

Thirty One Years of Geothermal Training in Iceland

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ABSTRACT

The Government of Iceland and the United Nations University (UNU) decided in 1978 to establish the UNU Geothermal Training Programme (UNU-GTP), with Orkustofnun (the National Energy Authority of Iceland) as the host institution. The mandate (www.unugtp.is) is to assist developing countries with significant geothermal potential to establish groups of specialists in geothermal exploration and development by offering six month specialized training for professionals employed in geothermal research and/or development. More recently, the UNU-GTP also offers a few successful candidates the possibility of extending their studies to MSc or PhD degrees in geothermal sciences or engineering in cooperation with the University of Iceland. The trademark of the UNU-GTP is to give university graduates engaged in geothermal work intensive on-the-job training in their chosen fields of specialization. The trainees work side by side with geothermal professionals in Iceland (the majority with ISOR–Iceland GeoSurvey). 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. During 1979-2009, 424 scientists and engineers from 44 countries have completed the annual six month courses. They have come from countries in Asia (43%), Africa (28%), Central and Eastern Europe (14%), and Latin America (15%). Since 2000, 20 have graduated with MSc. In 2009, thirteen have pursued their MSc and three their PhD studies at the University of Iceland. The UNU-GTP maintains contact with the majority of its 424 UNU Fellows. The annual Yearbook of the UNU-GTP (with research reports of Fellows of the year) is sent to over 300 former UNU Fellows, most of which are also in active e-mail contact. The UNU-GTP awards travel stipends to former Fellows to attend international geothermal conferences. The UNU-GTP also organizes Workshops and Short Courses on geothermal development in Africa (started in 2005), Central America (started in 2006), and in Asia (started in 2008). This is a contribution of the Government of Iceland to the Millennium Development Goals of the United Nations. The courses/workshops are set up in cooperation with energy and earth science institutions responsible for exploration, development and operation of geothermal energy utilities in the countries/regions. A part of the objective is to increase the cooperation between specialists in neighbouring countries in the field of sustainable use of geothermal resources. The courses may in the future develop into sustainable regional geothermal training centres. About 200 scientists and decision makers have participated in the workshops (1 week), and about 220 scientists have been trained at the short courses (1-3 weeks). Many former UNU Fellows are lecturers and co-organizers of the UNU-GTP Workshops and Short Courses.

1. INTRODUCTION

In 1978, the Government of Iceland and the United Nations University (UNU) decided to establish the UNU Geothermal Training Programme (UNU-GTP). Orkustofnun (the National Energy Authority of Iceland) became the host institution of the UNU-GTP. Specialized training is now offered in geological exploration, borehole geology, geophysical exploration, borehole geophysics, reservoir engineering, chemistry of thermal fluids, environmental studies, geothermal utilization, and drilling technology. 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 sustainable development.

The trademark of the UNU-GTP is to give university graduates employed in geothermal intensive on-the-job training in their chosen fields of specialization. The trainees work side by side with geothermal professionals in Iceland. The training is tailor-made for the individual and the needs of his institution/country. All participants are selected by private interviews during site visits to the countries concerned where UNU-GTP representatives visit geothermal fields, research institutions and energy utilities. Participants are selected for training in the specialized fields that are considered most relevant to promote geothermal development in their respective country. The candidates must have a university degree in science or engineering, a minimum of one year practical experience in geothermal work, speak English fluently, have a permanent position at a public energy agency/utility, research institution, or university, and be under 40 years.

During 1979-2009, 424 scientists and engineers from 44 countries have completed the annual six month courses. Of these, 43% have come from countries in Asia, 28% from Africa, 14% from Central and Eastern Europe, and 15% from Latin America. There have been 72 women (17%). Over 90 professionals have received shorter training (2 weeks to 4 months). In 2000, an MSc programme in geothermal science and engineering was started in cooperation with the University of Iceland. Twenty have graduated from the MSc programme and 9 are presently pursuing their MSc studies and 2 their PhD studies (October 2009). In many countries in Africa, Asia, Central America and Central and Eastern Europe, UNU-GTP graduates are among the leading specialists in geothermal research and development. They have been very successful, and have contributed significantly to energy development in their parts of the world.

The UNU-GTP has, through the years, kept in good contact with the other three international geothermal schools which were established in Italy (Pisa in 1970), Japan (Kyushu in 1970), and New Zealand (Auckland in 1978). Unfortunately, the Pisa school has not held its annual course since 1993 due to drastic cuts in government financing, but has occasionally held short courses (1-3 weeks) in developing countries. The

International Group Training Course at Kyushu University was closed in 2001 and the Diploma course at Auckland University in 2003 also due to withdrawal of government financing. Auckland University will, however, continue admitting students to MSc and PhD studies in geothermal as a part of its regular activities, and short courses are arranged. Kyushu University started a new doctoral course (with Japanese Government Scholarships) entitled "International Special Course of Environmental Systems Engineering" in 2002.

The UNU-GTP is thus at present the only international graduate school offering specialized training in all the main fields of geothermal science and engineering. MSc and PhD studies are also offered at the University of Iceland in cooperation with the UNU-GTP.

2. INSTITUTIONAL ENVIRONMENT AND ORGANIZATION

The UNU-GTP (www.unugtp.is) is operated at Orkustofnun (www.os.is), which has been an Associated Institution of the UNU since 1978. Orkustofnun is a government agency under the Ministry of Industry and Commerce. Its main responsibilities have been to advise the Government of Iceland on energy issues and related topics, and (until 2003) to carry out energy research and provide consulting services relating to energy development and utilization. Orkustofnun has an excellent library specializing in energy research and development (in particular geothermal and hydropower), with some 19,000 titles, subscriptions to 60 journals, and internet access to some 14,000 journals.

The Geoscience Division was separated from Orkustofnun, in 2003, and a new public company established, ISOR – (Iceland GeoSurvey (www.isor.is)), with basically the same operations as the former Geoscience Division. Of the 90 staff members at ISOR in 2008, 20 have PhD qualifications. The disciplines are represented as follows: 29 geologists, 18 geophysicists and reservoir physicists, 9 geochemists, 9 engineers, 3 geographers, 2 administrators, 10 technicians, 8 electricians and others. ISOR has chemical, geophysical, and petrological laboratories, and five logging trucks for geothermal wells. The integration of the UNU Fellows with the specialists and the research atmosphere at ISOR has continued as in the years previous to 2003. The UNU-GTP pays for the services of staff members at ISOR and Orkustofnun, in accordance with contracts. The UNU Fellows have full access to the research facilities and the multidisciplinary research environment of Orkustofnun and ISOR, which united, for over three decades, have been amongst the leading geothermal energy research institutions in the world.

The UNU-GTP also has a close cooperation with the University of Iceland (UI). Staff members of the Faculty of Science and the Faculty of Engineering have been amongst key lecturers and supervisors of the UNU Fellows in some subjects since the establishment of the UNU-GTP. A co-operation agreement was signed in 2000 between the UNU-GTP and the UI on MSc studies in geothermal science and engineering. The MSc is designed for UNU Fellows who have already completed the traditional six month courses at the UNU-GTP, which comprises 25% of the MSc programme.

The UNU-GTP has five full time staff members (employed by Orkustofnun), but lecturers and support staff are hired from ISOR, the UI, and other agencies/companies. Every year, about 50 staff members of these institutions render services to the UNU-GTP under contracts. This allows the

flexibility required to provide highly specialized training in the nine fields of specialization offered. Dr. Ingvar B. Fridleifsson is the founding Director of the UNU-GTP. Mr. Ludvik S. Georgsson has been the Deputy-Director since 1990. Ms. Thorhildur Isberg has been the administrator since 2006. Ms. Dorthe H. Holm, geologist, joined the UNU-GTP in May 2007. Mr. Markus A.G. Wilde joined as assistant in 2008.

The UNU-GTP is academically governed by a Studies Board, which is composed of experts (from ISOR, UI and Hitaveita Sudurnesja (HS)) responsible for each of the specialized courses. The UNU-GTP Director is the chairman of the Studies Board. Other members of the Studies Board are Dr. Hjalti Franzson (Borehole Geology), Mr. Knutur Arnason (Geophysical Exploration), Mr. Benedikt Steingrímsson (Borehole Geophysics), Dr. Gudni Axelsson (Reservoir Engineering), Dr. Halldor Armannsson (Environmental Studies), and Mr. Sverrir Thorhallsson (Drilling Technology), all from ISOR; Professor Stefan Arnorsson (Chemistry of Thermal Fluids), and Professor Pall Valdimarsson (Geothermal Utilization) from UI, and Dr. Gudmundur Omar Fridleifsson (Geological Exploration) from HS. Professor Stefan Arnorsson has been a member of the Studies Board from its establishment in 1979. The Studies Board does not have many formal meetings per year, but serves a very important role in setting the academic standards for the training and in designing training schedules for each individual UNU Fellow. The great devotion and unselfish work of members of the Studies Board through the years is gratefully acknowledged.

3. SPECIALIZED TRAINING

The approximate time schedule of the six month specialized courses is shown in Table 1. All participants attend an introductory lecture course (5 weeks, three lectures per day) which aims to provide 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 introductory course is followed by lectures and practical training in the respective specialized fields (7 weeks), and the execution of a research project (12 weeks) which is concluded with an extensive research project report. Excursions are also arranged to the main geothermal fields under exploration and utilization in Iceland. Seminars are held and case histories studied on each field.

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 detailed description can be found on the home page of the UNU-GTP (www.unugtp.is).

The following lines of specialized training are offered:

- **Geological exploration** offers practical training in basic geological and geothermal mapping, which is commonly the first step in the geothermal exploration of an area. Participants should have a degree in geology.

Table 1: Approximate time schedule for the six month specialized courses at UNU-GTP.**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

- **Borehole geology** gives training in making geological logs, analyses of drill cuttings and cores. The identification of alteration minerals (microscope and x-ray diffraction) and the interpretation of the alteration mineralogy forms an integral part of the course. Participants should have a degree in geology.
- **Geophysical exploration** is practical training in conducting geophysical surveys of geothermal areas and/or interpretation of such data. Emphasis is on the application of computers in the interpretation. Participants should have a degree in physics, geophysics or engineering.
- **Borehole geophysics** covers the essentials of geophysical measurements in boreholes used for geothermal investigations, with an emphasis on temperature and pressure measurements. Participants should have a degree in physics, geophysics or engineering.
- **Reservoir engineering** 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. Participants should have a degree in engineering, physics, geophysics, mathematics or hydrogeology.
- **Environmental studies** cover environmental impact assessments (EIA), laws and policies, the planning and execution of EIA projects and environmental auditing. Scientific methods suitable for environmental monitoring are assessed and biological impact, pollution and occupational safety considered. Participants should have a degree in science or engineering.
- **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. Participants should have a degree in chemistry, geochemistry or chemical engineering.
- **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. Participants should have a degree in

engineering.

- **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 deals with the selection of drilling equipment, well design, casing programs, cementing techniques, cleaning and repairs of production wells. Participants should have a degree in engineering.

Most of the teaching is done by tutorials and practical work where the teacher works with two or three trainees, and use is made of available textbooks and articles in journals. In some instances, however, text material and manuals have been made for the training. Some of the teaching material has been published in reports, and is available from the UNU-GTP (and on www.unugtp.is). UNU Fellows have, in many cases, used teaching material from the UNU-GTP to train colleagues in their own institutions.

One guest lecturer with an international reputation is invited every year as a UNU Visiting Lecturer to give a lecture series and to lead discussions with the trainees. The UNU Visiting Lecturers have stayed from one week to two months in Reykjavik. Table 2 lists the UNU Visiting Lecturers. Many of the lectures of the UNU Visiting Lecturers have been published and are listed by author in the reference list on www.unugtp.is.

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. The project topic is always selected with respect to the conditions of the home country of the participant. All project reports are published by the UNU-GTP. Since 1994, the reports have been published in the annual book "Geothermal Training in Iceland" (edited by Ludvik S. Georsson, international publishing code (ISBN 978-9979-68). Copies can be obtained upon request. The books are mailed regularly to former UNU Fellows, universities and leading geothermal research institutions in over 50 countries. All research reports from 1979-2008 have recently been made available on the home page of the UNU-GTP (www.unugtp.is).

Table 2: UNU Visiting Lecturers 1979-2009.

1979	Donald E. White	USA
1980	Christopher Armstead	UK
1981	Derek H. Freeston	New Zealand
1982	Stanley H. Ward	USA
1983	Patrick Browne	New Zealand
1984	Enrico Barbier	Italy
1985	Bernardo Tolentino	Philippines
1986	Russel James	New Zealand
1987	Robert Harrison	UK
1988	Robert O. Fournier	USA
1989	Peter Ottlik	Hungary
1990	Andre Menjoz	France
1991	Wang Ji-yang	P.R. China
1992	Patrick Muffler	USA
1993	Zosimo F. Sarmiento <i>UNU Fellow 1980</i>	Philippines
1994	Ladislau Rybach	Switzerland
1995	Gudmundur Bodvarsson	USA
1996	John Lund	USA
1997	Toshihiro Uchida	Japan
1998	Agnes Reyes <i>UNU Fellow 1979</i>	Philippines/ New Zealand
1999	Mike Wright	USA
2000	Trevor Hunt	New Zealand
2001	Hilel Legmann	Israel
2002	Karsten Pruess	USA
2003	Beata Kepinska <i>UNU Fellow 1994</i>	Poland
2004	Peter Seibt	Germany
2005	Martin Mwangi <i>UNU Fellow 1982</i>	Kenya
2006	Hagen Hole	New Zealand
2007	José Antonio Rodriguez	El Salvador
2008	Kun Wang <i>UNU Fellow 1998</i>	P.R. China
2009	Wilfred Elders	USA

On many occasions, UNU Fellows from a given country (e.g. Costa Rica, El Salvador, Kenya, Philippines) conduct multidisciplinary research (geology, geophysics, chemistry, reservoir engineering, environmental impact studies) over several years on data from the same area in their home countries under supervision of Icelandic specialists. All the countries mentioned above obtain 15-22% of their electricity from geothermal steam. In 2008, 16 of the 22 research projects dealt at least partly, with geothermal areas in the home countries of the Fellows.

Table 3 lists the countries of origin of the participants who have completed six month training during 1979-2008, and their specialized courses. Figure 1 shows the same on a world map. The largest groups of Fellows have come from China (70), Kenya (42), Philippines (31), El Salvador (27), Ethiopia (26), and Indonesia (24). Sixteen other countries have sent 5-19 participants.

Regular contact is held with former UNU Fellows by sending them the UNU-GTP yearbook and an annual newsletter. The majority of the Fellows keep in contact with the UNU-GTP and each other through correspondence. This has become much easier lately as some 250 former UNU Fellows (out of 402 graduates) are listed in the e-mail directory of the UNU-GTP. An updated directory is sent out twice per year to all alumni Fellows.

4. SELECTION OF PARTICIPANTS AND SITE VISITS

Candidates for participation in the specialized training must have a university degree in science or engineering, a minimum of one year practical experience in geothermal work, speak English fluently, be less than 40 years of age, and have a permanent position dealing with geothermal energy at an energy company/utility, research institution, or university in their home country.

Much care is taken in selecting the participants. Site visits are conducted by representatives of the UNU-GTP to the countries requesting training. 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 directors of the selected 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. All qualified candidates are interviewed personally. Training starts in late April and ends in October each year. Nominations (including the curriculum vitae of the candidates) must be received in Reykjavik before 1 September each year for participation in training starting the following year.

The site visits have played a very significant part in the work and in the success of the UNU-GTP. Since 1979, a total of 173 site visits have been conducted to countries requesting training, or an average of 6 site visits per year. The visits have been made by the permanent staff of the UNU-GTP (70%), and members of the Studies Board and other geothermal specialists mostly from NEA/ISOR. The UNU-GTP Director or the Deputy-Director normally undertakes the first site visit to a given country. In addition to visiting geothermal fields, research institutions, and interviewing candidates, the UNU-GTP representatives commonly participate in local or national/regional geothermal energy conferences/seminars, and in some cases give lectures or lecture series at selected institutions and universities. Indeed, many site visits are planned to coincide with regional conferences and seminars. In some cases, members of the Studies Board and other specialists from ISOR spend a few extra days in a given country/continent to make site visits for the UNU-GTP when they are travelling to conferences or on consultancy missions. In this way, the travel cost can be shared. In connection with the site visits, meetings are held with the UNU-GTP alumni in each country/region as practicable.

The site visits are very valuable for the quality of the training. The private interviews with candidates are aimed to secure the quality of the selected Fellows. During the 30 years of the UNU-GTP, only seven UNU Fellows (out of 409) have been unable to complete the six months of training, mostly for medical reasons. Visits to institutions and geothermal fields aim to tailor the training to the needs of the country and the institutions from which the candidates come. The site visits have, without doubt, contributed very significantly to the successful transfer of technology from Iceland to the recipient countries

A wealth of information and practical experience has been gathered and shared between the various countries participating in the UNU-GTP activities. The site visits have contributed significantly to make the UNU-GTP an international centre of learning.

Table 3: Fellows of the UNU Geothermal Training Programme in Iceland 1979-2009

FELLOWS OF THE UNU GEOTHERMAL TRAINING PROGRAMME IN ICELAND 1979-2009										
Country	Geological exploration	Borehole geology	Geophysical exploration	Borehole geophysics	Reservoir engineering	Chemistry of therm.	Environmen. studies	Geothermal utilization	Drilling technology	Total
Albania			1			1		2		2
Algeria	1							1		4
Azerbaijan				1		2	1			1
Bulgaria					2	2				5
Burundi	1									1
China		3	1	2	26	14	9	15	2	72
Costa Rica	2	2	2		2	2	2	4		16
Djibouti		2			2	1				5
Egypt		1		1	1	1				4
El Salvador	1	1	2	2	5	4	3	6	4	28
Eritrea	2		2			2				6
Ethiopia		3	4	1	5	4	1	6	2	26
Georgia								1		1
Greece			1					2		3
Guatemala		1			1	1				3
Honduras		1	1							2
Indonesia		5	3	2	5	1	2	5	1	24
Iran	1	3	1	1	2	1	3	7	1	20
Jordan	1			1	1	2		1		6
Kenya	1	4	11		6	8	7	3	5	45
Latvia								1		1
Lithuania					1			1		2
Macedonia						1				1
Mexico	1		1	1	3					6
Mongolia	1		1		1	2		4		9
Nepal						1		1		2
Nicaragua					4	3	1			8
Pakistan	1	1			1	1				4
Philippines		4	5	4	9	6		3		31
Poland		1		1	5	1		6		14
Romania						1		4		5
Russia	1				2	5	1			9
Rwanda	1				1			1		3
Serbia				1	1	1				3
Slovakia				1	1					2
Slovenia										0
Tanzania	3		1		1		1			5
Thailand		1		2		1		1		5
Tunisia					1			5		6
Turkey		1			1	4	1	3		10
Uganda	4	1	2		1	4	1			13
Ukraine					2					2
Vietnam	1		1		1	1			1	5
Yemen	2					1				3
Zambia								1		1
Total	25	35	40	21	93	78	32	84	16	424

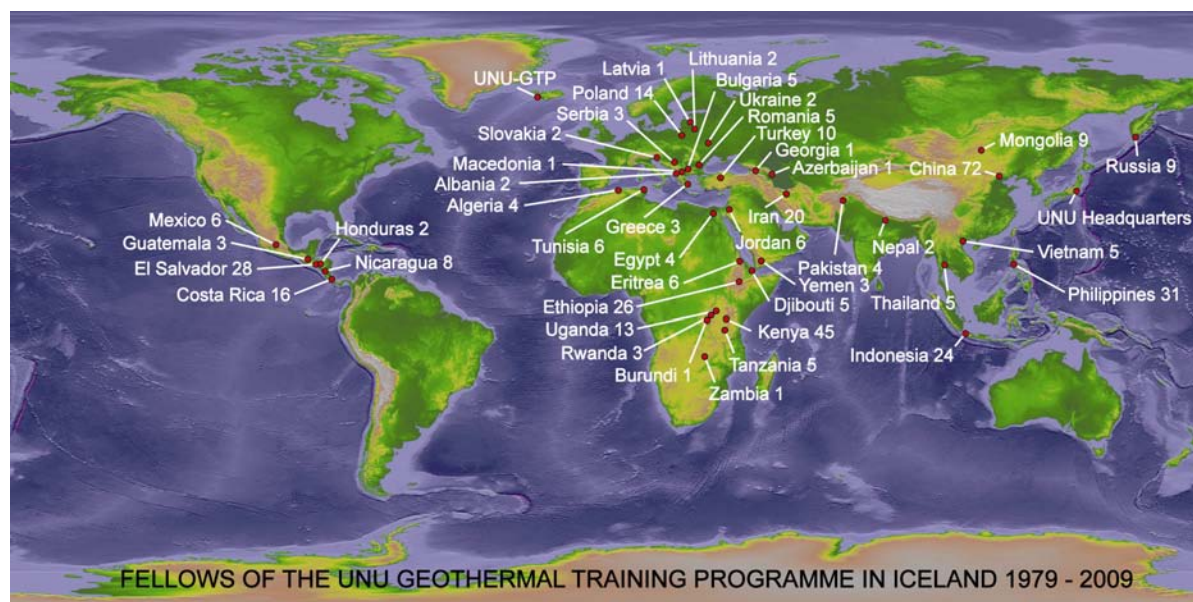


Figure 1: Geographical distribution of UNU Fellows completing six month courses 1979-2009

Participants from developing countries and some CEE countries (not EU members) normally receive scholarships financed by the Government of Iceland and the UNU that cover international travel, tuition fees and per diem in Iceland. The UNDP and the International Atomic Energy Agency (IAEA), and bilateral agencies have also financed fellowships for several trainees through the years. Qualified

participants from industrialized countries (including EU) can be accepted for UNU-GTP training if they have obtained similar scholarships.

5. MASTERS AND DOCTORAL PROGRAMMES

Since 2000, thirty former UNU Fellows (from Djibouti 1, China 1, Costa Rica 1, El Salvador 3, Eritrea 2, Ethiopia 2,

Indonesia 4, Iran 3, Jordan 1, Kenya 7, Mongolia 2, Philippines 2, and Uganda 1) have been admitted to the MSc programme in geothermal science and engineering in cooperation with the University of Iceland (UI). Many of our trainees have already completed their MSc or PhD degrees when they come to Iceland, but several excellent students who have only BSc degrees have made requests to come back to Iceland for a higher academic degree. Their six months in the UNU-GTP fulfil 25% of their MSc programme credit requirements. The aim of establishing the MSc programme in cooperation with the UI was to go a step further in assisting selected countries in building up their specialist groups and to increase their geothermal research capacity.

The first UNU Fellow to attend the MSc programme in geothermal engineering was Mr. Muthafar Emeish from Jordan (UNU Fellow 1999). He graduated in 2001. A total of twenty scientists and engineers have completed their MSc thesis during 2001-2009. Seven have come from Kenya (graduated in 2002, 2004, 2006, 2007, 2008), three from Iran (2005 and 2 in 2008), two from Indonesia (2009), and one from each of China (2008), Djibouti (2008), El Salvador (2009), Ethiopia (2009), Jordan (2001), Mongolia (2005), Philippines (2008), and Uganda (2005). The MSc theses have been published in the UNU-GTP publication series, and can be obtained from www.unugtp.is. Nine UNU Fellows are currently enrolled in the MSc programme in the fall semester of 2009. Five started in September 2008. They are Kiflom Gebrehiwot (UNU Fellow 2005, geologist from Eritrea), Yohannes Lemma (UNU Fellow 2007, geophysicist from Ethiopia), Manuel Rivera, (UNU Fellow 2007, mechanical engineer from El Salvador), Erlindo Angcoy (UNU Fellow 2006, chemical engineer from the Philippines), and Hary Koestono (UNU Fellow 2007, geologist from Indonesia). Four started in September 2009. They are Alejandro Rodriguez (UNU Fellow 2006, chemist from Costa Rica), Andi Joko Nugroho (UNU Fellow 2007, mechanical engineer from Indonesia), Andemariam Teklesenbet (UNU Fellow 2007, geophysicist from Eritrea), and Endy Kevin Padilla (UNU Fellow 2007, environmental scientist from El Salvador). All MSc Fellows have been on UNU-GTP Fellowships funded by the Government of Iceland.

The first three former UNU Fellows have been admitted to commence PhD studies at the University of Iceland in the academic year 2008-2009. The environmental scientists Gabriel N. Wetangula and Pacifica A. Ochieng are on UNU-GTP Fellowships (both from Kenya), and Daher Elmi Houssein (reservoir engineer from Djibouti) is funded by Reykjavik Energy.

6. BUILDING OF SPECIALIST GROUPS AND EVALUATION

The aim of the UNU-GTP is to concentrate its training efforts to assist in building up groups of specialists in the geothermal departments of selected countries with significant geothermal potential. Priority for training is given to candidates from carefully selected institutions from developing countries where geothermal exploration and development is already under way. The limiting factor is, in some cases, the availability of sufficiently qualified staff in the recipient institutions. The fact that participants must speak English fluently has, for example, hampered participation from certain parts of the world such as Latin America.

Figure 2 shows the number of Fellows completing the six month specialized training during 1979-2009 and the active MSc and PhD students. The number of Fellows has gradually increased, mostly controlled by available financing. There have always been waiting lists of qualified candidates. In the last few years, 18-22 UNU Fellows have graduated after six month courses each year, but the number of MSc Fellows conducting their studies has risen steadily from 4-5 to 16 in a year.

Table 4 shows how the leading recipient countries have sent professionals for specialized training in most of the courses offered. Relatively few experts have been trained in geological exploration and drilling technology, as these subjects are generally mastered in the home countries. The UNU-GTP has twice been evaluated as a part of the UNU system. In 1996, a detailed account was given within an assessment report on UNU training and fellowship activities (United Nations University, 1996). In 1998, a brief description was given in a report on the 20-year review and evaluation of the UNU (United Nations University, 1998). Both evaluations were very favourable to the UNU-GTP.

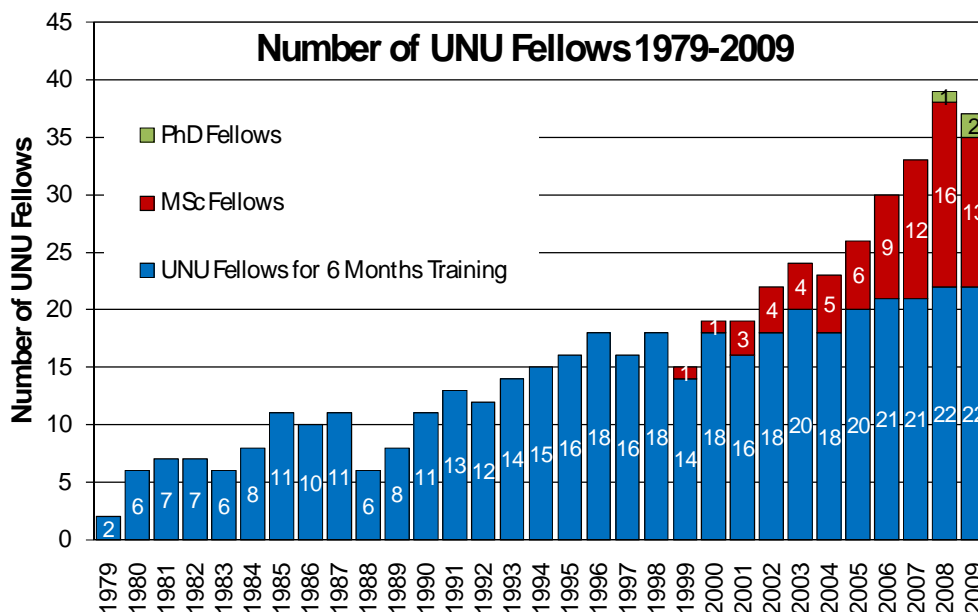


Figure 2: Number of UNU Fellows completing six month specialized courses and studying for MSc and PhD 1979-2009

Table 4: Number of Fellows from the five leading countries and chosen specializations 1979-2009

	China	Kenya	Philippines	El Salvador	Ethiopia
Geological Exploration		1		1	
Borehole Geology	3	4	4	1	3
Geophysical Exploration	1	11	5	2	4
Borehole Geophysics	2		4	2	1
Reservoir Engineering	26	6	9	5	5
Chemistry of Fluids	14	8	6	4	4
Environmental Studies	9	7		3	1
Geothermal Utilization	15	3	3	6	6
Drilling Technology	2	5		4	2
Total	72	45	31	28	26

Internal assessment of the training has, in the past, mainly taken the form of interviews with former trainees and their directors during site visits. Meetings are also arranged in connection with international geothermal conferences. Some changes have been made in the detailed contents of some of the specialized courses, based on the feedback from the trainees and their institutions. During the training, questionnaires (anonymous answers) are also used to obtain the opinion of the Fellows on the content of the lectures and the performance of the lecturers. Since 2004, questionnaires have been used to seek the opinion of the Fellows on individual phases of the training and research activities as well as their opinion on the general support and guidance from UNU-GTP staff, working conditions at the UNU-GTP office, the attitude and support of staff of Orkustofnun and ISOR, arrangements of accommodation, and daily allowance.

At the International Geothermal Conference held to celebrate the 25th anniversary of the UNU-GTP, former UNU Fellows presented papers on the contribution of UNU-GTP training to geothermal development in Africa, Asia, Central America, Central and Eastern Europe, and China (Mwangi, 2003; Benito and Reyes, 2003; Barrios, 2003; Kepinska, 2003; Zhao et al., 2003, respectively; the papers can be obtained at www.unugtp.is under *Special Events / 25th Anniversary*). These papers give valuable assessments on the UNU-GTP from the point of view of the respective regions. Similar papers were given by Mwangi (2008), Liu (2008), Barrios (2008), Malolepszy (2008), and Karim (2008) at the 30th Anniversary Workshop in August 2008 (the Workshop Proceedings are available on www.unugtp.is).

Generally speaking, the effort to have the training tailor-made to the abilities of the individual and the needs of the recipient country/institution seems to have been very successful. The number of fully qualified applicants each year is normally much greater than the number of scholarships available. All the participants are selected after private interviews by UNU-GTP staff, and on the recommendation of the recipient institutions. It is, therefore, not surprising that many of the former trainees have become the leading specialists in their countries, in their given fields. Our records indicate that about 80% of all our trainees have continued working in the geothermal sector for five years or more.

In many countries in Africa, Asia, Central America and Central and Eastern Europe, UNU-GTP graduates are among the leading specialists in geothermal research and development. They have been very successful, and have contributed significantly to energy development in their parts of the world.

7. SHORT COURSES AS CONTRIBUTION TO UN MILLENNIUM DEVELOPMENT GOALS

The Government of Iceland has secured core funding for the UNU-GTP to expand its capacity building activities by annual short courses/workshops in geothermal development in selected countries in Africa (started in 2005), Central America (started 2006), and in Asia (started in 2008). The announcement on this was made at the International Conference for Renewable Energies held in Bonn (Germany) 1-4 June 2004. This is a contribution of the Government of Iceland towards the Millennium Development Goals of UN.

The courses/workshops are set up in cooperation with the energy agencies/utilities and earth science institutions responsible for the exploration, development and operation of geothermal facilities in the respective countries/regions. A part of the objective of the workshops/short courses is to increase cooperation between specialists in the field of sustainable use of geothermal resources. The courses may in the future develop into sustainable regional geothermal training centres. Reports of the Millennium Workshops/Short Courses of the UNU-GTP can be seen on our webpage www.unugtp.is

The first workshop in Africa (“*Workshop for Decision Makers on Geothermal Projects and their Management*”) was held in Kenya in November 2005 with 35 participants (including lecturers) from Eritrea, Ethiopia, Kenya, Tanzania and Uganda, as well as Iceland and the Philippines. The second event in Africa was held in Kenya in November 2006 (“*Short course on surface exploration for geothermal resources*”). The purpose was to give “a state of the art” overview of the possibilities and status of surface geothermal exploration in East Africa. Twenty three trainees from Djibouti, Eritrea, Ethiopia, Tanzania, Uganda, and 10 from the host country (Kenya) took part in the course. Participation was by invitation only. The lectures and demonstrations were in the hands of four Icelanders (UNU-GTP and ISOR), 12 former UNU Fellows from KenGen and one from each of Eritrea, Ethiopia, and Uganda, as well as a senior official from Djibouti and Tanzania.

The third annual event in Africa (“*Short Course II on Surface Exploration for Geothermal Resources*”) was held at Lake Bogoria and Lake Naivasha, Kenya, November 2-17, 2007. The basis of the course was the same as in 2006, but it was extended with additional lectures and a week of field work, which was entirely handled by KenGen staff, while the lecturers from Iceland were involved in the rest of the course. In all, 30 trainees were invited and 25 lecturers took care of the teaching, the majority from Kenya, adding to that 5 Icelanders and one from most of the neighbouring E-African countries.

The fourth annual event in Africa (“Short Course III on Exploration for Geothermal Resources”) was held in Kenya 24 October – 17 November. This four week long course was as the previous courses co-organized by the UNU-GTP and the Kenya Electricity Generating Company, Ltd. (KenGen). The 37 participants came from 11 countries in East Africa: Kenya 18, Djibouti 2, Ethiopia 2, Eritrea 2, Tanzania 2, Uganda 2, Rwanda 2, Burundi 2, Zambia 2, DR Congo 1, and finally Yemen 2, which despite being on the other side of the Red Sea has common geological features with East Africa. This is the first time that Zambia and DR Congo have participated in UNU-GTP events. The first part was a week of field work in the Lake Bogoria region entirely under the guidance of KenGen instructors, followed by lectures and project work at Lake Naivasha. The teaching was in the hands of 4 experts from Iceland (UNU-GTP and ISOR), 19 experts from KenGen (all but one former UNU Fellows), and 5 experts from neighbouring countries (all former UNU Fellows).

A “Short Course on Geothermal Project Management and Development” was also held in Entebbe, Uganda, 20-22 November. It was co-organized by the UNU-GTP, KenGen, and the Ugandan Department of Geological Survey and Mines. It preceded the African Rift Geothermal Conference (ARGeo C-2 Conference) held in Entebbe 24-25 November. There were 24 participants from 11 African countries plus lecturers from El Salvador 1, Ethiopia 1, Iceland 5, Kenya 5, the Philippines 1, and Uganda 2. All the lecturers/instructors from Africa are former UNU Fellows. Proceedings of the annual Millennium Workshops/Short Courses of the UNU-GTP can be found on our webpage www.unugtp.is.

The first Millennium Development Goals event in Central America (“Workshop for Decision Makers on Geothermal Projects in Central America”) was held in San Salvador 26 November to 2 December 2006. The fifty participants came mainly from the four countries of Central America active in geothermal development, i.e. Costa Rica, El Salvador, Guatemala and Nicaragua. Lecturers came from the Central American countries as well as Iceland, Italy, Kenya, Mexico, Philippines and the USA. Among them were 9 former UNU Fellows. The aim of the workshop was to give high level decision makers from the energy and environmental ministries, leading geothermal agencies, and electric utilities in the region an overview of some of the key issues of geothermal development, with a special focus on environmental issues. The second event in Central America (“Short Course on Geothermal Development in Central America”) was held in El Salvador in November 2007, and dealt with geothermal development in Central America with special focus on resource assessment and environmental management, including lectures, debates and practical exercises. There were 61 participants, including 45 trainees from Costa Rica, El Salvador, Guatemala, Honduras, Mexico, and Nicaragua. The lecturers/instructors came from Costa Rica, El Salvador, Iceland, Kenya, Nicaragua, and the Philippines. The Workshop and the Short Course were co-hosted by UNU-GTP and LaGeo S.A, de C.V. in El Salvador.

The first Millennium Development Goals event in Asia (“Workshop for Decision Makers on Direct Use of Geothermal Resources in Asia”) was held in Tianjin 11-18 May, 2008. High ranking decision makers and leading geothermal experts were invited from the Peoples Republic of China as well as from Asian countries with significant

geothermal resources, including plans and markets for space heating (replacement for coal). The criteria for a country to be invited was a) that there is a need for space heating for at least a few months of the year, and b) that there are known geothermal resources near densely populated areas (towns, villages). Participants came from China, India, Iran, Jordan, Mongolia, the Democratic Peoples Republic of Korea, and the Republic of Korea. In addition, lecturers came from Iceland, Germany, Japan, Poland and Switzerland. There were 118 participants on the first day (including speakers). The Workshop was co-hosted by the UNU-GTP, the Tianjin Bureau of Land, Resources and Real Estate Management, and the Tianjin Bureau of Geology and Mineral Exploration and Development.

8. INTERNATIONAL COOPERATION

One of the roles of the UNU-GTP, according to the Agreement on the Status of Association with the UNU, is to “develop and maintain communication among developing countries and arrange, as necessary and appropriate, conferences, seminars, workshops and panels which would further the dissemination and application of practical knowledge” in geothermal energy. This has been fulfilled partly by direct cooperation with the UNU-GTP alumni and their institutions, and partly through active participation in international geothermal conferences, workshops, and seminars. The UNU-GTP has contributed to the organization of many international meetings such as the *1985 International Symposium on Geothermal Energy* (US Geothermal Resources Council, Hawaii 1985); *UN Workshop on the Development and Exploitation of Geothermal Energy in Developing Countries* (with UN/DTCD in Reykjavik 1986); the *World Geothermal Congress 1995* (International Geothermal Association, Italy 1995); the *World Geothermal Congress 2000* (International Geothermal Association, Japan 2000); and the *World Geothermal Congress 2005* (International Geothermal Association, Turkey 2005).

Former UNU Fellows have also been active with their colleagues in some countries in arranging regional and international conferences/workshops such as the annual *PNOC-EDC Geothermal Conference* in the Philippines; the *European Summer School on Direct Applications of Geothermal Energy* (sponsored by the European Commission and the International Geothermal Association, at Oradea University, Romania 2001); the *International Scientific Conference on Geothermal Energy in Underground Mines* (Poland in 2001); the *2002 International Symposium on Geothermal at the 2008 Olympics in Beijing*; the *KenGen Geothermal Conference* in Kenya 2002, which was expanded in 2003 under the title *2003 Eastern Africa Market Acceleration Conference*, and their follow-up the *African Rift Geothermal Conferences*, with *ARGeo C-1* held in Ethiopia in 2006, and *ARGeo C-2* held in Uganda in late 2008.

The UNU-GTP has been very active within the International Geothermal Association (IGA), with the Director serving as Chairman of the European Branch of IGA 1992-1995, and as IGA President 1995-1998. Many former UNU Fellows are active members in the respective national geothermal associations (e.g. in Costa Rica, El Salvador, Ethiopia, Indonesia, Philippines, Poland, Romania, Slovakia and Turkey) which are affiliated with the IGA, and six (from El Salvador, Ethiopia, Kenya, Poland, Romania and Uganda) are members of the present Board of Directors of IGA.



Figure 3: UNU Fellows with UNU-GTP staff and Studies Board at the WGC 2005 in Turkey; a third of the 318 UNU Fellows graduating 1979-2004 were authors of papers at the congress

The most memorable participation of UNU Fellows in the international arena was the World Geothermal Congress 2005 in Turkey (WGC 2005). The Congress is organized every five years by the IGA, this time with the Turkish Geothermal Association as a co-convenor. There were over 1300 participants from 80 countries. The UNU-GTP was very well represented. In all, 141 papers (20% of all papers) were authored or co-authored by 104 former UNU Fellows from 26 developing and transitional countries. The papers were divided between 23 of the 24 technical sessions of the conference. The level of activity of the UNU Fellows in the international geothermal community is well reflected in the fact that a third of the 318 graduates of the UNU-GTP from 1979-2004 were authors of refereed papers at the congress. The papers are accessible on www.unugtp.is.

Seventy seven former UNU Fellows from 25 countries attended the congress in Turkey (Figure 3). Most of them received travel fellowships funded by the UNU-GTP in Iceland and the UNU Centre in Japan. Sixty one UNU Fellows attended the WGC 2000 in Japan (out of 227 graduates at that time) and 35 the WGC 1995 in Italy (out of 161 graduates). The UNU-GTP policy to support the participation of former UNU Fellows in the WGC every five years has made it possible for a large number of professionals from all continents to share their research results and experience with the international geothermal community. Their enthusiasm and hard work gives them the opportunity to keep up with new technical developments as well as the pleasure of meeting friends and colleagues from various parts of the world, reminisce about the past, and plan for the future. These are the pillars of the network of UNU-GTP Fellows worldwide.

Through the years, the Director of the UNU-GTP has frequently been asked to represent geothermal energy in international working groups and at conferences, as the UNU-GTP is the most active UN centre dealing with geothermal energy at present. The most recent example is the *IPCC Scoping Meeting on Renewable Energy Sources* (in Lübeck, Germany, January 2008) where the Director was a keynote speaker and gave a paper entitled “*The possible role and contribution of geothermal energy to the mitigation of climate change*” (Fridleifsson et al., 2008). Similar papers were given on the other renewable energy sources (biomass, hydro, solar, tidal and wind energy). This is one of many

expert meetings organized by the IPCC (International Panel on Climate Change) in preparation for the renewal of the Kyoto protocol.

9. UNU-FTP AND OTHER UNU ACTIVITIES IN ICELAND

The UNU Fisheries Training Programme (UNU-FTP) started operating in Iceland in 1998 on the basis of an Agreement on Cooperation between the UNU, the Government of Iceland, and the Marine Research Institute. The training methods and mode of selection of participants is based on the experience of the UNU-GTP. Six specialized courses are offered: Quality Management of Fish Handling and Processing; Fisheries Policy and Planning; Marine and Inland Waters Resources Assessment and Monitoring; Fishing Technology; Management of Fisheries Companies and Marketing; and Aquatic Environmental Assessment and Monitoring. Under the able leadership of Dr. Tumi Tomasson, the Director, the UNU-FTP (www.unuftp.is) has in ten years grown in size similar to the UNU-GTP. A total of 187 Fellows from 30 countries have graduated during 1998-2009 after six months training. MSc and PhD studies have been taken up in cooperation with the University of Iceland. The UNU-FTP has held a number of short courses in Africa, Asia, and the Caribbean.

A third specialized training programme, the Land Restoration Training Programme (LRTP), is in a three year pilot phase in Iceland (started in 2007). The new training programme is built on the same concept as the UNU-GTP and the UNU-FTP. A seven week programme was operated in 2007, and the first six Fellows came for six months specialized training in April 2008, and an other group of six in April 2009. Once fully developed, the LRTP may offer six specializations: Land Degradation and Global Environmental Change; Remote Sensing and GIS; Assessment and Monitoring of Degraded Land; Restoration Project Planning and Implementation, Sustainable Land Management; and Capacity Development and Institutional Change. The LRTP is financed by the Icelandic Foreign Ministry. The implementing agencies are the Agricultural University of Iceland and the Icelandic Soil Conservation Service. The preparations are made in close cooperation with the UNU. The programme may become a formal UNU programme after the trial period.

10. FINANCES AND FUTURE PLANS

The activities of the UNU-GTP are mainly funded (over 90%) by the Government of Iceland, but the UNU also contributes a certain amount annually towards fellowships. International agencies (e.g. UNDP and IAEA) and bilateral agencies have also financed fellowships for several trainees through the years in connection with their geothermal projects. These have both been for six months and shorter periods of time. Fellowships awarded by UNU/Iceland have been restricted to six months training as well as MSc and PhD studies.

The current economic crisis (which started in 2008) will certainly have adverse effects on the contribution of Iceland to international development aid. Fortunately, the UNU programmes in Iceland were not seriously affected by cuts in the state budget for 2009, but the budget for 2010 is likely to be generally much more restrictive. The Government of Iceland has for over a decade contributed a higher amount annually to the UNU than any other institution within the UN system. The technically highly developed and sustainable use of the fisheries resources and the renewable energy resources have been instrumental in bringing Iceland from the category of developing countries in the 1960s, to the ranks of the ten countries with the highest BNP/capita since the 1980s. Iceland is prepared to share its experience with the developing and transitional countries through effective transfer of technology on the sustainable use of natural resources. The Government considers the UNU a most suitable venue for channelling a considerable part of its multilateral development aid. The feedback from the recipient countries has been very favourable.

The UNU-GTP will continue to focus on specialized training and capacity building. New countries will be added, but care will be taken not to spread the efforts too thin. After 30 years of operations, experience strongly suggests that to make technology transfer successful and sustainable, it is necessary to build up a group of at least ten geothermal specialists in a given country. In addition, support will continue to former UNU Fellows in different countries/regions through the Internet and by site visits, workshops and seminars.

In the coming five years, about 20 UNU Fellows will be accepted each year for the six month courses in Iceland, 5-6 former UNU Fellows will be admitted annually for MSc studies and 1-2 for PhD studies in cooperation with the University of Iceland. The series of workshops/courses in Africa, Asia, and Central America involve a significant expansion in the activities of the UNU-GTP. These courses may in the future develop into sustainable regional geothermal training centres. Requests for this have already come from Kenya and China.

To meet the requests of the developing countries for expansion of the capacity building and degree oriented research, it will be necessary for the UNU-GTP to strengthen further its ties with the University of Iceland and ISOR, as well as with the geothermal industry. The excellent network of UNU Fellows in over thirty developing and transitional countries is of great value for the promotion and development of geothermal resources in the world. This rather unique network of the United Nations University needs to be nurtured and expanded further. To meet these tasks, the UNU-GTP has to be strengthened as an institution both in Iceland and within the UNU.

REFERENCES

- Barrios Martinez, L.A. Contribution of UNU-GTP training to geothermal development in Central America-Mexico. Proceedings of the International Geothermal Conference on Multiple Integrated Uses of Geothermal Resources, Reykjavik, Geothermal Association of Iceland, 2003. S2 11-21.
- Barrios Martinez, L.A. UNU Fellows in Central America and Mexico 1979-2008. Proceedings, 30th Anniversary Workshop of the UNU-GTP, Reykjavik, Iceland, (2008), 14p.
- Benito, F.A., and Reyes, A.N.: Contribution of UNU-GTP training to geothermal development in Asian countries. Proceedings, International Geothermal Conference on Multiple Integrated Uses of Geothermal Resources, Reykjavik, Geothermal Association of Iceland, (2003), S2, 22-31.
- Fridleifsson, I.B., Bertani, R., Huenges, E., Lund, J.W., Ragnarsson, A., and Rybach, L., 2008: The possible role and contribution of geothermal energy to the mitigation of climate change. In: Hohmeyer, O., and Trittin T. (eds.), Proceedings of the IPCC Scoping Meeting on Renewable Energy Sources, Luebeck, Germany, 59-80.
- Karim, A.: Contribution of UNU-GTP training to geothermal development in Pertamina Geothermal Energy, Indonesia. Proceedings, 30th Anniversary Workshop of the UNU-GTP, Reykjavik, Iceland, (2008), 6p.
- Kepinska, B.: Contribution of UNU-GTP training to geothermal development in Central and Eastern European countries. Proceedings, International Geothermal Conference on Multiple Integrated Uses of Geothermal Resources, Reykjavik, Geothermal Association of Iceland, (2003), S2, 40-51.
- Liu, J.: The Role of UNU-GTP on Geothermal Development in China. Proceedings, 30th Anniversary Workshop of the UNU-GTP, Reykjavik, Iceland, (2008), 8p.
- Malolepszy, Z. Contribution of UNU-GTP training to geothermal development in Central and Eastern Europe. Proceedings, 30th Anniversary Workshop of the UNU-GTP, Reykjavik, Iceland, (2008), 6p.
- Mwangi, M.N.: Contribution of UNU-GTP training to geothermal development in Africa. Proceedings, International Geothermal Conference on Multiple Integrated Uses of Geothermal Resources, Reykjavik, Geothermal Association of Iceland, (2003), S2, 1-10.
- Mwangi, M.N.: Contribution of UNU-GTP training to geothermal development in Africa: Update 2008. Proceedings, 30th Anniversary Workshop of the UNU-GTP, Reykjavik, Iceland, (2008), 15 p.
- Zhao, P., Wang, K., and Liu, J.: Contribution of UNU-GTP training to geothermal development in China. Proceedings, International Geothermal Conference on Multiple Integrated Uses of Geothermal Resources, Reykjavik, Geothermal Association of Iceland, (2003), S2, 32-39.