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INDUSTRIAL USES OF GEOTHERMAL ENERGY IN EUROPE

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ABSTRACT

Great potential for high to low enthalpy geothermal energy utilization lies within industry applications. This sector is particularly convenient since it can provide high annual heat loading factor of the geothermal resource. Due to different reasons, such applications are not widespread. In this paper an overview is given of the industrial uses of geothermal energy in European.

INTRODUCTION

The thermal energy contained in geo-thermal fluids can be used everywhere where heat is necessary to complete some process. Certainly, this is true only if the geothermal resource is available at convenient location and has sufficiently high temperature and flow. Such resource can cover total or partial head energy demands of a given industrial process. Figure 1 outlines the main basins and geothermal resources in Europe, obviously the most present resources are located in medium temperature basins.

Possible field of use of the low to medium temperature geothermal energy is very wide (fig.2). Depending on the available geothermal resource and technical-technological organiza-tion of concrete industrial process, the use of geothermal energy can be independent or in combination with the heat of other origin (conventional, renewable).

°C	Application
180	evaporation of highly concentrated solutions; refrigeration by ammonia absorption; digestion in paper pulp
170	heavy weater via hydrogen sulphide process; drying of diatomaceous earth; digestion in paper pulp
160	drying of fish meal; drying of timber
150	alumina via Bayer's process
140	drying farm products at high rates; canning of food
130	evaporation in sugar refining; extraction of salts with evaporation and crystallization; fresh water by distillation
120	most multiple effect evaporations; concentration of saline solution
110	drying and curing of light aggregate cement slabs
100	drying of organic materials, seaweeds, grass, vegetables, etc.; washing and drying of wool
90	drying of stock fish; intense de-icing operations
80	space heating (buildings and greenhouses)
70	refrigeration (lower temperature limit)
60	animal husbandry; greenhouses by combined space and hotbed heating
50	mushroom growing; balneology
40	soil warming; swimming pools; biodegradation, fermentations
30	warm water for year-round mining in cold climates; de-icing; hatching of fish or turtles
20	fish farming

Fig.1 Lindal diagram for the possible applications of medium to low enthalpy geothermal resources

When high to medium geothermal resource is in question, the cascade use of the available energy would be the best combination. Figure 3 gives one idealized case.

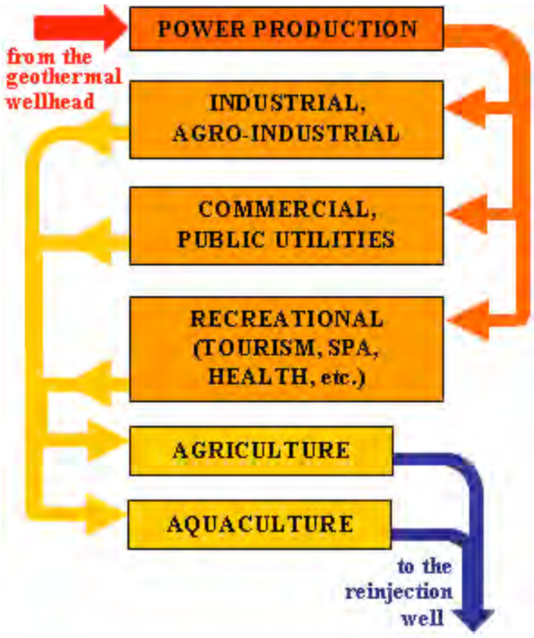

Fig.2. Idealized cascading geothermal direct-use development

1. GENERAL CHARACTERISTICS OF GEOTHERMAL TECHNOLOGY FOR INDUSTRIAL APPLICATIONS

The technology composition of a geothermal system for industrial use can be divided in two main parts. The first part includes the elements of the geothermal resource, the energy supply to the user and effluent fluid treatment, such are: completed geothermal well and wellhead, distribution line or network to the consumers, equipment for geothermal fluid treatment (chemical, physical), heat exchangers with relevant equipment and re-injection well. The second part is consisted of elements specific for the industrial application of geothermal energy like steam extraction system, upgrading system for geothermal fluid, equipment for adjustment of parameters (pressure, temperature and flow), processing apparatuses for implementation in the technological processes. If the industrial consumer uses waste heat from power production plant, than the first part of the system is excluded.

Steam extraction system. Multiple-temperature steam heating systems are routinely used in industrial process plants. In geothermal technologies, use of the steam flashed from geothermal fluid has many advantages because heat transfer rates with condensing steam are uniformly high, steam is less susceptible to fouling and as very important any scaling in the flash step can be controlled by proper design of the flash vessels and by the use of scale-suppressant additives. The used liquid after filtration is routed to the individual re-injection well where high-pressure pumps force the liquid into the receiving strata.

Upgrading system for geothermal fluids. The energy that is available initially from geothermal well is heat, usually in form of hot water or wet steam. The higher-level heat should first be extracted and a cascade use can then be accomplished to maximize energy utilization. The industries, such as pulp and paper and chemical industries, probably will require steam at varying pressures. In most cases, the heat is extracted for process use by heat exchanger, where the heat is transferred to a secondary fluid which is than used to perform the industrial process. Mechanical compression, although being capital cost intensive, is used for the high-grade energy upgrading of low level heat energy and pressure. The basic system for upgrading a geothermal fluid for various industrial process pressures has incorporated a flash vessel for the production of steam; a compressor driven by an isobutene turbine; an isobutene condenser, and a heat exchanger to heat and evaporate the condensed isobutene using the geothermal fluid.

The materials corresponding to the geothermal fluid properties must be utilized in order to enable durability and long-term exploitation of the equipment. High salinity geothermal fluids will cause high uniform corrosion as well as localized corrosion and will severely limit the use of carbon steels. The application of mild steels to geothermal environments requires that precautions should be taken for de-aeration, scaling, galvanic coupling, protection of exterior surfaces and steel specifications. By taking appropriate precautions, carbon steels can be used for thick-walled applications in contact with most geothermal fluids. Thin-walled applications will be limited by the susceptibility of these materials to localized attack, such as pitting and crevice corrosion.

Optimisation of Industrial Application of Geothermal Energy

Application of geothermal energy for industrial processes involves two typical cases: adjustments of existing process to the use of geothermal energy and new projects.

In the first case, optimisation should be used as an instrument for examination of economical advantages in application of geothermal energy, over some classical energy resources. This optimisation is determined both temporal and spatial. Optimisation within the system itself has an aim to examine which of the methods used in application of geothermal energy in existing technological equipment is more feasible. There are two available methods:

1. Direct application of chemically/ physically treated geothermal fluid, or
2. The application of heat exchangers using the heat of geothermal fluid for feeding the secondary thermal circuit.

Optimisation plans should include certain changes in the technological process in order to enable the application of geothermal energy and determination of the maximal energy level within one technological process.

Optimisation on the second level should include mathematical analysis of many factors which are decisive in the development of certain industrial technology. The most important among those factors are: the geothermal fluid parameters, chemical structure of the fluid, quality and price of the plant and parameters and regimes of the technological process itself. The equipment for environmental protection is to be mentioned as well.

The essential energy considerations for the industry are the cost, quality, and reliability. Geothermal energy may be attractive to an industry provided that:
(a) the cost of energy per kg or unit of product is lower than that presently used,
(b) the quality of geothermal energy is as good or better than the present supply, and
(c) the reliability of geothermal energy is available for the life of the plant.

Reliability and availability can only be proven by long-term use or testing. In some situations where available geothermal fluid temperatures are lower than those required by the industrial application, the temperatures can be raised by means of integrating thermal systems (boilers, upgrading systems, heat pumps, etc.).

2. EXAMPLES OF INDUSTRIAL APPLICATIONS OF GEOTHERMAL ENERGY IN EUROPE

Even though the Lindal's diagram illustrates many potential industrial applications of geothermal energy, the world's status of such uses is modest. The oldest industrial use is at Larderello, Italy, where boric acid and other borate compounds have been extracted from geothermal brines since 1790. The largest industrial applications in Europe are a diatomaceous earth plant and a fish dehydration plant in Iceland and tomato drying facility in Greece. These systems provide the best present example of industrial geothermal energy use. Still, there are list of smaller projects confirming the feasibility of geothermal energy for different industrial uses.

Drying and dehydration of agricultural products are one of the most important and prospective moderate-temperature uses of geothermal energy. It is feasible to dry various vegetable and fruit types with air temperatures from 40ºC to 100ºC. Figure 3 shows the geothermal tomato drying unit in N.Erasmio, 25 km south of Xanti, Greece. Geothermal drying of alfalfa, onion, pears, apples, tomatoes, paprika and seaweed are examples of this type of direct use.

In principle, classical drying technologies are used. The only difference is that except the use of fossil fuels for heating the drying air, a water/air heat exchanger is used. Due to the limitation of lower temperature of geothermal water on disposal, normally some corrections of drying time are necessary. It has been proven in practice that such corrections contribute to better quality of the final product.

The drying process is completed after 30 hours. The initial quantity of 4200 kg results with 400 kg dried products.

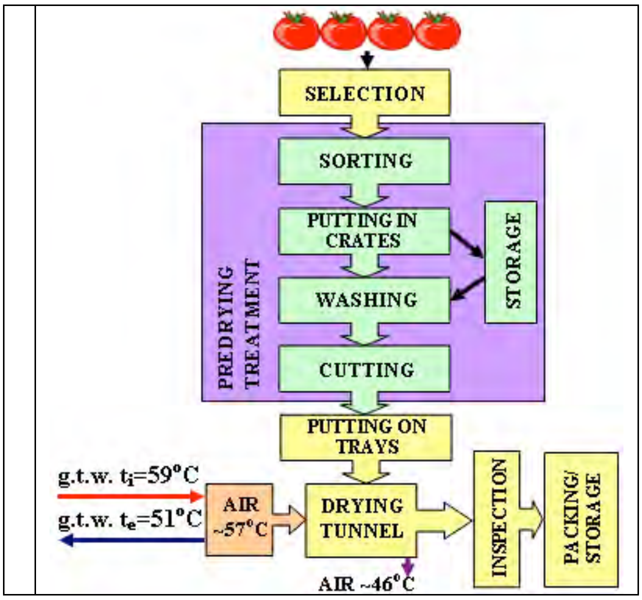

Fig.4 Fig.3. Tomato drying (Xanti, Greece)

The tomato drying unit in Xanti works profitable and is excellent examples for liability of geothermal energy for different vegetables and fruits drying.

Furthermore, there are also excellent experiences with grain cultures drying such are the rice drying unit in Kocani, Macedonia (fig.5), and the wheat drying unit in Szentes, Hungary (fig.6). Reached efficiency and economy of exploitation is competitive to any other plant of such character, using fossil fuels instead geothermal energy.

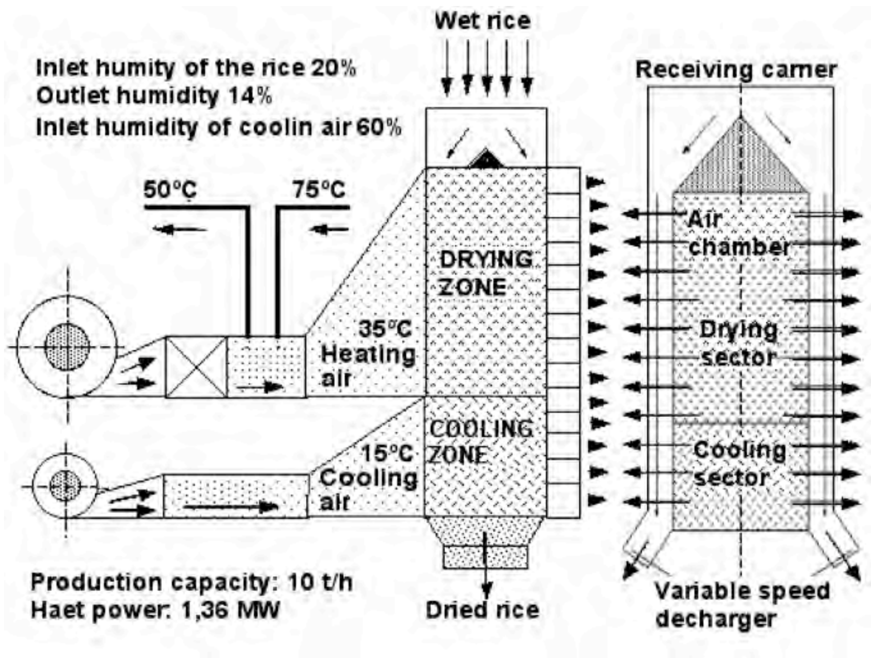

Fig.5 Rice drying unit in Kocani, Macedonia

A small, experimental wood drying facility currently is tested at the Polish Academy of Science site at the Zakopane geothermal district heating network (fig.7).

Additional and rather new industrial application of geothermal energy is the desalinization of sea water. That is a very important problem for a list of island communities in the world. MED-Vertical Tube distillation method is applied in the Kimolos (Greece) desalinization plant. It is based on the multi-effect distillation rising film principle at low evaporation temperatures (less than 70°C -ALFA LAVAL, 1993), due to the reduced pressure (almost vacuum). The rising film principle takes advantage of the fact that the inner tube surfaces are always covered with a thin film of feed water that prevents scale formation. The working principle is given in fig.8.

Fig.6. Grain drier in Szentes, Hungary

A small, experimental wood drying facility currently is tested at the Polish Academy of Science site at the Zakopane geothermal district heating network (fig.7).

Fig.7 Wood drying chamber in Zakopane, Polland

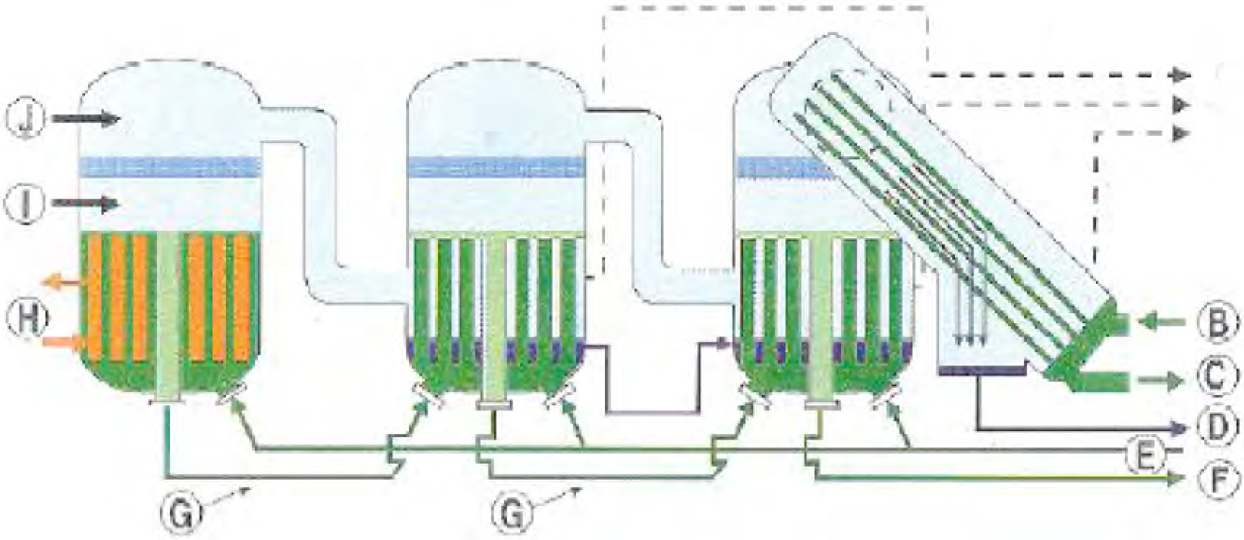

Fig.8. Schematic of a multiple effect distillation process: A. Vacuum chamber, B and C. Inlet and outlet of cooling seawater, D. Distillate product, E. Feed seawater, F. Brine outlet, G. Heat recovery from the brine, H. Condensate steam, J. Dry steam

The desalination unit can be designed in such an innovative way so that in the case that chemical composition of geothermal water allows it, it can be feasible to desalinate the low enthalpy geothermal water itself, instead of the sea-water. This would result in an increase of the energy efficiency of the unit simultaneously decreasing the required capital investments and operational costs (no heat exchangers, no sea-water preheating etc.). When chemical composition is convenient, except for desalinization, it is possible to use geothermal water itself as drinking water.

In Germany, geothermal water from a very deep aquifer, after being used for heating purposes for the district heating system (indirect system!), is processed in a "water factory" and then used as drinking water for the supply of the town. In Kocani (Macedonia), very low mineralized geothermal water is bottled and successfully supplied to the market.

A new project for the utilization of geothermal fluids as process heat started recently the operation in the S. Martino cheese factory at Monterotondo Marittimo (Tuscany). Production and sale of carbon dioxide from a geothermal well of the Torre Alfina geothermal field is still in operation.

Listed examples only confirm that possibilities listed in the Lindal's diagram are realistic and that is only a question of time when some different industrial uses of geothermal energy shall be introduced.

3. FUTURE PROSPECTIVE

Covering industrial processes energy demands still represents the smallest part of the geothermal energy direct uses. On the other hand the industry is very stable consumer on annual base, therefore can provide high annual heat loading factor of the geothermal resource. This is very important characteristic influencing the competitiveness of the geothermal resource over the conventional ones. Nevertheless, this realization has not motivated broad application, even the listed examples showed feasible exploitation. Probably the reasons for this state are the high temperature requirements for majority of industrial processes while the dominant geothermal resources are characterized with low to medium temperatures.

The industrial application of geothermal energy is still at the beginning in Europe. However, the existence of geothermal fields as well as the insufficient resources of conventional energy represents the challenge for further investigations in this field. Quality of geothermal resources that are available in Europe, dictates the use of this type of energy within the low-temperature technological processes. These processes are significantly engaged in different groups of processing industries. Therefore, the expectations for broader engagement of professional and scientific potentials in various disciplines, is quite legitimate.

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