Ingvar B. FRIDLEIFSSON
United Nations University
Geothermal Training Programme
Orkustofnun
Grensasvegur 9, Reykjavik, Iceland
e-mail: ibf@os.is

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GEOTHERMAL – PROSPECTIVE ENERGY SOURCE FOR DEVELOPING COUNTRIES

ABSTRACT

Geothermal energy is one of the renewable energy sources, which are collectively important to meet the energy demand in many countries, not least the developing countries. This will improve the standard of living of the poor, and will contribute to the spirit of the UN Millennium Development Goals, i.e. to make clean energy available at affordable prices. Almost 70% of the countries with quantified records of geothermal utilisation are categorised as developing and transitional countries. Some 70% of the world´s population lives at per capita energy consumption level below one-quarter of that of W-Europe, and one sixth of that of the USA. Over two billion people, a third of the world´s population, have no access to modern energy services. World population is expected to double by the end of the twenty-first century. To provide sufficient commercial energy (not to mention clean energy) to the people of all continents is an enormous task. The renewable energy sources are expected to provide 20–40% of the world primary energy in 2050, depending on scenarios. The technology has been developed for the main renewable energy sources, but the experience is mainly confined to the industrialized countries. A key element in the mitigation of climate change is capacity building in renewable energy technologies in the developing countries, where the main growth in energy use is expected. Geothermal already contributes significantly to the electricity production of several countries in Central America, Asia and Africa. The direct use of geothermal can also replace fossil fuels in densely populated areas where space heating and/or cooling is needed. The paper also points out the importance of professional education to create highly skilled manpower to develop renewable energy resources, including geothermal, in many countries and regions

KEY WORDS

Energy demand, energy supply, world population, geothermal energy, 21st century

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INTRODUCTION[1]

At the threshold of 21^{st} century the Millennium Declaration was adopted by the United Nations Millennium Summit (September 2000) – the largest gathering of world leaders in history. The declaration was a basis to define the Millennium Development Goals (MDGs). Most of these goals were set to be achieved by the year 2015 on the basis of the global situation during the 1990s. The MDGs provide countries around the world with a framework for development and time-bound targets by which progress can be measured (United Nations, 2006). In 2002, the World Summit for Sustainable Development (WSSD) held in Johannesburg brought energy and environmental issues to the centre of the global debate.

A key paper on energy and the MDGs is a report entitled *Energy Services for the Millennium Development Goals*, prepared by experts from Columbia University, the Energy Sector Management Assistance Program (ESMAP), the United Nations Development Program (UNDP) and the World Bank (Modi et al. 2006). Energy services include lighting, fuel for cooking and space heating, power for transport, water pumping and grinding, and numerous other services that fuel electricity and make mechanical power possible. The core message of the report is that energy services are essential to both social and economic development and that much wider and greater access to energy services is critical in achieving all of the MDGs.

Even though no MDG refers to energy explicitly, improved energy services – including modern cooking fuels, improved cook stoves, increased sustainable biomass production and expanded access to electricity and mechanical power – are necessary for meeting the goals (Modi et al. 2006). Whether in business, home or community life, what matters is the reliability, affordability and accessibility of the energy services.

1. WORLD ENERGY RESOURCES FOR GROWING POPULATION

Among the top priorities for the majority of the world's population is access to sufficient and affordable energy. There is a very limited equity in energy use in the different parts of the world. Some 70 per cent of the world's population have per capita energy consumption levels that are one-quarter of that of Western Europe and one-sixth of that of the United States. Over 2 billion people, one-third of the world's population, have no access to modern energy services. A key issue in improving the standard of living of the poor is to make clean energy available to them at prices they can cope with. World population is expected to double by the end of the twenty-first century. To provide sufficient commercial energy (not to mention clean energy) to the people of all continents is an enormous task.

Population growth is a central issue in studies of how to meet the energy requirements of the world. The next doubling of the world's population is expected to take much longer

[1] The present paper is partly based on previous papers of the author (summarized in Fridleifsson 2012).

than the last one, which took only 40 years. The population is expected to rise from the present 7 billion to approximately 10.4 billion by 2100, according to the 1996 long-range projection by the International Institute for Applied Systems Analysis (IIASA 1996). Virtually all of the population growth is expected in the South. By 2100, the population of the United States, Canada and the whole of Europe combined will drop to less than 10 per cent of the world total, according to studies by the World Bank, the IIASA and the United Nations.

The scarcity of energy resources forecasted in the 1970s did not occur. With technological and economic development, estimates of the ultimately available energy resource base continue to increase. Economic development over the next century will apparently not be constrained by geological resources. Environmental concerns and financing and technological constraints appear more likely sources of future limits (Fridleifsson 2002).

In all of the WEC's scenarios, the peak of the fossil fuel era has already passed (Nakićenović et al. 1998). Oil and gas are expected to continue to be important sources of energy in all cases, but the role of renewable energy sources and nuclear energy and the level to which these energy sources replace coal vary a great deal in the scenarios. In all of the scenarios, renewables are expected to become very significant contributors to global primary energy consumption, providing 20–40 per cent of primary energy in 2050 and 30–80 per cent in 2100. It is anticipated that renewables will cover a large part of the increase in energy consumption and will replace coal.

It is legitimate to ask whether these scenarios are realistic. Table 1 shows the technical potential – the yearly availability – of renewable energy resources (IPCC 2011). There is no question that the technical potential is sufficiently large to meet future world energy requirements. The question is, however, how large a part of the technical potential can be harnessed in an economically, environmentally and socially acceptable way. This will probably vary between the energy sources. It is worth noting, however, that the present annual consumption of primary energy in the world is about 510 EJ (IEA 2011).

Table 1

Ranges of technical potential of renewable energy sources in the world (source: IPCC 2011)

Tabela 1

Oceny potencjału technicznego odnawialnych źródeł energii na świecie (źródło: IPCC 2011)

Source	EJ per year
Hydropower	50–52
Biomass	50–500
Solar energy	1,575–49,837
Wind energy	85–580
Geothermal energy	128–1421
Total	1,888–52,390

World primary energy consumption in 2009 (IEA 2011) was as follows: fossil fuels provided 81 per cent of the total, with oil (33 per cent) in first place, followed by coal (27 per cent) and natural gas (21 per cent). Renewables collectively provided 13 per cent of the primary energy, mostly in the form of bioenergy (10 per cent) and much less by hydropower (2 per cent) and the "new renewables" (biomass, geothermal, wind, solar and tidal energy) (1 per cent). Nuclear energy provided 6 per cent of the world's primary energy.

If we look only at electricity production, the role of hydropower becomes much more significant. World electricity production was about 20,000 TWh in 1999, compared with 6,000 TWh in 1973 (IEA 2011). Most of the electricity was produced by coal (41 per cent), followed by hydro (16 per cent), nuclear (13 per cent), natural gas (21 per cent) and oil (5 per cent). Only 3 per cent of the electricity was provided by the "new renewables".

Table 2 shows the installed capacity and electricity production in 2009 for renewable energy sources (hydropower, bioenergy, and wind, geothermal and solar energy). The table clearly reflects the variable capacity factors of power stations using renewable sources. The capacity factor of 72 per cent for geothermal is by far the highest. Geothermal energy is independent of weather conditions, in contrast to solar, wind or hydro applications. It has an inherent storage capability and can be used for both base load and peak power plants. The relatively high share of geothermal energy in electricity production in relation to its installed capacity (1.6 per cent of electricity production compared with only 0.9 per cent of the installed capacity) reflects the reliability of geothermal plants, which can be (and are in a few countries) operated at capacity factors in excess of 90 per cent.

It should be stressed that Table 2 is not intended to diminish the importance of wind or solar energy. On the contrary, it serves to demonstrate that renewable energy sources can contribute significantly more to the mitigation of climate change by cooperating than by competing. The table shows that geothermal energy is available day and night, every day of

Table 2

Electricity from renewable energy resources in the world, 2009 (compiled from IPCC 2011)

Tabela 2

Generacja energii elektrycznej z odnawialnych źródeł energii na świecie, 2009 (zestawiono na podstawie IPCC 2011)

Source	Installed capacity		Production per year		Capacity factor
	GWe	%	TWh/year	%	%
Hydropower	926.0	78.9	3 551.0	83.8	44.0
Bioenergy	55.0	4.7	267.0	6.3	55.0
Wind energy	160.0	13.6	325.0	7.7	23.0
Geothermal energy	10.7	0.9	67.2	1.6	72.0
Solar energy	22.0	1.9	26.0	0.6	13.0
Total	1 173.7	100.0	4 236.2	100.0	41.0

the year, and can thus serve as a supplement to energy sources that are available only intermittently. It is most economical for geothermal power stations to serve as a base load throughout the year, but they can also, at a cost, be operated to meet seasonal variations and as peak power.

2. GEOTHERMAL ENERGY APPLICATIONS: STATE-OF-THE-ART AND DEVELOPMENT PROSPECTS

Geothermal resources have been identified in some 90 countries and there are quantified records of geothermal utilization in 79 countries. Electricity is produced by geothermal sources in 24 countries. Nine of these countries obtain 5–26 per cent of their national electricity from geothermal. The worldwide use of geothermal energy was reported in 2010 to be about 67 TWh/year of electricity (Bertani 2010) and 122 TWh/year for direct use (Lund et al. 2010). Figure 1 shows the installed capacity and the energy produced by geothermal on the different continents.

Electricity production increased by 21 per cent between 2005 and 2010, an annual growth rate of 3.8 per cent (Bertani 2010). Direct use increased by 60 per cent between 2004 and 2009, an annual growth rate of 9.9 per cent (Lund et al. 2010). Only a small fraction of the geothermal potential has been developed so far, and there is ample space for an accelerated use of geothermal energy both for direct applications and for electricity generation. Table 3 lists the top 16 countries in the world in geothermal electricity production and in direct use of geothermal energy (in gigawatt hours per year) as reported in 2010.

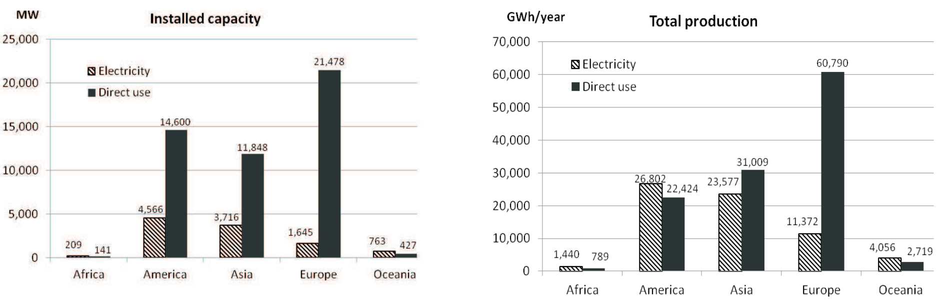

Fig. 1. Installed geothermal capacity and production for electricity generation and direct use, by continent (data from Bertani (2012) and Lund et al. (2011))

Rys. 1. Zainstalowane moce i produkcja geotermalnej energii elektrycznej i ciepła na poszczególnych kontynentach (na podstawie Bertani (2012) i Lund i in. (2011))

Table 3

Top 16 countries using geothermal energy (data on electricity from Bertani (2010) and on direct use from Lund et al. (2010))

Tabela 3

Zestawienie czołowych 16 krajów w zakresie wykorzystania energii geotermalnej (dane dot. energii elektrycznej wg Bertani (2010), zastosowań bezpośrednich wg Lund i in. (2010))

Geothermal electricity production, 2010		Geothermal direct use, 2009	
	GWh/year		GWh/year
United States	16,603	China	20,932
Philippines	10,311	United States	15,710
Indonesia	9,600	Sweden	12,585
Mexico	7,047	Turkey	10,247
Italy	5,520	Japan	7,139
Iceland	4,597	Norway	7,001
New Zealand	4,055	Iceland	6,768
Japan	3,064	France	3,592
Kenya	1,430	Germany	3,546
El Salvador	1,422	Netherlands	2,972
Costa Rica	1,131	Italy	2,762
Turkey	490	Hungary	2,713
Papua New Guinea	450	New Zealand	2,654
Russia	441	Canada	2,465
Nicaragua	310	Finland	2,325
Guatemala	289	Switzerland	2,143

Every year, the World Bank publishes tables of selected world development indicators in the *World Development Report*. Economies (countries) are divided into income groups according to their 2009 gross national income per capita per year. The groups are low-income countries (LIC), with USD 995 or less; lower-middle-income countries (LMC), with USD 996–3,945; upper-middle-income countries (UMC), with USD 3,946–12,195; and high-income countries, with USD 12,196 and above. The high-income countries are further divided into OECD and non-OECD countries. Table 4 shows how many of the 79 countries with quantified records of geothermal utilization fall within each of the World Bank categories. The table also compares the number of countries in each category that are among the top 16 countries using geothermal for electricity production and direct use, respectively. Among the top 16 countries in electricity production with geothermal in 2009, there are 6 LMCs, 5 high-income OECD countries, 4 UMCs and only 1 LIC (Kenya). Among the top 16 countries making direct use of geothermal, there hich production and direct use respectively.umber of countries in each category using geothermal for electricity production andare 14 high-income OECD countries, 1 UMC (Turkey) and 1 LIC (China), which is actually at the top of the list in terms of direct use of geothermal.

Table 4

Number of countries in different economic categories using geothermal for electricity production and direct use, 2010

Tabela 4

Liczba krajów należących do różnych kategorii ekonomicznych, w których stosuje się energię geotermalną do produkcji elektryczności i w sposób bezpośredni, 2010 r.

Economic category[a]	Number of countries	Top 16 countries using geothermal	
		Electricity production	Direct use
High-income OECD countries	29	5	14
High-income none-OECD countries	3	–	–
Upper-middle countries, UMC	22	4	1
Low-middle countries, LMC	21	6	–
Low-income countries, LIC	4	1	1

[a] As defined by the World Bank (2011)

Electricity generation. In the electricity sector, the geographical distribution of suitable geothermal fields is restricted and mainly confined to countries or regions on active plate boundaries or with active volcanoes (see Table 3 above).

Figure 2 shows the top 14 countries with the highest percentage share of geothermal in their national electricity production. Special attention is drawn to the fact that El Salvador, Costa Rica and Nicaragua are among the top seven countries in Figure 2 8, and that Guatemala is in tenth place. Central America is one of the world's richest regions in terms of geothermal resources. Geothermal power stations provide about 12 per cent of the total electricity generation of the four countries Costa Rica, El Salvador, Guatemala and Nicaragua, according to data provided by the countries (CEPAL 2010). The electricity generated in the geothermal fields is in all cases replacing electricity generated by imported oil. Hydro stations provide 46 per cent of electricity for the four countries, and wind energy 2 per cent. With an interconnected grid, it would be relatively easy to provide all the electricity for the four countries by renewable energy (Fridleifsson and Haraldsson 2011).

The geothermal potential for electricity generation in Central America has been estimated at some 4,000 megawatts electrical (MWe) (Lippmann 2002), and less than 500 MWe have been harnessed so far. With the large untapped geothermal resources and the significant experience in geothermal as well as hydro development in the region, Central America may become an international example of how to reduce overall emissions of greenhouse gases in a large region. Similar developments can be foreseen in the East African Rift Valley, as well as in several other countries and regions rich in high-temperature geothermal resources. This clearly demonstrates how significant geothermal energy can be in the electricity production of countries and regions rich in high-temperature fields, which are associated with volcanic activity. There are examples from many developing countries of rural electrification and the provision of safe drinking water, schools and medical centres in connection with the development of geothermal resources. Such projects are in line with the MDGs.

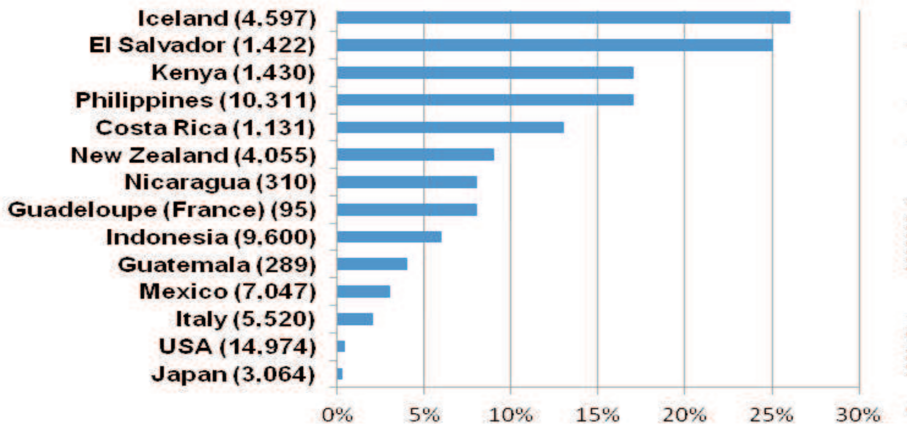

Fig. 2. The 14 countries with the highest percentage share of geothermal energy in their national electricity production. Numbers in parentheses give annual geothermal electricity production in GWh in 2010 (data from Bertani 2010)

Rys. 2. Zestawienie czołowych 14 krajów z największym udziałęm procentowym energii geotermalnej w całkowitej krajowe generacji energii elektrycznej. W nawiasach podano całowitą produkcję elektryczności w poszczególnych krajach (w GWh) w 2010 r. (dane wg Bertani 2010)

Kenya was the first country in Africa to utilize its rich geothermal resources and in the foreseeable future will be able to produce most of its electricity with hydropower and geothermal energy. Geothermal energy is also expected to play an important role in meeting the MDGs in undeveloped parts of eastern Baringo, Kenya, where less than 1 per cent of the population have access to electricity (Ogola et al. 2011a). Ethiopia and several other countries in the East African Rift Valley could follow suit. Indonesia is probably the world's richest country in geothermal resources and could in the future replace a considerable part of its fossil-fuelled electricity by geothermal.

Direct use. The main types of direct use of geothermal energy are: space heating, 63 per cent (of which 49 per cent is accounted for by heat pumps); bathing and swimming (including balneology), 25 per cent; horticulture (greenhouses and soil heating), 5 per cent; industry, 3 per cent; fish farming, 3 per cent; snow melting and other uses, 1 per cent (Lund et al. 2010). The main growth in the direct use sector during the past decade has been in geothermal (ground source) heat pumps (GHPs). This is owing, in part, to the ability of GHPs to utilize groundwater or ground-coupled temperatures anywhere in the world for heating and/or cooling.

In many developing and transitional countries, the main use of geothermal has been for washing and bathing, greenhouses and fish ponds (aquaculture). These activities significantly improve people's quality of life. In addition, tourism is often a significant source of income at geothermal locations.

The largest potential in the direct use sector is space heating and water heating, because these constitute a significant part of the energy budget in large parts of the world. In industrialized countries, 35–40 per cent of total primary energy consumption is used in buildings. In Europe, 30 per cent of energy use is for space and water heating alone, representing 75 per cent of total building energy use (Fridleifsson et al. 2008). The largest potential for direct use of geothermal is in China. Owing to geological conditions, there are widespread low-temperature geothermal resources in most provinces of China, which are already widely used for space heating, balneology, fish farming and greenhouses during the cold winter months and for hot tap water also in the summer.

Until recently, most GHP installations have been in North America and Europe, increasing from 26 countries in 2000, to 33 countries in 2005 and to 43 countries in 2010 (Lund et al. 2010). China is, however, the most significant newcomer in the application of heat pumps for space heating. The government of China has in recent years made significant efforts to save energy and reduce carbon dioxide (CO_2) emissions. In direct use applications in China, geothermal space heating has continued a steady increase of about 10 per cent annually. The annual increase has been 20–23 million m^2 of heating area (with partial cooling). The GHP installed capacity grew from 383 megawatts thermal (MWt) to 5,210 MWt in 2009 (Zheng 2010). GHP systems were installed in many games halls and stadiums for the 2008 Beijing Olympic Games. Renewable energy accounted for about 26 per cent of the total heating and cooling requirements of the Olympic venues in Beijing and served as a good demonstration of the use of these forms of energy. The total geothermal district heating area in China exceeded 30.2 million m^2 in 2010 (Zheng et al. 2010).

China is blessed with low-temperature geothermal resources in most provinces of the country. These have been used through the centuries for bathing, washing, fish farming, horticulture (greenhouses), etc. In the future, these resources will be used on a large scale for space heating as well as space cooling with the application of heat pumps. GHPs driven by fossil-fuelled electricity reduce CO_2 emissions by at least 50 per cent compared with fossil fuel fired boilers (Fridleifsson et al. 2008).

In Kenya, the main commercial application of geothermal energy for direct use is a flower farm near the Olkaria geothermal power station, where some of the greenhouses are heated during the night and thus kept dry by geothermal heat (Simiyu 2010). Some 30,000 people work on flower farms in the region (only a few use geothermal as yet), and it is estimated that tens of thousands of people earn their livelihood from this. The flower companies, which export cut flowers (mainly roses) by air to Europe, provide the staff and their families with good housing, water, electricity, schools and medical centres. Through this, all the MDGs of the United Nations are basically met. The Kenya Flower Council indicates that the flower farming industry employs 500,000 people indirectly through formal and informal industries such as transport, packaging, business suppliers, fertilizers, irrigation engineers, chemicals, consultants and auditors (350,000 indirect jobs are associated with the Lake Naivasha flower industry) throughout the product chain (Kenya Flower Council 2009; Ogola et al. 2012). About 75 per cent of the labour force in horticulture and the flower industries is female.

Another interesting (and unusual) example of the benefits of geothermal development in Africa is in Tunisia, where greenhouses replace cooling towers to cool irrigation water from 2–3 km deep wells in the Sahara desert (Mohamed 2010). Owing to the Earth's thermal gradient, the temperature of the water from the wells is up to 75 degrees Celsius and needs to be cooled to 40 degrees Celsius to be used for irrigation. Some 194 hectares of greenhouses have been built in the oasis. The main products are tomatoes and melons, which are exported to Europe. This has created a lot of jobs for both men and women. Here the geothermal energy development is a by-product of the irrigation project. It is planned to have 315 hectares of greenhouses in 2016.

Geothermal energy costs. Geothermal projects typically have high upfront investment costs because of the need to drill wells and construct power plants, transmission lines (for electricity) and/or insulated pipelines (for district heating systems). But the geothermal projects have relatively low operating costs. Operating costs vary depending on plant capacity, make-up and/or injection well requirements and the chemical composition of the geothermal fluids. Without fuel costs, operating costs for geothermal plants are predictable in comparison with combustion-based power plants, which are subject to market fluctuations in fuel prices (IPCC 2011).

Table 5 shows the levellized cost of renewable energy sources with commercially available technologies for electricity ($UScent_{2005}$/kWh) and direct use (USD_{2005}/GJ). For geothermal energy, the lowest unit prices are commonly obtained with co-generation of electricity and direct use (for example, hot water for space heating, swimming, greenhouses, fish farming, etc.). In such cases, the high-enthalpy steam is used for electricity production and the low-enthalpy water is used for heating and subsequently re-injected into the geothermal reservoir. In such cases very little energy goes to waste.

Table 5

Levellized cost of renewable energy sources with commercially available technologies for electricity and direct use (compiled from IPCC (2011))

Table 5

Zakresy kosztów energii ze źródeł odnawialnych produkowanej z użyciem dostępnych rynkowo technologii dla energii elektrycznej i bezpośredniego wykorzystania (zestawiono na podstawie IPCC (2011))

	Electricity ($UScent_{2005}$/kWh)	Direct use (USD_{2005}/GJ)
Biomass	2–36	1–82
Geothermal	2.5–17.5	7–78
Hydropower	1–15	
Ocean	12.5–32	
Solar	7.5–87	1.5–200
Wind	2.7–23	

3. GEOTHERMAL ENERGY FOR CLIMATE MITIGATION AND CLEAN DEVELOPMENT MECHANISM

One of the major concerns today is the ever-increasing emission of greenhouse gases into the atmosphere and the threat of global warming. It is internationally widely accepted that a continuation of the present way of producing most of our energy by burning fossil fuels will bring significant climate change, global warming, rises in sea level, floods, droughts, deforestation and extreme weather conditions. The sad fact is that the poorest people in the world, who have done nothing to bring about the changes, will suffer most. One of the key solutions to avoid these difficulties is to reduce the use of fossil fuels and increase the sustainable use of renewable energy sources. Geothermal energy, as well as other renewables, can play an important role in this aspect in many parts of the world.

As mentioned previously, it is of interest to compare Table 3 (the top 16 countries utilizing geothermal energy for electricity production and direct use) with Table 4 (the countries in the different economic categories). Among the top 16 countries in electricity production with geothermal in 2009, there are 6 LMCs, 5 high-income OECD countries, 4 UMCs and 1 LIC (Kenya). Electricity production with geothermal is thus relatively evenly spread between countries in the different economic categories. This is in considerable contrast to the list of the top 16 countries making direct use of geothermal, where there are 14 high-income OECD countries, 1 UMC (Turkey) and 1 LMC (China), which is actually at the top of the list of direct use of geothermal.

In the geothermal direct use sector, the potential is very large because space heating and water heating are significant parts of the energy budget in large parts of the world. In industrialized countries, 35–40 per cent of total primary energy consumption is used in buildings. More and more countries are seriously considering how they can use their indigenous renewable energy resources. The decision of the Commission of the European Union to reduce greenhouse gas emissions in the member countries by 20 per cent by 2020 compared with 1990 has resulted in a significant acceleration in the use of renewable energy resources. Most of the EU countries already have some geothermal installations. The same applies to the United States and Canada, where the use of GHPs is widespread for both space heating and cooling. Apart from China, the developing countries have as yet shown very limited interest in the installation of heat pumps for space heating/cooling. With their limited economic resources, climate mitigation through a reduction of CO_2 emissions is not among the top priorities.

Industrialized countries can, however, make significant contributions by assisting developing countries in this field, in the form of both technology transfer and financial support for energy projects. The global response to climate change began with the adoption of the United Nations Framework Convention on Climate Change (UNFCCC) in 1992, which was not legally binding, and subsequently the Kyoto Protocol in 1997, a legally binding instrument. One of the flexible market-based mechanisms introduced was the Clean Development Mechanism (CDM).

The CDM is currently playing a critical role in delivering renewable energy to developing countries, with geothermal energy being one of the contributors to the carbon credit market. The importance of geothermal energy in climate change and MDGs is that it provides energy services from a clean source, it is secure and it is free from fuel price fluctuations, thus increasing the amount of financial resources available for economic development and the attainment of the MDGs. The potential for combining mitigation and adaptation strategies in geothermal projects also has greater co-benefits in emissions reduction and improving coping mechanisms through direct and indirect utilization (Ogola et al., 2011b).

The potential of carbon finance has attracted several geothermal projects to be registered under the CDM. As of January 2012, 12 geothermal projects had been registered and were eligible to receive carbon credit revenues for 7 – 10 years (UNFCCC, 2012). All of these are electricity projects:

El Salvador (two 11.6 and 44 MWe power plants); Guatemala (25.2 MWe power plant); Indonesia (four 63 – 117 MWe power plants); Kenya (two 25 MWe power plants); Nicaragua (66 MWe power plant); Papua New Guinea (55 MWe power plant); Philippines (20 MWe power plant).

Two direct use projects were in 2012 under evaluation for eligibility. Both were geothermal district heating projects, one in China and one in South Korea.

4. PROFESSIONAL EDUCATION – A KEY FOR INCREASED USE OF GEOTHERMAL ENERGY IN DEVELOPING COUNTRIES

A key element in the development of renewable energy sources (geothermal included) as well as in the mitigation of climate change is capacity-building in the developing countries, where the main growth in demand and energy use is expected. An innovative training programme for geothermal energy professionals developed in Iceland is an example of how this can be done effectively (Fridleifsson 2010). The mandate of the United Nations University Geothermal Training Programme (UNU-GTP) is to assist developing countries with significant geothermal potential to establish groups of specialists through six months of specialized training for professionals already employed in geothermal research and/or development. Between 1979 and 2012, 515 scientists/engineers from 53 developing and transitional countries completed the six-month courses. In many countries in Africa, Asia, Central America and Central and Eastern Europe, UNU-GTP Fellows are among the leading geothermal specialists (for details: see Fridleifsson 2013). The UNU-GTP also organizes workshops and short courses on geothermal development (Georgsson, 2010) in Africa (started in 2005), Central America (started in 2006) and Asia (in 2008). This is a contribution of the government of Iceland towards the Millennium Development Goals. The courses and workshops are set up in cooperation with the energy and earth science institutions responsible for the exploration, development and operation of geothermal energy utilities in the respective countries/regions. Part of the objective is to increase cooperation between specialists in neighbouring countries in the field of the sustainable use of geothermal resources. The courses may in the future develop into sustainable regional geothermal training centres. This is well under way in Kenya for the benefit of African countries and in El Salvador for Latin American countries.

One way to measure the overall impact of the accomplishments of UNU Fellows is to look at their participation in the international arena, such as at the World Geothermal Congress (WGC), which is organized every five years by the International Geothermal Association (IGA). The WGC 2010 was held in Bali in Indonesia. There were over 2,000 participants from over 100 countries. Of the 1,034 refereed papers accepted by the Technical Committee and published in the proceedings, 199 papers (19 per cent) were authored or co-authored by 139 former UNU Fellows from 31 developing and transitional countries. The level of activity of the UNU Fellows in the international geothermal community is well reflected in the fact that one-third of the 424 graduates of the UNU-GTP between 1979 and 2009 were authors of refereed papers at the WGC 2010[2]. At the WGC 2005 in Turkey there were over 1,300 participants from 80 countries, and the conference proceedings included 705 refereed papers, 141 of which (20 per cent of all papers) were authored or co-authored by 104 former UNU Fellows (out of 318) from 26 developing and transitional countries.

The key to the success of the UNU-GTP is the selection of the UNU Fellows. Candidates for the specialized training must have a university degree in science or engineering, have a minimum of one year's practical experience in geothermal work, speak English fluently, be under 40 years of age and have a permanent position dealing with geothermal at an energy company/utility/research institution/university in their home country. Site visits are conducted by UNU-GTP representatives to countries requesting training. The potential role of geothermal in the energy plans of the particular country is assessed and an evaluation is made of its 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. All qualified candidates are interviewed personally.

Capacity-building and the transfer of technology are key issues in the sustainable development of renewable energy resources, including geothermal. Many industrialized and developing countries have significant experience in the deployment and operation of renewable energy installations for direct use and/or electricity production. It is important that they open their doors to newcomers in the field. This statement particularly refers to geothermal energy – we need strong international cooperation on the transfer of technology and the financing its development in order to meet the energy demand for growing population and for developing countries (Fridleifsson 2013).

[2] The papers are accessible at <http://www.unugtp.is> (accessed 31 January 2012)

5. CLOSING REMARKS

Renewable energy sources are expected to provide 20–40 per cent of the world's primary energy demand in 2050, depending on the scenario. Geothermal is expected to play an important role in many regions and countries. Nowadays it contributes already significantly to electricity production in several developing countries in Central America, Asia and Africa.

The direct use of geothermal can replace fossil fuels in densely populated areas where space heating and/or cooling is needed. The potential is very large because space heating/cooling and water heating are significant parts of the energy budget in large parts of the world. In industrialized countries, 35–40 per cent of total primary energy consumption is used in buildings. Most of the EU countries already have some geothermal installations. The same applies to the United States and Canada, where the use of GHPs is widespread for both space heating and cooling. Apart from China, the developing countries have as yet shown very limited interest in the installation of heat pumps for space heating/cooling.

The CDM has the potential of playing a critical role in delivering renewable energy to developing countries, with geothermal energy being one of the contributors to the carbon credit market. The potential for combining mitigation and adaptation strategies in geothermal projects also has significant co-benefits in emissions reduction and in improving coping mechanisms through direct and indirect utilization. As of January 2012, 12 geothermal projects to produce electricity had been registered and were eligible to receive carbon credit revenues (UNFCCC, 2012), and two direct use projects were under evaluation for eligibility. Both are geothermal district heating projects, one in China and one in South Korea. This is a good sign for the future.

A key element in renewables' deployment and in the mitigation of climate change is capacity-building in renewable energy technologies in the developing countries, where the main growth in energy use is expected.

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GEOTERMIA – PERSPEKTYWICZNE ŹRÓDŁO ENERGII DLA KRAJÓW ROZWIJAJĄCYCH SIĘ

STRESZCZENIE

Energia geotermalna należy do grupy odnawialnych źródeł energii, które są ważne dla zaspokojenia zapotrzebowania na energię w wielu krajach, zwłaszcza rozwijających się. Upatruje się w tym poprawę warunków życia ubogich, zgodnie z duchem Milenijnych Celów Rozwoju ONZ, m.in. zapewnieniem dostępu do czystej energii po przystępnych cenach. W blisko 70% krajach zaliczanych do rozwijających się lub w okresie przejściowym, w różnym zakresie jest wykorzystywana energia geotermalna. Około 70% ludności świata zużywa na jednego mieszkańca mniej niż jedną czwartą energii zużywanej w zachodniej Europie i mniej niż jedną szóstą zużycia w USA. Ponad dwa miliardy ludzi, czyli jedna trzecia ludności świata, nie mają dostępu do nowoczesnych usług energetycznych. Oczekuje się, że ludność naszego globu podwoi się do końca XXI w. Zapewnienie wystarczającej ilości energii (nie wspominając o czystej energii) mieszkańcom wszystkich kontynentów jest zatem ogromnym zadaniem. Oczekuje się, że w 2050 r. odnawialne źródła energii będą dostarczać 20–40% energii pierwotnej na świecie (w zależności od przyjętych scenariuszy). Technologie ich wykorzystywania zostały już rozwinięte, jednakże doświadczenia w ich stosowaniu ograniczają się głównie do krajów uprzemysłowionych. Kluczowym elementem w łagodzeniu zmian klimatu jest budowanie własnych zespołów specjalistów w zakresie technologii OZE w krajach rozwijających się, gdzie przewidywany jest główny wzrost zużycia energii. W niektórych z tych krajów w Ameryce Środkowej, Azji i Afryce, już obecnie znaczący udział w produkcji energii elektrycznej ma energia geotermalna. Ten rodzaj energii, wykorzystywanej w sposób bezpośredni, może również zastąpić paliwa kopalne w gęsto zaludnionych obszarach, gdzie niezbędne jest ogrzewanie i / lub chłodzenie. W artykule podkreślono także znaczenie profesjonalnej edukacji w przygotowywaniu odpowiednio wykwalifikowanych specjalistów dla rozwoju wykorzystania odnawialnych źródeł energii, w tym energii geotermalnej, w wielu krajach i regionach.

SŁOWA KLUCZOWE

Popyt na energię, dostawa energii, ludność świata, energia geotermalna, XXI wiek