POSSIBILITIES FOR ELECTRICAL ENERGY GENERATION FROM GEOTHERMAL ENERGY IN HUNGARY

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ABSTRACT

The potential for geothermal energy production in Hungary is among the beet in all Europe. In the majority of cases balneological and agricultural utilisation prevails. High pressure and high temperature reservoirs containing fluid have been found during the hydrocarbon research. An overall study deals with the geological - geophysical possibilities in Hungary. It sizes up the possibilities of geothermal energy production The chances of electrical energy production using geothermal fluid are excellent. This paper presents the above mentioned possibilities and characteristic parameters of geothermal energy that can be produced in Hungary.

1. INTRODUCTION

During 1992-1993, we were assigned a study to survey of the geothermal potential in Hungary. In the course of our work to complete this study, we accomplished, inter alia, the following objectives.

1 Surveyed the geothermal potential in Hungary, estimated inventories of geothermal fluids in terms of volumetric and heat values;

2 Examined the current state of geothermal energy utilisation, the possibility to extend utilisation; home perspectives of power generation via geothermal;

3 Dealt with the relation of geothermal energy utilisation and environmental protection;

4 Identified the interest and role of oil industries (MOL Co. Ltd.) in geothermal energy utilisation with regard to geological-technical possibilities, the overall cost effectiveness, legal and administrative situation and jobs.

5 Elaborated geological-technical recommendations at project level to establish and operate reference plants as a first stage in geothermal energy utilisation, in the fields assessed aa the most promising from proprietary, geological and technical aspects.

In making recovery calculations, based on the source potentials and the available parameters of surface utilisation systems, we determined the cost effectiveness for each project. We worked out proposals to prepare feasibility studies for on-site control in practice of possibilities outlined theoretically.

2. GEOTHERMAL POTENTIAL OF HUNGARY

The earth's crust under the Carpathian basin, and particularly Hungarian territory, is thinner than average, hence the geothermal attributes of this country are highly favourable. The average of the ground heat flows directed out from the earth's interior ranges among 90-100 mW/m^2, a value two times higher than the continental average.

The average geothermal gradient representing the temperature rise per unit increase in depth is 0.020-0.033 °C/m on earth in general, and usually 0.042-0.066 °C/m in Hungary.

Due to these thermal potentials, the stratum temperature at 1,000-meter depth reaches and exceeds 60°C.

There is no volcanic activity in Hungary and it does not belong to the geothermally anomalous zone of volcanic origin The conductive heat flow upward from the magma represents the basic geothermal source of energy.

Here, thermal waters filling the porous, permeable thick, sedimentary rock structures exceed 6 kilometres at several places and those sediments serve as the dominant carrier of geothermal energy.

Due to the anomalously high stratum temperatures mentioned above, the temperature of thermal waters from depth to the surface represents a considerable quantity of heat.

3. PAST AND PRESENT THERMAL WATER PRODUCTION

Productions and use of the deep seated subsurface water for various purposes can be trace back to historical times in Hungary, with intensive production only after the Second World War.

In Table 1, the total quantity of deep seated subsurface water brought to the surface to the present is summarised. As seen, the yield of produced water is significant.

Table 1
The yield of subsurface waters produced in Hungary since 1950, according to the current state on 31 December 1992.

Period (year)	Great plain (Million m^3)	Small plain (Million m^3)	Other (Million m^3)	Total (Million m^3)
1950-1960	64,7	1,3	15,5	81,5
1960-1970	346,8	4,9	45,3	397,0
1970-1992	6792,3	217,0	1373,4	8392,7
Σ	7190,2	223,2	418,7	8871,2

Thermal water utilisation areas are as follows:

		Percentage, % (1986)
a)	Drinking water supply	29.9
b)	Balneology	27.3
c)	Agriculture	26.0
d)	Communal heating	1.3
e)	Other	15.5

In Hungary, the number of thermal waters' wells amounted to 1106, in accordance with data of 1990 [VITUKI, 1990], and the total water quantity brought to the surface amounted to 600 Mm^3/year [VITUKI, 19931. With respect to the qualitative figures, Hungary remains at the level of international comparison [World Energy Conference, 1989].

	Direct heat utilisation purposes, MWt	Of this for agricultural energy, MWt	Production of electric energy, MW	Our placing in the world ranking list
HUNGARY	1580			3.
		565		1.
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As seen, we are ranked topmost for agricultural utilisation. The largest such systems are located in the south Plain (Szentes, Szegvár, Szeged, Szarvas), where the upper Pannonian water resources are used in a system of direct seasonal consumption.

Analysing the former and present conditions of domestic thermal water utilisation, the following can be stated:

a) basically, the utilisation has a double aim: direct heat utilisation and balneology;

b) utilisation is seasonal, covering only some 180 day in a year; on the other hand, the extent of heat utilisation within the applications for balneological purposes is not considerable;

c) the utilisation is extensive, the hot water used is not recirculated, but discharged to surface water reservoirs, living waters at national level, thus the majority of users consume the stored water resources in direct way;

d) the technical standard of utilisation is low at most sites, reaching only low efficiency, with a ΔT of only 30-35°C. This is confirmed by a comparison with the French factual data geothermal utilisation [Journees Internationales, 1991], that shows a utilisation efficiency some three times, under the recirculating conditions applied there;

e) there are no heat pump anywhere in Hungary for increasing utilisation efficiency,

f) there is no electric energy generated using geothmal basis.

When devising measures to be taken to increase the efficiency of domestic utilisation, attention will be paid to the specifics of the geothermal energy resources, namely:

- that geothermal energy represents not an alternative, but an additive energy resource that can be utilised in addition to other energy carriers, mainly fossil ones,
- that geothermal energy is practically inexhaustible, although concentrated only in some places here, as a local energy resource,
- that energy resource, with relatively low in their energy level and temperature, are hard to match with energy utilisation and heating system of other forms.;
- extending the utilisation is hampered by current legal difficulties (such as proprietorship).

In our view, the requirements and possibilities for optimising the domestic geothermal energy are as follows:

- to develop a reservoir system with consideration to environment protection and water conservancy, regulations are essential;
- the primary aim is for an integrated, multistage utilisation systems that unifies the electric current production - heat, salt and gas utilisation - that is non-energetic types of utilisation;
- only the implementation of financing, mining, heat utilisation, and services as a whole shall serve as utilisation framework;
- settling the proprietary conditions (Mine Law);
- financial support (tax and credit allowances) granted by the state, with preferred conditions for enterprises set up to start with geothermal energy utilisation, and encouraging entrepreneurial interests. Inclusion of foreign capital, technical equipment and expertise.

4. THE POTENTIAL FOR ELECTRICAL ENERGY GENERATION USING GEOTHERMAL RESOURCES

Electric energy generation is the first step in an up-to-date multistage geothermal energy utilisation that integrated with others, forms an efficient system.

Electric energy generation:

- reduce the seasonal nature, thus increasing efficiency, since a "non-stop" operation throughout the year can be implemented.
- reduce the local nature of geothermal energy, since the geothermal energy converted into electric power can be transported anywhere.

Within the scope of this study, we performed a separate review of domestic power generation using geothermal basis from the view of resources and technical possibilities, as well as with regard to efficiency as compared to other energy forms.

On the basis of our investigations and foreign experiences, the resource basis of binary power generation (ORC), in Hungary, is represented by the following:

a) thermal water wells with an outflow temperature above 80°C that had a hot water production capacity of 18 Mm^3/year in 1992 [KFH, 1991, VITUKI, 1993.;

b) wells low in hydrocarbon, deepened for petroleum and natural gas exploration, that showed considerable geothermal potential during stratigpraphic testing.

Among the non productive wells targeted at hydrocarbons, we took into account wells drilled to the Mesozoic reservoirs, with special attention to wells disclosing geothermal indications of high pressures and high temperature.

Areas suitable for electric current generation of basement type were outlined by [Stegena, 1987, Dövényi and Horváth, 1988], carried out special measurements [Nagy et al., 19911, including the outstanding magnetoelluric measurements to research the basement structure .

For example, DST measurements and the capacity test performed in the Well Nagyszénás-3 showed fluids in considerable quantity and at temperatures, suitable for power generation:

Produced fluid quantity	: ≈ 1,890 m^3/day
Production casing-head pressure	: 4.5 MPa
Production casing-head temperature	: 171 °C

Similar areas suitable for power generation were disclosed in the southern part of the territory between the Danube and Tisza rivers, in the Békés subsidence, in the fields of Zala Deep Karst, the Mid-Transdanubian areas and in other parts of the country.

For our preliminary calculations, we considered only the existing, oil and gas wells and the thermal wells in operation, reckoning with no new wells to be installed.

Our calculations of possible power production were based on foreign analogies and factual data [Bronicki and Doron, 19911 and are summarised in Table 2.

The expected cost effectiveness of current generation was studied.

With regard to power plant investment costs, the specific investment costs of geothermal mini power plant based on foreign factual data in

Table 3.
Preliminary **survey** of **Hungary's potential** for electric power **generation using** geothermal *energy*

	1. Thermal **wells (outflow** temperature **higher than** 80°C)	2.**Non-** ***producing*** wlls for **hydrocarbons**	Total
Utilisation heat ,Δ T, °C	≈20	≈ 40	
Quantity of electric energy[1]**,GWh/year**	**4,8**	210	215
Electric **power** (built-in), **MW**	1	24	25
tons000/year	**104**	**374**	478
Nd	**10** / **1,0**	**37,4**	38 / **4,8**
Saving of annual emission of CO_2 as harmful materials[4], [5]**tons000**	10	*700*	810
savingofannual emissionofNO, **as** harmful **materials,tons**	250	950	1100
savingofannual emission of CO as harmful materials, **tons**	500	3000	3500

1 current generation efficiency (COR), $\eta_e = 0.8$
2 Power plant **efficiency,** $\eta_e = 0.85$
3 Import oil price: **US$100/ton; US$1** = HUF100
4 Calculated **upon** ***the*** principle of "shortage **powa** plant'
5 For a power plant specific **value,** q_0 = **10465 kJ/kWh**

the function of geothmal fluid **temperature** for a built-in power of up to ***500*** kW

Temperature of primary liquid (hot water)	specific investment costs in US$/kW
140°C	1.348
80°C	**2.805**

For ORC current **generators** with a power above **1** MW, the specific investment *costs are* up US$1,000/kW.

Comparing the specific investment and current production costs of power **generation,** *on* geothermal basis, to the specific **costs** of domestic power plant models and the **import** investment **price,** a realistic picture **is** given of the cost effectiveness of domestic **geothermal** power generation.

Table ***5.***
Cost data of electric power plants of various models in Hungary (1991)

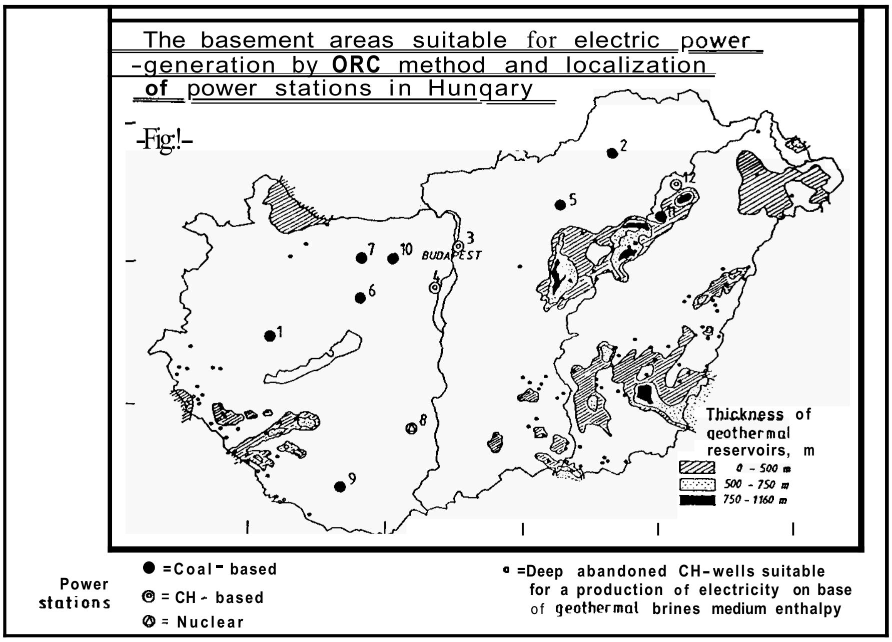
Electric power plant model	specific **US$/kW**	m F)
Lignite power station	**1600**	-
Coal power station		0,128 / **(3,8)**
Oil base power station	!	0,0225 / (3,0)
Nuclear power station	**1900**	0,015 / (2,0)
Double cycle	**750**	0,0225 / (3,0)
Import (CIS)	-	0,030 / **(4,0)**
Geothermal (ORC)	**1000-2850**	0,0135 – 0,03 / (1,08 – 2,4)

Among investment costs of electric power **generated using geothermal, the** coats of well **construction** were. not **taken** into account. The environmental saving effect of **the** geothd current **generation** (saving of **damages cawed** by **harmful missions)** were **expressed in Forints.**

From this **analysis** it *can* be **stated** that:

- with a view to the specific investment costs, the combined cycle **vapour/gas** power stations offer the **most** benefit. **The** investment **cost** of geothermal power **generators** is comparable to the **other** power plant model, **and** the **costs** are inversely proportional to the built-in electric power of the ORC unit to be **installed.**
- as for the **costs** of power production, nuclear power stations **alone** stand **ahead** of ORC electrical power generator. As for **the** operating coats not included in **this** comparison, the ORC **units is the cheapest to operate** and there are **no concerns** such as disposal of spent fuel **as** in **the case** of nuclear power **stations;**
- electric power generation **using** geothermal is cheaper **than imported** power, **so** the country's dependence *on* imports would be reduced;
- **utilising our geothermal** *energy* **resource** for electric power **production** purposes will not *create.* **a great** quantity of power in absolute terms, but it is an environment **saving** technology that does not pollute the **air** with harmful materials **and** this system **can** be **supported by using** the adequate **part** of **the** existing wells law in hydrocarbons.

Following the available geological **data,** maps of **isothermal depths, etc., we identified** the areas suitable for **geothermal** electric energy **production** throughout the *country* with considerations taken to factual **data** of the **existing** borings law in **hydrocarbons and** to a depth **interval** of 4,000 meters temporarily limiting the domestic boring potential **(Figure** 1).



5. ENVIRONMENTAL ASPECTS OF GEOTHERMAL ENERGY UTILISATION

As is commonly known, the utilisation of thermal water as a source of *energy* is environment-saving, since

- its *energy* conversion and recovery does not involve air pollution, because no harmful material is emitted into the air, in contrary to *coal*, hydrogen carbon, etc.;
- if the water transferring its heat power is reinjected into the aquifers, then even the contamination of the *surface* waters with heat ar salt will not occur.

The protection of our increasingly polluted environment continues to favor the utilisation of clean sources of *energy such* as geothermal energy.

When *expressing* environmental pollution in financial terms and quantifying the environmental damages, the first steps to support the utilisation of *energy* types causing contamination and environments saving technologies have been taken [Jászay and Rádonyi, 1991].

To quantify the emission of harmful materials polluting *the* atmosphere that is spared as a result of the small-scale utilisation of geothmal energy, applicable under the pment conditions without extra cost, we made some calculations.

Initial data for calculation:
(Heat quantity included in geothermal energy utilisation)

1	Annual quantity of produced thermal water: 380 Mm^3/year (stratum temperature above 50°C)	
2	Efficiency of surface utilisation:	40%
3	Heal step of utilisation, ΔT	40°C

The results obtained from these calculations give informative values far saving harmful emissions due to the thermal water utilisation for energetic purposes to the above designed *extent* (70-30°C), (Table 5).

Table 6
Estimates *on* emission saving

Parameters	CO_2	NOx emission	CO
1.Saved emission	218 million t	2690 t	8965
2.Ratio of the damage caused by emission in Hungary, percentage	≅ 3,0	1,2	--
3. Advantage from the saved emissions, million HUF/year	1520	2500	--

6. CONCLUSIONS

The current situation of our geothermal energy utilisation was analysed. As *stated,* quantitative figures of utilisation are favourable from a *global* point of view, but as for efficiency, a significant set-back is seen, because:

- *the* nature of thermal water production is extensive, destroying inventories far the most part;
- the extent of exclusive seasonal heat utilisation is low;
- water reinjection is not applied;
- *regulations on* environment protection are not meet,
- them is no electric current generation on geothermal basis.

As also stated, the inventory identified of thermal wells and wells deepened by *oil* industries but poor in hydro-carbons is suitable for production of electricity wing binary generators (ORC). Basement areas with reservoirs of medium and high enthalpy, suitable for current generation were identified.

From a *preliminary survey,* it was established that introducing the electric power generation *on* thermal bases would result in the following:

The quantity of produced electric current:	215 GWh/year
The quantity of petroleum to be *replaced* (imported):	500,000 tons/year
The value of the above:	4.8 bill. HUF/year
Saving of annual emission of harmful materials:	810,000 tons -CO_2 1,100 tons -NO_x 3,500 tons -CO

The investment and operational costs of electric power *generation on* geotheimal basis, as compared to domestic power plant models and import prices were studied.
As for introducing *the* geothermal power generation - under special conditions, the comparison *is* favourable.

The good beneficial effects of purification of domestic air space and environment known as *contaminated*, of the environment saving utilisation ability of geothermal *energy* sources. Adhering to the environmental responsibilities undertaken by the government would be highly promoted by integrating the thermal water inventories as an additive *energy* source in the national *energy* supply system

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