K4RES-H

KEY ISUE 5 : INNOVATIVE APPLICATIONS

GEOTHERMAL UTILIZATION FOR INDUSTRIAL PROCESSES

INTRODUCTION

Geothermal energy may be used in a number of ways in the industrial field. Potential applications could include drying, process heating, evaporation, distillation, washing, desalination, and chemical extraction.

In designing geothermal energy recovery and utilization systems, alternate possibilities could be considered for various applications. The usual approach for utilization of geothermal fluid by proposed industries is to fit the industry to the available fluids. An alternate approach is to fit the available fluids to proposed industries.
This alternate approach requires developing ways to economically upgrade the quality of existing geothermal fluids or the fluids derived from them.

Figure 1 below shows application temperature ranges for some industrial and agricultural applications.

While there are many potential industrial uses of geothermal energy, the number of European applications is relatively small. However, a fairly wide range of uses are represented, including heap leaching of precious metals, vegetable dehydration, grain and lumber drying, pulp and paper processing, diatomaceous earth processing, fish processing and drying, chemical recovery, and waste water treatment.

Industrial applications largely require the use of steam, or superheated water, while agricultural users may use lower temperature geothermal fluids.
The largest industrial applications in Europe are a diatomaceous earth plant and a fish dehydration plant in Iceland, a fishfarming of sturgeons in France and tomato drying facility in Greece. These systems provide the best present example of industrial geothermal energy use.

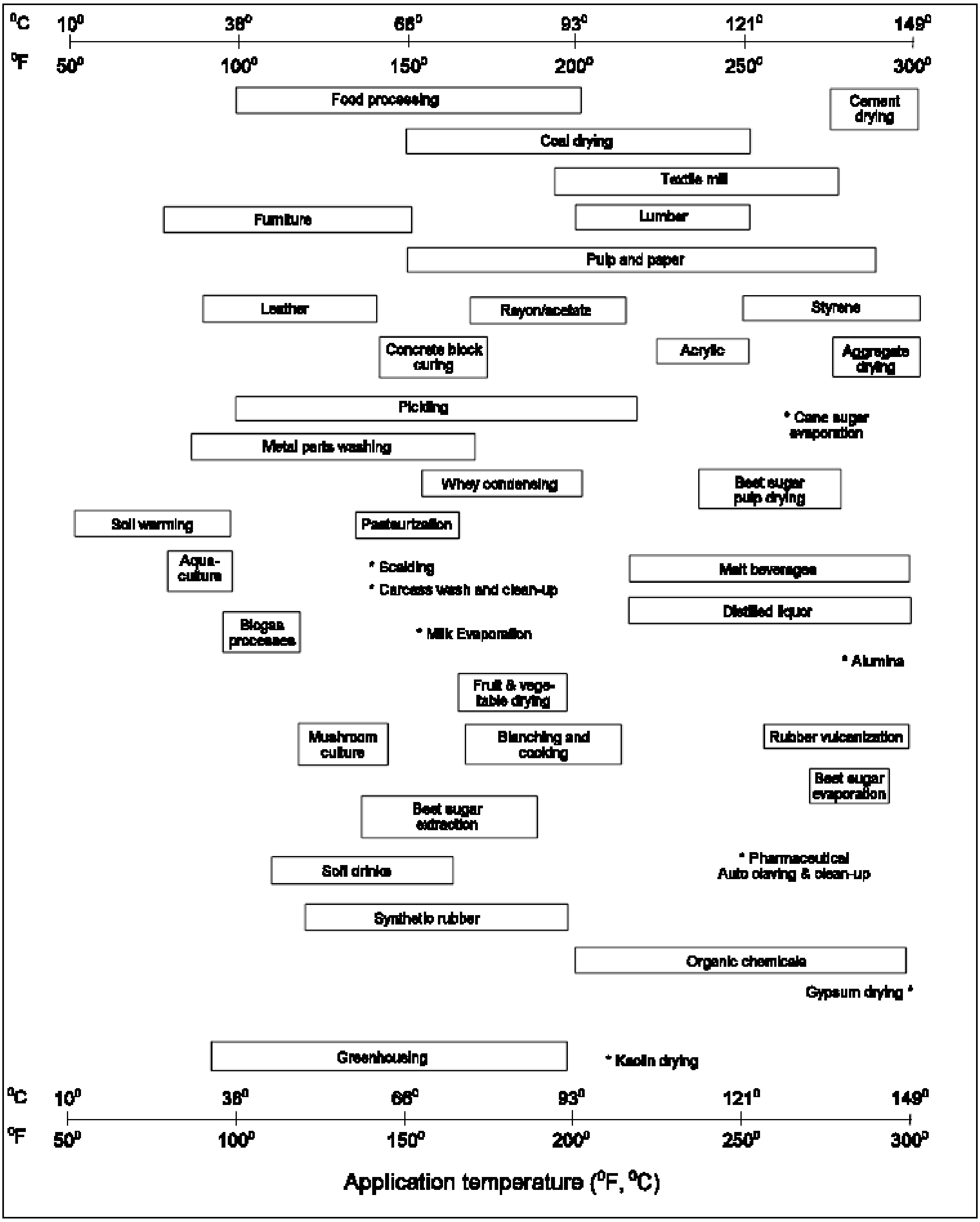


Fig. 1: Application temperature range for some industrial processes and agricultural applications (LINDAL-diagram)

STATE OF THE ART

Use of geothermal energy for tomato drying – possibilities in the Aegean islands

A new application of geothermal energy in the area of industrial drying has been established in a tomato dehydration unit in N. Erasmio, 25 km south of Xanthi, producing "sun-dried" tomatoes.
The unit, operated for the first time during the summer of 2001, uses low cost geothermal water to heat atmospheric air to 55℃ in finned tube air heater coils.
During its first year of operation 4 tn of high quality dried tomatoes were produced.

Dehydration (or drying) of fruit or vegetables is one of the oldest forms of food preservation methods known to man. The process involves the slow removal of the majority of water contained in the fruit or vegetable so that the moisture contents of the dried product is below 20%.
In the Mediterranean countries the traditional technique of vegetable and fruit drying (including tomatoes) is by using the sun, a technique that has remained largely unchanged from ancient times. However, on an industrial scale, most fruit is dried using sun (or sometimes solar drying), while most vegetable are dried using continuous forced-air processes.

Dried fruits and vegetables can be produced by a variety of processes. These processes differ primarily by the type of drying method used, which depends on the type of food and the type of characteristics of the final product :

1. Sun drying. It is limited to climates with hot sun and dry atmosphere with strong winds. Typical areas with such climates are most of the Mediterranean regions, and most of the Aegean islands. Solar drying can be also used.
2. Atmospheric dehydration by passing heated air over the food to be dried.
3. Sub-atmospheric dehydration
4. Freeze-drying, for added value products, such as coffee.
5. Electromagnetic drying (e.g. microwave drying).
6. Drying using the osmotic phenomenon.

The two last methods have been tried experimentally for the dehydration of fruits and vegetables, but no commercial installation is in place. Although vegetable drying aims primarily at food preservation, food drying also lowers the cost of storing, transportation and packaging. Industrial drying is usually carried out with the second method in batch or continuous processes.
Continuous processes include tunnel, fluidized bed, continuous belt and other driers. Tunnel driers are the most flexible and efficient dehydration systems and they are widely used in drying fruits and vegetables.

Geothermal energy is a possible energy source for heating the drying air.
Drying of agricultural products is probably the most important industrial application of low or medium-temperature geothermal energy (40-150℃). Fresh or recycled air is forced to pass through an airwater converter and to be heated to temperatures in the range 40-100℃. The hot air passes through or above trays or belts with the raw products resulting in the reduction on their moisture content. In geothermal drying, electric power is also used to drive fans and pumps.

Agricultural products that are dried using geothermal energy include : onion, garlic, apple, mango, pear, bananas, pineapple, alfalfa, grain, timber etc.
The largest dryings units, which started in the 60s and 70s, deal with drying of diatomaceous earth in Iceland and timber and alfalfa drying in New Zealand. Worldwide, the geothermal energy used for agricultural drying represents about 0.5% of the total geothermal energy use at the beginning of 2000. Except from a small pilot-scale cotton drier in Nea Kessani, Xanthi, which operated for a period of two-months in 1991 and demonstrated that geothermal drying is possible, no other application of geothermal drying has been reported in Europe.
Fig. 2 describes the first project of geothermal vegetable drying in Greece and present the possibilities of using geothermal energy for drying traditional agricultural products in the Aegean islands.

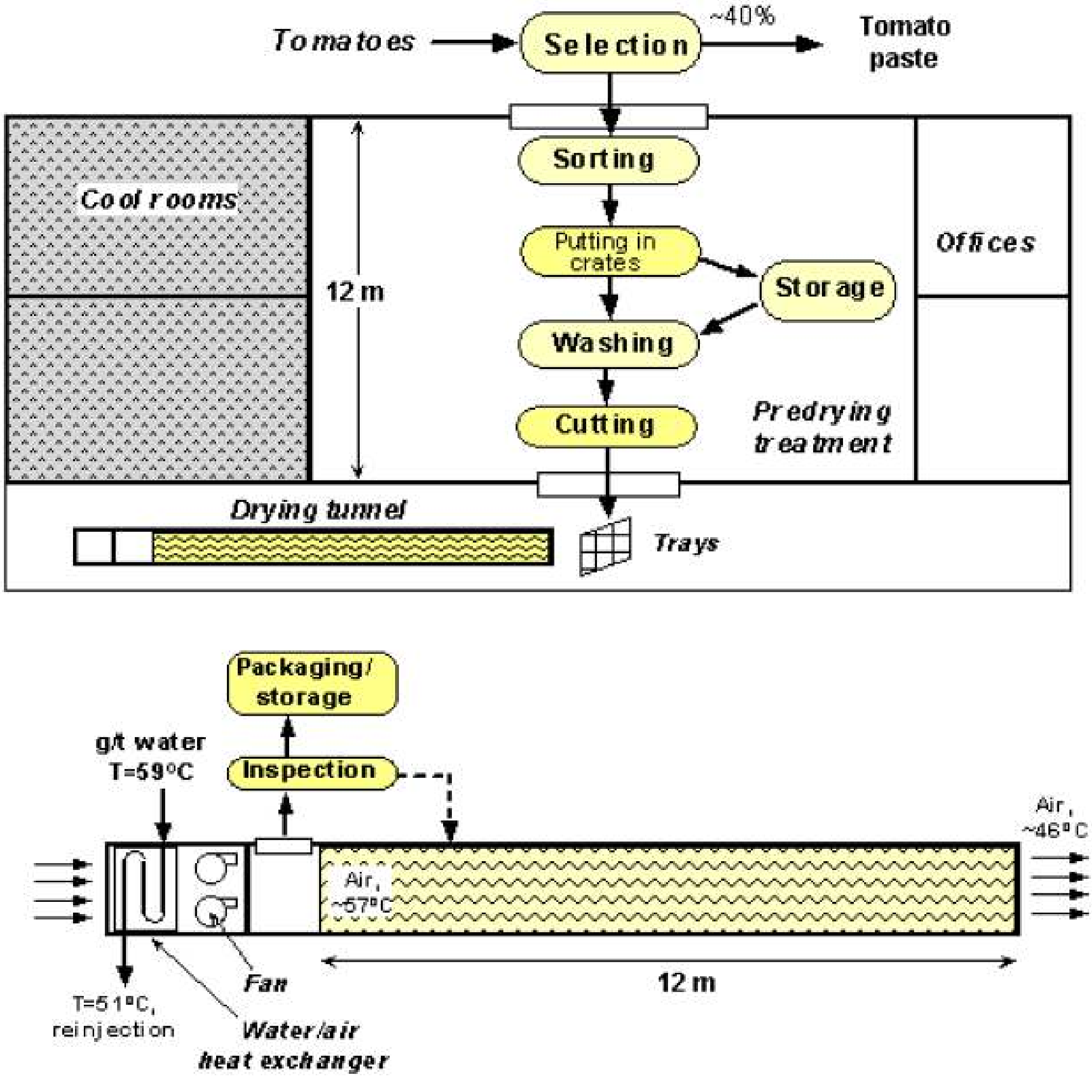


Fig. 2: Schematic diagram of the geothermal tomato drying system.

The drying of fish and utilization of geothermal energy, the icelandic experience

In recent years, the annual world production of dried, unsalted fishery products has been 350,000 tones, but the total world production of dried fish is 3,140,000 tonnes. Production of stockfish is about 10,000 tonnes; the main producers being Iceland and Norway, the biggest producers of the other dried products are countries in Asia and Africa. The annual export of dried cod heads from Iceland are about 15,000 tonnes. Dried petfood is a new industrial production in Iceland and a growing industry, the annual production being about 500 tonnes. There has been much interest in Iceland in producing dried fish for human consumption from the various small fish species, like blue whiting and low fat capelin. The annual production of dried seaweed and kelp in Iceland is about 4,000 tonnes.

The use of geothermal energy in fish processing, instead of oil and electricity, has many advantages. In the fishing industry, geothermal energy has mainly been applied to indoor drying of salted fish, cod heads, small fish, stockfish and other products. The first companies in this field were founded 25 years ago and now there are more than twenty companies. Most companies use geothermal energy for drying codheads and collar bone. In 2001, the consumption of hot water was about 2 millions tonnes or about 550 TJ.

Experiments have been done on the use of geothermal steam for fishmeal processing, but the company involved is no longer in business. It also seems to be possible to utilize geothermal steam for freeze-drying. There are unexplored possibilities in the utilization of geothermal energy in regions where there are good harbors located in geothermal areas.

Most of the research for drying in this field was done for about fifteen years ago. This time, the main work in these trials was to find out the best drying parameters to obtain the best products qualities and to optimize the drying processes.

In the trials, the air speed, air temperature, air humidity, product loading on each tray and the size of the drying tunnel were determined. The latest trials on this field are to find out the influences raw materials has on the products qualities and the stabilization of the product with the difference storage parameters.

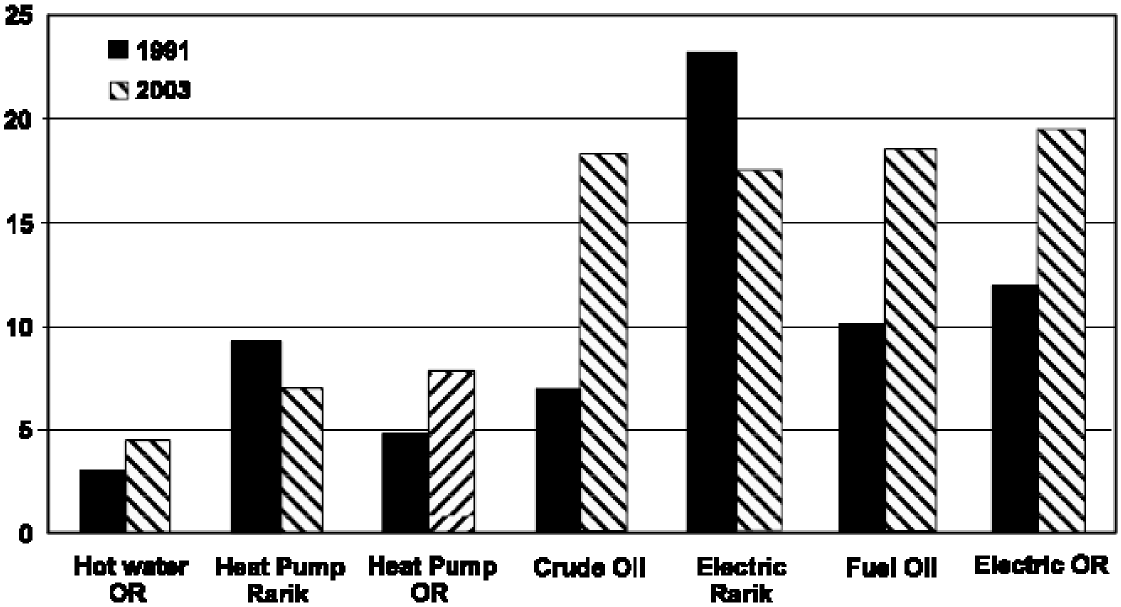
Utilization of geothermal energy for drying :

In Iceland, indoor drying has been tested in regions where geothermal energy is to be found. The reason is that the cost of oil or electricity for heating of the drying air during the drying process is considerably higher than the cost of hot water or geothermal steam. It is, therefore, more cost-efficient to locate the processing near inexpensive hot water and steam sources and collect the raw material and transfer it to the processing plant.

The price of energy for heating varies much from one energy source to another and from one location to another.

The price of oil has fluctuated but the price of hot water and electricity has changed less, although it tends to follow the price of oil. (See Figure).

The figure shows the energy costs of heating air for drying one kilogram of dried cod head in Iceland. The prices are extrapolated using the price in January of 2003 and the main assumptions are that the energy required for evaporating one kilogram of water in the drying process from a substance is about 5,800 kJ (1,400 kcal), the efficiency of oil boilers is estimated at 90%, coefficient of performance (COP) of heat pumps 2.5, and it is assumed that the hot water is cooled from 80 °C to 30 °C.



Comparison of prices for different types of energy for heating, ISK for drying one kilogram of dried cod head, based on cost in January 2003 (1 USD = 80 ISK). (OR= Reykjavik Energy and Rarik = Icelandic state electricity).

The advantages of using a geothermal heating system include :

(a) elimination of fire hazards,
(b) no contamination or discoloration of the product because there are no products of combustion in the air stream, and
(c) elimination of conventional fuels.

Exploitation of an existing geothermal well for fishfarming of eels and sturgeons : District du bassin d'Arcachon

This plant has been supported three times by the European Commission in 1981, 1989 and 1991.
The aim of the project was the recovery of an old oil wildcar to produce geothermal water to ensure the heat requirements of 5 hectares of greenhouses to be built. Finally the plant was constructed in 1993 and hot water used for fishfarming applications. The existing geothermal plant produces 200 m^3/h at 75 °C temperature to maintain by means of a plate heat exchanger a temperature of 17 °C in the ponds during all the yea. First year of exploitation (1992-93) has proved energy savings estimated at about 1 000 TOE.

The 200 m^3/h geothermal water flow at 75 °C will be used to heat the water of the ponds allowing breeding of 10 T of eels and 20 T of sturgeons. A new work over of the well with realization of additional seals and stimulations would increase the natural artesian flow rate from 130 to the required 200 m^3/h with a well head pressure of 3 Bars. The geothermal water will be transported to the plant (660 m) and after cooling via a plate heat exchanger discharged to the nearby coastal river.

The water coming from the river "La Leyre" is heated by the geothermal water at 75 °C via a plate heat exchanger. The well tests performed by BRGM in 1990 have demonstrated a 200 m^3/h assisted flow rate.

The perennity of the geothermal resource is proved because the well since 1984 has been producing 130 m^3/h by artesian flow.
The fishfarm itself has been constructed by a private company "l'Esturgeonniere" with the support of the DDA (Direction Departementale de l'Agriculture).
The geothermal loop (subsurface and surface equipments) has been installed in July-August 1992. The hydrodynamic conditions in the well while pumping are as expected and the whole installation including the fishfarm put into operation during August.
The sturgeons are in the ponds since the early 1993.
The testing of the geothermal loop and secondary loop is on going and the commissioning period ended on October 1, 1993.
The project is completed. The first tests indicate a performance corresponding to the feasibility studies. The fishfarm produces only sturgeons and the annual energy saving would reach 3200 TOE.

The geothermal loop was built in summer 1992 and comprises :
- electrical submerged pump
- a speed variator
- an exhaust tubing to produce water
- a well head
- a surface network to carry out the geothermal water to the fishfarm (600 m)
- monitoring equipments
- plate heat exchanger in titanium in order to avoid corrosion and scaling

Energy aspects :
During the heating season 1992-93, a net energy saving of 2.864 TOE has been realized measured and the extrapolation to a full year of production give an expected result of 4.000 TOE. This value can be compared with the design study carried out, in 1990 and which forecasted possible savings of 3.248 TOE/y. This result is not only attained but 20% higher.

Pulp, Paper, and Wood Processing

The site for the integrated newsprint, pulp and timber mills of the Tasman Pulp and Paper Company Ltd., located in Kawerau, New Zealand, is the largest industrial development to utilize geothermal energy. The plant site was selected because of the availability of geothermal energy.
Geothermal exploration at Kawerau started in 1952 with the main purpose of locating and developing the geothermal resource for use in a projected pulp and paper mill.
The mill produces approximately 200,000 tons of kraft pulp and 400,000 tons of newsprint each year.
In 1995, the Tasman Pulp and Paper Company was using a total flow of 0.60 million lb/hr from six wells to supply steam at two pressures, 200 and 100 psi. The geothermal steam, which is generated by separate flash plants in the bore field, is used:
1. For directly operating log kickers in the wood room, for timber drying for shatter sprays, and for combustion air heaters in the recovery boilers.

2. To generate clean steam in shell-and-tube boilers for use in the paper making equipment. Clean steam is necessary as the small percentage of non condensible gases in the geothermal steam can cause intolerable temperature fluctuations in paper-making equipment. These heat exchangers are the most important users of geothermal steam at Tasman.
3. For a 10 MW turbo-alternator installed in 1960, designed to exhaust to atmosphere. In 1968, a single effect evaporator was installed to use exhaust steam to provide additional black liquor evaporation capacity.
Geothermal supplies approximately 26% of the total process steam requirement and up to 6% of the electricity demand at Tasman.
A small, experimental wood drying facility currently is tested at the Polish Academy of Science site at the Zakopane geothermal district heating network.

Diatomite Plant

The production of diatomaceous earth at Namafjall, Iceland, utilizing geothermal energy, is an important development for geothermal energy because it serves as an example of the way in which cheap geothermal energy can make a process economic when, with conventional energy resources, the process could not be justified. The diatomaceous earth is dredged from the bottom of Lake Myvatn by a suction dredger, and the diatomaceous slurry is transmitted by pumping through a 2 miles pipeline to the plant site. Up to 50 ton/h of steam at 361oF/147 psig may be transmitted from bore holes 1,970 ft away. The capacity of this plant was 28,100 tons diatomite filter air in 1995.
Steam is used to keep the reservoirs containing settled diatomaceous earth ice-free and in the dryer, which is a rotary steam tube type. Of steam, approximately 30 ton/h are used for the dryer. Approximately 6 tons of dry diatomite is produced per hour. The diatomite's moisture content is reduced from 88 to 89% to 2 to 6% in the process.

Other Industrial Uses

The oldest known use of geothermal energy for industrial applications occurred in Italy. In circa 1500 B.C. the Etruscans used geothermal energy in the Tuscany region not only for therapeutic purposes, but also for the exploitation of the salt products deposited near the edges of the lagoni (fumaroles). Traces of boric salts have been found in the glaze of Etruscan plates and crockery, a fact testifying to how these people, many centuries before Christ, had already developed a high degree of artistry and technology in the grinding and chemical treatment of the borates, and also in the proportioning of these products with the other substances that composed their fine pottery.
In 1812, the first attempts were made to extract boric acid from boiling mineral springs scattered over a large area between Volterra and the mining center of Massa Marrittima. This boric acid was produced by evaporation of boric solutions in iron cauldrons with crystallization in wooden barrels. Brick domes were built over the natural outlets of steam, forcing the steam through an orifice to feed the evaporation boilers. Francesco Larderel was founder of the boric acid industry and in 1846 the area was named Larderello in his honor. With an increase in production, growth in trade, and refinement of the process, a wide range of boron and ammonium compounds were produced in the early 1900s. This process continued until World War II; after the war, the plant was put into operation again and continues to this day, using imported ores, to produce boric acid with approximately 30 ton of steam/h.

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). On the other hand, the ECOMILK project (Tuscany) is not more operational, and the industrial applications in the Larderello area have been reduced to 47 TJ/y. Production and sale of carbon dioxide from a geothermal well of the Torre Alfina geothermal field is still in operation.

Special feature: Possibilities of geothermal : drying in the Aegean islands

Greece, like several other Mediterranean countries, is rich in geothermal energy. In particular, in the Aegean island and coastal areas there are abundant easily accessible geothermal resources reaching almost 100ºC. A review of these resources can be found in Fytikas.
Islands with low and moderate temperature geothermal resources include Milos, Santorini, Kimolos, Kos, Nisyros, Evia, Chios, Lesvos and Samothraki.
Consequently, there is considerable potential for meeting some of the drying requirements of several agricultural products by geothermal energy.

In Santorini Island (and in other islands in Cyclades) a special variety of small tomatoes (cherry tomatoes) is cultivated for many years. Part of the product is consumed as fresh vegetable, while another part is dried in the sun and is sold as delicatessen. Low-temperature geothermal energy can be used efficiently for dehydrating this variety of tomatoes in these islands. Geothermal drying can be partially substitute the traditional 'sundrying' process and eliminate some of the quality problems of the dried products associated with this method. Geothermal water, with temperature as low as 60ºC, can be used to heat atmospheric air (to a temperature of 55ºC) in finned tube air heater coils (air-water heat exchanger).
In case the geothermal water is corrosive, as is usually the case with the saline geothermal waters encountered in the Aegean region, a second water-water heat exchanger may be required, constructed of corrosion-resistant materials.

It appears that in Cyclades the only traditional agricultural product that can be dried is tomato, because the cultivation of other vegetables and fruits is limited.
However, in Evia and the islands of Northern Aegean several fruits (apricots, prunes, figs), and vegetables (e.g. peppers, onions, garlic, asparagus, tomatoes and alfalfa – used for animal feeding) can be dehydrated using geothermal energy.

In the summer of 2001, a new direct use of geothermal energy was demonstrated in N. Erasmio, Xanthi, dealing with the dehydration of tomatoes. It was shown that low-temperature geothermal energy can be used efficiently and reliably in heating the drying air needed in the dehydration process. With geothermal dehydration the product retains the deepred colour, the nutrients and flavours of the fresh tomatoes and high-quality "sundried" tomatoes are produced.

The success of the tomato drying will certainly lead to the extension of the unit regarding its capacity, drying period and drying crops (e.g. peppers, asparagus, figs and apricots). Actually, in a pilot scale the unit was used successfully in May 2002 to dehydrate not well dried figs. It is noted that the capacity of the unit (geothermal water, heat exchanger, air fans) is more than double of the 2001 production. Geothermal drying of fruits and vegetables can be accomplished with water temperatures as low as 55℃, something that is fulfilled by most low enthalpy geothermal resources in Greece.

There is a large low-temperature geothermal potential in several Aegean Islands (Santorini, Milos, Kos, Chios, Lesvos etc.) that can be used for “sun-drying” of locally produced fruits and vegetables. In particular, geothermal energy drying of cherrytomatoes seems to be a viable process in the Cyclades Islands, where this product is cultivated and served as a specialty.
Other vegetables and fruits that can be geothermally dehydrated are apricots, prunes, figs and asparagus.

MARKET POTENTIAL

Industrial applications yet constitute the smallest sector of geothermal direct use. The industrial sector, at least in theory, offers a very attractive target for geothermal use. Industrial processes operate at high load factor relative to other geothermal applications, offer a concentrated load at a single location and in some cases are characterized by energy as a significant portion of production cost. Together these qualities suggest attractive conditions for geothermal application.

Historically this has not translated into extensive use however. In fact, over the past 20 years, only a handful of projects have been initiated and several of these have ceased operation. The single remaining large application, food dehydration, has been very successful with large facilities currently operating in Greece, France...

The issues that have prevented wide-scale use of geothermal in the industrial sector relate to the high temperature requirements for most processes, the use of steam rather than hot water and the fact that geothermal resources tend to be dominated by low-temperature hot water production. Though it is unlikely that large potential exists in the industrial sector there may be some niche opportunities which to date have not been capitalized upon.

Agriculture has been one of the economy sectors where the direct application of geothermal energy had a quite quick development, thanks to the intensive work of the FAO CNRE Network for geothermal energy use in agriculture during the 80-ies of the past century. Main fields, where practical experience and positive technical/technological and economical results have been gained, are as follows:

Heating of greenhouses

About 900 ha of greenhouses are presently heated with geothermal energy, about 50% of which are located in Mediterranean countries. That is about 14% of the total geothermal direct application in the world. After the initialization in France, Macedonia, Greece and several Central/East European countries in late 70-ies and early 80-ies, and development of a set of different heating technologies accommodated to the requests of different types of greenhouse constructions, cultures (flowers and vegetables) and available temperatures of geothermal water, a process of continual development all over the world is in flow.

Present “know how” enables competitive economical solutions both for the simple and sophisticated greenhouse constructions and growing technologies and easy incorporation in centralized integrated or district heating projects. However, final success of the applied technical solutions and economy of exploitation still depend very much on quality of initial technical design of the heating system(s).

Open fields heating

Low temperature heating of the plant roots provokes earlier and quicker development of many cultures and, in that way, harvesting during the spring months, when the prices at

the market are much higher than during summer. Earliest trials in France during the 80-ies have been unsuccessful due to the wrong choice of cultures (corn and similar grain cultures). However, the example of growing the asparagus in Greece proved the opposite, i.e. it's a very profitable use of geothermal energy which shall have quite a quick development during the coming years.
Enough developed technologies are available, which can be applied in different climate conditions and grown cultures. Economy of use depends mainly on the choice of grown cultures.

Irrigation with warm water

By the application of irrigation of the plants with warm water cold shocks are avoided and convenient feeding is enabled. It's an obligative measure in sophisticated greenhouse completes, but during the recent years is more and more in use also in the simple ones and open field growing of different plants.
This type of geothermal energy application is normally applied as the last phase of cascade systems, enabling improvement of its total economy.

Aquaculture

Fish farming in warm water is a proven geothermal energy direct application in many countries in the world, as are Italy, France, Hungary, Greece, U.S.A., China, etc. Problems of development are more connected to the biological than to the technical/technological problems.
Recently, also the algae growing (spirulina) is developed in Bulgaria and Greece and shall be probably a promising field for future development.

Exploitation of an existing geothermal well for fishfarming of eels and sturgeons : District du bassin d'Arcachon

This demonstration plant is technically successful and the energy impact of 4.000 TOE/y of natural gas saved represents a big reduction of CO_2 emission in this area.
The fishfarm is also successfull, the sturgeons are produced as expected.
This montage appears well adapted to valorise local energy resources and should be replicated. The limiting factor in this type of project is to find the good candidate to invest in a new industrial activity.
The failure of the first project (greenhouses : no horticultural candidates to use the heat at the surface) is a relevant example of problem but the success of the fishfarm realization proves also that the obstination of the public authority in the geothermal sector is necessary to overcome all the difficulties linked to renewable energies development.

Drying of agricultural products

Low temperature drying of different agricultural products enables improvement of the quality of final products and very competitive prices of used heat. Excellent examples are the rice drying unit in Macedonia and vegetable drying line in Guatemala. Drying of alpha-alpha and other animal food is also developed in different countries in the world.

Uses in food processing industry

Food processing industry is one of the most promising field for economical direct application of geothermal energy. However, due to the influence of different local factors, very poor practical experience is available (China). Anyhow, it is proved that existing technologies can be easily accommodated to the geothermal energy use and it can be expected that development shall begin, sooner or later.

All together, geothermal energy use in agriculture and food processing industry participates with about 25%, i.e. lower than 7-8 years ago (26%). Principal reason is the problematic transition process of Central/Eastern European countries, previously leading in direct application development. Together with the stabilization of their economies, a quicker process of development can be expected during the coming years. Very positive is the example of Tunisia where development of geothermal energy use in agriculture was in continual acceleration during the recent 10 years. This proves that direct application in agriculture and food processing industry is not a monopoly only of middle and high developed countries but a good chance for improving profitability of these economic sectors in less developed ones.

BARRIERS TO GROWTH

Although industrial processes consume substantial amounts of heat, the temperatures at which the heat is required are far above the typical range encountered in low-temperature geothermal resources. As a result, it is unlikely that most industries will be able to take advantage of geothermal resources.

By carefully targeting those processes characterized by the lower temperature heat input requirements, possibly taking advantage of power plant effluent and technologies such as vapor recompression, there may be niche applications which can yield attractive savings.

Although the industrial processes have been sorted by energy use and temperature level, many other issues can impact the ability to use geothermal resources and the ranking should be considered very preliminary.

Geographic limitations would be a critical factor. For paper, celluose fibre and chemical based industries, proximity to feed stocks may be a significant consideration. To gain a more realistic picture of the potential, a more detailed evaluation of the most favorable processes addressing such issues as geography, production volume, transportation costs and other issues would be necessary.

In parallel an evaluation of the role, if any for vapor recompression would be useful. An examination of hardware requirements, availability, costs, performance of existing systems in industry and suitability for geothermal fluids (materials) would help to bring clarity to the prospects for this technology.

Temperature requirements of industrial processes

Part of the reason for the general lack of industrial applications is the nature of the way industry uses heat. An evaluation of industrial energy use found that of 97% of all processes required heat input in the form of steam at 121℃ or higher. An examination of direct-use wells reveals that 99% of all wells are 121℃ or less. In the context of geothermal, temperatures above 121℃ are in the ra nge of resources that would be used for electric power generation rather than direct-use. In most industrial processes, opportunities for lower temperature heat input are satisfied through heat recovery within the process itself and unless the steam is consumed in the process, no boiler make-up water heating is required.

The opportunities in the industrial sector, though attractive from an energy use perspective, are fundamentally mismatched to direct use geothermal in terms of temperature (assuming higher temperature resources are used for electric power generation).

RECOMMENDATIONS

The most important energy considerations for an industrial complex are the cost, quality, and reliability.

Geothermal energy may be attractive to an industry providing :

(a) the cost of energy/lb 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.).

REFERENCE TO MORE DETAILED SOURCES OF INFORMATION

Kaviar à la Gascogne Miosleteich
Text Werner Bussmann
Design Oliver Joswig
Published by Geothermische Vereinigung e.V.

Industrial Applications
Paul J. Lienau and John W. Lund
OIT Geo-Heat Center

Examples of Industrial Uses of Geothermal Energy in The United States
John W. Lund
Geo-Heat Center
GHC BULLETIN, September 2003

Industrial Processes And The Potential For Geothermal Applications
Kevin Rafferty
Geo-Heat Center
GHC BULLETIN, September 2003

The Drying Of Fish And Utilization Of Geothermal Energy - The Icelandic Experience -
Sigurjón Arason
Icelandic Fisheries Laboratories and The University of Iceland,
GHC BULLETIN, December 2003

Use Of Geothermal Energy For Tomato Drying – Possibilities In The Aegean Islands
N Andritsos1, P. Dalampakis2 and N. Kolios3
International Summer School on Direct Application of Geothermal Energy