Low-Enthalpy Geothermal Resources for Power Generation

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Foreword

Today majority of the countries depend on imports of fossil fuels to secure their energy and developmental activities. The global proven oil reserves were estimated to be around 137 trillion liters at the end of 2004 and expected to last for another 40 to 50 years. This security will not last for long and developing countries have increasingly to compete with the developed world in future for fossil fuel. The best option available for the developed countries, and developing countries as well, is to have an energy source mix and reduce dependency on fossil fuels. Non-conventional energy sources play an important role in making these countries more energy independent. Developing non conventional energy has two fold advantages: (1) makes the country energy independent and (2) reduces the CO_2 emission and secures the environment for the future generations. Low-enthalpy geothermal energy is one such source that the developing countries are looking as an option to be energy independent.

From a modest start of 10 kW in 1904 in Larderello Italy, geothermal energy to day is generating greater than 8900 MWe in 25 countries supplying 56,831 GWh/year, operating with an average capacity factor of 73% and producing power online 97% of time. About 1% of the world's population is currently using this energy today. The current production is from established high-enthalpy systems but a large volume of low-enthalpy resources, whose potential is much larger, is lying unutilized in many developing and developed countries. This energy needs to be exploited to make the countries move towards energy independence.

The greenhouse gas emissions are unevenly distributed between the regions of the world. The total greenhouse gas emitted by all the countries is about 6234 million tonnes carbon dioxide per year. Asia and Pacific region contributes maximum amounting to 2167 million tonnes carbon dioxide per year. India and China in the Asian region are the maximum emitters while the North American countries contribute substantially from the Pacific region. Some of the developing countries have already entered in to carbon trade with developed countries to secure their energy supply. This may help in reducing the carbon dioxide emission but does not give energy independence to these countries.

The current book is being published at a time when all the countries are carving for more electricity and be energy independent. The authors unveiled all the provinces where low-enthalpy geothermal resources are lying untapped and contribute substantially to the future electricity demand. Both exploration techniques and economics of power production from small power plants to meet rural electricity demand are well documented in the book. Cost comparison between diesel generated power and geothermal power demonstrates the benefits to the rural areas in terms of cost, socio-economic values, rural employment and preservation of the environment by using this non conventional energy source.

I complement the authors for their contribution to improve the energy security of developed and developing countries and to global climate change mitigation. I am sure that this book will be useful not only for the students but also to researchers, energy planners and policy makers.

Prof Ashok Misra
Director, IIT Bombay, India

Authors' preface

The geothermal resources of the earth are huge, with low-enthalpy resources (<150 °C) having a manifold larger potential, and much wider regional distribution compared to high-enthalpy resources. High-enthalpy resources are presently used for power generation in 16 countries with a total installed capacity of 9000 MW_e. The available resources are vast compared to the total net electricity demand, which is expected to double in the next three decades, with the highest world demand rate expected in the developing countries. Only a small part of this geothermal energy is being extracted economically using existing technology. Geothermal resources are also much larger compared to all fossil fuel resources put together. Compared to other renewables, geothermal resources allow for a much more efficient and stable power supply. This energy is freely available to humanity, and the method to harness it for the betterment of humanity lies in the hands of those who need it. The technology for low-enthalpy geothermal resources is growing at so fast a rate, that in the near future non-renewable fossil fuels may be obsolete! Continuous development of innovative drilling and power generation technologies especially, makes low-enthalpy geothermal resources the best option available to meet the required future electricity demand. It will also guarantee energy security and energy independence for both developing and developed countries, while at the same time drastically reducing greenhouse gas emissions, and thus mitigating global climate change. Antagonists may argue that geothermal sources alone may not meet all the future energy demands of the developed and developing world. This may be true in the short run, but in such situations mixing energy sources is a viable option to meet future electricity demands and mitigate climate change. In the long run, when enhanced geothermal system techniques become more commercial, all the countries may leave CO_2-free atmospheres behind for posterity to enjoy. If the MIT 2006 report has any value, this will be fact and not fiction.

A report published in the Finance and Development report of the World Bank in 1997 states, "*Energy markets do not function efficiently in many developing countries, particularly in rural areas, where nearly 2 billion people do not have electricity . . . Inadequate energy markets threaten to dampen economic growth, hobble development, and keep living standards low*". Seven years after this statement was made, the scenario had not changed in the rural sector. This is evident from the Annual Meeting address by the World Bank President in 2004, that reads, "*We must give higher priority to renewable energy. New and clean technologies can allow the poor to achieve the benefits of development without having to face the same environmental costs the developed world has experienced*" The current situation (2008) is no better than what rural developing countries were in a decade ago. Today, 90% of the world population living in rural areas in developing countries has no way to meet basic needs like nutrition, heating, and light in spite of the fact that technologies for developing renewable energies have jumped by leaps and bounds, especially with respect to geothermal energy.

Generating electricity from low- and high-enthalpy geothermal energy resources could provide uninterrupted power supply to these rural masses. Case studies described in this book clearly demonstrate how low-enthalpy geothermal resources can be utilized for improving the socio-economic status of rural areas in developing countries. Additional industrial applications such as greenhouse cultivation, space heating, using the spent fluids from heat exchangers, etc., will further uplift the economic status of the rural population by creating employment.

A shortage of trained manpower for exploration and exploitation programs related to geothermal energy resources could be a future problem, especially in the developing countries. A cursory glance at the recent country updates in the Proceeding of the World Geothermal Congress 2005, reveals that allocation of manpower for developing geothermal resources is not only far below that required but also insufficient in most developed countries. There is a lack of and urgent need for easily understandable and accessible information in a comprehensive form on low-enthalpy geothermal resources practically available all over the world. No doubt, such information does exist in several published scientific papers, but, this information is difficult for graduate students, researchers and decision makers, to collect within a short period of time. This is especially true in the case of students in developing countries, who face difficulties accessing such information. This, together with the absence of a comprehensive book that deals with all aspects of low-enthalpy resources, including occurrence, exploration methods, technologies, economics, and global climate change mitigation potential, inspired us to write this book.

This book explains the occurrences of low-enthalpy systems lying unutilized in both developed and developing countries, and their vast potential in different regions and large economies for power generation.

After a general introduction we address, in Chapter 2, the electricity demand and source mix forecasts for future decades in different regions and large economies, and the role of geothermal resources in the 2004–2030 scenario for power generation.

Chapters 3 and 4 deal with the distribution and potential of low-enthalpy resources guaranteeing energy security and independence for both developing and developed countries, while at the same time reducing CO_2 and other greenhouse gas emissions.

In Chapter 5, geographic distribution of low-enthalpy resources is given together with their geological, tectonic, geochemical, and geophysical characteristics. To understanding both wet and enhanced geothermal systems, a sound concept of the geological and tectonic features that control the geothermal systems needs to be understood. With this in mind, we have tried to bring major geothermal provinces associated with different tectonic regimes around the world together and explain all the possible sources where low-enthalpy geothermal energy resources occur for future development.

In Chapters 6 and 7, geochemical and geophysical exploration methods are discussed. Simple geochemical and geophysical methods are essential in understanding the systems during pre-drilling stages. The most expensive component in geothermal power development is the drilling. The cost can be reduced by applying the above methods to understand the geothermal reservoir conditions and to better locate sites for exploratory drill holes.

Chapters 8 and 9 deal with available power generation techniques, and the economic aspects of low-enthalpy geothermal resources. Power generation techniques are important in geothermal energy development programs. In the present competitive world providing affordable electricity to the rural masses without government subsidy, is a challenge. We have shown how this is possible by using a free energy source such as geothermal, which is independent of fluctuations in oil, coal, and other energy source materials' cost. The initial cost of developing geothermal power projects may be higher than those for fossil fuel based plants, but the advantages of using geothermal sources are quite large because these costs are absorbed in the system itself. For example, unit cost of electric power is low in the case of coal-based power plants, but it has hidden cost in the form of environmental mitigation. In the end, the consumer has to pay for both the electric power as well as cleaning the environment. But in the case of geothermal, there is no hidden cost, the investment is made one time, and the unit cost of power, unlike fossil fuel based power, does not fluctuate with time and space.

Finally, in Chapter 10 we discuss the potential of low-enthalpy geothermal resources for rural electrification and give some case studies for small-scale power plants. Electric sector reforms are transforming the potential owners and operators of small geothermal projects from public utilities to private power producers. Reforms are intended to improve the overall economic efficiency of the electric sector and may open new opportunities for small geothermal projects in this more competitive market. The economic analysis together with the case studies described in Chapters 9 and 10 should interest the government officials involved in drawing electricity reforms in developing countries. Future technological developments in terms of drilling, heat exchangers, and binary fluids add additional advantage to low-enthalpy geothermal resources development. Such technologies will place the geothermal resources at the top of the energy ladder. Developing countries have immense opportunity to increase their country's GDP and develop economic growth by becoming energy-independent countries in the next decade through geothermal energy resources.

The comprehensive integral approach of low-enthalpy geothermal resources in this book makes it a convenient source that aims at developing a strong human resource base in developing and developed countries. Developing countries have a good opportunity to overcome their current and future electricity demands by utilizing this resource. The book is intended not only for graduate and research students as a primary dictionary, but also should prove useful for professional geologists, engineers, and people involved in energy planning and greenhouse gas mitigations. The book also addresses members of pertinent national, regional, and international communities involved in energy and climate change mitigation issues. It is a useful information source for decision and policy making, for administrative leaders both in governments and in international bodies such as the United Nations family, the international and regional development banks, financial institutions, and donors, concerned with technical and economic cooperation with developing countries. As authors, we hope that this book will be useful for many people helping society to effectively use the huge available low-enthalpy geothermal resources, providing energy security and energy independence to their countries, and thus contribute to global climate change mitigation.

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About the authors

Dornadula Chandrasekharam (1948, India) has been a Professor in the Department of Earth Sciences, Indian Institute of Technology Bombay (IITB), since 1987. Currently he is the Head, Centre of Studies in Resources Engineering. He obtained his MSc in Applied Geology (1972) and PhD (1980) from IITB. He has been working in the fields of volcanology, groundwater pollution, and geothermics for the past 25 years. Before joining IITB he worked as a Senior Scientist at the Centre for Water Resources Development and Management, and Centre for Earth Science Studies, Kerala, India for 7 years. He was a Third World Academy of Sciences (TWAS, Trieste, Italy) Visiting Professor to Sanaa University, Yemen Republic between 1996–2001, and a Senior Associate of Abdus Salam International Centre for Theoretical Physics, Trieste, Italy from 2002–2007. He received the International Centre for Theoretical Physics (ICTP, Trieste, Italy) Fellowship to conduct research at the Italian National Science Academy (CNR) in 1997. Prof. Chandrasekharam extensively conducted research in low-enthalpy geothermal resources in India and is currently the Chairman of M/s GeoSyndicate Power Private Ltd., the only geothermal company in India. He is a member of the International Geothermal Association, and has widely represented the country in several international geothermal conferences. He conducted short-term courses on low-enthalpy geothermal resourses in Argentina and Costa Rica. He has supervised 17 PhD students and published 73 papers in international and 35 papers in national journals of repute. He is the Editor of "Geothermal Energy Resources for Developing Countries" (2002) and "Natural Arsenic in Groundwater" (2005) published by AA Balkema Publishers. He is one of the executive members of the International Society of Groundwater for Sustainable Development (ISGSD).