GEOTHERMAL TRAINING – NEEDS AND AVAILABILITY

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1. INTRODUCTION

The development of geothermal resources requires a dedicated group of highly skilled specialists from many disciplines of science and engineering. Because of its diversity, geothermal energy research is not taught as a separate subject at universities, but is a field where specialized theoretical work and practical training is required at post-graduate level. The training of geothermal specialists has mainly taken place on-the-job within companies and institutions. But especially for the benefits of the developing countries, international geothermal schools have contributed significantly in the transfer of geothermal technology from the leading geothermal countries to newcomers in the field.

The pioneering countries of geothermal development (Hungary, Iceland, Italy, Japan, New Zealand, and the USA) started developing their geothermal resources basically from scratch. Engineers, geologists, chemists, and physicists combined forces within each country. The first groups of geothermal specialists were commonly built at government agencies such as the USGS (USA), DSIR (New Zealand), and the State Electricity Authority (later named Orkustofnun, Iceland). Much experience was drawn from established disciplines such as groundwater hydrology, mineral exploration, oil exploration, oil production etc. Many key people in the early days of geothermal development first met at the United Nations Conference on New Sources of Energy in Rome in 1961. That meeting was a milestone in international cooperation in geothermal energy research and development.

2. INTERNATIONAL TRAINING CENTERS

One of the main constraints of geothermal energy development in many countries is a shortage of skilled manpower (geoscientists and engineers) with practical experience. The developing countries rely heavily on foreign consultants, but in many cases the consultants have to work for a considerable time in a given country to be able to adjust their expertise to the special characteristics of the geothermal resources in that country. It is very important to secure that the experience obtained during exploration and development of a particular field be maintained within the country when the consultants depart. This is best done by assigning fully qualified local experts to work as counterparts with the foreign consultants.

The lack of trained professionals has been addressed by aid programmes supporting the training of geothermal technologists. Such programmes have been operated since the 1970´s at the geothermal schools in Iceland (the United Nations University Geothermal Training Programme in Reykjavik), Italy (the International School of Geothermics in Pisa, but the annual courses in Pisa have not been held since 1993), Japan (Kyushu University), Mexico (Autonomous University of Baja California in Mexicali), and New Zealand (the Geothermal Institute at the University of Auckland). However, the number of fully funded training places available per year is limited to less than 60 (Iceland 16-18, Japan 15, New Zealand 20-25, Mexico 1 or 2) which is not sufficient as more and more countries are starting to use geothermal resources. The training at these centres is for scientists and engineers with university degrees. Some developing countries, for example the Philippines, have already built up a strong core of geothermal experts with the assistance of the international training centres and by suitably qualified staff working side by side with foreign consultants. Most of the developing countries, however, have a long way to go towards becoming self sufficient in the expertise needed to harness the geothermal energy resources that may reside unused in the countries.

Universities in many countries have also offered postgraduate courses and research in geothermal topics leading to M. Sc. and Ph.D. degrees. These have been an important training ground for participants both from industrialized and developing countries. Amongst the leading ones are Stanford University and Berkeley University in the USA, and Auckland University in New Zealand. National and regional geothermal training seminars have also played an important role, especially in the countries of Latin America, Indonesia, and the Philippines. The University of Iceland has recently started accepting students for M.Sc. degrees in co-operation with the United Nations University Geothermal Training Programme.

3. GEOTHERMAL TRAINING AVAILABLE TO C&E EUROPE

Despite their long tradition in the direct application of geothermal water in health spas and horticulture, the countries of Central and Eastern Europe have in many aspects been isolated and lagging behind in geothermal technology. The opportunities for geothermal training have been much more restricted for people in these countries than in the developing countries. The short courses organized almost annually during the last decade by the International Summer School in Skopje (Macedonia) have, however, served a valuable purpose and have created good contacts between specialists in individual countries. But much more is needed. The existing international geothermal schools can hardly cope with the present needs of the geothermal industry in the developing countries. More training places need to be added specially for the countries of Central and East Europe, at both professional and technician levels. In addition to long and short courses at the international schools, regional courses and specialized travelling courses should also be considered.

Until recently, only a few of the countries of Central and Eastern Europe were eligible for scholarships awarded through the United Nations. Only those countries which had a recipient status within the United Nations Development Programme (UNDP) could receive UN scholarships for geothermal training. This excluded all the republics of the former Soviet Union. The countries with UNDP recipient status included Albania, Poland, Romania, Turkey, and the republics of former Yugoslavia, but excluded countries with relatively high per capita income such as Czechoslovakia and Hungary.

The categories of recipient countries were changed within the UN system in the mid 1990´s. At present, all of the republics of the former Soviet Union and most of the countries of Central and Eastern Europe are eligible for UN fellowships. The only countries within the region with a national income per capita too high to receive UN fellowships at present are the Czech Republic, Greece, Hungary and Slovenia.

According to available statistics from the four main international geothermal schools (in Iceland, Italy, Japan, and New Zealand) the number of participants from the countries of Central and Eastern Europe attending six months or longer training has been as follows: Iceland 31, Italy 15, Japan 1, New Zealand 17. The 31 people trained in Iceland came from Bulgaria (5), Greece (3, on special scholarships from Brussels), Lithuania (1), Macedonia (1), Poland (5), Romania (5), Russia (1), Serbia (3), Slovakia (2), and Turkey (5). The 27 people trained in Italy came from Bulgaria (3), Czechoslovakia (1), Greece (10), Hungary (2), Macedonia (1), Poland (2), Romania (3), Yugoslavia (5). The person trained in Japan came from Albania. The 17 people trained in New Zealand came from Greece (1), Romania (3), and Turkey (13).

As mentioned above, the Pisa school has not held its annual course since 1992 due to drastic cuts in government financing. The school has, however, in recent years organized a few short courses and seminars abroad. The main options for the countries of Central and Eastern Europe are the training centers in Iceland and New Zealand.

The United Nations University Geothermal Training Programme has been operated at Orkustofnun in Iceland since 1979. This programme offers 9 specialized courses each of which takes 6 months. The courses offered are Geological Exploration, Borehole Geology, Geophysical Exploration, Borehole Geophysics, Reservoir Engineering, Environmental Studies, Chemistry of Thermal Fluids, Geothermal Utilization and Drilling Technology. M.Sc. studies are also offered at the Faculty of Science and the Faculty of Engineering of the University of Iceland in co-operation with the UNU Geothermal Training Programme. A further description will be given of the UNU Geothermal Training Programme in this paper. The reader can also obtain up to date information from the home page at the web site www.os.is/unugtp/ Many of the trainees in Iceland specialize in the exploration and development of low-temperature resources for direct utilization (for space heating, greenhouses, fish farming and spas) as can be seen from the list of project titles in the home page. The UNU Geothermal Training Programme receives its basic funding for operations and scholarships from the Government of Iceland (80%) and the United Nations University (20%).

The Geothermal Institute at the University of Auckland (New Zealand) offers 9 months diploma courses with specialization in earth sciences and engineering. They also offer one 3 months specialized course each year in either Geothermal Reservoir Engineering or in Environmental Impact Assessment (offered in 1999). Graduates can also work for post-graduate degrees in geothermal specialities at the Faculty of Science (M.Sc. and Ph.D.) and the Faculty of Engineering (M.E. and Ph.D.). Further information can be obtained on the Internet at the web site www.auckland.ac.nz/gei/

The Geothermal Institute receives its basic funding for operations and scholarship from the New Zealand government.

4. GEOTHERMAL TRAINING IN ICELAND

The Geothermal Training Programme of the United Nations University (UNU) has operated in Iceland since 1979 with six months annual courses for professionals from developing countries. Candidates must have a minimum of one year practical experience in geothermal work in their home countries prior to the training. Specialized training is offered in geological exploration, borehole geology, geophysical exploration, borehole geophysics, reservoir engineering, chemistry of thermal fluids, environmental studies, geothermal utilization, and drilling technology. Each trainee attends only one specialized course. The training is conducted in English. The trademark of the training is to give university graduates engaged in geothermal work very intensive on-the-job training in their chosen fields of specialization. The trainees work side by side with professionals of Orkustofnun, an agency actively working on most aspects of geothermal research, exploration, and development. The training is tailor-made for the individual and the needs of his institution/country. The aim is to assist developing countries with significant geothermal potential to build up groups of specialists that cover most aspects of geothermal exploration and development. Priority is given to candidates from institutions where geothermal work is already under way. All candidates are selected by private interviews. Candidates from developing countries and most Central and Eastern European countries receive scholarships (covering tuition fees, per diem and international travel) financed by the Government of Iceland and the UNU. Upon completion of their training the participants receive a UNU Certificate. During 1979-1999, 227 scientists and engineers from 35 countries have completed the 6 month courses, and over 70 have received shorter training (2 weeks to 4 months).

Table 1: Time Schedule for the UNU Geothermal Training Programme in Iceland

UNU GEOTHERMAL TRAINING PROGRAMME IN ICELAND

Week	Geological Exploration	Borehole Geology	Geophysical Exploration	Borehole Geophysics	Reservoir Engineering	Environmental Studies	Chemistry of Thermal Fluids	Geothermal Utilization	Drilling Technology
1 2 3 4 5	Lecture course on all main aspects of geothermal energy exploration and utilization, practicals and short field excursions								
6 7 8 9 10	Field geology Maps and photos Structure analysis Hydrogeology	Drilling Petrological logging Alteration Mineralogy	Resistivity methods Thermal methods Magnetics Gravity	Course on well logging and reservoir engineering including: Logging and well testing practises Reservoir physics Reservoir simulation Tracer tests Computer programs		EIA Project planning Chemistry Physics Biology Monitoring Revegetation Health and safety	Sampling of fluids and gas Scaling and corrosion Analytical methods Thermodynamics Geothermometers	Heat transfer and fluid flow Control systems	Drilling equipment Drilling procedures Well design Safety Management Rig operations
11 12	Excursion to the main geothermal fields of Iceland								
13 14	Field work in deeply eroded strata	Aquifers Modelling	Data processing techniques	Logging methods Data evaluation	Responses to exploitation	Gas dispersion and abatement	Water rock interaction	Design of plants and systems	Cementing Completion
15 16 17 18 19 20 21 22 23 24 25 26	Project and report	Project and report	Project and report	Project and report	Project and report	Project and report	Project and report	Project and report	Project and report

The approximate time schedule of the Training Programme is shown in Table 1. The duration is 6 months. In general, all participants are expected to attend an introductory lecture course that lasts 4-5 weeks (three lectures and a practical each day). The aim of the lecture course is to provide a background knowledge on most aspects of geothermal energy resources and technology, and to generate an appreciation for the interrelationship between the various disciplines necessary in geothermal projects from the initial exploration to the stages of implementation and utilization. Participants have to take two written tests during the introductory lecture course. The lecture course is followed by practical training in a specialized field and the execution of a research project that is concluded with an extensive research project report. Study tours are arranged to all the main geothermal fields under exploration and utilization in Iceland.

All participants receive training in using PC-computers for word processing, interpretation of data as well as in using the Internet. Each of them is provided with a personal PC during their training in Iceland. Experience has shown that most trainees have access to PC-computers at home, and they can take their diskettes home and continue the work there. Thus there has been a considerable transfer of computer technology from Reykjavik to geothermal institutions in the developing countries. All the participants are trained in using the Internet and encouraged to do so. In August 1999, about 100 former UNU Fellows are listed in the e-mail directory of the Geothermal Training Programme. An updated directory is sent out twice per year to all alumni of the Programme.

The main emphasis of the training is to provide the participants with sufficient understanding and practical experience to permit the independent execution of projects within a selected discipline in their home countries. Nine specialized lines of training are offered (Table 1). Each participant is meant to follow only one line of training, but within each line there is considerable flexibility. A significant part of the practical training is done in connection with the research projects of the Fellows. In many cases the participants bring with them data from geothermal projects in their home countries, but sometimes the research projects are integrated with geothermal exploration or utilization projects that are in progress in Iceland at the time of training. The project topic is always selected with respect to the conditions of the home country of the participant. Many of the project reports are written in such a way that they serve as manuals for performing certain measurements or interpretations dealt with in respective reports. All the project reports are published by the Training Programme. Since 1994, the reports have been published in the annual book "Geothermal Training in Iceland" which has an international publishing code (ISBN 9979). Copies can be obtained upon request. The reports are mailed regularly to former UNU Fellows and many of the leading geothermal institutions in the developing countries. The titles of the reports from 1979-1999 and the abstracts from 1988-1999 can be found on the home page of the Geothermal Training Programme (www/ os.is/unugtp/).

4.1 Specialized Courses

The **geological exploration** course offers practical training in basic geological mapping, which is commonly the first step in the geothermal exploration of an area. Participants analyze the geological structure of an area with regard to siting drill holes, both thermal gradient and production wells. Many of the participants have also been trained in mapping surface geothermal manifestations, including shallow temperature surveys and measurement of flow rates of springs. The field work is commonly conducted both in active geothermal and volcanic areas and in deeply eroded areas where the roots of extinct volcanoes and hydrothermal systems can be inspected. Participants should have a degree in geology.

The **borehole geology** course gives training in making geological logs, analyses of drill cuttings and cores, and, in some cases, fluid inclusions. The identification of alteration minerals (microscope and x-ray diffraction) and the interpretation of the alteration mineralogy forms an integral part of the course. Many of the participants receive training in collecting and interpreting data on aquifers and in making geological models of geothermal reservoirs based on their own data and data from other disciplines. Participants should have a degree in geology.

The **geophysical exploration** course is for practical training in conducting geophysical surveys of geothermal areas and/or interpretation of such data. The essentials of heat flow surveys, magnetic and gravity surveys, as well as resistivity depth soundings and profiling are covered. During the latter half of the training a selection can be made between further specialization in electrical surveys (Schlumberger, dipole, head-on profiling, TEM, MT, AMT, SP), magnetic surveys and gravity surveys. Emphasis is laid on the application of computers in the interpretation of geophysical data. Participants should have a degree in physics, geophysics or engineering.

The course in **borehole geophysics** covers the essentials of geophysical measurements in boreholes used for geothermal investigations, with the main emphasis on temperature and pressure measurements, but including lithology logs such as electrical resistivity, caliper, porosity and density logs, and well completion logs such as CCL, CBL, inclination and spinner logs. The participants undertake well measurements, but most of the time is devoted to the interpretation of logging data. Participants should have a degree in physics, geophysics or engineering.

The **reservoir engineering** course covers the methodology needed to obtain information on the hydrological characteristics of geothermal reservoirs and to forecast the long term response of the reservoirs to exploitation. Both surface and downhole measurements are considered and the interpretation of flow tests of wells, injection tests and interference tests. It is also possible to specialize in production engineering of geothermal fields. The course requires a sound background in mathematics. Participants should have a degree in engineering, physics, geophysics, mathematics or hydrogeology.

The **environmental studies** course covers environmental impact assessments (EIA), laws and policies, the planning and execution of EIA projects and environmental auditing. Aspects of reservoir engineering and geothermal chemistry are treated, including sampling and analytical methods, injection and tracer studies, scaling and corrosion along with methods of interpretation. Physical methods of monitoring geothermal areas such as aerial thermography, refraction measurements, seismic monitoring and gravity and levelling methods for subsidence are studied. Biological impact is considered in some detail as well as the management of wastes, toxic chemicals, air pollution and noise. Occupational health and safety are introduced and abatement methods such as H2S abatement and ground revegetation feature too. As a bacground, energy statistics and forecasts are considered and case histories of exploration and environmental impact studies introduced. The projects are from wide-ranging disciplines as are the Fellows themselves who are required to have a degree in science or engineering. This course was officially opened in 1998.

The course on **chemistry of thermal fluids** gives an insight into the role of thermal fluid chemistry in geothermal exploration and exploitation, including sampling, analysis of major constituents and the interpretation of results. Much emphasis is placed on the application of chemical thermometers and the calculation of mixing models. Environmental aspects of the thermal fluids are also considered. The participants need a solid background in chemistry. They should have a degree in chemistry, geochemistry or chemical engineering.

The course in **geothermal utilization** deals with the civil, mechanical and chemical engineering aspects of geothermal fluids in pipes, equipment and plants. The feasibility of projects and environmental factors are also considered. Due to the wide spectrum covered by geothermal engineering, the participants have to be very selective in their specialization. Most of the participants specialize in the design and/or feasibility studies of district heating systems and/or in the application of geothermal steam and water in industry. One specialization is the selection, instalment and operation of downhole pumps in geothermal wells. Participants should have a degree in engineering.

The course in **drilling technology** provides engineers with the information and on-site training necessary to prepare them for the work of drilling engineers or supervisors. The course is thus training in the planning and supervision of drilling and not in the task of drilling itself. The course deals with the selection of drilling equipment, the design of wells and casing programs, as well as cementing techniques. The cleaning and repairs of production wells is also covered. Participants should have a degree in engineering.

4.2 Selection of Participants

Specialized practical training is considerably more expensive than group training because of the high teacher-to-student ratio. On average, a full time teacher takes care of three students during the intensive training. The total cost of training per student in Reykjavik (including international travel and per diem) is over USD 30,000. Much care is therefore taken in selecting the participants. The selection procedures of the UNU are adhered to, which involve site visits by representatives of the Training Programme to the countries of potential candidates and personal interviews with all candidates. The potential role of geothermal energy within the energy plans of the respective country is assessed, and an evaluation made of the institutional capacities in the field of geothermal research and utilization. Based on this, the training needs of the country are assessed and recipient institutions selected.

The candidates must have a university degree in science or engineering, a minimum of one year practical experience in geothermal work, speak English fluently, and have a permanent position at a government energy company, research institution, or university. The directors of such institutions are invited to nominate candidates for training in the specialized fields that are considered most relevant to promote geothermal development in the respective country. Nominations, including the curriculum vitae of the candidates, should be sent to the Training Programme in Iceland. The candidates should normally be under 40 years in age. Training starts in late April and ends in late October each year. Nominations must be received in Reykjavik before 1st August each year for participation in the training starting the following year. Due to the high cost of international travel, site visits for interviewing candidates cannot be held in all requesting countries every year. Therefore, interviews are held in a given country for candidates for two or three years at a time.

Participants from developing countries and most Central and Eastern European countries normally receive scholarships financed by the Government of Iceland and the UNU that cover international travel, tuition fees and per diem in Iceland. The participants therefore do not need other funds for their training. The UNDP and the International Atomic Energy Agency (IAEA) as well as the European Union have also financed fellowships for several trainees through the years. Qualified participants from industrialized countries can also be accepted on condition that they obtain similar scholarships from their own institutions/countries. The total cost per participant is, as stated above, about USD 30.000.

In the last five years there have been 14-18 Fellows per year. There is a steady flow of requests from all over the world for training at the UNU Programme, and only a portion of the requests can be met. In view of this, it is planned to continue with the six months specialized research and training as the main activity of the Programme. A few outstanding former UNU Fellows will also be enrolled for a M.Sc. Programme in geothermal science and enegineering in cooperation with the University of Iceland. Many of our trainees have already completed their M. Sc. or Ph.D. degrees when they come to Iceland, but several excellent students who have only B. Sc. degrees have made requests to come again to Iceland for a higher academic degree. Their six months studies in Iceland will form a part of their graduate programme.

5. GEOTHERMAL MANPOWER DEVELOPMENT

The organizers of the World Geothermal Congress (WGC'95) asked representatives of most participating countries to fill out data forms with various information on present and planned development of geothermal energy for electricity and direct use, including information on the allocation of professional personnel (university graduates) to geothermal activities per year during 1990-1994. This was also done for the International Geothermal Symposia organized in Hawaii by the Geothermal Resources Council (GRC) in 1985 and 1990. In all there were 57 responses to the WGC'95 questionnaires, but unfortunately many countries only provided part of the information requested (Freeston, 1995). Figures on manpower were in fact missing from most of the key developing countries on the geothermal scene, and many of the industrialized countries.

In order to get a picture of the human resources development during 1975-1994, Fridleifsson (1995) compiled Table 2 by taking figures from the country updates of the GRC International Symposia in 1985 and 1990 as well as figures from the country updates of the WGC'95. In addition, he obtained information for 1994 from El Salvador, Kenya, and from the PNOC of the Philippines. The sparse format of the present paper does not allow the full references of the papers where the figures come from. The figures should be looked on as indicative only.

Table 2 shows the number of professional personnel in geothermal energy work in France, Iceland, Italy, El Salvador, Kenya and the Philippines. The installed capacities in electric (MWe) and direct (MWt) utilization are also shown for 1985 and 1994 respectively. The figures for all the countries, except the Philippines, show relative stagnancy and, in fact, a marked reduction for both Mexico and France. The drop in manpower in France from 69 in 1985 to 24 in 1994 reflects the fact that since the drop in oil prices

Table 2: Professional Personnel in Geothermal Activities and Installed Geothermal Capacities

	1975	1980	1985	1990	1994	Installed 1985		Installed 1994	
						MWe	MWt	MWe	MWt
France			69	42	24	4	300	4	456
Iceland	69	130	110	109	100	39	889	50	1443
Italy	140	180	240	220	250	519	288	626	308
El Salvador			36	104	51		95		105
Kenya				33	43	34		45	45
Mexico			331	53	260		645	753	28
Philippines	58	455	397	812*	1204*		894		1051

*Figures for the Philippines in 1990 and 1994 are PNOC staff only
(NPC, PGI and the Department of Energy staff figures not available)

in 1985, geothermal energy has not been competitive with other energy sources for space heating. During 1980-1986, some 60 new district heating projects were commissioned in France, but none since 1986 due to the drop in oil prices (Boisdet et al., 1990; Fridleifsson and Freeston, 1994). The development in Iceland also reflects that there have been few new projects since 1990. The situation in Iceland will be dealt with in more detail later in the present paper. In Italy, a major renovation has been undertaken in many of the early electric power stations, older units dismantled and new installed. There has also been considerable activity in direct use, including two new district heating systems (in the towns of Ferrara and Vicenza) commissioned in the early 1990's (Allegrini et al., 1995).

In El Salvador (Campos, 1995) and Kenya (N'gang'a, 1995), there are competent groups of geothermal specialists working on the extension of presently exploited fields and exploring new areas for future developments. In both countries, geothermal energy is considered the least cost option for increased electricity production. But for financial/political reasons there have been delays in the investments. In both countries, plans are basically ready for considerable expansion. These will require a significant increase in trained geothermal personnel. Many of the key specialists in both countries have received a part of their training in Iceland and New Zealand.

The country with the highest expansion in manpower in recent years is the Philippines. The manpower policy (Tolentino and Buning, 1985) of the Geothermal Division of the Philippine National Oil Corporation (PNOC) during the 1980's and 1990's has been highly successful. Despite a hiatus in the geothermal development during 1984-1990, new personnel were recruited and trained within the company. Most years, a few PNOC staff members have gone to the geothermal schools in Iceland and New Zealand, but the bulk of the training has been on-the-job within the projects. Local specialists have gradually taken over from foreign consultants (mainly from New Zealand) who have been generous in training their Filipino colleagues. The geothermal staff of PNOC are presently by far the strongest workforce for geothermal exploration and field development in the world. The manpower figures for the Philippines during 1975-1985 (Tolentino and Buning, 1985) include the staff of all the main actors, i.e. the PNOC, the National Power Corporation (NPC), and the Philippine Geothermal Incorporated (PGI). The 1990 and 1994/1995 data (Sarmiento, personal communication) represent PNOC staff only.

6. EXAMPLES FROM ICELAND

Good examples of how the geothermal manpower resources in a country shift from exploration, research and development (R&D) activities, to design and construction activities, and further to the operation of power utilities can be sought to Iceland (Fridleifsson, 1995). In 1994, with an installed capacity of 1434 MWt and 50 MWe, Iceland allocated about 100 professionals/year to geothermal research, development and operations during the last five years. Some 33 of these worked at Orkustofnun (exploration, research, training, and consulting services), 7 at universities, 30 in private industry (mostly engineering consulting services), and 30 worked for public utilities (mostly municipal district heating companies).

It is interesting to look back and see how many professionals were working in geothermal in the country before the oil crisis, during the peak of geothermal development work in the country around 1980, and to compare it with the present situation when 85% of the population uses geothermal water for space heating and 5% of the electricity is generated by geothermal steam (95% of the electricity is hydro generated). Table 2 shows the allocation of professionals per year to exploration-R&D (including universities), design and construction supervision (consulting engineers), and to geothermal power utilities operations in Iceland at five year intervals during 1965-1995. The geothermal energy use for space heating is shown (in TWh/a) in Table 2 as well as the total primary energy use of geothermal (in PJ/a) for all purposes in the country (space heating, industry, electricity production etc.).

Table 3 shows how the sharp increase in the exploration-R&D workforce associated with the first and the second oil crises (1973 and 1978) stops in the early 1980's when geothermal resources had been harnessed to heat over 80% of houses in the country. The workforce in this sector has not only decreased since the mid 1980's, but the emphasis has also gradually shifted from exploration work in new areas to reservoir engineering, monitoring, and optimization of the harnessing of exploited geothermal fields.

Table 3 Professional Personnel and Geothermal Use in Iceland 1965-1995

	1965	1970	1975	1980	1985	1990	1994
Exploration, R & D	7	9	25	56	59	43	40
Consulting engineers	7	7	34	53	26	40	30
Public utilities	4	7	10	21	25	26	30
Total	18	23	69	130	110	109	100
Geothermal energy use TWh/a	1.1	1.7	2.4	3.4	4.4	5.0	5.5

(space heating)							
Primary energy use PJ/a (all geothermal use)	6.1	11.4	16.2	26.7	39.1	43.5	42.7

New municipal district heating systems were constructed and existing ones extended during the 1970's and 1980's. Since the 1960's, most of the geothermal design work and construction supervision has been in the hands of consulting engineers in Iceland. The demand for consulting services (design and supervision of the construction of geothermal pipelines, distribution systems, and power stations, as well as control systems and operational management) has been more fluctuating through the years than the exploration-R&D work, and more affected by major individual projects. The figures for 1990 and 1995 mainly reflect the extension of the Reykjavik Heating Service (the Nesjavellir project, renovation of distribution systems, and snow-melting systems for pavements). If new markets are not found for geothermal utilization in the country, the manpower in design and construction supervision is likely to be reduced in a similar manner to what happened in the exploration-R&D sector in the late 1980's.

The total number of staff members of the geothermal public utilities was 265 in 1994, but thereof 30 with university degrees. There has been a steady increase in the number of university graduates in the public utilities with the increased sophistication in the operational systems. More and more of the manual work (construction and maintenance) is carried out by contractors.

7. DISCUSSION

Significant experience in geothermal exploration and development is available in some 30 countries (Fridleifsson, 1995). But the manpower resources are unevenly distributed in the world. Several developing countries have built up strong groups of geothermal professionals. Many of the key people of these groups have received training at the international geothermal schools operated in Iceland, Italy, Japan, and New Zealand, but most of the training has taken place on the job in the respective countries. More training is needed for people from many developing countries and the countries of Central and Eastern Europe at both professional and technician levels. In fact, Central and Eastern European countries have had only limited access to the international training centers.

In addition to long and short courses at the international schools, regional courses and specialized courses travelling from country to country should be considered. Many of the countries of Central and Eastern Europe have completed initial surveys and in some cases have started utilization projects of their geothermal resources and are at a stage of wishing to develop the resources using up-to-date technology. They are, however, handicapped both by the lack of finance and an infrastructure of trained personnel.

Most of the countries of Central and Eastern Europe have recently become eligible for scholarships from the United Nations system and bilataeral aid agencies which allow them to send qualified candidates for training at international geothermal schools. Countries with a relatively high per capita income, such as Hungary and Slovenia, are not eligible for such scholarships. It is possible for these countries to send candidates by covering the cost themselves or by obtaining funds from international cooperative programs. It is outside the scope of the present paper to discuss such funding possibilities.

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