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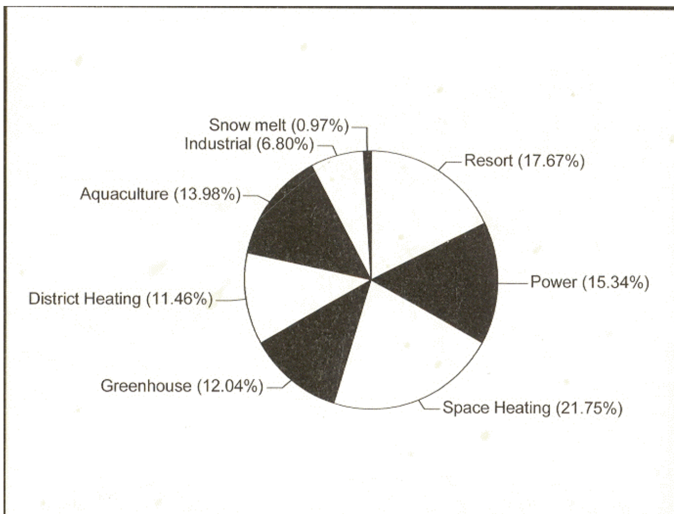
GHC Technical Assistance and International Activities



Leading Countries with Direct-Use	Installed MWt	Production GWh/a
Japan	1159	7500
Iceland	1443	5878
China	1914	4717
USA	1905	3971
Hungary	750	3286
New Zealand	264	1837
France	309	1359
Italy	314	1026

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A Quarterly Progress and Development Report on the Direct Utilization of Geothermal Resources

CONTENTS Page

Cover: Top left: GHC Technical Assistance Reports: top right: Akranse-Borgarfjordur pipeline at Deildatunga, Iceland; bottom left: eel farm in slovakia; and bottom right; world direct-use figures.

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Oregon Institute of Technology
3201 Campus Drive
Klamath Falls, OR 97601
Phone: 541-885-1750
Email: geoheat@oit.edu

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EDITOR

John W. Lund
Typesetting/Layout – Donna Gibson
Graphics – Tonya “Toni” Boyd

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RECENT DIRECT-USE TECHNICAL ASSISTANCE ACTIVITY

Kevin Rafferty
Geo-Heat Center

INTRODUCTION

The U.S. Department of Energy is currently developing a long-range plan to guide its geothermal activities for the next 10 years. As part of this task, a meeting was recently held in Klamath Falls to examine those issues related in direct use. To acquaint those in attendance with recent trends in industry activity, a summary was prepared of Geo-Heat Center technical assistance (TA) activity over the past two years. The following data is based on contacts made with the public, through the TA program between October 1996 and September 1998. This information provides a clear picture of the areas of current activity in direct use and as a result, the most likely areas to remain most active in the short-term future.

Figure 1 provides a summary of all Geo-Heat Center technical assistance activity over the past two years. The focus of this article is direct use. It is apparent from the data, however, that geothermal heat pump (GHP) requests for assistance constitute a significant part of the Center's TA volume. Approximately 80% of the requests for GHP assistance are related to residential systems. Interestingly, most of these requests are received via email and the typical contact is an individual planning a large (2500 sq. ft to 6000 sq. ft) home in a rural setting in a moderate-to-cold climate. This suggests that our activity in this area is an accurate reflection of the niche market currently served by GHP systems in the residential sector.

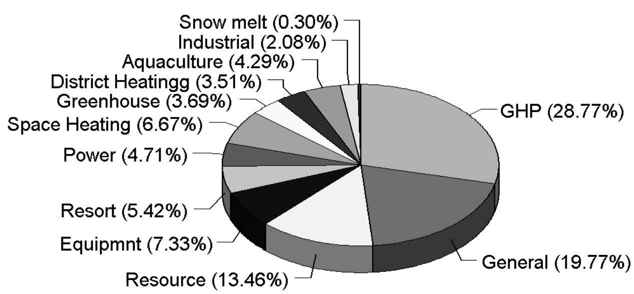

Figure 1.

General requests for information (19.8%) are related to tours of geothermal facilities provided by Geo-Heat Center staff, information requests related to geothermal statistics, project locations, and the growing area of email requests from school children for help with their homework.

The Resource category (13.5%) represents requests related to general locations of resource areas in the U.S., specific locations of hot springs and general information about geothermal energy. These requests do not involve a specific project.

Figure 2 focuses on only the requests for assistance that are clearly related to direct-use projects. It is apparent that the distribution is quite even with respect to the various uses. Resort applications (17.7%) are virtually all related to expansion and repair of existing resorts, pools and similar facilities. Over the entire two-year period, only one new resort project was initiated. This project, located in Washington State, is currently in construction. Little new project development is occurring in the resort category.

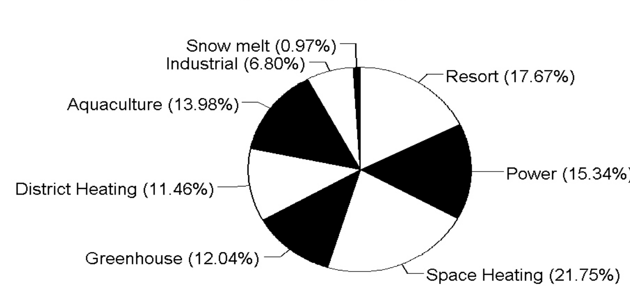

Figure 2.

Power generation requests (15.3%) are generally of two types. The first involves questions about a particular project or level of development in a particular state. This involves only providing general information which is available in the literature. The second, and much more common, type of power generation request is project related. The typical case involves an individual who has a geothermal resource on his property and needs information about how to go about generating electricity. Invariably, our response involves explaining the nature of geothermal power plants in terms of scale, basic operation, performance, flow requirements and general economics. There is a commonly held misconception that generating power with geothermal is similar to buying a solar panel or a Coleman generator and that resources of 100°F are perfectly suitable for the application. There were no projects identified in the past two years, as a result of TA contacts, that involved a realistic power generation application.

The remaining categories, Space Heating, Greenhouse, District Heating, Aquaculture and Industrial, are the key direct-use project related categories. Superficially, it would appear that there is a good balance between these uses. In terms of number of contacts, this is true. However, to determine in which of these areas there is the greatest level of project development activity, it is necessary to look in greater depth at the nature of contacts in each of the categories.

Figure 3 presents a breakdown of contact types for the Space Heating category. Space heating, as it is used here, relates the heating of single buildings rather than multiple buildings (which is covered under the District Heating category). The number of contacts in Figures 3 through 7 are broken down into four types: contacts relating to existing projects, contacts related to new projects, contacts related to international requests, and non-project related requests. Approximately one quarter of space heating requests for assistance are related to existing projects. These include primarily maintenance, repair and equipment replacement issues for operating systems. Nearly 44% of the contacts are directly related to new projects including such topics as equipment selection, feasibility, cost and resource development. The small percentage of requests from the international sector is a reflection of the fact that individual building space heating with geothermal is not common in other countries. When geothermal is used for space heating it is normally in conjunction with district heating. Non-project related contacts in this area are responses to general space heating information requests, communications related to staff activities in the American Society of Heating, Refrigeration and Air-Conditioning Engineers (ASHRAE) and occasionally mis-labeled logbook entries.

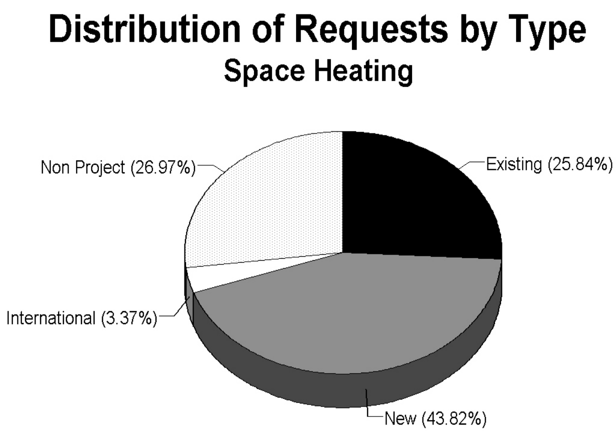

Figure 3.

Figure 4 presents a similar summary for the Aquaculture category. Geothermal applications of aquaculture generally involve the raising of warm-water fish species. Roughly 10 % of our contacts are related to existing operations. This low percentage is likely a reflection of the relatively simple mechanical arrangement used in these systems with which operators have little problem. The bulk of aquaculture contacts (61 %) is related to the development of new projects. This results from the explosive growth in aquaculture in general over the past several years. Most new geothermal applications are involved with Tilapia which is the fastest growing single species in aquaculture in general. International requests for aquaculture assistance constitute only about 10 % of the total maybe related to the fact that much of the aquaculture activity outside the U.S. is in much warmer climates precluding the need for heat. Non-project requests are most often requests for Geo-Heat Center publications on this topic, particularly those relating to the past work with Macrobrachium Rosenbergii (Malaysian prawn) performed here at OIT.

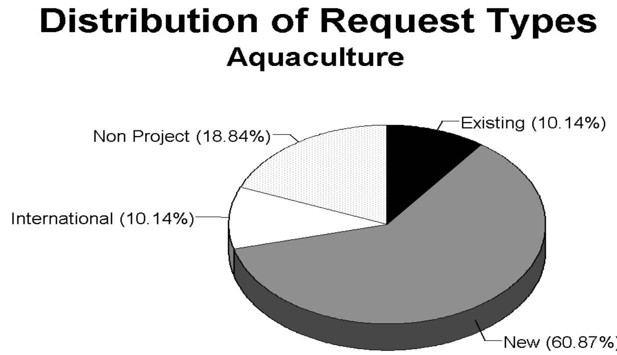

Figure 4.

Figure 5 presents the distribution of requests for Greenhouse applications. Again, a substantial percentage (58%) of the contacts involve new project development. As with other categories, requests for assistance with existing projects (21 %) are most often related to equipment replacement or maintenance.

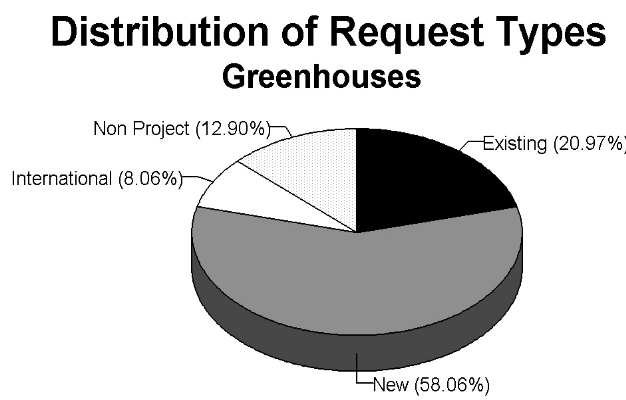

Figure 5.

Figure 6 presents the distribution of requests for assistance in the area of District Heating. The largest single category here is the non-project related area. This is a reflection of Geo-Heat Center staff activities on the ASHRAE District Heating and Cooling Technical Committee. All communications relating to committee activities are logged as district heating. In addition, tours provided by Geo-Heat Center staff of local geothermal facilities for visitors to Klamath Falls are logged as district heating. Due to the complex nature of district heating systems and the extensive piping networks required, a much higher percentage (31%) of requests for assistance are related to operations and maintenance than for other direct-use applications. New project-related requests are the smallest portion of this category. This is a reflection of the negligible level of activity in district heating in the U.S.

In fact, all of the activity in new project development is related to only two systems in the past two years—neither of which has entered construction. International requests are a reflection of the higher level of district heating practiced in other countries—particularly Europe.

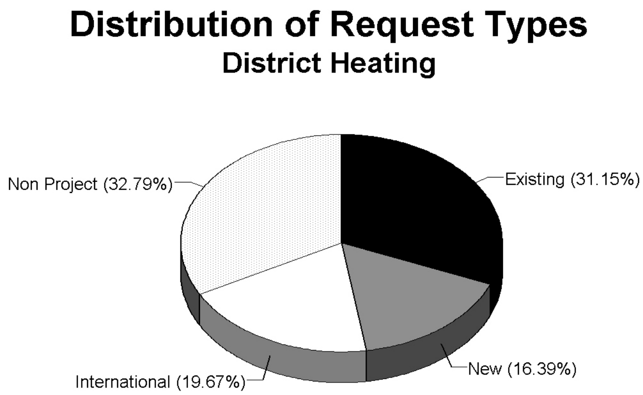

Figure 6.

Industrial applications are summarized in Figure 7. Industrial applications include such uses as dehydration, gold mining and refrigeration. Industrial applications in the U.S. are few, but tend to be very large in scale and quantity of energy displaced. The distribution of requests underscores the low level of new project development with only 3% of contacts related to this area. International and non-project related constitute equal shares of the remaining contacts. These are requests for generic application publications (refrigeration, dehydration, etc) or for information on the use of geothermal for industrial applications in general. Dehydration is of particular interest to Pacific Rim nations. Of note is the fact that none of the requests for assistance are related to existing systems. This is likely a reflection of the more sophisticated nature of the system owners in industrial applications.

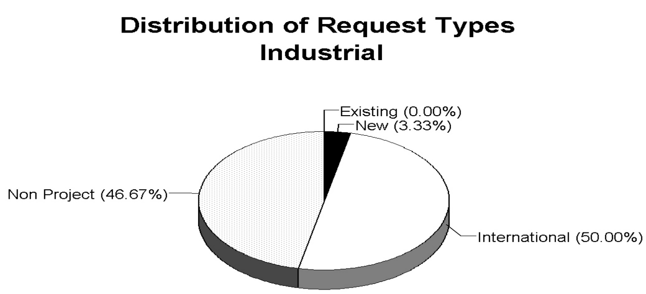

Figure 7.

Figure 8 is a summary of the new project activity in the five application areas presented earlier. It is apparent that the new projects are resulting from three principle areas: space heating, greenhouses and aquaculture. Less than 10% of new project-related contacts were in the areas of district heating and industrial applications, and as mentioned above, none of these are actually in construction.

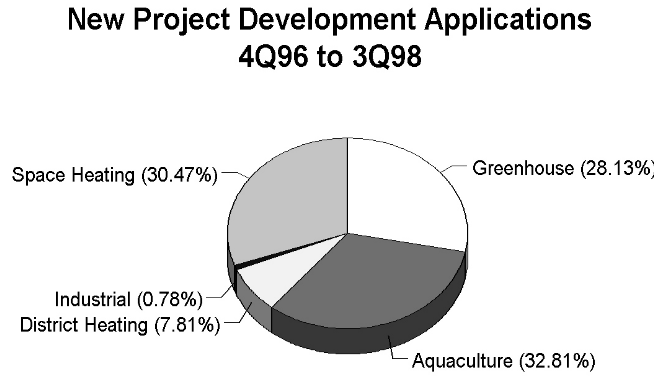

Figure 8.

Promoting greater use of geothermal resources for direct use could best be done by targeting those areas in which there is already a clearly defined interest on the part of developers. Fortunately, both the greenhouse and aquaculture industries have well established professional and industry groups (and publications) to serve as information conduits for these efforts.

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DIRECT USE OF GEOTHERMAL ENERGY AROUND THE WORLD

Ingvar B. Fridleifsson
President, International Geothermal Association
Orkustofnun, Grensasvegur 9, 108 Reykjavik, Iceland

SUMMARY

Geothermal energy has been produced commercially for nearly a century, and on the scale of hundreds of MW for over four decades both for electricity generation and direct use. The world direct-use energy production is about 37 TWh/a (installed capacity of 10,000 MWt in nearly forty countries), and is, with the exception of China, mainly in the industrialized, and central and eastern European countries. Fourteen countries have installed capacities over 100 MWt. The main uses are space heating (33%), heat pumps (12%) for heating and cooling, bathing (19%), greenhouses (14%), aquaculture (11%) and industry (10%). The application of the ground-source heat pump opens a new dimension in the scope for using the earth's heat, as heat pumps can be used basically everywhere and are not site specific as conventional geothermal resources. Geothermal energy, with its proven technology and abundant resources, can make a very significant contribution towards reducing the emission of greenhouse gases worldwide. It is necessary, however, that governments implement a legal and institutional framework and fiscal instruments allowing geothermal resources to compete with conventional energy systems and securing economic support in consideration of the significant environmental benefits of this energy source.

INTRODUCTION

Geothermal utilization is commonly divided into two categories (i.e., electric production and direct application). The minimum production temperatures in a geothermal field generally required for the different types of use are shown in Figure 1 (Lindal, 1973). The boundaries, however, serve only as guidelines. Conventional electric power production is limited to fluid temperatures about 150°C, but considerably lower temperatures can be used with the application of binary fluids (outlet temperatures commonly at 100°C). The ideal inlet temperatures into houses for space heating using radiators is about 80°C; but, by using radiators of floor heating, or by applying heat pumps or auxiliary boilers, thermal waters with temperatures only a few degrees above the ambient can be used beneficially.

It is a common misconception that direct use of geothermal is confined to low-temperature resources. High-temperature resources can, of course, also be used for heating and drying purposes even if the process is at a very low temperature. Refrigeration is, in fact, only possible with temperatures above about 120°C. The world's two largest industrial companies using geothermal energy (the Kawerau paper mill in New Zealand and the Kisilidjan diatomite plant in Iceland) both use high-temperature steam for their processes. The largest geothermal district heating service in the world (the Reykjavik District Heating serving about 152 thousand people), obtains 75% of its heat from low-temperature fields (85 - 130°C) and 25% from a high-temperature field (300°C production temperature). In addition to the straightforward use of hot water or steam, combined heat and power units and cascaded use (where a number of temperature requirements are met from a single source) offer the potential for maximum energy extraction and economics.

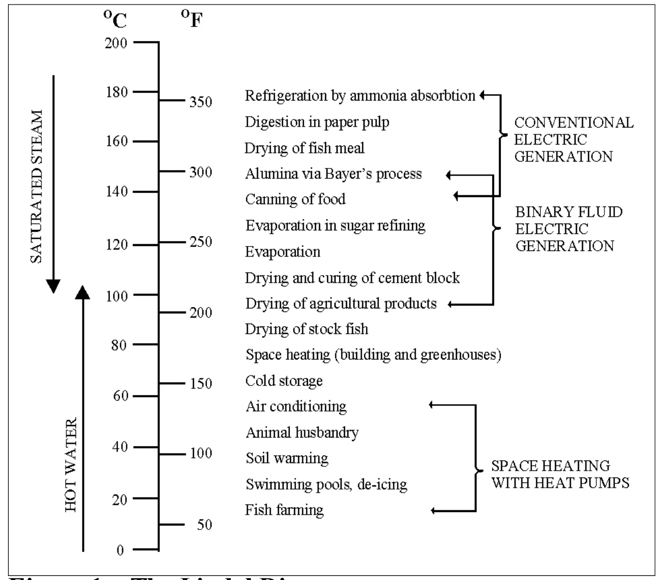

Figure 1. The Lindal Diagram.

WORLDWIDE USE OF GEOTHERMAL ENERGY

Geothermal energy has been produced commercially for nearly a century, and on scale of hundreds of MW for over four decades both for electricity generation and direct use. At present, there are records of geothermal utilization in 46 countries in the world (Stefansson and Fridleifsson, 1998). The electricity generated in these countries is about 44 TWh/a, and the direct use amounts to about 37 TWh/a (Table 1). Geothermal electricity generation is equally common in industrialized and developing countries, but plays a more important role in the latter. The world distribution of direct utilization is different. With the exception of China, the direct utilization is a serious business mainly in the industrialized, and central and eastern European countries. This is to some extent understandable, as most of these countries have cold winters where a significant share of the overall energy budget is related to space heating. Direct use of geothermal is very limited in Africa, Central and South America, as well as the Asian countries apart from China and Japan.

Table 1. Electricity Generation and Direct Use of Geothermal Energy 1997 (Stefansson and Fridleifsson, 1998)

	Electricity Generation			Direct Use		
	Installed Capacity MWe	Total Production GWh/a	%	Installed Capacity MWt	Total Production GWh/a	%
European Union	754	3,832		1,031	3,719	
Europe, other	112	471		3,614	14,790	
Europe, total	866	4,303	10	4,645	18,509	50
North America	2,849	16,249		1,908	3,984	
Central and South America	959	6,869				
America, total	3,808	23,118	53	1,908	3,984	11
Asia	2,937	13,045	30	3,075	12,225	33
Oceania	365	2,901	6	264	1,837	5
Africa	45	390	1	71	355	1
World Total	8,021	43,756		9,963	36,910	

It is of interest to note that Europe has only a 10% share of the world total electricity generation with geothermal; whereas, it has about 50% share of the direct use. It is the reverse for the Americas, with a 53% share of the electricity generation and only 11% share of the direct use. For Asia, Oceania and Africa, the percentage share of the world total is similar for electricity generation and direct use.

DIRECT USE OF GEOTHERMAL ENERGY

Direct application of geothermal energy can involve a wide variety of end uses, as can be seen from Figure 1 (Lindal, 1973). It uses mostly existing technology and straightforward engineering. However, in some cases, the technology is complicated by dissolved solids or non-condensible gases in the geothermal fluids. The technology, reliability, economics, and environmental acceptability of direct use of geothermal energy has been demonstrated throughout the world. In comparison with electricity production from geothermal energy, direct utilization has several advantages, such as a much higher energy efficiency (50 - 70% as opposed to 5 - 20% for conventional geothermal electric plants), generally the development time is much shorter, and normally much less capital investment is involved. Last, but not least, direct application can use both high- and low-temperature geothermal resources and is, therefore, much more widely available in the world. Direct application is, however, much more site specific for the market, as steam and hot water is rarely transported long distances from the geothermal site. The longest geothermal hot water pipeline in the world is 63 km, in Iceland. The production cost/kWh for direct utilization is highly variable, but commonly under 2 U.S. cents/kWh.

Data is available for the direct use of geothermal resources in some forty countries. The quality of the data is, however, high variable. Country papers were presented for most of these countries in the "Proceedings of the World Geothermal Congress" in Florence (Italy) in 1995. Freeston (1996) summarized these papers and gave a very comprehensive description of the situation in each country. The International Geothermal Association is preparing a new collection of country papers and national energy data for the World Geothermal Congress in Japan in the year 2000.

Table 2 shows the installed capacity and produced energy in the top eight direct-use countries in the world. It is worth noting that the two countries with the highest energy production (Japan and Iceland) are not the same as the two with the highest installed capacities (China and USA). the reason for this is the variety in the load factors for the different types of use.

Table 2. Top Eight Countries in Direct Utilization (Stefansson and Fridleifsson, 1998)

	Installed MWt	Production GWh/a
Japan	1159	7500
Iceland	1443	5878
China	1914	4717
USA	1905	3971
Hungary	750	3286
New Zealand	264	1837
France	309	1359
Italy	314	1026

TYPES OF DIRECT USE

Lund (1996) has recently written a comprehensive summary on the various types of direct use of geothermal energy. Space heating is the dominant type (33%) of direct use in the world; but, other common types are bathing/swimming/balneology (19%), greenhouses (14%), heat pumps for air cooling and heating (12%), fish farming (11%), and industry (10%).

Table 3 shows the types of direct use of geothermal in the top four countries in direct utilization in the world–all of which have a well developed tradition for direct use. It is very interesting, however, to see that each of the countries has its speciality in the direct use of geothermal. Iceland is the leader in space heating. In fact, about 85% of all houses in the country are heated with geothermal (Ragnarsson, 1995). The USA leads the way in the application of heat pumps for heating and cooling buildings (Lund, 1996). Over 70% of Japan's direct use is for bathing/swimming/balneology at the famous "onsen" (Uchida, 1997). China has a more even distribution of the geothermal usage than the other countries; but, nearly 50% of the use in China is for fish farming (Ren, et al., 1990). It is noticeable that of these four countries, as yet, only the USA makes a significant use of heat pumps. Several European countries (e.g., Germany, Switzerland, Sweden and France), however, also have a widespread utilization of ground-source heat pumps for space heating.

Table 3. Types of Direct Use in the World and the Top Four Countries (in %)

	World	Japan	Iceland	China	USA
Space Heating	33	21	77	17	10
Heat Pumps (heating/cooling)	12	0	0	0	59
Bathing/Swimming/ Balneology	19	73	4	21	11
Greenhouses	14	2	4	7	5
Fish Farming	11	2	3	46	10
Industry	10	0	10	9	4
Snow Melting	1	2	2	0	1
	100	100	100	100	100

HEAT PUMP APPLICATIONS

Geothermal energy has until recently had a considerable economic potential only in areas where thermal water or steam is found concentrated at depths less than 3 km in restricted volumes analogous to oil in commercial oil reservoirs. This has recently changed with developments in the application of ground-source heat pumps using the earth as a heat source for heating or as a heat sink for cooling, depending on the season. This has made it possible for all countries to use the heat of the earth for heating and/or cooling, as appropriate. It should be stressed that the heat pumps can be used basically everywhere and are not as site-specific as conventional geothermal resources.

Switzerland, a country not known for hot springs and geysers, gives an example of the impact this can have on the geothermal applications in what previously would have been called non-geothermal countries. The use of heat pumps in Switzerland (Rybach and Goran, 1995) amounts to 228 GWh/y. The population of the country is about seven million. If the same level of use would materialize in other European countries north of the Alps and west of the Urals (350 million people), the utilization of geothermal through heat pumps would amount to some 11,400 GWh. This is comparable to the total direct use of geothermal in Europe at present (18,500 GWh/y).

Geothermal heat pumps have been found to perform very well throughout the USA for heating and cooling buildings. At the end of 1997, over 300,000 geothermal heat pumps were operating nationwide in homes, schools and commercial buildings for space heating and space cooling (air conditioning), providing some 8,000 - 11,000 GWh/y of end-use energy according to different estimates. The geothermal heat pumps have been officially rated among the most energy efficient space conditioning equipment available in the USA. They reduce the need for new generating capacity and are found to perform at greater efficiencies than conventional air-source heat pumps used for air conditioning.

Financial incentive schemes have been introduced by several electric utilities in the USA encouraging house owners to use groundwater heat pumps for space cooling/heating purposes and thus, reduce the peak loads on their electric systems. The Geothermal Heat Pump Consortium has established a U.S. $100 million 6-year program to increase the geothermal heat pump unit sales from 40,000 to 400,000 annually and thus, reduce greenhouse gas emissions by 1.5 million metric tonnes of carbon equivalent annually (Pratsch, 1996). One-third of the funding comes from the U.S. Department of Energy and the Environmental Protection Agency; whereas, two-thirds come from the electric power industry. Financial incentive schemes have also been set up in European countries such as Germany and Switzerland.

THE ROLE OF GEOTHERMAL ENERGY IN ICELAND

Iceland is located astride the mid-Atlantic ridge, and is richly endowed with geothermal resources. Iceland has also large hydro-resources, which are used for the generation of electricity. In 1997, the total primary energy consumption in the country was 106 PJ or 2,541 thousand tonnes of oil equivalent. This was supplied by geothermal energy (48.1%), hydro-power (17.6%), oil (31.9%) and coal (2.4%). About 66% of the total primary energy consumption was thus served by renewable energy sources (geothermal and hydro). This is a higher share of renewable energy than in any other country.

Direct use is the main utilization of geothermal energy in Iceland (see Table 3 for types of use). At present, geothermal energy contributes only about 6% to the generation of electricity in the country, the main part being generated from hydro. By the year 2000, when the geothermal power plants presently under construction will be online, the share of geothermal energy in the electricity generation will be in excess of 15%. Two of the three main power plants have co-generation of electricity and hot water for district heating, thus securing efficient use of the geothermal resources.

The main reason for the advanced use of geothermal energy in Iceland is that geothermal energy is much cheaper than other energy sources for heating purposes. On average, the energy cost for heating is only some 20 - 30% of the cost by oil. The district heating companies are owned by the municipalities and are in most cases highly profitable. Typical prices of geothermal energy to the consumers for heating purposes are in the range 1.1 - 1.6 U.S. cents/kWh. The cost of electricity generation from geothermal steam is also quite favorable in Iceland, about 3 U.S. cents/kWh. The savings of the Icelandic economy by using geothermal energy for heating of houses instead of using imported oil, is estimated about 110 million U.S. $ per year or about 400 U.S. $ per capita.

INTEGRATED USE WITH OTHER ENERGY SOURCES

Geothermal plants are characterized by a low-operating cost, but a relatively high investment cost. The price of the heat/energy, therefore, implies a high-fixed cost which has to be taken into consideration when integrating geothermal into energy supply systems using two or more energy sources. Conventional development of geothermal energy requires 1 to 3 km deep wells, the drilling of which is relatively expensive. Once a geothermal plant is installed, the operating cost is very low, since water as the energy carrier is available on the spot. The "fuel" is paid up front with the drilling for the hot water/steam. Geothermal production wells have in several countries been operated for several decades with only minor servicing. Geothermal energy is very suitable for base-load plants and thus, can be in competition with other base-load plants such as heat and power co-generation units. The decision pro or contra geothermal energy use will always depend on the actual location, and the importance that people give to clean environment which comes with geothermal.

With due consideration to the above mentioned economic constraints, geothermal district heating plants can be combined very favorably with conventional peak-load plants. The latter have a low investment cost, high operation cost and high pollution. Therefore, they are kept in operation for as short periods as possible. In Europe, it is common practice that such plants cover the peak load, but produce only 10 - 20% of the amount of heat required annually. Thus, the above economic constraints have only little influence on the ecological advantages of geothermal energy. In case the temperature of the geothermal reservoir is not sufficient for the district heating system, then it can be raised by heat pumps or auxiliary boilers. These systems produce significantly less emission of greenhouse gases than conventional thermal plants using fossil fuels.

ENVIRONMENTAL CONSIDERATIONS

Geothermal fluids contain a variable quantity of gas, largely nitrogen and carbon dioxide with some hydrogen sulphide and smaller proportions of ammonia, mercury, radon and boron. The concentration of these gases are usually not harmful, but should be analyzed and monitored. The amounts depend on the geological conditions of different fields.

It should be stressed that the gas emissions from low-temperature geothermal resources are normally only a fraction of the emissions from the high-temperature fields used for electricity production. The gas content of low-temperature water is in many cases minute, like in Reykjavik (Iceland); where, the CO_2 content is lower than that of the cold groundwater. In sedimentary basins, such as the Paris basin, the gas content may be too high to be released, and in such cases, the geothermal fluid is kept at pressure within a closed circuit (the geothermal doublet) and reinjected into the reservoir without any de-gassing taking place. Conventional geothermal schemes in sedimentary basins commonly produce brines which are generally reinjected into the reservoir and thus, never released into the environment. The CO_2 emission from these is thus zero.

GROWTH OF GEOTHERMAL DEVELOPMENT

The growth rate of geothermal development has in the past been significantly affected by the prices of the competing fuels, especially oil and natural gas, on the world market (Fridleifsson and Freeston, 1994). As long as the oil and gas prices stay at the present low levels, it is rather unlikely that we will see again the very high annual growth rates for geothermal electricity of 17% as was the case during the oil crises of 1978-1985. The growth rate is, however, quite high due to the fact that geothermal energy is one of the cleanest energy sources available on the market. During 1975 -1995, the world average growth rate in geothermal utilization for electricity generation was 9% p.a., which is one of the highest growth rates experienced in the use of a single energy source.

The average growth rate in the direct use of geothermal energy seems to have been about 6% p.a., during the last decade. It is high affected by the competing prices of oil and gas on the world market. The large potential and growing interest for the development of direct applications in China for fish farming, public baths, greenhouses and district heating, and the great surge of installations of geothermal heat pumps in recent years exemplified by the USA, Switzerland and Germany, give a cause for optimism for the growth rate of direct applications.

Examples of high growth rate in the direct use of geothermal are found in countries such as Turkey and Tunisia. In Turkey, the installed capacity for direct use (mostly space heating) was 140 MWt in 1994, and had grown to 274 MWt in May 1997. It is expected to be 2,500 MWt in year 2000 and 3,600 MWt in year 2005 (Simsek, 1997). In Tunisia, geothermally-heated greenhouses have expanded from 10,000 m^2 in 1990 to 800,000 m^2 in 1997 (Said, 1997). They are expected to reach 1,750,000 m^2 in the year 2002. The greenhouses in Tunisia do, in fact, replace cooling towers five months per year to cool irrigation water from deep wells from 75 to 30^oC in oases in the Sahara Desert. The main products are tomatoes and melons for export to Europe.

WHAT IS EXPECTED OF GEOTHERMAL AND OTHER "NEW"AND RENEWABLES?

It is of interest to look at what is expected from geothermal energy in the future in international energy plans. Are there similar expectations for geothermal energy as there are for solar energy and wind energy? The world consumption of geothermal energy was about 13 Mtoe/a in 1995. With the high growth rate expected, the aggregate consumption of geothermal energy (for electricity and direct use) might be as high as 340 Mtoe/a by the year 2020 (Björnsson, et al., 1998). This is a very much higher figure than estimated for geothermal energy within the international energy community. A study organized by the World Energy Council (WEC Commission, 1993) includes forecasts for the various energy sources, including solar, wind, and geothermal energy, for the year 2020.

There are presented maximum and minimum possibilities, based on whether there will be major policy support or not. Table 4 shows that geothermal energy is expected to contribute some 40 Mtoe in the year 2020 in case of no special support and 90 Mtoe in the case of major policy support. Wind energy is expected to contribute 85 - 215 Mtoe, and solar energy 109 - 355 Mtoe in the minimum and maximum cases, respectively. The WEC Commission clearly expects relatively little from geothermal energy in the year 2020 irrespective of whether special policy support is given for the "new" energy sources or not. Both the minimum and maximum cases of the WEC Commission are very significantly lower than the 340 Mtoe/a by the year 2020 estimated as a realistic possibility by an Icelandic group in preparation for the 17th WEC Congress in Houston (Björnsson, et al., 1998).

Table 4. Expected Contributions from Three "New" Energy Sources in 2020 (WEC Commission, 1993)

	Minimum		Maximum (major policy support)	
	Mtoe	%	Mtoe	%
Solar	109	47	355	54
Wind	85	36	215	32
Geothermal	40	17	91	14
Total	234	100	661	100

The very low expectations that the WEC Commission has for the potential contribution from geothermal energy, compared to the other "new" energy sources, probably reflects to a certain extent the strength of the solar and wind energy lobbies. The geothermal community has the habit of being shy and keeping information to itself; whereas, the commercial interests of the manufacturing industries and the international associations behind solar and wind energy have secured greater success in public relations.

DISCUSSION

As shown in Table 1, the worldwide use of geothermal energy amounts to about 44 TWh/a of electricity and 37 TWh/a for direct use. A new estimate of the geothermal potential of the world (Björnsson, et al., 1998), shows the "Useful Accessible Resource Base" for electricity production to be some 12,000 TWh/a. A very small fraction of the geothermal potential has, therefore, been developed so far, and there is ample space for an accelerated use of geothermal energy for electricity generation in the near future. The scope for direct use of geothermal energy is even more plentiful, as the "Useful Accessible Resource Base" is estimated 600,000 EJ, which corresponds to the present direct use of geothermal energy for some five million years.

Björnsson, et al. (1998) maintains that if the development of hydro and geothermal energy is vigorously pursued, these resources could fulfill a very important bridging function during the next few decades until clean fuels technology and that of other renewables have matured enough to provide a meaningful share of the world energy supply. While the share of hydro power and geothermal energy resources in the world energy supply will remain modest, their technology is, in contrast to that of other renewables, mature with a century of practical experience. Unfortunately, very few decision makers at national, not to mention world level, realize the potential that geothermal energy may play in the world energy scenario as a clean and sustainable energy source.

Following the United Nations conferences on the environment in Rio (1991) and Kyoto (1997), the European Union has committed itself to reducing the overall emission of greenhouse gases by at least 8% below 1990 levels in the commitment period 2008 - 2012. Prior to the year 2012, only geothermal energy, hydro and, to a lesser extent, wind energy appear technically ready to make a significant contribution towards an overall reduction in the CO_2 emissions in Europe. In spite of this, as yet, the role of geothermal energy is very limited in the energy strategy plans for Europe.

The situation in the USA is considerably brighter at present for the development of geothermal energy. The U.S. Department of Energy's Office of Geothermal Technologies has recently identified five strategic goals for geothermal energy as a preferred alternative to polluting energy sources (USDOE-OGT, 1998). The following are amongst the strategic goals: a) supply the electric power needs of seven million U.S. homes (18 million people) from geothermal energy by the year 2010; b) expand direct use of geothermal resources and application of geothermal heat pumps to provide the heating, cooling and hot water needs of seven million homes by the year 2010; c) meet the basic energy needs of 100 million people in developing countries by using U.S. geothermal technology to install at least 10,000 MW by the year 2010; d) by the year 2010, develop new technology to meet 10% of U.S. non-transportation energy needs in subsequent years.

In most countries, a significant percentage of the energy usage is at temperatures of 50 - 100°C, which are common in low-enthalpy geothermal areas. Most of this energy is supplied by the burning of oil, coal or gas at much higher temperatures with the associated release of sulphur, carbon dioxide and other greenhouse gases. The scope for using geothermal resources alone as well as in combination with other local sources of energy is, therefore, very large. The application of the ground-source heat pump opens a new dimension in the scope for using the earth's heat, as heat pumps can be used basically everywhere and are not as site-specific as conventional geothermal resources. Geothermal energy, with its proven technology and abundant resources, can make a very significant contribution towards reducing the emission of greenhouse gases worldwide. The energy market is, however, very conservative when it comes to changes. It is necessary that governments implement a legal and institutional framework and fiscal instruments allowing geothermal resources to compete with conventional energy systems and securing economic support in consideration of the environmental benefits of this energy source.

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AKRANES AND BORGARFJORDUR DISTRICT HEATING SYSTEM

Árni Ragnarsson[(1)] **and Ingólfur Hrólfsson**[(2)]
(1) Orkustofnun, Grensásvegur 9, 108 Reykjavík, Iceland
(2) Hitaveita Reykjavíkur, Grensásvegur 1, 108 Reykjavík, Iceland

INTRODUCTION

In Iceland, there are about 30 geothermal district heating systems in operation in towns and villages. In most cases, they serve practically the total population of the respective communities, and totally about 83% of the house heating market in the country. All of them are community-owned, and they distribute and sell hot water on the basis of a monpoly. In addition to this, there are about 25 small privately-owned systems, each serving 50 people or more, mainly in rural areas, and a great number of smaller systems serving individual farms. Thus, the total share of geothermal heating in the country is about 85%. Reykjavik Municipal Heating is by far the largest of the district heating systems serving about 155,000 people, or more than half of the population of the country. The total installed capacity of all the geothermal district heating systems in Iceland is about 1,400 MW.

Akranes and Borgarnes are two towns in the western part of Iceland, about 100 km north of Reykjavik. They are situated at the coast, and have 5,200 and 1,700 inhabitants respectively. In Akranes, fishing and fish processing are the main employment, and Borgarnes is a center of commerce and services for the Borgarfjordur district, northeast of the town (Figure 1).

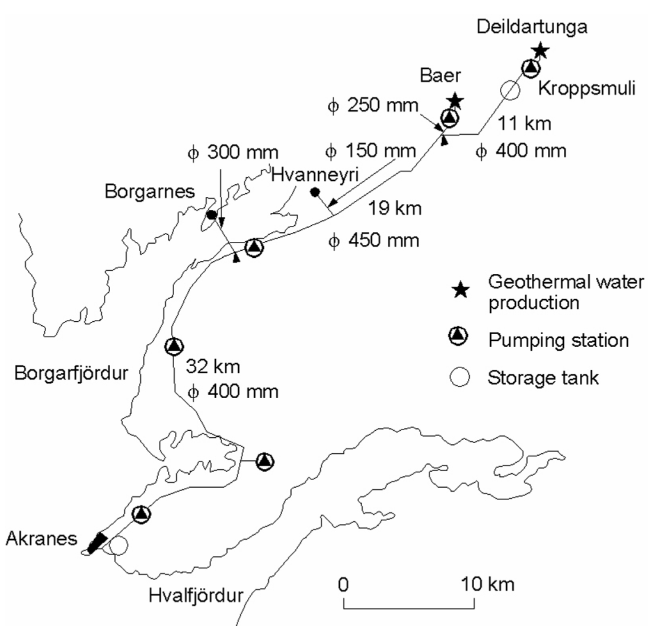

Figure 1. Overview of the district heating systems showing the transmission pipeline.

Geothermal investigations for Akranes started as early as around 1950; but in spite of several attempts, a geothemal field, which could be utilized economically, was not found for a long period. After the increase in oil prices in the early 1970s, futher studies were carried out. On the basis of the results of those studies, it was decided to build a combined district heating system for Akranes, Borgarnes, Hvanneyri (agricultural school) and some farms in the Borgarfjordur region. The water is piped from the hot spring Deildartunga, which is one of the largest hot springs in the world. Besides that, the system utilizes two wells at the farm Baer. The utilization of the hot spring makes the system different from most other district heating systems in Iceland, which are based on water from wells.

Akranes and Borgarfjordur District Heating System was established in 1979. Before that time, space heating in this area was both by oil (93%) and electricity (7%). The system has now been split into three companies: one that is responsible for all the hot water production and transmission, and one district heating system for each of the two communities.

SYSTEM DESCRIPTION

The springs at Deildartunga supply 180 L/s of water at 96°C and the wells at Baer can produce about 20 L/s in artesian flow. Thus, the combined supply capacity is 200 L/s. Currently, however, the system is using only 170 L/s at peak load, which are taken from the Deildartunga hot springs. The wells at Baer are only used if the supply from Deildartunga is interrupted for some reason and flows cannot be maintained by the storage tanks.

The collection system at the springs is very simple. An arrangement of low walls guides the boiling water into the collection pipes. These conduct the fluid to a nearby pumping station that pumps the water up to a storage tank at the highest point in the pipeline at Kroppsmuli a few km away. The system also includes two storage tanks to maintain supplies to Akranes and Borgarnes if breaks in the transmission pipeline occur. The tank at Borgarnes has a capacity of 2,500 m^3 and that at Akranes 2,000 m^3. These give the maintenance crews several hours in which to repair breaks. Pumping stations are at six different places in the system.

The distribution system is a single pipeline system, made of buried steel pipes, pre-insulated by polyurethane. The total pipe length of the distribution system is 107 km; thereof, 57 km in Akranes, 23 km in Borgarnes and 27 km in the rural areas. The water supplied is used directly by the users in their radiator systems and as domestic hot water. The return water is disposed of through the local wastewater system.

The total installed capacity of the system is about 60 MW and the annual energy supplied to the users was 382 TJ in 1997. The annual water consumption is about 2.2 million m^3. Of that, 60% is consumed in Akranes, 30% in Borgarnes and 10% in the rural areas of Borgarfjordur. In Akranes, the water temperature at the inlet to the distribution system is 77° C and the average temperature to the users 72.5°C. Corresponding values for Borgarnes are 82° C and 76.5° C respectively.

The original plans did not assume that the houses heated by electricity would be connected to the district heating system, as they did not have hot water radiators installed. Later, it was decided to make an effort to include these houses also, and today about 3/4 of the houses originally heated by electricity are connected to the district heating system.

The operation of the district heating system has from the beginning been based on two rather simple separate control systems, one in Akranes and another in Borgarnes. From 1993, the flow rate and water temperature at three different places in the system has been automatically monitored. These old systems have just been replaced by a new modern computerized system for control and monitoring of the whole district heating system. It gives the operatores a real time overview of all the main parameters and prepares reports of different types based on historical data. It is expected that this new system will increase the operational safety, and by better flow control and increased monitoring reduce the maintenance cost of the pipeline system.

THE TRANSMISSION PIPELINE

The transmission pipeline from Deildartunga to the storage tank at Akranes is 62 km long. It is probably the longest geothermal transmission pipeline in the world. Most of the pipeline (43 km) has a diameter of 400 mm and the rest (19 km) a diameter of 450 mm. The majority of the transmission pipeline is made of asbestos cement. A cross-section of the pipeline is shown in Figure 2. The main reason for the choice was a relatively low installation cost, which was of vital importance as the transmission pipeline represented over half of the total investment cost of the total system. Calculations showed that pre-insulated steel pipes would have made the system uneconomical compared to oil heating. The difference in installation cost lies mainly in the simple layout method possible with asbestos pipes; while, steel pipes require good protection against water. Also, asbestos has good thermal properties for this type of application. However, it is rather fragile and the pipeline suffers from frequent breaks. It should be pointed out that the system was built short time before asbestos was recognized as hazardous to people's health and later forbidden as a pipe material. Insulated steel pipes of a total length of 2.7 km are used where the conditions are unfavorable, like where the pipeline crosses streams and the fjord to Borgarnes.

No foundations as such were laid under the asbestos pipe. The ground was simply leveled and a layer of volcanic ash laid as a bedding material. The pipeline was laid directly on the ash and the exposed surface was covered by 50 mm thick rockwool segments. About 2/3 of the pipe surface is insulated in this way. A trench was dug alongside the pipeline and the excavated earth used to cover the pipeline. The parallel trench serves as a drainage channel.

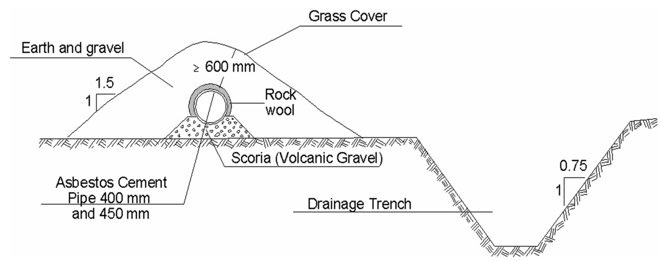

Figure 2. Cross-section of the asbestos tranmission pipeline.

The inlet water temperature to the transmission pipeline at Deildartunga is 96°C. The temperature drop along the pipeline depends strongly on the flow rate, resulting in considerable temperature drop at low flow rates. Also during periods of heavy rain, the insulation gets wet and the temperature drop can be very high. The flow rate is regulated to keep a constant supply temperature of 77°C from the pumping station at Akranes. During summer, a typical flow rate is 120 L/s and 170 L/s during winter. The excess flow, spilled to keep the water temperature at an acceptable level, can vary from 80 L/s during summer to no excess flow during winter peaks.

The asbestos pipeline has performed satisfactorily in spite of between 20 and 30 breaks each year. They are detected automatically and repaired quickly, and with high cost. In most cases, the users do not notice these breaks. The frequency of the breaks has not increased over the years and even decreased over the past few years.

One of the most important factors influencing the lifetime of an asbestos pipeline is the dissolution of calcium from the cement, which is the binding material of the pipe. This reduces the strength of the pipe and destroys it over time if the dissolution continues. The rate of dissolution depends mainly on the chemical composition of the water. Monitoring of the calcium dissolution from the pipeline between Deildartunga and Akranes over the years shows that it decreasing, indicating that the pipeline will keep sufficient strength for at least the next 20 to 30 years.

One problem with the transmission pipeline is that the earth cover has eroded and in some places consolidated due to drying, so the pipeline has sunken below the original ground surface level. In attempt to solve this problem, trenches have at some places been dug on both sides of the pipeline. It is important to have some vegetation on the earth covering the pipeline, mainly to stabilize it and also to improve the insulation and prevent water infiltration. This has been difficult to achieve without building fences on both sides of the pipeline.

Steel pipes mounted above the ground on foundations have required some maintenance. These pipes have an aluminum sheet, which protects the rockwool insulation and prevents water from coming in contact with the steel. It has shown to be difficult to make the sheet tight enough and keep the insulation dry, especially at the foundations, with the result of an external corrosion of the pipes. This problem is well known by other district heating systems in Iceland.

Figure 3. Collection and pumping station at Deildartunga.

TARIFF SYSTEM

From the beginning, Akranes and Borgarfjordur District Heating System used a tariff system based on maximum flow restriction. The user was charged by the maximum flow selected, but not by the volume of the water consumed. This kind of system was widely used in Iceland in earlier days; but, today this method is mostly restricted to rural areas.

In 1992, a new tariff system was introduced. The basis for that is the conventional tariff system used in Iceland, that is a fixed-annual charge and a variable charge proportional to the quantity of water used. In addition to that, a new method was introduced including tariff corrections based on the water supply temperature at the individual user.

The tariff correction is based on a calculated average water temperature at each individual user. The calculations use the measured annual water consumption of each user in the previous year and an overall water consumption history for the whole system on a daily basis. By using the water temperature at the inlet to the distribution system (77°C in Akranes and 82°C in Borgarnes), a computer model calculates the temperature drop in every single pipeline in the system. From that, an average water temperature at each user can be drived. A water temperature of 80°C at the user is used as a basis for the tariff correction. For every 1°C below that temperature, the waterprice is reduced by 2%. This price reduction is approximately proportional to the reduced useful energy content in the water because of the temperature reduction. Thus, all users should in principle pay the same energy price.

In the beginning, the new tariff system was met by criticism by many users. To give the users opportunity to be better informed about the water conditions, a big sign was installed at the pumping station in Akranes, showing the temperature of the water leaving the station. After few years experience, the model now calculates the temperature drop with a high accuracy and is considered to result in much fairer prices for the services. Comparison between groups of houses with different inlet water temperatures shows that they have similar heating costs. The new tariff system has resulted in considerably lower water consumption, both during summer and winter. This is because the old tariff system based on maximum flow restriction did not encourage customers to maximize the heat extracted from the water. Similar reduction in water consumption has been observed in other district heating systems in Iceland, which have changed the tariff system from maximum flow restriction to water meters.

HEATING COST

The total investment cost of the system was about 43 million US$ (1998 prices). This cost was divided as follows: wells, 1.2 million US$ (3%); transmission pipeline and pumping stations, 24 million US$ (55%); and distribution system, 18 million US$ (42%). These figures are only rough estimates, as the system was built at a time of high inflation rate in Iceland, which makes the 1998 comparison difficult.

Because of the high investment costs of the system, the heating costs for the customers of Akranes and Borgarfjordur District Heating System have been among the highest of all district heating systems in Iceland. Lower oil prices than predicted at the time of construction have also made the system less favorable economically, compared to other alternatives, than expected. Despite this, the system will unquestionably prove to be a good investment in the long run, especially if factors like savings in import of oil and environmental benefits are considered.

While the original tariff system was used, the customers tried to reduce their heating costs by choosing low-maximum flow settings, and in some cases, even met peak demand periods by heating by electrical ovens. This resulted in lower revenues for the system than expected. As the operating costs of the system were mainly fixed-capital costs, this resulted in financial problems for the operators. In the late eighties, the state took over 4.5 million US$ (1998 prices) of the total debt and this made it possible to lower the water prices. From that time until 1993, the water price was index regulated to keep it at a constant real value. Since then, the water price has been reduced by about 10%. Taking into account the inflation rate, this corresponds to about 25% reduction in real water prices.

Figure 4. Aboveground steel insulated pipe and buried asbestos cement pipe.

A typical family house of the size 535 m^3, built in the late eighties, uses about 630 m^3 of water each year, or 1.2 m^3 water per m^3 house volume. This water consumption is low compared to many other district heating systems in Iceland wher the water prices are lower. The heating costs is about 1,100 US$ per year. Of that, 25% is fixed-annual charge and 75% variable charge according to the amount of water used. In spite of the water price reduction, the last years the heating cost in Akranes and Borgarnes is still among the highest of all district heating systems in Iceland. It is, for example, about 60% above the heating cost in Reykjavik. Compared to alternative heating methods, the heating cost in Akranes and Borgarnes is similar to electricity, which is subsidized by the state. Heating cost by oil is now about 30% higher.

ORGANIZATIONAL CHANGES

According to an agreement between the Ministry of Energy and the communities in the Borgarfjordur area, the organization of production, distribution and sale of energy was changed in the area from January 1, 1996. The partners contributed by holdings or by taking over loan so the total debt of the district heating system was reduced by 50%. The purpose of this was to achieve more economical energy distribution and thereby, lower energy prices. As a part of this reorganization, Akranes and Borgarfjordur Distirct Heating System was split in three parts. The function of the original company was reduced to providing only hot water production and transmission from Deildartunga to Akranes and Borgarnes as well as distribution in the rural areas. The hot water distribution and sale in Akranes was taken over by a new community-owned company, Akranes Energy Utility, which also produces and distributes electricity as well as cold water. In a similar way, the hot water distribution and sale in Borgarnes was taken over by a new community-owned company, Borgarnes District Heating. Akranes and Borgarfjordur District Heating System now sells hot water in wholesale to the other two companies, Akranes Energy Utility and Borgarnes District Heating. It has no employees, but is served by the two community utilities with maintenance work and other services.

Before the reorganization, the number of employees was about 17 and most of them were transferred to the two community utilities. In connection to these changes, a thorough inspection of the whole production and transmission system was carried out by a consulting engineering company (Gunnarsson, 1996).

CONCLUSIONS

The 18 years experience with the 62 km long transmission pipeline, made of asbestos cement, from the hot springs at Deildartunga to Akranes and borgarfjordur is good. In spite of high investment cost, the district heaing system has been able to produce hot water at reasonable prices, thus reducing the import of oil in favor of an indigenous energy source. The organizational changes made are expected to result in more economical operation and lower energy prices in the future.

Last summer, a tunnel under the fjord Hvalfjördur was opened, shortening the driving distance between Reykjavik and Akranes by some 50 km. The distance between the northernmost part of the Reykjavik District Heating distribution system and Akranes is now less than 20 km. This has created the idea that in the future, it might be found economical to connect these two systems through the tunnel instead of maintaining the long transmission pipeline to Akranes.

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MUSHROOM GROWING PROJECT AT THE LOS HUMEROS, MEXICO GEOTHERMAL FIELD

María Elena Rangel Rangel
Gerencía de Proyectos Geotermoeléctrícos, Comisión Federal de Electrícidad, Mexico
Translated by: Marcelo J. Lippmann, Lawrence Berkeley National Laboratory

INTRODUCTION

There are several projects of direct (non-electrical) use of geothermal energy in Mexico. Personnel of the Comisión Federal de Electrícidad (CFE) has experience in various of these projects, like drying of timber and fruits, space heating, food processing, etc.

At present, at the Los Humeros geothermal field in the state of Puebla, some 200 km east of Mexico City, a mushroom growing project has been in operation for a number of years.

There are two basic requirements for a commercial mushroom growing operation: 1) the capacity to control temperature and moisture conditions, and 2) the ability to inhibit the growth of competing, undesirable mushrooms which contaminate the commercial product. In other words, a plant growing edible mushrooms not only requires a source of heat, but its installations should be as hermetic as possible, and the operations have to be conducted under rigorous aseptic conditions.

Taking this in consideration, CFE built the Los Humeros mushroom plant using for heat source the geothermal steam from Well H-1. The main purpose of the project was to take advantage of residual geothermal energy in a food production operation and to develop the appropriate technology.

In 1992, existing installations were renovated, preparing appropriate areas for pasteurization, inoculation and production. The mushroom Pleurotus ostreatus var. florida and columbinus was used.

A year later, CFE proposed the construction of improved facilities for growing edible mushrooms. New materials and equipment, as well as different operation conditions, were proposed on the basis of the experience gained in the initial project. The construction and renovation activities were completed in 1994.

CHARACTERISTICS OF THE PLANT

The plant is divided into three working areas plus a warehouse.

Section A. It has three areas originally planned for inoculation, incubation and production. Currently, this section is only involved in production and harvesting activities.

Central Section. It is the pasteurization area.

Section B. Originally, it was supposed to be similar to Section A; but, now it contains areas where inoculation, incubation and dehydration is done.

The characteristics of the different working areas are given in Table 1.

Table 1. Characteristics of the Working Areas in the Plant

AREA	CHARACTERISTICS	EQUIPMENT
Pasteurization	Area: 60 m^3; three 2 m x 2 m x 1 m tanks for hydration, drainage and pasteurization. The pasteurization vat is heated by circulating geothermal steam.	0.80 m x 0.75 m x 1.75 m hydration and pasteurization trays; heating system based on a coil through which geothermal steam circulates; cart to move the trays.
Inoculation	Area: 44 m^2; 9 m^2 working table.	Air filtering system with a capacity of 2,500 m^3/hour; 0.04 micron filter.
Incubation	Area: 48 m^2; heating system based on the circulation of geothermal steam; capacity of up to 320 15-kg substrates.	Thermometers and hygrothermometers.
Production	Area: 92 m^2 heating systems; capacity of up to 411 15-kg substrates.	Ventilation system with a capacity of moving 1,500 m^2/hour air equivalent; thermometers and hygrothermometers.

PRODUCTION PROCESS

Substrates

Substrates is the material whose degradation sustain the growth of the mushrooms growing on it. The type of substrate depends on the mushroom. Pleurotus ostreatus feeds on the products from the degration of lignite and cellulose; one could use as substrate industrial clippings and agricultural waste products (straw, stubble, pulp, bagasse, etc.) (Figure 1).

Figure 1. Mushrooms growing on substrates.

Substrate Treatment

The wheat straw used at Los Humeros as substrate is simultaneously hydrated and pasteurized by immersing it in 90°C water for two hours. This eliminates sugars, removes the ceraceous (waxy) layer, starts the decomposition of the cellulose and assures a growth medium free of competing organisms (other fungi, bacteria, etc.). The water in the pasteurizing vat is heated by circulating geothermal steam (Figure 2).

Figure 2. Wheat straw used for substrates.

Seeding

Seeding is done by mixing the mycelium or inoculum with the substrate. To guarantee a good seeding, the temperature sbould be in the 20 - 21°C range. The seeded area should be completely clean to avoid contamination. The substrate moisture should be around 75% (Figure 3).

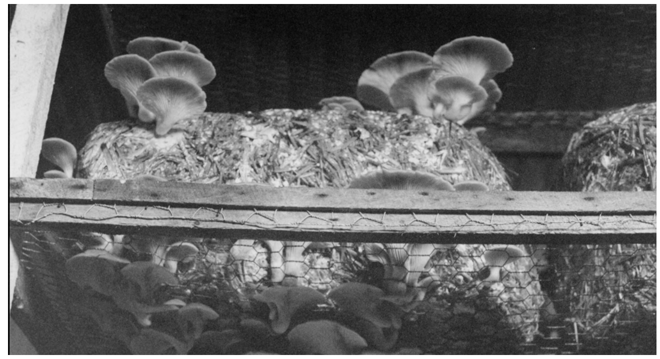

Figure 3. Mushrooms growing on substrates.

Incubation

During the first 24 hours, the mushrooms grow little while adapting to the medium. Increased growth starts about 48 hours after seeding, depending on ambient conditions. During this vegetative state of the mushroom, the temperature has to be between 22 and 26°C. Optimally, the incubation period should not exceed 17 to 22 days. It is vital to carefully control ambient conditions during this time; future production strongly depends on it (Figure 4).

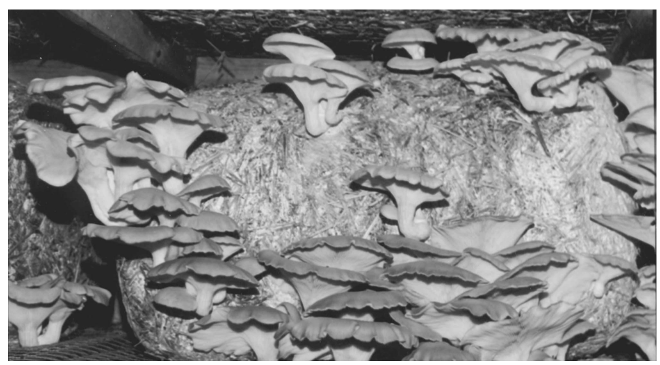

Figure 4. Mushrooms during incubation period.

Production

In substrates with fully developed mycelia, primordia of fruiting structures appear in a few days. When this happens, the humidity and temperature conditions will have to be changed to 90 - 95°C and 24 - 26°C, respectively. That is why the substrate trays are moved to the production area. The primordia will start growing immediately and fruting bodies will appear in about five days (Figure 5).

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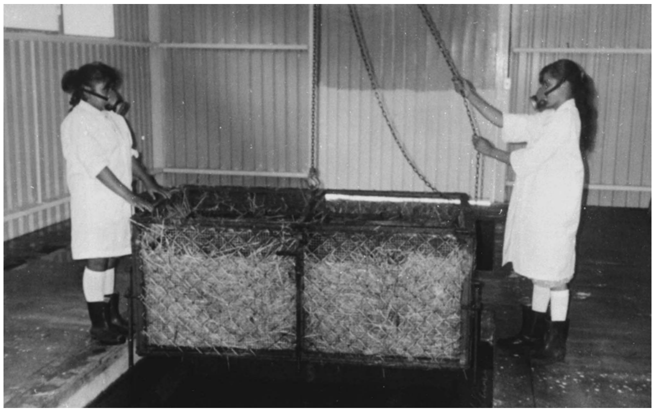

Figure 5.   Substrates trays.

Harvest

The fruiting bodies are harvested when they are fully developed, the larger ones first, leaving the smaller ones for later. The bodies are removed by cutting the base of the stalk with a clean, sharp blade. Four to six days after harvesting, the next sprouts begin to appear.

Each of the 15-kg substrate may produce three to four harvests; however, 80% of the production is obtained during the first two harvest (Figure 6).

Figure 6.   Bagging substrates straw.

Plagues and Diseases

Beginning with the incubation stage, a very common problem is the attack by insects and rodents which will affect the crop. Production may be totally lost since insect larvae feed on mycelia and fruiting bodies, damaging the product making it non-marketable. On the other hand, the rodents feed on the grain hosting the mycelia and contaminate the substrate with fungi that will compete with the crop.

RESULTS

The operation of the mushroom growing plant has been improved since its beginning, for example.

The use of water has been reduced by 75% by simultaneously carrying out the hydration and the pasteurization of the substrate.

The amount of inoculum needed has decreased by 37.5%.

The yield of the substrate has increased. Up to four crops may be obtained from 15 kg of substrate.

In addition, a better control of temperature and moisture conditions has resulted in increased production as shown in Table 2.

Table 2.   Production Data

MONTH	1997 HARVEST (in kg)	1998 HARVEST (in kg)
January	20	109
February	106	187
March	86.5	125
April	128	296
May	254.5	302.5
June	228	54*
July	74	168
August	68	?
September	247	?
October	184	?
November	90.8	?
December	57	?

* Note: In June 1998, the plant underwent maintenance requiring the clearance ofthe production area.

The problem of contamination by molds and other fungi was solved by using longer pasteurization times. This has substantially reduced losses that occurred initially.

However, there still exist problems--some related to local environmental conditions and others to the design of the plant and equipment used. This results in unstable rate of production.

GEOTHERMAL UTILIZATION

The flow rate is 2.0 tonnes per day of a steam-brine mixture, taken directly from the wellhead at a temperature of 130°C. The water used for pasteurization has a temperature of 90°C. The room temperatures are kept within the following ranges: 1) 20 -22°C for inoculation, 2) 18 - 22°C for incubation, and 3) 15 - 20°C during growth.

CONCLUSIONS

The replacement of fossil fuels and/or electricity by geothermal steam has lowered pasteurization, incubation and production costs.

The operation of the mushroom plant has resulted in new technology that uses geothermal steam in foodstuff production. It is a showcase for direct application of geothermal energy and as such, is being presented to schools, universities and government groups visiting the installations.

By working on the project, local people have been trained in a new and non-traditional activity.

The production of edible mushrooms has given the local population a new and healthy source of food which is available yearlong at an affordable price.

ACKNOWLEDGMENT

Thanks to Luis Quijano Leon of CFE, Morelia, Mexico for his assistance in preparing this article.

GEOTHERMAL EEL FARM IN SLOVAKIA

John W. Lund, Geo-Heat Center
Ján Thomka and Katarina Šarlinova, Turčianske Teplice, Slovakia

Turčianske Teplice, a small town in west-central Slovakia, has written records of using thermal waters since 1281. It was then known as the village of Aqua Calida Teplica in Hungary. A spa was developed, and was visited not only by the Hungarian nobility, but also by the nobility from Poland and Austria. The town was, until around the turn of the century, part of the Austro-Hungarian empire. It then became part of the new state of Czechoslovakia in 1918, and since 1993, part of the Slovak Republic. It has been a spa town, using 46°C (115°F) geothermal waters in indoor and outdoor pools, as well as rehabilitation center for over 700 years (Figure 1).

Figure 1. The Blue Spa of Turčianske Teplice.

In 1992, an eel raising farm was started on the outskirts of the town and since 1994, it has been operated by the firm of Janex Slovensko. The farm, using a specialized water recirculation system, raises a species of migrating eels (Anguilla anguilla). A 220-meter (660-ft) deep well at 42°C (108°F) provides 3 L/s (48 gpm) to the facility for heating through a plate heat exchanger (Figure 2). This is the maximum flow permitted, so as not to influence the springs and wells at the spa about 1 km (0.6 mile) away. For this reason, the flow is monitored carefully by the state. A second geothermal well at 52°C (126°F) and 1,500 meters (4,900 ft) deep is used only as an observation well. Cold water, which is heated by the geothermal water, is pumped from wells near the Turiec River 2.8 km (1.7 miles) away at 8° to 12°C (46° to 54°F), depending upon the season, for use in the various holding or raising tanks.

The eels are caught in a Monte stage as Glass Eels, when they migrate from the sea to river estuaries. At that time, they weigh about 0.3 grams (0.01 oz) and are 2.5 to 3 years old. They are then shipped to be raised at the farm for 18 to 20 months where they reach a weight of 150 grams (5 oz)(Figure 3). The main aim of the farm is to raise the eels under optimum raising conditions. Under natural conditions, eels can grow to 1.5 meters in length, weight 5 to 7 kg and live 5 to 15 years. The eels are harvested in the spring and fall, mainly for export. Carp are harvested in between these seasons for stocking local ponds and reservoirs.

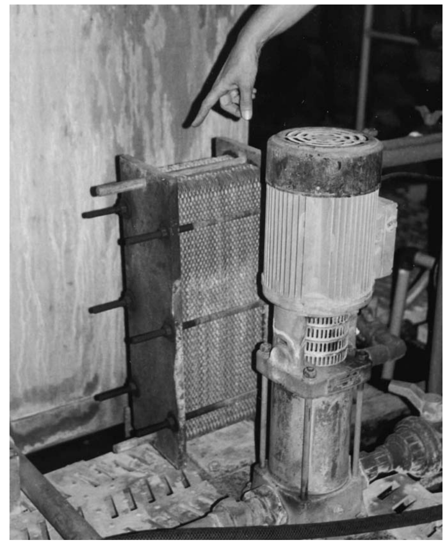

Figure 2. Plate heat exchanger inside the facility.

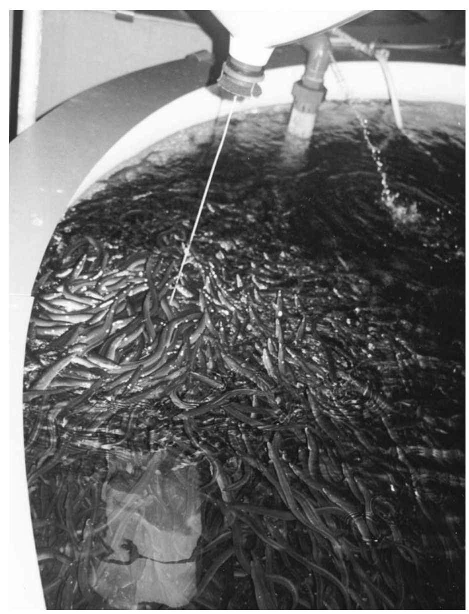

Figure 3. Eels feeding themselves in the holding tanks by turning the long rod to release the food..

The eel growing facility is housed in a two-story quonset-shaped building that covers approximately one hectar (2.5 acres)(Figure 4). The equipment is based on technology from Spain and uses a specialized filtration system that recirculates the water to the tanks.

Figure 4. Overview of the building..

The eels are raised in 60 circular tanks four meters (13 feet) in diameter that hold six cubic meters (1,585 gals) of water (Figure 5). Each tank will hold from 5,000 to 30,000 eels weighting 500 to 1,500 kg (1,100 to 3,300 lbs) depending upon the size. The heated water is supplied to these circular tanks at 25°C (77°F)

Figure 5. View of the holding tanks.

Freshwater is brought in from the wells near the Tureic River and passes through a small plate heat exchanger where it is heated by the geothermal water (Figure 6). The geothermal water is then wasted, and the waste water from the tanks, in most part (90%) filtered, biologically adjusted and enriched by oxygen, and then goes back into the holding tanks (Figure 7). The remaining 10% is treated in a purification device (COV) and disposed to a stream. The disposal is permitted and monitored by the state.

The market eels are harvested monthly and shipped by truck to Holland and Denmark. Only about one percent of the harvest is sold locally, as it is not a normal part of central European diet. Approximately, 50 tonnes (55 tons) are shipped annually at a selling price of about US$ 8.90 per kg (US$ 4.00 per lb).

The facility, which operates 24 hours per day, employs eight people, four electricians and four biologists.

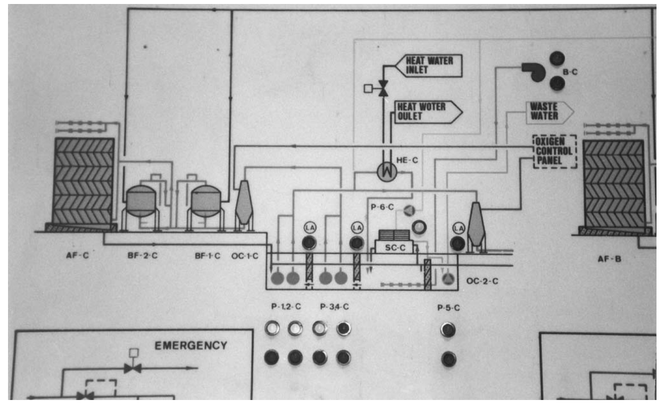

Figure 6. Diagram of the water flows in the facility.

Figure 7. Filtration tanks.

The economy of the eel raising facility is influenced by the temperature of the water in the holding tanks. The volume and ability to keep the temperature constant is dependent upon the geothermal water which is used for heating. The 3 L/s geothermal flow is not sufficient in the winter months; thus, there is a decrease in the eel growth rate. As a result, the size of the facility is constrained due to the limitation of the geothermal flow.

One proposal to increase the geothermal well flow is to produce from the deeper well at 52°C (126°F) and inject into the shallower 42°C (108°F) well. This would hopefully recharge the reservoir and minimize the impact on the nearby spa springs and wells. In addition, since the proposed production and injection wells are at different horizons, this should reduce or eliminate thermal breakthrough. Using the higher temperature well, a greater ΔT could be extracted, keeping the flow at a minimum or a greater flow could be used, since recharge is proposed.

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GEOTHERMAL TRAINING CENTERS IN THE WORLD

M. H. Dickson and M. Fanelli
CNR-International Institute for Geothermal Research
International School of Geothermics
Piazza Solferino 2, Pisa 56126, Italy

ABSTRACT

The first geothermal training centers began operating in Pisa (Italy) and Kyushu (Japan) in 1970, at the request of UNESCO. From 1979 on, they were joined by another five training centers in Auckland (New Zealand), Reykjavik (Iceland), Mexicali (Mexico), Skopje (Macedonia), and Los Azufres (Mexico). The courses organized in these centers last from one - two weeks to eight - nine months, and they cover all aspects of the research and utilization of geothermal energy. At the moment, these centers seem capable of providing all the qualified and competent personnel required for geothermal projects currently in-flow; but, this situation could deteriorate in the future.

INTRODUCTION

The first "industrial-scale" non-balneological utilization of geothermal energy is a part of geothermal history. The rudimentary direct heat utilization set up in the Larderello area in 1827, on what could be considered an industrial scale for the time, was used to extract boric acid from the geothermal fluids. In 1904, the first experiment in producing geothermal electric energy, using a steam-driven piston engine and dynamo, also took place in the Larderello area. Industrial production of electrict energy followed in the next decade, and has developed progressively since then.

Exploitation of geothermal energy worldwide developed at a very solw rate, despite the fact that high- and low-enthalpy geothermal fluids were known to be present in many parts of the world (the circum-Pacific areas, the African Rift, eastern Europe, etc.), and it had been demonstrated that these resources could be utilized in a number of applications. Suffice to say that, Italy was the only country prodiucing geothermal electricity up until 1958, when New Zealand began generating electricity of geothermal origin at Wairakei (in a 6.5-MWe plant).

Fortunately, the international organizations were able to appreciate the significance of this energy source, especially for the developing countries. In Ausust 1961, the United Nations organized a Conference on New Sources of Energy in Rome, during which the participants discussed the status and future of geothermal energy and the other renewable sources of energy (i.e., solar, wind and tidal). At the time of this conference, the geothermal electric power installed in the world was about 410 MWe, most of which was in Italy. Only 0.9% was installed in the developing countries, at Pathé in Mexico.

The Rome Conference in 1961 was reported worldwide, and played a significant part in making geothermal energy known not only to technicians, but also, and more importantly, to the policy-makers, who finally became aware of this source of energy, its many forms of application, its relatively harmless effect on the environment, and its competitiveness with other energy sources. The conference also emphasized the fact that it was an "indigenous" energy, which is particularly attractive aspect for poorer nations, as its utilization could reduce imports of premium-priced fuels from abroad. Nevertheless, in the decade between 1960 and 1970, little progress was made in the developing countries, despite the efforts of the international organizations to finance geothermal projects; although, a few were indeed launched during this period. The geothermal power installed in the world rose to 711 MWe in 1970; but, most of this was in the industrialized nations. The power installed in the developing countries increased from 3.5 to 4.4 MWe; but, their percentages of the total dropped from 0.9 to 0.6.

The snail-like pace of geothermal development in the non-industrialized countries can be blamed on a variety of factors. The main reason was, as it always was, and still is, aggravated by a lack of interest on the part of the policy-makers, and inadequate information. Another major reason for the delayed progress was the small number of geothermal experts available in these countries, capable of carrying out research independently right from the initial reconnaissance phase, and of working in conjuntion with experts sent in by the international organizations.

UNESCO was the first international organization to tackle the problem of the lack of local geothermists. In August 1968, it convened a "Group of Experts on Training in Geothermal Energy" in Paris, with the objective of defining the number and type of geothermists who would be needed in the next few years to implement the geothermal projects of the developing countries. The experts present at this meeting are a part of geothermal history: John Banwell, Robert Fournier d'Albe, Masami Hayakawa, Elena Lubimova, James McNitt, Marco P. Marchetti, Gudmundur Palmason and Ezio Tongiorgi. The main conclusions reached by the Group were: a) the specific geothermists needed were geologists, geophysicists, geochemists, drilling engineers and production engineers; and b) about 25 new geothermists/year would be needed in the first half of the 1970s.

This number (25/year) was soon to be exceeded. A survey in the mid-1970s showed that the projects financed by the international organizations were absorbing from 35 to 40 new geothermists each year. Added to these were the experts sought for projects under bilateral agreements and others required by countries that were eagar to create a geothermal staff before lauching their exploration programs. Based on the number and type of requests received by the International School of Geothermics in Pisa, we estimate that at least 60 new geothermists were needed each year in the second half of the 70s.

Following on the meeting of its Group of Experts, UNESCO appealed to its member countries with geothermal experience to provide training for geothermists from the developing countries. This appeal was met by the governments of Japan and Italy, and in January 1970, the Post-Graduate Course in Geothermics began in Pisa, later to become the International School of Geothermics. In September that same year, the Group Training Course in Geothermal Energy was launched in Kyushu. At the end of the 1970s, the two centers, in Kyushu and Pisa, wer able to train a total of 30 experts per year between them. During that period, the course in Japan lasted 2 1/2 months and concentrated on training within the 5 sectors indicated by the Group of Experts of UNESCO; whereas, the course in Italy lasted 9 months and was a general character.

As the training centers sponsored by UNESCO could meet only a part of the requirements of the developing countries, the UNDP contacted the government of New Zealand in 1975 with a request to set up a geothermal training center there. The agreement between the UNDP and New Zealand was formalized in 1978 and the Geothermal Diploma Course launched in Auckland in January 1979. In that same period, the United Nations University (UNU) also came to an agreement with the Icelandic government. As a consequence, the UNU Geothermal Training Programme began operation in Reykjavik in March 1979.

At the beginning of the 1980s, there were, therefore, four geothermal training centers sponsored by international organizations in Pisa, Kyushu, Auckland and Reykjavik. The four centers trained a total of 67 new geothermists in 1980 alone. Between 1980 and 1985, they were training between 60 and 70 geothermists per year.

During this period in 1983, the Geothermal Diploma Programme was set up in Mexicali. Their program of training lasts one year and has had a variable number of trainee participants, from 12 in the period 1984-85 to 2 only in 1991. It is more regional in character and the official language being Spanish.

In the meantime, the geothermal situation worldwide was gradually evolving in a more positive direction. By the late-1970s, we were beginning to see the fruits of the projects launched at the beginning of the decade and in the 1980s, we experienced a boom, especially in the developing countries. The geothermal power installed in the world in 1970 was 711 MWe, 4.4 of which was in the developing countries, corresponding to 0.6% of the total. Twenty-five years later, the total worldwide had reached 6,798 MWe with 2,580 MWe of this figure in the developing countries, corresponding to 38% of the total. By the end of 1997, these figures had risen to 7,925 MWe, 3,389 MWe and 43%, respectively.

This trend has had its effect on the request for new geothermists, which has increased gradually from year to year. The major political events have also had an influence. The collapse of the communist regimes in eastern Europe, for example, gave a renewed impetus to industry in this area, and consequently, also to the development of their geothermal resources. These nations are keen to train new experts, especially in the mid-to-low enthalpy sector.

From a combined capacity in 1985 of over 70 experts per year trained in the four classical geothermal schools, the suspension of the long-term course in the school in Pisa in 1992, as a result of the economic crisis in Italy, brought this figure down to less than 60 experts per year. In the period 1970 - 1995, however, these four schools prepared a total of 1,850 geothermists. Even assuming that about half of them are no longer in geothermal, this still leaves more than 900 experts in service. A few countries could now begin in-house training (as would appear to be the situation in the Philippines). The number of geothermal experts currently being trained each year may effectively be sufficient to meet the needs of the geothermal community worldwide; but, this could only be confirmed by a specific survey.

Regional or national short courses also seem to be very effective, concentrating as they do on topics of local interest. These courses are relatively inexpensive and, in conjunction with the traditional long-term courses, can make a significant contribution to providing experts for particular fields. Two courses of this type have been launched in recent years: one in Skopje, Macedonia in 1989, initially targetted at citizens of eastern Europe and the Circum-Mediterranean countires, and now in expansion worldwide; and the other, in 1995, in Los Azufres, Mexico, and mainly directed at the Latin-American countries. The International Geothermal Association (IGA), through its Education Committee, could play an important role in coordinating this type of activity.

There are now seven geothermal training centers operating in the world. A short description follows for each beginning with the oldest.

INTERNATIONAL SCHOOL OF GEOTHERMICS - PISA, ITALY

The school in Pisa, which began its activity in January 1970, has its headquarters in the International Institute for Geothermal Research (CNR). The school is sponsored by UNESCO, and its training activity is financed by the National Research Council, the Italian Ministry of Foreign Affairs, and in part, by UNESCO.

Between 1970 and 1992, the school organized 22 annual long-term courses, each lasting an average of 8 months. The objective of the courses was to prepare experts in geothermal exploration. A total of 324 geothermists attended this course in Pisa, which has now been suspended.

At present, the school organizes short courses of 10 - 15 days each, on local or specific topics. These courses are generally held abroad, at the request of the host county. So far, seminars and workshops of this type have been held in Colombia, Italy, Thailand and Venezuela.

For more information, contact: +39 050 47066 (Fax).

GROUP TRAINING COURSE IN GEOTHERMAL ENERGY (ADVANCED) - KYUSHU, JAPAN

This course was founded in September 1970 and is sponsored by UNESCO. Financed by the Japan International Cooperation Agency (JICA), it is organized by Kyushu University in its Geothermal Research Center in Fukuoka.

The 4-month course, running from mid-August to mid-December, is held in English and covers all aspects of the development of a geothermal project. Lectures and exercises are integrated with one month field work and excursions. On completion of the course, the trainees receive a certificate. Between 1970 and 1995, a total of 320 specialists were trained at this course. Scholarships are available.

For more information, contact: +81 9 366 31350 (Fax)

GEOTHERMAL DIPLOMA COURSE - AUCKLAND, NEW ZEALAND

The course in Auckland began in February 1979, and was sponsored by the United Nations Development Programme (UNDP) until the end of 1989. UNDP sponsorship will begin again in 1997. The course is financed by the New Zealand Ministry of Foreign Affairs and Trade (MFAT), and organized by the Geothermal Institute of Auckland University.

The Diploma Course generally runs from the beginning of March to the middle of November each year, providing a period of broad training in geothermal technology and lectures on specialized topics, inegrated with 3 weeks of field work. Trainees can, if necessary, attend a 12-week intensive course in English prior to the Diploma Course, as well as a 1-month course on computing. On successful completion of three written examinations and a written project, the trainees receive a "Diploma in Geothermal Technology."

By 1997, a total of 519 specialists had attend this course. About 35 places are available each year (for earth scientists and engineers). Scholarships are available.

The Geothermal Institute also offers 3-month courses in Reservoir Engineering and Environmental Aspects..

For more information, contact: +64 9 373 7436 (Fax).

UNU GEOTHERMAL TRAINING PROGRAMME - REYKJAVIK, ICELAND

The Reykjavik training programme was launched in March 1979, and is sponsored by the United Nations Univeristy (UNU). Financed since then by the Government of Iceland and the UNU, it operates within the Geothermal Division of Orkustofnun, the National Energy Authority of Iceland.

Lasting a total of six months, the programme consists of an initial 5-week period of introductory lectures for all trainees, followed by specialized studies tailor-made for the individual student, integrated by field work and excursions. Emphasis is laid on practical, on-the-job training. On completion of the programme, the participants receive a UNU Certificate.

By 1997, a total of 197 trainees had attended this course. Scholarships are available.

For more information, contact: +354 568 88 96 (Fax).

GEOTHERMAL DIPLOMA PROGRAM - MEXICALI, MEXICO

The Mexicali training program began in January 1983, and is offered by the Universidad Autonoma de Baja Califiornia (UABC), in collaboration with the Instituto de Investigaciones Electricas (IIE), the Consejo Nacional de Ciencia y Tecnologia, and the Comision Federal de Electricidad (CFE). It is held in the Engineering Institute of UABC.

The program lasts one year, January - December, and covers the earth science and engineering disiplines involved in the exploration and exploitation of geothermal resources. Spanish is the official language. Lectures are integrated with a number of field trips to geothermal fields in Mexico and the USA. On successful completion of the program, and after passing an oral examination or written project, the trainees receive the degree "Especialista en Geotermia."

By 1994, a total of 63 specialists had completed their training at UABC. Scholarships are available.

For more information, contact: +65 66 41 50 (Fax).

INTERNATIONAL SUMMER SCHOOL ON DIRECT APPLICATION OF GEOTHERMAL ENERGY - SKOPJE, MACEDONIA

The Summer School (ISS) was founded in 1989 by the Cyril & Methodius University of Skopje, the International School of Geothermics of Pisa, and the Aristolelian University of Thessaloniki. The ISS has its headquarters in Skopje. The main sponsors of its training activity are UNESCO, FAO and the International Geothermal Association (IGA).

The courses generally last 1 - 2 weeks and are attended by 20 - 30 participants. Financial support is available. Held in English, the courses are directed at providing an update on the state-of-the-art in direct uses of geothermal energy. So far, courses have been held in Yugoslavia-Greece, Macedonia, Bulgaria, Romania, Turkey and the Azores, attended by a total of 200 participants. Each participant receives a certificate of attendance.

The courses are generally preceeded or followed by a workshop.

For more information, contact: +389 91 119 686 (Fax).

GEOTHERMAL TRAINING CENTRE - LOS AZUFRES, MEXICO

Training activity began in 1995 and is organized by the Comision Federal de Electricidad (CFE) in its Geothermal Training Centre in Los Azufres geothermal field. The courses are directed at Mexican and foreign technicians and engineers involved in R&D in the geothermal sector. Practical, hands-on training is emphasized in these courses, which last 1 - 2 weeks. They are generally held in Spanish, but English is available on request. The center can accomodate up to 30 participants per course.

The first course, on geothermal petrography, was held in October 1995.

For more information, contact: +43 14 39 70 (Fax).

Of the seven training centers described above, three are in Europe, two in Latin-Americas, one in Asia and one in Oceania. Together, they cover practically all sectors of geothermal research and utilization and, in theory, should now be capable of meeting the worldwide demand for geothermal experts. However, what seems a satisfactory situation could dramatically take a turn for the worst in the near future, because of the relentless paring down of funds set aside for training. The first signal of an imminent crisis occurred in 1993, when the Italian government cut back on the funds allotted to international courses, which led the International School of Geothermics in Pisa to suspend its long-term course. Between 1993 and 1998, the UNESCO contribution was also gradually reduced by more than a third, which suggests that the international organizations are also beginning to feel the pinch. It would appear that some of our colleagues in the other training centers are also facing similar difficulties with funds. The economic problems of many European countries, in the aftermath of the European Union single currency, the recession in Japan and the economic crisis in southeast Asia in general, with the inevitable consequences in many industrialized countries, are all factors that will tend to complicate the future for geothermal development as a whole, and training in particular. Clearly every effort must be made to combat this negative trend of affairs, and the main actions that should be taken are, in our opinion:

- optimization of the structure of the courses to reduce cost as much as possible without jeopardizing their efficiency, and

- coordination of the existing courses, again to reduce costs. Apart from avoiding any overlapping of the courses, this could, for example, eventually mean adopting the same textbooks and other teaching material.

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