RENEWABLE ENERGY RESOURCES FOR CLIMATE CHANGE MITIGATION

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Abstract. Climate change has been identified as one of the greatest challenge by all the nations, government, business and citizens of the globe. The threats of climate change on our green planet 'Earth' demands that renewable energy share in the total energy generation and consumption should be substantially increased as a matter of urgency. India's energy development programme has been put under severe pressure with the ever-increasing demand supply gap. Due to predominance of fossil fuels in the generation mix, there are large negative environmental externalities caused by electricity generation. So it has become imperative to develop and promote alternative energy sources that can lead to sustainability of energy and environment system. Renewable electricity has become synonymous with CO2 reduction. Present communication provides a brief description about such alternative and sustained energy sources, i.e., renewable energy resources, their potential and achievements in India. Also role as important tool for climate change mitigation.
Keywords: *Renewable energy, GHGs, Climate change, Carbon dioxide, mitigation*

Introduction

Climate change has implications for both human and natural systems and could lead to significant changes in resource use production and economic activity. In response to the impact and possible affects of climate change international, regional, national and local initiatives are being developed and implemented to limit and mitigate GHGs concentration in the Earth's atmosphere. The global concern for sustainable development and climate change has brought concentration of energy policy makers towards the renewable energy sources since these provide energy, without emissions of greenhouse gases (GHGs) and are also abundant resource available for future. Climate change affects populations by changing basic life conditions, for example, food availability, and by causing habitat loss and fragmentation [1, 2, 3, 4].

Renewable energy refers to energy resources that occur naturally and repeatedly in environment and can be harnessed for human benefit. Examples of renewable energy systems include solar, wind, hydro and geothermal energy (getting energy from the heat in Earth). Biomass, rivers, and even garbage (waste generated) are also source to renewable energy.

Climate change occurred as a consequence of anthropogenic activities like combustion of fossil fuels, industrial processes, deforestation and GHGs release into atmosphere. Power sector alone contributes to the scale of 40% to the total carbon emissions [5]. In a study covering the period 1901-87 for India have shown that the countrywide mean maximum temperature has risen by 0.6°C, and the mean minimum temperature has decreased by 0.1°C [6]. Last ten years (1995-2004), with exception of

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1996 are among the warmest 10 years on record with 2004 as the 4th warmest year since accurate records commenced in 1861 [7].

A wide range of climatic change impacts are observed, for instances, greater frequency and intensity of tsunamis, droughts, wildfires, floods, storms; also snowstorms, tornados, spread of infectious pests, pathogens and heat waves which, could cause greater human illness and premature mortality. Also, it is intimately connected to the alarming rate of extinction of species and biodiversity loss that could become the sixth largest extinction spasm in planetary history. Clean air policy, including the promotion of renewable energy and energy efficiency, can substantially reduce these negative impacts.

Renewable energy technologies meet the two basic conditions, to be eligible for assistance under UNFCCC mechanism; firstly, they contribute to global sustainability through GHGs mitigation; and secondly, they confirm to national priorities by leading to the development of local capacities and infrastructure. In addition, the steadily growing awareness of the importance of environmental protection is an important aspect of renewable energy.

Energy scenario in India

The share of fossil fuel in the current primary fuel-mix of the country is dominant as coal, oil and gas together account for around 65 per cent. Share of renewables, including large hydro, nuclear and others is 34 percent. During the previous decade (1991-2001), total primary energy has grown at an annual average rate of 3.6 per cent whereas primary commercial energy growth has been higher at an annual average rate of 5 per cent. Non-commercial energy, however, grew at a lower rate of 1.3 per cent per annum during the decade. The growth rate of electricity generation was 5.5 per cent per annum.

Power generating capacity of India is expected to increase from 106GW to 212GW from 1996 to 2010. Indian power sector is prominently based on fossil fuels, with about 3/5th of the country's power generation capacity being dependent on vast indigenous reserves of coal. Natural Gas based generation capacity has grown very rapidly in the last decade due to lower capital requirements, shorter construction periods, and higher efficiencies and has a twelfth share in overall capacity. Nuclear capacity remains almost restricted at about 3 percent of the total [8]. Hydro power continues to grow very slowly due to various socio-environmental barriers and has almost a quarter shares in the total generation capacity at present. In the national energy scene, renewable technology capacity (renewables in this communication refer to small hydro, wind, cogeneration and biomass-based power generation, and solar technologies and exclude large hydropower), aggregating 4000 MW as of March 2006 [9]. This is a minuscule 3 percent of the present estimated potential of renewables in the country with over total capacity of over 126,838 MW. This percentage has grown to double since last year when it was just 1.5%of the total installed capacity. Fig 1 shows the installed capacity of India with their percentage contribution in present generation.

Current growth rate of renewable contribution will continue at a slower pace and energy from renewables is not expected to increase its share in the fuel-mix in any significant manner at least upto 2051-52 as under the likely and optimistic scenarios its share is expected to increase to 39.23 and 53.13 percent respectively. [10]

The current per-capita energy use in the country is around one-third the global average and one-ninth that of OECD countries. The energy intensity of the national

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growth process is 0.20 MMTOE/US$ PPP1billion whereas the global average is 0.24 MMTOE/US$ PPP 1 billion, thereby demonstrating that the Indian economy consumes a somewhat lesser amount of energy per unit of output than the global average.

A marked disparity between the energy consumption pattern in urban and rural segments also forces a shift of energy scenario towards renewable energy systems. Villages and areas situated in remote and far flung areas can be depended on only self generating source like renewables.

Renewable technologies are now matured and well understood technologies, thus it is now possible to connect them to grid and also they offer possibilities of distributed generation at or near actual load centre, thereby saving on costly establishment and maintenance of transmission and distribution networks.

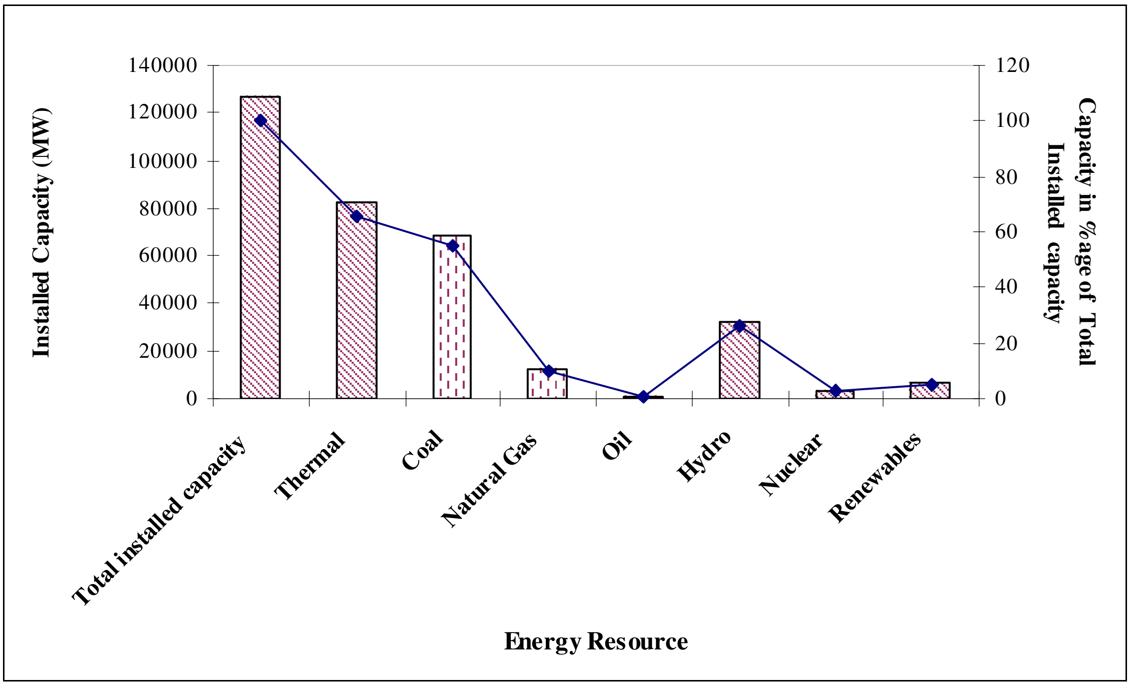

Figure 1. *Total installed capacity distribution India (126838.97 MW)*

Indian renewable energy programme (IREP)

India has the largest decentralized solar energy programme, the second largest biogas and improved stove programme, and the fifth largest wind power programme in the world. The energy policy also focuses on development of decentralised energy systems based on renewable sources especially for use in rural areas. Key drivers for renewable energy in the country are large untapped potential IREP is the largest and the most extensive among developing countries of the world. Today,; Demand-supply gap; Concern for environment; Need to strengthen India's energy security; Pressure on high-emission sectors from their shareholders and Solution for rural electrification.

Indian renewable energy program was primarily launched as a response to the perceived rural energy crisis in the 1970s [11]. Initiated with a target oriented supply push approach, it primarily sought to develop niche applications, such as in rural areas where grid electricity was unavailable. Cash subsidies were and are still being provided for promoting renewable energy technologies (RETs) in India. CASE (Commission on

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Additional Sources of Energy) was created in 1980, and then the DNES (Department of Non-conventional Energy Sources) was set up in September, 1982 [12]. In the initial stages of the programme, the technologies were not mature and there was little international experience in implementation. However, renewables were promoted as a panacea to the energy problems, and doing 'too much too soon' resulted in unrealistic expectations leading to failures [13]. In the early nineties, under the economic liberalization process, the programme received an impetus with a shift in emphasis from purely subsidy-driven dissemination programs to technology promotion through the commercial route. DNES was converted into a fully-fledged Ministry (Ministry of Non-conventional Energy Sources, or MNES) in July 1992, making India the only country in the world with a ministry dedicated to promoting renewable energy technologies (RETs) [14]. By 1998, a multi-pronged strategy led to the development of the world's largest SPV lighting program, fourth largest wind power program, and second largest biogas and improved stove programs [15].

Under Renewable Energy Plan, 2012, government has proposed draft renewable energy policy and programme interventions required to achieve goals of meeting the minimum rural energy needs; 10% share for renewables to set up about 12,000 MW generation capacity; deployment of solar water heating systems in 1million homes; electrification by renewables of at least one quarter of 18,000 un-electrified villages; deployment of 5 million solar lanterns and 2 million solar home lighting systems; coverage of 30 million households through improved Chullhas (wood stoves); setting up of further 3 million family size biogas plants. The remaining 1.25 lakh census villages and 56 per cent households are unelectrified. The Government has announced coverage of all these unelectrified census villages with 100 per cent household coverage by 2009.

Further RE plan 2012 aims at more female participation in the RE programme for their employment and empowerment; availability of minimum cooking energy to all households; to provide cost effective energy for water pumping, irrigation, drinking and for rural electrification and all round rural development through the Integrated Rural energy Programme (IREP). India has a vast potential (of over 100,000 MW) for renewable energy resources [12]. Table 1 presents the available potential and achievements in India. Data in the table predicts that while several technologies have made considerable progress, the achievements as compared to potential are still very small.

Although considerable experience and capabilities exist on renewable electricity technologies including the development of indigenous biomass gasifier technology and manufacturing base for wind power and solar photovoltaic, a number of barriers still remain to be overcome. The push policies adopted since the nineties have been successful in creating a fairly large and diversified manufacturing base and an infrastructure (technology-support groups and facilities, as well as the nodal agencies) to support RET design, development, testing, and deployment. But commercialization of the technologies have been limited due to low reliability of the devices, lack of remunerative tariffs for RET-generated electricity, and a lack of consumer-desired features (in terms of the services and the financial commitments) in the design and sales-package. Further Distortions in the energy and electricity prices and non-internalisation of the socio–environmental externalities have impeded the progress of RETs by adversely affecting their competitiveness compared to conventional energy sources.

Table 1. *Renewable energy potential & achievement in India (as on March 2004) [10]*

Source/Sector	**Potential**	**Achievement**
A. Power From Renewables		
1. Wind	45,000 MW	2,002 MW
2. Solar Photovoltaic Power	20MW/sq km	47 MW
3. Small hydro (upto 25 MW)	15,000 MW	1,520.35 MW
4. Biomass Cogeneration power	19,500MW*	570.9MW
5. Energy Recovery from waste	1700 MW	30.8 MW
Total power from Renewables	**81, 200 MW**	**4127. 37 MW**
B. Decentralised Systems		
1. Solar water heating (Collector area)	140Million m^2	0.70 Million m^2
2. Solar PV	20 MW/sq.km	47MW
a. Street lighting systems	-	47969Nos
b. Home lighting systems	-	256673 Nos.
c. Solar lanterns	-	509894Nos
d. SPV power Plants	-	1637 kW
3. Solar PV Pumps	-	6368 Nos.
4. Wind pumps	-	945 Nos.
5. Hybrid Systems	-	199.35 kW
6. Biogas Plants	12 Millions	3.44 Millions
7. Improved Chullas (wood stoves)	120 Millions	35.89 Millions
8. CBP/IBP/NBP plants	-	3,902 Nos.

MW= Mega Watt; sq m =Square meter; kW=kilo watt;* Gasifiers are included

Renewable energy sources

Renewables can also replace fossil fuels for reducing the greenhouse gases emissions. The country possesses renewables energy sources in abundance the potential capacity is estimated to be 126,000MW.The largest source (79,000 MW) including ocean, thermal and tidal/wave power [16]. Major renewable energy sources of interest to us are biogas, improved cooking stoves, biomass, solar energy, wind energy, small hydro power, energy recovery from wastes and other new and emerging technologies. Figure 2 presents the achieved capacity (in MW) of renewable energy sources in India.

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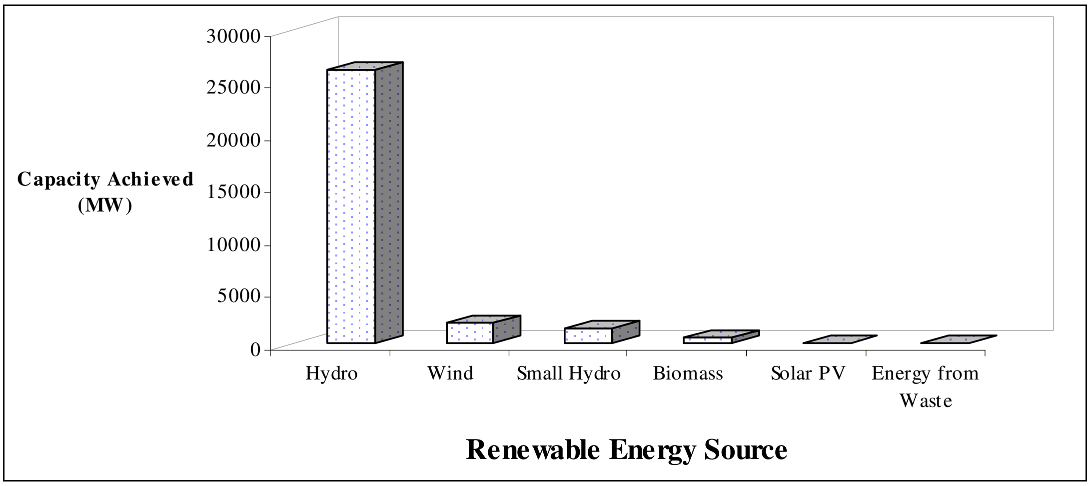

Figure 2. *Renewable energy status in India*

Wind energy

Wind energy, although intermittent, is one of the fastest growing renewable resources in terms of installed capacity. Being the fifth largest wind power producer after Germany, US, Denmark and UK, the generation capacity of country is 2002 MW (1210MW power from commercial projects). About 6.5 billion units from wind power projects are fed to various state grids or to the captive consumers. Major states with higher capacity and potential of wind power are Tamil Nadu Andhra Pradesh, Karnataka, Kerala, Madhya Pradesh and Maharastra.

It is intermittently and strongly influenced by geography and topography (terrain effects). There is a cubic relationship between instantaneous wind speed and available power. It have been observed that the net energy output of a 600kW machine operating in a wind farm would be 1500MWh/yr on a site with an annual mean wind speed of 7.5 m/s at a height 25m above ground level and 2100MWh/y on a site with an AWMS of 9.0m/s at 25 m. The use of wind as a renewable energy source involves the conversion of power contained in masses of moving air into rotating-shaft power. The conversion process utilizes aerodynamic forces (lift and/or drag) to produce a net positive turning moment on a shaft, resulting in production of mechanical power that can be converted to electrical power.

The country's wind power potential has so far been assessed at 45,000 MW with 1% land availability for wind power generation in potential areas. Assuming a capacity utilization factor of 25 percent, the identified potential can generate electricity equivalent to around 8.5 MMTOE per annum. It has been assumed that with better resource assessment and further increase in conversion efficiencies, the identified potential will be harnessed and around 10 MMTOE equivalent of electricity will be generated by 2051-52 [10,14].

Biomass power : cogeneration and gasifiers

Biomass is potentially the world's largest and most sustainable energy source. Biomass is and will remain central to any strategy for determining a rural energy solution. Current biomass share in the primary fuel-mix is not expected to decrease significantly as most scenarios suggest that the share of biomass would hover around 25 per cent or more during the 21st century. Biomass, on the other hand, is renewable and if consumed with care, its ill effects such as excessive smoke and release of particulate matter in the atmosphere can be nullified. Biomass, although available in abundance in rural India is paradoxically in short supply mainly because of the inefficient utilization route it is currently being put through.

Currently, biomass accounts for around 30 percent of the domestic primary energy consumption. A major task for energy scientist and policy makers is to increase biomass yield from energy plantations. By incorporating improved plantation techniques through elite planting material developed from clonal propagation plantation, around 15-25 MT biomass/hectare can be obtained using short rotation period of 6-8 years. Considering that some estimates place the quantum of such land at more than 100 million hectare, around 1200 million MT of biomass production per year is achievable from 60 per cent of the waste land. Primary energy demand of 564 MMTOE can be thus met from this source.

In a country like India, biomass holds considerable promise as 540 million tons of crop and plantation residues are produced every year, a large portion of which is either wasted, or used inefficiently. Conservative estimates indicate that even with the present utilization pattern of these residues and by using only the surplus biomass materials, estimated at about 150 million tons, about 17,000 MW of distributed power could be generated [17].

India being an agricultural based country. About 12 million biogas plants for 4 million cattle dung, thus tapping a third of the potential, which is good in comparison to simple-to-disseminate energy device like the LPG in rural India (users are about 7 millions) [18]. A target of installing 0.18 million family type biogas plants had been set up for the year 2004-05. Recent estimates suggest that the impact of traditional biomass cook stove results annually in 0.5 million deaths and around 500 million cases of various illness forms that include acute upper and lower respiratory problems, chronic bronchitis, asthma, tuberculosis and cataract. Women and child in the country are the worst sufferers of this form of pollution.

The deployment of gasification/biomethanation processes in conjunction with bio-fuel run generators, cook stoves and lamps will help in mitigating the problem of rural energy related pollution to a very large extent. The various applications of biomass energy include thermal or heat, mechanical water pumping for irrigation and power generation including village electrification and industrial applications. Biomass combustion efficiency in a traditional cookstove is around 10 per cent. In an improved cook stove it could be anywhere from 20 per cent upwards. In high pressure high temperature combustion electricity producing systems, efficiency levels could be anywhere between 20-40 per cent. The current efficiency level of bio-energy use of 10 percent or less is sought to be doubled, if not tripled through more efficient conversion processes. Through increased biomass production coupled with higher conversion efficiency attainment of a higher per-capita energy consumption level is sought to be achieved in rural areas.

Currently, biomass contributes 14% of the total energy supply worldwide and 38% of this energy is consumed in developing countries, predominantly in rural and traditional sectors of the economy. About 90% of the extracted wood is used for fuel [19]. Photosynthesis provides 120 billion tonnes of biomass every year, corresponding to about five times the total world's energy need. There are several routes of converting biomass into useable energy form. Most conventional form is to burn it to produce heat.

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Bio-ethanol and bio-diesel are now produced which can be used to fuel transport sector [20]. Cogeneration technology, with socio-economic benefits to produce both process heat and electricity, based on multiple and sequential use of a fuel for generation of steam and power, aims at surplus power generation in process industries such as sugar mills, paper mills, rice mills and wastes like rice husk, coconut, wood and agriculture waste.

Since biomass fuels have high nitrogen content, control of NOx would also need to be addressed. It have been estimated that around one-third the land area of the country or around 10^7 m ha is waste-lands, which can be put to use in a major way for energy crop plantations. For the purpose of this Policy Statement, it has been assumed that around one-half of the estimated extent of waste-lands could be developed for energy cropping to include wood, leafy biomass and bio-fuels. Mature cost-effective technology availability is the major barrier to the deployment of bio-energy systems. Bio-energy conversion systems need to be developed, perfected and made cost-effective. Development of bio-energy technology for grid electricity, distributed generation and stand alone systems/devices will be in furtherance of the aforesaid aim. Bio-energy will be mainstreamed as a major energy source through technology development and energy crop plantations.

Biofuel, whose characteristics can be made more or less to resemble diesel with transesterification, is a promising alternate fuel. Cultivation of oil seeds required for bio-fuels is being encouraged in several states. Although current estimated yield is only 1 MT/ hectare, biodiesel has the added advantage of being a great employment generator. Biofuels are being tried out in modified primus stoves, petromax lamps and diesel engines, the latter for stationary, portable and transport applications.

Small hydro power (SHP)

Presently, an estimated potential of about 15,000 MW of SHP exists in India. MNES currently has a database of 4,096 potential sites with an aggregate capacity of 10,071 MW for projects upto 25 MW. Keeping in view of the policy of Government of India to encourage private participation in the field of power generation, thrust of SHP programme is to set up commercial SHP projects.

As per estimates presented by the Central Electricity Authority (CEA), the economically exploitable hydro potential in the country has been assessed at 84,044 MW at 60% load factor which corresponds to an approximate installed capacity of 150,000 MW from 845 schemes.

Assuming that even if 50 percent of this potential was to be harnessed by 2050, the total hydro installed capacity could be around 100,000 MW by then (including around 25,000 MW already installed). This will translate into around 50 MMTOE equivalent of electricity. With numerous rivers and their tributaries in the country, the small hydro sector presents an excellent energy opportunity with an estimated potential of 15,000 MW. About 10 percent of this has been exploited so far.

Solar photovoltaics and thermal

India receives about 300 clear sunny days in a year i.e., equivalent to over 5,000 trillion kWh/year, which is greater than the total energy consumption of India in a year. Solar photovoltaics (SPV) with an aggregate capacity of 47 MWp, has a two and a half percent contribution in the renewable based power generation capacity [21].

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SPV systems have found applications in households, agriculture, telecommunications, defense and railways others. Solar thermal power generation potential in India is about 35 MW per sq. km [14]. Also widely employed by in India are non-grid thermal technologies, solar water heating, solar cookers, solar air heating, and, solar thermal building design. Solar water heaters in domestic field, saves energy (electricity or furnace oil) that used to heat water and thus conserves conventional sources of heat energy.

Solar technologies for most applications currently having low efficiencies, are highly capital intensive and not cost-competitive. Single Crystal Czocharalski (CZ) Silicon cells have efficiencies in the range of 14 – 17 per cent, whereas passive emitter, rear locally diffused (PERL) cell have efficiencies approaching 25 per cent. The challenge is to increase overall system efficiency and bring down costs so as to make solar products affordable apart from making solar electricity cost-competitive.

It has been assumed from literature that 1 million hectare area is capable of generating 236 MMTOE of solar electricity. Even if only 5 million hectare or around 5 per cent of the waste lands were to be deployed for solar power generation, a total amount of around 1200 MMTOE electricity demand could be met from this source alone. However, if system efficiency could be raised from the current level of 15 per cent assumed herein, the land mass area required for the purpose would reduce proportionately. Estimates indicate 800 MW per year potential for solar thermal based power generation in India during the period 2010 to 2015, with worldwide advancements in the parabolic trough technology [22].

Emerging developments in renewables

Urban, municipal and industrial wastes can be pyrolysed or plasma gasified, which have high potential for energy extraction to the tune of 1,700 MW, comprising 1,000 MW of power from urban and municipal wastes and about 700 MW from industrial waste. Gasification process produces syngas that consist mainly of hydrogen and CO and it can be burned in suitably equipped gas turbines and reciprocating engines. Concentration have also been shifted towards the Energy from Chemical Sources i.e., Fuel Cells; Hydrogen Energy; Geothermal Energy; Alternative Fuels for Surface Transportation; Biofuels; Ocean and Tidal Energy.

At least two major barriers that would need to be addressed in the case of hydrogen are system efficiency and system cost, apart from safety related aspects. Despite the fact that fuel cells are theoretically capable of achieving 83 per cent efficiency levels for combined heat and electricity applications since they are not constrained by the limits imposed by the Carnot cycle (real fuel cells, in general, generate only about 60-70 per cent of the theoretical maximum), the electrolysis electricity to hydrogen to fuel cell electricity route offers only 40 per cent efficiency for combined heat and power applications and even lower for only electricity applications.

Hydrogen obtained from electrolysis is around 3 items more expensive then that obtained from fossil fuel. At present, natural gas is the cheapest source of hydrogen with coal as the second choice.

The cost of some fuel cells per peak watt of output could be the same as that for solar photovoltaic cells, which currently cost around Rs 150/$watt_p$ as compared to Rs. 2/ watt for an IC engine. A mid-size passenger car requires around 75 kw_p (equivalent to 100 hp) power output, with city buses requiring atleast three times that level. This apart,

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switching to a hydrogen infrastructure would require heavy investments in the region of atleast Rs 1,00,000 crore. [10]

Other emerging renewable resources on which now government is shifting its concentration as sustainable energy source is ocean energy. There are a number of other renewable energy technologies, such as tidal, ocean currents, wave, hot dry rock, ocean thermal energy which are currently at technology demonstration stage [16]. Some of these technologies will offer potential in the future.

Energy from wastes

The rising piles of garbage in urban areas caused by rapid urbanization and industrialization throughout India represent another source of non-conventional energy. On an average Almost 450 gms of solid waste is generated per person per day in India. Good potential exists for generating approx. 15,000 MW of power from urban and municipal wastes and approx. 100 MW from industrial wastes in India [17]. It has been estimated that about 70 MW equivalent power could be generated from urban & municipal waste alone. This potential is likely to increase further with our economic growth [23,16]. Energy from waste can be in form of biogas, steam, fuel pallets or direct electricity generation. Waste can be animal waste, agriculture residue, abbatoir waste.

Ministry of Non conventional Energy sources in its recent estimates have indicated that about 40 million tonnes of solid waste and about 5000 million cubic metres of liquid waste is generated every year in the urban areas of the country. National Programme on Energy Recovery from Urban and Industrial Wastes was launched during the year 1995-96 with the following objectives: (i) creation of conducive conditions with financial and fiscal regime to promote, develop and demonstrate the utilisation of wastes for recovery of energy; (ii) improvement in the waste management practices through adoption of renewable energy technologies for processing and treatment of wastes prior to disposal; and (iii) promotion of projects for recovery of energy from wastes from Urban and Industrial sectors.

Geothermal

The best geothermal fields are located within well-defined belts of geologic activity. Today, geothermal power generation plants have a total installed capacity worldwide of more than 8,000 MW and can be deployed for base-load electricity production. Geothermal energy converting systems can provide electricity with an annual capacity load factor of over 90 percent. Low–medium temperature geothermal resources exist at seven geothermal provinces in India in the form of 400 thermal springs with surface temperatures varying from 47 – 98°C [14].

Ocean Energy

Ocean energy consists of two types of energy: thermal energy from the sun's heat, and mechanical energy from the tides and waves. Oceans cover (361,132,000 sq km) i.e., 70.8% of Earth's surface, making them the world's largest solar collectors. India has a water area of 314,400 sq km [16]. The sun warms the surface water a lot more than the deep ocean water, and this temperature difference stores thermal energy. Thermal energy is used for many applications, including electricity generation. There are three types of electricity conversion systems: closed-cycle, open-cycle, and hybrid.

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The total power of waves breaking on the world's coastlines is estimated at 2 to 3 million megawatts. In favorable locations, wave energy density can average 65 megawatts per mile of coastline. India has a coast line of 8,041 kms which can act as a suitable option. For wave energy conversion, there are three basic systems; channel systems, float systems and oscillating water column systems. The mechanical power created from these systems either directly activates a generator or drives a turbine/generator.

Further oceans act as sinks and are currently absorbing 7.4GtCO_2/yr (0.9ppmv/yr). The amount of CO_2 that can be taken up by the oceans in a given year is a function of wind speed, air, and water temperatures and concentration gradient and is, therefore difficult to determine [16].

Climate change mitigation initiatives

Three major advantages of renewable energy resources are, firstly, these powers will never run out; secondly these reduce dependence on current power sources and most importantly they put extra burden on environment by reducing Carbon dioxide emissions.

Technological improvements in efficient combustion of coal, renewable energy sources can effectively reduce CO_2 emissions. Electricity generation from renewables is assuming increasing importance in the context of large negative environmental externalities caused by electricity generation, due to the predominance of fossil fuels in the generation mix. Rising energy demand has led to a rapidly rising trend of energy emissions from India. Although the per capita carbon emissions for India are quite low at present (about 20 times lower than US per capita emissions), total annual emissions exceed 200 million tonnes of carbon [21]. The economy has high carbon intensity due to a large share of coal in the energy mix. Following a low carbon intensity path is complicated by the fact that there are large indigenous coal reserves, but limited oil and gas reserves. While India has experience with emerging renewable technologies, the capital and foreign exchange constraints are likely to restrict a shift away from coal, unless the economic and fiscal policies to relax these constraints are instituted under a cooperative global regime.

Present, the only mechanism by which any responsible and developing country like India can participate in the global emissions limitations regime is through a cooperative instrument such as the Clean Development Mechanism (CDM). CDM is a voluntary mechanism for promoting GHG emissions mitigation projects in Non- Annex I countries in cooperation with Annex I countries [25]. CDM projects can reap benefits such as technology transfers, improvements in local environment and share of surplus from CDM projects [26].Indian is party to UNFCC and also have agrees the Kyoto protocol.

In order to mitigate Greenhouse gases on large scale use of renewable energy resources is a must. Latest projections by the Ministry of Non-conventional Energy Sources plan an additional 10 GW of renewable capacity between 2000 and 2012, constituting 10 percent of the overall power generation capacity additions [14]. A study by Ghosh et al, 2002 [27] suggest that Biomass and cogeneration technologies have more than a 60 percent share in the total mitigation by RETs. These technologies have the highest share in mitigation in the short-term (by 2015), as they offer cheap mitigation opportunities. Wind and solar generation, being guided by availability of wind and sunshine, limits the mitigation potential of these technologies. Generation by small hydro, and hence its mitigation potential, is constrained by water availability due to sharing of water resources for irrigation purposes. Mitigation by wind progressively increases over time with stricter mitigation requirements, but their share in overall mitigation is limited to about 15 percent of the total by all renewable technologies.

Conclusions

Tightening of carbon emission constraints leads to alterations in the energy mix on the supply side, and this thereby increases investments in renewable energy. The challenges of present energy scenario offers India a window of opportunity in the form of renewable energy sources to expand and diversify its energy supply towards greater sustainability, as well as environmental and social responsibility. India has witnessed substantial growth of renewable energy technologies in the country during the last two decades. This growth can be attributed to the participation of the private sector, as a consequence of favourable policy frameworks and investment options and opportunities available for such technologies. However, much more remains to be done in harnessing the true potential of renewables in the country. MNES, IREDA and other networking agencies are to achieve the targets by 2012 to reduce dependence on fossil fuels, which would result in a clean and green ‘Earth’.

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