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Annual Utilization Factor – Prerequisite for Feasibility of Direct Geothermal Energy Use

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ABSTRACT

The price of the energy produced; therefore the feasibility of direct geothermal energy use largely depends on the annual utilization factor which has to be above certain value to obtain sustainability, competitiveness and further development. Speaking about low temperature geothermal resources (up to 100°C), this can be achieved either by single steady consumers (like industry) or with combination of users to enable full year utilization of the resource as also the full available capacity (temperature difference).

On the other hand, there are the available potential consumers determined with the local social, economical, geographical and traditional background. Consequently, when development of low-temperature geothermal resource is in question careful approach and strategy for its implementation is necessary. But, also, as new development offers an opportunity from the start to be set at sound basis and in a timely manner to define the expectations for future expansion and development.

Furthermore, the combination with other locally available renewable energy sources would enable local self-sustainability and energy independency – important factors to boost the local economy and social progress (job creation, emigration prevention). Finally, the orientation towards sustainable use of renewable energy sources redounds to clean environment, making the region desirable place for living and tourism.

In the paper an overview is made of the possible low-temperature geothermal energy consumers, obtained annual utilization factor, possible combinations with other RES and expected results and benefits. It concerns potential regional geothermal development in Macedonia.

1. INTRODUCTION

Macedonia belongs to the countries with relatively high utilization of renewable energy sources. This is due to the large utilization of fire wood and hydro resources. Also, Macedonia has long history on direct use of geothermal energy. From the other side the main characteristic of the country is agriculture meaning rich solar radiation and considerable biomass residues whose use is at symbolic level.

The present use of geothermal energy is much lower than the available installed capacities, while the Strategy for RES utilization foresees increase in the production by 5 times up to 2020. To achieve this target, serious actions are needed in adapting legislation and regulations, in formation of real price for the heating unit, in promotion and facilitation of investments, in research and development, but maybe most important are the actions which should be taken by the Government.

The key to successful development of geothermal energy in the Balkans requires a combination of political commitment and decision making as well as support mechanisms including well defined governmental targets, technological advances and public acceptance. (Bojadzieva, 2008)

Geothermal energy development in Macedonia is already more than 20 years in stagnation. The reasons are multiple and discussed many times. New developments of geothermal energy use are hardly expected due to the economic situation in the country and global economy crisis. However, there are possibilities to improve the operation and productivity of the existing capacities by increasing their annual utilization factor and where appropriate by combination with other RES. Such investments are much lower than development of new projects and can bring benefits in many aspects.

2. RES UTILIZATION IN MACEDONIA

With RES participation of 13.8% (3016 GWh) in the final energy consumption in 2005 yr., Macedonia belongs to the countries with relatively high utilization of these types of energy resources.

Biomass resource, mainly represented by firewood and charcoal (80%), has significant place in the energy balance of Republic of Macedonia with 166 ktoe (1930 GWh; 6950 TJ), participating with 6% in the total primary energy use or 9.5% in the total final energy consumption. The share of biomass in total RES used in RM is 53%. There are also other types as agricultural residuals (branches, rise husks, straw, peelings, etc.), where large part of the straw is used for fertilization, forage and cellulose production (therefore not available for energy purposes). The major use of the biomass as energy source is in the households (430000 units or 76%) for space heating, covering 30-33% of the total energy demand.

The first biodiesel fuel factory in RM has been opened in 2007 yr., with annual capacity of 30.000 tons. As raw material, imported unrefined rape oil is used.

Current hydro-energy potential in Macedonia is represented with the big hydropower plants (installed capacity of 550 MW, average annual production 1400 GWh) and small hydropower plants (installed capacity 27 MW, average annual production 80 GWh).

Macedonia has long year experience in geothermal energy use, but the last 20 years is a period of stagnation of the geothermal development. From 21 ktoe annually in 2001 yr., the production has dropped to 9 ktoe (≈400 TJ or 110 GWh) in 2006. In the total primary energy use, geothermal energy participates with 0.4% and in the final energy use with 0.5%. The use of this potential is at local level and due to the relatively low temperature (the highest is 78°C in the Kocani region), it is mainly utilized for greenhouse heating, while the geothermal fluids have considerable utilization in balneology.

The geothermal, as final energy is planned with 400-520 GWh up to 2020 yr. To accomplish this target, beside already undertaken activities for utilization of the existing wells and location of new ones, additional actions from the side of the Government are necessary.

Solar thermal energy is at symbolic level of utilization (mainly for sanitary water heating), although the geographical position and climate offer very good perspective. It is expected that solar thermal systems will become more attractive when the real market price of electricity will be introduced in 2015 yr., as also expected additional increase due to the emitted greenhouse gases.

On the other hand, owing to the preferential feed-in tariffs, there is pronounced interest for solar photovoltaic (PV) systems for power generation. Nowadays, the planned 10 MW installed capacity in PV plants is already engaged.

Concerning wind energy, the installed capacities are symbolic. Several studies for determination of optimal locations for construction of wind generators and assessment of the wind energy potential have been made so far. (Strategy for RES utilization, 2010)

2.1 Geothermal energy application in Macedonia

So far, 18 geothermal fields are known, with more than 50 geothermal wells and springs. The total outflow is about 1000 l/s, with temperatures between 20 to 78°C.

The use of the thermal waters in Macedonia is comprised of several geothermal projects and many thermal spas. They are all completed and operate from the 80-ties of the last century. The use of the potential for energy purposes is on local level. Due to the relatively low temperature (the highest is in the region of Kocani), it is mainly used for heating greenhouses and minimal quantities are used for space heating of some administrative buildings, hotels and schools. There are have been industrial uses in Kocani as well (paper factory, rice drying), but they are out of operation for a long period. It is very rare practice to heat the spa facilities with geothermal energy, but nowadays is gaining increased interest.

Table 1 summarizes the energy characteristics of the three largest geothermal projects in Macedonia. Relatively high value of the capacity factor is due to the overexploitation of the resource during the heating season, since none of the greenhouse complexes utilize additional heat source when the outside air temperatures are low. Another obvious characteristic is the high outlet temperature. Also, evidently, greatest part is used for greenhouse heating either cited as district heating – those systems utilize very small portion for heating public buildings while the rest is used for heating greenhouses.

Table 1: Annual geothermal energy utilization

Locality	Type	Maximum Utilization			Capacity	Annual Utilization		CF
		Flow Rate	Temperature (°C)			Ave. Flow	Energy	
		kg/s	In	Out	MWt	kg/s	TJ/yr	
1	**D**	**53**	**69**	**30**	**8.65**	**35**	**180.05**	**0.66**
	G	30	69	30	4.89			
	G	10	69	25	1.85			
	B	8	45	25	0.67			
	H	13	69	40	1.58			
2	**G**	**21.5**	**61**	**30**	**2.79**	**15**	**61.14**	**0.69**
3	**D**	**180**	**75**	**30**	**33.90**	**57**	**338.32**	**0.31**
	G	170	75	30	32			
	H	10	75	40	1.46			
4	**H**	**80**	**50**	**40**	**3.35**	**5**	**6.60**	**0.06**
			TOTAL		**48.69**		**586.11**	**0.43**

1 – Bansko, 2 – Istibanja, 3 – Kocani, 4 - Negorci
D-District heating, G-Greenhouse heating, B-Baths

3. ANNUAL UTILIZATION FACTOR

Sustainable geothermal utilization involves energy production at a rate, which may be maintained for a very long time (100-300 years). This requires efficient management in order to avoid overexploitation, which mostly occurs because of lack of knowledge and poor understanding as well as in situations when many users utilize the same resource, without common management. Energy-efficient utilization, as well as careful monitoring and modeling, are essential ingredients in sustainable management. Reinjection is also essential for sustainable utilization of geothermal systems, which are virtually closed and with limited recharge. (Axelson. 2005)

Geothermal systems are characterized by high investment cost. The investment in geothermal systems consists essentially of the preliminary design, drilling, surface equipment and sometimes retrofitting the heating systems to geothermal heating. The annual operating costs are low. These costs contain only maintenance and power for pumps (downhole, circulation, injection). Heat engineering based on geothermal water is profitable when the scale of heat production and low operating costs make up for unavoidable and relatively high capital expenditures connected mainly with drilling costs. (Kuzinak, 1990)

Geothermal heat production is a supply technique for the base load of large consumer systems. The high expenditures on the development must be refinanced by heat sales with possibly high numbers of full load utilization hours.

Geothermal energy use is closely connected to district heat supply, within a higher capacity range. Large industrial, but above all agricultural plants (greenhouses), offer considerable consumer potentials, too. (Jenei, 2010)

Geothermal energy is typical base load energy. The total costs are essentially determined by the fixed capital costs. The specific costs per unit energy decrease almost proportionally with the increase of the heat sales (service life of the plant). The use of a geothermal heat supply presupposes the assessment of local heating sales. The bigger the connected load of a heat consumer/district heat supply network is - more favorable the demand characteristics (number of full load utilization hours) are. The lower the heating network temperatures are, in particular of the return flow temperatures, the more favorable the conditions are for geothermal heat supply. In other words, the higher the annual utilization factor is, the lower specific cost per unit energy is obtained and the shorter the ROI period is. (Jenei, 2010)

Annual heat utilization of geothermal capacity is described with: average flow (m_{av}), extracted energy (Q_{an}) and capacity factor (CF) or annual utilization factor, with following relations: (Thorhallsson S. and Ragnarsson A., 2008)

$$P = m_{max} \cdot (T_{in} - T_{out}) \cdot 0.004184 \text{ [MWt]}$$

$$Q_{an} = m_{av} \cdot (T_{in} - T_{out,r}) \cdot 0.1319 \text{ [TJ/yr]}$$

$$CF = 0.03171 \cdot Q_{an}/P$$

P - geothermal system capacity
m_{max} – maximal flow [kg/s]
Q_{an} - energy use
m_{av} – average flow [kg/s]
CF - capacity factor

3.1. Strategies to increase CF

Figure 1 gives clear indication and proof that the unit heat price decreases with the mass flow and CF increase. Therefore, the strategies to obtain high values of CF would be:

1) To maximize the flow rate (to the sustainable limits)
2) To maximize the temperature drop by:
   - Consumers which can provide as low as possible return temperature.
   - Cascading of consumers or heating systems.
3) To select heat consumers with high and as constant as possible thermal needs.
4) Coordinated utilization (daily and seasonal).
5) Short-term storage (to provide even daily or seasonal supply).

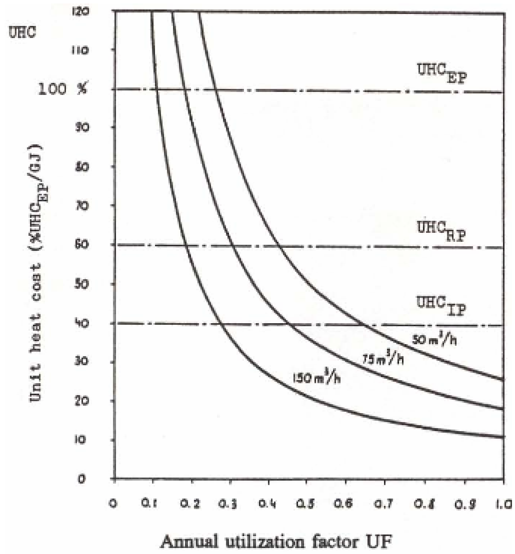

Figure 1: Unit heat cost variations as a function of annual utilization factor for three selected flows. (Kuzinak, 1990)

4. OPPORTUNITIES FOR GEOTHERMAL DEVELOPMENT IN MACEDONIA

New developments of geothermal energy use are hardly expected due to the economic situation in the country and global economy crisis. However, there are possibilities to increase the current annual utilization factor of the existing geothermal capacities which seems to be feasible and more applicable in the given circumstances. The main advantage is that the big investment costs on geothermal field development, surface equipment and in many cases distribution network would be avoided. Nevertheless, investments are necessary in retrofitting and providing/connecting suitable consumers.

Considering the increase of the flow – this strategy is largely used as already mentioned, since no any user is willing to switch additional heat source when base heat load is exceeded. This leads to overexploitation of the resource which in long-term perspective can cause damage and loss of the resource.

When increase of temperature drop is in question the results given in table 2 might be obtained., when outlet /return temperature is 15°C.

Table 2: Potential increase of capacity and annual utilization with outlet temperature of 15°C.

Loca-lity	Maximum Utilization				Annual Utilization		
	Flow Rate	Temp. (°C)		Capa-city	Ave. Flow	Ener-gy	CF
	kg/s	Inlet	Outlet	MWt	kg/s	TJ/yr	
1	53	69	15	12.00	35.00	250	0.66
2	21.5	61	15	4.14	15.00	91	0.69
3	180	75	15	45.2	57.00	451.1	0.31
4	80	50	15	11.7	5	23.1	0.06
		TOTAL		73.04		815.2	0.43

1 – Bansko, 2 – Istibanja, 3 – Kocani, 4 - Negorci

Such an approach can bring to increase in the capacity for 58% and in energy use 39% when the value of the capacity factor remains the same. If the increase of the temperature drop is to be achieved in frame of the existing consumers (meaning mainly heating greenhouses), the obvious solution is to apply soil (laid and burred) heating in cascade after aerial heating. Or, additional consumers to be connected in cascade after greenhouses – low-temperature heat utilizes like spas, swimming pools, fish farming, open field heating, etc.

Yet, the available capacity is underutilized; even only three projects are under attention.

4.1 Geothermal system in Kocani (retrofitting option)

Municipality of Kocani covers area of 382 km^2, at altitude of 348 m, with almost 40 thousands inhabitants. The rate of unemployment is around 38%. The industrial zone covers area over 60 ha with over 100.000 m^2 of buildings. There are many different industrial sectors: graphical, metal, food, textile, construction, catering, trade, wood, car services and other. The municipality has great potential for tourism development in: recreation and sport, culture, history, spa, rural tourism etc.

Current production of thermal water with 78°C is 300 l/s (26000 m^3/day, $1.35 \cdot 10^6$ m^3/annually), of which 80 l/s are injected back to the aquifer. Thermal water is extracted from three wells (one additional is monitoring well) and brought to a tank of 1000 m^3. The use of the pumps is synchronized with the demand and other criteria such are the outside temperatures, day and night regime.

The geothermal water is carried to three heating systems: glasshouse complex Kocansko pole (1982 yr.) and rice drying unit (1983 yr.); glasshouse complex Mosha Pijade (1983 yr) and district heating for Kocani (public houses, schools, households, industry). The heating season is from October to May. In the last years, the consumption from agriculture and industry is decreased, while the consumption from households and public buildings is slightly increased.

The largest consumer (90%) are the greenhouses (20 ha of glasshouses), the rest is used for heating some households and public buildings and one small part is used in the paper industry. The enlargement of the network has not been possible due to financial reasons. The capacity loss and all other variations in the use, decrease the system performance.

The price of the geothermal energy is regulated by Council of Municipality of Kocani. Currently the price comprises only the quantity of used water while the extracted heat is neglected.

One of the deficiencies observed during 3 decades of operation is the temperature loss from the distribution station (72-75°C) to the final consumers in the town (60-65°C) at 7 km distance. This is due to the large pipe diameter (300 mm) and small consumption (18-20 l/s). One of the possibilities to improve the situation is to increase the number of consumers, since the distribution line goes through the industrial zone and hotel complexes, which at present is not achievable. Therefore, some intermittent solution should be obtained in order to increase the temperature of the heating fluid back to 75°C. There is a possibility to replenish the heat loss (temperature drop) with other renewable energy source. Kocani valley is rich with agricultural production (rice and 20 ha of greenhouse cultivations), the biomass residuals (rice husks and straw, leafs, stems, etc.) indicate potential for possible combination with the geothermal energy, i.e. to replenish the distribution heat loss. Such a solution would enable to solve the present situation and would improve the performances of the system in future (to meet total or part of the pick load requirements). At the moment some initial steps are undertaken to enable assessment of the biomass potential and feasibility of the eventual combination / hybridization with the geothermal system.

The main advantages of the Kocani geothermal system are: the high stability of the resource, relatively high temperature, many potential users at short distance and already long experience with system operation and management. But main disadvantage is the price of the heating unit which doesn’t allow for real economical assessment of the potential investments neither assessment of the ROI period, which in turn does not promote investments in this sector. Not only that, the current price of the geothermal energy does not even cover the current operation costs, not to speak about development and improvements of the system.

4.2 Geothermal field in Dojran (new development)

Municipality of Dojran covers area of 132 km^2. at altitude of 148 m, at south-eastern part of Macedonia. The lake Dojran is in the frames of the municipality and it is the smallest valley type lake in Macedonia with a maximal depth of 10 m. Climate of the Dojran Lake is under strong Mediterranean influence.

Main economic activities of the population are tourism, agriculture and fishing, with obvious stagnation over the last 20 years resulting with quite low level of the living standard and high emigration rate.

The geothermal system in Dojran is located near Dojran Lake. The system is drained through one natural spring and through several exploitation drillings, made in the period 1986-97. The estimated area covered by the geothermal field is 15 km^2, with average thickness of 300 m. The estimated capacity of this system is 200 km^3 and the estimated temperature is about 50-80°C.(Popovski et al., 2009)

Geothermal field is still not well investigated and precise prognosis about the temperature and flow cannot be given without realization of at least two-three deeper exploration boreholes. Based on the characteristics of explored geothermal fields of the same chain, flows of 40-60 l/s per borehole and temperatures of 50-80ºC can be estimated as realistic.

Maximal total continual flows are going up to 100-130 l/s, resulting with heat capacity between 4,0-15,0 MW per well or totally up to 20 MW.

Due to the geographical position the region is rich with solar radiation (1.500-1.540 kWh/m^2) and due to agriculture and vegetation there is considerable biomass potential, too. The problem is that there is no organized collection of forest, agricultural residues; therefore this potential is not available for use. Wind and hydro potential are estimated as poor.

Taking into account the natural resources on disposal, economy and social background, and depending on the results of more detailed exploration of the geothermal resource, it is proposed to compose system which will utilize renewable energy sources (geothermal, solar, biomass) to produce combined heat and power or only heat. The district heating system (distribution line along the coast of the lake) would be available for heating residential/commercial houses and buildings, hotels (with spas and indoor pools) and industrial processes (e.g. drying). In cascade, after this part, the system would heat greenhouses, aquacultures, swimming pools, open field production, etc. When heating is not required, the energy is available for sanitary warm water preparation together with the industrial processes (especially drying and processing of the agricultural products) and spa facilities. Such composition of users would enable relatively high values of the annual utilization factor which in turn influences the feasibility of such an investment.

The proposed composition would have positive influence on the:

- Revival of the tourism and prolongation of the touristic season from 1-2 to 5-6 months (or more) per year;
- Revival of fishing by introduction of intensive breading technologies;
- Introduction of more intensive agricultural production, particularly of out-of-season vegetable and flowers;
- Introduction of more intensive use of forest residues and agricultural waste for energy production purposes.
- Development of small business sector, based on the needs of listed development directions and small seasonal trade for the need of population and tourists.

Either very well accepted and acknowledged as very promising and beneficial for the region, so far there is no any progress in conducting the idea. The constraints are many, but at the moment the prevailing are the economical and the lack of capacities in the local governance.

5. CONCLUSIONS

Macedonia belongs to the countries with relatively high utilization of renewable energy sources which is mainly due to excessive use of fire wood. From the other side, proven and available RES like geothermal and solar are by far underutilized. RES offer possibilities for local sustainable development accompanied with economical, social and environmental benefits.

Annual utilization factor is a good indicator for the feasibility of direct use geothermal project. As such it also gives strategies how to increase the annual use of geothermal resource, which in turn opens wide possibilities for local sustainable development and prosperity.

Instead developing new geothermal projects connected with high investments and exploration activities, the existing capacities can be brought to optimal level of use either by interventions in the current heating systems or by connection (and cascading) of additional suitable consumers. Again, it is not an easy task, but if determination and commitment exist it is achievable.

Suitable combination of geothermal energy with other RES can improve the performance of the geothermal system and bring additional benefits.

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