Chapter 4
Climate Change Mitigation with Renewable Energy: Geothermal

Alper Baba

Abstract On a global scale, there is increasing evidence that climate is changing and of a discernible human influence. Many of scientists are confident that if current emissions of greenhouse gases continue, the world will be warmer, sea levels will rise and regional climate patterns will change. According to some scientist, global temperatures are expected to rise faster over the next century than over any time during the last 10,000 years. From this token, geothermal energy is now considered to be one of the most important alternative energy sources to minimize climate change. Geothermal technologies for power generation or direct use operate with little or no greenhouse gas emissions. Geothermal energy is generally accepted as being an environmentally-friendly energy source, particularly when compared to fossil fuel energy sources. Geothermal resources have long been used for direct heat extraction for district urban heating, industrial processing, domestic water and space heating, leisure and balneotherapy applications. Geothermal energy is used in more than 80 countries for direct heat application and 24 countries for power generation. Re-injection of fluids maintains a constant pressure in the reservoir, thus increasing the field's life and reducing concerns about environmental impacts. Geothermal energy has several significant characteristics that make it suitable for climate change mitigation.

Keywords Climate change • Environment • Geothermal energy • Renewable energy

4.1 Introduction

Due to global warming, global temperatures are expected to rise faster over the next century than any 100 years period during the past 10000 years [1–2]. Recent reports from the Intergovernmental Panel on Climate Change [3–4] confirm that climate

A. Baba (✉)
Geothermal Energy Research and Application Center, Izmir Institute of Technology, Urla 35430, Izmir, Turkey
e-mail: alperbaba@iyte.edu.tr

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change is occurring at a larger and more rapid rate of change than was thought likely only 6 years ago. Eleven of the last 12 years (1995–2006) rank among the 12 warmest years in the instrumental record of global surface temperature (since 1850). The 100-year linear trend (1906–2005) of 0.74°C [0.56–0.92°C] is larger than the corresponding trend of 0.6°C [0.4–0.8°C] (1901–2000) [1, 2, 5]. Climate warming observed over the past several decades is consistently associated with changes in a number of components of the hydrological cycle and hydrological systems such as: changing precipitation patterns, intensity and extremes; widespread melting of snow and ice; increasing atmospheric water vapour; increasing evaporation; and changes in soil moisture and runoff. There is significant natural variability in all components of the hydrological cycle, often masking long-term trends. There is still substantial uncertainty in trends of hydrological variables because of large regional differences, and because of limitations in the spatial and temporal coverage of monitoring networks [6]. At present, documenting inter-annual variations and trends in precipitation over the oceans remains a challenge [3].

Greenhouse gases are considered to be the foremost parameter influencing the climate change. Carbon dioxide (CO_2) is the most important anthropogenic greenhouse gas with annual emissions growing by about 80% between 1970 and 2004 [4]. The long-term trend of declining CO_2 emissions per unit of energy supplied reversed after 2000. Global atmospheric concentrations of CO_2, methane (CH_4) and nitrous oxide (N_2O) have increased markedly as a result of human activities since 1750 and now far exceed pre-industrial values determined from ice cores spanning many thousands of years. During the past 50 years, the sum of solar and volcanic forcing would likely have produced cooling. Observed patterns of warming and their changes are simulated only by models that include anthropogenic forcing [5]. Global carbon dioxide (CO_2) emissions from residential, commercial, and institutional buildings are projected to grow from 1.9 Gt C/year in 1990 to 1.9–2.9 Gt C/year in 2010, 1.9–3.3 Gt C/year in 2020, and 1.9–5.3 Gt C/year in 2050. It must also be noted that 75% of the 1990 emissions are attributed to energy production [3].

Controlling greenhouse gases emission and adapting human settlements to withstand the extreme climatic conditions have become the most formidable challenges of our times. Geothermal energy development has thus great CO_2 emission reduction potential when substituting fossil sources of energy. Geothermal energy is one of the contributors to any future energy mix. The advantages of geothermal energy are numerous. It is an environmentally friendly and economically rewarding resource, which is still only marginally developed. Its two main utilization categories power generation and direct use are already introduced in many countries around the globe [7]. Geothermal development estimates for 2050 indicate that CO_2 emissions could be mitigated by 100s of Mt/year with power generation from geothermal resources and more than 300 Mt/year with direct use, most of which could be achieved by geothermal heat pumps [8]. Based on these fundamentals, the purpose of this study is to explain application of geothermal energy and its effect on climate change and to assess environmental impacts of the utilization of geothermal resources.

4.2 Application of Geothermal Energy

People have been using geothermal energy for bathing and washing of clothes since the dawn of civilization in many parts of the world. However, it was first in the twentieth century that geothermal energy was used on a large scale for direct heat extraction for district urban heating, industrial processing, domestic water and space heating, leisure, balneotherapy applications and electricity generation. Prince Piero Ginori Conti initiated electric power generation with geothermal steam at Larderello in 1913. The first large scale municipal district heating service started in Iceland in 1930 [9]. In 2010, geothermal resources have been identified in more than 80 countries and there are quantified records of geothermal utilization in more than 50 countries in world. The result shows that use of geothermal energy for both electrical generation and direct heat extraction is going to accelerate in the near future.

4.2.1 Direct-Use of Geothermal Energy

Direct-use of geothermal energy is one of the oldest, most versatile and also the most common form of utilization of geothermal energy [10]. The early history of geothermal direct-use has been well documented for over 25 countries in the *Stories from a Heat Earth – Our Geothermal Heritage* [11] that documents geothermal use for over 2,000 years [12].

As of 2009, direct utilization of geothermal energy worldwide is 50,583 MWt. The total annual energy use is 438,071 TJ (121,696 GWh). The five countries with the largest installed capacities are: USA, China, Sweden, Norway and Germany accounting for 60% of the world's capacity, and the five countries with the largest annual energy use are: China, USA, Sweden, Turkey, and Japan, accounting for 55% of the world use. However, an examination of the data in terms of land area or population shows that the smaller countries dominate, especially the Nordic ones. The largest increase in geothermal installed capacity (MWt) over the past 5 years are: United Kingdom, Korea, Ireland, Spain and Netherlands; and the largest increase in annual energy use (TJ/year) over the past 5 years are: United Kingdom, Netherlands, Korea, Norway and Ireland. All of these increases are due to geothermal heat pump installations [12]. During the last decade, a number of countries have encouraged individual house owner to install ground source heat pumps to heat their houses in the winter and cool them in the summer.

Summary of various categories of direct use worldwide is given in Fig. 4.1. The result shows that geothermal heat pumps were increased exponentially during the last 10 years. Other uses also increased with a linear trend.

Geothermal fluids contain certain minerals leached from the reservoir rock and variable quantities of gas, mainly carbon dioxide and a smaller amount of

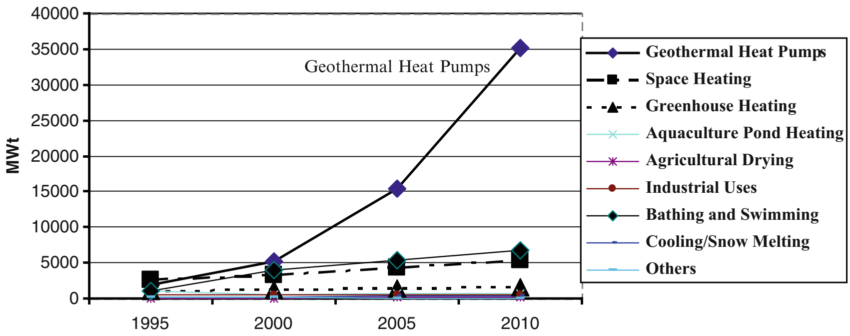

Fig. 4.1 Summary of the various categories of direct use worldwide, referred to period 1995–2010 [12]

hydrogen sulphide. The gas composition and quantity depend on the geological conditions encountered in different fields. Virtually the entire mineral content of the fluid and some of the gases are reinjected back into the reservoir. Most non-condensable gases are released to the environment. Some plants remove H_2S in a gas treatment process before releasing CO_2 to the environment. At one plant in Kizildere, Turkey, the non-condensable gases are scrubbed of H_2S, and CO_2 are recovered to provide about 80% of CO_2 used by the country's soft drinks industry [13].

4.2.2 Power Generation of Geothermal Energy

Electricity is produced with geothermal steam in 24 countries spread over all over the world. The worldwide total installed capacity of geothermal power plants is given in Fig. 4.2. The present value of 10.7 GW is an important result. The expected target from hydrothermal resources of 70 GW for year 2050 is very ambitious, as can be seen from Fig. 4.3 [14].

4.3 Greenhouse Gas Emissions and Climate Impacts

For the last century, human activities have been altering the global climate. Climatic warming is a fact; it endangers the environmental living conditions as well as global economy [8]. The global average surface temperature increased from 1900 to 2006 by at least 1.0°C; during the same time period the CO_2 content of the atmosphere doubled [4]. It is widely recognized that the most probable cause of climatic warming is the increasing content of greenhouse gases in the atmosphere. Observations show that the Earth's surface has warmed by approximately 0.6°C during the twentieth

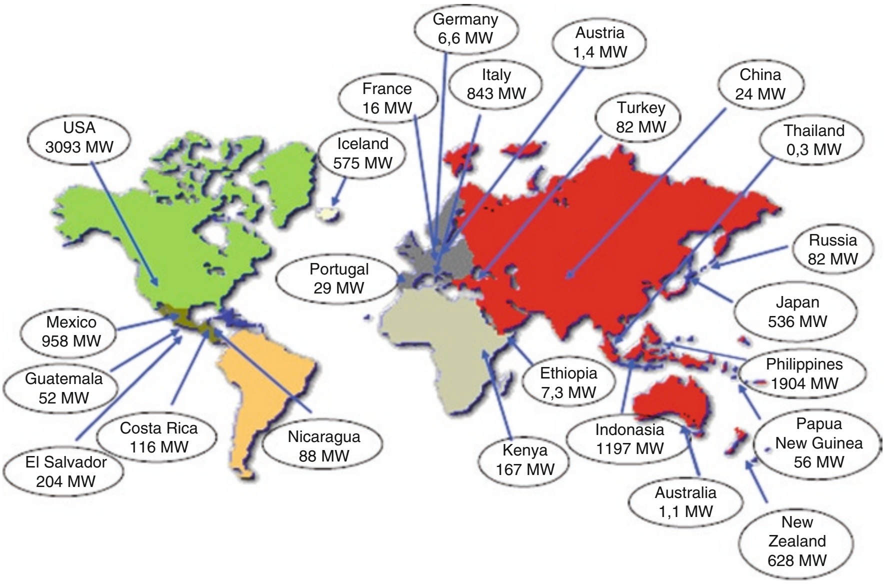

Fig. 4.2 Installed capacity in 2010 worldwide (total 10.7 GW) [14]

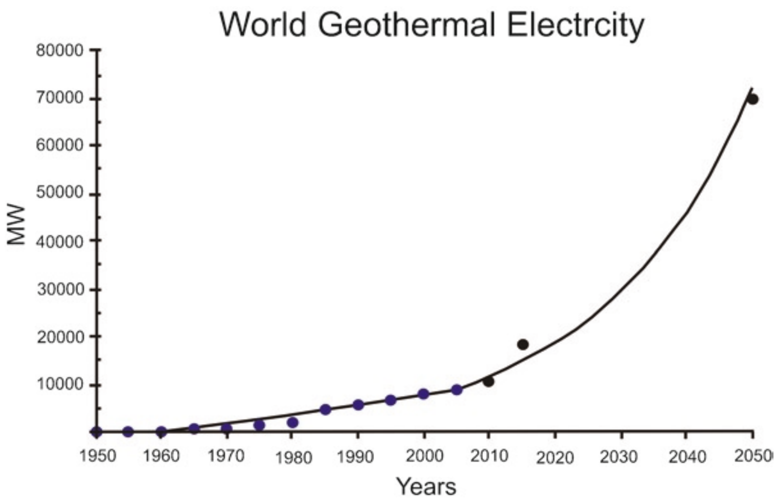

Fig. 4.3 Forecasting up to year 2050 [14]

century [16]. Atmospheric abundances of the major, human-generated greenhouse gases, i.e. CO_2, CH_4, and nitrous oxides (NOx), reached their highest recorded levels in modern history by the year 2000 and are continuing to rise. About 37% of incremental atmospheric CO_2 accumulation is caused by electric power generation, mainly from coal combustion power plant [17].

When compared to other energy source of power generation, geothermal power plants have much lower CO_2 emissions. The results show that geothermal power production has a significant environmental advantage over burning fossil fuels for electrical power production. Electrical production from geothermal fluids results in an order of magnitude less CO_2 per kilowatt-hour of electricity produced compared to burning fossil fuels (Fig. 4.4).

A highly respected source (World Energy Assessment – a collaborative effort between UNDP, UNDESA and the World Energy Council) attests the largest potential value to geothermal energy among all forms of renewable energy sources. The comparison is given in Fig. 4.5. The values are given in capacity units, i.e. energy per unit time. It is obvious that geothermal energy has the largest capacity, although the accuracy of the reported number is limited [7].

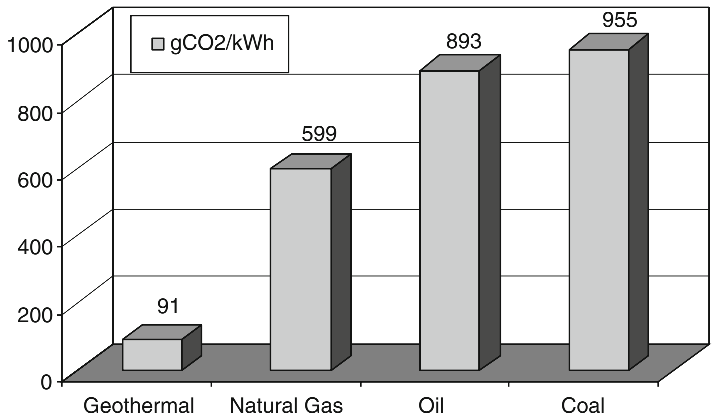

Fig. 4.4 Comparison of CO_2 emission from electricity generation from different energy sources [15]

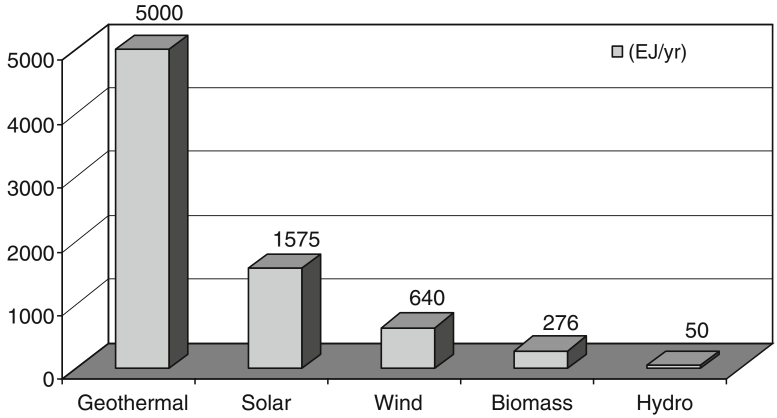

Fig. 4.5 Potential of renewable energy sources [18]

CO_2 emission from geothermal power plants in high temperature fields is about 120 g/kWh (weighted average of 85% of the world power plant capacity). With the present engineering solutions, it could be possible to increase geothermal power from the expected value of 11 GW for year 2010 up to a maximum of 70 GW in 2050; the gradual introduction of the new developments (binary plants, EGS systems) may boost the growth rate with exponential increments, thus reaching the global world capacity of 140 GW in 2050. The corresponding electricity production of about 1,000 TWh/year in 2050 will mitigate (depending on what is substituted) hundreds of million tons CO_2/year. Future technology including reinjection will result in negligible emissions (10 g CO_2/kWh). The extrapolations to year 2050 are given in Figs. 4.6 and 4.7 [7, 8].

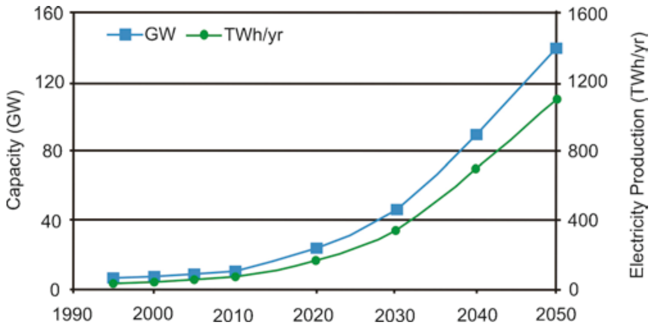

Fig. 4.6 Installed global geothermal capacity and electricity production 1995–2005 and forecasts for 2010–2050 (From Fridleifsson et al. [8, 19])

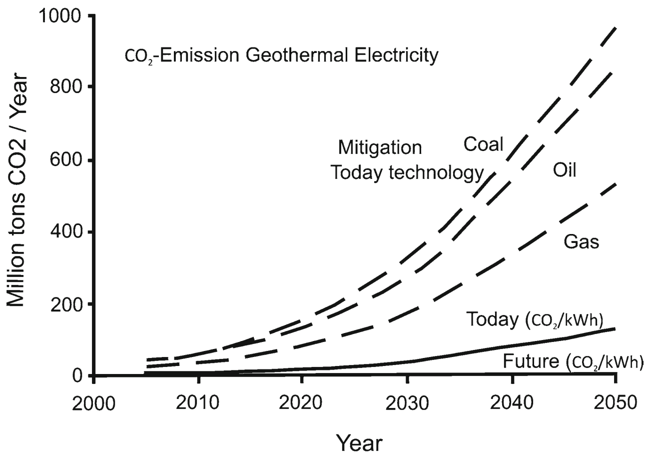

Fig. 4.7 Mitigation potential of geothermal power plants in the world and assumptions for emission of 120 CO_2/kWh for today and 10 g CO_2/kWh for future technology (From Fridleifsson et al. [7, 19])

Geothermal technologies for power generation or direct use operate with little or no greenhouse gas emissions. Since no burning processes are involved they are low in CO_2 emissions. Geothermal energy development has thus great CO_2 emission reduction potential when substituting fossil sources of energy. Further development – depending on future growth rates – could reduce CO_2 emissions even more significantly. The current and future potential contributions to reduce CO_2 emission by geothermal power generation and direct use have been assessed in a study carried out for the Intergovernmental Panel on Climate Change [8, 19].

4.4 Conclusion

Geothermal resource utilization although widely accepted as a clean energy source, has also contributed to the decreasing of air quality due to carbon dioxide emissions. Several studies have shown that CO_2 emissions from geothermal systems occur naturally and in some cases these natural emissions exceed the amount of CO_2 emitted from the geothermal power plant utilizing the geothermal resource.

Geothermal technologies produce little or no greenhouse gas emissions since no burning processes are involved. Geothermal development estimates for 2050 indicate that CO_2 emissions could be mitigated by 100s of Mt/year with power generation from geothermal resources and more than 300 Mt/year with direct use, most of which could be achieved by geothermal heat pumps.

The environmental benefits of geothermal development are obvious: increasing development can help to mitigate the effects of global warming. The societal benefits are developing in parallel: the positive effects are also increasing, regionally and globally. More importantly, improved and increased injection to sustain reservoir resources has diminished the CO_2 released from geothermal power plants.

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