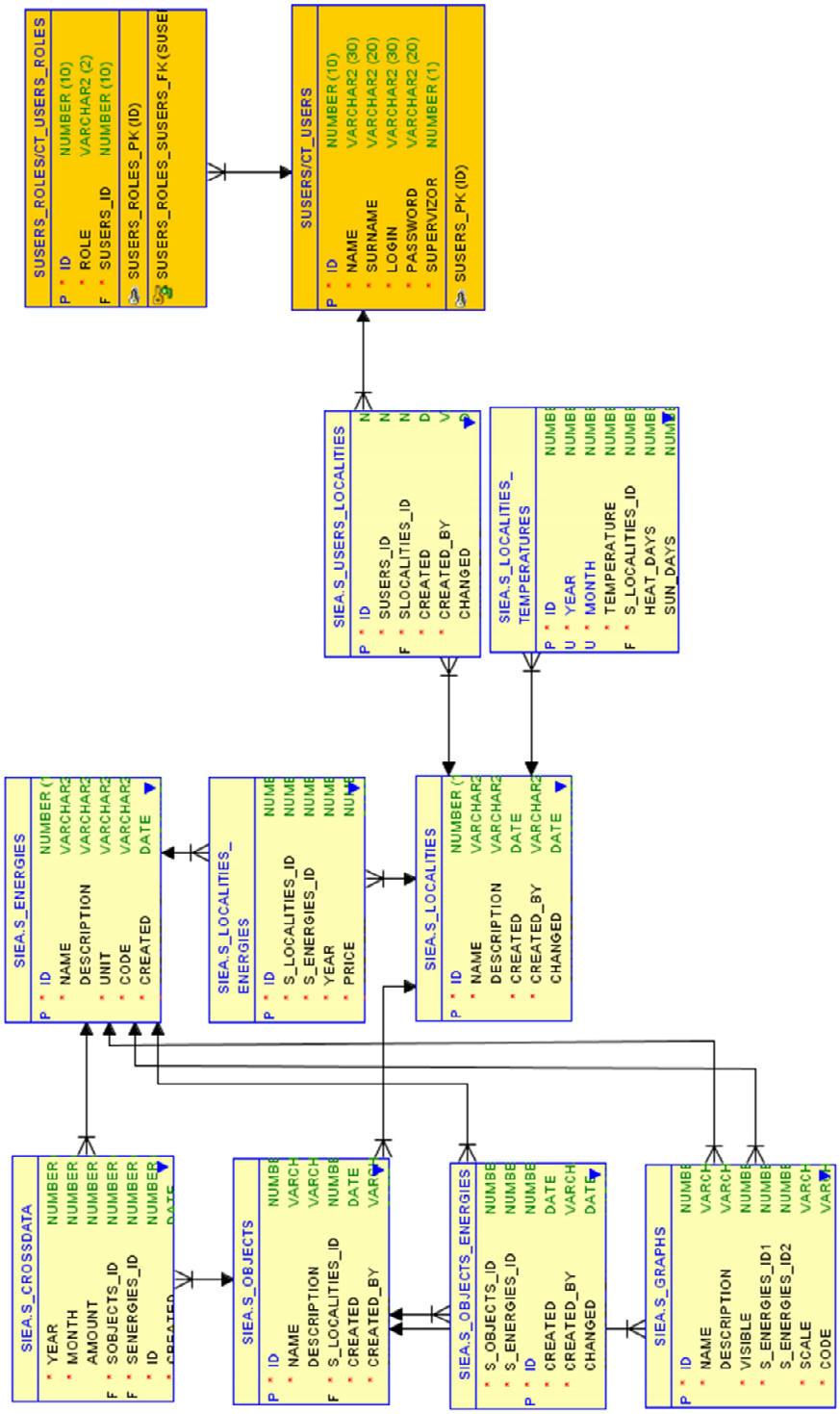


Figure 3.5.12. Entity relational diagram

Technologies and physical architecture

The hardware and software technologies ensuring operation of the application (figure 3.5.13; tables 3.5.1 – 3.5.2):

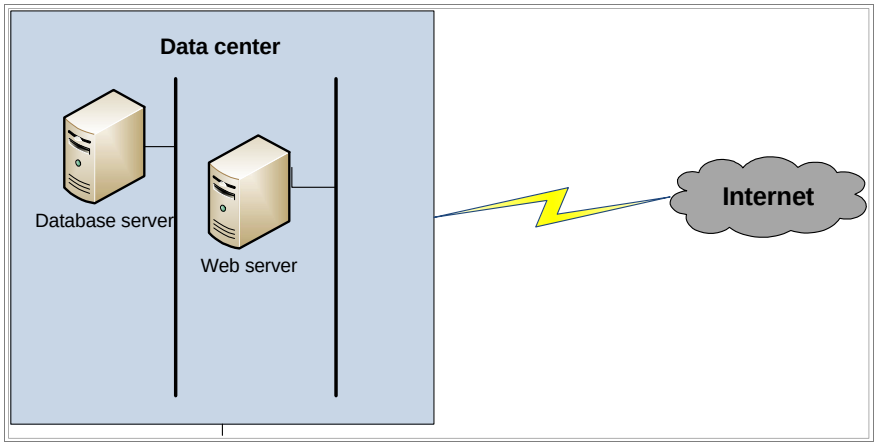


Figure 3.5.13. Data center

Table 3.5.1. Database server

Database server
HW:
- 16 cores48 GB - RWM - 8 TB disc store
SW:
- OS MS Windows 2008 EE 64bit - Oracle SE

Table 3.5.2. Web server

Web server
HW:
- 2 cores - 4 GB RWM - 600 GB disc store
SW:
- OS MS Windows 2003 SE - MS IIS 6.0 - MS.NET Framework 4.5

3.5.5 General results from the monitoring in the GALANTA pilot site to date

Three blocks of flats in Galanta (on Česká, Železničiarska, and Mierová Streets) represent very similar types of buildings and achieved very similar energy savings. The benefits of the measures implemented as part of the GEOCOM project (introduction and integration of geothermal and solar energy, thermal retrofitting, other energy efficiency measures) are indicated in the example of the block of flats on Česká street illustrated on figures 3.5.14 – 3.5.20.

Looking at the table on figure 3.5.15, one can note the relatively small difference in electricity production between summer and winter. The excess electricity produced and not consumed by the appliances in the common areas (such as the elevator) is fed into the mains electricity network.

From figure 3.5.16 the savings in geothermal heat consumption in the block of flats made due to the thermal insulation carried out in the GEOCOM works in 2011 is clearly visible. The values shown in this figure represent the total consumption in kWh in the current year. For comparison and detection of the real savings degree-days were used (based on a temperature of 20°C that is normalised for flats) (figure 3.5.17).

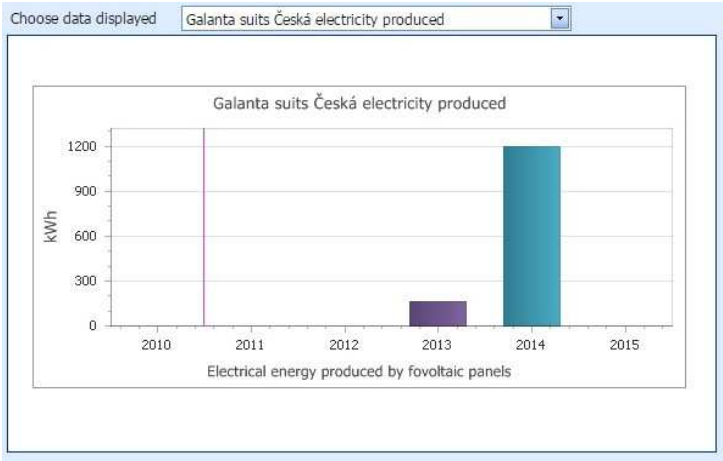


Figure 3.5.14. By installing photovoltaics for common functions and areas in the block of flats on Česká street part of the electricity needed for the elevator and the lighting of the common areas was replaced by this ecological source. Total electricity production was 1.198 kWh in 2014 (production in individual months is shown on figure 3.5.15). In 2013 the PV panels were only operating for a few months so the electricity production was significantly lower

Drag a column header here to group by that column

New	Year	Month	Object	Energy	Amount
Clear	2014,0		Suits Česká 1437 (Galanta)	Electricity from FV panels [kWh]	
Edit Delete	2014	12	Suits Česká 1437 (Galanta)	Electricity from FV panels [kWh]	79
Edit Delete	2014	11	Suits Česká 1437 (Galanta)	Electricity from FV panels [kWh]	86
Edit Delete	2014	10	Suits Česká 1437 (Galanta)	Electricity from FV panels [kWh]	88
Edit Delete	2014	9	Suits Česká 1437 (Galanta)	Electricity from FV panels [kWh]	82
Edit Delete	2014	8	Suits Česká 1437 (Galanta)	Electricity from FV panels [kWh]	96
Edit Delete	2014	7	Suits Česká 1437 (Galanta)	Electricity from FV panels [kWh]	107
Edit Delete	2014	6	Suits Česká 1437 (Galanta)	Electricity from FV panels [kWh]	105
Edit Delete	2014	5	Suits Česká 1437 (Galanta)	Electricity from FV panels [kWh]	115
Edit Delete	2014	4	Suits Česká 1437 (Galanta)	Electricity from FV panels [kWh]	117
Edit Delete	2014	3	Suits Česká 1437 (Galanta)	Electricity from FV panels [kWh]	114
Edit Delete	2014	2	Suits Česká 1437 (Galanta)	Electricity from FV panels [kWh]	108
Edit Delete	2014	1	Suits Česká 1437 (Galanta)	Electricity from FV panels [kWh]	101

Figure 3.5.15. Electricity production by PV panels in 2014 – data with monthly periodicity. Block of flats on Česká Street, Galanta. Screen shot from monitoring system

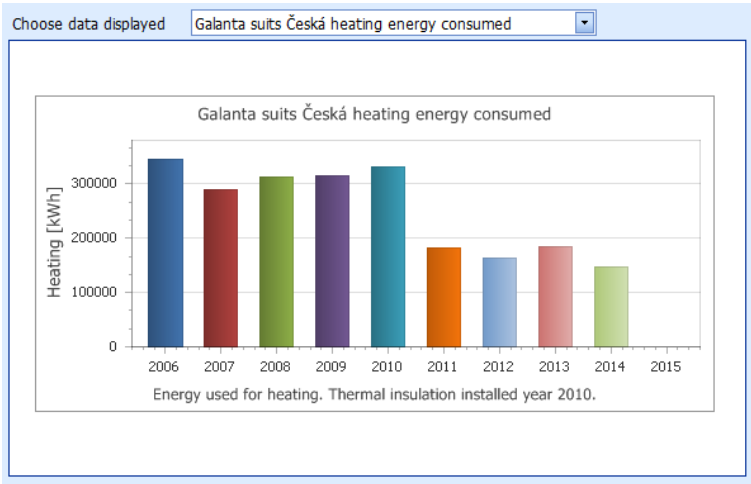


Figure 3.5.16. The progress of heat consumption in block of flats on Česká street in Galanta

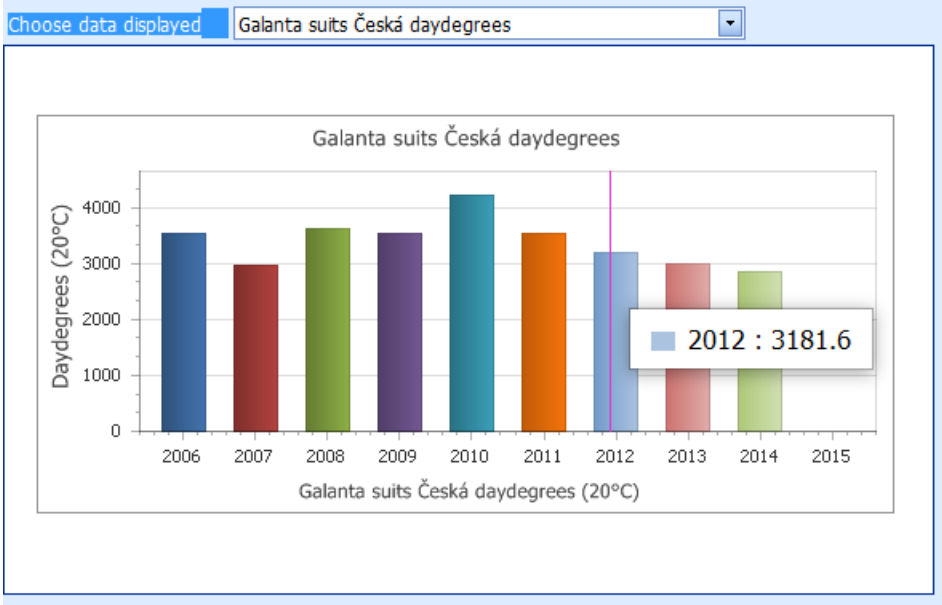


Figure 3.5.17. Day-degrees of the block of flats on Česká street, Galanta
The graph shows the warming trend in recent years; 2014 was the warmest year in long term

For the calculation of savings the following items were taken into account: average energy consumption for heating prior to 2011, degree–days and real weather conditions. Similarly the savings in the years after the thermal insulation of that block of flats were calculated (i.e. converted using degree–days). The highest real thermal energy savings in percentage terms were 35.5% – achieved in 2014 (figure 3.5.18).

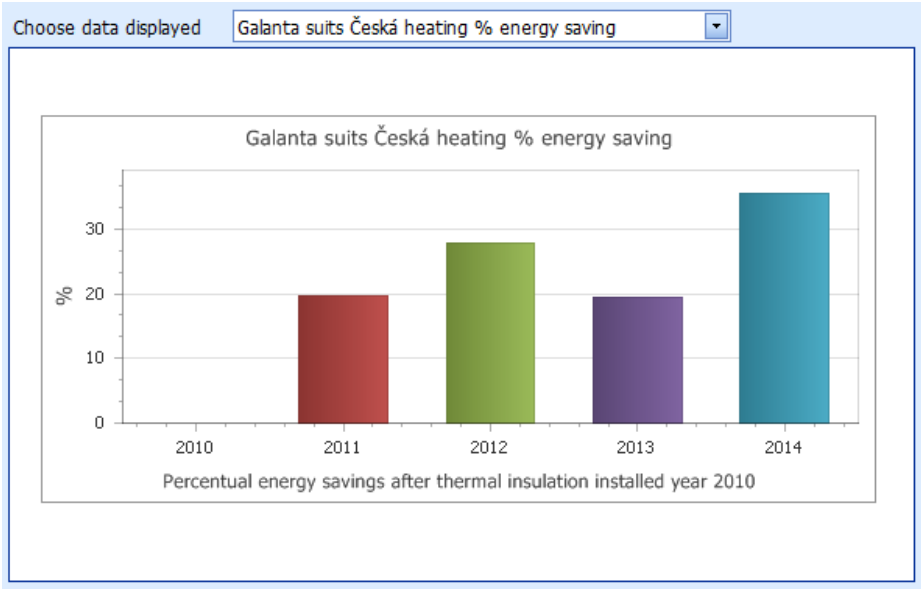


Figure 3.5.18. Savings of energy for heating achieved by the thermal insulation of the block of flats on Česká Street, Galanta

The monitoring system keeps track of energy prices and the results of the reduction in consumption achieved can be converted to a financial value (figures 3.5.19 – 3.5.20).

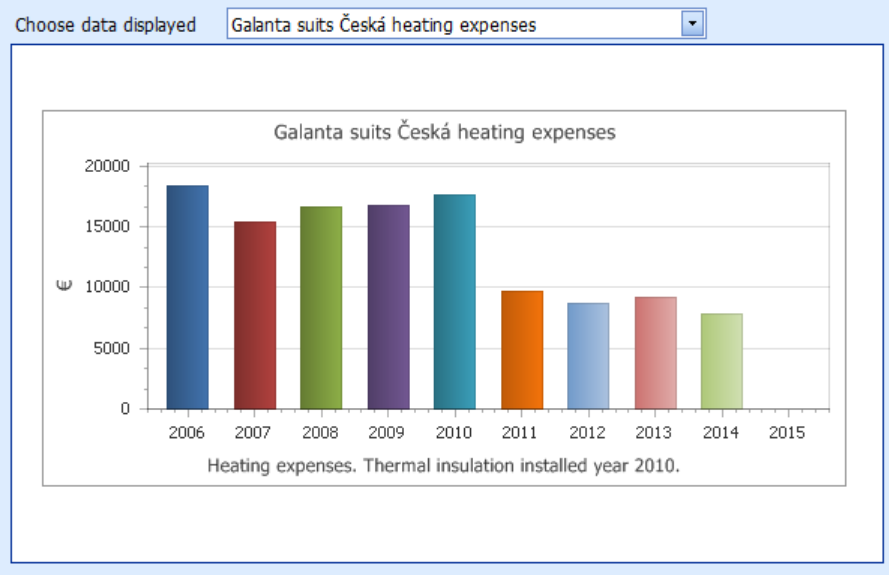


Figure 3.5.19. The progress of the real cost of energy for heating in the block of flats on Česká street, Galanta

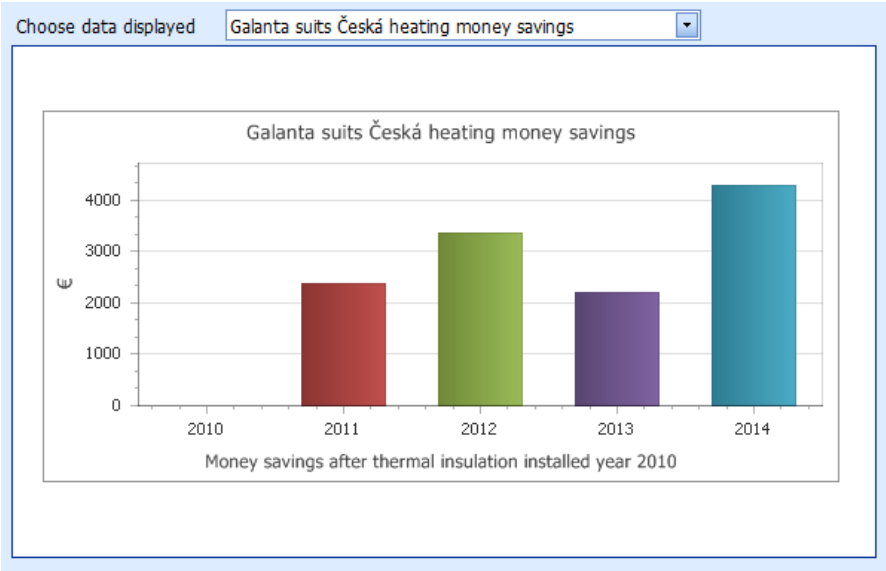


Figure 3.5.20. Cost savings on energy for heating in EUR in block of flats in Česká street, Galanta

In a similar manner to the Galanta case, the monitoring system displays the results achieved by the GEOCOM project in the remaining two demonstration sites: Montieri and Mórahálom.

3.5.6 Final remarks

The data collected in the online monitoring system of rational energy measures and installations in the GEOCOM pilot sites prove that introducing renewable energy sources for heating (geothermal energy) and electricity generation (solar energy) coupled with thermal retrofitting and energy efficiency measures results in a significant decrease in energy use and its costs, increases the comfort and satisfaction of various groups of users (municipal, public, private). These are important energy, economic, environmental and social benefits in both local dimensions, the residents and the municipalities, to whom the GEOCOM demonstration works were addressed – and on a wider scale by contributing to the realisation of national and EU policies expressed in the "3x20%" set of directives and other policies.

The online monitoring system described here (the details of which you are encouraged to learn about in more detail) provides a good example of efficient geothermal energy use for heating and of its integration with other renewables and energy efficiency measures, especially the thermal retrofitting of buildings. These are urgent, relatively simple, and very much needed activities in many Central and Eastern European countries.

The results of the monitoring to date have proved that the GEOCOM investment works at the demonstration sites were worthwhile and the project calls for them to be carried out in many other localities in Europe that have geothermal energy potential suitable for space heating purposes.

References

https://www.asphere.sk/siea

http://geothermalcommunities.eu/

www.asphere.sk/siea/pages/public/DataView.aspx?VID=code

4 BENEFICIARIES' PERCEPTION OF GEOTHERMAL ENERGY AND RATIONAL USE OF ENERGY MEASURES INTRODUCED THANKS TO THE GEOCOM WORKS (ON A BASIS OF THE QUESTIONNAIRE SURVEY) – THE CASE OF MONTIERI PILOT–SITE

(Aleksandra Kasztelewicz, Beata Kępińska, Leszek Pająk – MEERI PAS)

4.1 Introduction

The implementation of geothermal and other renewable sources (RES), as well as rational uses of energy (RUE) measures brought important social and economic results for the GEOCOM beneficiaries in particular pilot–sites (highlighted in chapters 3.2 – 3.4). These issues were also the subjects of dedicated study addressing the beneficiaries in Galanta, Montieri and Mórahalom. It was done in the framework of the GEOCOM as a socio–economic research based on quantitative method (questionnaire survey) to learn the perception of RES and RUE's implementation by their direct beneficiaries in the pilot– sites. This chapter presents selected results of that research on an example of Montieri. This is an extension of qualitative information given in chapters 3.3.6 – 3.3.7 on social benefits for the local community and satisfaction with the results of the GEOCOM works, geothermal energy and the RUE measures applied in that locality.

The outcomes of socio–economic research for all three GEOCOM pilot sites are given in more details in a separate report (*www.geothermalcommunities.eu/downloads).*

Two basic methods were applied to obtain necessary information: quantitative (questionnaire survey) and qualitative (open opinions and comments). Among the respondents were representative groups of beneficiaries of GEOCOM investment works, mayors of particular municipalities, and appointed experts. The experts' role was to objectively assess the state of geothermal energy and RUE perception by the GEOCOM beneficiaries and public. The research was performed in two sets:

1. a preliminary Questionnaire survey (2010-2012) before the GEOCOM investments started. It made possible to gain a kind of reference background and orientation on local inhabitants – future beneficiares' attitudes, state of knowledge on renewables and rational use of energy's measures before their implementation and before they could experience their results.

2. a Questionnaire survey done in 2015, i.e. after completion of demonstration works in pilot–sites and after first heating season when some first experiences and beneficiaries' feedback appeared.

It was expected that throughout the GEOCOM duration some evolution and changes in individual local citizens' approaches towards renewable energy and its rational uses would be visible. Therefore such an initial background was helpful for the comparisons, evaluations and learning the positive changes in social acceptance and growth of knowledge and awareness related to renewable energy and rational energy use's measures. As an outcome of the research one gained an insight on the level of social understanding and opinions on the following items, e.g.:

- user's satisfaction (with the implemented measures, information, energy advice, feedback-systems on consumption, etc.),
- users' involvement (investing in energy efficiency measures, organized in local agencies, tenants' organizations),

- analysis of beneficiaries' perception about changes in the municipalities affected by the project demonstration works and acceptance of the GEOCOM measures.

The results of the–above–listed surveys enabled to compare the state of social perception and understanding before, during and after implementation of RES and RUE specially when some benefits would be experienced by the users.

4.2 Selected results and benefits of introducing geothermal energy source and rational use of energy's measures – opinions of the GEOCOM beneficiaries in Montieri

Information campaign on GEOCOM works

The GEOCOM investment works were preceded and than accompanied by information campaign addressed to local community, especially future beneficiaries. Various forms of information activities were conducted. In case of Montieri information activities were organized by local Municipality, some Italian GEOCOM partners, sometimes in cooperation with the students from Politecnico di Torino. High satisfaction with information campaign was expressed by ca. 74% of all respondents (figure 4.2.1). Moreover, the experts evaluated that the beneficiaries' involvement in GEOCOM demonstration works (in various forms) was also high, and only less than 30% of them showed no commitment (figure 4.2.2).

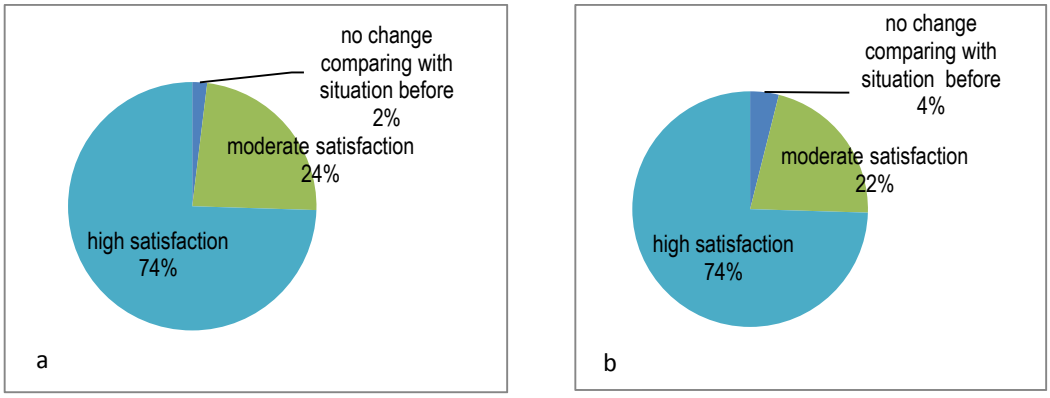


Figure 4.2.1. Beneficiaries' satisfaction with the GEOCOM information campaign in Montieri, 2015
a – information campaign on the Project, b – information campaign on RES / RUE measures introduced

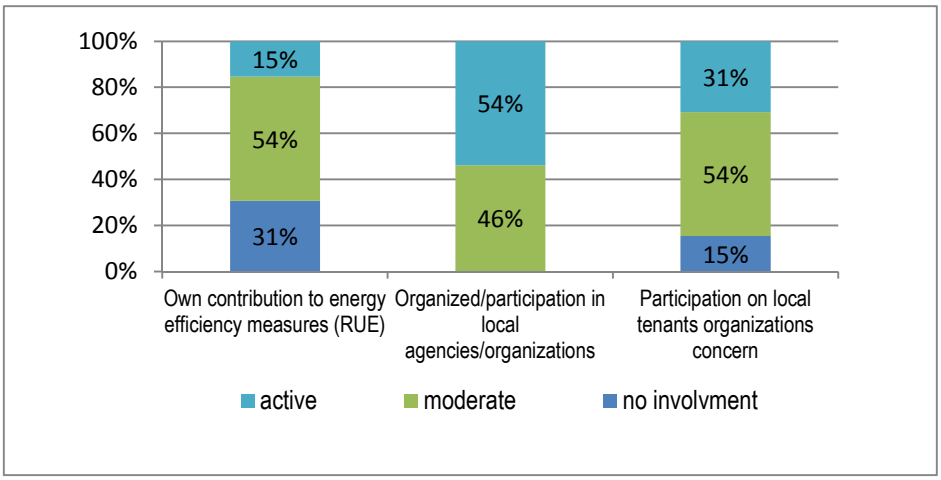


Figure 4.2.2. Beneficiaries' involvement in the GEOCOM works in Montieri, 2015

Energy sources

In the past several different energy sources were used in Montieri for space heating and domestic hot water preparation – the main source was wood (69%) and fuel oil (44%) (figure 4.2.3a). Currently in 425 buildings embraced by the GEOCOM works geothermal energy was introduced (figure 4.2.3b) provided by newly-constructed district heating system. For the preparation of domestic hot water the electricity (65%) and fuel oil (29%) were applied (figure 4.2.4a), now heat for this purposes also comes from geothermal source entirely (figure 4.2.4b).

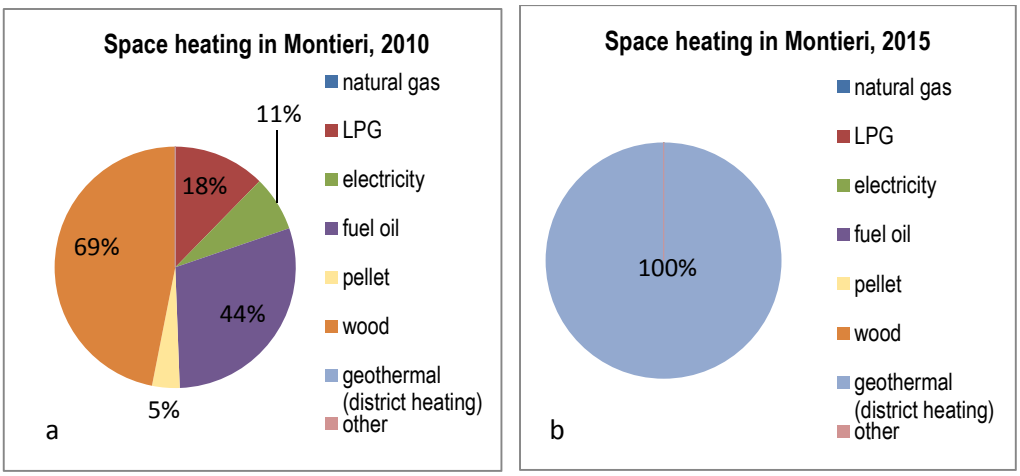


Figure 4.2.3. Energy sources used for space heating in beneficiaries' households before (a) and after (b) the GEOCOM works in Montieri

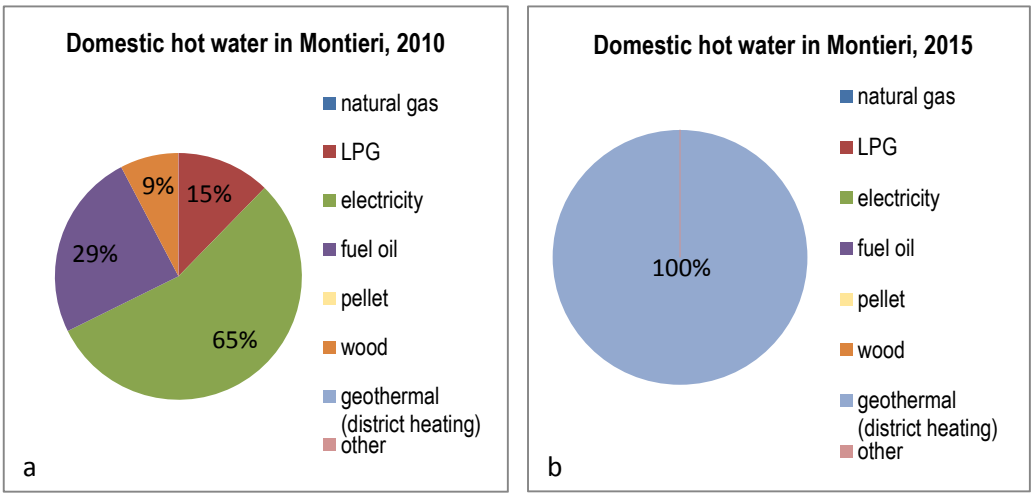


Figure 4.2.4. Energy sources used for domestic hot water preparation in beneficiaries' households before (a) and after (b) the GEOCOM works in Montieri

Level of users' satisfaction

During the socio–economic research in 2010 the beneficiaries' satisfaction with the quality and comfort of previously offered thermal energy services and comfort were examined. Figure 4.2.5 shows that beneficiaries were not satisfied (up to 83% beneficiaries) with offered services but after the

investment works the vast majority (93%) is satisfied with implemented changes. Furthermore, the beneficiaries were generally satisfied with energy advise during the GEOCOM activities (figure 4.2.6).

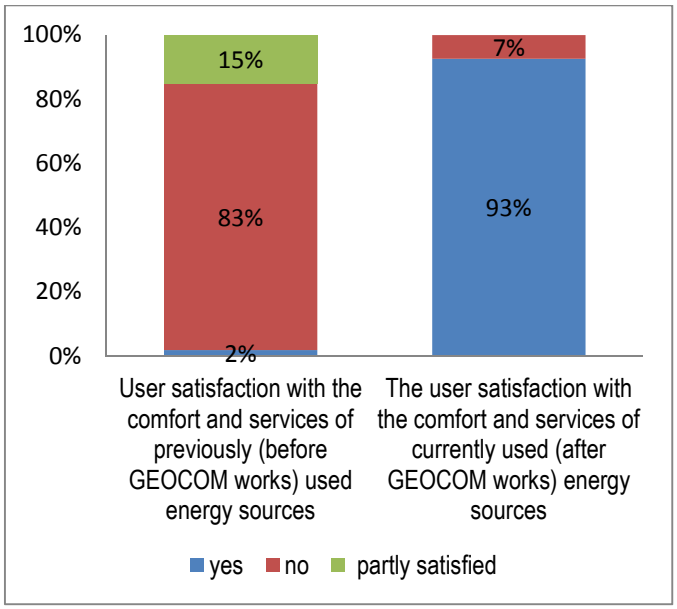


Figure 4.2.5. Beneficiaries' satisfaction with the comfort and services of thermal energy sources used before (left) and after (right) GEOCOM works in Montieri

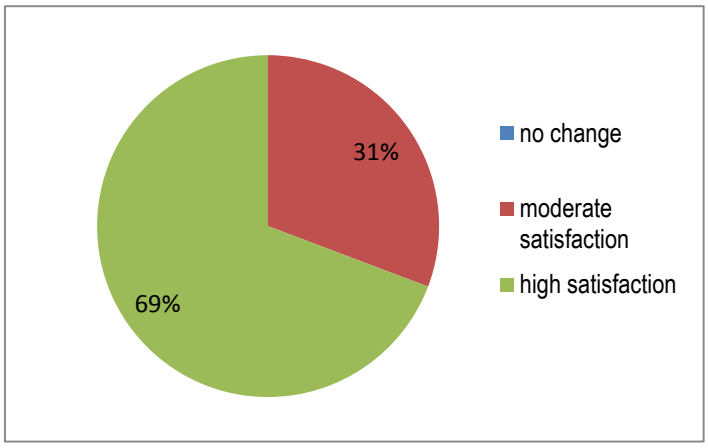


Figure 4.2.6. Beneficiaries' satisfaction with energy advise during the GEOCOM works in Montieri

One of the main goal of the GEOCOM project in Montieri was to reduce the energy demand by introduction of integrated renewable energy and rational use of energy's technologies into historic buildings. The citizens of that municipality – the GEOCOM beneficiaries were mostly pleased with applied solutions such as (figure 4.2.7):

- type of introduced energy source,
- effects of thermal retrofitting,
- methods to control,
- energy costs' decrease.

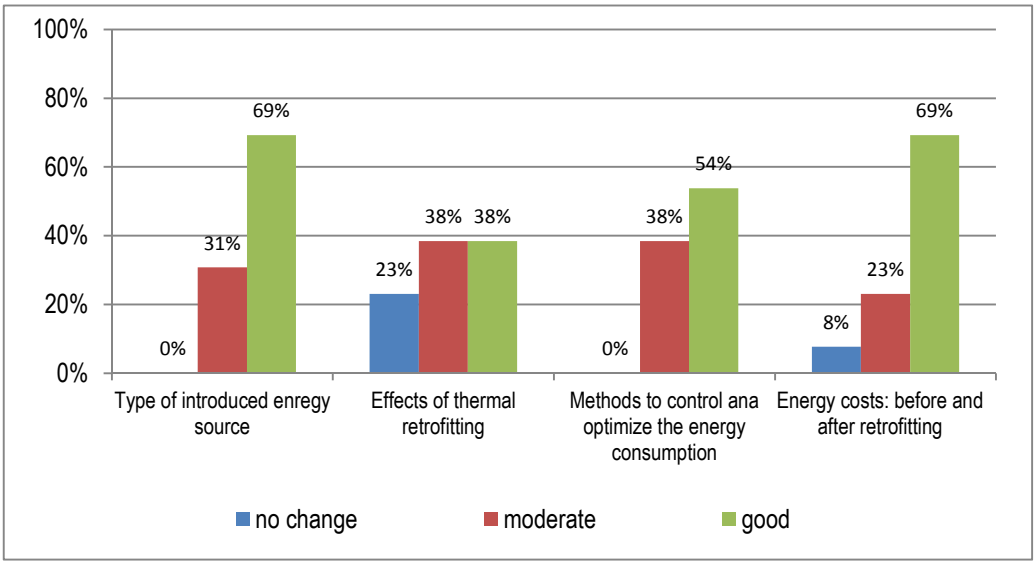


Figure 4.2.7. Beneficiaries' satisfaction with applied geothermal /RES and RUE measures thanks to the GEOCOM works in Montieri, 2015

Public opinion on costs of geothermal and other RES

Opinions on the costs of geothermal, other renewable energy sources (or any type of energy source) affect to way of public perception of these types of energy. These costs are usually compared with the average income per capita in particular country / locality concerned. In Montieri, in case of half of the beneficiaries the average monthly income per capita ranks within the 500 – 1 000 EUR; one third of these revenues are between 1 000 – 1 500 EUR/month, and only 13% of beneficiaries have an income higher than 1 500 EUR/month (figure 4.2.8).

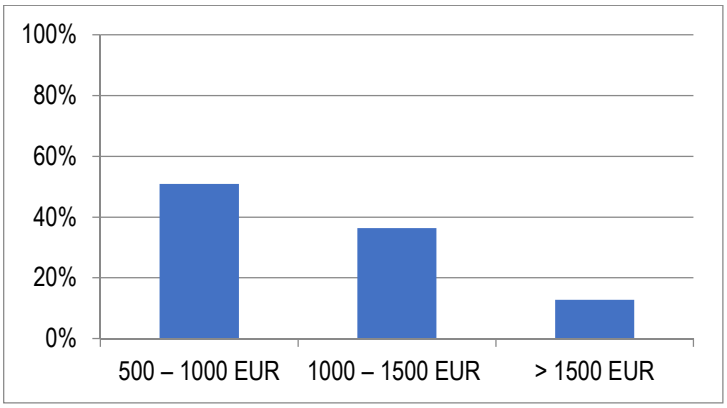


Figure 4.2.8. Average monthly income per capita of beneficiaries' households in Montieri

Reduction of the heating costs thanks to implementation of RES and RUE measures was among the greatest of expectations for the beneficiaries in Montieri. Before starting project works in 2010, for almost half of the beneficiaries these costs amounted to an average of 1 000 – 2 000 EUR/year (figure 5.2.9. According to experts for the vast majority of the GEOCOM beneficiaries they were too high (that amount was equal to the average monthly income per household in more than half of the Montieri population).

It is worth to point out that after the GEOCOM works these costs decreased by half (!) (figure 5.2.10) thanks to introduction of geothermal energy which replaced other more expensive heat sources (in that fuel oil, electricity, LPG).

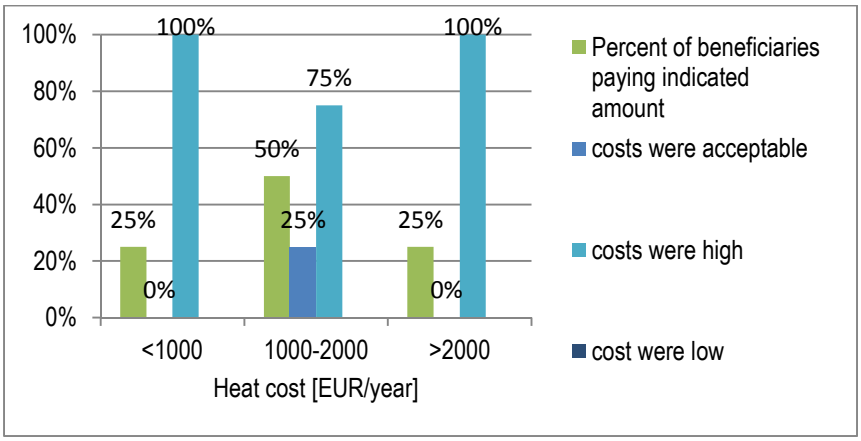


Figure 4.2.9. Tentative costs of heating the individual household/building in the group of beneficiaries in Montieri before GEOCOM works, 2010 (experts' opinion)

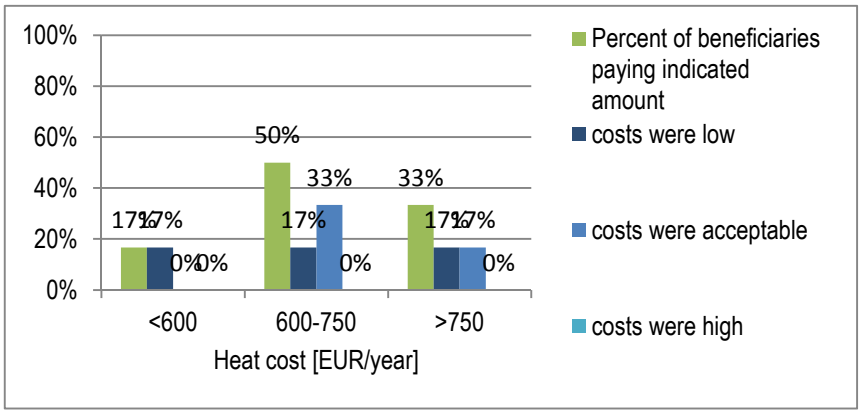


Figure 4.2.10. Tentative costs of heating the individual household/building in the group of beneficiaries after introducing geothermal energy thanks to GEOCOM works in Montieri, 2015 (experts' opinion)

Figures 4.2.11 and 4.2.12 present the average annual costs for heating and electricity before the GEOCOM investment works. For most of the users these costs were too high in both cases. The electricity costs often contained some share consumed for space heating and domestic hot water (what was among the main reasons of high electricity bills).

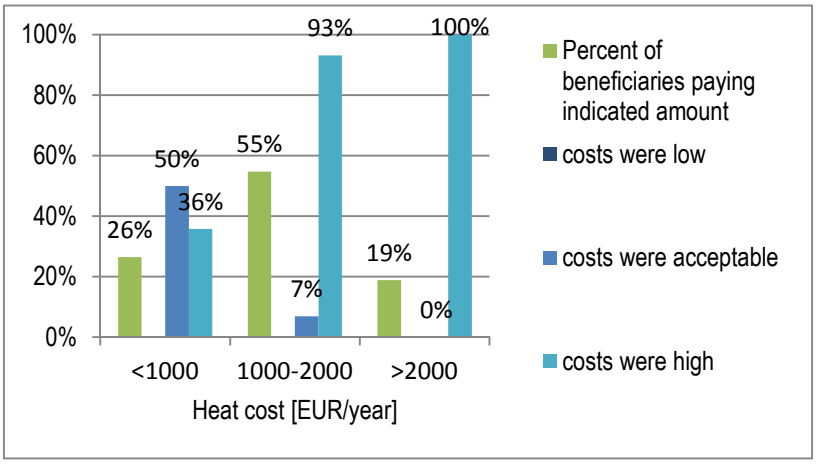


Figure 4.2.11. Tentative heat energy costs before GEOCOM works in Montieri, 2010 (users' opinion)

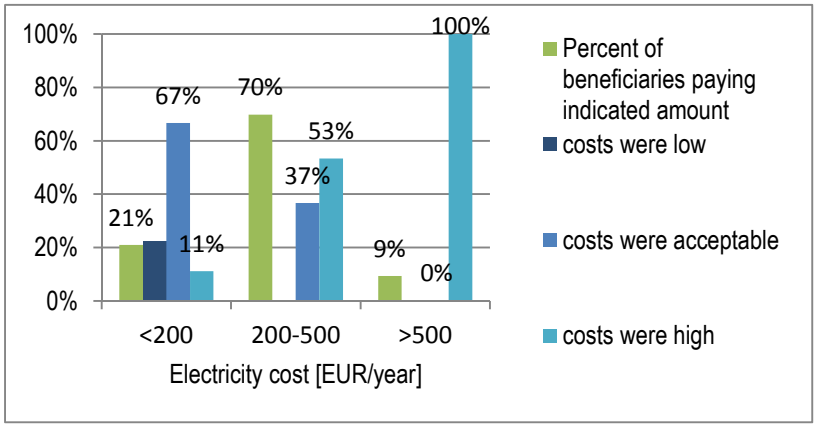


Figure 4.2.12. Tentative electricity costs before GEOCOM works in Montieri, 2010 (users' opinion)

After introduction of geothermal energy in Montieri the heating costs decreased nearly twice. In case of electricity costs they are considered as low and acceptable for most of the respondents – GEOCOM beneficiaries (figure 4.2.13 and 4.2.14). This positive fact is a direct consequence of a cessation of electricity consumption for heating purposes – not needed since it is an access to cheaper geothermal heat source.

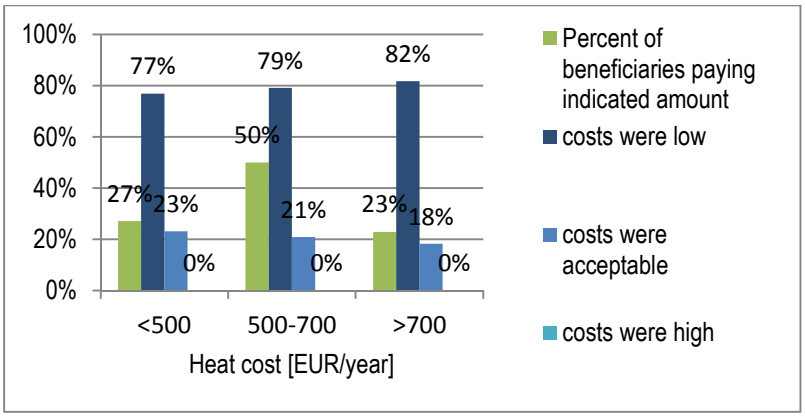


Figure 4.2.13. Tentative heat costs after GEOCOM works in Montieri and introducing geothermal energy, 2015 (users' opinion)

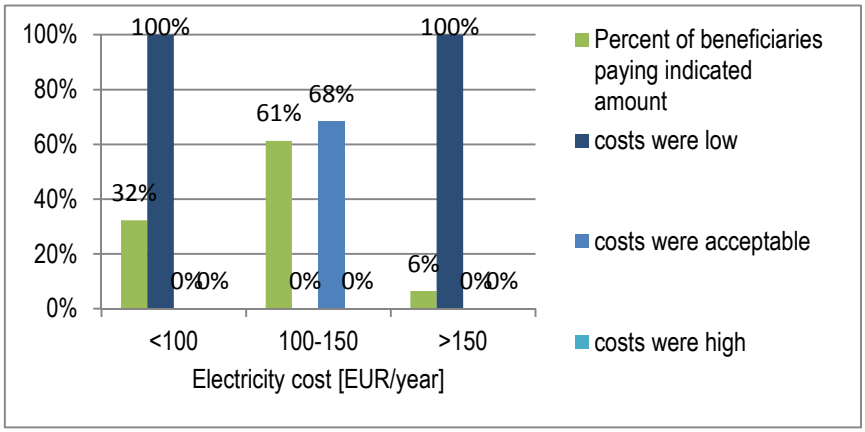


Figure 4.2.14. Tentative costs of the electricity after GEOCOM works in Montieri, 2015 (users' opinion)

Figure 4.2.15 presents an annual unit heating costs relative to the occupied surface before and after GEOCOM project works. Significant cost reduction is observed.

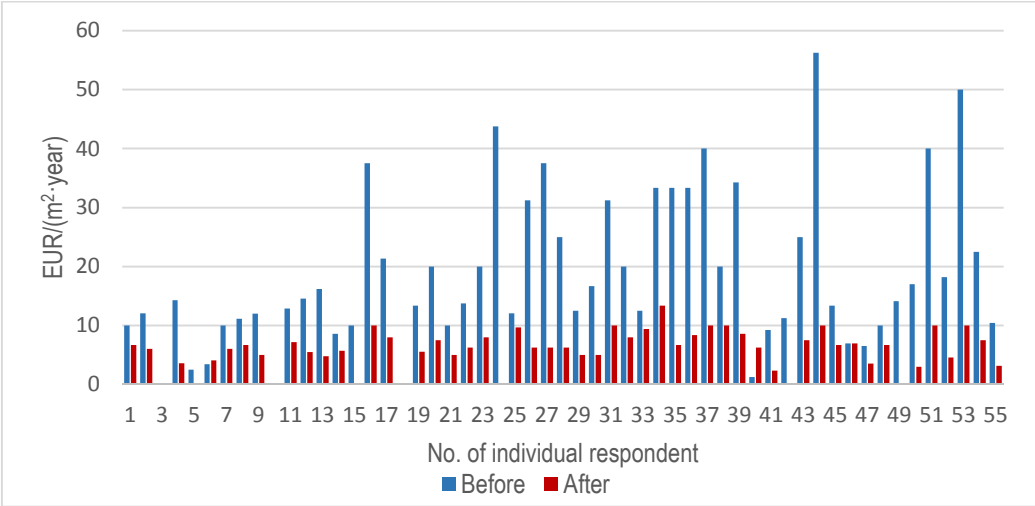


Figure 4.2.15. Average unit cost for heating in Montieri before and after GEOCOM project works

Thermal retrofitting's effect

In addition to the change of the heat source in Montieri also some retrofitting works were carried out to reduce current energy demand. The thermal retrofitting of selected dwellings of town center was done applying the materials and methods in conformity with their historic value. Figure 4.2.16 shows the retrofitting effect by comparing annual energy consumption in beneficiaries' dwellings before and after GEOCOM works – thermal energy saving after retrofitting in all cases can be observed. Figure 4.2.17 presents the comparison of the average annual heat price before and after GEOCOM implementation works – this is a figure of a special importance since it makes clearly visible that geothermal has been proved to be significantly cheaper heat source among all other available sources (which were also used before the introduction of geothermal heating to some of Montieri's buidings thanks to the GEOCOM activities).

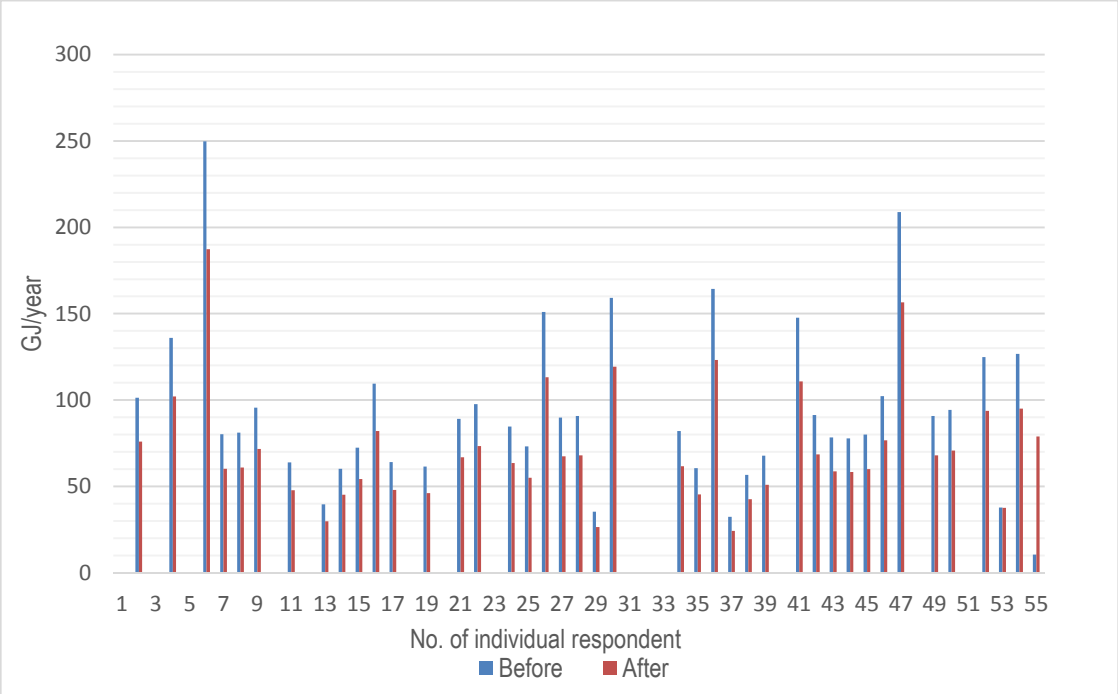


Figure 4.2.16. Thermal retrofitting effect in Montieri expressed by comparison of annual heat consumption by individual beneficiary before and after GEOCOM works

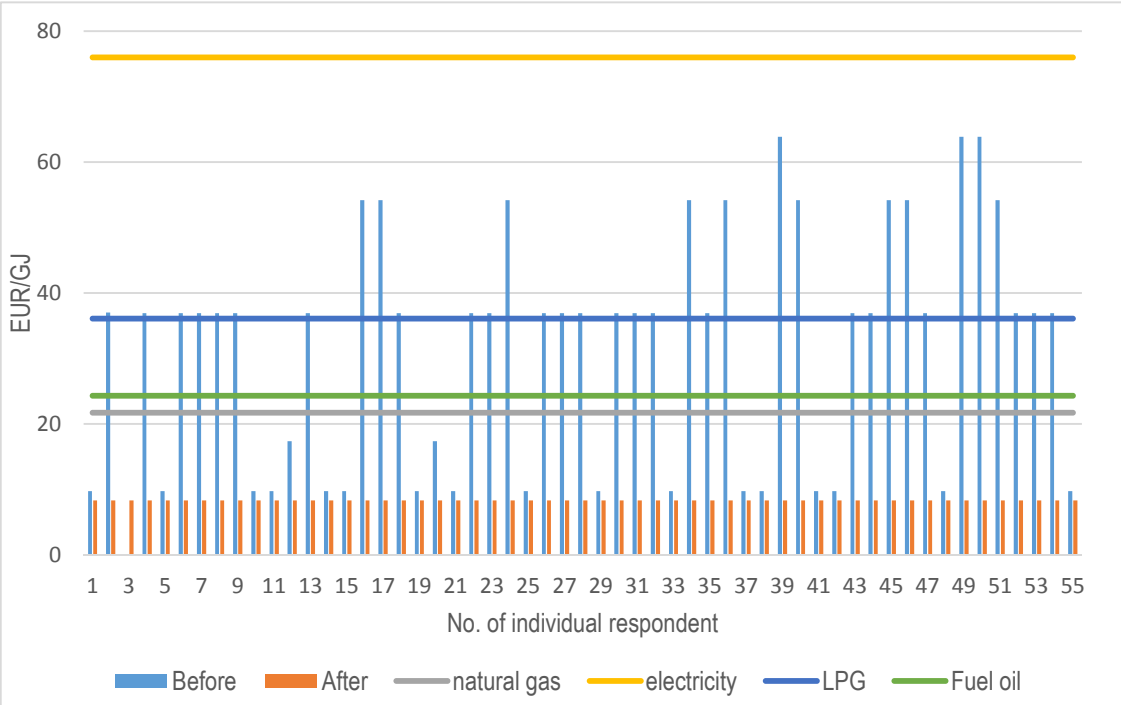


Figure 4.2.17. Comparison of unit heat prices in beneficiaries' buildings before and after GEOCOM works in Montieri (for reference added are costs of natural gas, electricity, LPG and fuel oil)

4.3 Final remarks

The feedbacks and opinions shared by the beneficiaries of the GEOCOM investment works as well as appointed experts proved the good coupling effects of RES and RUE introduced in Montieri municipality. These confirmed also the results and conclusions received as effects of other aspects of that project (as described in other chapters of this Handbook).

According to the GEOCOM beneficiaries their annual energy demand was reduced by approx. 25% thanks to thermal retrofitting works (figure 4.2.13). Retrofitting actions combined with the use of geothermal and other renewable energy source (solar) reduced significantly the energy costs paid by the recipients – from approx. 30 to even 80% (figure 4.2.12). Also thanks to that, costs of energy are acceptable for almost the all beneficiaries (figure 4.2.10). Before the GEOCOM project the level of acceptability of the energy costs was much lower (figure 4.2.9) – only 57% of respondents regarded them as acceptable. Before the execution of modernization works most of the buildings were characterized by the unit energy price [EUR/GJ] higher than the rates characteristic for electricity. After carrying out the Project works the unit price of thermal energy has fallen to the values markedly lower than characteristic for other sources like natural gas, fuel oil and LPG (figure 4.2.17) – it was thanks to providing geothermal heat to many users – the GEOCOM beneficiaries.

The positive GEOCOM results in Montieri have also another important social aspects connected with the fact that its population is rather advanced in age. This was also visible in age distribution among the GEOCOM beneficiaries as a whole and those taking part in the socio–economic research and Questionnaire survey: more than half (67%) of the respondents were beneficiaries aged over 60 years old, the other large group were people aged between 40 – 60 years (22%), 11% were aged 20–40 years (figure 4.2.18).

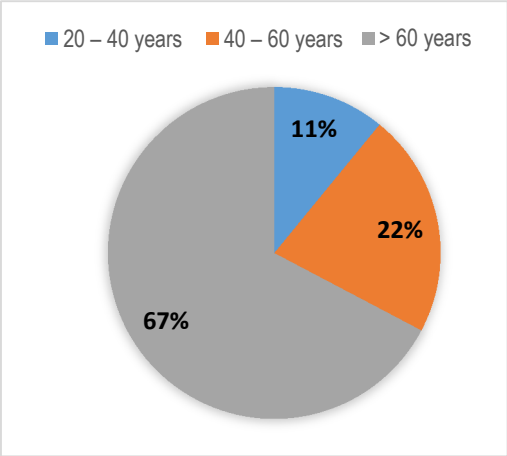


Figure 4.2.18. Age groups of Questionnaire survey's respondents – the GEOCOM project beneficiaries in Montieri (Questionnaire survey was done as part of socio–economic research)

Such an age structure of the beneficiaries makes particularly important the comfort and ease of use of introduced geothemal energy source, security of supply, virtually maintenance-free, cleaner air positively affecting the health and – last but not least - lower prices and costs. These are important social effects achieved thanks to the GEOCOM project realization. Similar benefits and effects one may expect in other localities, too, specially in cases when local communities achieve increasingly advanced age (as a result of the aging population in several European countries).

Acknowledgements:

The authors of this chapter acknowledge the GEOCOM beneficiaries in the pilot–sites, appointed experts, mayors and other representatives of Galanta, Montieri, Mórahalom municipalities, as well as all other GEOCOM partners who expressed their feedbacks, submitted information, were involved in the Questionnaire survey, collected, and commented its outcomes. The cooperation and involvement of all of them created an indispensable background on which this chapter is based.

5 SELECTED ASPECTS ACCOMPANYING GEOTHERMAL ENERGY EXPLOITATION AND USES IN THE GEOCOM COUNTRIES

(Tamás Medgyes, Balázs Kóbor, János Szanyi – University of Szeged, Mihály Kurunczi – BRUNNEN Ltd.)

5.1 Introductory remarks

The exploitation and use of geothermal resources is usually associated with several important considerations which should be taken into account to ensure that their development is done in a rational way in order to maintain the renewable nature of these resources. Some of these, which were taken into account during the GEOCOM project, are listed below:

- injection of spent geothermal water: in Central and Eastern European countries (as well as in many others) a lot of attention needs to be paid to this issue as generally the most appropriate way of maintaining the long-term sustainable exploitation of geothermal resources. This is also of particular concern in relation to the problems arising from a high degree of mineralisation of the water (which sometimes occurs) and the specific features of the sandstones as reservoir rocks (a common situation in CEE countries, such as those in the Pannonian basin, European Lowlands, etc.);
- the transboundary flows of geothermal waters where they are being exploited in adjoining areas of different countries sharing the same geothermal aquifers (and the related necessity of joint monitoring and management) – many such issues relate to the situation in Central and Eastern Europe;
- the possible recovery of methane [non industrial amounts] from geothermal water and its use for practical local purposes (rather than treating this gas as a waste), e.g. to drive a turbine that produces electricity to power e.g. heat pumps (such as those installed in the integrated heating system in one of the pilot project sites – Mórahalom).

Along with good practice in the use of geothermal energy in integration with other renewable resources and the rational use of energy presented previously, the-above-mentioned considerations provide a comprehensive insight into the issues presented in this Handbook. They were subjects of separate reports elaborated as parts of the GEOCOM works and are available at *www.geothermal-communities.eu/downloads*:

- RES integration concept paper,
- Transboundary utilisation model,
- Reinjection to sandstone reservoirs technology showcase,
- Integrated use of waste gases from geothermal water.

In this chapter the selected aspects of integrated use of waste gases (methane) from geothermal water are described, in addition to those given in chapter 3.4 (on the basis of research and implementation works in Mórahalom – the GEOCOM pilot–site). These issues may be interesting also for operators and investors in other localities (both in Hungary and in other countries) where geothermal water may contain methane in the amount prospective for its practical use.

5.2 Integrated use of waste gases from geothermal water – the case of Hungary, selected aspects

5.2.1 Generals

The presence of gas content in subsurface waters is a general phenomenon in the basin sediments of the Great Plain (Panonian basin) the most common types of gases are carbon dioxide, nitrogen, hydrogen sulfide and radon, and methane in some cases (the combustible gas – subject of practical use in integrated energy system established in Mórahalom – a pilot–site of the GEOCOM project). In the course of the production of geothermal wells and on the impact of pressure reduction – upon reaching the bubble point – the gas dissolved in the water is released and the density of the water column reduces. The released gas bubbles facilitate the elevation of the water onto the surface, thus gases dissolved in the water have a positive impact from the aspect of production. Upon reaching the bubble point pressure, more and more gases are released from the upflowing gaseous artesian water. As a consequence, the density of medium filling the well section gradually decreases. Beside the increasing amount of released gases, part of the gas content still remains in dissolved form.

The ratio of gas dissolved in the water and released, and also the comparability of various test results is influenced by water recovery and gas separation methods. The pumping method of the well can also have a significant impact on gaseousity, as a consequence, at well inspections tests must be carried out applying the expected amount of operational water recovery. For the study of the gas content of geothermal wells of the Southern Great Plain, the research team from the University of Szeged has created a database using the data of the Archives of the Department of Mineralogy, Geochemistry and Petrography of the University of Szeged and of Geo–Log Kft. The database includes 182 gas tests carried out in 6 counties (Békés, Csongrád, Bács-Kiskun, Pest, Jász-Nagykun Szolnok and Hajdú-Bihar). For the majority of geothermal wells in most cases the results of only one – usually from the time of construction – gas test were available, in a smaller proportion of wells one could rely on 2, in some cases on 3–5 series of data.

The database includes the most common data used for the identification of wells (name, number of county, cadastre number, EOV coordinates, total depth, height above mean sea level, year of drilling), some additional information (top of filter, bottom of filter, outlet water temperature, total salt content), plus the most important measured parameters of gas tests (date of test, composition of separated gas in the volume percent of measured components, the composition of dissolved gas in the volume percent of measured components, the total separated gas and methane content, the total dissolved gas and methane content and the total gas and metal content).

Due to lack of data some cells were left empty in the database. In most cases the county number or the cadastre number facilitating identification is missing, generally in the case of wells constructed in the last 10 years. The total dissolved salt content is also often missing, since only the results of hydrochemical tests completed simultaneously with the gas tests were included in the database. In some cases the height above mean sea level of geothermal wells or data related to outlet water temperature or gas test is not included. Although they are not included in the final database, it must be noted that in the case of the few gas tests completed in the 50s and 60s, only the specific total gas and methane content is included in the test reports.

The spatial distribution of available data is very uneven. The most series of data (127) is available from Csongrád County, whereas the database only includes 16 series of data from Békés County, 5 from Bács–Kiskun County, 14 from Hajdú-Bihar County, 19 from Jász–Nagykun Szolnok County and 1 single

series of data from Pest County. It becomes evident that some wells of Pest, Hajdú-Bihar and Jász–Nagykun–Szolnok Counties are located in the middle or northern areas of the Great Plain, however, they are still included in the database for the sake of comparability with areas of the Southern Great Plain and other areas of the Great Plain. The 127 series of data achieved in Csongrád County belong to the tests completed on 86 geothermal wells, which are scattered in nearly all parts of the county. However, most data is accumulated in the Szentes–Csongrád–Mindszent triangle whereas only one well was found in the eastern and western part of the county, respectively. Out of the above mentioned 86 geothermal wells in Csongrád County, the depth range of 60 wells is 1 500–2 250 m. The database includes available information of the gas tests donr in 1976 – 2014.

5.2.2 Recomended technologies for the utilisation of additional gas content in geothermal wells

Sampling methods for the determination of the gas content of subsurface waters

The purpose of the gas tests is to determine the methane content of the waters in order to investigate fire and explosion hazards, and to gain information on the layers explored. The determination of the quantity and quality of the gases produced with water is a difficult task, since as the influence of pressure decreases, upon reaching bubble point, the gas partly separates from the water, thus a two–phase medium arrives at the surface (Szanyi et al. 2013).

Gas tests include two elements – on-site sampling and a laboratory test on the samples. From experience it is known that there is no fundamental difference between laboratory tests, even if the gas analysis is carried out by means of a varied range of technologies. As opposed to this, significant differences can occur in the course of the sampling, even though the samples were taken in accordance with the specifications (Galbácsés Seres, 1981). Gas sampling has strict rules, since during the sampling and transportation chemical reactions can take place that might alter the final results. In the case of gas–unsaturated waters, water should be entered into the sample collection vessel in a way ensuring that the gas content of water does not change either by gas intake, or by gas loss. The gas content of gas saturated waters can be defined in two different ways (Galbácsés Seres, 1981):

- by means of deep sampling: it is unjustified using this for the determination of fire and gas hazards, though it might be important for the collection of hydrogeological information. In the case of water production by means of a compressor, deep sampling must be applied. In the course of deep sampling a complete well should be constructed, a test vehicle should be parked over the well head, and the probe should be lowered in a way similar to a standard geophysical test. In the course of deep sampling the gas remains in a dissolved state in the closed sampling vessel (Szanyi et al. 2013);
- by means of separation: in the course of which it can be determined how much gas non-soluble at atmospheric pressure is present in water contained in pipes or wells. At separation we should aim at excluding any gases from the sample that derive from outside sources.

In the course of full flow separation, the water yield of the well is driven through equipment in which the isolation and separation of gases non-soluble at atmospheric pressure takes place. The main problems concerning full flow separation (Galbácsés Seres, 1981) are:

- expensive equipment, difficult to operate,
- more persons required for operation,
- the connection of the well with the full flow separator is tiresome,
- the well is excluded from water supply for a longer period,
- in most cases it can be substituted by part flow separation.

Prior to the start of full flow separation it is advisable to fill the separator tank with the water to be examined and to rinse it with a volume of water which is two or three times the volume of the tank. The water-gas solution is introduced into the separator through a perforated end pipe. As the separator is open through the gas outlet pipe, pressure practically identical to atmospheric pressure is present in the tank and most of the gas leaves the water–gas solution and thus the separation of gas and water takes place (Enviroinvest Kft, 2009). By the opening of appropriate switches the operational water level can be set in the separator and the water flow rate can be adjusted in a way that the boundary of the water–gas phase in the separator area should remain approximately constant (Varga and Takács, 1984). Following the determination of the operational water level of the separator, the amount of water discharged from the separator is measured by the water gauge built into the discharge pipe, and the temperature of the gas and the amount of the separated gas–water mixture is measured by means of appropriate gauges located at the discharge pipe. The size of the tank must be chosen in a way that the water stays in it for at least 2 minutes. In order to prevent the water leaving the tank prematurely, a submersible pipe is applied for the drainage of the water. During measurement the discharge end remains shut. Further parameters (e.g. atmospheric pressure) required for the measurement results are measured by a pressure gauge or manual equipment (Enviroinvest Kft, 2009). If the water yields are small it is recommended this is done for 2 hours, in case of larger water yields the separation of an amount of water equal to 10 separator volumes (Varga and Takács, 1984) is advisable.

If there is partial flow separation, the quantity of gases dissolved in water is determined from the partial flow of wells. Proper separation can be done in the following cases (Galbács and Seres, 1981):

- on the separation of network waters,
- on the examination of the efficiency of degassers,
- on the examination of positive wells: if the water has a proper amount of separable gas content, and the water is led into the separator through a pipe led into the well down to the depth of single phase water,
- in pump wells: separation must take place in conditions in accordance with regulations.

If the flow rate of the separated gas is below the value of 0.5 cm^3/L, and the measurement was carried on for longer than 1 hour, in practice the amount of separated gas in the water of the well can be ignored, separated gas does not have to be taken.

In the course of sampling it is important to comply with general regulations and health and safety regulations issued by the operator. Furthermore, in gas hazard areas intrinsically safe tools and units must be used. In closed or improperly ventilated locations, the operator must ensure that no explosion hazard is present (Varga and Takács, 1984).

In compliance with Decree 12/1997 KVHM the following gas tests should be carried out:

- survey accuracy examinations: their results can only differ from technological accuracy examinations by a maximum of 20%,
- technological accuracy examinations: the samples and parameters examined are determined with a maximum of 5% difference from their actual state,
- the regulation requires ± 5% accuracy in the measurement of water quantities, ± 3% accuracy in the measurement of gas quantities, ± 0,5^{o}C accuracy in the measurement of temperature and ± 0.1 bar accuracy in the measurement of barometric pressure.

Following the arrival of samples at the laboratory we should aim to complete the laboratory tests as soon as possible in order to reduce storage time of the samples to the minimum.

Samples taken in gas pipettes must be stored horizontally, in one row; the vacuum sample collection vessels should be stored vertically, with breakage and shock protection, at room temperature. Samples taken by means of the flow through method should be stored upside down at a temperature of+ 4°C. The examination of gas content can be carried out by laboratories approved by the National Accreditation Board. The results of the gas tests must be recorded in compliance with Appendix 2 of the above Decree. Major results to be recorded:

- location, number, cadastral number, filtering, year of construction, normal and operational water level etc. of the well,
- date of sampling,
- point of connection of separator, location of sampling, volume of separator (m^3), operational capacity of the well prior to test (Lmin),
- results of the flow rate test: flow rate of water (L/min), water temperature (^{o}C), separator pressure (kPa), flow rate of gas (L/min), gas temperature (^{o}C), flow rate of total free gas (L/min), total free gas content (L/m^3),
- results deriving from gas analysis data: flow rate of free gas anoxic (L/min), free gas content anoxic (L/m^3), free methane content (L/m^3),
- amount of methane, oxygen, nitrogen and carbon dioxide in the separated gas or dissolved in the water expressed in volume percent,
- amount of specific total gas content, amount of specific total methane content,
- data regarding the water quality of the well.

Utilisation of a gas engine

With the current gas and electricity price structure it is advisable to consider a small-scale gas engine power plant. The 30–35% primary energy savings achievable easily supports the rapid (4–6 years) financial return of such systems. Gas engine units can easily be matched with burner systems, where the heat in the water jacket of the engine and the energy recovered from the flue gas heat exchanger can be utilised in the hot water cycle. Following the contract with the power supplier and the construction of electricity connections, the electricity produced could be fed into the network, which will be purchased at the compulsory feed–in tariffs in the case of public institutions, and at the market price in other cases. In this case the additional permission procedure of the connection and the expenses associated with it, plus the compulsory 15-minute schedule submission of the balance group of the feed–in system, should also be considered. In the case of smaller – 100–200 kW – systems, of appropriate scale, the on–site utilisation of the heat and electric power is also possible.

The appropriate sizing and selection of the motor is a task of crucial importance. The small energy plant can only be measured on the basis of real heat demand and heat utilisation, otherwise the desired saving will not be achieved. The utilisation of such a unit is ideal if there is continuous heat demand and the production unit is able to operate for 7 000 – 8 000 hours per year. It should be emphasised that appropriate, professional operation is of crucial importance. Small scale gas engine power plants can also be used for cold energy production by means of an absorption refrigerator. This complex method is called trigeneration.

It becomes evident from the above that the width of the range of engines provided by manufacturers is also important and small gas engines play a most important role. The selection ranges from 33 kW_e to 3–4 MW_e. Manufacturers build from the engines they have developed or the engines produced by the largest manufacturers (MAN, Mercedes, Perkins, MTU). The greatest capacity generator units are installed along with their own engine control system, which is supplied with a comprehensive, web–based monitoring system. The heat utilisation system is based on this, and the unit thus created is

installed on a board. Afterwards the complex is built into an indoor or outdoor container that is supplied with appropriate noise reduction. The system delivered to site is ready to use.

The small power station is a marketable product in itself. However, due to its high cost it might be interesting to consider it along with some kind of financial solution. In the case of traditional capital investment, the customer finances the system, which becomes his property, and thus he can enjoy the entire amount of the savings. The other end of the line is an ESCO (Energy Savings Company) contract, in which case an investor installs, operates and finances the system and supplies energy to the customer for 5–10–15 years depending on the contract. At the end of the contract the still modern system can be purchased at residual value. Table 5.2.1 gives a costs' comparison of different energy carriers: solid, liquid, gaseous – both traditional and RES ones as well as costs of energy derived from them (in reference to Hungary). It also gives a background for placing the costs related to natural gas used for energy generation. The data show that this fuel is a competitive option and also support the purposefulness of its extraction from geothermal water in particular cases.

Table 5.2.1. Comparison of expenses of different energy sources

Name	Calorific value	Density [g/cm^3]	Price	Price [HUF/MJ]
Solid fuels				
Charcoal	31 MJ/kg	0.35	60 HUF/kg	1.9
Coal	30 MJ/kg	0.80	30.5 HUF/kg	1.1
Lignite (briquette)	20 MJ/kg	0.75	23.5 HUF/kg	1.2
Wood pellets	18 MJ/kg	1.25	32 HUF/kg	1.7
Grass pellets	15 MJ/kg	1.10	42 HUF/kg	2.7
Sunflower seed pellets	21 MJ/kg	1.05	42 HUF/kg	1.9
Straw, corn stover, baled	17 MJ/kg	0.10	6 HUF/kg	0.2
Oak, acacia firewood	15 MJ/kg	0.50	18 HUF/kg	1.2
Liquid fuels				
Petrol	45 MJ/L	0.80	260 HUF/L	7.2
Diesel	43 MJ/L	0.85	250 HUF/L	6.8
Biodiesel	37 MJ/L	0.85	125 HUF/L	3.4
Sunflower oil	34 MJ/L	0.85	250 HUF/L	6.8
Bioethanol	27 MJ/L	0.79	200 HUF/L	5.4
Gaseous fuels				
Propane gas	46 MJ/L	0.0020	400 HUF/L	8.7
Natural gas	35 MJ/m^3	0.00080	101 HUF/m^3	3.0
Natural gas – with 40% price subsidy	35 MJ/m^3	0.00080	78 HUF/m^3	2.4
Biogas	28 MJ/m^3	0.00080	170 HUF/GJ	0.2
Household electric power			40 HUF/kWh$_e$	10.4
Electric power night-time operation controlled			21 HUF/kWh$_e$	5.7
Energy cost of geothermal heat pump in case of liquid heating system COP = 4-5				
Driven by electric power	Daytime operation 6–20 h	–	7 – 9 HUF/kWh$_e$	2.0 – 2.6
Driven by electric power	Night-time operation 20–6h	–	4 – 6 HUF/kWh$_e$	1.2 – 1.5
Driven by natural gas engine	24 hour operation	–	2 – 3 HUF/kWhe	0.6 – 0.8
Driven by biogas engine	24 hour operation	–	1 – 2 HUF/kWh$_e$	0.3 – 0.5

5.2.3 Operation of a small gas engine power plant

The operational principle of gas engines is similar to that of any other four stroke vehicle engine, the only difference being that it is fuelled by biogas, natural gas, or in this case, associated gas. The gas is introduced to the cylinders at the appropriate pressure and mixed with the amount of air required for combustion. This task is fulfilled by the turbocharger. Following the start-up procedure, the engine operates at a constant operational speed, unlike car engines. In the case of gas engines a capacity increase does not require a change of rpm, the excess performance originates in the increasing amount of gas-air mixture introduced into the cylinders. The required performance is controlled by the operator; the adjustment of the amount of gas mixture is carried out by the automatic controls. The generator connected to the engine shaft produces electric power, which ends up in the external electricity network by the introduction of an appropriate transformer. The synchronisation of the generator and the network, the protection, the monitoring and the control of the system and of the engine, is realised by technological control equipment. While the engine performs its role in the production of electric power, it also heats up (just like car engines). Besides, "waste heat" appears in various systems required for the operation of the engine. This kind of "heat source" is hot lubricating oil, heat produced in the production of the gas mixture and exhaust gas in particular. These kinds of heat, considered useless for the production of electricity, are utilised through heat exchangers for the heating of the water supplying the heating system. The utilisation of this quantity of excess heat means that the gas engines can achieve an efficiency exceeding 90%, whereas the efficiency of condensation electric power production does not exceed 50–55%, even in the most modern gas–steam turbine cycle. This difference ensures that the heat produced by means of gas engines can be supplied at lower cost.

Description of the technology

The gas engine produces electric power with favourable efficiency, at the same time the heat produced can also be utilised at the same rate. Part of the flow of water returning from district heating systems is introduced to the gas engine, where its temperature – by its recirculation from the feed side – is set at approx. 80C°. The temperature of the district heating water is increased by the heat transferred in the oil cooler, in the mixing cooler and in the water cooler of the engine cycle. A further increase in water temperature can be achieved by cooling the exhaust flue gas below 120°C. Afterwards the water, heated to approximately 99°C, is mixed with the water flow of the district heating system. In order to ensure the operation of gas engines in the transitional period or in the summer, air cooled heat exchangers (so-called forced heaters) are applied, which ensure the discharge of the excess heat into the environment. The gas mixed with the preheated combustion air reaches the appropriate level of pressure through the turbocharger driven from the flue gas side. The heated gas mixture cools down in the two-phase mixture cooler to the temperature optimal for the operation of the gas motor. The crank shaft, and thus the generator, is driven by the gas/air mixture burnt in the four stroke gas engine. Following operation the flue gas, by driving the turbocharger, enters the environment through the catalyser, the primary silencer, the flue gas/water heat exchanger, a further two silencers and the chimney. The NO_x content of the discharged flue gas does not exceed the value of 500 mg/Nm^3 (in accordance with ISO).

Utilisation of associated gases of geothermal waters by means of a gas engine

The technology developed by two industrial gas engineers, Miklós Ferenci and his colleague, József Heckl at the turn of the century, might not solve the problems of the Hungarian economy, which is in a vulnerable situation as far as energy supply is concerned. However, it might be of assistance. It is a well-known fact that the land of our country is extremely rich in geothermal waters, the energy

content of which is not utilised. The technology designed to recover then burn the methane dissolved in water aids the better utilisation of heat resources. The so-called associated gas can be transformed into heat and electricity by means of combined energy production in small gas engine power plants. On the basis of current regulations, the operator of the Hungarian electricity system purchases electricity obtained from renewable energy resources at fixed -– remarkably high – rates. Heat can be used for, amongst other purposes, the heating of spas. There is a third kind of business utilisation opportunity for recovered methane. In the carbon dioxide quota trade operated in the European Union, the recovery of methane – which does not enter the atmosphere as happens in the case of hot water wells – means a price six times higher compared to carbon dioxide. Therefore, the utilisation of geothermal water associated gas is an activity even more attractive from the business point of view.

Combined heat and power production

The expression means that from the same energy resource, i.e. burning gas in a gas engine, we produce electricity, produced by means of the generator driven by the gas engine, and we produce heat with high efficiency by utilising the heat production of the gas engine. Heat is produced by cooling water, lubricating oil, the heat utilisation of the flue gas and the cooling of the turbocharger. Generally, the ratio of electric power produced to heat is 40/60%.

A gas engine is a specially converted Otto engine, the rotational energy of which is transformed into electric power by a generator. They do not require a high pressure gas supply; they can be operated from the normal network. Their great advantage is that their load can be adjusted over a wide range, without fundamentally changing the overall efficiency. The production capacity ranges from a few kW_e to a few MW_e. There is the possibility of building modular systems and continuous expansion. The engines can be operated by means of remote monitoring. It is a rational solution for those in need of electricity and heat at the same time. It is also useful for those who would like to control and monitor their energy production and would also like to comply with environmental regulations. It is advisable to apply gas engine combined energy production in those areas where the demand for electricity, heating and cooling appears simultaneously, and the equipment is in operation for at least 6500 hours per year. Electricity purchased can be set against the electricity produced or the excess can be sold to the local electricity supplier at favourable prices.

The heat produced (which is water at 90°C or 127°C) can be used for sanitary hot water production throughout the year, it can be used for heating in winter, or we can even satisfy our industrial or agricultural heat demands. Gas motors are basically fuelled by natural gas, although biogas, propane gas or associated gas from geothermal wells can also be utilised.

Combined energy production based on natural gas as a basic energy resource might be a solution for those who would like to assure their energy supply under favourable economic terms, who desire continuous, good quality energy production, expect long–term, high efficiency operability, wish to pursue active environmentally friendly politics, and would like to control and manage their energy production and use individually.

The gas engine can be fuelled by natural gas, wood gas, biogas, landfill gas, mine gas (damps) and by the gas associated with geothermal wells.

Cogeneration

Cogeneration means the production of two different kinds of energy (electricity and heat) from an identical primary energy source – within one procedure, which can be realised by a gas engine or by turbines. Cogeneration is a rational and highly efficient solution for energy consumers who require heat and electricity simultaneously, and wish to control their energy use or are able to feed electric

power into the public network. Cogeneration has twofold aims, which are both closely related: on the one hand, combined energy production can be realised with remarkably greater total energy efficiency which results in significant primary energy savings, and thus cost reduction. On the other hand, due to lower fuel use, pollutant emissions (CO_2) are greatly reduced, which means environmental advantages.

Advantages of combined heat and power production:

- 86% of the energy input can be utilised,
- 37% of the utilisable energy is electricity, 49% is heat energy,
- as opposed to separate electricity production (condensation power plant) and separate heat production (boiler, heater), 35% less fuel (natural gas) is used, and there is less greenhouse effect producing carbon dioxide and less waste heat enters the environment,
- the investment – depending on its utilisation – returns in 3– 5 years,
- the gas engine ensures 97% availability, which means reliable long term operation (over 15 – 20 years).

Application areas:

- sanitary hot water production equipment for district heating systems,
- hospitals,
- office buildings of public institutions,
- larger hotels,
- swimming pools, spas,
- food processing plant (dairy industry, meat industry, etc.),
- chemical plant,
- agriculture: greenhouses (cultivation of grocery or flowers), temperature controlled water fish farms.

Trigeneration

The combined heat and power production described above is supplemented with absorption cooling. This means that this kind of gas engine heating–cooling–energy producing unit can be used in multiple ways. Besides electricity production, which is realised by the gas engine–generator unit, the heat to be utilised can be used for not only heating, but also cooling. Cooling capacity is 70% of heating capacity. As a result, electricity production can be sustained continuously for 7 800 – 8 200 hours throughout the whole year. In other words, trigeneration is the more advanced form of cogeneration, which by using heat, ensures the production of cold energy, by means of an absorption refrigerator. This technological solution is less common, despite the fact that cogeneration systems can be operated on a yearly basis with more utilisation and higher efficiency, achieving remarkable energy savings and complying with legal regulations. A trigeneration system can be developed by the application of well–known and proven technologies. The innovation lies in the connection of various pieces of equipment. Thus, the reliability of the equipment has been proven.

The payback time of trigeneration units is often more favourable than that of a traditional cogeneration system, the reasons for which are the following: more efficient energy use, number of operating hours per year increased due to broader scale energy utilisation, economies of scale: more significant heat use allows the selection of larger, thus more efficient, equipment which reduces the costs of the investment/built–in capacity (Ft/kW_e). By the use of the so far unutilised energy the negative effect of the associated gas, which is presently discharged into the atmosphere, on the environment ceases.

The implementation of the technology does not influence the operation of the well, no by–product is produced, and the composition of the geothermal water remains unaltered.

Advantages of trigeneration:

- advantages listed as the advantages of combined heat and power production,
- larger rate of utilisation potential by means of cooling in summer,
- wider range of possible applications.

Application areas:

- shopping centres,
- cultural institutions (cultural centres, theatres, etc.)
- office buildings of public institutions,
- hotels,
- hospitals,
- food processing plant (dairy industry, meat industry, beer industry, canning industry etc.),
- refrigeration plant,
- chemical plant.

5.2.4 Burning in gas heaters

Pure thermal utilisation can be realised by means of a Bunsen burner or a gas blower burner. In the case of heating, associated gas heaters operated by small capacity (10–30 kW_e) atmospheric burners or large capacity gas blower burners could be applied.

The gas heater obviously operates with a buffer tank, to which the heating of the building and the fermentation area is connected, the plant water supply and potentially the hay or grain drying is also included. It is a cost efficient solution for the heater if we use a flow through water heater (gas boiler), which is operated by an atmospheric burner and it is mainly used for the heating of plant water. The capacity is 5–30 kW_e. It is compulsory to build in safety features (e.g. a pilot burner) into all heating equipment in order to prevent the emission of unburnt gas.

Preparation and management of the gas

Gas discharged from geothermal wells is nearly 100% saturated with steam, or it may happen that due to its high hydrogen sulphide or other content, the pipelines, units, the gas gauge or gas consumer units corrode. In the case of intensive mixing, aerosol formation might take place, i.e. very fine liquid droplets exit the base material, which are taken and displaced by the gas. This might lead to crust formation.

The first rough dewatering of the gas takes place in the tanks and the pipelines, while it cools down to ambient temperature. The pipeline should not be exposed to frost nor should it be isolated. It should not take the form of a siphon, i.e. sink branches in the pipe network. It should be laid in such a way that the condensed water can flow back to the tank or the container. A freely laid gas pipeline is made of plastic tubes, whereas metal pipes are used within the building.

5.2.5 Degassing procedures

If the gas content of geothermal wells is not utilised, it should be removed or reduced below a given value in order to prevent explosion.

In compliance with Decree 12/1997 VIII. 29) KHVM degassing of geothermal waters belonging to gas hazard grades „B" and „C" must be carried out in order to ensure the safety of facilities and to prevent explosion. In the case of gas hazard grade "B", degassing must be assured by the application of operational methods and safety measurements. In the case of gas hazard grade "C" according to MSZ–10–226, degassing equipment must be provided to the National Standard, unless the total water consumption is a maximum of 5 m^3/day, or the water is utilised in an open area.

The gas hazard of geothermal wells is primarily caused by the methane content of the waters. If the amount of dissolved methane exceeds the value of 10 L/m^3, the plant must be pronounced a fire and gas hazard. The explosion limit of air containing methane is 5–15% by volume. From the point of view of safety the highest methane concentration in air should be 20% of the lower explosion limit, therefore, a maximum 10 litres of methane is allowed per m^3 of air (Bélteky and Korim, 1974).

In the geothermal water reaching the surface, gases are present in free and dissolved form due to the decrease in pressure. The ratio of dissolved and free gas is determined by physical and chemical factors. Important factors are the solubility of the given geothermal water, its saturation, its pressure and temperature relations and the components of the gas mixture.

The degassing procedure can be natural or artificial. Natural gas discharge takes place on the thermal air–water boundary due to the concentration difference between the two phases, and it finishes when the partial pressure of the given gas balances between the two phases. The intensity of gas discharge is determined by the initial concentration difference, therefore gas diffusion is more significant from waters with greater gas content (Karácsonyi, 1982). Natural gas diffusion takes place in the case of reservoirs. Natural gas diffusion at the normal state of the water can be expressed by the following equation (Karácsonyi, 1982):

$$G = K * F * \Delta C$$

where:

- G: amount of gas leaving the water [kg/h]
- F: surface area of the water with the atmosphere [m^2]
- K: diffusion coefficient [m/h]
- ΔC: pressure driving the gas diffusion process [kg/m^2]

The diffusion coefficient (K) is the amount of gas passing through one unit of surface between the liquid and gas phases in a unit of time, the value of which is 0.005–0.15 m/h at the plain phase limit and 0.1–0.3 m/h in the case of displacement. The pressure driving the gas discharge process (ΔC) can be determined from the initial gas concentration and the equilibrium gas concentration (Karácsonyi, 1982).

Artificial degassing means physical or chemical interventions that accelerate the degassing process of the geothermal water reaching the surface. Where physical degassing is concerned, the aim is to accelerate the diffusion of gases, whereas in the case of chemical interventions the aim is to bind the gas by the addition of additives. The major factors facilitating physical degassing are the following (Karácsonyi, 1982):

- an increase in the surface area by breaking the water surface into drops (resulting from the natural gas discharge equation, gas diffusion is directly proportional to the surface area, therefore gas diffusion increases with its increase),
- favourable layout of the surface area in order to reduce surface tension (inert gas bubbled through the liquid from the bottom increases gas diffusion efficiency),

- increase of the speed of gas diffusion (for example by increasing flow intensity),
- increase of the force driving the gas diffusion process (air is mixed with gaseous water prior to its introduction into the degassing equipment; by increasing the pressure difference between the water field and the gas field, the diffusion procedure accelerates.

Factors facilitating gas diffusion work together in practice, therefore, in the selection of the degassing procedure, the original phenomena should be examined including various parts of the process, taking into consideration all the circumstances influencing the process simultaneously (Karácsonyi, 1983).

The simplest degassing procedure is two–stage production. In the first stage the recovered gaseous water enters a tank where part of the gas is discharged at atmospheric pressure. In the second stage the water minus a significant part of its gas content is pumped from to the tank into another tank (e.g. water tower), where proper ventilation should be ensured (Bélteky and Korim, 1974).

In the case of geothermal waters, gas separator tanks are often used for the separation of liquid and gas phases. The gas separator tanks can increase the force driving gas diffusion, the size of the specific surface, or even increase the specific surface maintaining the force driving the gas diffusion at the same time. The appropriate degassing technology might be selected in the knowledge of specific problems.

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6 AUTHORS' CONCLUDING REMARKS

The Handbook presents selected results of the research and work conducted within the framework of the GEOCOM project. Particular attention has been paid to the numerous positive effects of the investment projects at the three pilot sites: Galanta (Slovakia), Montieri (Italy) and Mórahalom (Hungary). These represent best practice in geothermal energy management in combination with other renewables and measures for the rational use of energy. They also clearly demonstrate that such energy systems are feasible and entirely rational in Central and Eastern Europe as well as in other parts of Europe. It should be noted that they bring multiple benefits as demonstrated by the cases of the three GEOCOM pilot cities, *inter alia*:

- an increase in the use of local renewable energy sources, including geothermal energy (which can be extracted in many countries as well as in Central and Eastern Europe, but has so far been overshadowed by other RES);
- the local utilisation of the combustible gases present in geothermal waters for small-scale co-generation of electricity and heat (in most other cases such gases are treated as waste because of their non-industrial quantities);
- modern, innovative energy and technological solutions;
- improved energy efficiency and the more rational use of energy (thanks to e.g. thermal retrofitting measures, innovative solutions, modern management and monitoring systems);
- significant environmental effects (manifesting themselves, *inter alia*, in reducing or preventing the emissions of CO_2 and the other greenhouse gases generated during the combustion of fossil fuels for heat or electricity generation purposes);
- a decrease in the cost of heat and electricity and their prices;
- increased comfort of operation and maintenance of energy systems for their users;
- high social acceptance of the introduction of geothermal and other renewable energy sources among residents and direct beneficiaries, and satisfaction with the effects achieved (including without limitation that resulting from lower energy costs);
- increased awareness of the renewable energy resources available to local communities, local governments and other stakeholders, and the consequent recognition of their considerable potential and reliability, especially in heat production;
- the active involvement of local communities in the work carried out through participation in information activities concerning the introduction of geothermal energy and other renewable energy sources and also the rational use of energy;
- an impetus to modern and sustainable local economic development;
- a practical contribution through specific local activities to the achievement of the EU goal stated in the 2009 "3x20%" Directive by individual regions and Member States. Demonstrating that this can be successfully achieved through the more widespread use of highly promising geothermal energy resources in CEE countries. The parameters and quality of these resources provide a clear case for finally treating geothermal energy on a par with other RES (and its neglected position

so far has been evidenced by, among other things, its marginal share in the current final energy consumption statistics in all CEE countries as well as in many other European states).

CEE countries have prospective geothermal resources suitable for broad-ranging development – both independently and in combination with other local RES. Relevant examples are provided e.g. in the best practice cases presented in this Handbook. These are diverse and adjusted to the specific features of individual pilot sites in terms of urban planning and construction, the demand for energy as well as the different types of renewable energy resources and their parameters. Other parameters taken into account include the different sources of heat and electricity used prior to the implementation of the GEOCOM investment project, different levels of per capita income as well as the differences in the prices applicable and the costs incurred by GEOCOM beneficiaries in individual municipalities.

The research and work conducted as well as their diverse effects were received very favourably by the local mayors, communities and direct beneficiaries, i.e. the users of the innovative energy systems installed thanks to the GEOCOM project.

All this makes the best practice examples from the three pilot sites of the GEOCOM project relevant and useful for many other towns and cities in Central and Eastern European countries with adequate local renewable energy sources (geothermal and other ones). This is because these examples may convince stakeholders of the feasibility of the rational and innovative development of these sources and the multiple associated benefits, and may encourage them to take appropriate measures in this regard.

Contributors to this Handbook, and all the GEOCOM partners, are convinced that it is possible and entirely feasible. This opinion has been to a large extent reinforced by the aforementioned project. We therefore hope that the best practice examples presented in this Handbook (as well as other results and project reports) will prove useful to a wide range of interested municipalities, communities and other stakeholders from different localities and countries in Europe, since this has been one of the objectives of this important project.

The direct objective of the GEOCOM project was to demonstrate successful, innovative and inspiring examples for the use of geothermal energy for heat generation employing innovative, environmentally sustainable and cost competitive technologies combined with innovative energy efficiency measures and retrofitting. All three pilot– sites' cases presented in this Handbook should be considered as intermediary phase between ongoing investments and planned projects in the future that will take into account the lessons learnt from the Concerto phase. The authors of this Handbook and all GEOCOM partners hope that the described project results and approach will help to take decisions, facilitate future investment in geothermal resources and help its better understanding and perception among the investors, local and regional decision makers, the public and other stakeholders.

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