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Geothermal Update of Hungary 2000–2004

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ABSTRACT

Information is provided on the status of geothermal direct heat use in Hungary, with emphasis on developments from 2000 to 2004.

During the four years since WGC2000 there have been 12 new geothermal developments in Hungary.

The geothermal energy was utilized in direct use, no electricity has been generated.

The summarized data relative to direct use in Hungary in Hungary in slight degree was increased (utilization of geothermal heat was decreased in agriculture and increased in communal heating and SHW supply).

The main consumer of geothermal heat is remain the agriculture, however is remained among the leaders on the utilization of geothermal heat in the World.

Geothermal energy utilization is estimated to be 342,5 MW, of geothermal power and it currently supplies 2905,2 TJ/yr. of heat energy through direct heat application in Hungary, as of January 1, 2004.

Geothermal heat pumps represent about 4,0 MW, of installed capacity.

The quantity of the produced thermal water for direct use in year 2003 was approximately 22,9 million cu.m. with average utilization temperature of 31 ^{o}C.

The main consumer of geothermal energy is remain the agriculture (57%).

The proportion of geothermal energy utilization in the energy balance of Hungary, despite the significance proven geothermal reserves, is low (0,29%).

1. INTRODUCTION

This paper represents results of the geothermal development in Hungary between 2000 and 2004.

Geothermal development covers the thermal water management and utilization of the geothermal energy represented by geothermal fluids for direct use.

1. GEOTHERMAL BACKGROUND

The Carpathian Basin, with Hungary at its centre, is one of the biggest sedimentary basins in the world and has an extensive geothermal system "Geothermal energy has no knowledge of country borders".

The main geothermal reservoir systems in Hungary are the Mesozoic carbonate-karstic basement rocks and the Pliocene-Upper Pannonian porous sedimentary formations. Their wells produce water that is mostly in the low-to-medium temperature range (30–100 ^{o}C). According to different assessments of its geothermal resources (Boldizsár, 1967; Bobok et al., 1988 and Árpási, 1992) Hungary has the biggest underground thermal water reserves and low-to-medium enthalpy geothermal potential in Europe.

2. GEOTHERMAL UPDATE

The main data of geothermal energy utilization for direct uses in Hungary by January 1, 2004 as reported by Árpási, shown in Table 1.

As a result of the analysis for the geothermal update of Hungary by 1 January, 2004 the following conclusions can be drawn:

a) the geothermal energy is utilized in the form of direct use (Table 2)

b) areas of the direct use

agricultural utilization

communal use (space heating and domestic hot water)

industrial use

The number of geothermal heat utilizing organizations was 130, the number of the settlements utilizing geothermal energy was 45, and the number of spas utilizing geothermal heat for direct use was 10 in 2004.

As for the agricultural purpose geothermal heat utilization, however, Hungary is among the leaders on geothermal heat in agriculture the World list (195.1 MW_t and 1501.8 TJ/year).

d) As was analyzed in a study (Árpási, 1998) the current situation of geothermal heat utilization in Hungary as indicated in Table 2 shows that the quantitative utilization is good in the World comparison, but with respect to efficiency, we lag considerably behind, because:

the geothermal energy utilization does not have the necessary unambiguous legal basis,

the thermal water production and direct use are o extensive nature,

the efficiency of the mostly only seasonal type of geothermal heat utilization is low,

fundamentally no reinjection is applied.

3. GEOTHERMAL DEVELOPMENTS

3.1. Direct use

The research of new possibilities for the direct use is first of all reasonable due to the fact that it is mostly seasonal in Hungary, too, i.e. traditional applications are mainly used only in the heating season, in open systems without reinjection.

Regardless of the fact whether the geothermal energy is utilized in the agriculture, industry or for the district heating, it can be equally stated that the old systems by now have became physically outdated and obsolete.

As indicated in papers (Korim, 1997 and Árpási, 1998) the integrated, multipurpose thermal water utilization in energy cascade use is playing especially an important role.

3.2. Cost analysis of thermal water utilization for direct use in open and closed system (without and with reinjection)

Utilization of geothermal fluids planned to be realized in closed system: production – utilization – reinjection of thermal water in the doublets or triplets. Two possibilities exists for forming of doublets:

a) drilling of new production and reinjection wells

b) recompletion of abandoned CH-boreholes drilled by Hungarian oil and gas companies for production and reinjection wells.

The variant b) could be preferred due the following motives:

a) Recompletion of an abandoned CH-boreholes into water production/reinjection well is essentially cheaper than drilling of new wells. Well-known fact that drilling, completion cost of new wells inside of given geothermal project equal to 40% of the total cost of the project.

Recompletion cost of existing abandoned CH-well to a water production/reinjection wells is equal to 10% of above mentioned cost for new wells.

b) All geological well logging and well-test data etc. are became well-known for the users;

c) The given abandoned CH-borehole has a full casing construction, cement, perforation, etc.

According to a ranking process carried out of MOL-Geothermy Project among 3000 abandoned CH-wells have been drilled in course of oil and gas exploration in Hungary about 800–1000 wells suitable for the production of geothermal fluids, and amount of wells with measured/expected well-head temperature (higher than 100 ^{o}C) during production are 70–80 pcs. Highest well-head temperature in Hungary measured of production of wet steam – is 171 ^{o}C.

In base of abandoned CH-wells (recompletion, bottom hole and surface measurement “long term” production test etc, a doublet would formed suitable for multistage integrated use of geothermal fluids ie. power generation – direct use – balneological use, in framework of a **geothermal pilot project.**

Cost analysis was carried out in base of real data of doublet Szeged-Felsőváros (1995–1996) that was formed by recompletion of 2 abandoned oil wells.

Geothermal reservoir: Upper Pannonian sandstones or Mesozoic rocks of basement

Variants of the estimation: Variant A and B

According to a data are given in Table 4 the total implentation cost are:

Variant A (drilling of new production and reinjection wells), M USD: 1,56

Variant B (existing production well and drilling or

recompletion of new reinjection well): 1,40

Operation costs in open system (without reinjection) and in doublet (with reinjection)

The main items of the operation costs are following:

power supply

personal and maintance

royalty (Decree 48, 20 § (2), 1993)

Cost of power supply (average) is: 1,75 ÷ 2,0 USD ¢/KW_h

Cost of personal and maintance (average) is 30% of the operation costs.

Royalty is equal to 2% of value of the utilized geothermal in case of utilization heat step less than 50% if the utilization step more than 50%, no paid the royalty:

Maintance (average) estimed cost is equal to 5% of the total establishment cost of the project.

The aim to increase geothermal energy use will consequently result in the considerable reduction of air pollution (e.g. reduction of CO_2 emission is 806 kt/year).

4. CONCEPTIONS OF GEOTHERMAL ENERGY UTILIZATION IN HUNGARY

A several studies were elaborated during last 5 years between 1999 and 2004.

In conceptual study (Árpási, et.al 1999, modified in 2002) are given the planned total and specific utilization data of geothermal energy in 2010 year.

The total energy consumption of Hungary was 1,020 PJ in 2002. The proportionate rate of geothermal energy, based on the status on 1 January, 2004, was **2,9 PJ**, which represents a **0.29%** proportionate rate in the total energy consumption of the country.

It is a realistic objective to enhance the proportionate rate of thermal energy in the national energy balance to **1%**, which means **10.5 PJ/year** geothermal heat energy utilization being projected, to the total energy consumption of 2002.

The time period of this objective is between 2003–2010 (8 years).

The extension of the utilization to the planned extent can be realized in two ways:

By the increase of he efficiency of the existing heat utilizing systems,

By the establishment – by investment – of new geothermal heat utilizing systems.

The total capital cost in the case of new geothermal heat utilization investments is 300 million USD, based on a specific capital cost of 400 USD/kW_t (Árpási, 2002).

The **10,5 PJ** geothermal heat quantity can be produced in the utilization systems with calculated geothermal power of **540 MW$_t$**.

The detailed cost/price analysis was carried out in 2002 according the conception elaborated by Árpási, M. et.al. (1999–2002).

The results of these calculations are given in Table 5.

4.1. Requirements on geothermal energy related to EU membership of Hungary

Before 1990, a year of major political and economic changes in Hungary (conversion of the country to democracy and a market economy), fossil fuels were cheap and frequently sold at prices below production cost. A great deal has changed since then, especially in terms of more realistic electricity and fossil fuel prices (but not natural gas). The attitude of the competent Hungarian authorities to the exploitation and utilization of geothermal energy, as a major renewable energy source (RES) in Hungary, is that of indifference, as it was beforehand, despite the declaration made by the Hungarian government(s) in support of this energy form.

The European Union, on the other hand, has assigned high priority to all renewable energy sources, not only in its declarations, but also in a tangible way, putting real programs into operation. EU member states have declared their approval of the progressive development of RES in a number of official documents, such as the White Paper, Blue Book etc., in which they set the objective of attaining a minimum market penetration by the RES of 12% by the year 2010. The EU Directive on the promotion of electricity produced from RES obliges the member states to raise the level of electricity produced from RES to 22% by 2010, from the current level of 13.9% in 2002.

Hungary became a fully-paid member of the European Union on 1 May, 2004.

The EU directives obliges Hungary as a member of the EU on promotion of the utilization of renewable energy sources (RES).

In Hungary there is no electricity generation from geothermal energy, and the only renewable source that could be used for electricity generation is geothermal. Legislation on the production of “Green Electricity” in Hungary was enacted as Decree 56/2002 on 28 December 2002, issued by the Ministry of Economy and Transport, enforcing the obligatory purchase of electricity from RES at cost-covered prices (8–12 US¢/kWh). In Hungary the contribution of RES is now (2003) at 3.6% (82% comes from burning wood), compared to an average of 5.8% for the European Union.

The EU member states, as well as other industrialized countries with adequate conventional energy sources, are promoting the utilization of RES for mainly ecological reasons, but also in order to reduce their dependence on imports of fossil fuels, essentially crude oil and natural gas, which are for the most part located in politically and strategically unstable countries in the Near and Middle East and Russia.

According to the EU Directives 2001/77/EU on the promotion of utilization of the renewable energies (RES) including electricity produced from RES given in Table 6.

The EU obliges for Hungary on promotion RES is a very hard task for Hungarian Governments.

In result of analysis of international – mainly European – updates on utilization RES could be ascertainbled that Hungary is strongly behindhanded with promotion on utilization RES in all among them on utilization of geothermal energy.

The possibility and conditions of performance of EU obliges on promotion of utilization RES – within them geothermal energy – by E. Dr. Unk Jánosné et.at., 2004.

The summarized results of analysis carried out in study this for planned geothermal utilization in 2010 (direct use + power generation) are given in Table 7.

Proportion of different renewable energy sources in geothermal development between 2004–2010 for full filment of obliges related to Hungary in base of EU directive 2001/77 is shown in Fig. 1.

4.2. Possibility of multipurpose integrated utilization of geothermal fluids including power generation

The multipurpose utilization of geothermal fluids (power generation + direct use + balneology) in integrated system stands to reason, because of efficiency of utilization thermal water significantly higher than in one-step utilization e.g. in open systems without reinjection what is common in Hungary, now.

The multistage utilization thermal waters existing only in some places in Hungary, i.e.:

Spas	Type of utilization
Harkány	direct use (heat pump) + balneology
Kecskemét	direct use (heat pump) + balneology
Bük	direct use (heat exchanger) + balneology
Tiszaújváros	direct use + balneology
Hódmezővásárhely	direct use (communal heating and SHW supply) with reinjection + balneology

The main data of the biggest multistage utilization system of thermal water in city Hódmezővásárhely given in Table 8.

Process diagram of the utilization of thermal heat (1st and 2nd Phases) in City Hódmezővásárhely is shown in Fig 2.

The plant of multistage utilization of geothermal energy is being constructed by Aquaplus Ltd. in city Zalaegerszeg with planned geothermal capacity 8,0 MW$_t$.

Indications of geothermal fluids medium and high enthalpy have been appeared in course of oil and gas exploration in Hungary.

In Fig 3. are shown the deep exploration wells with in a which were measured data (slug test and DST) of geothermal indications mainly from Middle Triassic dolomites and the basement rocks, with outflow temperature more than 100^{o}C.

According to preliminary assessment about 80 abandoned CH-wells as suitable after recompletion of there into doublets (production) reinjection.

The measured data in oil and gas exploratory well K-6 are given in Table 9. The well-head one of recently abandoned CH-well is shown in Fig 4.

The doublet suitable for multistage utilization of geothermal fluids including geothermal based power generation.

Process diagram of the multiple integrated use of geothermal fluid with outflow temperature more than 100^{o}C and with high content of dissolved gas is shown Fig 5.

This utilization system of geothermal fluid would be includes a following steps:

electricity generation by binary unit (ORC, Kalina type process),

electricity and heat production by gas engine,

absorption cooling,

heating for greenhouses,

industrial use,

aquaculture,

balneological use.

5. HEAT PUMPS

(Present situation and future on utilization of heat pumps in Hungary)

A well-known fact that the heat pump is a patent for invention of Hungarian scientist prof. Heller (1948), he suggested in 1950 that the building of the Hungarian Parliament would be heated by heat pump.

"No one is prophet in his own country"

The fact to be noted that building of Parliament up to 1953 was heated by geothermal heat extracting from thermal water coming from production well in the Margaret Island.

Situation on heat pump market in Hungary is miserable, now.

Hungary has a big backwordness in utilization and production of heat by heat pumps in comparison with neighbouring countries (Slovakia, Slovenia, Czech Republic).

The Committee on that Pump of EU in 1996 offered to Hungary a financial support, therefore this support without payback was not invoked by Hungary with explanation that use of heat pump would be has a viability in some cases, only.

The very low level of use at heat pump in Hungary would be reduced to a following facts:

a) spreading of heat pump no supported by Hungarian state, on the other hand the natural gas has a price support, of 50%,

b) hindering "activity" of very strong natural gas lobby in country;

c) In "technical" side some delusions are being flourished in Hungary concerning heat pumps, as:

Extraction of the energy in value 3-4 times more than invested energy (COP = 4-5) is impossible. It is more unbelievable than "perpetuum mobile";

in estimation of efficiency of heat pumps losses of 60% connected with electricity generation have to be taken into consideration;

existing high implementation costs of heat pumps;

in case of signifacut spreading of heat pumps in Hungary the coal fired power plants wit low efficiency must be holded upwards.

In consequence of above outlined reasons heat pumps have been implemented only in some places e.g Spas Harkány and Kecskemét, Meat-packing plant Szekszárd, Kalocsa etc.

According to a results of analysis given in study compiled by E. Dr. Unk Jánosné et. al (2004) the operation cost of heating by heat pumps in 37% lass then a natural gas fired heating, this difference will be increased in next future because of on obligatory increasing of consumer price of natural gas in value 100% and suspension of subsidization for it.

The results of analysis made in study E. Dr. Unk Jánosné et.al (2004) for comparison of operation costs in case of use of heat pumps and costs of gas-fired heating are given in Table 10.

According to a this study planned value of utilized geothermal heat by heat pumps in year 2010 will be equal to **0,31 TJ/a**.

The necessary conditions for achieving this goal are:

Implementation cost in period 2004-2010:

96 M USD (total)

Governmental financial support:

24 M USD (25%)

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Table 1. Actual data of the geothermal energy utilization in Hungary by 1 January, 2004

Geothermal heat utilization are (direct use)	*Quantity of produced thermal water* M cu.m./year	*Utilization heat stage** ΔT, ^{o}C	*Utilized geothermal heat* (TJ/year) PJ/year)	*Thermal power* MW_t
1	2	3	4	5
1. Agriculture	10.498	34.1	1501.8 (1.5)	195.1
2. Communal heating and SHW supply	12.398	27.0	1016.7 (1.01)	103.0
3. Other	3.37	27.4	386.8 (0.39)	44.6
Total	22.9	31.0	2905.2 (2.9)	342.5

* Weighted average

Table 2. Data of thermal water management in Hungary

Estimated reserves of geothermal fluids			*Thermal water production* Mcu.m/a (kg/s)	*Type of thermal Water utilization*	*Percentage according to the type*	*Utilized geothermal energy*	*Percentage of utilized geothermal heat in comparison with dynamic reserves* %
Static volumetric reserves, cu.km	*Dynamic reserves,* (at ΔT=40 ^{o}C)						
	Volumetric Mcu.m/a	*Heat content,* PJ/a					
1	*2*	*3*	*4*	*5*	*6*	*7*	*8*
4000	380	63.5	103.0 (3266.0)	1. Balneology	36.7	2.9	3.8
				2. Drinking water supply	29.9		
				3. Agriculture	24.5		
				4. Space heating, SHW and industria	8.9		

Table 3. Geological, technical and economical data of geothermal doublets

Parameters	Variants	
	A	B
1. Lithology of geothermal reservoirs	Upper Pannonian (Pliocene sandstone)	Secimentary and methamorfic rocks of basement
2. Depth of production well, m	1500	2500
3. Outflow temperature, ^{o}C	60	100
4. Temperature of reinjected spent water, ^{o}C	35	40
5. Utilization heat step, ΔT ^{o}C	25	60
6. Yield of thermal water, cu.m/h	100	500
7. Peak load hours of utilization, h/season	4000	
8. Utilized geothermal heat, GJ (PJ)	25120 (0,025)	120600 (0,12)
9. Market value of utilized geothermal heat[1], M USD[2]	0,141	0,673

[1] Market value of the utilized geothermal energy was estimated in base of price of natural gas in Hungary equal to 4,46 USD ¢/GJ (30 April, 2004)

[2] 1 USD = 250 HUF (30 June, 2004)

Table 4. Investment cost of doublets for utilization of geothermal energy in Hungary

Technological units	*Cost of wells and surface loops in open systems (drilling of new wells) M USD*		*Cost of recompletion of abandoned CH-boreholes into reinjection well of the doublets (establishments of reinjection)*	
	A	B	A	B
	2	3	4	5
1. Drilling cost of new production well	0,317	0,468	0	0
2. Technological units technology of water treatment and reinjection	0,172	0,264	0	0
3. Drilling cost of new reinjection well	0,34	0,52	0,34	0,52
4. Cost of implementation of units of power supply, measurement and control Architecture (implementation of buildings) engineering and management costs	0,180	0,256	0,12	0,172
Implementation cost (total)	***1,009***	***1,512***	***0,46***	***0,692***

Table 5. Actual data of utilization geothermal energy for electricity generation in 31 December, 2000 in comparison with estimated data of planned utilization in 31 December, 2010 according to a modification of the study (Árpási, M. et.al. 2002)

	Period of realization of the conception: 2003–2010	*Basic year* 2003	*Year of final realization* 2010*
1.	**Electricites generation**		
1.1	Installed capacity of electricity generation, MW_e	-	80
1.2	Quantity of produced electricity GWh/a	-	600[1]
1.3	Specific cost of power generation USD/kW_e	-	1000[1,4]
1.4	Implementation cost (total) M USD	-	80,0[4]
1.5	Production cost of geothermal based power generation USD ¢/kWh	-	5–7,2
2.	**Direct use**		
2.1	Installed capacity of direct use MW_t		1030
2.2	Utilized geothermal for direct use PJ/a	325,0	11,4
2.3	Specific implementation cost M USD/kW_t	3,0	400
2.4	Implementation cost (total) M USD	-	282
2.5	Value of replaced natural gas M PJ/PJ	-	34[4]
2.6	Volume of replaced natural gas M USD	-	410
2.7	Value of replaced natural gas M USD	-	4,92[2, 4]
2.8	Pay-back period years	-	5,7

[1] Calculated in base of actual power generation in the World

[2] In comparison with natural gas purchase price 120 USD/1000 cu.m. (1 March, 2002)

[3] Costs and prices in 1 January, 2002

[4] no discounted costs (prices)

[5] without power generation

* implementation of binary (ORC, Kalina) units and geopressured type plant (Fáb-Nsz)

Table 6. Directives of EU on promotion of utilization of RES for Hungary

Parameters		*Years*	
		2002	*2010*
1.	Proportion of RES in total energy consumption, %		
	in EU countries (averaged)	5,8	**12,0**
	in Hungary	3,6	**12,0**
2.	Production of electricity from RES, GWh/a	19	**1700***
3.	Proportion of geothermal based electricity generation in Hungary, %	-	**3,6***

* The original prescriptions of EU were 5600 GWh/a and 12%, successively

Table 7. The planned parameters of geothermal energy (direct use + electricity generation) in 2010

Parameters	*Direct use*			*Power generation*		
	Actual (2002)	*Growth*	*Total in 2010*	*Actual* (2002)	*Growth*	*Total in 2010*
1. Quantity of utilized geothermal energy, PJ/a	2,8	8,7	**11,6**	-	-	-
2. Installed capacity						
direct use, MW_t	342,5	1076	**1418,9**			
power generation, MW_e				-	98	**98**
3. Quantity of produced electricity, GWh/a						
binary units	-	-	-	-	604	
binary units + gas engine					142	**746**
geopressured type power plant					462	**462**
4. Total investments cost for promotion of utilization of geothermal energy, M USD	**2109,2**					
5. Financial support, required in total investment cost, %				**33**		
6. Specific cost of financial support, USD/MWh				**200**		
7. Total amount of financial support for promotion of geothermal energy, MUSD				**410,2**		
8. Total amount of required financial support for promotion of utilization of RES in period 2004–2010 in Hungary, MUSD	**2109,2**					

Table 8. The main data of geothermal energy utilization system (I–II Phase) in city Hódmezővásárhely

Utilization	*Quantity of utilized thermal water* thousand cu.m/year	*outflow temperature in wells, °C*	*Utilization step ΔT, °C max*	*Utilization geothermal heat TJ/year*	*Geothermal power, MW_t*	*Production cost, USD/GJ*				
						Geothermal heating			*Gas-fired utilization*	
						SHW supply	*Communal heating*	*Utilized geothermal heat (total) USD/MW_t*	*SHW*	*Communal heating*
	Thermal water production									
1. SHW supply	160000	43	23	-	0,57	0,32	-	-	1,68	-
2. Communal heating	257000	80-86	40-60	122,0	7,4	-	1,92	-	-	5,52
3. Summarized	**417000**	-	-	-	**8,0**	-	-	**308**	-	-

Table 9. The main-measured data (DST) in one of former oil and gas exploration well (recently abandoned CH-well)

Parameters	*K-6 well*
1. Interval of perforations, m	**3031-3039**
2. Lithology: clays and marles of Jurassic and dolomites of Middle Triassic	**2990-2500**
3. Measuring depth, m	**2840**
4. Choke, dia, mm	**10**
5. Flow-rate of water, cu.m./d (l/sec)	**414** (4,8)
6. Production rate of natural (dissolved) gas, cu.m./d	**2260**
7. GFR, cu.m./cu.m	**5,46**
8. Pressures, MPa	
8.1. formation pressure in static conditions	**33,052**
8.2. well-head pressure in closed conditions (tubing)	**6,096**
8.3. well-head pressure in dynamic conditions (tubing)	**5,135**
9. Formation temperature, ^{o}C	**144 (at 2840 m)**
10. Estimated flow-rate of water, cu.m./day (34,7)	**3000** (34,7)
11. Out-flow temperature at estimated water flow-rate, ^{o}C	**155**

Table 10. Comparison of operation costs in case of different type of heating systems for family house

Utilization	*Unit of measure*	*Efficiency of heating*	*Operation cost USD¢/kWh*	*Total cost USD/a*
1. Fuel (boiler-oil)	litre	0,7	9,4	753,6
2. Natural gas for house holders*	cu.m	0,8	1,72	137,8
3. Coal (imported)	kg	0,65	2,97	128,7
4. District heating (gas fired boilers)	USD¢/cu.m./a	0,74	5,98	478,8
5. Heat pump (water coupled)	**kWh**	**4,00**	**2,1**	**167,5**

* governmental subsidized price of 50%

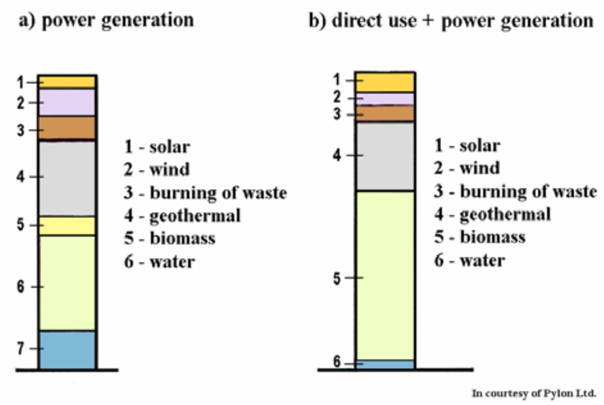

Fig. 1. Planned proportion of different RES in 2010 (%)

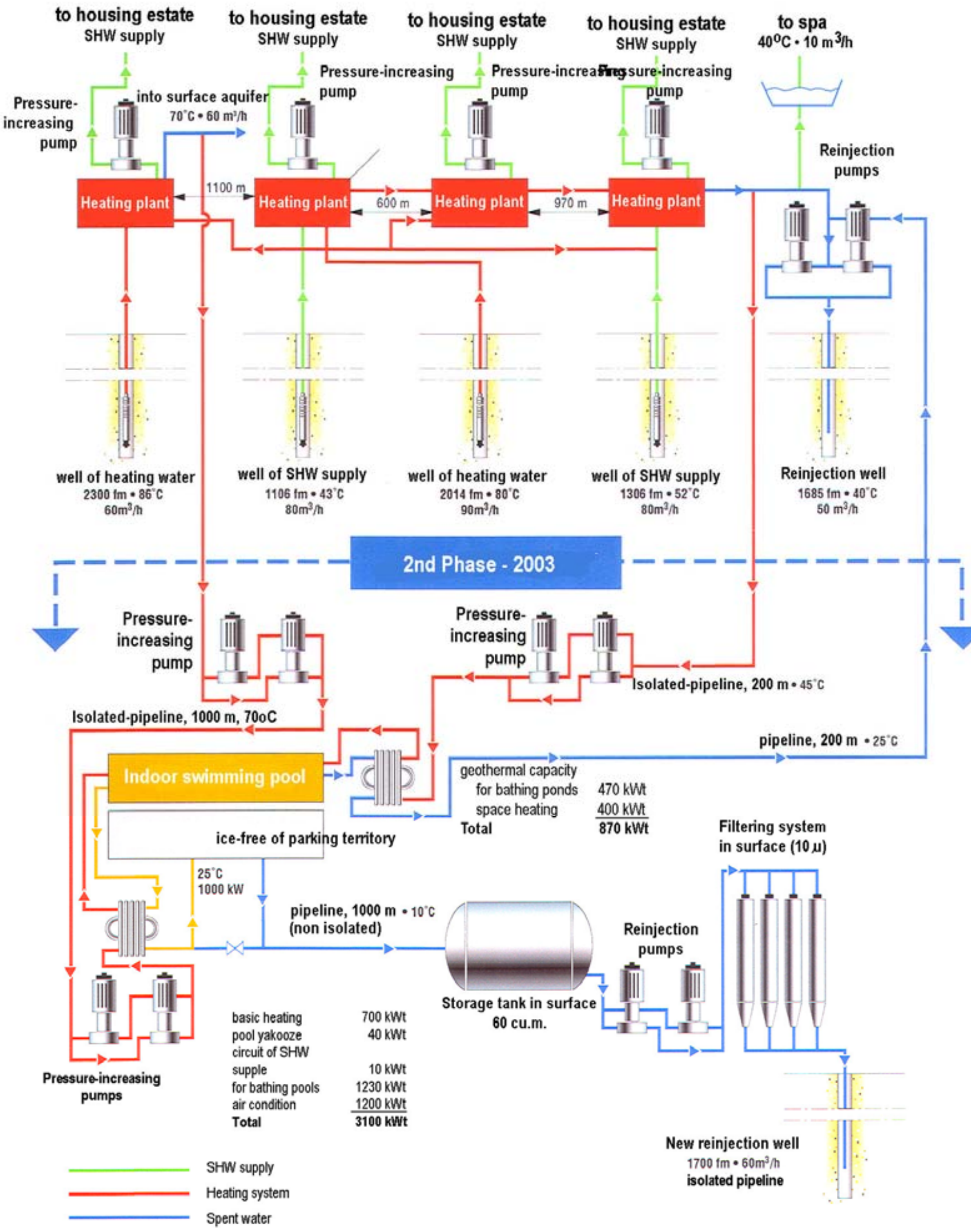

Fig. 2. Process diagram of the multi-purpose utilization of thermal water in city Hódmezővásárhely (2004)

Courtesy of Aquaplus Ltd. and the Hungarian Society on Geothermal Energy (HSGE)

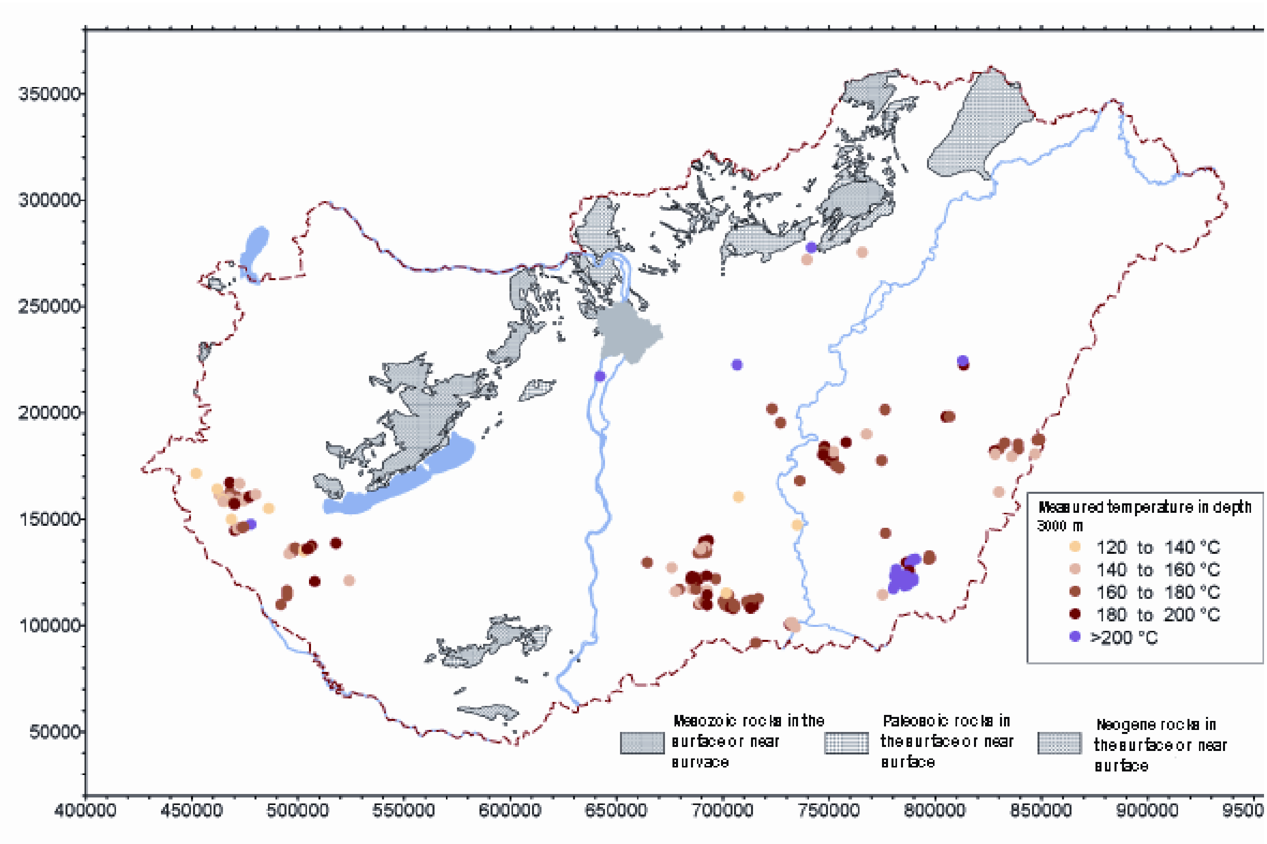

Fig 3: Map with CH-exploration wells in which were measured temperature more than 120°C in Mesozoic formations with depth less than 3000 m

Fig 4: Well-head of abandoned CH-well X1 suitable for wet-steam production

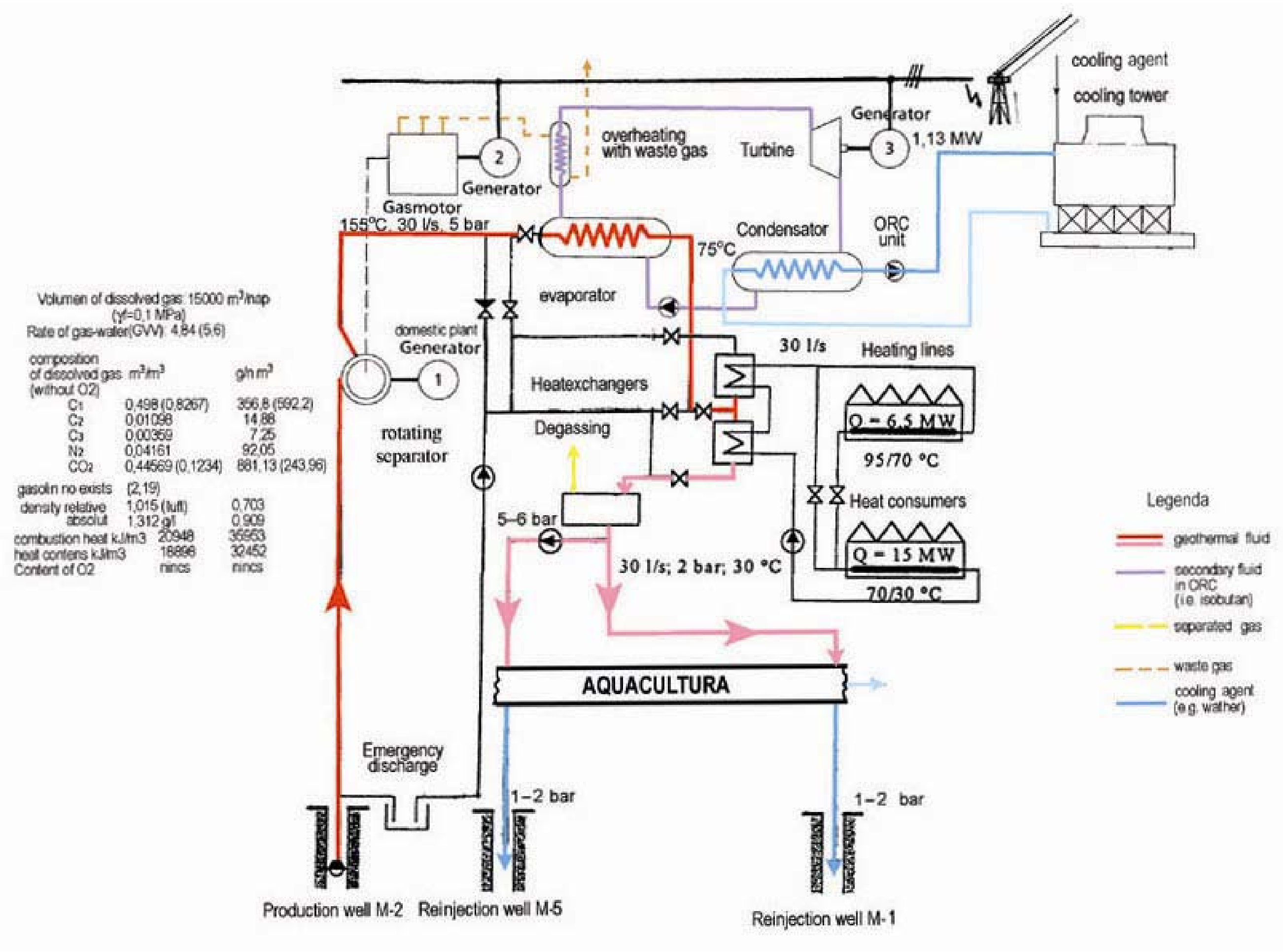

Fig 5: The process diagram for the multiple integrated use of geothermal fluid wet steam with high content of dissolved gas X area (Hungary)

TABLE 1. PRESENT AND PLANNED PRODUCTION OF ELECTRICITY

	Geothermal		*Fossil Fuels*		*Hídro*		*Nuclear*		*Other Renewables (specify)*		*Total*	
	Capacity MWe	*Gross Proc.* GWh/yr	*Capacity* MWe	*Gross Proc.* GWh/yr	*Capacity* MWe	*Gross Proc.* GWh/yr	*Capacity* MWe	*Gross Proc.* GWh/yr	*Capacity* MWe	*Gross Proc.* GWh/yr	*Capacity* MWe	*Gross Proc.* GWh/yr
In operation in January 2004	no	no	5172	16588	7	26	1840	13964	2	7,4	7025	30600,2
Under construction in January 2004												
Funds committed, but not yet under construction in January												
Total projected use by 2010	**98**	**624**	**5172**	**16588**	**26**	**142**	**1840**	**13964**	geothermal: 98 biomass: 60 wind: 96 hydro: 26 solar: 3 biogas: 15 communal waste: 12 **310**	geothermal: 525 biomass: 344 wind: 178 hydro: 142 solar: 3 biogas: 40 communal waste: 48 **1384**	**7446**	**35302**

TABLE 3. UTILIZATION OF GEOTHERMAL ENERGY FOR DIRECT HEAT AS OF 31 DECEMBER 2003

1) I = Industrial process heat
C = Air conditioning (cooling)
A = Agricultural drying (grain, fruit, vegetables)
F = Fish and animal farming
S = Snow melting
H = Space heating & district heating (other than heat pumps)
B = Bathing and swimming (including balneology)
G = Greenhouse and soil heating
O = Other (please specify by footnote)

2) Enthalpy information is given only if there is steam or two-phase flow

3) Capacity (MWt) = Max. flow rate (kg/s)[inlet temp. (°C) - outlet temp. (°C)] x 0.004184 (MW = 10^6 W)

or = Max. flow rate (kg/s)[inlet enthalpy (kJ/kg) - outlet enthalpy (kJ/kg)] x 0.001

4) Energy use (TJ/yr) = Ave. flow rate (kg/s) x [inlet temp. (°C) - outlet temp. (°C)] x 0.1319 (TJ = 10^{12} J)

or = Ave. flow rate (kg/s) x [inlet enthalpy (kJ/kg) - outlet enthalpy (kJ/kg)] x 0.03154

5) Capacity factor = [Annual Energy Use (TJ/yr)/Capacity (MWt)] x 0.03171

Note: the capacity factor must be less than or equal to 1.00 and is usually less, since projects do not operate at 100% of capacity all year.

Locality	Type[1]	Maximum Utilization					Capacity[3]	Annual Utilization		
		Flow Rate	Temperature (°C)		Enthalpy[2] (kJ/kg)			Ave. Flow	Energy[4]	Capacity
		(kg/s)	Inlet	Outlet	Inlet	Outlet	(MWt)	(kg/s)	(TJ/yr)	Factor[5]
130 organisations and persons	G							429,6	1882.9	0,4
2655 dwellings in 9 cities	D							154,8	636,3	0,5
2 users	I							6,1	28	0,5
6 spas	O*							86,6	358	0,8
TOTAL								677,1	2905.2	

Note: please report all numbers to three significant figures.

***Direct use in the spas (but no bathing and swimming)**

TABLE 5. SUMMARY TABLE OF GEOTHERMAL DIRECT HEAT USES AS OF 31 DECEMBER 2003

[1] Installed Capacity (thermal power) (MWt) = Max. flow rate (kg/s) x [inlet temp. (°C) - outlet temp. (°C)] x 0.004184
or = Max. flow rate (kg/s) x [inlet enthalpy (kJ/kg) - outlet enthalpy (kJ/kg)] x 0.001

[2] Annual Energy Use (TJ/yr) = Ave. flow rate (kg/s) x [inlet temp. (°C) - outlet temp. (°C)] x 0.1319 (TJ = 10^{12} J)
or = Ave. flow rate (kg/s) x [inlet enthalpy (kJ/kg) - outlet enthalpy (kJ/kg) x 0.03154

[3] Capacity Factor = [Annual Energy Use (TJ/yr)/Capacity (MWt)] x 0.03171 (MW = 10^6 W)
Note: the capacity factor must be less than or equal to 1.00 and is usually less,
since projects do not operate at 100% capacity all year

Use	Installed Capacity[1] (MWt)	Annual Energy Use[2] (TJ/yr = 10^{12} J/yr)	Capacity Factor[3]
Space Heating[4]	100,6	1016,7	0,5
Air Conditioning (Cooling)	no	no	no
Greenhouse Heating	196,7	1502.5	0,4
Fish and Animal Farming	no	no	no
Agricultural Drying[5]	no	no	no
Industrial Process Heat[6]	1,8	28	0,5
Snow Melting	no	no	no
Bathing and Swimming[7]	no	no	no
Other Uses (specify)	42,9	358	0,8
Subtotal	**342,5**	**2905.2**	2,2
Geothermal Heat Pumps	4,0 (estimated)	no data	COP: 3-4 (averaged)
TOTAL*	**692,0**	–	–

* with the balneological use: 350 MW_t (estimated)
[4] Includes district heating (if individual space heating is significant, please report separately)
[5] Includes drying or dehydration of grains, fruits and vegetables
[6] Excludes agricultural drying and dehydration
[7] Includes balneology
Note: please report all numbers to three significant figures.

TABLE 6. WELLS DRILLED FOR ELECTRICAL, DIRECT AND COMBINED USE OF GEOTHERMAL RESOURCES FROM JANUARY 1, 1999 TO DECEMBER 31, 2003

1) Include thermal gradient wells, but not ones less than 100 m deep

Purpose	Wellhead Temperature	Number of Wells Drilled				Total Depth (km)
		Electric Power	Direct Use	Combined	Other (specify)	
Exploration[1)]	(all)	no	no			
Production	>150° C	no	no			
	150-100° C	no	no			
	<100° C	no	4			
Injection	(all)		2			
Total			6			12

TABLE 7. ALLOCATION OF PROFESSIONAL PERSONNEL TO GEOTHERMAL ACTIVITIES

(Restricted to personnel with a University degrees)

(1) Government
(2) Public Utilities
(3) Universities
(4) Paid Foreign Consultants
(5) Contributed Through Foreign Aid Programs
(6) Private Industry

Year	Professional Person-Years of Effort					
	(1)	(2)	(3)	(4)	(5)	(6)
2000	no	2	3	no	no	20
2001	no	2	2	no	no	21
2002	no	2	2	no	no	25
2003	no	2	2	no	no	25
2004	–	–	–	–	–	–
Total	no	2	2	no	no	25

TABLE 8. TOTAL INVESTMENTS IN GEOTHERMAL IN 2003 US$

Period	Research & Development Incl. Surface Explor. & Exploration Drilling	Field Development Including Production Drilling & Surface Equipment	Utilization		Funding Type	
			Direct	Electrical	Private	Public
	Million US$	Million US$	Million US$	Million US$	%	%
1990–94	–	–	–	–	–	–
1995–99	0,25	0,1	0,15	no	40	60
1999–2003	0,30	0,15	0,21	no	80	20