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Energy Independence through CDM using geothermal resources: Indian Scenario

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Although fossil fuels like coal and oil play a major role in meeting the energy demand, GHG emission reduction strategy demands primary energy source mix. Among the renewable energy sources, geothermal energy plays a major role since it has the advantage in terms of cost, land requirement, environmental protection and capacity to support base load electric power supply. India has a large geothermal potential and the oil industry too has a major role to play in reducing CO_2 emissions by effectively utilizing its abandoned oil and gas wells to tap this source for power generation. Similarly, heat from underground coal fires can be utilized for power generation using heat exchanger technology that is commonly used in geothermal power generation. By adopting a source energy mix through renewables, the country in the next decade can become energy independent.

Keywords*: CDM, EGS, OECD, carbon credit, GDP, Carbon dioxide emission, geothermal, granite*

Introduction

Energy independence and greenhouse gas (GHG) emission from fossil fuel based power plants are a great concern for both the developed and developing countries today. The demand for electricity over the world is projected to rise from the current 16,424 TWhr to 30,364 TWhe in 2030 (Chandrasekharam and Bundschuh, 2008). In non-OECD countries (Organization for Economic Cooperation and Development/ developing countries) the demand for electricity is expected to grow at the rate of 3.5% compared to 1.3% in OECD countries. The reason for this demand in the non OECD countries is due to steep population and economic growth while in the OECD countries this demand will be only due to economic growth (Fig. 1). Therefore it is important for the non-OECD countries to be judicious in planning for future energy needs and avoid socio economic issues arising out of environmental problems. Per capita primary energy consumption, per capita GDP and per capita CO_2 emissions are interlinked and are lower in the non-OECD countries. India and China will compete with each other to climb the GDP ladder in spite of a step growth in population (Fig. 1). In fact China has gone up the ladder compared to India due to its policies in implementing energy source mix option and reducing CO_2 emissions. China has accomplished this through extensive use of geothermal energy resources for power generation and for direct applications.

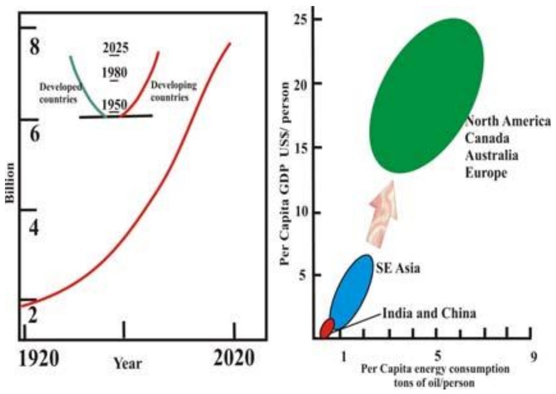

Figure 1. Population and GDP growth trends of non OECD and OECD countries (source: Chandrasekharam and Bundschuh, 2008).

India as on today is generating 141, 080 MWe and is expected to double this generation capacity by 2015000 MWe by burning 263 million tones of coal thus generating 870 million tones of CO_2. Coal remains India's most important fuel, its use nearly tripling between now and 2030. Much of India's coal needs in future will have to be met by imports. India will continue to rely on imported coal for reasons of quality (high ash content) and for economic reasons (IEA, 2007). By 2030 hard coal

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imports by India is projected to increase by seven fold. (UNEP, 2008, IEA, 2007).

Power and CO_2 emission scenario

64.4% of electricity is generated from coal thermal power plants while a meager 7.6% is generated by renewable sources that include wind, solar, biomass and biogases (Table 1). Geothermal does not figure in the renewable although > 265 MWt of energy from the thermal waters is being utilized at preset (Chandrasekharam and Chandrasekhar, 2010). Independent power producers generate only 10855 MWe. Thus a major percent of power is generated by public sector companies. India is planning to increase the power production by 78577 MWe by 2012 to increase per capita electricity consumption from 631 kWhr to 1000 kWhr (MOP, 2008). With respect to the electricity growth rate in non-OECD countries, India's growth rate <4 %. India can not achieve anticipated per-capita consumption by merely burning an additional 263 million tones of coal. This will only drift the country away from implementing CDM unlike other European countries. In fact its future economic competitor, China, is reducing CO_2 emission and phase out hydrochlorofluorocarbons (HCFC) emissions completely by the year 2015 by utilizing its low enthalpy energy geothermal energy resources for heating and cooling of residential and commercial buildings (UNEP, 2011, Jiurong and Jianping 2005). However, there is a hope for the country to reduce emission volume if larger share of less carbon intensive energy sources (i.e. geothermal, wind and solar) are used as primary energy mix. This will yield a saving of 27% in CO_2 emissions by 2030 by reducing the emissions by 0.9 Gt. Besides this, the country can also utilize its sizable number of abandoned oil wells and underground coal fires to generate power using geothermal technology.

Table 1. Power generating scenario from various sources

Plant/Fuel Type		MWe		Percentage	
Thermal		90895		64.4	
	Coal		75002		53.1
	Gas		14691		10.4
	Oil		1201		0.9
Hydro		35209		24.9	
Nuclear		4120		2.9	
Renewable		10855		7.6	
Total		141080			

Black carbon emission

Like carbon dioxide, black carbon (BC) has a tremendous influence on the global climate change. Although the radiative forcing of BC (+ 0.34 W/m^2) is smaller than CO_2 (+1.66 W/m^2), this is very significant (IPCC, 2007). BC stay in the atmosphere for about week while CO_2 lingers in the atmosphere for over 100 years. Thus if BC emission is controlled, then a significant control on the global climate change can be achieved. Rural India depends mainly on fuel wood, dung cake and agricultural waste as sources of energy and are consumed maximum in that order in India. According to 1996-2001 data, 302 Mt of fuel wood, 121 Mt of dung cake and 116 Mt of agricultural waste was consumed in India (Gadi et al., 2003). The consumption of these fuels has increased by several folds due to increase in population and hence demand. These estimates vary from author to author due to several uncertainties are (for e. g. see Sekhar Reddy and Venkataraman, 2002, Bond et al., 2004, Streets et al., 2003) due to extrapolation of data such as population, per capita consumption (varies by a factor of 3), economic data etc. and also due to over prediction of fuel-use measurements!!. However, BC emission from different sources mentioned above can be considered as the minimum values for the purpose of evolving strategy for carbon mitigation through geothermal in the present paper. The BC content in bio-fuels have been estimated by several worker (Sekhar Reddy and Venkataraman, 2002, Bond et al., 2004, Streets et al., 2003, Parashar et al., 2005) and on an average fuel wood, dung and agricultural waste emit 0.8g/kg, 2.2g/kg and 1g/kg respectively (Parashar et al., 2005, Sekhar Reddy and Venkataraman, 2002). Thus, the total BC emission by India is 1343 Gg (Sahu et al., 2008). A major contribution of BC arises from rural India where traditional energy sources are still in use and this is especially true in the case of villages located in cold climatic regions such as the central regions of the Himalayas. One such village is Leh located in Ladakh province of Jammu & Kashmir State. Leh alone contributes 82 Mg of BC while Kargil, another village in the Himalayas contributes 70 Mg of BC to the atmosphere over the Himalayan glaciers. The per capita BC emision by India is about 1200 g/y (Sahu et al., 2008).

Black carbon and Glaciers

The BC over the Himalayas has tremendous effect on the thermal insulation over the glaciers. The BC settles down along with the snow during winters and changes the albedo of the ice thus formed. The BC content in ice cores from ERG glacier in the Tibetan Himalayas is 20 μg/kg while global average BC content in snow is about 5 μg/kg (Ming et al., 2009). This is alarmingly high since 15 μg/kg of BC in snow reduces about 1% of its albedo (Warren and Wiscombe, 1980). It is not surprising to see a 92 m high Gangotri glacier black in appearance due to both debris as well as BC (Fig. 2). It is now well established fact that the Himalayan glaciers, in particular

Figure 2. Gangotri glacier with debris and BC.

the Gangotri glacier, in deed are retrieving at the rate of 18m/year, due to deposition of BC as well CO_2 emissions not only from the Himalayan villages but also from emissions originating from the south east Asian countries in general (Naithani et al., 2001, Ramanathan and Feng, 2009, Xu, et al., 2009, Menon et al., 2010, Ming et al, 2009). Between 1990 and 2000 ice cover over the Himalayas decreased by about 0.9% due to BC effect and emissions from the Indian subcontinent contributed nearly 36% to the decreased ice cap over the Himalayas (Menon et al., 2010).

Geothermal resources in India

The geothermal energy of the Earth is unlimited. Only a part of the geothermal energy stored in the crust to a depth of about 3-4 km is estimated to be 43 x 10^6 EJ corresponding to about 1194 x 10^6 TWh (Bijörnsson et al. 1998). Even the small part (<1%), that corresponds to the currently available share and can be extracted economically using the existing technology is vast compared to the total world net electricity generation, which is expected to grow from 16,424 TWh in 2004 by 85% to reach 30,364 TWh in the year 2030 (EIA 2007). Thus geothermal resources are much larger compared to all fossil fuel resources put together whose energy and electricity equivalents are 36,373 EJ and 1,000,400 TWh, respectively corresponding to 1317.4 billion barrels of oil (corresponding to 8062 EJ or 223,900 TWh); 6183 trillion cubic feet of natural gas (corresponding to 6678 EJ or 185,500 TWh), and 998 billion short tons of coal (corresponding to 21,634 EJ or 600,900 TWh) (EIA 2007). If we consider that actually only a small part of the geothermal energy resources can be tapped, for example, from either low enthalpy wet geothermal systems (WGS), that is available around high enthalpy systems, or enhanced geothermal systems (EGS) applying artificial fracturing of the geothermal reservoir, or using advanced heat exchanger technologies, which reduce the minimum fluid temperature required for power generation, the world's geothermal resource will remain available for future generations long after the last drop of oil is produced. Continuous development of innovative drilling, power generation technologies and efficient heat exchangers, makes this source the best future option available to meet the growth energy demand in the world. According to the MIT report on geothermal energy (MIT report 2006), geothermal energy is going to be the future energy sources for the developed and the developing world and can sustain for centuries with out causing damage to the environment.

Nearly 400 low to medium enthalpy thermal springs are distributed in seven geothermal provinces in India (Fig. 3). The surface temperatures of these springs vary from 47 to 98°C. Extensive geological, geophysical and geochemical investigation on the thermal waters and thermal gases have been carried out (Chandrasekharam, 2000, 2005 and the references therein). Besides the low enthalpy geothermal resources, India has a large EGS potential that is waiting to be exploited (Chandrasekharam and Chandrasekhar, 2008a, 2010, Chandrasekhar and Chandrasekharam, 2007, 2008, 2009). These geothermal sites are pilgrimage centres and the thermal waters are directly being used for balneology and for cooking (Chandrasekharam, 2007).

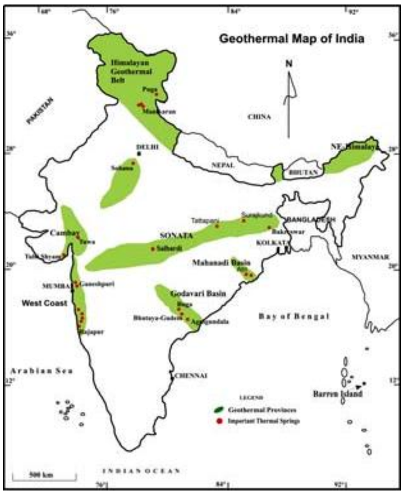

Figure 3. Geothermal provinces of India

Estimates on 50 thermal springs located around important pilgrimage centres show direct utilization of 265 MWt energy (Chandrasekharam and Chandrasekhar, 2010). In fact all the 400 thermal springs are accessible for utilization and if exploited will provide > 10 fold the current utilization. The distribution of the thermal springs in different geographic and temperature zones is advantageous for direct utilization purpose like space heating and cooling, dehydration and green house cultivation. With the advanced drilling technology and efficient heat exchangers, geothermal resources in India, besides generating power, can contribute significantly in mitigating GHG emissions and mitigate global warming and become CDM forerunner in the world. In addition to the existing low enthalpy wet geothermal systems, the country has huge EGS resources spread across all its states extending from the Himalayas to the southern part of the country. Its EGS strength is drawn from high heat generating granites occupying a surface area of 15000 sq. km. For example, EGS reserve estimate made on a small granite exposed area of 1000 km^2 in Ladakh in the Himalayan Geothermal Belt is about 61160 x 10^{12}kWhr. Similar EGS reserve in Madhya Pradesh and Andhra Pradesh (1000 km^2 granite) is 24464 x 10^{12} and 111200 x 10^{12} kWhr (Chandrasekharam and Chandrasekhar, 2008a, 2010).

Abandoned oil and gas wells and underground coal fires

A large number of oil and gas wells, with depths varying from 3 to 4 km, exist in several countries that are struck dry or cease to produce oil or gas. The geothermal gradient in such wells vary from 40 to 45 ºC with bottom hole temperature > 150 ºC and pressures ranging between 5 to 20 bars and above. Production of geothermal power from such wells will not only add more to the renewable energy power but also help in recovering the cost incurred in drilling such deep wells. Each well, can generate 3 to 5 MWe of power that can be supplied to the grid. Several designs of heat exchangers that can be used to extract heat from such wells are available to suit the physical and temperature and pressure conditions of the well (Davis and Michaelides, 2009).

Similar technology exists to extract heat from underground fire in coal mines. The depth here are not as deep as oil wells but the heat available is much more compared to the bottom whole temperature of the oil wells.

CDM through geothermal energy source mix

On an average geothermal power plant emit 0.893 kg CO_2/MWhr while coal power plants emit 953 kg CO_2/MWhr (UNFCCC, 1997). The combined (wet low enthalpy and EGS) geothermal potential of India, taking in to account the 150000 sq. km high heat producing granites, spread over the continent extending from the HGB to the southern part of the continent, is, on a conservative side amounts to 18348 10^{14} kWhr (Chandrasekharam and Chandrasekhar, 2008a). At a growth rate of ~ 4 %, by 2030 coal alone will add about 414 x 10^6 MWhr. By utilizing the geothermal energy source, India can save about 396 x 10^9 kg of CO_2. At the current CER rate of ~ 10 euros/tCO_2, this amounts to 396 x 10^7 euros. This amount is more or less equal to the US$ 1.25 trillion estimated (see section 2) for energy infrastructure development. Further, 33 % (245 x 10^6 MWhr, only coal power) of electricity in India is utilized by the building sector (commercial and domestic). A major amount is spent for space cooling, refrigeration and hot water supply. This amounts to emission of 234 x 10^9 kg CO_2. If India utilizes low enthalpy geothermal sources (through Ground source Heat pumps: GHPs) and save additional revenue of 234 x 10^7 euros under CER. Further, geothermal has an edge over other renewable like wind and solar in terms of land requirement, cost, plant load factor and number of units generated per year (Table 2).

In fact CDM can be implemented immediately in Leh Ladakh in J&K State using geothermal energy and earn substantial savings through CER. Leh, gets its electricity from 6 diesel generators that generate 8 MWe (49056 MWhr) burning 3 million litres of diesel and emitting about 41 x 10^6 kg CO_2 (@ 817 Kg CO_2/MWhr, for oil, UNFCCC, 1997) (Chandrasekharam and Chandrasekhar, 2008b).

Table 2. Efficiency of geothermal compared to wind and solar PV (Compiled from NREL, 2009)

Activity	Wind	Geothermal	Solar (PV)
Land Requirement	35-65 acres/ MWe	0.75 - 1.2 acres/ MWe	5-11 acers /MWe
Levelized cost	175 paise/kWh	150 paise/kWh	950 paise/Kwh
O & M cost	120 paise/ kWh	80 paise/ kWh	550 Paise /Kwh
PLF	17-24% (Subject to wind availability)	95% (base load power)	8-12% (Subject to availability)
Carbon Credits	80 % of PLF	100% of PLF	80% of PLF
Avg Units produced Per MWe Per Year	1.4 Million Units /Annum (Subject to wind availability)	8.3 Million Units / Annum	0.7 - 1 Million Units/Annum (Subject to availability)

Incidentally Leh is located within the HGB (Puga and Chumathang geothermal fields, Figure 3) which has potential of generating > 250 MWe (about 2 x 10^9 kWhr) from wet geothermal sources (Chandrasekharam, 2005, Chandrasekharam and Chandrasekhar, 2008). In addition to this, the EGS potential of the high heat generating granites of HGB, on a conservative account is about 1501 x 10^{15} kWhr (Chandrasekhar and Chandrasekharam, 2008). By implementing CDM through geothermal energy sources, besides providing projected electricity demand to Leh (54 MWe) in the next decade, the region can save the currently retreating Gangotri glacier (retreating at the rate of 18 m per year, Chandrasekharam and Chandrasekhar, 2008b) and preserve the pristine Himalayan environment for the future generation (Chandrasekharam and Chandrasekhar (2008b). The retreating glaciers of the Himalayas could present the most far-reaching challenge to the region. The Himalayas are a vital life-sustaining resource for South Asia. Any damage to the pristine Himalayan ecosystem will influence the monsoon dynamics of SE ASIA there by posing unprecedented threat to water supply, flood risks, sea level rise and damage to coastal ecosystem and causing severe damage to the agricultural ecosystem (IEA, 2007).

Further, in Leh, due to its geographical location and climatic condition (temperature in winter is around -35°C), diesel is being used for space heating during winter months (Sept-Feb) creating an additional CO_2 emission. This region is suited for creating space heating facility on a regional scale using the widely spread geothermal resources. In fact the HGB has the potential to generate surplus electricity through geothermal resources and make J&K and neighboring states zero electricity deficit.

Considering the carbon credits a country can gain through CDM, this is good instrument to India to develop its huge geothermal energy resources. Although India is branded as the most extensive coal user, emitting substantial amount of CO_2 (ranks second in the non OECD countries, IEA, 2007 and also see section 1), by implementing CDM through low carbon geothermal energy resources, India can become the leader among the non OECD countries in piling up huge carbon credits, like Europe, and lead the other developing countries in south east Asia and Africa and central Americas. As shown above, only by implementing low carbon energy sources energy for future buildings in the urban sector, India can reduce importing hard coal from other countries and build high capital to support geothermal projects. CDM of the Kyoto Protocol has paved the way to alternative financing portfolio regarding energy efficiency improvement projects in this sector, in collaboration with the international financial players like Europe and Japan. These two countries are active in the global carbon market for the last several years. Europe completely dominated the CDM market in 2006 with 86% transaction volume with China dominating CDM market accounting for more than 70 % global transaction volume. China's trade is mostly focused on non-CO_2 GHG reductions related to energy efficient projects (China ranks first in the non OECD countries, IEA, 2007). In the long term such energy efficiency projects may not fully support CDM mechanism unless source energy with less carbon emissions, like geothermal dominates the market.

Conclusions

Clean Development Mechanism under Kyoto Protocol is an excellent instrument for India to raise above all the non- OECD countries with respect to controlling carbon emissions, earning carbon credits, improving the environmental and GDP growth in the next two decade provided it exploit its geothermal potential to its maximum capacity in all sectors like power, building and food processing. While China is exploiting its geothermal resources and plans to expand further in the HGB, India still allowing its pristine Himalayan ecosystem to degrade, in spite of repeated scientific reports indicating the potential of geothermal resources in the NW Himalayan region. India's estimated wet geothermal potential (80 x 10^9kWhr) EGS potential (18348 x 10^{14} kWhr) is far greater than the future projected electricity demand from coal based thermal power plants by 2030.

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