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AGRICULTURAL AND INDUSTRIAL USES OF GEOTHERMAL ENERGY IN EUROPE

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ABSTRACT

Geothermal energy use in agriculture was one of the most important development directions in Europe during the 80-ies of the last century. However, it is recently the field of application with the biggest stagnation. Except in Hungary, there is practically no new projects in Europe during the last 10-15 years. Reasons can be located in lack of adequate and economically justified technologies, complicate maintenance and exploitation, environmental problems and, most of all, absence of governmental support and good organization. It is possible to state that most of them can be overcame by right approach to the problem and, based on the reached experience, to justify re-opening of a new process of development with significant economical and environmental benefits for the regions where hydro-geothermal resources are on disposal.

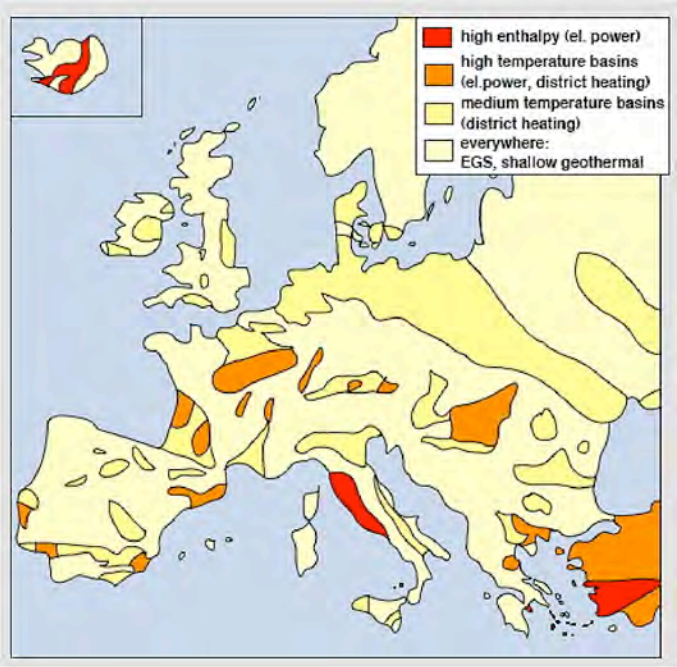

Fig.1. Disposition of geohydrothermal resources in Europe (Aquater, 2003)

INTRODUCTION

Probably not under particular attention, like some other renewable energies, like wind, solar and biomass, still Europe is the "most geothermal" continent in the world, at least when direct use is in question. About 45% of total flow, 40% of the total installed capacity and 50% of the annual direct utilization are located in 29 European countries (Lund, 2005). Quite large geothermal resource (Fig.1) is distributed all over the continent, however with different characteristics and possibilities for development. Higher temperatures (over 150ºC), convenient for electricity production, are present only in some regions in Iceland, Italy and Turkey. Middle temperatures (80-150ºC) are present in several regions of Spain, France, Germany, Central and South European countries and Turkey. They are convenient for list of direct uses but also for electricity production with newer production technologies or in combination with fossil fuels and other RES. Reservoirs with low temperature (30-80ºC) are spread practically in all the countries in Europe. They are convenient for many direct uses, as proved in many European countries.

When agricultural uses are in question, it's necessary to underline that practically all the known technologies have been developed in Europe, and then spread all around the world.

Biggest geothermally heated greenhouse complexes in the world are in the Central and South European countries (Fig.2). During the seventies and eighties of the past century, this type of use has been the direct application promoter in many countries, much more than the space heating or balneology, etc.

However, during the recent decade, composition of geothermal energy users slowly changed, due to the change of different influencing factors. A strong development of the space heating, balneology and heat pumps use can be identified and a much slower development of agricultural uses with complete stagnations in countries, which have been previously promoters of it.

It's interesting to analyze the reasons that caused the negative change and to try to find where is the position of agricultural uses in the future geothermal development process in Europe.

1. RECENT AGRICULTURAL GEOTHERMAL DEVELOPMENT IN EUROPE

Agricultural uses are very important part of geothermal energy application experience. During the seventies and eighties of the past century, this type of use has been the direct application promoter in many East European countries, much more than the space heating or bal-neology, etc. Precise orientation about the real geothermal agricultural development in Europe from 1995 to 2005 is not on disposal. Available data (Lund, 2005) are not precise and does not allow orientation about development status because development rates are influenced of the different number of countries and mode of estimation of composition of the direct uses.

Anyhow, some conclusions can be extracted. First of all, we have rough estimation for composition of direct uses at world level, both for 2000 and 2005, and rates of development, i.e.:

- Geothermal application in agriculture lost its importance in comparison with 1995 and particularly with 1990; and
- Except for heating greenhouses (due to the introduction of data from new countries), in allthe other

Stagnation in all the categories of agricultural uses is present also in Europe due to abandoning of some bigger projects in Italy and Central and East European countries in transition (Table 1).

Lost of importance is present worldwide (Fig.3), mostly due to the quick development of the ground heat pumps use but also due to the real stagnation in development (Popovski, 2004).

Thanks to the positive change of EU politics to RES development during the recent 10 years, even still marginalized, also geothermal energy application began to be interesting for larger investments. Several larger district heating systems opened a new development process, followed with new agricultural projects in Hungary, Romania, Bulgaria, etc. Particularly significant is the example of Turkey, where geothermal development got a priority treatment, resulting with the highest development rate in all the world.

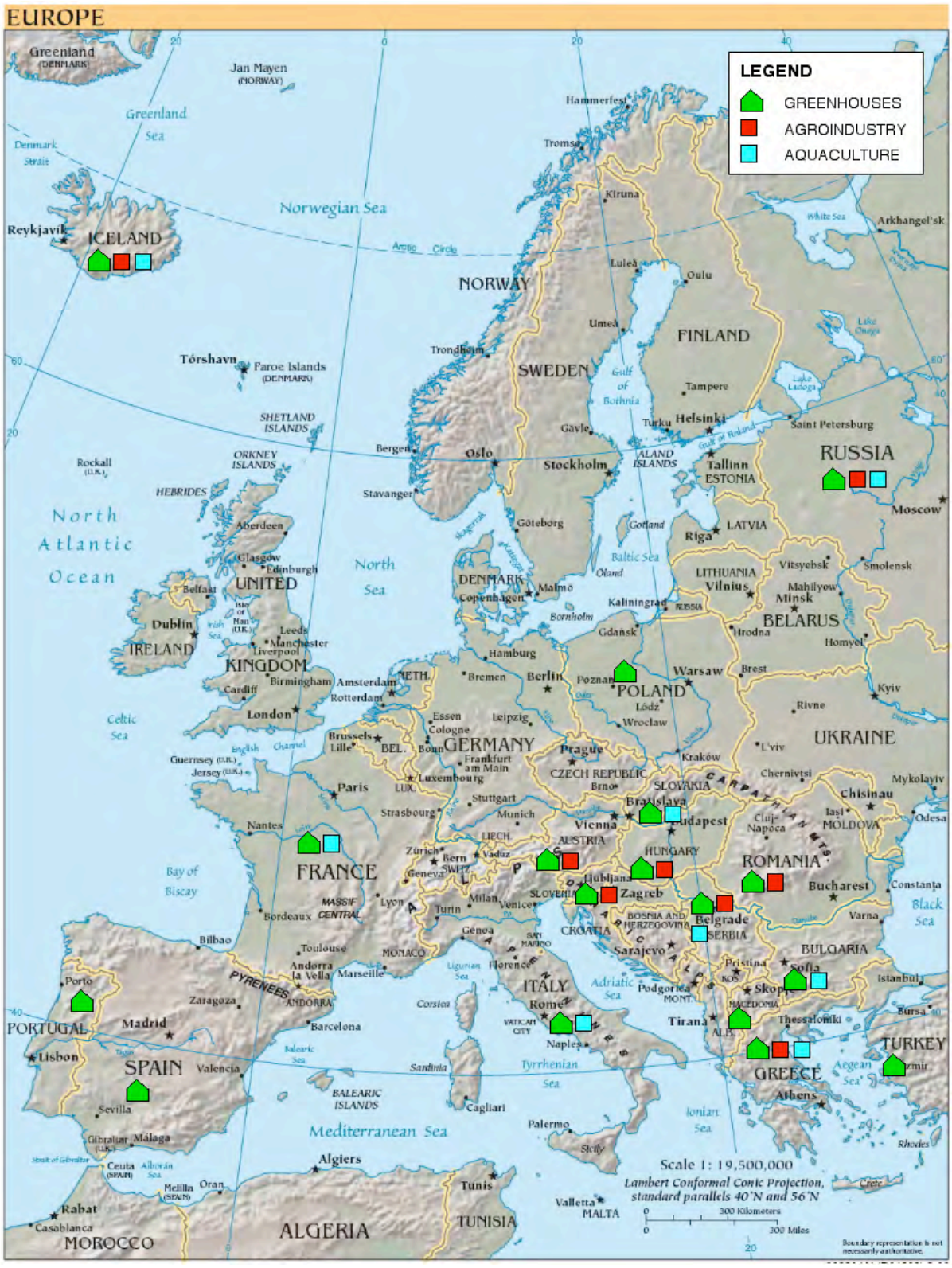

Fig.2. Agricultural uses of geothermal energy in Europe

2. TYPES OF GEOTHERMAL ENERGY USE IN AGRICULTURE IN EUROPE

Generally, four types of direct application of geothermal energy in agriculture can be identified, i.e.:

- Heating greenhouses;
- Aquaculture (fish farming and algae production);
- Drying agricultural products; and
- Soil heating (open field plant root system heating).

Far most important is heating the green-houses (60%), than aquaculture (26%), drying agricultural products (23,9%) and only one case of open field heating (0,1%).
Reasons for the stagnations are a complex composition of influencing factors of different nature. Some of them are common for all types of direct application of geothermal energy but some are characteristic only for agricultural uses, such as are:

2.1. Political transition process of South/East European countries

Countries, where the biggest geothermally heated greenhouse complexes have been developed in 80-es of last century (Hungary, Macedonia, Bulgaria, Romania …) where (and still are) passing a painful political transition process with lost of regular treatment and

Table 1. Distribution of agricultural uses in Europe (IGA, 2005)

Nº	COUNTRY	TOTAL DIRECT USE	GREEN-HOUSES	INDUSTRY	AQUA-CULTURE
		MWt	MWt	MWt	MWt
01	Austria	62,50	1,80	2,10	
02	Bulgaria	109,70	16,90		
03	France	291,90	12,60		20,80
04	Georgia[1]	1.498,10	291,40	363,90	295,40
05	Greece	74,75	22,18	0,24	8,87
06	Hungary	342,50	196,70	1,80	
07	Iceland	1.787,00	55,00	65,00	65,00
08	Italy	387,00	133,60		132,40
09	Macedonia	62,36	58,83		
10	Poland	67,25	1,00		
11	Portugal	30,60	1,79		
12	Romania	156,50	26,76	13,60	3,59
13	Russia	307,00	160,00	29,00	4,00
14	Serbia	88,80	15,40	5,30	6,40
15	Slovakia	186,30	31,80		4,60
16	Slovenija	49,68	7,92	0,75	
17	Spain	22,28	14,93		
18	Turkey	1.077,00	131,00		
	TOTAL	**6,601,22**	**1.179,61**	**481,69**	**541,06**

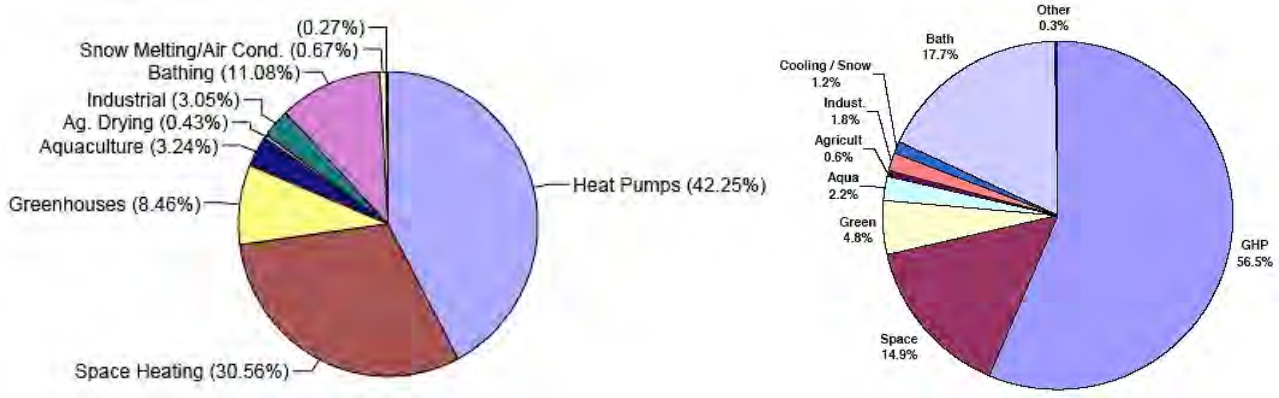

Fig.3. Categories of geothermal energy use capacity in the world in 2000 and 2005 (Lund, 2000 and 2005)

[1] Given only by one author. Not confirmed.

development strategy for agricultural production and food processing. Previous large agro combines have been divided in small parts, unable to organize and run successfully the complicate protected production of vegetables. Some of the earlier big producers survived but many of them decayed. Changeable political situation thwarted possible foreign investors to invest in expensive agricultural projects (Popovski, 2004), particularly when the main interest of Western developed countries was more to develop the market for own agricultural products than to develop possible competition.

A slight positive change can be followed during the recent years (Popovski, 2008), which should (hopefully) have positive influence to the development process of geothermal application in agriculture.



Fig.4. Large glasshouse blocks heated by geothermal energy in Bulgaria, Hungary, Macedonia, Romania, Serbia, Russia ….. (Popovski, 2008)



Fig.5. Soft plastic covered greenhouses in Greece, Hungary, Italy, France, Spain (Popovski, 2008)

2.2. Type of users

There were two different approaches during the initial period of development. One, in ex-sociallist countries, with development of large greenhouse complexes and other, in other South European countries, with development of small units. Advantage of the first approach, enabling better organization of exploitation and maintenance of heating completes, provoked development of some larger units also in the second group of countries (Italy, France). Except in Bansko (Macedonia) and (in some cases) in Greece, small type of users have been mostly of rather short life time. In middle and Northern European countries heating of greenhouses by geothermal energy has not been accepted, except in Hungary and Slovakia.

Aquaculture applications have been (and still are) mostly developed in France, Iceland and Italy. Open ponds breeding of fishes is prevailing but there are also some modern plants with completely indoor breeding cycle. In Bulgaria and Greece, successful experience have been collected with the algae spirulina growing.

From the professional point of view, experiences with drying agricultural products are excellent. However, that was not confirmed by the wider spreading of this type of geothermal energy use in agriculture. The oldest



Fig.6. Spirulina production in Bulgaria and Greece (Popovski, 2008)

one, rice drying plant in Kocani (Macedonia) is abandoned, there is no information about the destiny of the wheat drying plant in Hungary, small drier unit in Serbia is still working, as is the tomato drying plant in Greece. However, there are new reports for larger industrial uses in Iceland, Russia and Georgia. Anyhow, no new development is reported during the recent 5 years.

After the unsuccessful trial in France with open field heating of corn culture in 80-es of the last century (uneconomical), the experience with early cultivation of asparagus in Greece is excellent and, both technically and economically, fully confirmed during last 5 years.



Fig.7. Open field production of asparagus in Greece (Popovski, 2008)



Fig.8. Drtung tomatoes in Greece (Popovski, 2008)



Fig.9. Drying wood in Poland (Popovski, 2008)



Fig.10. Wheat drying in Hungary (Szita, 2007)



Fig.11. Fish ponds in Greece, France, Hungary, Russia … (Popovski, 2008)

2.3. Daily and annual heat loading factors

Except for aquaculture, that's the weak point of agricultural uses of geothermal energy, connected to the high specific initial investment costs. Daily and annual heat loading factors for heating greenhouses are very changeable and low. Highest heat demand during the day is early in the morning and lasts two-three hours. Immediately after that no heating is necessary (greenhouses are solar collectors!). Only during the night, rather stabile but low heat demand appears. If looking annually, in the Middle and South European conditions, the story is similar, i.e. more than six months no or very low heat requirements are characteristic. All together, in Europe, annual heat loading factor goes from 0,15 to 0,40, depending on the geographic position.

That is not the case with drying plants during the harvest season. Heat requirements are, more or less, stabile and constant over the day but only for 2-3 months during the year. The same is with the open field heating.

Result of the above said is that better economy can be reached in two ways, i.e.:

- By installing additional peak loading boilers, fired with fossil fuels or biomass; or
- By simplifying maximally technical design of heat supply completes.

Both solutions are complicating the exploitation of heating systems, i.e. additional boilers result with additional employment of trained workers and complicate exploitation and maintenance, and simple connection completes (means direct connection to geothermal well!) results with complicate and insecure exploitation due to the corrosion and scaling problems and improper regulation of heat supply.

In any case, final result for the improperly designed, completed and exploited geothermal heating systems is expensive except "free of charge" heating, as it was expected.

2.4. Technologies

Technologies for heating greenhouses with geothermal energy has been mostly developed during the 80-es of last century. However, thanks to the collected experiences, a process of correction of initially applied solutions is constantly in flow, mainly with:

a) Avoiding direct connections to geothermal well (bigger complexes); and
b) Increasing the participation of low-positioned "vegetative" heating systems.

For aquaculture plants mainly technologies already developed for low-temperature waste water are applied. For drying plants, existing drying technologies have been applied, accommodated to the use of lower temperatures of the heating fluid. For the open field heating, the existing technology for soil heating in greenhouses has been used.

Generally, it can be stated that enough good technologies are on disposal. However, many problems connected to their application can be identified (Popovski, 2007), such as are:

a) Intention to use "universal" systems for heating greenhouses. Designers either don't have enough information and knowledge on existence and characteristics of different heating systems, or do not know that each plant culture has particular requests connected to the vertical temperature profiles and surrounding concrete climate.
b) Always present intention towards "possible simplifications" in order to decrease necessary investment costs, resulting with problems in exploitation and maintenance (direct connections to geothermal wells) or following the necessary changes of internal temperatures, dependent on the changes of light intensity.

Both are resulting with decreased productivity and, with that, to the decreased economy of production.

2.5. "Independent" or "dependent" use of geothermal energy

In most of the cases, because not having possibility to connect the user as consumer to large geothermal district heating systems, but also due to impression that geothermal energy is "free of charge" when being independent (by using own production well(s)), most of agricultural producers are designing, completing and exploiting own "independent" geothermal heating systems. That increases necessary investment costs (resulting with un-fortunate "simplifications") and "introduces" continual complications with proper heat supply and maintenance of the system (Popovski, 2008). Result is that negative experience is prevailing the positive ones and that the final price of used heat can become quite high.

2.6. Absence of proper treatment

Geothermal energy use in agriculture has no particular treatment neither like other RES nor fossil fuels in some countries (natural gas in Netherlands or special price of heavy oil in some others). Wind energy, solar energy or biomass are under particular attention of EC and different support systems for their development and exploitation are in flow, resulting with a quicker development and spreading of sectors using them. Absence of similar treatment of geothermal energy result with diffi-

culties in development and un-competitiveness in exploitation (Popovski, 2008).

3. POSSIBILITIES FOR REMOVING PRESENT PROBLEMS

As elaborated in the point 3 of this paper, present problems and possibilities for resolving them can be grouped in three major groups, i.e.:

- Treatment of heat production from geothermal energy as RES, whose development should be supported according to EC strategy of development, and directives (legislation, state measures for support (incentives, financial support, risk guarantees, …);
- Correct techno/economical approach to organization of development, completion and ex-ploitation of geothermal projects; and
- Application of correct choice of technologies and equipment for designing and completing of geothermal projects, and organization of proper exploitation and maintenance.

The first one should be treated together with the problematic of other RES wider introduction and exploitation in the EC. However, it's necessary to underline the fact that geothermal energy is mostly not treated like that (Popovski, 2004), resulting with lagging in comparison with the development of wind, biomass and solar energy application development. Plus, there are problems needing particular attention and efforts to be resolved (risk guarantee, high specific investment costs, etc.). Initial steps are already taken by the WB (GEF fund) and some countries (France, Germany, …) connected to resolving the problem of covering the risks. However, that's far not enough and cannot give successful results without accepting necessary state support measures and defining concrete strategies of development and necessary measures to implement them. When application in agriculture is in question, possibilities to improve the present negative situation should be found in the present worldwide increase of the energy and food prices, i.e. to incorporate geothermal energy application in the measures for organization of more intensive and guaranteed out of season high quality food production. That should be easier to reach in higher developed Middle and Northern European countries which are already advan-ced in RES development, which shall be followed by the other ones.

Obviously, present approach to organization of development, completion and exploitation of geothermal projects, either for large greenhouse complexes or small agricultural projects is not good enough to guarantee good economy and comfortable exploitation of them. Treatment of agricultural projects as "independent" ones does not offer neither enough high annual heat loading factors nor possibilities for introduction of sophisticated technical solutions for completion, exploitation and maintenance of geothermal energy resource. According to the existing positive experiences, connection to existing geothermal district heating systems or composition of new ones consisting users with different daily and annual heat loading factors and possibilities for introduction of cascade use of the temperature difference on disposal, is improving very much the economy of use. Such projects offer economically justified proper technical completion, exploitation and maintenance of geothermal resource. Final user, i.e. vegetables, flowers or fruits grower and farmers do not have direct contact with that complicate problematic but use the benefit of cheap energy. Unfortunately, application of such an approach returns us to the previous group of problems, i.e. development of expensive district heating systems is not possible without a complex strategic approach, consisting detailed planning of the financing, technical/technological design, as short as possible completion with enough consumers, etc., and that's not possible without adequate state support.

Finally, it's already clear that any simplification of technical design in order to decrease the investment costs, orientation towards cheap equipment and materials finally results with un-proper and insecure heat supply with all negative consequences to the productivity and quality of production in question. If, twenty years before, high price of plate heat exchangers and computerized automatic regulation completes has been the reason to avoid their application, it is not like that now-a-days and it is already proven that it is economically justified to use them in any district heating system or even in independent larger agricultural pro-

jects (Popovski, 2008). Very good is example of the Reykjavik district heating system (Fig.12), composed of several type of users, all with different daily and annual heat loading curves.

For small independent users, as are small greenhouses, it is not the case. Investment costs for such equipment can become higher than the ones for the whole project and low specific production rates cannot repay them. Probably the only solution to prevent from expensive complications with geothermal water treatment, in order to prevent from corrosion and scaling problems, is application of "down-hole heat exchanger" technology. Except the direct application of the water or expensive solutions with plate heat exchangers, made of inox materials. Technology is simple and secure, cheap for shallow wells and removing the corrosion and scaling problems. However, when deeper wells are in question, this solution become expensive and not feasible.

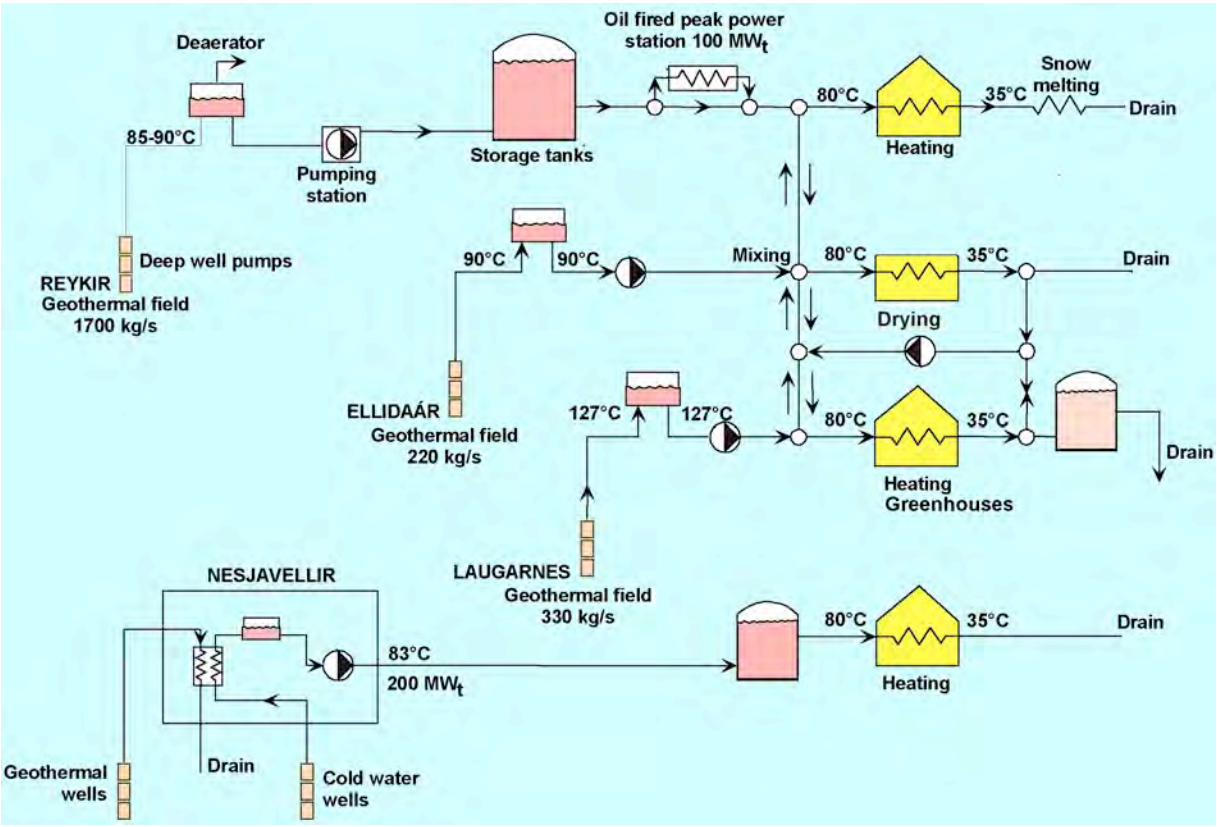

Fig.12. Simplified diagram of the district heating system in Reykjavik, Iceland (Gunlaugsson, 2004)

4. OVERALL ESTIMATION

A complex combination of influencing factors during the recent two decades resulted firstly with slowing and than stagnation of development of geothermal energy use in agriculture. Practically no advance can be followed in any type of application during the period when other types of renewables are in rather fast development. However, it's important to underline that no one of them "replaced" geothermal energy in the characteristic fields of use. Before making any statement, recommendation or conclusion, it is necessary to reply to the following basic questions:

- Are the proven fields of application estimated as priority sectors for economy development of national economies in question, i.e. enough big and important to justify organization of additional efforts in order to overcome the present negative situation?
- If yes, is the energy supply of such importance that can influence significantly the economy of their future work and development? and
- Can geothermal application be competitive to the other possibilities on disposal according to the present level of "know-how" and market conditions and predicted changes in near

future?

As evaluated in points 3 and 4 of this paper, replies are neither easy nor simple. i.e.:

- Generally, proven fields of application are estimated as important in most of the European countries. However, except probably in Netherlands for greenhouses, they are not estimated as priority ones like is the essential production of food (cereals, vegetative oil, meat…). On the other hand, consumption of out of season fresh products became a regular habit of an European consumer. Increase of this market resulted with a rather stabile development of production and increase of import from some Northern African countries. Predictions are that such a process shall follow during the next one-two decades. Therefore, even with the mentioned limitations, the answer to the first question is positive. Market for development is big enough and present participation of geothermal energy application is very small, which altogether justify organization of necessary activities to significantly increase the participation, particularly in Middle and Southern European countries.
- Answer to the second question is yes. Production costs of all the production sectors depend very much on the price of energy, which already influences final prices of products. Present variation of energy prices shall not stop but, on the contrary, shall be even accelerated during the coming decades and can result with very negative consequences to the development of many food production sectors due to the increase of price of food for final users. Under such a light, possible field for geothermal energy application shall be very much enlarged due to the fact that offering a stabile energy price during all the period of exploitation.
- With all the elaborated limitations, it is already proven that geothermal energy application in agriculture is competitive to any energy source on disposal, either fossil or renewable ones, however under the conditions that projects are properly designed, exploited and with an adequate maintenance. And, that's possible only if resolving the problems of positive treatment of geothermal energy like other RES (solar, wind, biomass, …), creating a system of proper risks covering and organizing a convenient system of development financing , in order to decrease the negative influence of the initial high investment costs. Reached experience and "know-how" during the last two decades offer high enough technologies and equipment to enable much better completion of the heating systems than the ones in use (developed 15-20 years before). However, distribution of the "know-how" is rather uneven and concentrated in rather small number of European countries.

Listed answers justify the following statements:

- There is need and there are possibilities for development of geothermal energy use in agriculture, at least there where shallow geothermal resources exist and where geothermal district heating systems are already organized or can be organized;
- There are enough high technologies and "know-how" on disposal to perform a wider development process in order to significantly increase participation of geothermal energy in the production sectors in question. Organized international collaboration can help to transfer the necessary "know-how" also to the countries where it doesn't exist or it is not sufficient;
- If not reaching the positive treatment of some other RES and getting proper support for development, geothermal energy cannot take the position it deserves in agriculture in Europe.

5. CONCLUSIONS

Overview of the present situation of geothermal energy use in agriculture confirms already known fact that direct application of geothermal energy didn't succeed to prove that is one of the RES which can play a significant role in present and future energy balances at national and world level. There, where it was recognized as other energy sources, political changes have been stopping its further development (Hungary and South/East European countries). No real change of the public acceptance has been present in the other European countries.

Primary and most important task during the coming years is to fight for getting the position of geothermal energy which it deserves between the other RES. According to the present level of knowledge, when geothermal energy use in agriculture is in question, it is for sure

much more prospective energy source than any RES in all Southern, East and some Central European countries, where existence of large and rather shallow hydro-geothermal energy sources are proven.

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