Presented at Workshop for Decision Makers on Geothermal Projects in Central America, organized by UNU-GTP and LaGeo in San Salvador, El Salvador, 26 November to 2 December 2006.

UNITED NATIONS MILLENNIUM DEVELOPMENT GOALS AND GEOTHERMAL DEVELOPMENT IN CENTRAL AMERICA

Marcelo J. Lippmann
Staff scientist (retired)
Lawrence Berkeley National Laboratory,
Berkeley, CA 94720,
USA

1. INTRODUCTION

In September 2000, the General Assembly of the United Nations adopted the UN Millennium Declaration, whose purpose was to meet the needs of the world's poorest. All the countries and leading development institutions of the world agreed with the blueprint of the Declaration (United Nations, 2005). The eight Millennium Development Goals (MDGs) were to:

1. Eradicate extreme poverty and hunger
2. Achieve universal primary education
3. Promote gender equality and empower women
4. Reduce child mortality
5. Improve maternal health
6. Combat HIV/AIDS, malaria and other diseases
7. Ensure environmental sustainability
8. Develop a global partnership for development

Most of these goals were to be achieved by the year 2015; the baseline for the assessment of progress was set in 1990 for most of the MDG targets. Machinea et al. (2005) present a Latin American (and Caribbean) perspective of the MDGs.

The development of environmentally friendly energy sources, like geothermal energy, and their wider integration into the energy picture of a country or region would contribute both directly and indirectly to reaching the MDG targets.

Access to electricity, especially if generated using clean, renewable energy sources, would improve the lives of many people, particularly of those living in rural areas or in the slums of larger cities. It would reduce the need for burning (in many cases imported) fossil fuels to produce electrical power, and it would avoid the harmful effects associated with combustion, like air pollution and release into the atmosphere of carbon dioxide, the main greenhouse gas responsible for global warming.

Another important aspect to consider, particularly in Central America, is the large amount of wood that is being utilized for cooking. This wood use has led to wide deforestation, which is the main cause of land erosion, agricultural soil losses, mudslides, and larger and more frequent floods. Also, the burning of wood, particularly if the wood is wet or unseasoned and the combustion is incomplete, results in high levels of pollution around the stove and homes. These damaging effects would be avoided if access to electricity would be more widespread.

2. GEOTHERMAL ENERGY

Geothermal energy is literally the heat contained within the earth that generates geological phenomena on a planetary scale. Nowadays, "geothermal energy" is often used to refer to the earth's heat that can, or could, be recovered and exploited by humankind (Dickson and Fanelli, 2003).

Fridleifsoon (2006) discussed the position of geothermal energy among the world's energy sources. According to this author, 72 countries worldwide were utilizing this renewable energy source for electricity generation and/or direct uses (e.g., heating buildings and greenhouses, balneology, aquaculture, industrial applications) in 2005.

Geothermal fluids (steam or hot water) usually contain gases such as carbon dioxide (CO_2), hydrogen sulphide (H_2S), ammonia (NH_3), methane (CH_4), and trace amounts of other gases, as well as dissolved chemicals (e.g., NaCl, B, As and Hg). Potential problems associated with these fluids are avoided by treating the gases being discharged by the power plants and by re-injecting the heat-depleted liquids back into the reservoir (Dickson and Fanelli, 2003). The chemical composition of gases and fluids is highly variable depending on the geological setting of the geothermal fields. According to Fridleifsson (2001), in conventional (not binary) geothermal plants, 13–380 g of CO_2 are released for every kWh of electricity produced, whereas for coal-fired plants the average values are 1042 g/kWh, for oil-fired plants 906 g/kWh, and for natural gas-fired plants 453 g/kWh. Also, we should emphasize that a typical geothermal power plant emits only 1% of the sulfur dioxide (from hydrogen sulfide), less than 1% of the nitrous oxides, and 5% of the carbon dioxide released by a coal-fired plant of equal size. Even binary-cycle geothermal power plants and direct-use installations may cause minor environmental problems, but simply adopting closed-loop systems and preventing gaseous emissions can largely overcome these.

In other words, geothermal is a clean and environmentally friendly source of energy and one that is indigenous (i.e., the "fuel" to be used in the plants does not have to be imported from other countries).

In addition, mainly because of technological advances, geothermal energy has become competitive when utilized in the generation of electricity. According to GEA (2006), an economically competitive geothermal power plant can cost as low as 2800 U.S. dollars per kW installed. (The capital cost for geothermal power plants ranges from 1150 to 3000 dollars per installed kW; REPP, 2003).

While the cost of a new geothermal power plant is higher than that of a comparable natural gas facility (in the U.S., natural gas is the fossil fuel that competes economically with geothermal energy because of its lower emissions), natural gas construction costs account for only one third of the total, with the remaining corresponding to that of the fuel. The initial construction costs of a geothermal facility, in contrast, represent two-thirds or more of total costs. So, while initial investment is higher for geothermal projects, natural gas and geothermal energy are economically comparable over the long term.

Also from GEA (2006), according to most geothermal developers, the cost of new geothermal projects is 5.5–7.5 U.S. cents per kWh. The actual cost depends on the characteristics of the geothermal source (e.g., temperature and chemistry of the fluids, depth and properties of the reservoir), the power technology being used (e.g., flash, binary), tax polices and regulations.

Geothermal energy provides other benefits that offset any marginal increase in price over fossil fuel technologies; these are (taken from the Website of the Geothermal Energy Association; http://www.geo-energy.org/aboutGE/powerPlantCost.asp),

- **Geothermal energy is reliable.** Because geothermal resources are available 24 hours a day regardless of changing weather, geothermal energy is as reliable as any fossil fuel facility.
- **Geothermal energy is renewable**. Geothermal resources are sustainable because of the heat from the earth and water injection, and thus will not diminish like fossil fuel reserves.
- **Geothermal energy produces minimal air emissions.** With geothermal, emissions of nitrous oxide, hydrogen sulfide, sulfur dioxide, particulate matter, and carbon dioxide are extremely low, especially when compared to fossil fuel emissions.
- **Geothermal energy can offset other environmental impacts.** Electricity generation from geothermal resources eliminates the mining, processing, and transporting of fuel required for electricity generation from fossil fuel resources.
- **Geothermal energy is combustion free**. Unlike fossil fuel power plants, no smoke is emitted from geothermal power plants, because no burning takes place: only steam is emitted from geothermal facilities.
- **Geothermal energy conserves precious freshwater resources.** Geothermal plants use 5 gallons (about 19 liters) of fresh water per MWh, while certain types of geothermal plants use no fresh water. This compares with 361 gallons (about 915 liters) per MWh used by coal facilities.
- **Geothermal energy minimally impacts land**. According to the U.S. Department of Energy, geothermal energy uses less land than other energy sources.
- **Geothermal energy is competitive with other energy technologie**s when environmental costs are considered. A 1995 study estimates that costs of power generation would increase 17 percent for natural gas and 25 percent for coal if environmental costs were included.
- **Geothermal energy serves as a price stabilizer**. Because geothermal has such low fuel costs, and uses a fuel supply that is not transported long distances or reliant on unstable markets, the price of geothermal power remains constant over the life of the plant.

3. CENTRAL AMERICA AND GEOTHERMAL ENERGY

Because of its particular geologic framework, most of Central America is poor in fossil fuels, but is blessed with abundant geothermal resources (Fig. 1). Those of high temperature (>150ºC) can be developed for electrical power generation; the low-temperature resources can be used in direct-heat applications.

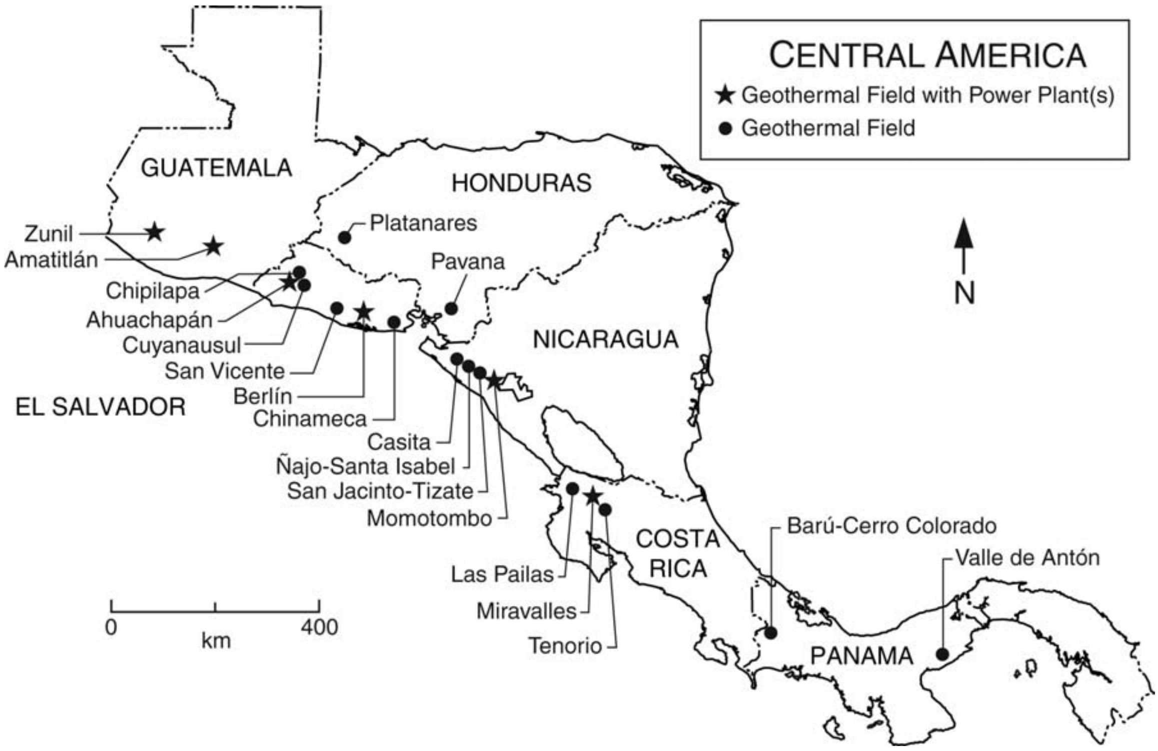

FIGURE. 1. Central America. Location of geothermal fields (from Lippmann, 2002)

Lippmann (2002) estimated that the geothermal electricity-generating capacity for Central America could be in the 2000–16,000 MW range (Table 1). The amount of heat that could be extracted from the low-temperature geothermal areas might be even larger, but no assessment of these resources is available for the region.

In spite of the abundance of geothermal resources in Central America only a relative minor amount has been developed for power generation in the region (Table 2); the total running capacity is 349 MWe. Note that the data in Table 2 is for 2005 or earlier; we expect that updated numbers will be presented in other papers in this document.

TABLE 1. Geothermal Potential for Electricity Generation in Central America
(From Lippmann, 2002)

Country	Geothermal Potential (in MWe)	
	Range mentioned in publications	**Most probable values**
Costa Rica	400-3500	1000
El Salvador	400-4140	500
Guatemala	800-4000	1000
Honduras	25-500	130
Nicaragua	300-4000	1750
Panama	25-200	50
Totals	1950-16,340	4430

TABLE 2. Central America - Geothermal power generation in early 2005
(Data from Table 1 of Bertani, 2005)

Country	Installed capacity (MW_e)	Running capacity (MW_e)	Annual energy produced (GWh/y)(1)	Number of units	Percent of national capacity	Percent of national energy
Costa Rica	163	163 (2)	1145	5	8.4	15
El Salvador	151	119	967	5	14	22
Guatemala	33	29	212	8	1.7	3
Nicaragua	77	38	271	3	11.2	9.8

(1) Data for 2003
(2) No data were available for “running capacity”; it was therefore assumed to be equal to installed capacity. A rough estimate based on the energy produced, with a load factor of 90%, gives approximately 145 MWe

Lippmann (2003) commented that in early 2003, most geothermal activities in the region were focused in sustaining production at existing power plants and that exploration for geothermal resources had decreased significantly because of:

1. Governments were giving investment priority to other sectors of their economies.
2. Oil prices were low (in the 10–20 dollar per barrel range).
3. Private companies preferred investing in more “traditional” electrical generation schemes (like hydropower and fossil-fuel burning power plants).
4. Geothermal projects had difficulty in obtaining long-term loans. Banks and private investors had become less willing to take the risks associated with exploration and development of geothermal areas.
5. Support for geothermal exploration (and development) by local governments and international agencies had diminished.

Since then, most of these conditions have not changed, or only very little. However, governments in the region are showing more interest in developing the renewable energy resources of their countries, including geothermal energy. This change likely results from high oil prices, the instability of the oil market (which could increase national security risks), the uncertainties in future climatic conditions (which could affect the output of hydroelectric projects), and the desire to reduce CO_2 emissions and/or the environmental impact associated with the burning of fossil fuels to generate power.

Several geothermal power plants have come on line in the region, and others are being contemplated, since 2003. However, the level of development is small considering the potential size of the Central American geothermal resources. Very little data are available on the lower temperature geothermal resources of the region. Lund et al. (2005), in their worldwide overview, mention the use of low-enthalpy geothermal fluids to heat a few swimming pools in Costa Rica, as well as in a fruit dehydration plant and concrete block factory in Guatemala. There is no reference to the utilization of geothermal heat for drying coffee beans or other agricultural products.

The direct impact of geothermal development on the economy of a country has not been mentioned here yet. Kagel (2006) studied the socioeconomic aspects of geothermal electrical generation on the U.S. economy; the results of her analysis might also be applicable to Central America. According to this author, geothermal development contributes to the economy not only through employment and taxes, but also by stimulating other sectors. Kagel mentions that geothermal projects provide 10 times more jobs per megawatt than natural gas power plants, and that for every dollar invested in geothermal energy, the resulting growth of output to the economy would be 2.50 dollars. Using the numbers cited in Kagel (2006), geothermal energy would provide 4.0 construction jobs per installed MW, and 1.7 operation and maintenance jobs per MW, whereas a power plant burning natural gas would only generate 1.0 and 0.1 jobs per megawatt, respectively. One should emphasize that these jobs would be mainly in rural, less developed areas, where the overwhelming majority of the population targeted by the MDGs is living.

4. CONCLUSIONS

Development of geothermal resources within Central America would significantly contribute to achieving the Millennium Development Goals. By generating electricity using geothermal fluids (a clean, renewable and indigenous source of energy) and by allowing larger sectors of the population to gain access to electricity, the living conditions of everyone would improve, particularly those of the poorest. The environment in the region would be cleaner (less pollution associated with burning fossil fuels and wood), deforestation would be reduced, more jobs would be created (especially in rural areas), and the countries of Central America would be better protected against future disruptions in the oil market and climatic changes.

Acknowledgments

The author thanks Daniel Hawkes (LBNL) for his useful editorial comments.

REFERENCES

Bertani, B., 2005. World geothermal generation 2001-2005. *Geothermics 34*, 651-690.

Dickson, M.H., Fanelli, M. (editors), 2003. *Geothermal energy: Utilization and technology*. UNESCO publishing, Paris, France, 205 pp.

Fridleifsson, I.B., 2001. Geothermal energy for the benefit of the people. *Renewable and Sustainable Energy Reviews 5*, 299-312.

Fridleifsson, I.B., 2006. *Geothermal energy and its position among the world's energy sources*. Paper presented at the International Energy Conference ENERGEX 2006, 12-15 June 2006, Stavanger, Norway, 9 pp.

GEA, 2006. Geothermal Energy Association Website (http://www.geo-energy.org).

Kagel, A., 2006. Socioeconomics and geothermal energy. *Geothermal Resources Council Trans. 30*, 1045-1051.

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

Lippmann, M.J., 2003. Time is of the essence. *Geothermal Resources Council Bulletin 32*, 38-43.

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

Machinea, J.L., Bárcena, A., León, A. (coordinators), 2005. The Millennium Development Goals: a Latin American and Caribbean perspective. CEPAL, Santiago, Chile, 321 pp. (http://www.eclac.org/publicaciones/xml/0/21540/lcg2331.pdf}

REPP, 2003. Geothermal energy: A Renewable Energy Policy Project issue brief (http://www.crest.org/geothermal/index.html)

United Nations, 2005. UN Millennium Development Goals Webpage (http://www.un.org/millenniumgoals/index.html)