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UNU Geothermal Training Programme in Iceland: Capacity Building for Geothermal Energy Development for 36 Years

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ABSTRACT

From its establishment in 1978, the United Nations University Geothermal Training Programme (UNU-GTP) has specialized in capacity building for geothermal exploration and development for professionals from developing countries. This has been achieved through training and post-graduate academic studies in Iceland as well as short courses, workshops and training in the developing countries themselves. The annual six month training in Iceland, given since 1979, is the basic operation of the programme, with the aim of giving university graduates engaged in or groomed for geothermal work, intensive on-the-job training in their chosen discipline. Specialized training has been offered in nine fields: Geological Exploration, Borehole Geology, Geophysical Exploration, Borehole Geophysics, Reservoir Engineering, Chemistry of Thermal Fluids, Environmental Sciences, Geothermal Utilization, and Drilling Technology. By 2014, a total of 583 scientists and engineers from 58 countries have completed the annual six month specialized courses offered, or equivalent training, with the 2013 group of 34 individuals the largest to date. Of these, 37% have come from countries in Asia, 36% from Africa, 15% from Latin America and the Caribbean, 11% from Central and Eastern Europe, and 1% from Oceania. Former UNU Fellows are among the leading specialists in geothermal research and development in many countries.

The MSc and PhD programmes that are offered in cooperation with the University of Iceland, and now also Reykjavik University, were established to go a step further in assisting selected developing countries to strengthen their specialist groups and increase their geothermal research capacity, through admittance and support for postgraduate academic studies. The six month training at UNU-GTP fulfils 25% of the MSc programme credit requirements. Since 2001, 40 former UNU Fellows have completed an MSc degree in geothermal science or engineering through the UNU-GTP MSc programme ((end of 2014). The recipients of the first three UNU-GTP PhD Fellowships to date are Kenyans, with the first one defending her PhD thesis in early 2013.

The operations of UNU-GTP have, however, not been limited to Iceland. Training activities in developing countries, usually referred to as the UN Millennium Short Courses, were initiated 10 years ago, with Workshops for Decision Makers, followed by annual Short Courses, starting in East Africa (Kenya) in 2005 and Central America (El Salvador) in 2006. The aim has been to increase efforts in geothermal capacity building and further regional cooperation in geothermal development. These series have also provided a basis for UNU-GTP to offer customer-designed short courses and training in line with needs in key partner countries.

1. INTRODUCTION

The United Nations University Geothermal Training Programme (UNU-GTP) was established in Iceland in 1978. The goal of UNU-GTP has been to assist developing countries with significant geothermal potential to establish groups of specialists in geothermal exploration and development with the basic knowledge necessary for sustainable geothermal development. Since 1979, annual 6 month courses have been held in eight different lines of geothermal science and engineering for professionals from developing countries with the ninth study line added in 1997. The programme is hosted at Orkustofnun – The National Energy Authority of Iceland.

The hallmark of UNU-GTP is to give university graduates engaged in geothermal work intensive on-the-job training in their chosen fields of specialization. The UNU Fellows 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 developing countries UNU-GTP representatives visit geothermal fields, research institutions and energy utilities. Fellows are selected for training in the specialized fields that are considered most relevant to promote geothermal development in their respective country.

During 1979-2014, 583 scientists and engineers from 58 countries have completed the six month course, or its equivalence. Of these, 37% have come from Asia, 36% from Africa, 15% from Latin America and the Caribbean, 11% from Europe and 1% from Oceania. During this period, 118 women have completed the programme, i.e. 20% of the participants.

More recently, UNU-GTP also offers successful UNU Fellows the possibility of extending their studies to MSc or PhD degrees in geothermal sciences or engineering in cooperation with the University of Iceland and Reykjavik University. The MSc programme was started in 2000 in cooperation with the University of Iceland, and the PhD programme in late 2008. In late 2014, 40 MSc Fellows had completed their degree, with 12 pursuing their studies. In addition, the first PhD Fellow defended her thesis in 2013, with 2 pursuing their studies in Iceland. A similar cooperation agreement with Reykjavik University was signed in 2013, with the first MSc Fellow starting in August 2014.

The UNU-GTP Millennium Short Courses are a special contribution of the Government of Iceland to the Millennium Development Goals of the United Nations. A part of the objective is to increase the cooperation between specialists in neighbouring countries in

the field of sustainable use of geothermal resources. About 200 scientists/engineers and decision makers have participated in the 3 one week workshops, and almost 800 scientists/engineers have now been trained at the annual Short Courses, which have extended for 1-3½ weeks. Many former UNU Fellows are lecturers and co-organizers of the UNU-GTP Workshops and Short Courses.

Since the start of the Workshops/Short Courses in 2005/6, the long term aim has been for the courses to develop into sustainable regional geothermal training centres. In Central America, the financial basis for the establishment of a Diploma Course in Geothermal Energy at the University of El Salvador (UES) was already secured in 2012 for 3 years, by the Nordic Development Fund (NDF) and the Inter-American Development Bank (IDB). Scholarships are given to participants from all of Latin America. UNU-GTP was in an advisory position here, assessing the set-up and advising on contents of the course. Work is now on-going on strengthening its background, in order to make it financially sustainable. UNU-GTP foresees a similar development in 2014-2015 in East Africa. With plans of fast-tracking geothermal in the region, it is urgent to get a regional geothermal centre established, so capacity building in the region can keep up with the ambitious plans of geothermal development (Georgsson et al., 2015).

The need for geothermal training has now grown beyond what UNU-GTP is able to fulfil and service through its regular financing from the Official Development Assistance of the Government of Iceland. Therefore, UNU-GTP has taken its training activities one step further and offers courses or training fulfilling special needs of a paying customer. The content of these events has varied significantly, based on the needs of the respective client, including regular short courses and hands-on training, with a time frame varying from a few days to several months for individual events. This need has also seen additional UNU Fellowships funded by the partner countries/institutions, either directly or through international or bilateral agencies. This has especially been evident in the period from 2010, during which up to one third of the UNU Fellowships have been funded that way, as can also been seen from the considerably bigger groups of UNU Fellows in this period.

Currently, UNU-GTP is the only international programme offering specialized training in all the main fields of geothermal science and engineering. 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 successful, and have contributed significantly to geothermal energy development in their parts of the world. This paper describes the operations of UNU-GTP with emphasis on the activities in Iceland, giving insight into its history, the current status and some thoughts about future development. A thorough description of its activities on-site in the developing countries is found in another paper by Georgsson et al. (2015).

2. THE ORGANIZATION OF UNU-GTP

UNU-GTP is operated at Orkustofnun - the National Energy Authority of Iceland (*www.os.is*), which has been an Associated Institution of UNU since 1978. Orkustofnun is a government agency under the Ministry of Industries and Innovation. Its main responsibilities are to advise the Government of Iceland on energy issues and related topics. UNU-GTP cooperates closely with ÍSOR – Iceland GeoSurvey, the main Icelandic geoscientific research institution, where the majority of the teachers at UNU-GTP are employed. UNU-GTP also has a close cooperation with the University of Iceland (UI), and more recently also Reykjavík University (RU), with several of its key lecturers and project supervisors coming from the universities. Similarly, many of Iceland's main engineering and energy companies have contributed significantly to teaching and supervising at UNU-GTP.

UNU-GTP has now six full time staff members (employed by Orkustofnun), but lecturers and support staff are hired or contracted from its cooperation partners, in line with the needs at the given time. Every year, 50-70 staff members of these institutions render services to UNU-GTP under contracts. This gives the necessary flexibility required to provide the highly specialized training in the nine fields of specialization offered to date. Mr. Lúdvík S. Georgsson is the current Director of UNU-GTP, having taken over in 2013 from the founding Director, Dr. Ingvar Birgir Fridleifsson. Mr. Ingimar G. Haraldsson joined UNU-GTP in 2010 and is now the Deputy Director, mainly responsible for Short Courses and Training abroad, Ms. María S. Gudjónsdóttir is the new Project Manager, mainly responsible for the 6 month training. Ms. Thórhildur Ísberg joined UNU-GTP in 2006 and is now serving in the capacity of School Manager, while Ms. Málfrídur Ómarsdóttir, Environmental Specialist and Editor, joined UNU-GTP in 2012, and Mr. Markús A.G. Wilde, Service Manager, joined part-time in 2008, but has been working as permanent full-time employee since 2012.

UNU-GTP is academically governed by a Studies Board, which is composed of experts (from ÍSOR, UI and RU) responsible for each of the specialized study lines. The UNU-GTP Director is the chairman of the Studies Board. In 2014, other members of the Studies Board are Dr. Hjalti Franzson (Borehole Geology), Dr. Thráinn Fridriksson (Chemistry of Thermal Fluids), Ms. Saeunn Halldórdóttir (Reservoir Engineering), Dr. Björn Hardarson (Geological Exploration), Mr. Gylfi Páll Hersir (Geophysical Exploration), Mr. Benedikt Steingrímsson (Borehole Geophysics), Mr. Sverrir Thórhallsson (Drilling Technology), all from ÍSOR; Professor Brynhildur Davídsdóttir (Environmental Sciences) from UI and Dr. Páll Valdimarsson (Geothermal Utilization) from RU and Atlas Copco. The studies board is scheduled to meet every three months and serves an important role in setting the academic standards for the training. The devotion of the individuals of the Studies Board to UNU-GTP through the years is greatly appreciated.

3. THE SPECIALIZED TRAINING IN ICELAND

3.1 The 6 month Training Given in Recent Years

The approximate time schedule of the six month specialized courses is presented in Table 1. All participants attend the introductory lecture course (6 weeks, usually with 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 course. The introductory course is followed by lectures and practical training in the respective specialized fields (6 weeks), in some cases with a test at the end. The most important part is though the execution of an individual research project with supervision from an expert in the field (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 (2 weeks). Seminars are held and case histories studied on each field. Training starts in late April and ends in October each year.

Table 1: Detailed time schedule and content of the 6 month training in Iceland.

WEEK	Geological Exploration	Borehole Geology	Geophysical Exploration	Borehole Geophysics	Reservoir Engineering	Chemistry of Thermal Fluids	Environmental Science	Geothermal Utilization	Drilling Technology
1	Introductory Lecture Course Main aspects of geothermal energy exploration and utilization Practicals and short field excursions								
2									
3									
4									
5									
6									
7	Field geology Lithological, tectonic & hydrothermal mapping Temperature surveying	Sample preparation Cutting analysis Petrography Lithological & alteration logs	Thermal methods Magnetics - Gravity Seismic methods Resistivity of rocks Resisitivity methods: DC, TEM & MT	Well logging & testing - theory & practises Logging and testing demonstrations Reservoir physics & well/reservoir modelling Monitoring response to exploitation		Sampling of fluid & gas Wet steam wells Analytical methods Thermodynamics Data processing and interpretation	EIA project planning Chemistry - Physics Biology - Monitoring Revegetation - Safety	Thermal design of power plants & source systems - Direct use of geothermal heat Scientific modelling of utilization systems	Drilling equipment & procedures Well design Rig operations - Safety Management Cementing
8									
9									
10									
11	Excursion to some of the main geothermal fields of Iceland, geothermal power plants and direct use facilities								
12									
13	Gradient wells Remote sensing - GIS	XRD - Fluid inclusions Logging software	Processing & modelling resistivity data - GPS	Resource management & reinjection Data processing & software applications		Water-rock interaction Corrosion & scaling	Gas dispersion & abatement Corrosion & scaling	Power plant components Control systems Corrosion & scaling	Completion - Testing Problems Drilling software
14									
15	Project and report writing								
26									

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 have been offered (Table 1). Each participant is meant to follow only one line of training, but within each line there is some flexibility. A detailed description can be found on the UNU-GTP web page (*www.unugtp.is*). Lines of specialized training have been the following:

- **Geological Exploration** giving 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.
- **Borehole Geology** gives training in geological logging, and 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 interpretation of the data. The emphasis is on resistivity measurements, but insight also given into thermal, magnetic, gravity and seismic methods. Participants should have a degree in geophysics, physics, mathematics 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, including reservoir physics, well and reservoir modelling, resource assessment and monitoring responses. Participants should have a degree in engineering, physics, geophysics, mathematics or hydrogeology.
- **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, thermodynamics, water-rock interaction and the interpretation of results. Participants should have a degree in chemistry, geochemistry or chemical engineering.
- **Environmental Science** covers 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, mitigation measures, and occupational safety considered. Participants should have a degree in science or engineering. The environmental line was added in 1997.
- **Geothermal Utilization** deals with thermal design of power plants and systems, power plant components, control systems, and corrosion and scaling. Direct utilization is also given due scope with scientific modelling of utilization systems. 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 programmes, cementing techniques, cleaning and repairs of production wells. Participants should have a degree in mechanical engineering.

A significant part of the practical training is done in connection with the research projects of the Fellows. The project topic is always selected with respect to the conditions of the home country of the participant. Whenever possible, the participants bring with them data from geothermal projects in their home countries to use as a basis for the project. In 2013, 25 of the 34 projects dealt, at least partially, with geothermal areas in the home countries of the Fellows. All project reports are published by UNU-GTP. Since 1994, the reports have been published in the annual book *Geothermal training in Iceland* (edited by Lúdvík S. Georgsson, international publishing code ISBN 978-9979-68). Copies can be obtained upon request. The books have been mailed to former UNU Fellows, universities and leading geothermal research institutions in over 50 countries. All research reports from 1979-2013 are also available open-file at the UNU-GTP website.

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 UNU Fellows. The UNU Visiting Lecturers have usually stayed 1-2 weeks in Reykjavik. Table 2 lists the UNU Visiting Lecturers during the 2000s. Many of the lectures of the UNU Visiting Lecturers have been published and are available on request in printed format, or open-file at the UNU-GTP website (*www.unugtp.is*) under *Publications*.

Table 2: UNU Guest Lecturers 2000-2014.

2000	Trevor Hunt	New Zealand	2008	Wang Kun *UNU Fellow 1998*	China
2001	Hilel Legman	Israel	2009	Wilfred Elders	USA
2002	Karsten Pruess	USA	2010	Roland N. Horne	USA
2003	Beata Kepinska *UNU Fellow 1994*	Poland	2011	Ernst Huenges	Germany
2004	Peter Seibt	Germany	2012	Cornel O. Ofwona *UNU Fellow 1996*	Kenya
2005	Martin Mwangi *UNU Fellow 1982*	Kenya	2013	Kevin Brown	New Zealand
2006	Hagen Hole	New Zealand	2014	Malcolm Grant	New Zealand
2007	José Antonio Rodriguez	El Salvador			

Table 3 lists the countries of origin of the participants who have completed six month training during 1979-2014, and the specialized courses they have attended. The largest groups of Fellows have come from Kenya (100), China (83), El Salvador (38), Philippines (36), Ethiopia (34), Indonesia (29) and Iran (22). Eight other countries have sent 10-20 participants. Kenya overtook China as the leading recipient country in 2013. Regular contact has been held with former UNU Fellows by sending them the UNU-GTP yearbook and an informal annual newsletter. The majority of the Fellows keep in contact with UNU-GTP and each other through e-mail correspondence, or through Facebook or other internet platforms. Figure 1 shows the annual number of UNU Fellows in Iceland completing the 6 month training in Iceland and studying for MSc and PhD during 1979-2014. The 2013 group of 34 UNU Fellows in Iceland is the largest to date (Figure 2). In 2012-2013, a breakthrough was also reached in that through courses and advanced training, sponsored by the customer, UNU-GTP was for the first time able to give a similar training to the 6 month training in a partner country, with 5 borehole geologists from KenGen being trained on site in Kenya. Consequently, they were given a similar status to the 6 month UNU Fellows in Iceland, meaning that in all 39 trainees completed this kind of training in 2013.

Table 3: Fellows of UNU Geothermal Training Programme 1979-2014.

Country	Geological exploration	Borehole geology	Geophysical exploration	Borehole geophysics	Reservoir engineering	Chemistry of therm.	Environmen. studies	Geothermal utilization	Drilling technology	Total
Albania								2		**2**
Algeria	1		1			1		1		**4**
Azerbaijan							1			**1**
Bangladesh	1		1		2	1				**5**
Bolivia						1				**1**
Bulgaria				1	2	2				**5**
Burundi	1							1		**2**
China		3	1	2	34	15	10	16	2	**83**
Comoros			1							**1**
Costa Rica	2	2	3		2	3	2	4		**18**
Djibouti		3			3	1		2	2	**11**
Dominica						1				**1**
Ecuador					1					**1**
Egypt		1		1	1	1				**4**
El Salvador	1	2	2	2	5	8	4	10	4	**38**
Eritrea	2		2		1	2				**7**
Ethiopia		4	6	1	6	5	1	8	3	**34**
Georgia								1		**1**
Greece			1					2		**3**
Guatemala		1			1	1				**3**
Honduras		1	1					1		**3**
India								2		**2**
Indonesia		5	3	2	6	1	3	8	1	**29**
Iran	1	3	1	1	2	2	4	7	1	**22**
Jordan	1			1	1	2		1		**6**
Kenya	1	21	16	1	12	15	10	8	16	**100**
Latvia								1		**1**
Lithuania					1			1		**2**
Macedonia						1				**1**
Malawi	1							1		**2**
Mexico	1		1	1	4			1		**8**
Mongolia	1		1		1	2		5	1	**11**
Morocco			1							**1**
Nepal						1		1		**2**
Nicaragua		1			5	5	2			**13**
Pakistan	1	1			1	1				**4**
Papua N.G.	1	1	1				1			**4**
Philippines		4	6	6	11	6		3		**36**
Poland		1		1	5	1		6		**14**
Portugal					1				1	**2**
Romania						1		4		**5**
Russia	1				2	5	1			**9**
Rwanda	1	1	2		2	1	2	2		**11**
Serbia				1	1	1				**3**
Slovakia				1	1					**2**
Sri Lanka	1		1		1					**3**
St.Kitts & Nevis					1			1		**2**
St.Vinc. & Gre.					1					**1**
Sudan								1		**1**
Tanzania	3	2	1		1	1	1			**9**
Thailand		1		2		1		1		**5**
Tunisia					1			5		**6**
Turkey		1			1	4	1	3		**10**
Uganda	4	2	3		1	5	1			**16**
Ukraine					2					**2**
Vietnam	1		1		1	1			1	**5**
Yemen	2	1				1				**4**
Zambia								1		**1**
Total	**29**	**62**	**57**	**24**	**124**	**100**	**44**	**111**	**32**	**583**

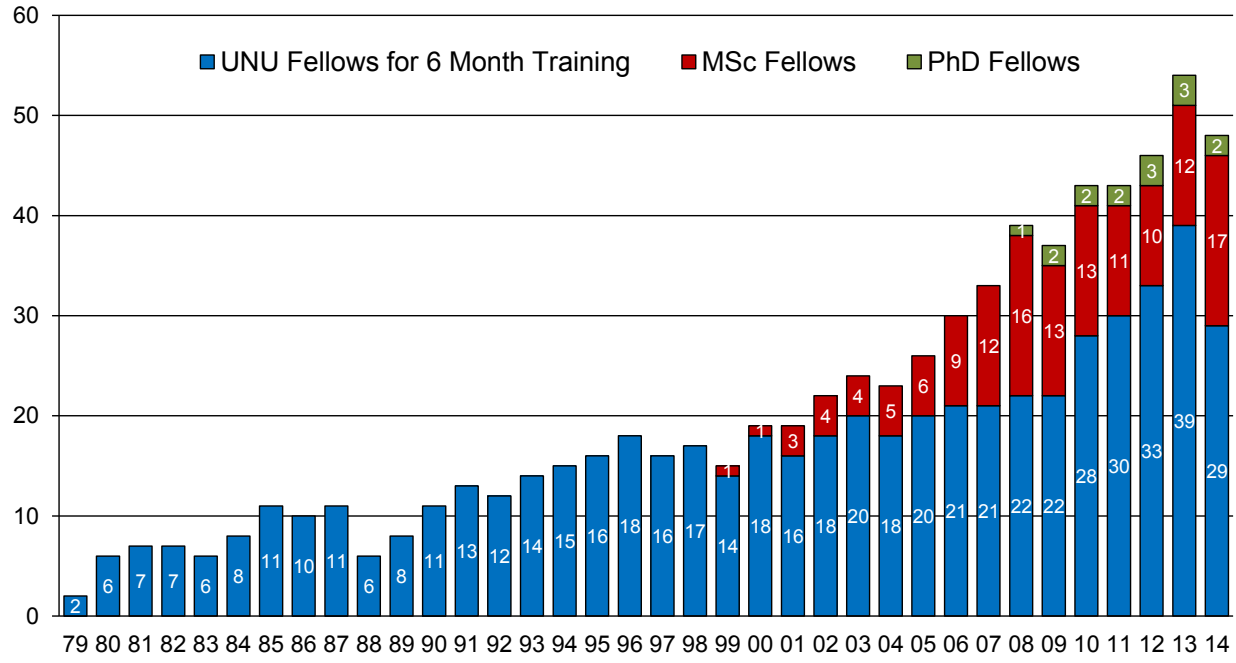

Figure 1: UNU Fellows completing the 6 month training and studying for MSc and PhD in Iceland in 1979-2014.

Figure 2: The 2013 group of UNU Fellows in Iceland – the largest group to date with 34 participants.

From Table 3, it can be seen that the leading recipient countries (Kenya, China, El Salvador, Philippines and Ethiopia) have sent professionals for specialized training in most of the courses offered. Relatively few experts have though been trained in Geological Exploration, Drilling Technology and Borehole Geophysics. The former two subjects are usually mastered in the home countries. However, a significant increase has been experienced in the need for training drilling engineers in the last 2-3 years, associated with the increased drilling efforts in some of the partner countries, especially Kenya.

3.2 Selection of UNU Fellows and Site Visits

Candidates for participation in the 6 month training in Iceland must have a university degree in science or engineering and speak English fluently. Furthermore, they should have a minimum of one year‘s practical experience in geothermal work, be less than 40 years of age, and have a permanent position dealing with geothermal energy at a non-private energy company/utility, research institution, or university in their home country.

Much care is taken in selecting the participants. The traditional selection procedure is through site visits, which are conducted by representatives of 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 relevant to promote geothermal development in the respective country. All qualified candidates are interviewed personally by an UNU-GTP staff member or its representative.

The site visits have played a very significant part in the work and the success of UNU-GTP. Since 1979, a total of more than 200 site visits have been conducted to countries requesting training, or an average of almost 6 site visits per year. Most of the visits have been made by permanent staff members of UNU-GTP (75%), but others by members of the Studies Board and other geothermal specialists mostly from ÍSOR/Orkustofnun. The Director or the Deputy-Director of UNU-GTP normally undertake the first site visit to a given country. In addition to visiting geothermal fields, research institutions, and interviewing candidates, UNU-GTP representatives sometimes participate in local or national/regional geothermal energy conferences/seminars. Indeed, many site visits have been planned to coincide with regional conferences and seminars. In other cases, members of the Studies Board or other specialists, contracted by UNU-GTP, spend a few extra days in a given country to make site visits for UNU-GTP when they are travelling to conferences or on consultancy missions. In this way, the travel costs can be shared. In connection with the site visits, meetings are held with UNU-GTP alumni in each country/region as practicable to learn about their status and progress at work.

In recent years, the Millennium Short Course Series in East Africa and Central America (see Section 5) have also served as venues for selection of candidates for the more advanced training in Iceland. The courses enable the participants to show their ability and strength and thus they may get an opportunity for an interview, which consequently opens for the possibility to be selected for the training in Iceland. Thus, the Millennium Short Course Series have reduced considerably the need for conventional site visits to developing countries. In a few cases, computer telephone interviews have also been used. More than 50% of the UNU Fellows in Iceland in 2013 and 2014 were interviewed through the Short Course Series.

The interviews are very valuable for the quality of the candidates selected for training in Iceland. A good indicator of this is that during the 36 years of the 6 month training in Iceland, only eight invited UNU Fellows have not been able to complete the six months of training, and these exception have in most cases been due to medical reasons. This can be compared to the 583 individuals having completed the 6 month training. Site 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 sharing and transfer of specialized knowledge from Iceland to the developing countries.

Participants from developing countries normally receive Fellowships financed by the Government of Iceland that cover international travel, tuition fees and per diem in Iceland. In earlier years UNU also contributed to this. In recent years the need for training has grown beyond what UNU-GTP has been able to service through its regular finances. Due to that about a third of the Fellowships in 2010-2014 have been funded by partner countries/institutions of UNU-GTP, either directly or through international or bilateral agencies, such as the International Atomic Energy Agency (IAEA) and Icelandic International Development Agency (ICEIDA). Qualified participants from EU countries, who have also been accepted in exceptional cases, from Greece and Portugal, have been financed through special funding from the European Free Trade Association (EFTA).

3.3 Evaluation

The aim of UNU-GTP is to concentrate its training efforts to assist in building up groups of specialists in selected developing countries with significant geothermal potential. Priority for training is given to candidates from carefully selected geothermal institutions in developing countries where geothermal exploration and development is already under way. The number of UNU Fellows has gradually increased (Figure 1), mainly controlled by available financing from the Government of Iceland, which in recent years has on-average been sufficient to cover the costs of about 20 UNU Fellowships annually, with perhaps 1-2 additional UNU Fellowships funded through other financial mechanisms. The significant change seen in this in 2010-2014, with an increased number of UNU Fellowships funded through other financial mechanisms, allowing the number of available UNU Fellowships to grow beyond 30 on average for this period, is something we foresee to continue. It is also a clear recognition of the quality of the training offered at UNU-GTP, when countries like Kenya and the Philippines are ready to find ways to finance UNU Fellowships in Iceland.

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 UNU-GTP. Internal assessments of the training have, 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, 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 the staff of Orkustofnun and ÍSOR, arrangements of accommodation, daily allowance, etc.

At the International Geothermal Conference partly held to celebrate the 25th anniversary of UNU-GTP in 2003, former UNU Fellows presented papers on the contribution of UNU-GTP training to geothermal development. Similar papers were given at the UNU-GTP's 30th Anniversary Workshop in August 2008, on Africa (Mwangi, 2008), Central America (Barrios, 2008), Central and Eastern Europe (Malolepszy, 2008), China (Liu, 2008) and Indonesia (Karim, 2008). The papers give valuable assessments on UNU-GTP from the point of view of the respective regions.

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 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. Our records indicate that about 80% of all our trainees have continued working in the geothermal sector for five years or more, and for most of them working in geothermal or at least in renewable energy development becomes the career of their lives. 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.

3.4 Future organization of the study lines

It is clear, that the training which UNU-GTP has offered in Iceland for the last 36 years has been successful. However, with new emphasises and demands of geothermal projects in the developing countries, some revision of the study lines in the 6 month training is needed. There is ongoing work on revising the study lines and the study structure. More emphasis may be given to group work and on interdisciplinary work among the Fellows during their 6 months studies and more emphasis will be put on project management and financing of projects. This should meet the needs of some countries, where geothermal projects are becoming larger and more complicated and hence stronger knowledge in project management and financial planning is needed. The emphasis on the current study lines of geothermal science and engineering will, however, remain high since these disciplines form the basis of every geothermal project in the world.

The revised structure of the 6 month training is expected to be ready for implementation in 2015.

4. THE MASTERS AND DOCTORAL PROGRAMMES

The aim of establishing an MSc programme in cooperation with the University of Iceland was to go one step further in assisting our partner countries to strengthen their specialist groups and increase their geothermal research capacity, through admittance and support for postgraduate academic studies. The six months training at UNU-GTP fulfils 25% of the MSc programme credit requirements (30 of 120 ECTS). Since 2001, 40 former UNU Fellows have completed (in late 2014) an MSc degree in geothermal science and engineering through the UNU-GTP MSc programme, in cooperation with the UI. The MSc graduates come from China 2, Costa Rica 1, Djibouti 1, El Salvador 5, Eritrea 2, Ethiopia 2, Indonesia 4, Iran 3, Jordan 1, Kenya 13, Mongolia 1, Nicaragua 1, Philippines 2, Rwanda 1, and Uganda 1. All of the MSc Fellows have received UNU-GTP Fellowships funded by the Government of Iceland. In late 2014, 12 additional former UNU Fellows are pursuing their ongoing MSc studies in Iceland. Included here is the first former UNU Fellow doing his MSc studies at Reykjavik University, through a similar cooperation agreement as with UI. The MSc theses have been published in the UNU-GTP publication series, and can also be obtained from the UNU-GTP webpage (*www.unugtp.is*).

Finally, four former UNU Fellows, all coming from Africa, have now (late 2014) been admitted to PhD studies at the University of Iceland on UNU-GTP Fellowships, with the first ones starting in the academic year 2008-2009. On February 15, 2013 a milestone was reached in the operations of UNU-GTP when Dr. Pacifica F. Achieng Ogola became the first of these to defend her PhD thesis (Ogola, 2013). Coming from Kenya she was in fact the first person from Africa to graduate with a doctoral degree from the UI. Two are pursuing their PhD studies while one will start in 2015, all from Africa.

5. THE UN MILLENNIUM SHORT COURSE SERIES

From 2005, funding has also been secured for additional training efforts, taking the training to the developing countries. This was Iceland's official contribution to the UN Millennium Development Goals, and has been implemented through regular workshops/short courses hosted in selected countries on different continents, in cooperation with local energy institutions/companies (Fridleifsson, 2004; 2010; Georgsson 2010). The first phase has usually been a week-long workshop during which decision makers in energy and environmental matters in the target region have met with the leading local geothermal experts and specially invited international experts. The status of geothermal exploration and development is introduced and the possible role of geothermal energy in the future energy mix of the region discussed. The purpose has been, on one hand, to educate key decision makers in the energy market of the respective region about the possibilities of geothermal energy and increase the awareness of the necessity for more effort in the education of geothermal scientists in the region, and, on the other hand, to strengthen the cooperation between specialists in the different countries of the region. This is followed by specialized Short Courses for earth scientists and engineers on surface exploration, deep exploration, production exploration, drilling etc., in line with the type of geothermal activity and the needs of the respective region. These have been referred to as the "*UN Millennium Short Course Series*". Presently, workshops for decision makers have been held for East Africa (in Kenya 2005), for Central America (in El Salvador 2006) and for Asia (in China in 2008). Specialized Short Courses have since been held annually in Africa and almost annually in Central America. Material presented and written for these events has been published on CDs and is also available on the website of UNU-GTP (*www.unugtp.is*).

5.1 Short Courses in East Africa

The Short Courses in East Africa have certainly proven to be a valuable addition to the capacity building activities of UNU-GTP in Africa. They have now become well established as a good initial training opportunity for young East-African geoscientists and engineers engaged in geothermal work. The participants are given a solid introduction to state-of-the-art techniques used in the exploration for geothermal resources and the possible development of this valuable renewable energy source. In total, 492 Africans (plus Yemeni) have participated in these events during 2005-2014. During the same period 128 UNU Fellows from the region have been trained in Iceland. It is clear that with the Short Courses UNU-GTP has been able to reach a far larger number of geoscientists and engineers in East Africa than through its conventional training in Iceland, and, thus, it has been possible to spread geothermal knowledge to a wider region and audience, and contribute to potential geothermal development in new countries. The Short Courses have also been an important element in catalysing increased cooperation between the countries in East Africa. In that case Kenyans have, to a large extent, been in the role of the donor, while countries like Rwanda, Comoros, Zambia and most recently

Sudan have utilized Kenya's knowledge and contracted Kenyan experts for local exploration projects. Similarly, geothermal exploration projects financed by the ICEIDA, e.g. in Djibouti and Eritrea, have been carried out partly with a multinational group including qualified experts from the neighbouring countries who have been trained by UNU-GTP earlier in their career.

5.2 Short Courses in El Salvador

The Short Courses in El Salvador have brought new and important components to geothermal development in Central America. They have not only increased the available training capacity for the region, but also furthered cooperation between the countries in geothermal development. The geothermal development in Central America has gone further than in East Africa, which means that the future need in capacity building is more varied. In the last 3-4 years the target area also has expanded to the whole of Latin America and the Caribbean. A total of 370 individuals has participated in these events by 2014. A continued need is foreseen for alternating Short Courses covering a range of topics from surface exploration to development, field management, production monitoring, environmental aspects, drilling, utilization and more, as the events so far give a good indication of. As participation can be expected to cover a wider geographical area than in the early years of the series, reaching countries where geothermal resources have not been developed to the same extent as in Central America and Mexico, the focus may shift somewhat towards a greater emphasis on exploration. Many of the small nations of the Eastern Caribbean region have substantial geothermal resources to be developed. Participation from this region can be expected to become a significant factor for the Short Courses in the near future. Similarly, participation from South America is also expected to increase, as interest grows in the development of the significant high-temperature resources associated with the Andes Mountain range.

A detailed description of the Workshops / Short Courses of UNU-GTP in Africa, Latin America and Asia is given by Georgsson et al. (2015), and more information can also be found at the UNU-GTP webpage (*www.unugtp.is*).

6. SPONSORED CUSTOMER DESIGNED SHORT COURSES AND TRAINING ACTIVITIES

The latest capacity building service of UNU-GTP is the customer-designed short courses or training offered for partner countries, and opened in 2010. This new service was triggered by the urgent need for training in countries planning fast-tracking of geothermal development, while it has also been an offspring of the regular training, and the Millennium Short Course Series and the material prepared there. This has proven a good opportunity for some countries/institutions in need of a rapid capacity building process, beyond what UNU-GTP can service under its conventional operations, and which have themselves the strength or the support of external sources (e.g. multilateral or bilateral aid agencies) to finance such events. The paying customer defines the outline of the Short Course, while UNU-GTP is responsible for the quality of the contents. In 2010-2014, 20 events, Short Courses or Advanced Training have been held for eight different customers in four continents. The contents have varied from general geoscientific courses to more specialized ones, such as on borehole geology, geothermal drilling, as well as scaling and corrosion in geothermal installations. Similarly, the length has varied from a few days to 6 months, based on the need and goals. For further information see Georgsson et al. (2015).

7. UNU-GTP WEBSITE AND OPEN PUBLICATIONS

Open access publication has always been the motto of UNU-GTP, which is in line with the general policies of the United Nations University, supporting free access of scientific material for developing nations. The reports of the UNU Fellows in Iceland have been distributed free of charge to geothermal institutions worldwide, and the same applies to publications of study material. The annual report book *Geothermal training in Iceland* has also been sent to all active former UNU Fellows, and to geothermal institutions worldwide. With the general internet use, since the early 2000s, the reports have also been published open access in a pdf-version at the UNU-GTP website. More recently, all older reports have also been made available there. The same applies to the UNU-GTP Workshops and Short Courses, and the UNU-GTP Anniversary Publications. Papers written for these events and published in books and/or on CDs, are also all available in open access publication on the website (*www.unugtp.is*).

It is safe to say that with all the material now accessible on the UNU-GTP website, UNU-GTP has created one of the largest open access databases in the world on geothermal exploration, development and utilization. This is easy to verify by searching for material on geothermal on the internet, through one of the large search machines, as material published by UNU-GTP will inevitably get high view scores. It is therefore interesting to look at some statistics. Table 4 shows the most viewed publications in 2013 and the number of views. The Millennium Short Course Series are obviously attracting much attention as papers presented there are in 5 of the 8 top seats. The number of views can also be considered very high for such specialized literature.

Table 4: Most viewed online publications of UNU-GTP for the year 2013.

No.	No. views	Title and author of publication	Publication year and type/event
1	901,795	*Piping design: the fundamentals*, by José Luis Henriquez and Luis Aguirre	2011 – El Salvador Sh. Course
2	128,734	*Gravity and magnetic methods*, by José Rivas	2009 – El Salvador Sh. Course
3	107,308	*Design and selection of deep well pumps for geothermal wells,* by Udom Kunaruk	1991 - report 8
4	103,622	*East African Rift System – an overview,* by Dr. Kristján Saemundsson	2010 – Kenyan Sh. Course V
5	96,954	*Absorption refrigeration system as an integrated condenser cooling unit in a geothermal power plant*, by Tesha	2009 - MSc thesis - report 1
6	84,286	*Environmental impact assessment, general procedures,* by Pacifica F.A. Ogola	2007 – Kenyan Sh. Course II
7	63,801	*Geothermal power plant cycles and main components*, by Dr. Páll Valdimarsson	2011 – El Salvador Sh. Course
8	50,568	*Petrology and mineral alteration in hydrothermal systems*, by Agnes G. Reyes	2000 - UNU Guest Lecturer 1998 - report 18-1998

Additionally, it is interesting to see the geographical distribution of the UNU-GTP website's visitors. Iceland is at the top, but Figure 3 shows the relative number of visits from other countries in 2013. It must be noted that here it is only possible to see from

which country the visitor is, but not what is being viewed. However, it is clear from Figure 3 that the UNU-GTP website reaches audiences from all over the globe.

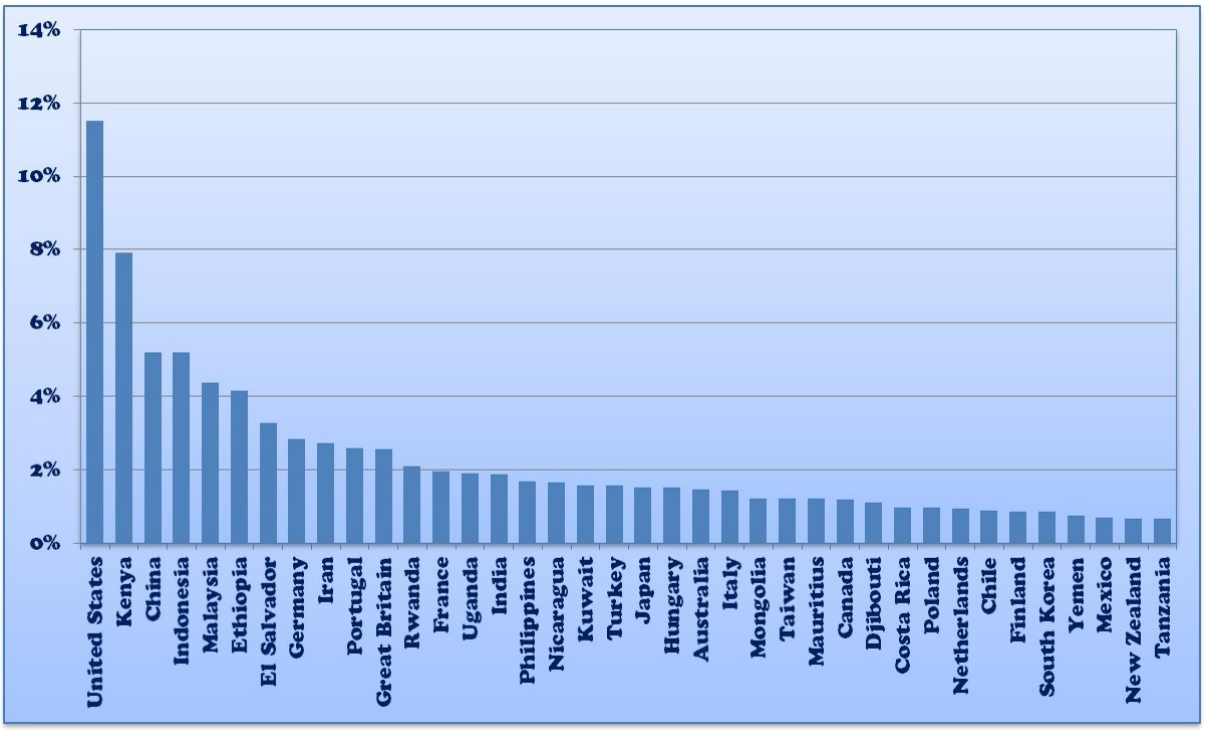

Figure 3: Relative number of visits of the UNU-GTP website in 2013 by country.

8. INTERNATIONAL COOPERATION

According to the "*Agreement on the Status of Association with the UNU*", UNU-GTP has a role 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. Taking some examples, UNU-GTP has contributed actively to the organization of many international meetings with emphasis on the World Geothermal Congresses organized every 5 years by the International Geothermal Association (IGA), in Italy in 1995, in Japan in 2000, in Turkey in 2005 and in Indonesia in 2010. UNU-GTP has assisted in providing funding for fellowships for participation in the congresses for former UNU Fellows who have presented papers at these events.

Former UNU Fellows have also been active with their colleagues in some countries in arranging regional and international conferences/workshops such as the biennial African Rift Geothermal or ARGeo conferences in East Africa, held since 2006. UNU-GTP has been quite active in participation of these regional geothermal events, and in some cases given support for individuals from the developing countries for participation.

UNU-GTP has also been quite active within the International Geothermal Association (IGA), with the former Director serving as IGA President 1995-1998, and the present Director serving on the Board of Directors since 2013. Many former UNU Fellows are also active members in the respective national geothermal associations (e.g. in China, Costa Rica, El Salvador, Ethiopia, Indonesia, Kenya, Philippines, Poland, Romania and Turkey) which are affiliated with the IGA, and five (from China, El Salvador, Ethiopia, Kenya and Poland) are members of the present Board of Directors of IGA (elected in 2013).

Participation of UNU Fellows in the international World Geothermal Congresses has always been important. The event in 2010 in Bali, Indonesia (WGC2010) was certainly a highlight in this regard. With over 2000 participants, UNU-GTP was very well represented. In all, 199 papers (about 20% of all papers) were authored or co-authored by 139 former UNU Fellows from 31 countries, and 114 of these attended the congress (Figure 4), representing more than a quarter of the 424 graduates of UNU-GTP from 1979-2009. Many of these received travel fellowships funded by UNU-GTP in Iceland. Seventy seven former UNU Fellows attended the congress in Turkey in 2005, 61 attended the congress in Japan in 2000 and 35 the congress in Italy in 1995.

UNU-GTP's 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. This 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.

The year 2013 saw UNU-GTP receiving unconventional international recognition. In late 2013, LaGeo in El Salvador awarded the annual Victor de Sola award to UNU-GTP for its large contribution to geothermal development of the country and the region for more than 25 years. Furthermore, UNU-GTP was one of 10 nominees for the Nordic Council´s Environmental Prize in 2013.

Figure 4: At the World Geothermal Congress in Bali, Indonesia in 2010, 114 former UNU Fellows attended. They are seen here with some of the staff and teachers at the UNU-GTP reunion organized in connection to the congress. A special guest of honour was the President of Iceland, Mr. Ólafur Ragnar Grímsson.

9. FINANCING GEOTHERMAL CAPACITY BUILDING

The primary source of funding for UNU-GTP has been from the budget of the Icelandic Government – Ministry for Foreign Affairs (MFA) and is classified as Official Development Assistance (ODA). Prior to 2010, only minor additional funding came from international agencies (e.g. UNDP and IAEA) or bilateral agencies (ICEIDA) financing a few UNU Fellowships through the years, often in connection with geothermal projects. As was to be expected, the contributions from the Government of Iceland in recent years have been influenced by the economic crisis which hit Iceland in 2008. Annual contributions have been in the range 1.6-2.0 M USD – influenced also to some extent by a fluctuating exchange rate of the Icelandic krona (ISK). It must though be stated that the four UNU programmes in Iceland generally have a very strong support from the Icelandic Government, which has identified UNU as a key implementing agency in its development cooperation agenda. The government contribution to the UNU programmes in Iceland is expected to increase again in the medium term with improving financial climate in Iceland.

The last few years have, however, seen quite a big change in the financial spectre of UNU-GTP, which has to some extent counteracted the effect of the financial crisis in Iceland. Foreign funding has come in, not only through the customer designed short courses and training (Section 6 and Georgsson et al., 2015), but also with an increasing number of UNU Fellowships for 6 month training financed by partner countries often with assistance from multilateral or bilateral aid agencies. In total, about 30-40% of the finances of UNU-GTP in 2010-2014 have come from these sources, on average about 1.2 MUSD annually. This has not only been positive for UNU-GTP but also for its partner institutions in Iceland, from which teachers and supervisors have been contracted in difficult times for the geothermal industry in Iceland when local geothermal projects have been scarce.

It is, however, important to underline the importance of the contribution from the Icelandic Government, which is the basis for the conventional operations of UNU-GTP, through which it can meet the requests of partner nations for capacity building in geothermal energy development.

10. LOOKING TO THE FUTURE

For the first 20 years of its operation, the United Nations University Geothermal Training Programme was synonymous with the 6 month specialized training in Iceland. In the last 15 years, however, the operations have evolved and expanded as opportunities for post-graduate studies have become available in Iceland and the training has moved to the developing countries, through workshops, short courses and longer training efforts.

The training which UNU-GTP has offered in Iceland for the last 35 years has been successful. However, with increased development of geothermal energy in the developing countries and larger projects, some revision of the study lines in the 6 month training is needed. There is ongoing work on revising the study lines and the study structure, with more emphasis given to project management and financing of projects. This should meet the needs of some important partner countries. The emphasis on the current study lines of geothermal science and engineering will, however, remain high since these disciplines form the basis of every geothermal project in the world.

A natural next step for UNU-GTP is to support the establishment and operation of permanent geothermal training centres in the developing countries. UNU-GTP has already been called upon for a supporting role in the Regional Geothermal Training Programme at the University of El Salvador and has been approached for the backing of a Geothermal Centre of Excellence in Kenya. In the latter case, it is foreseen that UNU-GTP could be quite involved while the centre is establishing permanence and reputation, but with time the support could be reduced. The long term vision of UNU-GTP has been that regional geothermal centres should be established in key partner countries that have the necessary resources and infrastructure. UNU-GTP is ready to

support such undertakings and may in the future increasingly focus on such centres. The more specialized geothermal training in Iceland is though expected to continue to be the basis of its operations.

Based on the current funding availability, it is foreseen that UNU-GTP will offer about 20 UNU Fellowships for the revised 6 month studies annually, with additional 10-15 financed through other sources. Around 5 MSc Fellowships and 1 PhD Fellowship are expected to be offered annually in the coming years. The UN Millennium Short Course Series will continue to be offered in cooperation with local geothermal entities, possibly also attached to regional geothermal centres in East Africa and El Salvador. The customer-designed short courses and training will be offered with increasing breadth in scope.

With advances in on-line education, it is also possible that the internet will be used to a greater extent in the operations of the programme, e.g. in supporting geothermal training centres in the developing countries. In spite of the large practical and on-hands component of geothermal training, on-line lecturing can play a supporting role to the more conventional teaching methods.

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