HUMAN RESOURCES IN GEOTHERMAL DEVELOPMENT

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SUMMARY - Some 80 countries are potentially interested in geothermal energy development, and about 50 have quantifiable geothermal utilization at present. Electricity is produced fiom geothermal in 21 countries (total 38 TWh/a) and direct application is recorded in 35 countries (34 TWh/a). Geothermal electricity production is equally common in industrialized and developing countries, but plays a more important role in the developing countries. Apart from China, direct use is mainly in the industrialized countries and Central and East Europe. There is a surplus of trained geothermal manpower in many industrialized countries. Most of the developing countries as well as Central and East Europe countries still lack trained manpower. The Philippines (PNOC) have demonstrated how a nation can build up a strong geothermal workforce in an exemplary way. Data from Iceland shows how the geothermal manpower needs of a country gradually change from the exploration and field development to monitoring and operations.

1.0 INTRODUCTION

Geothermal energy has come of age as an energy source. Commercial production on the scale of hundreds of MW has been undertaken for over three decades both for >electricity generation and direct utilization. Initially, the development of geothermal resources was restricted to a few industrialized countries. But during the last two decades, the number of countries using geothermal energy has been steadily increasing. Most of the new projects have been in the developing countries. This paper will deal with a few parameters that have affected the manpower development in the world in the past and may do so in the future.

2.0 WORLD DISTRIBUTION OF GEOTHERMAL UTILIZATION

At the World Geothennal Congress (WGC'95) in Florence in May 1995, there were participants from over 70 countries, and country updates were presented from 48 countries. These were summarized by Freeston (1995) and Huttrer (1995). Evaluating available data *after* the WGC'95, Stefansson (1995) describes the status of geothermal development in 83 countries, and quantifies the use of geothermal energy in 47 of these. He reports the worldwide installed capacity for electricity generation 6.543 MW_e and the installed capacity for direct use 9.047 MW,. The figures for the produced (or consumed) energy *are,* however, quite similar. Annually, about 38 TWh are generated in geothermal power plants, whereas the annual use of direct heat amounts to about 34 TWh (Stefansson, 1995).

Electricity is being produced from geothermal resources in 21 countries. There are 15 countries with an installed capacity over 10 MW_e, thereof 6 industrialized countries (total installed capacity 4.088 MW_e; Russia included) and 9 developing countries (total installed capacity 2.441 MW,. There are 8 countries (4 developing and 4 industrialized) with over 100 MW„ and 4 with over 500 MW_e installed (Italy 626 MW_e, Mexico 753 MW_e, Philippines 1.051 MW„ and USA 2.817 MW_e).

Quantified direct use of geothermal resources is known in some 35 countries (Stefansson, 1995). There are 30 countries with an installed capacity of over 10 MW„ thereof 12 industrialized countries (total 4.920 MWJ, 11 Central and East European countries (total 1.616 MWJ, and 7 developing countries (total 2.491 MWJ. There are 13 countries (2 developing, 4 Central and East European, and 7 industrialized) with over 100 MW_t installed, and 4 countries with over 500 MW_t installed (China 2.143 MW_t, Hungary 638 MW„ Iceland 1.443 MW„ and USA 1.874 MWJ.

Based on this, one can generalize by saying that geothermal electricity production is equally common in industrialized and developing countries. Looking at the share of geothermally generated electricity in individual countries, it is clear that geothermal energy plays a much more significant role in the electricity production of the developing countries than the industrialized ones. Good examples of this are El Salvador, Kenya, Nicaragua, and the Philippines. In all of these countries, 10-20% of the electricity is generated with geothermal steam. *Costa* Rica is likely to join this group of countries shortly, as Mainieri and Robles (1975) expect some 15% of the country's electricity to be generated by geothermal in year 2000. In Mexico, 4,6% of the electricity generated in 1994 was from geothermal (Quijano-Leon and Gutiérrez, 1995). Geothermal electricity in Indonesia may reach a similar level (34%) in the next decade or so (Radja, 1995). Geothermal electricity is unlikely to be of equal significance for the energy sector of individual industrialized countries due to the high electricity consumption per capita in these countries and the lack of sufficient geothermal resources. The only present exception to this statement is Iceland, where 5% of the electricity is being produced from geothermal (the remaining 95% by hydro).

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 East 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. Furthermore, the sun is less reliable in many industrialized countries for drying. Freeston (1995), in his summary of the country updates of the WGC'95, states that it is evident from the papers that there is a large potential for the development of low to moderate enthalpy direct use across the world which is not being exploited due to financial constraints and the low prices of competing forms of energy. The main potential for direct utilization in the developing countries is at present mainly in various drying processes (fruits, fish etc.). Space cooling with geothermal energy will hopefully become an important sector for geothermal utilization in the future.

3.0 MANPOWER DEVELOPMENT

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 the 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 fiom the leading geothermal countries to newcomers in the field.

3.1 Historic Perspective

The pioneering countries of geothermal development (Hungary, Iceland, Italy, Japan, New Zealand, and the USA) started basically from scratch in developing their geothermal resources. 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.

The large attendance at the United Nations Symposium on the Development and Utilization of Geothermal Resources in Pisa in 1970, showed that geothermal energy was already at that time taken seriously as an energy source in a large number of countries. At the onset of the first oil crisis in late 1972, there were well established geothermal specialist groups working in several countries. The oil crisis caused a wave of interest for new and renewable energy sources all over the world. Geothermal energy obtained a lot of attention, as, unlike most other "new" energy types, it was already an established commercial energy source in the pioneer countries mentioned above. International agencies, in particular within the United Nations system, had already after the Rome and Pisa conferences started providing technical assistance to the developing countries in geothermal exploration. This work was intensified. The late 1970's and early 1980's were boom years for geothermal consultants, as their services were requested both at home and abroad. Many international geothermal "experts" received their hands-on-training in consultancy work during these years. The overseas work was both in the developing countries and in the industrialized countries (such as in Europe).

This boom basically ended in 1985 with the sharp drop in oil prices on the world market. Since then, relatively few newcomers have been on the geothermal scene. Geothermal work has been drastically cut in many countries. There has been a large reduction in the number of personnel working in geothermal development in many industrialized countries. Many of these people transferred to work in environmental projects, nuclear waste disposal projects, oil and mineral exploration. There has, however, been a high growth rate in geothermal development in several countries during much or parts of the period 1985-1995. This has particularly been the case in countries where geothermal energy has shown to be the least cost alternative to meet the expansion of the energy demand in the countries/regions concerned. Examples of such countries are China, Costa Rica, Iceland, Indonesia, Nicaragua, Philippines, and for a part of the time in California (USA). If (or when) the oil prices rise again to the levels of 1979-1984, it is very likely that a large number of countries will again start a progressive policy to develop their geothermal resources. The dust will be cleared off many project proposals fiom the 1980's that were put on the shelf. In our discussion on manpower requirements in geothermal, we should not forget that oil prices may start soaring again.

3.2 Examples from Individual Countries

The organizers of the 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.

Table 1 - Professional Personnel in Geothermal Activities and Installed Geothermal Capacities

	1975	1980	1985	1990	1994	Installed 1985 MW_e	MW_t	Installed 1994 MW_e	MW_t
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	253	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 order to get a picture of the human resources development during 1975-1994, I have compiled Table 1 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, I have 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 1 shows the number of professional personnel in geothennal energy work in France, Iceland, Italy, El Salvador, Kenya and the Philippines. The installed capacities in electric (MW_e) and direct (MW_t) 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 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 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 ate 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 figures for 1990 and 1994/1995 (provided by Sarmiento, personal communication), and represent PNOC staff only.

The expansion in the geothermal electric capacity of the Philippines from 890 to 1071 MW_e in the last three years is expected to be followed by an additional 851 MW, being commissioned by mid 1997 (Javellana, 1995). He expects the geothermal generation power to be 2152 MW, by the year 2000. With most of the clearly identifiable geothermal fields in the country now being developed and/or coming into commercial operation by year 2000, it is likely that the manpower peak within PNOC will soon be reached. Furthermore, it is likely that the emphasis of the geothermal work will gradually shift from the exploration and field development activities to design, construction, monitoring, and operations.

Table 2- 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 (space heating)	1.1	1.7	2.4	3.4	4.4	5.0	5.5
Primary energy use PJ/a (all geothermal)	6.1	11.4	16.2	26.7	39.1	43.5	42.7

3.3 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. With an installed capacity of 1434 MW_t and 50 MW_e, Iceland has allocated about 100 professionals/year to geothermal research, development and operations during the last five years (Ragnarsson, 1995). In 1994, 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 2 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.

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.

4.0 SYSTEMATIC GEOTHERMAL TRAINING

In the late 1960's it was recognized that to speed up geothermal development in the developing countries, it would be advisable to set up geothermal training courses aimed at the needs of the recipient countries. UNESCO convened a Meeting of Experts on Training in Geothermal Energy in Paris (France) in 1968. Upon recommendation from this meeting, the first international geothermal schools were started in 1970 in Italy (Pisa, a 9 months course at the International School of Geothermics) and Japan (Fukuoka, 3 months course at the Geothermal Research Centre, Kyushu University). Both of these courses were initiated by UNESCO in co-operation with the respective governments.

Two new geothermal schools were opened in 1979, in New Zealand (Auckland, 9 months diploma course at the Geothermal Institute, Auckland University, offering specialization in earth sciences and engineering), and in

Iceland (Reykjavik, 6 months theoretical and practical training in eight specialized courses at the UNU Geothermal Training Programme at Orkustofnun). The New Zealand school was initiated by the UNDP and the NZ government, whereas the Iceland school was initiated and is still operated by the United Nations University (UNU) and the government of Iceland. In 1983, a geothermal school was started in Mexico (1 year come at the Universidad Autonoma de Baja California). 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 short courses and seminars abroad.

All of the international schools are primarily aimed at the needs of the developing countries. The demand for these schools is very high. However, the number of fully funded training places available per year is at present limited to less than 60 (Iceland 16, Japan 15, New Zealand 20, and Mexico 1 or 2, plus occasional fellowships for training from international banks and aid institutions financing individual geothermal projects).

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 the University of Auckland 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.

Despite their long tradition in the direct application of geothermal water in health spas and horticulture, the countries of Central and East Europe have in many aspects been isolated and lagging behind in geothermal technology. The opportunities for geothermal training is much more restricted for people in these countries than in the developing countries. The short courses organized recently by the International Summer School in Skopje (Macedonia) have 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.

5.0 DISCUSSION

Some 80 countries are potentially interested in geothermal energy development. Of these, some 50 have quantifiable geothermal utilization at present. In most of these, investments have already been made at the level of 1 million USD during the last two decades. Fridleifsson and Freeston (1994) estimated that some 30 countries had invested over 20 million USD each in geothermal over the period 1973-1992, 12 countries over 200 million USD, and 5 countries over 1 billion USD.

Significant experience in geothermal exploration and development is available in some 30 countries. But the manpower resources are unevenly distributed in the world. Just as the oil crisis created a lot of interest in geothermal during 1973-1986, the drastic fall in oil prices in 1985 caused a lot of new projects to be cancelled or put on the shelf. In countries where geothermal energy has proven to be the least cost energy option, existing projects have been extended and new projects started.

A large number of geothermal experts have become redundant in several of the industrialized countries since the mid-1980's and turned over to other work. The developing countries have kept relatively more of their experts in geothermal work. 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. But most of the training has taken place in the respective countries. Qualified local engineers on-the-job and scientists have received excellent training by working as counterparts side by side with international consultants.

An outstanding example of a successful manpower policy can be seen within PNOC in the Philippines. Many countries could adopt a similar policy. It is long due that the Philippines start an international geothermal school. The magnitude of their projects and the great practical experience of their specialists makes the Philippines an excellent location for on-the-job training in the development of geothermal for electricity production.

Irrespective of the development of international oil and gas prices, there is still a great need for geothermal training of people in many developing countries. The need for geothermal training is also considerable in the countries of Central and East Europe. Many of these 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. The international geothermal schools have less than 60 fully funded places each year. 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 courses travelling from country to country should also be considered.

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7.0 REFERENCES

Allegrini, G., Cappetti, C, and Sabatelli, F. (1995). Geothermal development in Italy: Country update report. *I.G.A., Proceedings of the World Geothermal Congress* 1995, 201-208.

Boisdet, A., Ferrandes, R., Fouillac, C., Jaudin, F., Lemale, J., Menjoz, A. and Rojas, J. (1990). Current state of exploitation of low enthalpy geothermal energy in France. *G.R.C. Transactions,* Vol. 14, 55-61.

Campos, T. (1995). Wellhead units and geothermal development in El Salvador. *I.G.A., Proceedings of the World Geothermal Congress* 1995, 93-98.

Freeston, D. (1995). Direct uses of geothermal energy 1995. *I.G.A., Proceedings of the World Geothermal Congress* 1995, 15-25.

Fridleifsson, I.B. and Freeston, D. (1994). Geothermal Energy Research and Development. *Geothermics,* Vol. 23, 175-214.

Huttrer, G.W. (1995). The status of World Geothermal Power Production 1990-1994. *I.G.A., Proceedings of the World Geothermal Congress* 1995, 3-14.

Javellana, S.P. (1995). Country update of Philippine geothermal development and operations 1991-1995. *I.G.A., Proceedings of the World Geothermal Congress* 1995, 289-292.

Mainieri, A. and Robles, E. (1995). Costa Rica country update report. *I.G.A.., Proceedings of the World Geothermal Congress* 1995, 81-85.

N'gang'a, J. (1995). Country update report for Kenya 1991-1994. *I.G.A., Proceedings of the World Geothermal Congress* 1995, 233-237.

Quijano-Leon, J.L. and Gutiérrez, L.C.A. (1995). Present situation of geothermics in Mexico. *I.G.A., Proceedings of the World Geothermal Congress* 1995, 245-250.

Ragnarsson, A. (1995). Iceland country update. *I.G.A., Proceedings of the World Geothermal Congress* 1995, 145-161.

Radja, V.T. (1995). The role of geothermal energy in the context of future electric power supply in Indonesia. *I.G.A., Proceedings of the World Geothermal Congress* 1995, 173-190.

Stefansson, V. (1995). Geothermal energy. Commentary. 1995 Survey of Energy Resources. *World Energy Council* (in press).

Tolentino, B.S. and Buning, B.C. (1985). The Philippines' geothermal potential and its development. *G.R.C. Transactions,* Vol. 9 - international volume, 157-174.