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GEOTHERMAL ENERGY IN THE WORLD AND A GLIMPSE OF CENTRAL AMERICA

Ingvar Birgir Fridleifsson and Ludvik S. Georgsson
United Nations University Geothermal Training Programme
Orkustofnun, Grensasvegi 9, Reykjavik
ICELAND
ibf@os.is lsg@os.is

ABSTRACT

An overview is given of the energy utilization in the world and the operations of the UNU Geothermal Training Programme in Iceland are presented, with emphasis on Central America.

Based on the World Energy Assessment Report update on the status in 2001 (WEA, 2004), the primary energy consumption in the world was assessed as 400 EJ, with about 80% coming from fossil fuels, and only 14% from renewable energy sources. The contribution of the renewables is discussed and their possibilities. The current share of the renewables in the energy production is mainly from biomass and hydro, but in a future envisioned through depleting resources of fossil fuels and environmentally acceptable energy sources, geothermal energy with its large technical potential is expected to play an important role.

Central America is one of the world´s richest regions in geothermal resources. Geothermal power stations provide about 12% of the total electricity generation of the four countries Costa Rica, El Salvador, Guatemala and Nicaragua. The electricity generated in the geothermal fields is in all cases replacing electricity generated by imported oil. Hydro stations provide 48% of the electricity for the four countries, and wind energy 1%. With an interconnected grid, it would be relatively easy to provide all the electricity for the four countries by renewable energy. The geothermal potential for electricity generation in Central America has been estimated some 4,000 MWe, 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 the overall emissions of greenhouse gases in a large region.

1. INTRODUCTION

Geothermal energy is one of the renewable energy sources that can be expected to play an important role in an energy future where the emphasis is no longer on fossil fuels, but on energy resources that are at least semi-renewable and long-term environmentally acceptable, especially with regard to emission of greenhouse gases and other pollutants. For developing countries which are endowed with good geothermal resources, it is a reliable local energy source that can at least to some extent be used to replace energy production based on imported (usually) fossil fuels. The technology is proven and cost-effective. For developing countries that have good resources and have acquired the necessary local expertise it has become very important. A good example of this is Kenya, as well as the Philippines, El Salvador and Costa Rica, where geothermal energy has become one of the important energy sources providing for 10-20% of the electricity production. Iceland should also be mentioned as the only country where geothermal energy supplies more than 60% of the primary energy used. This is done through direct use for space heating, bathing, etc., and through production of electricity.

Geothermal systems can be classified into a few different types, but with reference to variable geological conditions each one is in principle unique, so that good knowledge is needed through exploration. Furthermore, development of a geothermal system for electrical production is a capital intensive undertaking, and thus requires financial strength, or at least access to good financing. Thus, for developing geothermal resources, good training and expertise are needed for the exploration and development work, and strong financial backup for the project.

Here, the role of geothermal energy in the world's energy mix is presented with some emphasis on Central America, and examples are given on its use in Central America and Iceland. But first the United Nations University Geothermal Training Programme is introduced.

2. THE UNU GEOTHERMAL TRAINING PROGRAMME

In late 2009, the United Nations University Geothermal Training Programme (UNU-GTP) completed its 31st session. It has operated in Iceland since 1979 offering six month annual courses for professionals from developing countries. From being one of four geothermal schools established in the 1970s, the UNU-GTP is now the only international graduate school offering specialized geothermal training. The aim is to assist developing countries, with geothermal potential, in capacity building in order to make the countries self sufficient in geothermal development. The trademark is to give university graduates engaged in geothermal work intensive on-the-job training. The training is conducted in English and tailor-made to suit the needs of the home country. UNU Fellows generally receive scholarships financed mainly by the Government of Iceland. Since 2000, cooperation between the UNU-GTP and the University of Iceland (UI) has opened up the possibility for a few UNU Fellows to extend their studies to MSc level, with the six months training adopted as an integral part (30 out of 120 ECTS). In 2008, the cooperation was expanded to include PhD studies, with two former UNU Fellows commencing PhD studies in the academic year 2008-2009.

As a contribution to the *UN Millennium Development Goals* and through the contribution of the Icelandic government, the UNU-GTP has expanded its activities by annual workshops/short courses in Africa (started in Kenya in 2005), Central America (started in El Salvador in 2006), and Asia (started in China in May 2008). The events are organised in cooperation with local energy agencies responsible for geothermal development (Fridleifsson, 2008; Georgsson, 2010 (in press)). A part of the objective is to increase geothermal cooperation inside the region, and to reach out to countries with potential and interest in geothermal development which have not yet received quality training. This has made it possible for the UNU-GTP to reach out to an increasing number of geothermal scientists and engineers.

Central America (including Mexico) has always been a major cooperating partner of the UNU-GTP. Amongst the 424 graduates of the UNU-GTP (1979-2009), 63 (15%) have come from six of these countries. The largest group has come from El Salvador (28), followed by Costa Rica (16) and Nicaragua (8). Former UNU Fellows have been in leading positions in the geothermal research and development in most of these countries. Out of 29 UNU MSc-Fellows participating in the MSc programme, twenty have graduated. Among those graduating this year was the first Salvadorian. Three are currently pursuing their MSc studies in Iceland, coming from El Salvador (2) and Costa Rica (1). Figure 1 shows the group of UNU Fellows attending 6 months training in Iceland in 2009.

For more information on UNU-GTP, see Fridleifsson (2005; 2008), or the web page (*www.unugtp.is*).

FIGURE 1: The group of UNU Fellows who attended the 6 months training in Iceland in 2009, with the Ystihver geyser, N-Iceland in the background just after an eruption

3. THE ROLE OF GEOTHERMAL ENERGY TODAY

Geothermal energy is a resource that has been used by mankind for washing and healing through its history. In the 20th century, geothermal gradually came on-line as an energy source for electricity production and to be used directly, besides bathing and washing, for heating of houses, greenhouse heating, aquaculture etc. According to energy reviews based on surveys for 2004, presented in combination with the World Geothermal Conference 2005, geothermal resources have been identified in some 90 countries while quantified utilization is recorded in 72 countries. Electricity is produced from geothermal energy in 23 countries. In 2004, the worldwide use of geothermal energy was estimated to be about 57 TWh/a of electricity (Bertani, 2005), and direct use 76 TWh/a (Lund et al., 2005).

In the modern world, access to clean energy at affordable prices is a key issue to improve the standard of living. However, at present, two billion people, a third of the world´s population, have no access to modern energy services, and in addition the world population is expected to double by the year 2100. Furthermore, the world energy consumption is expected to double in the new century. So the task in providing clean energy to people in the coming century is enormous (Fridleifsson, 2003).

Today´s energy consumption relies on fossil fuels. Table 1 shows the use of primary energy in 2001 based on the UN World Energy Assessment Report update (WEA, 2004). Fluctuating oil prices and growing environmental concerns will most likely lead to considerable reduction in emissions of greenhouse gasses. Renewable energy sources are expected to play an increasingly bigger role in the 21st century. The technical potential of the renewable energy sources is certainly large enough (WEA, 2004).

TABLE 1: World primary energy consumption (WEA, 2004)

Energy source	Primary energy EJ	%
Fossil fuels	**332**	**79**
Oil	147	35
Natural gas	91	22
Coal	94	22
Renewables	**57**	**14**
Traditional biomass	39	9
Hydro, geothermal, wind, solar, tidal	18	5
Nuclear	**29**	**7**

The use of geothermal energy has increased steadily during the last few decades and has been in the third seat of the renewables in electricity production (after hydro and biomass), but has recently been overtaken by wind energy as number three. Geothermal is thus presently in fourth place.

Table 2 shows the installed capacity and electricity production in 2005 for renewable energy sources, namely hydro, biomass, wind, geothermal, and solar energy (Fridleifsson et al., 2008). The data for the table is compiled from "Tables" in the 2007 Survey of Energy Resources (WEC, 2007). It should be noted that the installed capacity for biomass is not given in the "Tables", but reported as "in excess of 40 GW" in the text. The capacity factor for biomass is thus uncertain. No figures are given for the installed capacity and electricity production of tidal energy in the *2007 Survey of Energy Resources* (WEC, 2007). Tidal energy is therefore absent from Table 2.

The table clearly reflects the variable capacity factors of the power stations using the renewable sources. The capacity factor of 73% for geothermal is by far the highest. Geothermal energy is independent of weather conditions contrary to solar, wind, or hydro applications. It has an inherent storage capability and can be used both for base load and peak power plants. However, in most cases, it is more economical to run the geothermal plants as base load suppliers. The relatively high share of geothermal energy in electricity production compared to the installed capacity (1.8% of the electricity with only 1% 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%.

TABLE 2: Electricity from renewable energy resources in 2005;
compiled from Tables in 2007 Survey of Energy Resources (WEC, 2007)

	Installed capacity		**Production per year**		**Capacity factor**
	GWe	**%**	**TWh/yr**	**%**	**%**
Hydro	778	87.5	2,837	89	42
Biomass	40*	4.5	183	5.7	52*
Wind	59	6.6	106	3.3	21
Geothermal	8.9	1.0	57	1.8	73
Solar	4	0.4	5	0.2	14
Total	**890**	**100**	**3,188**	**100**	**41****

*The installed capacity for Biomass is not given in the WEC 2007 Survey of Energy Resources, but said "in excess of 40 GW" in the text. The capacity factor is thus uncertain.
**Weighted average.

It should be stressed that Table 2 is not published here in order to diminish the importance of wind or solar energy. On the contrary, but it shows that geothermal energy is available day and night every day of the year and can thus serve as a supplement to energy sources which are only available 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. This applies both to electricity production and direct utilisation for heating/cooling.

A comparison of the cost of energy is difficult, because of differences in taxation and subsidies. But a survey in the World Energy Assessment Report update (WEA, 2004) proves that the renewables are definitely competitive. The survey shows the electrical energy cost to be 2-10 UScents/kWh for geothermal and hydro, 4-8 UScents/kWh for wind, 3-12 UScents/kWh for biomass, but higher for solar energy. The investment cost is also assessed to be quite similar for the different energy sources, 1000-3500 USD/kW for hydro, 500-6000 USD/kW for biomass, 800-3000 USD/kW for geothermal and 850-1700 USD/kW for wind.

In 2004, electricity was produced from geothermal energy in 23 countries, increasing by 16% from 1999 to 2004 (Bertani, 2005). Table 3 lists the top fifteen countries producing geothermal electricity in the world in 2004, and those employing direct use of geothermal energy (in GWh/year). The largest geothermal electricity producer is the USA, with almost 18,000 GWh/a, but amounting to only half a percent of their total electricity production. It is different for most of the other countries listed in Table 3, with geothermal playing an important role in their electricity production. That certainly applies to the second country on the list, The Philippines, where the production of more than 9,000 GWh/a means that geothermal supplies 19% of the total produced electricity. The same applies to Kenya, the total production of 1088 GWh/a puts the country in 10th place with regard to world production and constitutes 19% of the total electricity production in Kenya. For direct use (Lund et al., 2005), China heads the list with Sweden having propelled into second place over a few years through rapidly increasing use of ground source heat pumps, followed by the USA, Turkey and Iceland. With direct use of geothermal energy insignificant in Central America, it is not surprising that no Central American country is seen on the list of countries highest in direct use of geothermal energy.

TABLE 3: Top fifteen countries utilising geothermal energy in 2004;
data on electricity from Bertani (2005) and on direct use from Lund et al. (2005)

Geothermal electricity production		**Geothermal direct use**	
	GWh/yr		**GWh/yr**
USA	17,917	China	12,605
Philippines	9,253	Sweden	10,000
Mexico	6,282	USA	8,678
Indonesia	6,085	Turkey	6,900
Italy	5,340	Iceland	6,806
Japan	3,467	Japan	2,862
New Zealand	2,774	Hungary	2,206
Iceland	1,483	Italy	2,098
Costa Rica	1,145	New Zealand	1,968
Kenya	1,088	Brazil	1,840
El Salvador	967	Georgia	1,752
Nicaragua	271	Russia	1,707
Guatemala	212	France	1,443
Turkey	105	Denmark	1,222
Guadeloupe (France)	102	Switzerland	1,175

4. GEOTHERMAL ELECTRICITY IN CENTRAL AMERICA

Central America is one of the world´s richest regions in geothermal resources. Geothermal power stations provide about 12% of the total electricity generation of the four countries Costa Rica, El Salvador, Guatemala and Nicaragua, according to data provided from the countries at the World

Geothermal Congress in 2005 (Bertani, 2005). The electricity generated in the geothermal fields is in all cases replacing electricity generated by imported oil. Hydro stations provide 48% of the electricity for the four countries, and wind energy 1%. With an interconnected grid, it would be relatively easy to provide all the electricity for the four countries by renewable energy. The geothermal potential for electricity generation in Central America has been estimated some 4,000 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 the overall emissions of greenhouse gases in a large region (Fridleifsson, 2007). Similar development can be foreseen in the East African Rift Valley, as well as in several other countries and regions rich in high-temperature geothermal resources.

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. Figure 2 shows the top fourteen countries in the world 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 six top countries in Figure 2, and that Guatemala is in eleventh place.

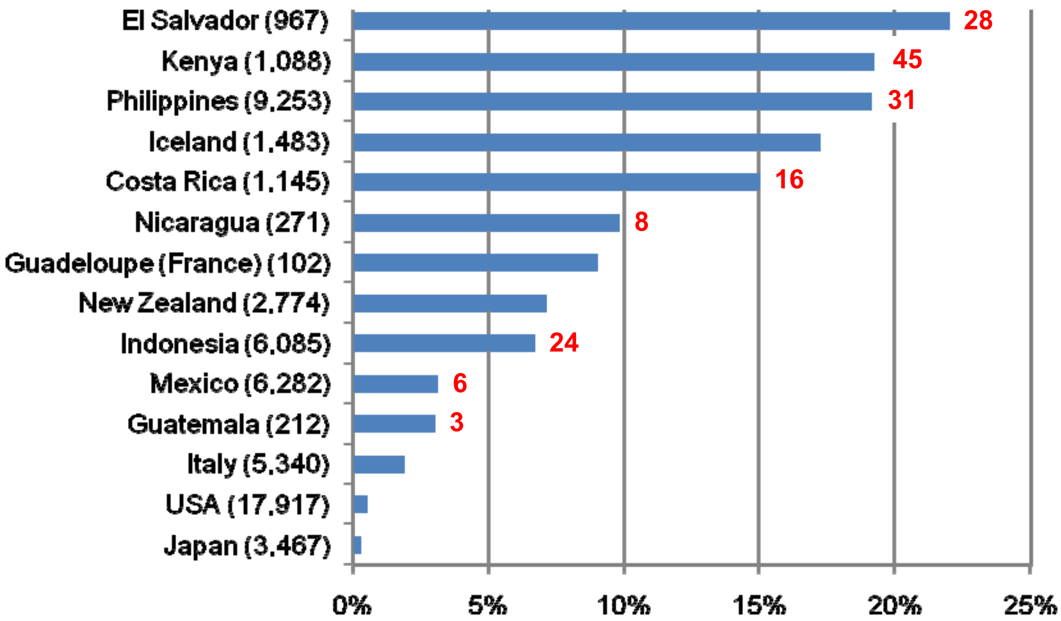

FIGURE 2: The fourteen countries with the highest % share of geothermal energy in their national electricity production (Fridleifsson, 2007). Numbers in parenthesis give the annual geothermal electricity production in GWh in 2004 (Bertani, 2005). The numbers of UNU-GTP graduates from each country are shown in red to the right of the columns

This clearly demonstrates how significant geothermal energy can be in the electricity production of countries and regions associated with volcanic activity and thus rich in high-temperature fields. There are examples from many developing countries of rural electrification and the provision of safe drinking water as well as schools and medical centres in connection with the development of geothermal resources. These projects are in line with the *Millennium Development Goals*.

Geothermal development started early in Central America. The first geothermal power plant was built in El Salvador where the Ahuachapán plant came on line in 1975 with a 30 MWe unit. The Ahuachapán plant has now an installed capacity of 95 MWe, and steam to produce about 85 MWe. The other large geothermal power plant in El Salvador is in the Berlín field (Figure 3), now with an installed capacity of 109 MWe. With the increased capacity of these plants, the geothermal power production in El Salvador has increased from 400 GWh in 1995 to 1,293 GWh in 2007, and the market share from 12 to 25%. Other areas are now being explored for development, such as the San Vicente and Chinameca fields (Henriquez, 2008).

FIGURE 3: The Berlín geothermal power plant (Henriquez, 2008)

The biggest geothermal power plant of Central America is the Miravalles power plant in Costa Rica, with an installed capacity of 163 MWe from 5 units, supplying now about 15% of the needs of the country. It is still the only geothermal power plant in Costa Rica but other geothermal systems are now being developed such as the Las Pailas and Borinquen areas (Yock, 2008). Figure 4 shows a photo of the Miravalles power plant.

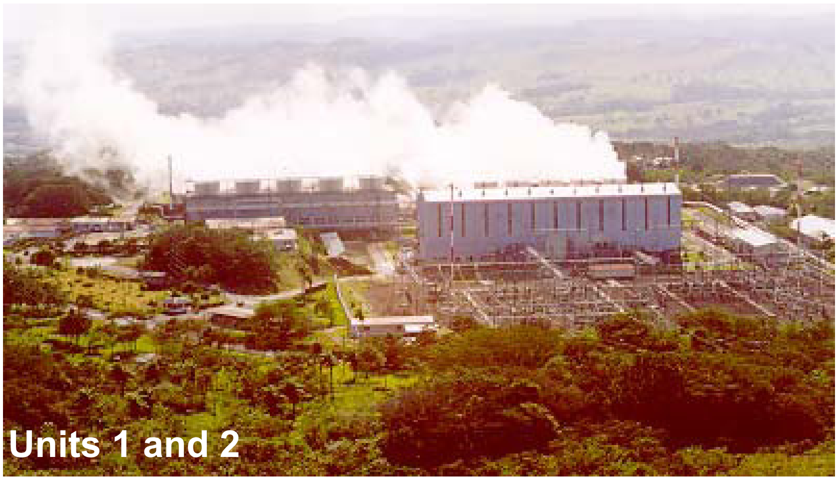

FIGURE 4: The Miravalles geothermal power plant (Vallejos-Ruiz, O., 2006)

The Momotombo geothermal power plant in Nicaragua has also been running for many years, with the first unit coming on line in 1983. The field was overexploited for a long period leading to a drastic decline in the electrical production. After additional drilling and installing of a new 7MWe bottoming unit and implementation of full reinjection by ORMAT, the current operator of the field, the Momotombo geothermal field can now produce 32 MWe of its 77 MWe installed capacity. A smaller plant has recently been installed in San Jacinto, with an installed capacity of 10 MWe. Other explored fields include: El Hoyo, Granada-Masaya-Nandaime, Cosiguina, Casita - San Cristóbal, El Ñajo, Chiletepe-Managua, Masaya-Tipitapa and Ometepe (Porras, 2008).

In Guatemala, two geothermal plants have come on line in recent years. The Zunil geothermal power plant (Orzunil) was commissioned in 1999 with 28 MWe installed capacity and the Amatitlan plant in

2007 with 24 MWe. Prefeasibility studies have also been carried out by INDE in the areas of Tecuamburro and Moyuta (Asturias, 2008).

The potential for electrical production from geothermal resources is not as good in Honduras and Panama. However, they have resources that could be utilized to their benefit, though the temperatures are not expected to be as high as in the other countries.

5. EXAMPLES OF USES OF GETHERMAL ENERGY IN ICELAND

Iceland is a unique country with regard to utilization of geothermal energy, with more than 60% of its primary energy consumption from geothermal energy. Direct use plays the most important role here with 89% of houses in the country heated by geothermal energy. Other uses include greenhouses, fish farming, industry, snow melting, swimming pools, etc., but even so only a fraction of the potential is used. Electrical production from geothermal power plants has also been developed rapidly in the last 6 years, amounting to about 25% of the total electrical production at the end of 2008 with an installed capacity of about 573 MWe (Figure 5). Figure 6 shows the Nesjavellir power plant in SW-Iceland.

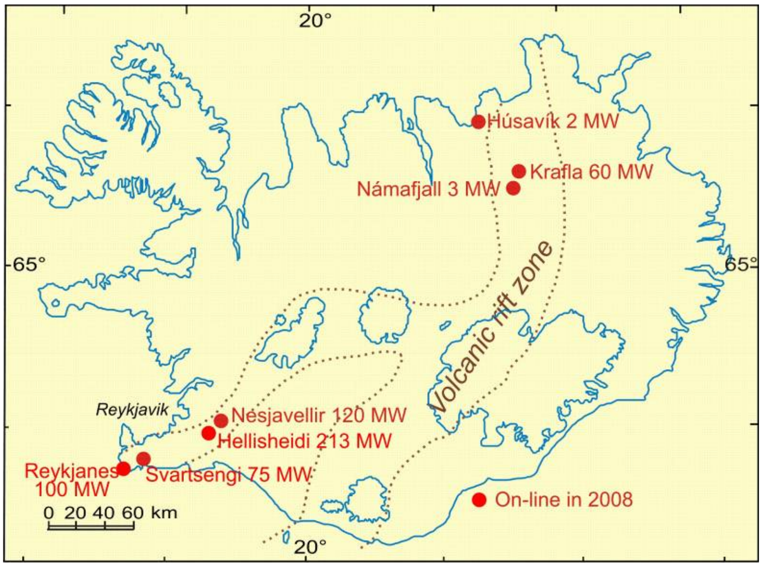

FIGURE 5: Geothermal power plants in Iceland in 2008

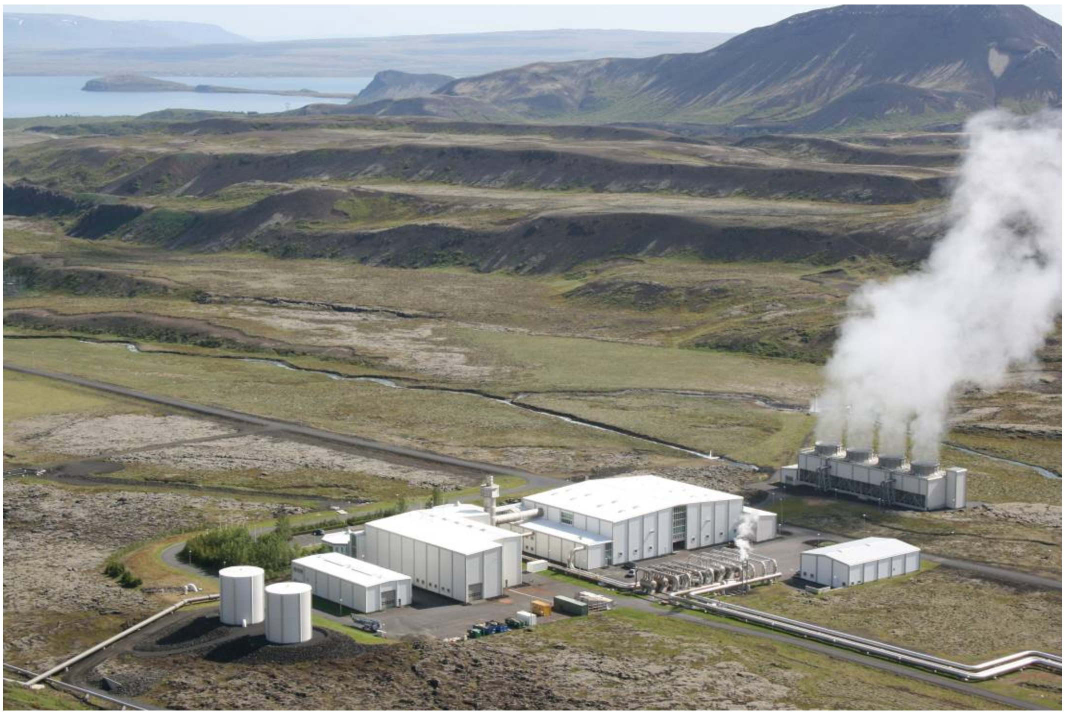

FIGURE 6: The Nesjavellir power plant in SW-Iceland produces now 120 MWe and hot water amounting to 300 MWth; the photo was taken in 2008

It can be said that geothermal energy is a way of life in Iceland. Reykjavik Energy supplies the capital, Reykjavik, and its surroundings, in total close to 200,000 people, with hot water for heating through 12 months of the year, making it the largest municipal heating service in the world. The geothermal swimming pools in Iceland are found in almost every village and small town. The most famous bathing place is, however, the Blue Lagoon (Figure 7), a byproduct of the Svartsengi power plant and located in a hostile lava field, 5-10 km from the nearest towns. It has become a landmark for Iceland and a must for any tourist to visit.

FIGURE 7: UNU Fellows bathing in the Blue Lagoon in 2003

6. DISCUSSION

One of the major concerns of mankind today is the ever increasing emission of greenhouse gases into the atmosphere and the threat of global warming. It is internationally accepted that a continuation of the present way of producing most of our energy by burning fossil fuels will bring on significant climate changes, global warming, rises in sea level, floods, draughts, deforestation, and extreme weather conditions. And the sad fact is that the poorest people in the world, who have done nothing to bring on 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 can play an important role in this aspect in many parts of the world.

More and more countries are seriously considering how they can use their indigenous renewable energy resources. The recent decision of the Commission of the European Union to reduce greenhouse gas emissions by 20% by 2020 compared to 1990 in the member countries implies a significant acceleration in the use of renewable energy resources. Most of the EU countries have already considerable geothermal installations. The same applies to the USA where the use of ground source heat pumps is widespread both for space heating and cooling.

Capacity building and transfer of technology are key issues in the sustainable development of geothermal resources. Many industrialised and developing countries have significant experience in the development and operations of geothermal installations for direct use and/or electricity production. It is important that they open their doors to newcomers in the field. We need strong international cooperation in the transfer of technology and the financing of geothermal development in order to meet the Millennium Development Goals and the threats of global warming.

REFERENCES

Asturias, F., 2008: Geothermal resources and development in Guatemala. *Proceedings of the 30th Anniversary Workshop of UNU-GTP, Reykjavik,* CD, 8 pp, (available on *www.unugtp.is*).

Bertani, R., 2005: World geothermal power generation in the period 2001-2005. *Geothermics, 34,* 651-690.

Fridleifsson, I.B., 2003: Status of geothermal energy amongst the world´s energy sources. *Geothermics, 32*, 379-388.

Fridleifsson, I.B., 2005: Twenty five years of geothermal training in Iceland. *Proceedings of the World Geothermal Congress 2005, Antalya, Turkey,* CD, 10 pp.

Fridleifsson, I.B., 2007: Geothermal energy and the Millennium Development Goals of the United Nations. *Proceedings of the European Geothermal Congress 2007, Unterhaching, Germany,* 30 May – 1 June, 2007.

Fridleifsson, I.B., 2008: Thirty years of geothermal training in Iceland. *Proceedings of the 30th Anniversary Workshop of UNU-GTP, Reykjavik,* CD, 15 pp, (available on *www.unugtp.is*).

Fridleifsson, I.B., Bertani, R., Huenges, E., Lund, J.W., Ragnarsson, A., and Rybach, L., 2008: The possible role and contribution of geothermal energy to the mitigationof climate change. In: Hohmeyer, O., and Trittin, T. (eds.), *IPCC Scoping Meeting on Renewable Energy Sources, Proceedings*. Luebeck, Germany, 20-25 January 2008, 59-80.

Georgsson, L.S., 2010 (in press): UNU Geothermal Training Programme - Taking the training to the developing countries. *Proceedings of the World Geothermal Congress 2010, Bali, Indonesia*, 9 pp.

Henríquez M., J.L, 2008: An update on the geothermal development in El Salvador. *Proceedings of the 30th Anniversary Workshop of UNU-GTP, Reykjavik,* CD, 8 pp, (available on *www.unugtp.is*).

Lippmann, M.J., 2002: Geothermal and the electricity market in Central America. *Geothermal Resources Council, Transactions, 26,* 37-42.

Lund, J.W., Freeston, D.H., and Boyd, T.L., 2005: Direct application of geothermal energy: 2005 worldwide review. *Geothermics, 34*, 691-727.

Porras M., E.A., 2008: Twenty five years of production history at the Momotombo geothermal field, Nicaragua. *Proceedings of the 30th Anniversary Workshop of UNU-GTP, Reykjavik,* CD, 7 pp, (available on *www.unugtp.is*).

Vallejos-Ruiz, O., 2006: Reservoir management and power production in the Miravalles geothermal field, Costa Rica. *Proceedings of the Workshop for Decision Makers on Geothermal Projects in Central America, San Salvador, El Salvador,* UNU-GTP and LaGeo, CD SC-02, 20 pp, (available on *www.unugtp.is*).

WEA, 2004: *World Energy Assessment: overview 2004 update*. Prepared by UNDP, UN-DESA and the World Energy Council**.** United Nations Development Programme, New York, 85 pp.

WEC, 2007: *2007 Survey of energy resources*. World Energy Council 2007, 427-437, (available on *www.worldenergy.org*).

Yock F., A., 2008: Geothermal resources development in Costa Rica. *Proceedings of the 30th Anniversary Workshop of UNU-GTP, Reykjavik,* CD, 8 pp, (available on *www.unugtp.is*).