RENEWABLE ENERGY STRATEGIES FOR INDIAN POWER SECTOR

by

Ghosh Debyani, Shukla P.R., Garg Amit and Ramana P.V.

A Centre De Sciences Humaines (CSH) Occasional Paper

Table of Contents

I INTRODUCTION

Overview of the Indian Power Sector

Electricity consumption in India has more than doubled in the last decade, outpacing economic growth. The primary energy supply in the country is coal-dominant, with the power sector accounting for about 40 percent of primary energy and 70 percent of coal consumption. It is also the single largest consumer of capital, drawing over one-sixth of all Indian investments over the past decade. (CMIE, 2000) The Indian power sector is characterized by large demand-supply gap. Official estimates place the present energy shortage at around 5 percent, with peak power shortage of close to 10 percent (http://powermin.nic.in, 30/04/2001). Faced with unreliable power supply, many industries have invested in on-site power generation that now accounts for more than 10 percent of total capacity (CMIE, 2000). The distribution losses have reached staggering proportions in most of the regions accounting for more than half of the total power generated**,** largely due to theft, non-metering, poor collection and inefficiencies in the distribution network. Five regional grids operate in India, with regional grids connecting state transmission networks within a region. But progress in setting up of an integrated national grid has been slow due to poor coordination among regional authorities, and technical and financial problems. The pace of rural electrification has been slow. More than 80,000 villages in the country are still to be electrified, with a significant number of such villages located in economically backward and difficult regions. The inefficiencies in the overall electricity system can be traced back to the institutional structure in the power sector, with government assuming predominant role in electricity supply. Operational inefficiencies grew in the absence of competition and financial discipline, undermining the power sector's financial health. State Electricity Boards (SEBs) in particular were wide open to political influence and tariff distortions due to subsidies and cross-subsidies across consumption sectors, with the average electricity tariffs remaining about one-fifth below the average cost of supply (TEDDY 1999/2000). This weakened power sector investment incentives and drained public funds, undermining the power sector's financial health. By the early 1990s, the sector was overdue for sweeping reforms to enhance revenues and mobilize investment in the short run, and to change ownership and the regulatory structure in the long run. Reforms underway fall broadly into the categories of SEB corporatization, privatization of power corporations, unbundling (vertical divestiture), and institutional restructuring among which the setting up of regulatory commissions at the center and states and formation of the central transmission utility are significant. The greatest challenge in the reforms process has been restructuring and rationalization of electricity tariffs, in the face of strong socio-political influences.

The technologies available for electricity generation are myriad, reflecting in turn the diversities in resource endowments across the various regions, regional development patterns, fuel transportation infrastructure, demand characteristics, socio-environmental and political issues. Due to the availability of vast indigenous resources, coal remains the mainstay of power generation providing about three-fifths of the country's power. Large hydropower at present has about one-quarter share, and has shown a declining trend over the past decade. Gas-based power has grown very rapidly from almost nothing to one-twelfth of total generation in the last decade due to the low risk associated with lower capital requirements, shorter construction periods, and higher efficiencies. Nuclear contributes around 3 percent share. Renewable technology capacity, (renewables in this paper include small hydro, wind, cogeneration and biomass-based power generation, and solar technologies), other than large hydro, aggregating 3000 MW as on 31st December 2000, has a three percent share in the overall generation capacity. (CMIE, 2000). India has a significant program to support renewable power, exemplified by wind power capacity that rose from 41 megawatts in 1992 to 1267 MW by the end of 2000 (MNES, 2000).

The electricity consumption in India has been increasing rapidly due to growing industrialization, modernization of agriculture and rising incomes. However, the per capita electricity consumption at 318 kWh remains very low, six times below the global average, five-percent of that in the U.S.A and, nearly a half of that in China (WRI, 1998). Over the past two decades, the electricity consumption has grown at the rate of close to 9 percent per year, with very large increases in the agricultural and household sector consumptions. They have a 20 to 30 percent share respectively in the overall consumption. The phenomenal rise in energy consumption from agricultural activities is due to greater irrigation demand by new crop varieties and the very low price of electricity for that sector. The gap between electricity tariffs and cost of supply is mainly due to subsidized rates for agriculture. Industrial consumers pay higher costs and provide a cross-subsidy worth over US$5 billion[1] in 1997, equal to almost half of power sector investments that year (TEDDY 1999/2000). Concerns about the environmental impacts of power plant projects have been growing with the power sector having a substantial share in the fossil fuel related emissions, land degradation and water pollution.

Position of Renewables in the Power Sector

The Indian government initiated a renewable energy program to diversify national energy sources about two decades back. The renewable energy power generation capacity as on December 2000 was 3000 MW, accounting for 3 percent of the overall generation capacity. The total potential of renewables in the country is estimated at 100,000 MW. (MNES, 2000) Till now, contribution of renewable energy technologies in the total electricity generation has been at around one percent of the overall generation due to the low capacity utilisation of most of the renewable energy technologies. The installed capacities of the technologies vis-à-vis their estimated potential is shown in Table 1.

Table 1: Progress of Renewable Energy Technologies for Electricity Generation

Technology	Cumulative Installation as on 31st December, 2000	Estimated potential
Small Hydro (MW)	1341	15,000
Wind (MW)	1267	45,000
Biomass and Cogeneration+ (MW)	308	19,500
Solar PV# (MW)	47 MWp	
Solar Thermal (MW)	*	
Note: The potential for solar energy is estimated at 20 MW/km^2		

+ Estimation of the biomass and cogeneration potential is at 16000 MW and 3500 MW respectively. The installed capacity of biomass-based combustion power is 63 MW and cogeneration based power generation capacity aggregates to 210 MW. Installed capacity of biomass gasifiers is 35 MW

Among the total installed capacity, grid-interactive solar power for peak load shaving in urban centres and providing voltage support in rural areas aggregates 1.04 MW

* A 140 MW integrated Solar Combined Cycle Power Plant (ISCCPP) is being implemented at Mathania in Jodhpur, Rajasthan.

Source: MNES Annual Report, 2000-2001;

[1] All monetary figures in this paper are in 1999-2000 prices and assume a conversion rate of Rs.47 to 1$.

India is the only country to have a full-fledged national ministry to deal with renewables. The Indian renewable energy program was launched primarily as a response to the perceived rural energy crisis in the 1970s. It was initiated with a target-oriented supply push approach with provision of direct cash subsidies for promotion of the RETs. Primarily, the programme sought to develop niche applications, such as in rural areas where grid electricity was unavailable as renewables are suitable for decentralised power generation. In the early 90s, 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 commercial route. The strategy for promotion of renewables was through fiscal incentives and elimination/reduction of direct subsidies, encouragement to private entrepreneurs for investing in renewable energy technologies (RETs) through measures like accelerated depreciation and reduced import duties, and funding assistance from multilateral and bilateral agencies. 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. 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. However, a number of barriers still remain to be overcome, if RETs have to become commercially viable alternatives. In the initial years after launching of the programme, promotion of RETs as a panacea to solve energy problems with unrealistic high expectations about their performance led to disappointments due to the low level of maturity of the technologies and little international experience in their usage. The 'push' approach limited the deployment of RETs by fixed targets and allocated budgets that did not create signals for the market to develop. In some cases, poor technology selection led to failures as in the case of wind energy pumps. Problems were encountered in creating supporting infrastructure for penetration of the technologies such as training and information programmes, operation and maintenance of the technologies and monitoring. 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. Lack of R&D focus and low R&D budget allocation have posed a barrier in bringing down the technology costs and enhancing their competitiveness.

Electricity generation from renewables is assuming increasing importance in the context of large negative environmental externalities associated with the process of electricity generation, which are mainly caused by the predominance of fossil fuels in the generation mix. Managing environmental and social impacts has drawn considerable attention in policy-making, project development, and operations. Over the past three decades, surface mining of coal has increased, and poor mining practices have caused significant deforestation and land degradation (ESMAP, 1998). There is increasing environmental concern about the contribution of coal-fired power generation to air emissions. Coal burned in power plants on an average has an ash content of 40 percent and more. Low-quality fuel, together with low combustion efficiencies of 33 percent in pulverized coal plants (ESMAP, 1998; Biswas, 2000), generate large amounts of ash and particulates along with emissions of sulphur dioxide ($S0_2$), nitrogen oxides (NOx), carbon dioxide (CO_2), and heavy metals. Power sector contributes about 40 percent of the total carbon emissions (SAR, 1996). Social and environmental impacts of hydro projects have been a cause of major controversies and have lead to massive delays in project completion.

The energy scenario in India, especially the power sector, is characterized by growing demand-supply gap, inherent inefficiencies, distorted pricing mechanisms, weak institutional structure, environmental unsustainability and socio-political influences. The future economic development trajectory is likely to result in rapid and accelerated growth in energy demand, with attendant shortages and problems. The growing energy consumption is likely to lead to increasing emissions of gases, compounding the pollution problems at the local level and increasing Green House Gas (GHG) emissions. For instance, a long term projection (Shukla and Pandey, 1998) of the business-as-usual scenario over a forty year period (1995-2035) indicates that energy consumption shall treble; electricity generation shall rise by 5.4 times; coal shall continue to be the main source of fuel; the carbon emission shall go up by 3.6 times; and the carbon intensity shall increase. Therefore, it is imperative to develop and promote alternative energy sources that can lead to sustainability of the energy system. Although at present the contribution of renewable electricity is small, the capabilities promise the flexibility for responding to emerging economic, socio-environmental and sustainable development needs.

II REVIEWING THE ROLE OF RENEWABLE ENERGY

Evolution of the Renewable Programme: Successes and Impediments

For over two decades, the Renewable Energy Technology (RET) dissemination program began primarily as a response to the challenge of the newly perceived rural energy crisis (WGEP 1979). It started with the creation of CASE (Commission on Additional Sources of Energy) in 1980, and then the DNES (Department of Non-conventional Energy Sources) in September, 1982. DNES was converted into a full-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) (MNES, 1999-2000).

In the initial phase that stretched till the early 90s, the programmes had a target-oriented supply-push approach to develop, disseminate, and demonstrate RETs. The programmes were by a social orientation and began primarily as populist measures. Government agencies identified the equipment suppliers and fixed the technology price. The target setting was controlled by financial allocation made from the government budget. Individual technologies were promoted through design and development support, and through the establishment of large-scale demonstration programme. This policy regime was 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. Provision of financial incentives like subsidies, 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 limited the commercialisation of the technologies.

During the early 1990s, the orientation of the renewable energy programme was altered as part of the overall reforms process. There was a shift from financial to fiscal incentives for faster diffusion of renewable energy technologies. In order to give the required focus on commercialisation, market orientation, and to have greater involvement of the private sector, the MNES was restructured in 1993 into sectoral groups of (a) rural energy, (b) urban/ industrial energy, and (c) power generation. Through the restructuring, emphasis shifted towards policies, planning and institutional linkages to promote RETs within each sector. Three technologies – wind power, small hydropower and solar photovoltaic power – were targeted for commercialisation under a set of revolving funds created from international finance, mainly from the World Bank. The management of this task was entrusted to the Indian Renewable Energy Development Agency (IREDA), an autonomous financial institution created in 1987 under the MNES (http://www.mnes.nic.in) Direct subsidies on various RET programs were either removed or drastically reduced, and several fiscal incentives were provided instead, to users as well as manufacturers. Exceptions to this were biogas, improved stoves and solar photovoltaic (SPV) lighting programs which continued with MNES subsidies, albeit much rationalized. Private entrepreneurs were encouraged to invest in RETs by taking advantage of the fiscal benefits such as accelerated depreciation, sales tax and import duty exemptions, reasonable buy-back rates, etc. Facilities were established for banking and wheeling of power, third-party sale, concessions/exemptions in state sales tax and octroi. To encourage investment, some of the measures introduced included waiving of industrial clearance for setting-up of renewable energy industry and waving of clearances from Central Electricity Authority for power generation projects upto Rs.100 crores. With this multi-pronged strategy, India developed, by beginning of 1998, the world's largest SPV lighting program, fourth largest wind power program, and second largest biogas and improved stove programs (MNES, 2000). Some of the existing measures for encouraging foreign investment in renewable energy projects include allowing foreign investors to enter joint ventures with Indian partners for financial and/or technical collaboration, automatic approvals for upto 74 percent foreign equity participation in a joint venture projects, allowing 100 percent foreign investment as equity, and encouraging foreign investors to set up renewable energy based power generation projects on Build-Own-and-Operate basis. (http://www.mnes.nic.in)

Throughout the renewable energy programme, progress of renewable energy technologies and their large-scale commercialisation have been impeded by a number of barriers. When the renewable energy programmes were launched in the early 1980s, 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 (Sinha, 1992). The policy driven push approach failed to create signals for market development and the programmes became self-constraining. Targets and the allocated budgets limited them. Since the early 90s, the technology push approach embodied fiscal and financial incentives such as subsidised interest rates, capital subsidies, long repayment schedules, tax concessions, low import tariffs, duty waivers and accelerated depreciation. But these incentives were not sustainable in the long run. Lack of R&D focus and low R&D budget impeded lowering of technology costs and performance improvements. In some cases like wind, poor technology selection led to failures. Pricing policies in the energy sector that do not internalise the costs of the environmental externalities impeded the progress of renewable energy technologies (RETs). Some of the programmes encountered implementation barriers in setting up of supporting infrastructure including training, operation and maintenance, awareness creation, monitoring, etc (Ramana, 1991; TERI, 1989). The programmes failed to develop an orientation towards commercialisation of the technologies along with providing energy services to the consumer with the setting up of marketing, sales and servicing infrastructure. The next section traces the development of specific renewable energy technologies, their existing status and some of the issues related to technology penetration.

Renewable Energy Technologies for Electricity Generation

Small Hydro Power

Status: Hydro based power generation upto 25 MW capacity, classified as small hydropower, offers a number of advantages for electricity generation. It has been one of the earliest known renewable energy sources, in existence in the country since 1897 (TEDDY 2000) with a present installed capacity of 1341 MW (MNES, 2001). Estimates of MNES place the small hydro potential in India at 15,000 MW and more than 8000 MW up to 15 MW capacity have been identified through more than 4000 sites in different states of India (TEDDY 2000). Since a large potential of this technology exists in remote hilly areas, development of small hydropower for decentralised power generation leads to rural electrification and local area development. The gestation period of the technology is low and the indigenous manufacturing base is strong. Watermills or 'gharats' are used widely in the rural areas for operations such as milling and husking of grains and these can be used for electricity generation with some upgradations/modifications

Development Stages: Initially, the development of SHP was restricted to small hilly streams in the Himalayan region that had few alternative sources of power. Later, between 1930 and 1950, some low head SHP installations came up on a number of canals on the Ganga. Though the earlier Five-Year Plans did give priority to rural electrification, no comprehensive plans were made for the development of SHP. Development of this technology received some impetus during the Eighth Five-Year Plan with additional fund allocation. India has a well-established manufacturing base for the full range and type of small hydro equipment. During 1989 to 1993, in congruence with the supply-push approach adopted by the government, demonstration projects were set up in various States to regenerate interest of State Governments/SEBs along with provision of financial incentives like capital subsidy of up to 50 percent of the cost of project cost. (http://www.mnes.nic.in, 30/01/01) Policy initiatives for private participation in SHP started during 1993-94, keeping in view the overall policy of Government of India to encourage private sector participation in the field of power generation. So far, thirteen states namely, Himachal Pradesh, Uttar Pradesh, Punjab, Haryana, Madhya Pradesh, Karnataka, Kerala, Andhra Pradesh, Tamil Nadu, Orissa, West Bengal, Maharashtra and Rajasthan have announced policies for setting up commercial SHP projects through private sector participation. The MNES has also evolved a package of incentives and subsidies for the development of this sector, with special emphasis on mini/micro hydel projects in remote hilly regions. Most of the SHP projects are canal-based grid connected. However, there are some stand-alone projects that are decentralized and are managed by local community/ NGOs. About 35 portable micro hydel sets of 5-15 KW have been installed in remote and isolated locations to promote decentralised electricity generation. Policy initiatives undertaken by MNES include financial support during survey and investigation and project preparation, capital and interest subsidies for demonstration projects, renovation and modernisation works and for setting up of commercial projects. A programme for development/upgradation of water mills, popularly known as 'gharats', has been taken up by state nodal agencies and local organisations such as Water Mills Associations, cooperative societies, registered NGOs and other local bodies. According to estimates of National Watermillers' Association, half a million 'gharats' in villages can generate about 2500 MW of electricity at the rate of 5 kW per 'gharat'. International assistance is available in the form of World Bank loan of US $70 million for setting up of irrigation canal/dam-based small hydro projects of up to 15 MW capacity. The world's first GEF (Global Environment Facility) project with an outlay of US $15 million had been operationalized in 1994 through the MNES and the UNDP (United National Development Programme) for setting up of demonstration projects and preparing a national plan for the development of small hydel projects in the entire Himalayan region.

Technology penetration issues: A number of barriers have impeded the penetration of small hydropower and the pace of growth has been slow. The investment costs of small hydro technology are substantially high due to terrain inaccessibility and lack of suitable transportation linkages in remote hilly areas. Supply-demand mismatch arises due to the fact that remote hilly areas having high small hydro potential usually have low demand for power, thereby limiting its viability as a decentralised power generation option. Transmission of power to areas with higher demand, away from the source, necessitates high investment cost for construction of transmission networks in difficult terrain. Institutional barriers in small hydro power development are the inadequate state plan allocation, lack of coordination among planning and implementing agencies, delays in the clearances and allotment of private sector projects, low priority of the SEBs to take up the projects, and lack of clear policy for private sector participation. In the case of stand-alone systems which involve local participation, success of small hydro development depends to a large extent on local capacity building programmes, setting up of appropriate institutional arrangements for demonstration, training and awareness programmes that help in technology adaptation and maintenance. Even though a large potential exists through upgradation of 'gharats' in rural areas, community participation has been limited to a few demonstration projects. Only private commercial participation is allowed with no law for the involvement of individuals, committees or communities. The government funds projects and maintains them. Realising the fact that community-based run-of-the-river hydel projects can help in partly solving the rural power crisis, states like Himachal Pradesh and Kerala have taken some initiatives. But a long road lies ahead for India to tread the path of success and solve the rural energy crisis in the country.

Experiences of other countries: In the case of small hydropower development, there are interesting lessons to be derived from success stories around the world, especially from neighbouring countries like Nepal and China (Down to Earth, 2000). Nepal has a high hydropower potential, and its present small hydro generation capacity stands at about 125 MW. Small hydropower programme was initiated way back in 1977 with the setting up of Small Hydel Development Board for supplying electricity to remote areas. In 1981, the government formulated a national development strategy for hydropower development to provide the rural masses new opportunities for self-reliance. ADB started funding microhydel projects in 1981 and till now its funding supports about 80 percent of the total projects in the country. Policy changes were initiated with delicensing of upto 100 kW capacity in 1984 that was revised upwards to 1000 kW in 1985. Initiatives were taken to encourage private participation in the power sector. Incidentally, Nepal is the first Asian country to privatise its power sector. The government provides a subsidy on electricity generation and transmission equipments. A large number of *ghattas* in Nepal have been upgraded for power generation and independent power supply projects have also been set up. Since the early 90s, institutional reforms delegated the management of small hydro projects to farmers by the formation of co-operatives. Under REDP's (Rural Energy Development Programme) decentralised and community based rural energy programme initiated in 1996, the small hydropower programme achieved a high degree of success. The key driving forces for the programme's success have been government policy initiatives to stimulate community participation, local capacity building measures and community empowerment through social mobilisation. The local Governance Bill initiated community participation in electricity supply, irrigation and agriculture and the community residing in rural areas was empowered for decision-making regarding the purchase of equipments, supply of power and fixing of costs. A bottom-up approach was adopted for decision-making where bodies such as the Village Development Council were involved at the lowest level from where the decision-making flowed to the District Energy Committee and was finally sanctioned by the District Development Committee. The Agricultural Development Bank of Nepal provided funding for the microhydel projects and in an ideal situation, the users contributed about 30 to 40 percent of the costs.

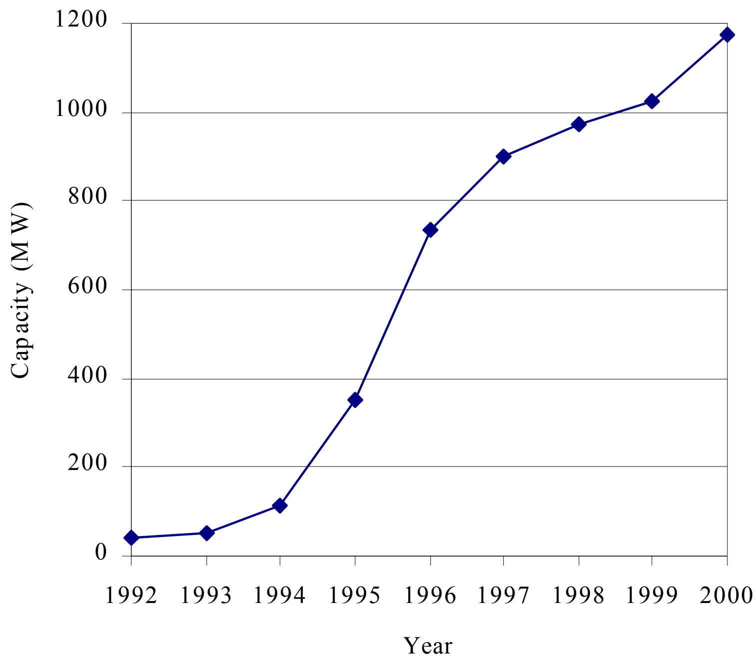
China charted a separate energy policy for rural areas as part of integrated rural development programmes. This provided the drive for decentralised rural electrification. Small hydropower projects were taken up as part of the poverty alleviation programmes and importance placed on their environmental friendliness. Funding was solely from local sources. The government played the role of an observer while enforcing standards and providing funding for R&D. The local administration owned and implemented the small hydro projects. Integrating the small hydro projects with irrigation and flood control works ensured water management. The success of the programme can be measured by the fact that while in 1975, only about 50 percent of the villages was electrified, it was as high as 95 percent in 1996 (Down to Earth, November 30, 2000, Vol.9, No.13, *Power to the People*; pgs: 32-44).

Wind Power

Status: India is positioned among the top five countries in wind power installation after Germany, USA, Denmark and Spain. Wind power capacity reached nearly 1267 MW by December 2000 with an aggregate generation of about 6.5 billion units of electricity. Private projects constitute around 95.5 percent of the total capacity and the rest are demonstration projects. Out of the total energy generated, about 80 percent consumption is for captive purposes while the rest is sold to the grid. Wind energy is one of the clean, renewable energy sources that hold out the promise of meeting energy demand in the direct, grid-connected modes as well as stand-alone and remote 'niche' applications (for instance water pumping, desalination, and telecommunications) in developing countries like India. The Ninth Plan (1997-2002) proposes a capacity addition of 1000 MW, with a capacity addition of 200 MW in the first year of the Plan (http://www.mnes.nic.in). Estimates by the MNES place the realisable wind energy potential in India to be 45,000 MW (MNES, 2000). Technical potential is estimated to be 10,000 MW, assuming 20 percent grid penetration, which is expected to go up with the augmentation of the grid capacity in potential states. The states with high potential of wind power are Gujarat, Andhra Pradesh, Tamil Nadu, Karnataka, Kerala, Madhya Pradesh and Maharashtra. The latest projections by the Ministry of Non-conventional Energy Sources plan additional 10 GW of renewable capacity by 2012 (MNES, 2001). It is envisaged that around 60 percent of this capacity or 6000 MW may come from wind power. ***Development Stages:*** The Indian Wind

Energy programme was initiated in 1984 with the objectives of wind resource assessment, setting up demonstration projects and providing industry-utility partnerships. The first wind farms in India were established in the coastal areas of Tamil Nadu, Gujarat, Maharashtra and Orissa. Before 1992, the installed capacity was just 41.18 MW, set up mainly through the demonstration program of the government. Subsequently, there was a steep jump in the generating capacity (Figure 1).

Figure1 Growth in Wind Power Capacity



S

ource: MNES Annual Report, 2000-2001.

Note: Figures in the graph are till March 2000

In the early stages of the wind power programme, the optimism with regard to wind power generation was centred on the demonstration effect of wind farms, which were supported largely by multilateral and bilateral funding agencies. For more than two decades, government programs alone drove the demand for wind power. Although there were multiple suppliers, government was the single dominant consumer, fixing technology prices on a cost-plus basis. Price signals therefore did not reflect market conditions. Reform policies initiated by the government after 1992 expanded the market's role in wind power development. Following the initial phase of government sponsored demonstration projects, the wind energy sector was liberalised for private participation in 1992 supported by appropriate policy incentives, fiscal incentives and institutional arrangements. A package of incentives was offered to wind power plant entrepreneurs, which included tax concessions (accelerated depreciation, tax holidays, excise and customs duty relief), soft loans and liberalised foreign investment procedures. The most attractive fiscal incentive was 100 percent accelerated depreciation on wind power equipment in the very first year of project commissioning (Rajshekhar et.al, 1999). The incentives altered the competitive advantage of wind power within the prevailing market dynamics in the Indian electricity sector and generated significant demand 'pull' for wind power by the private sector. Banking and foreign exchange reforms aided this. Technology transfer was facilitated by international wind turbine companies (often with generous financial backing from the governments of their home countries) competing to supply technology, and Indian companies forming joint ventures with wind equipment suppliers. To a certain extent, decline in California's wind energy programme led to dumping of wind power equipments to India that often had associated quality problems in equipments. Large imports took place from Denmark and Netherlands too. But during the course of technology adaptation, implementation experience lowered the costs of wind power and enhanced manufacturing and servicing capacity lowered the risk. In this technology development path, the government acted as a facilitator. The country at present has developed a strong indigenous manufacturing base for wind power equipments, with about 80 percent of the equipments being manufactured indigenously. Adherence to technical specifications has improved technology performance. There are a number of manufacturers engaged in the production of wind turbine equipment, either in joint venture or as license production with international collaborators. The growth rate in wind power capacity that peaked in 1995/96 subsided thereafter. After a period of explosive growth that pushed India's wind energy utilization up to the world's third highest, investment fell sharply from mid-1996 to the end of 1998. This can be partly attributed to lowering of tax-credit benefits due to levying of MAT (Minimum Alternate Tax), reduction of corporate income tax by the Union Government, withdrawal of third-party sales in some states and very low availability. The private sector investment took advantage of the concessions offered by the government. But with the introduction of the minimum alternate tax (MAT) in 1996/97, attractiveness of investment in wind power plants decreased (Rajshekhar et.al, 1999).

Policies for wind power development offer a number of incentives for private participation in wind power development both at the centre and in the states. Some of the measures include transmission and distribution through the grid at economic tariff (with escalation provision), and wheeling and banking of electricity. Access to the grid is guaranteed to wind producers via mandatory wheeling (transmission from one region to another via a third). Fourteen states have introduced policies based on MNES guidelines that include 2 percent wheeling charges, banking up to one year, third-party sales at remunerative prices, buy back facility at minimum price of Rs.2.25 per kWh for base year 1994-95, capital subsidies, sales tax concessions, and 5 percent annual escalation in tariff. The central government provides financial assistance to the states in the form of covering 60 percent cost of the wind turbine equipment, maintenance spares, and erection & commissioning (subject to a benchmark cost of Rs.3.2 crores/MW) costs, while all other costs are borne by the state. Central and state power generating agencies such as National Thermal Power Corporation (NTPC), National Hydroelectric Power Corporation (NHPC) and State Power Development Corporation are being asked to earmark a certain share of their new capacity additions from renewable sources like wind (MNES, 1999-2000).

Technology penetration issues: The unsustainability of the financial incentives for promoting wind power development manifested itself in sharp decline in the wind power capacity growth. Rising use of wind power—fuelled by tax rebates increased tax revenue losses to levels that were financially unsustainable for the government budget. Low capacity utilisation (the assessment was based on 20 percent utilisation, but in most cases they were found to be lower) raised generation costs. The levelised generation cost of electricity using wind power is not competitive with generation from other sources such as coal. The reduced cost of wind power, combined with greater awareness of the need to internalise environmental costs from conventional power sources, may enhance its market penetration. The scale of operation of is often constrained by the operational problems in matching the availability (supply) with the load duration curve. Wind power is quite often seasonally variable, with the peak output from wind turbines occurring during the monsoon season. Out of the commercial wind energy projects, 70 percent of the investors at present account for only 30 percent of the power produced, while the remaining 30 percent of the investors generate 70 percent of the total wind power (Down to Earth, Volume 8, No.3, June 30, 1999; ***Gone with the Wind***). There are contentions between the SEBs and the promoters of wind power projects due to the reactive power requirements of wind farms. The reactive power requirements, needed to charge their coils before they can start generation, can be quite substantial. This energy is drawn from the state grid. According to most SEB directives, the reactive power requirement should not be more than 30 percent of the wind energy generated. But in certain cases, the requirement could go up to 60 to 70 percent, especially when there are repeated start-stop operations during low wind speed periods (http://www.indiainfoline.com, 07/02/01). This has been a major bone of contention between the SEB and the promoters in Tamil Nadu. Wind energy development has been largely hindered by unstable and non-uniform policies across states. For instance, the Tamil Nadu Electricity Board (TNEB) recently announced a slashing of the power purchase price by 50 paise per unit of wind power to Rs.2.25. Wind energy development is also facing rough weather due to a Allahabad High court order on a petition filed by an organisation (called *Swadeshi Products Protection Forum*) that initiates probing into anti-dumping of foreign wind power equipments. This led to IREDA putting on hold all loans to wind power investors and the MNES stopping the issuing of deemed export certificates to wind mill manufacturers for import of components. (FE, 20th May 2001) Such fluctuations in the policies deter investors and hinder technology penetration. Sustainable development of wind power will require addressing the economic, technical and institutional barriers being faced.

Biomass-based Power Generation/Cogeneration

Status: Biomass, consisting of woodfuels, crop residues and animal dung continues to dominate energy supply in rural and traditional sectors, having about one-third share in the total primary energy consumption in the country. Co-generation technology, 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, etc. The aggregate biomass combustion based power and sugar-cogeneration capacity by the end of December 2000 was 273 MW, with 210 MW of cogeneration and the rest biomass power. In the area of small-scale biomass gasification, a total capacity of 35 MW has so far been installed, mainly for stand-alone applications. The combined potential of biomass and sugar-cogeneration based power generation is estimated to be 19.5 GW. The cogeneration potential from bagasse in existing

430 sugar mills is alone about 3.5 MW, with Maharashtra and Uttar Pradesh accounting for about 2 GW potential (TEDDY 2000).

Development Stages: The prime power generation technologies using biomass are direct combustion, cogeneration and gasification. Bioenergy systems are ideal for decentralised power applications as well as grid connections. Power generation systems can range from small scale (5-100 kW), medium scale (1-10 MW) to large-scale (about 50 MW) (Ravindranath and Hall, 1995) applications. Unlike other energy forms like wind, small hydro and solar, biomass power is not site specific, i.e. it can be set up at any location where plants can be grown and domestic animals reared. Cogeneration and biomass based power generation offer attractive alternatives for captive power generation when grid electricity supply is unreliable. Biomass based power generation offers *environmental benefits* such as reclamation of degraded land and improvements in land productivity, lower level of emissions during generation- both of GHGs like carbon dioxide and local pollutants like particulates and SO_X. Organized production of wood fuels (through commercial or co-operative sector) and modernized conversion has potential to make wood fuels a competitive commercial fuel vis-à-vis the fossil fuels. Power projects based on biomass plantations have the potential to offer new avenues of employment through collection, storage, handling and utilization of biomass materials especially in rural areas, promote rural industries and generate rural employment. Besides, energy plantations can become means to restore deforested and degraded lands in tropical and subtropical regions.

A National Programme on Biomass Power/Cogeneration is being implemented which focuses on the following- biomass-based power generation; cogeneration; research and development; and biomass resources assessment. The objectives are to optimally utilise a variety of biomass material such as agricultural residues, agro-industrial residues, forestry-based residues and dedicated energy plantations by adoption of state-of-the-art advanced technologies. Progress in biomass conversion technologies in the last two decades, either based on gasification or combustion, have largely improved their potential to be used as competitive technologies. Some of the thrust areas for technology advancements are development of high-pressure boilers and new turbine configurations; cost effective biomass handling, storage and drying systems;

feasibility of blending or co-firing of mix of biomass materials, or with fossil fuels; installation and evaluation of Pilot Dendro-thermal Power Plant; and indigenous technology development/adaptation for advanced biomass gasification involving gas turbines in combined cycle mode. Advanced technologies like biomass-integrated gasifier gas turbine technology (BIG/GT), steam injected gas turbine (STIG) and intercooled steam-injected gas turbine (ISTIG) technologies can achieve very high conversion efficiencies of about 45 percent or more. Policy initiatives have been taken by the Government for promotion of biomass and cogeneration based power generation. The Ninth Plan focus for bagasse based cogeneration includes awareness building programmes through launching demonstration programmes in cooperative/private sugar industries. Private participation for setting up power projects is being encouraged through the joint venture route, where foreign investors can set up projects on Build Own and Operate basis (MNES 2001). As part of the technology-push approach financial incentives are being provided in the form of interest rate and capital subsidies, tax exemptions, central and excise duty concessions and accelerated depreciation for promotion of megawatt scale biomass energy programmes, and providing technical and financial support for the preparation of Detailed Project Reports (DPRs). Several states provide incentives in the form of buy-back/wheeling/banking of generated electricity by the State Electricity Boards, incentives in the form of sales tax exemptions, and participation in equities and grants.

Technology Penetration Issues

Cogeneration: Various issues need to be addressed to exploit the potential of cogeneration based power generation. Large incremental investment requirements for setting up cogeneration units are a constraint in setting up cogeneration facilities in some of the existing industries. The incremental investments required for generating about 9 MW of surplus electricity from a 2500 TCD sugar mill is estimated to be around Rs.230 million. (Ravindranath and Hall, 1995) Sugar mills, which have the highest cogeneration potential, operate only seasonally and utilities are unwilling to purchase power from such units. Some of the technical barriers faced by the industries are upgradation of existing mills, installation of power generation systems, synchronisation and feeding of electricity to the grid. Sometimes the sugarcane bagasse may be channelled for alternative uses, e.g. for paper production. The market for surplus power from sugar mills is not ensured and there is no clear government policy in this regard. Appropriate policy regime with respect to wheeling, banking and buy-back of power generated from the co-generating units does not exist. The factors that are likely to shape cogeneration based power are future energy prices, both from cogeneration as well as from competing systems; presence and expansion of those industries from which a high potential for power generation using cogeneration techniques exist; technical developments; State and Central Government policies.

Biomass based power generation: For setting up of large-scale biomass based electricity generation technologies, the most important issue is ensuring a *continued and reliable supply* of biomass, especially woodfuels. Sustained supply of biomass will require enhanced production of energy crops where critical issues related to land availability, enhancing productivity through technological interventions and other economic operations related to biomass supply will come to the fore. An important issue in this context would be land availability for ensuring reliable supply of biomass vis-à-vis its utilisation for foodgrain production. The delivered cost of fuel, including the cost of biomass and the transportation cost, is an important factor that determines the competitiveness of this form of generation with that from other sources. The setting up of a fuelwood market will involve huge fund requirements for afforestation programmes; empowerment and involvement of local communities; and harvesting, transportation, marketing and pricing of forest products. Co-operative bioenergy systems could be launched where farmers in a given catchment area launch a cooperative- each farmer is given some land dedicated to energy plantation, while professionals handle the management of the entire system. A shift in the perspective with respect to biomass energy strategies will be necessary to treat biomass as a competitive and modern energy supply source, reorient technology policy, integrate biomass policy with development and environment policy and support development of competitive energy markets using biomass technologies. In the short term there needs to be enhanced utilization of biomass, more information dissemination programmes to promote usage, technology transfer, coordination among institutions and subsidy to biomass technologies. In the medium term, there should be development of scale economy based technologies, R&D of conversion technologies, removal of distortions in energy tariffs and Institutional development. In the long run, the infrastructure related to biomass energy usage should be adequately developed along with institutions and policies for competitive biomass energy service markets.

Solar Technologies

Status: Solar Photovoltaics (SPV) contribute at present around two and a half percent of the power generation based on renewable energy technology in India. Solar photovoltaic systems with an aggregate capacity of 47 MWp have been deployed for different applications (MNES 2001), that includes twenty-one fifteen grid interactive solar photovoltaic power projects aggregating 1.615 MWp for providing voltage support in rural areas and peak load shaving in urban areas. Solar thermal technologies have a very high potential for applications in solar water heating systems for industrial and domestic applications and for solar cooking in the domestic sector. Solar Thermal Power Generation potential in India is about 35 MW per Sq. Km 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 (TEDDY 1999/2000). A project for setting up of a 140 MW integrated solar combined cycle power project has been initiated at Jodhpur in Rajasthan. It comprises of 35 MW solar thermal component based on parabolic trough collectors and 105 MW power generation based on naphtha/gas. This project is going to be implemented by Rajasthan State Power Corporation Limited (RSPCL). It is one of the largest such projects in the world, being funded by Global Environment Facility grant and loans from German KfW (MNES, 2001).

Development Stages: Dissemination of SPV technology has been undertaken by a technology-push approach adopted by the government. In the initial years, considering that SPV technology was relatively new and unproven, a major fraction of the budgetary allocation for SPV was put into research and development programme. In 1992, SPV was one of the three RETs identified as targets under the programme to commercialise renewable energy technologies with international assistance provided by a consortium of multilateral and bilateral agencies, and facilitated by the World Bank. As part of this approach, SPV programme developed two distinct components: (i) a socially oriented dissemination programme implemented by state nodal agencies with MNES subsidies; and (ii) a market-oriented scheme implemented by the

Indian Renewable Energy Development Agency (IREDA) with financial assistance from international agencies. Thrust was placed on technology dissemination in remote and relatively inaccessible regions of the country and financial incentives were provided to state nodal agencies, SEBs and private utilities (MNES 2000). Initiatives to set up grid interactive SPV systems were launched in 1995 by the MNES in the range of 25-100kW. At present, MNES is promoting setting up megawatt sized SPV based power generation projects through State Electricity Boards, State Nodal Agencies and private electric utilities. The government provides two-thirds of the total project cost subject to a maximum of Rs.2 crore per 100 kWp. The manufacturers of solar cells and modules are also allowed to implement the project by entering into a suitable power purchase agreement (PPA) with the State Electricity Boards. At present, the indigenous manufacturing base for Solar PV systems is small and about 80 percent of the silicon wafers needed for the manufacture of solar cells are imported (MNES, 1999-2000).

Technology Penetration Issues: The technologies for power generation using solar thermal technology are parabolic dish, parabolic trough collectors, central receivers, solar ponds and solar chimneys. Among these, parabolic trough collector technology has commercial applications in regions such as California. The advantages of the Solar PV technology compared to conventional fossil fuel systems are its modularity that makes it possible to install any size from a few watts to megawatts and flexibility in size and operation that allows SPV systems suitable for decentralised power generation in remote areas. Solar thermal technologies for power generation too are suitable for decentralised and grid applications.

In spite of the advantages SPV based electricity generation offers, progress of SPV systems has been slow all over the world. Solar Photo Voltaic (SPV) and Solar Thermal Power are far less economically viable than the other technological options (Ramana et.al, 1998; Shukla 1997c). SPV is yet to attain technological maturity to the extent that it can be treated as completely commercial to be marketed as an off-the-shelf product. One of the main reasons attributed for this is the unfavourable economics due to the high investment cost of the system that renders SPV unattractive in comparison to other energy technologies. The cost of electricity generation from SPV on a life cycle basis is over 10 times higher compared to coal-fired thermal power. The price is estimated to be Rs.20 crores/MW for SPV and Rs.11 crores/MW for Solar

Thermal (Ramana P.V., 1998). The R&D activities aim towards achieving higher efficiencies of solar cells, reduction in the production cost of SPV cells, modules and systems and improvements in the design and reliability of PV systems. Advancements in polycrystalline thin film technologies are expected to bring down the cost of PV modules in future. (MNES, 2000) Apart from technology costs, there are also a number of transaction costs involved in commercialising the SPV technology, which are high and varied. These include promotion campaigns, creating after sales service infrastructure, quality control measures, cost of co-financing, conducting feasibility studies, developing business plans, etc. Some of the factors attributed for high transaction costs are expensive and time consuming project identification, challenging project implementation in a number of small-scale installations, high costs of credit collection and risks associated with marketing, contracting and information collection. Incorporating the high transaction costs in the economics of SPV raises the cost of the delivered energy and renders the technology uncompetitive. Due to the high investment cost of the technology, the adopter's risk perception is high and this leads to non-adoption. Studies on the penetration of solar technologies for off-grid solar power systems in developing countries such as India, Indonesia and Sri Lanka reveal that access to credit in the rural areas is one of the single most important factors influencing the diffusion of Solar Home Systems (SHS) (Miller et. al, 2000). The World Bank loan programme for the development of the PV market in India revealed that the most economically and viable applications of PV lay in the home lighting sector; for two and four light solar home systems, as well as centralised PV stations for 100 rural households. However, the programme did not ensure flow of low-interest credit to the rural consumers and did not provide sufficient support for market infrastructure development. The credit for PV technology went to the corporate rather than the rural sector due to the high-risk perception for rural credit. Some experts are of the opinion that approaching the rural credit organisations would have been a much better strategy, especially since India has a very strong network of rural banks. The funds instead flowed to large corporations who took advantage of the tax incentives provided by the government. No initiatives were taken for rural sector delivery mechanism. High import duties on PV modules (while international prices were USD 4-4.5$/W, the import prices were about USD 6.9/W), adversely affected the competitiveness of the technology. But there are a few important lessons to be learnt from the

World Bank lending programme in Indonesia, which was more successful than the India case. The loans in the Indonesia case were provided for working capital, which were used for development of sales and marketing network. In order to bring in private sector participation, the GEF grant in this case was provided as a supply side subsidy of USD100 per system installed. But the Indonesian programme suffered a huge setback due to the financial crisis, and the devaluation of the currency hit the programme. Some of the key policy lessons derived from World Bank experiences are ensuring the flow of rural credit through appropriately designed channels by selection of credit organisations having a strong network in rural areas, offer long-term loans to entrepreneurial start-up companies which becomes critical to rapid development of market infrastructure, phasing out of import duties on PV modules, and providing supply side grant for the rapid development of a market infrastructure for technology dissemination. Internalisation of the environmental externalities associated with conventional fossil fuel technologies can aid in improving the relative competitiveness of renewable energy technologies like Solar PV.

This paper assesses the renewable energy trajectories under future scenarios over a 35 year time horizon between 2000 and 2035 and the consequent policy implications. It integrates the present assessment of factors that most affect the penetration of renewable energy technologies with events that are most likely to affect future renewable energy paths. The barriers that affect renewable energy penetration are built in the future with varying degrees of intervention for removal of barriers and promotion of renewable energy technologies. The scenarios are based on alternative images of the future. The baseline scenario assesses the renewable energy path based on assessment of the present policies, strategies and measures that affect power sector renewable energy usage and the most likely trajectory of future events under business-as-usual. This scenario serves as a benchmark for assessing renewable energy trajectories under alternative futures. These scenarios have incorporated in them specific policy interventions for accelerated deployment of renewables, environmental interventions both at the local and global level, and integration of renewable energy policies with global environmental interventions.

III ASSESSING FUTURE PATHS

Analytical Framework

The assessment of future paths for analysing the role of renewable energy in the power sector is carried out within an overall energy system framework. The assessment of renewable energy options for power sector is integrated with the overall technology strategy assessment for the sector, embedded in the energy system. The present analysis examines renewable energy strategies for electricity generation under different future scenarios. The time period for analysis is over the next 35 years, from 2000 to 2035.

The methodology uses an integrated bottom-up modelling framework that has the following components- an energy system model, end-use sector models and a demand projection model that separately projects demands for thirty-seven end use services. These bottom-up models have very detailed representation of technological options in energy supply and enduse sectors in terms of costs, fuel inputs and emission characteristics. Energy system analysis uses MARKAL (Market Allocation), which is an energy systems optimization model (Berger et al, 1987, Fishbone and Abilock, 1981, Shukla, 1996). For each period, the MARKAL model decides the energy and technology for forty years while minimizing the discounted capital and energy cost. The energy enduse sectors are broadly categorised as industries, transportation, agriculture, residential and commercial. Each individual sector is analysed individually using AIM/ENDUSE model (Asian-Pacific Integrated Model– End-use Component) (Morita et al, 1994, Morita et al, 1996, Kainuma et al, 1997) that selects the technology mix within each end-use sector while minimizing the discounted costs of capital, energy and materials. Soft-linkage between the supply and demand side takes place by providing the technology mix for each end-use sector as an input to MARKAL together with exogenous bounds on technology penetration. Demand model for projection of enduse energy services uses logistic regression method (representing transition from high growth to saturation) based on past sector level consumption data as well as estimates, if available, from other detailed studies for some future years along with expert opinion on the future trajectories of these sectors. Similar representation is commonly used for technology penetration in the energy and environment context (Edmonds and Reilly, 1983; Grubler et al, 1999).

Scenarios

The study presents five scenarios. Scenario are alternative images of how the future can unfold, they are neither predictions nor forecasts (SRES, 2000). They are based on internally consistent and reproducible set of assumptions about the key relationships and driving forces of change, which are derived from an understanding of both history and current situation and describe relationships between important drivers of resource availability, productivity and technological change. The scenarios represent the playing out of certain economic, social, technological, environmental and policy paradigms.

Assessment of renewable energy strategies for the power sector examines renewable energy options for electricity generation under a baseline scenario, environmental intervention scenarios (local and global), renewable energy accelerated deployment scenario and a carbon tax-cum-subsidy scenario. These scenarios represent those factors most likely to affect the future of renewables in the Indian power sector. Important exogenous model specifications for these scenarios include the demand trajectories derived from overall macro-economic projections, investment constraints, discount rate, energy supply limitations, energy prices, technology costs and performance parameters, bounds on technology penetration, and environmental characteristics. Baseline scenario presumes continuation of current energy and economic dynamics and provides a reference for comparing the impacts of policies or alternate futures.

Baseline

The baseline scenario assumes what is often called a "business-as-usual" dynamics. The storyline depends on an understanding of how the energy sector dynamics, and specifically the power sector dynamics, have been evolving in the past as well as an analysis of the present situation and most likely future trajectory. It incorporates changes in the economic growth rates and growth patterns, structural changes in the economy, changes in consumption patterns, rates of technological progress, penetration of new technologies, alterations in energy supply and energy prices, dependence on foreign imports, enforcement of environmental laws and regulations, trade flow dynamics, regulatory reforms, initiation and success of institutional changes and policy interventions affecting the energy sector in general and the power sector in particular.

Over a period of next 35 years (2000-2035), the compounded annual rate of growth (CARG) in GDP is assumed to be 5 percent with an annual growth rate of around 6 percent in the initial years declining to about 4 percent in the later periods. The scenario assumes structural changes in the economy based on present dynamics and expert opinion on future trajectories and experiences from other countries. For example, this is partly reflected in the rising share of the commercial sector with increasing service orientation and decline in the agricultural sector share in gross value additions (see Table 2). Past trends show that shares of Industry, Transport and Commercial sectors in the GDP are steadily rising at the expense of agriculture. Projections for residential sector ensure consistency with the growth in Private Final Consumption Expenditure (PFCE).

Table 2 Projection of Gross Value Addition (GVA) shares in baseline scenario (percent)

Sector	2000	2010	2020	2035
Industry	31.2	32.5	33.5	34.2
Commercial	37.7	39.3	40.3	41.3
Transport	5	5.3	5.4	5.6
Agriculture	26.1	22.9	20.8	18.9
Residential*	72.1	69.5	67.4	64.9

*For the residential sector, the figures indicate Private Final Consumption Expenditure as percentage of GDP.

Among the energy forms, coal supply continues to dominate over other energy forms but imported natural gas consumption increases steadily with the domestic gas reserves likely to be exhausted by 2015. In the base case, the technological progress is represented through autonomous efficiency improvements in the stock of existing plants, penetration of advanced technologies due to certain policy interventions, retrofitting of existing technologies into improved ones, retirement of old and inefficient technologies and better environmental performance of technologies. The penetration of technologies like hydro and nuclear is restricted by numerous social, environmental, political and other factors. Technology penetration is also limited by the availability of investments. Logistic regression method is used for end-use demand projections for, while maintaining overall consistency with the macroeconomic projections. The demand technology assumptions cover the average energy efficiency of various existing technologies, the future technology spectrum and their characteristics, the penetration levels, prices, etc. Improved versions of existing technologies (retrofit options) and new technologies expected to penetrate are introduced in later years as energy efficient options.

There is sufficient evidence of recent policy decisions in India that are aimed at controlling local pollution levels and would reduce $S0_2$ emission coefficients from fuel combustion activities in near future. This is built in the model by gradually introducing local pollution control measures in order to meet stricter environmental standards. It presumes no policy interventions for GHG emissions control other than normal non-market and long-term policy interventions related to energy and technology.

Accelerated Deployment of Renewables (ADR)

This scenario assumes specific policy interventions for penetration of renewable technologies over the baseline scenario. Some of the interventions discussed here are built in the baseline scenario as per the ongoing policies and most likely future expectations. However, interventions in this scenario place an additional thrust for promotion and accelerated deployment of renewable energy technologies over and above the baseline assumptions.

The key driving forces for this scenario are thrust on renewable energy deployment for both decentralised and grid applications for electricity supply. There are specific national targets set for supplying a certain percentage of the total power sector generation from renewables. These targets are fixed at about 5percent total electricity generation from renewables in 2015, that increases to 7 percent in the medium-term (2025) and reaches about 10 percent of the total electricity generation in the long-term (2035). It presupposes interventions for substantial learning investments in renewable energy technologies that facilitate cost reductions through scale economies, increases the commercialisation possibilities of these technologies and leads to their higher penetration. Technological progress is accelerated, both in terms of autonomous efficiency improvements of existing technologies and earlier and higher penetration of advanced technologies as compared to baseline scenario. There is a thrust on developing manufacturing capabilities within the country and easing of import restrictions for deployment of advanced technologies like Solar PV. It presupposes the success of technology transfer mechanisms and increasing North-South and South-South co-operation for global sharing of learnings and costs. For decentralised applications, renewable energy promotion is integrated with local and regional development policies and rural electrification strategy. Training, information and awareness programmes along with local capacity building measures are undertaken to ensure the success of these programmes. Renewable energy technologies are pushed for meeting distributed generation requirements. There are interventions for setting up sustainable financial mechanisms like a network of micro-credit facilities. It assumes that the demonstration projects set up in the early years, mainly through international assistance, are successful in setting up sustainable and replicable commercial models that can be adopted widely. Centralised biomass based electricity generation facilities are driven by the development of a commercial biomass fuel supply market with well set-up transportation linkages. Under reforms, there are interventions to promote the widespread deployment of renewable energy technologies in conditions of restructuring and unbundling where the marginal costs of providing energy services are high due to network constraints. Polices leading to the enforcement of favourable buy-back rates for renewable energy (through schemes such as price guarantees, buying a certain percentage of renewables based power) push renewable technologies in the short (next 15 years) and medium term (next 25 years). As part of an overall sustainable development policy and increasing consciousness regarding socio-environmental issues, the relative competitiveness of renewable energy technologies is enhanced through specific interventions for the internalisation of socio-environmental externalities for energy supply technologies. Measures to provide utility incentives in renewable energy investment include mechanisms set up for trading in renewable energy certificates.

Global Environmental Interventions (GEI)

The ultimate objective of the United Nations Framework Convention on Climate Change (UNFCC) is to achieve stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system (SAR, 1996). The global greenhouse gas agreements are likely to set up a carbon market. India's participation in the global carbon market will depend upon the global carbon price. Potential for carbon mitigation domestically at cheap cost, i.e. at costs that are significantly lower than the carbon price will provide opportunities to generate substantial contribution from participation in the global carbon market.

Rising energy demand has lead to rapidly rising trend of energy emissions from India. Due to a large share of coal in the energy mix, Indian economy has high carbon intensity and the rapidly rising trend of emissions is likely to continue. Although the per capita emissions for India are quite low at present (about 20 times lower than US per capita emissions), the total annual emissions exceed 200 million tonnes of carbon. Carbon mitigation in India is complicated by the fact that India has large coal reserves, but limited oil and gas reserves. The substitution away from coal will make the country dependent on imported energy, which has energy security implications. 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 co-operative global regime.

In this context, it is interesting to explore the potential of the Indian energy system to meet national emission targets along with mitigation costs. Since power sector has a very large share in the energy consumption, it will be interesting to explore the power sector potential for carbon emission reduction and the contribution of renewables in response to these signals. This will provide signals to the policy maker to identify specific mitigation measures and prioritize them based on their reduction potential. There are opportunities for RETs under the new climate change regime as they meet the two basic conditions to be eligible for assistance under UNFCCC mechanisms: they contribute to global sustainability through GHG mitigation; and, they conform to national priorities by leading to development of local capacities and infrastructure. While the Kyoto Protocol has not proposed any binding emissions limitation commitments for developing nations, instruments such as Clean Development Mechanism- CDM (UNFCCC 1997 - Article 12) and the possibilities of emissions trading are likely to provide economic incentives for significant emissions mitigation in developing countries. The altered competitive dynamics have chances of favouring renewable energy usage. In this context, issues related to compliance of developing countries to participation in GHG adaptation and mitigation activities and setting up of related business opportunities need to be kept in mind. Exogenous factors that are likely to affect renewable energy penetration in India and their emerging competitiveness are forestry option as carbon sink, emerging competitiveness and penetration of clean coal technologies and future policies with respect to nuclear energy.

In this paper, the impact on renewable energy technologies for electricity generation is considered in the context of response of the overall energy system to global carbon market signals. At present, the only mechanism by which a developing country like India can participate in the global emissions limitations regime is through a new co-operative instrument, the Clean Development Mechanism (CDM) defined in the Kyoto Protocol under the UNFCC. CDM is a voluntary mechanism for promoting GHG emissions mitigation projects in Non-Annex I countries in co-operation with Annex I countries. CDM can provide benefits such as access to the global carbon market for emissions reduction trading, technology transfers, improvements in the local environment and share of surplus from CDM projects (Shukla et al., 2000). For carbon mitigation analysis, five sub-scenarios with different levels of cumulative mitigation targets are considered. The mitigation targets are for 5, 10, 15, 20 and 25 percent reduction over the cumulative emissions in the baseline scenario for the period 2005 to 2035. This paper refers to the 5 percent cumulative mitigation scenario as low mitigation, 15 percent as medium and 25 percent as high mitigation scenario.

Local Environmental Interventions (LEI)

This scenario evaluates the impact of sulfur dioxide emissions control in the entire energy system on the power sector, and specifically the impact on renewables. The two sets of driving forces that influence future sulfur emissions are level and structure of energy supply and the degree of $S0_2$ control policy interventions assumed. These driving forces are linked to the economic development. With increasing affluence, the energy use per capita rises and there is a shift from traditional solid fuels towards cleaner fuels at the point of end-use. Emissions rise initially (with growing per capita energy use), pass through a maximum, and decline at higher income levels due to structural changes in the end-use fuel mix and also control measures for large point sources, that results in a roughly inverted U pattern of $S0_2$ emissions or concentrations. This pattern also emerges from literature on environmental Kuznets curve (1958). Grubler (1999) argues that S02 control and intervention policies in many industrializing countries (particularly those with high population densities) are likely to phased more quickly than in many industrialized countries like North America, Japan or Korea. Sulphur control legislations are being increasingly adopted by developing countries that range from reduction of sulphur content in oil products (e.g. China, Thailand and India) through a maximum sulphur content in coal (e.g. in China) to $S0_2$ controls in coal-fired power plants (China, South Korea, Taiwan and Thailand) (SRES, 2000). The abatement of local air pollution, including control of S02 emissions, reaps both environmental and economic benefits. According to World Bank estimates, in China, the current damage by environmental pollution is about 8 percent of GDP, while abatement costs would be between 1 and 2.5 percent of GDP (SRES, 2000). The IPCC scenario results (IS92c and IS92d) for world and regional emission trajectories show that emissions in the OECD countries will continue their declining trends in line with sulphur reduction policies. Emissions outside OECD will rise initially with increasing energy demand, but sulphur controls will be progressively phased in to mitigate against impacts of high-unabated $S0_2$ emissions on health, agriculture, ecosystems and tourism (SRES, 2000).

Power sector contributes about 50 percent of the total sulfur emissions in the entire Indian energy system, mainly from conventional pulverised coal power plants. Power sector emissions are expected to grow rapidly in future with growing coal consumption. At present there are no limitations for sulphur emissions from power generation, but future legislations are expected for control of emissions. There is a government directive that all power plants with capacities more than 500 MW will require space provision for fitting of Flue Gas Desulphurisation Units (FGD) to pulverised coal plants. Some of these policy interventions, which are likely to come in future, are built in the baseline scenario. This scenario assumes stricter emissions control measures as compared to base scenario. Model results for the entire energy system show that sulphur emissions from the entire energy system reach an annual maximum value of about 8.5 MT in 2020 in baseline. Emission limitations are applied over baseline emissions. Three sub-scenarios are considered- weak, moderate and strong control regimes. Under weak control regime, maximum annual sulfur emissions are limited to 7 MT per annum. Moderate and strong control regimes have maximum annual emission reduced by 30 percent and 40 percent of the maximum baseline emission respectively. The emission limitations are assumed to be imposed from 2010 onwards.

This scenario does not consider any specific interventions for control of particulate emissions from coal based power plants. Installation of ESPs for the control of emissions of suspended particulate matter (SPM) with more than 99 percent removal efficiency is mandatory in India. But experiences show that in most of the power plants, the stack gas concentrations exceed the limits for SPM due to poor quality of the coal used, poor operating and maintenance procedures and flue gas temperature not within the range needed for optimal ESP operation. Improvements in the performance of the existing ESPs are constrained by the space limitations, age of the plant and complete requirement of reorientation the auxiliaries. This paper assumes interventions for control of particulate emissions in the baseline scenario itself. Some of the measures include setting up of a stricter monitoring and control regime, improvements in the coal quality by washing and better operation and maintenance procedures.

Carbon Tax-Cum-Subsidy Scenarios (CTS)

This scenario presumes the setting up of a global carbon market along with trading mechanisms for carbon credits between developed and developing countries. India participates in the global carbon market through emerging global instruments for technology transfer, such as the Clean Development Mechanism under the Kyoto Protocol, and continues its participation in the global carbon market in later periods through appropriate trading mechanisms. External financing mechanisms are necessary in the initial periods for undertaking mitigation activities and lowering the overall burden of costs on the various contributing sectors. This scenario assumes that the revenue generated from participation in the global carbon market is recycled back to the energy sector in order to enhance the competitiveness of the sector. Policy interventions, targeted at recycling the revenue generated from emissions reductions, back to these sectors, help in lowering the mitigation costs and ensures the sustainability of the regime. For renewables, it specifically assumes that the revenue generated from renewable energy contribution in carbon mitigation is recycled back to lower the investment costs of the technologies that accelerate their penetration. This scenario therefore assesses the combined impact of setting up of renewable energy market linkages with global carbon market and subsidization of renewable energy technologies.

IV SCENARIO RESULTS

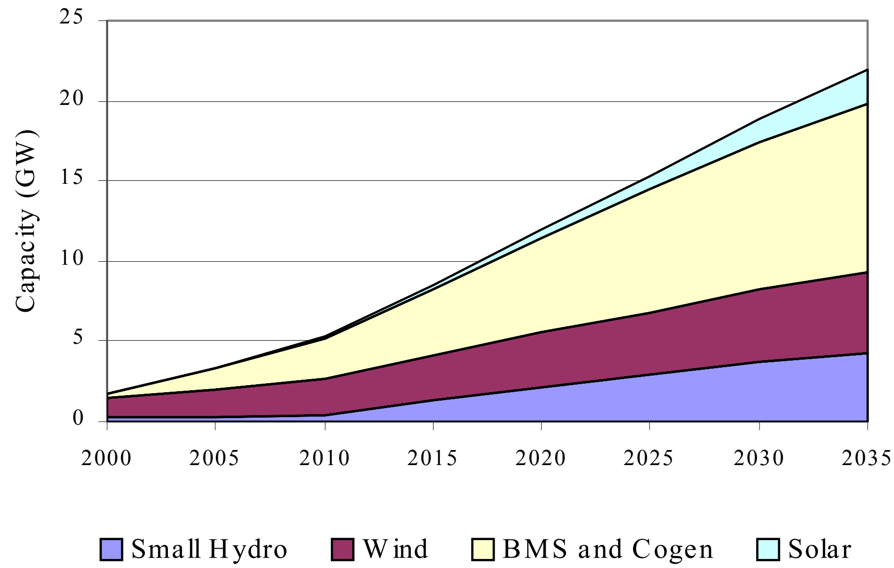
Technology Trajectories

Baseline projections

The economy grows around sevenfold in the baseline scenario in the next 35 years, between 2000 and 2035, with electricity demand rising almost five-folds in the same period. Improvements in electrical energy intensity of GDP are driven by increasing efficiency in enduse electricity caused by autonomous efficiency improvements in technologies, overall process improvements in industries, penetration of advanced technologies and adoption of energy conservation measures. There is almost a three times increase in the overall electricity generation capacity in the next 35 years. Coal continues to dominate in the capacity mix, but with a share declining from about 60 to 50 percent over the same period. In the next decade, power sector coal consumption increases one and half times the present consumption, almost doubles in 2020, and reaches about 650 MT in 2035. A notable feature of the technology trajectory is the substantial increase in natural gas based capacity share from the present 7 percent to one-fifth of the total capacity in 2035, with rapidly rising gas consumption that reaches about three times the present consumption level in the next decade. Large hydro capacity reaches about 70 GW capacity in 2035, while maintaining around one-fifth share in the overall capacity. Nuclear share in the capacity rises from the present 2 percent to 5 percent in 2035.

Renewables grow at a much faster rate than the overall generation capacity, with a thirteen times increase in renewables capacity over 2000 to 2035. In the baseline scenario, projections for renewables (comprising of small hydro, wind, biomass-based, cogeneration, solar and geothermal technologies) exhibit an increase in overall generation capacity share from around 1 percent at present to about 6 percent in the next 35 years reaching 22 GW in 2035 (see Figure 2) with an average annual growth rate of about seven and a half percent.

Figure 2: Capacity Projections of Renewables in Baseline Scenario (GW)



Advancements in the performance of these technologies are reflected in a rise in the generation share from the present less than 1 percent to around 5 percent share in 2035. The latest projections by the Ministry of Non-conventional Energy Sources plan additional 10 GW of renewable capacity by 2012, which is likely to constitute 10 percent of the overall power generation capacity additions (MNES, 2000). Baseline scenario results in this study project a capacity addition of only 60 percent of this value, i.e. around 6 GW of capacity additions in next 12 years. The capacity projections are constrained by a number of barriers, with investment availability being a major constraint. These are discussed in detail in later sections.

Wind power capacity doubles in 2010 from the present capacity level, and there is a 2.5 times increase in 2020. Wind power attains a capacity of about 5 GW in 2035. But its share in generation remains low at about 20 percent among renewable technologies due to low capacity utilisation of wind turbines guided by the wind availability regime. A technology push policy along with R&D thrust and learning innovations enhances technology penetration in the short and medium run. But in the long run, penetration of wind power penetration is driven by development of indigenous manufacturing capabilities and increasing competitiveness of wind technology.

There is a substantial increase in biomass and cogeneration technology capacities, with their combined capacities reaching around 4 GW by 2015. By 2035, their capacity reaches more than 10 GW. From 2015 onwards, biomass and cogeneration technologies maintain a 50 percent share among renewables. High conversion efficiency coupled with its low investment costs makes investment in cogeneration technology attractive and a large part of the potential is exploited within the next decade. With declining agricultural growth rate in later years, growth in cogeneration capacity slows down. Expectations about the development of a biomass supply market, technological advancements and increasing commercialisation of the technologies lead to increasing deployment of biomass conversion technologies for centralised electricity generation as well as decentralised applications. Growth in biomass capacity is critically dependent on ensuring a sustainable biomass supply, which in turn requires large areas of land for biomass cultivation, setting up of transportation networks and establishing a market for this commodity.

Small hydro capacity grows at an average annual rate of 9 percent, reaching 4.3 GW in 2035. This increases its share in the renewables capacity from the present 9 percent to about one-fifth share, while maintaining a 15 percent share in the total generation by renewables. Solar technologies increase their capacity shares from the present 2 percent to close to 10 percent by 2035, with the aggregate capacity of solar PV and solar thermal capacity attaining close to 2 GW capacity by 2035. Penetration of solar technologies will depend largely on their costs coming down internationally, lowering of their capital intensity and establishing institutions for co-operative R&D and technology transfers. Geothermal has a very low share of less than 1 percent in the total renewables capacity.

Accelerated Deployment of Renewables (ADR)

Interesting insights emerge on examining the results of capacity projections of renewables across other scenarios and comparing them with the baseline projections (see Table 3). A combination of push policies and pull mechanisms, along with specific strategies geared towards advancements and promotion of renewable energy technologies lead to their enhanced competitiveness in the Accelerated Deployment of Renewables (ADR) scenario. This results in a substantially higher penetration of renewables compared to baseline. In the short-term (say 2015), there is a 40 percent higher penetration of renewables. The learning experiences provided by the push policies enhance competitiveness of the technologies and accelerate penetration in later periods. In the medium-term (2025), the penetration is as high as 60 percent over the baseline while in the long-term (2035), there is nearly doubling of the baseline capacity. In the short-term, small hydro and cogeneration technology capacities increase substantially, with about one and a half times the baseline capacities. The enhancement in competitiveness of wind technologies in the medium term results in doubling of the wind capacity over baseline. Thrust on technological advancements and setting up of a commercial fuel supply market drive biomass and cogeneration penetration to more than 50 percent over baseline capacity.

Table 3: Renewable Capacities across Scenarios (GW)

Scenarios	**2015**	**2025**	**2035**
Baseline	8.5	15	21.9
ADR	12.4	25.4	41.2
LEI Strong control	10.9	20.6	33.1
GEI Low mitigation	9.7	18.4	27.8
Medium mitigation	12.5	24.8	40.8
High mitigation	17.5	35.3	57.8
CTS Low mitigation + Subsidy	10	19.5	30.6
Medium mitigation + Subsidy	13.4	27	49
High mitigation + Subsidy	19.4	39.3	66.3

Solar technology capacities in the long-term attain about two and a half times baseline capacities in this scenario caused by drastic reductions in the technology cost due to learning experiences. Table 4 shows the renewable capacity break-up in ADR scenario.

Table 4: Renewable Energy Capacities in ADR scenario (GW)

	2015	**2025**	**2035**

Small Hydro	1.9	4.5	6.6
Wind	4.1	7.6	11.7
Biomass and Cogen.	5.9	11.9	17.7
Solar	0.5	1.4	5.2

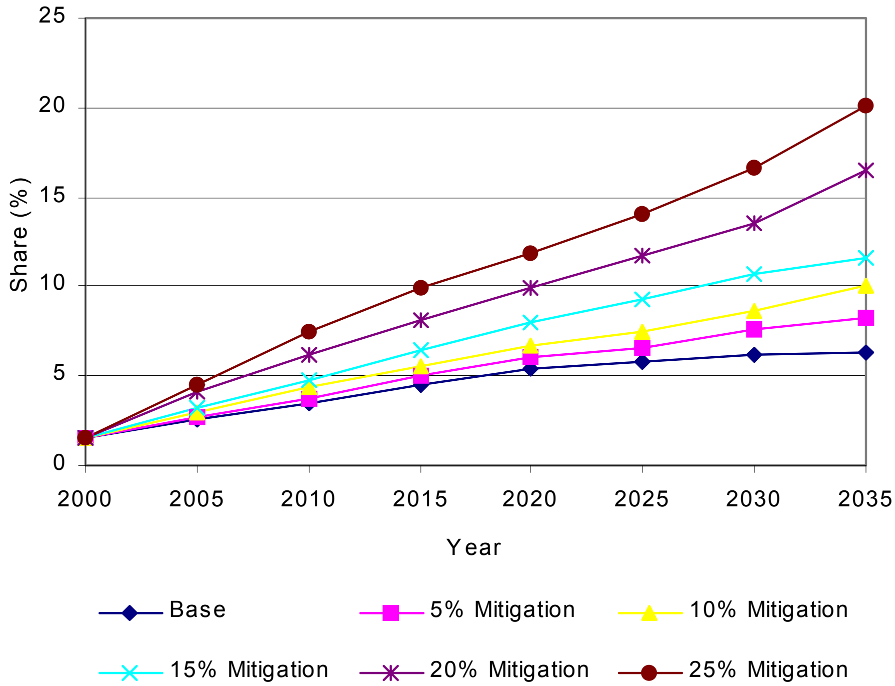
Local Environmental Interventions (LEI)

Local environmental interventions consisting of weak and moderate control of sulphur emissions scenarios lead to very little changes in renewable capacities over baseline. Sulphur emissions are controlled by penetration of clean coal technologies, especially Sub-critical Pulverised Coal (Sub-cr PC) combustion technology fitted with Flue Gas Desulfurisation (FGD) Units. Our analysis reveals that adoption of coal technologies fitted with pollution control equipments offer cheaper emissions control options as compared to fuel switching (to natural gas) or penetration of non-fossil fuel base technologies. A strong sulphur emissions control regime drives renewable energy technology penetration in the long-term resulting in almost one-third rise in capacity over baseline (see Table 3). This is largely contributed by capacity increases in wind and Solar PV technologies. At present, kerosene is used for lighting in a large number of rural areas where access to grid electricity is difficult. The deployment of Solar PV technology for meeting decentralised power generation requirements in such areas will to a large extent combat the environmental problems associated with kerosene use besides improving greatly the socio-economic well-being of the populace residing in such regions.

Global environmental interventions (GEI)

Global environmental interventions lead to significant shifts in renewable energy trajectories and alter their contribution in the overall generation capacity (see Table 3 and Figure 3). With tightening of carbon emission mitigation requirements, the share of renewables in the overall generation capacity increases progressively (see Figure 3).

Figure 3: Share of Renewables as percent of Total Capacity



Even a weak mitigation scenario (cumulative mitigation requirement of 5 percent over baseline emissions in next 35 years) leads to a 5 percent increase in the renewables capacity as early as 2005. The capacity rise in the short-term (in 2015) under this regime is more than 10 percent over baseline, with progressive increase to an additional one-fifth capacity by 2025 and more than one-third increase in capacity in the long-term (2035). But a moderate carbon mitigation scenario (cumulative mitigation requirement of 15 percent over baseline emissions in next 35 years) leads a much higher degree of renewables penetration with more than a one-third increase in capacity over baseline in 2005. Stricter mitigation requirements in later time periods accelerate growth in renewables and lead to about 45 percent capacity increase in 2015, 60 percent increase over baseline in the medium term (2025) and almost doubling of the capacity in the long-term (2035). A strong mitigation scenario (cumulative mitigation requirement of 25 percent over baseline emissions in next 35 years) leads to significant alterations in the technology mix for electricity generation that increases the renewables capacity by more than half in the next 5 years, a doubling in capacity by 2015 and progressively three times increase in capacity of renewables in the long-term (2035). These capacity increases are caused by various degrees of contribution from the different renewable technologies whose capacity projections under the five mitigation scenarios along with the baseline results are shown in Figures 4A to 4D.

An interesting observation is that under the ADR scenario, the renewable energy penetration follows very closely the medium mitigation trajectory till about 2015. In the medium mitigation scenario, a cumulative mitigation target of about 430 MT of carbon over 2000 to 2015 from the entire energy system has a 35 MT mitigation share from renewables in the power sector. Technology push policies in the ADR scenario result in emissions mitigation of this order. But beyond 2015, pull mechanisms under global intervention scenarios with mitigation requirements of more than a billion tonnes between 2015 and 2025 and more than 2 billion tonnes in the following decade (2025-2035), achieve the same degree of penetration as that observed under ADR. Share of renewables in the power sector total emission reduction over 2015 to 2035 approximates at 10 percent.

Figure 4A: Small Hydro Capacities

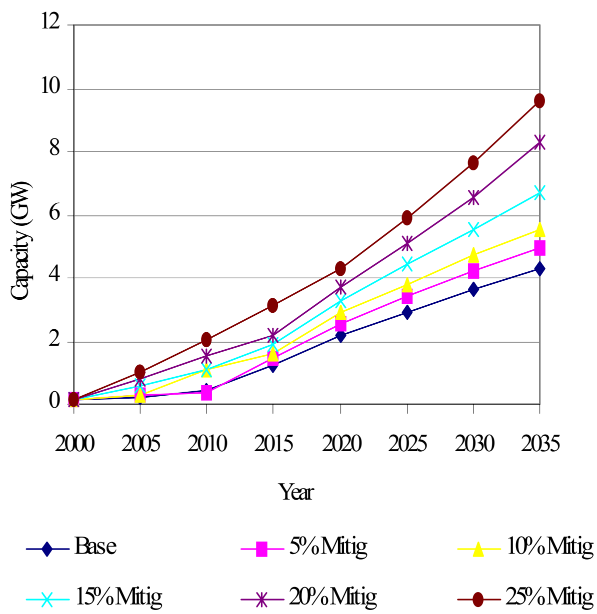


Figure 4B: Wind Capacities

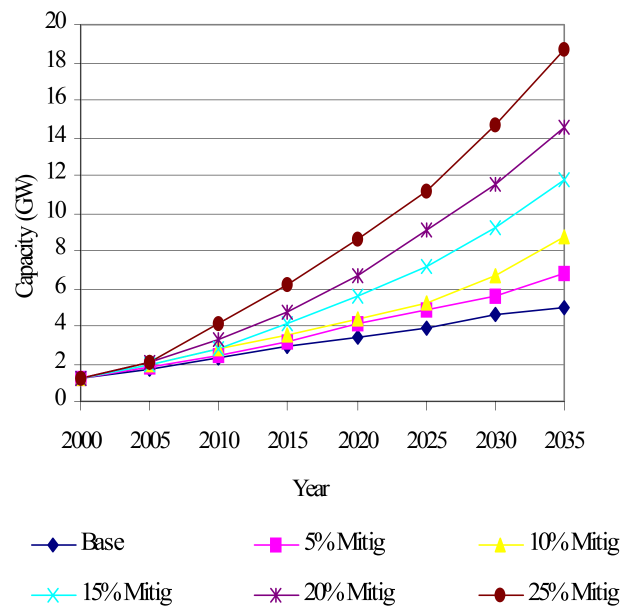


Figure 4C: Biomass & Cogen Capacities

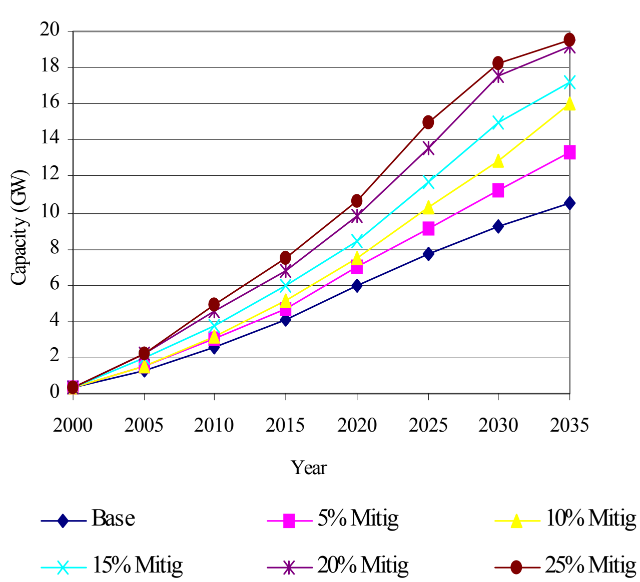
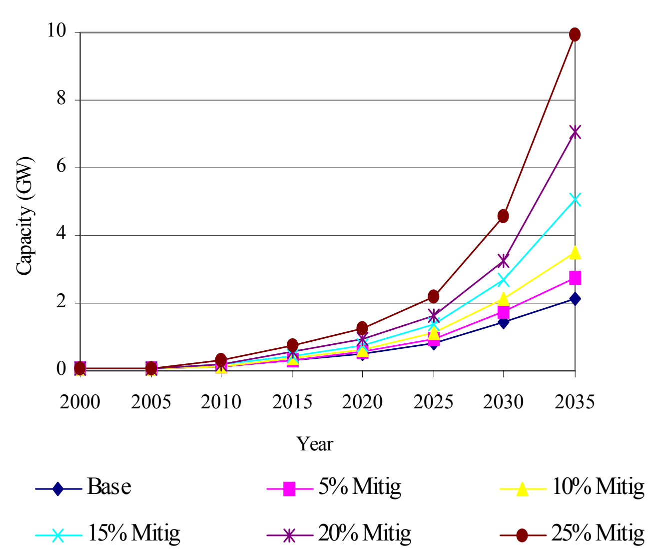


Figure 4D: Solar Capacities

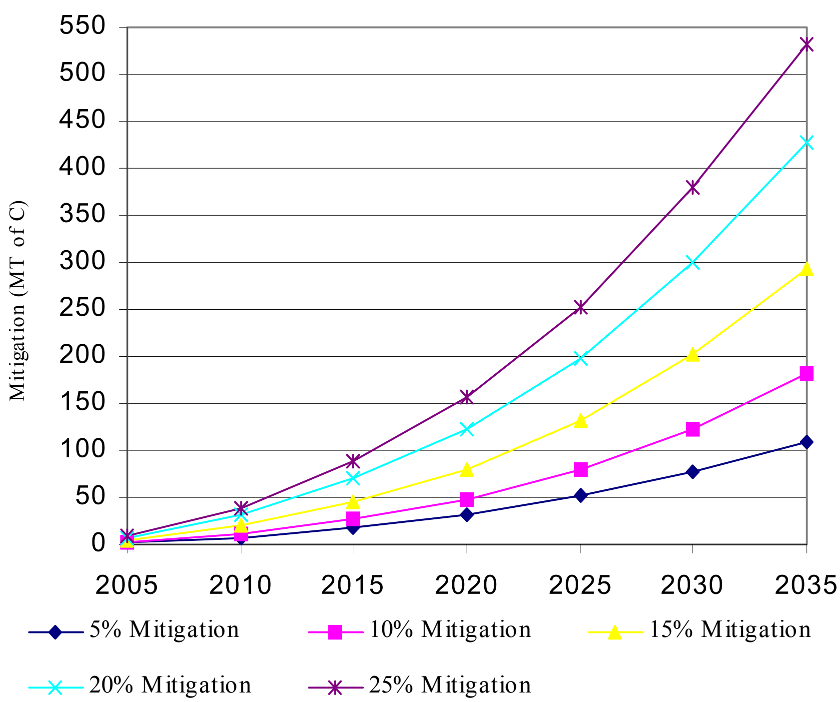


Analysis results reveal that among renewable energy technologies, global environmental interventions cause substantial wind capacity rise in the short and medium-term (see Figure 4B). Growing indigenous expertise in the area of wind power generation with enhancement of manufacturing capabilities contributes to substantial share of wind power among renewables in the short and medium term. Global environmental interventions drive upto about 2 GW of wind power penetration by 2005, and weak and medium mitigation scenarios by 2015 increase wind power capacity to about 3 and 4 GW respectively. But stricter mitigation requirements (25 percent cumulative mitigation trajectory over a period of 35 years) result in increasing the capacity to around 6 GW as early as 2015. In the long-term (2035), enhancement of wind power capacity ranges from about a third rise under weak mitigation scenarios, with almost a three times rise in capacity over the long-term, as compared to baseline. Cogeneration offers cheap mitigation opportunities due to the high efficiency of the process and opportunities for exploitation of a large potential through appropriate policies and implementation mechanisms. Weak and medium mitigation scenarios result in a 30 to 40 percent increase in capacity in the short-term over baseline. Medium-term capacity rise in cogeneration, till 2015, is about one and half times over baseline capacity under weak and medium mitigation scenarios and the capacity almost doubles under a strong control regime. The capacity growth slows down in later time periods. Biomass contribution to mitigation increases progressively over time, with a large potential being realised in later years that is initiated with the setting up of a biomass fuel supply market and advancements in biomass combustion and gasification technologies (see Figure 4C). By 2025, there is a one and half to two times capacity rise over the baseline under medium and strong mitigation scenarios respectively. A strong mitigation regime can initiate the early setting up of a commercial fuel market and enhancement of technological competitiveness that lead to 80 percent rise in capacity over baseline by 2015. Realisation of the relatively easily exploitable potential of small hydro, driven by global environmental interventions, results in almost 1.5 times to 2.5 times capacity increase in baseline in the next 15 years (see Figure 4A). Medium and strong cumulative mitigation requirements drives exploitation of the potential in relatively remote and difficult to access areas involving setting up of costly infrastructure after about two decades. A substantial increase in penetration of solar technologies under strong mitigation scenarios as compared to baseline in the long-term is driven by setting up of a global carbon market that triggers enhancement of technological competitiveness by learning experiences, technology transfer mechanisms, and international co-operation in R&D (see Figure 4D).

Renewable and Carbon Market Linkages

<u>Mitigation Potential, Costs and Contribution by Renewable Energy Technologies (RETs):</u> Cumulative mitigation potential by electricity generation from renewable energy technologies has a 12 to 15 percent share in the overall power sector cumulative mitigation potential. Results for the entire energy system reveal that in turn, the power sector share in overall mitigation potential from the entire energy system is substantial at around 55 to 70 percent across the different mitigation scenarios. The carbon supply curves in Figure 5 represent across time the cumulative mitigation of carbon emissions by RETs across five scenarios.

Figure 5: Carbon Supply Trajectories for Renewables



The mitigation potential of RETs show some distinctive patterns (Table 5). Biomass and cogeneration technologies have more than 60 percent share in the total mitigation by renewable energy technologies across all scenarios and time periods. In the short-term (by 2015), it has the highest share in mitigation, as its potential is the easiest to realise and it offers cheap mitigation opportunities. The generation by other renewable technologies such as wind and solar is guided by the availability of natural resources that leads to their low capacity utilisation. For small hydro technologies too, the water availability along with sharing of water resources for power generation and irrigation purposes poses a constraint on the amount of electricity generated. Though the mitigation by wind based power generation progressively increases over time with stricter mitigation requirements, their share in overall mitigation is limited to about 15 percent of the total by all renewable technologies. Most of the wind sites having high potential get tapped in early years, and exploitation of more difficult sites in later periods results in low capacity utilisation and a slowing down in the mitigation share. Share of solar technologies increases in later time periods with stricter mitigation requirements, but even in the long-term, their share in the overall mitigation by renewables is limited to about 5 percent.

Table 5: Cumulative+ Carbon Mitigation Potential by RETs (MT of C) and their Shares in mitigation (percent)*

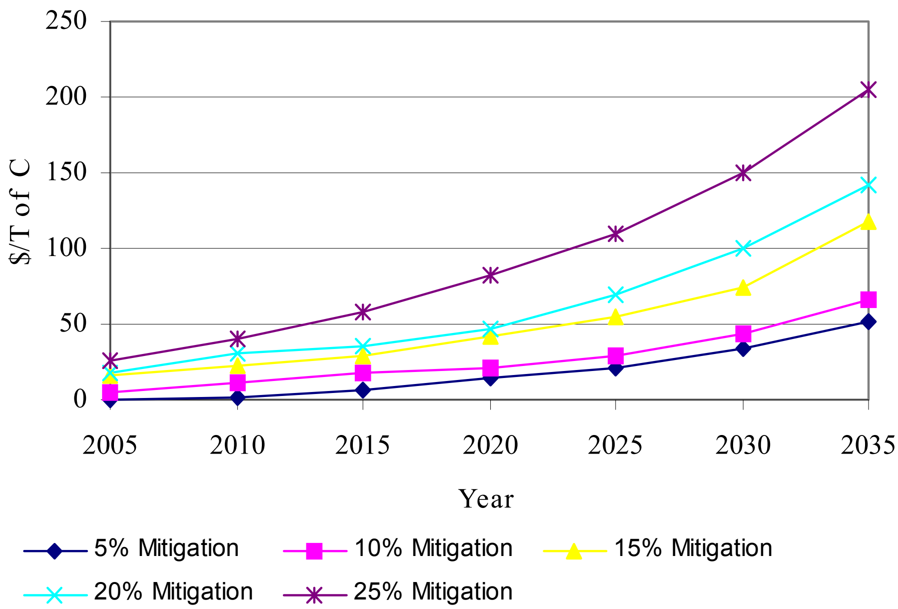
Scenario	Technologies	Cumulative Mitigation Potential (MT of C)		
		2015	2025	2035
5 % Mitigation	Small Hydro	2.6 (15)	7 (13.7)	13.8 (12.5)
	Wind	0.7 (4)	4 (7.8)	9.4 (8.5)
	Biomass & Cogen.	13.9 (80.3)	39.9 (77.9)	84.5 (76.8)
	Solar	0.1 (0.6)	0.3 (0.6)	2.3 (2.1)
15 % Mitigation	Small Hydro	8 (17.8)	21.3 (16.3)	42.9 (14.7)
	Wind	3.2 (7.1)	14 (10.7)	35.7 (12.2)
	Biomass & Cogen.	33.2 (74.1)	93.2 (71.1)	202.4 (69.1)
	Solar	0.4 (0.9)	2.5 (1.9)	11.8 (4)
25 % Mitigation	Small Hydro	20.5 (23.2)	47.6 (18.9)	93.6 (17.6)
	Wind	9.4 (10.6)	34.7 (13.8)	80.8 (15.2)
	Biomass & Cogen.	56.9 (64.4)	162.5 (64.5)	328.5 (61.8)
	Solar	1.5 (1.7)	7.2 (2.9)	28.6 (5.4)

+ The cumulative estimation is from the year 2000

* The numbers without bracket in the table represent the cumulative carbon mitigation potential in MT of C and the numbers in brackets represent their share in the cumulative mitigation potential of all renewable energy technologies

Marginal Cost of Mitigation: Opportunities for carbon mitigation in India arise in the context of functioning of a global carbon market. The global carbon price signals determine the long-term optimal mitigation trajectory that India is going to follow. Mitigation activities will be undertaken only under conditions of marginal cost mitigation cost being less than the marginal benefits. Figure 6 shows the marginal cost trajectories under the different mitigation scenarios for the entire energy system, as derived from the analytical framework used in this paper.

Figure 6: Marginal Cost of Carbon Mitigation



These in turn reflect expectations about the global carbon price trajectories that drive the mitigation targets. Each mitigation target internalises the cost of carbon emissions, a strong mitigation regime corresponding to a higher marginal mitigation cost. This kind of intervention regime significantly alters competition among energy sector technologies. As the cost of fossil energy increases with higher mitigation targets, renewable energy technologies become more competitive. The marginal cost rises over time as cheaper mitigation options, such as demand side improvements in the energy system, are exercised early on with more costly interventions taking place in later periods. Some of the mitigation options on the demand side of the energy system like improvements in the efficiency of agricultural pumpsets used for irrigation, use of more efficient lighting systems in the residential sector offer no-regret mitigation choices. These options offer considerable other benefits (termed as ancillary benefits) such as productivity improvements, enhanced cost effectiveness, improvements in the quality of life, etc. On the other hand, in the energy supply side, interventions like adoption of advanced Supercritical Pulverised Coal combustion technology takes longer time due to high inertia of the technological stock. Such changeovers are associated with large investment requirements, long life times of the technologies, and complexities in decision-making processes. The analysis in this paper estimates the contribution from renewables in the overall energy system mitigation activities (see Table 6). The average mitigation costs for weak mitigation targets (cumulative mitigation of 5 percent over base scenario emissions in the next 35 years) are less than 5$/T of C till about 2015. The average costs remain below 50$/T of C even in the long-term after about 35 years, with cumulative contribution from renewables in the power sector estimated at about half a billion dollar. A medium mitigation scenario with 15 percent cumulative emission reduction requirements as compared to the baseline emissions over a period of next 35 years, has an average mitigation cost at less than 50$/T of C by 2025, with almost a doubling of the average cost in the next decade.

Table 6: Average Mitigation Costs, Average Contribution and Cumulative Contribution from Renewables in Power Sector

Scenarios		2015	2025	2035
5 % Mitigation	Average cost[a] ($/T of C)	4	18	37
	Average contribution[b] ($/T of C)	2.6	3.5	8.1
	Cumulative contribution[c] (Billion $)	0.03	0.14	0.57
15 % Mitigation	Average cost ($/T of C)	26	48	97
	Average contribution[b] ($/T of C)	3.1	6.2	20.9
	Cumulative contribution (Billion $)	0.15	0.66	3.23
25 % Mitigation	Average cost ($/T of C)	50	97	178
	Average contribution[b] ($/T of C)	7.6	12.7	26.8
	Cumulative contribution (Billion $)	0.66	2.68	9.18

[a] The Average cost estimation is for a period of 5 years
[b] The Average contribution estimation is for a period of 5 years
[c] The starting period for cumulative contribution estimation is 2005.

The cumulative contribution rises steadily approaching 3 billion $ in the next 35 years. Following a strong mitigation scenario with cumulative reduction requirements of about 25 percent over baseline emissions in the next 35 years leads to supply side interventions too in the short-term resulting in average mitigation costs of about 50$/T of C in 2015. The average costs approach 180$/T of C in a period of 35 years, with cumulative contribution from renewables in the power sector approaching 10 billion $ during the same time period.

Clean Development Mechanism (CDM) Potential Estimation

Clean Development Mechanism (CDM) is the only participatory mechanism for developing country Parties in project activities, as specified in the Kyoto Protocol to the U.N. Framework Convention on Climate Change. This paper estimates the contribution from potential CDM projects for renewable energy technologies in the power sector (see Table 7).

Table 7: CDM Contribution by Renewables in Power Sector (2000-2012)

Scenarios	Mitigation (MT of C)	Revenue (Million $)	Contribution (Million $)	Unit Contribution ($/T of C)
5 % Mitigation	11	38	14	1.3
10 % Mitigation	18	231	52	2.9
15 % Mitigation	30	710	104	3.5
20 % Mitigation	47	1399	220	4.7
25 % Mitigation	58	2573	434	7.4

The analysis remains valid even if CDM strictly does not remain applicable for developing countries' participation. The same analysis would hold true in case of any kind of participatory mechanism emerging under global environmental interventions. The time period for assessing the mitigation potential and costs and contribution would accordingly need to be adjusted, as this analysis estimates these for the period valid under the Kyoto protocol. The cumulative carbon mitigation during the Kyoto period (2000-12) depends upon the long-term optimal mitigation trajectory that the country chooses to follow, which in turn is dependent upon expectations about the carbon price in the global market. Estimation is carried out for CDM projects for cumulative mitigation targets of 5, 10, 15, 20 and 25 percent over baseline emissions during a period of 35 years. Close to 10 MT of mitigation during 2000-12 under a 5 percent scenario can provide net earnings of around 14 million $ with a total revenue earning of close to 40 million $. The total revenue as well as the net contribution increases progressively along emission trajectories having stricter mitigation, following rising carbon prices. Around

50 MT of mitigation between 2000 and 2012 has a revenue flow of more than a billion $, with almost doubling of the total revenue flow for a cumulative mitigation of about 60 MT during the same period.

Policies and measures targeted at recycling the net contribution from emissions reductions, due to specific sectoral interventions, back to these sectors can help in lowering the mitigation costs and ensure the sustainability of the regime. Some external financing mechanisms will be necessary in the initial periods for undertaking mitigation activities and lowering the overall burden of costs on the various contributing sectors. The recycling of the carbon revenue generated from emissions reduction in the power sector can aid in bringing down the electricity costs so that the overall economic competitiveness is not affected. Biomass and cogeneration technologies have a very high potential CDM contribution (see Table 8a and 8b that show the capacity additions of the RETs during the period 2000-12 under various scenarios along with the corresponding CDM contribution from the RETs).

Table 8a: Cumulative Capacity Addition of RETs during 2000-2012

Technologies	**Cumulative capacity addition during 2000-2012 (GW)**					
	Baseline	**5percent Mitigation**	**10percent Mitigation**	**15percent Mitigation**	**20percent Mitigation**	**25percent Mitigation**
Small Hydro	1.5	2.1	2.8	3.1	4.1	5.7
Wind	3.3	3.8	4.6	5.2	6.6	9.4
Biomass & Cogen.	2.9	3.4	3.6	4.4	5.1	5.5
Solar	0.15	0.17	0.19	0.22	0.32	0.43

Table 8b: CDM Contribution from RETs

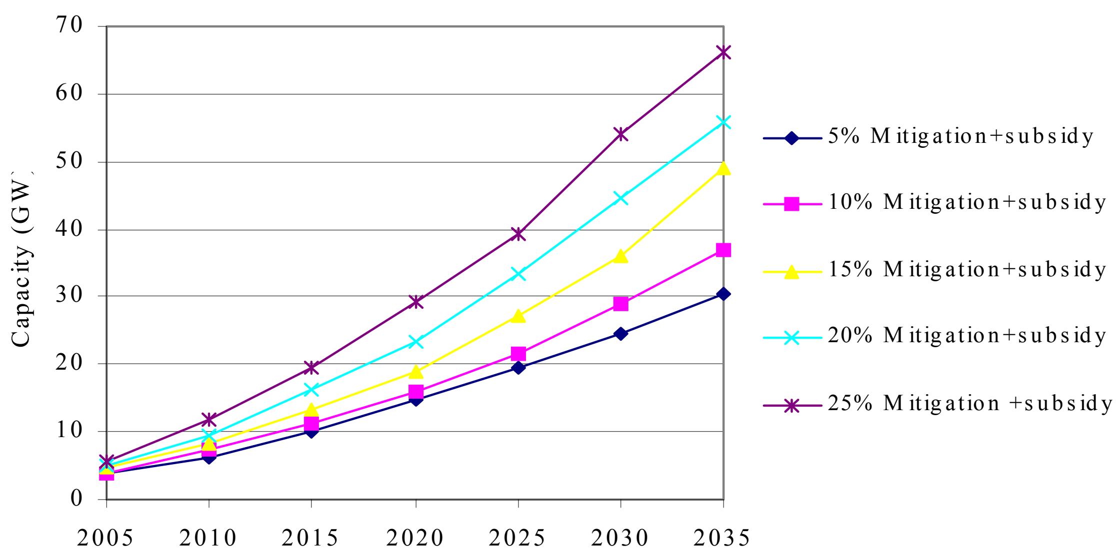
Technologies	**CDM Contribution (Million $)**				
	5percent Mitigation	**10percent Mitigation**	**15percent Mitigation**	**20percent Mitigation**	**25percent Mitigation**
Small Hydro	2.3	10.9	20.2	45.9	107.9
Wind	0.4	4.6	6.1	14.5	40.1
Biomass & Cogen.	11.3	36.3	77.2	157.8	280.4
Solar	0.05	0.2	0.6	1.7	5.5

These two technologies combined have a CDM contribution ranging between 60 to 80 percent of the total contribution from renewable technologies during the period 2000-2012, while having only 30 to 40 percent share in the additional capacity build-up over baseline. A strong mitigation trajectory (25percent mitigation scenario) leads to around 280 million $ contribution in the next twelve years from these two technologies alone. The high contribution is caused by the high rates of capacity utilisation of these two technologies as compared to other renewables that are dependent upon the availability of natural resources for their capacity utillisation. Wind power, in spite of having a 40 percent share in the additional capacity build-up among renewables, has a less than 10 percent share in the CDM contribution. While solar technologies have a 2 percent share in the additional capacity build-up, their share in CDM contribution is close to 1 percent. Small hydro technologies have higher availability than wind and solar technologies with contribution share ranging between 20 to 25 percent, while having a 20 to 30 percent share in additional capacity. Therefore in response to global environmental interventions and emerging possibilities of setting up of a global carbon market in which developing countries like India could participate, substantial investments in biomass and cogeneration technologies within the next decade would offer economic mitigation opportunities. The analysis presumes that biomass is grown in a sustainable manner, which affirms its carbon neutrality. Some of the other related issues in this context are structuring of policy incentives for private participation and investments in cogeneration for which an attractive potential exists in many industries, advancements in biomass gasification and combustion technology especially in the area of integrated gasification technology, lowering of technology costs through learning experiences, setting up of biomass supply infrastructure and development of market mechanisms for trading in this commodity along with collection, storage and transportation mechanisms, practicing of sustainable agricultural practices, arrangements for grid connectivity, rural area development programmes with local capacity building measures.

Capacity Projections in Carbon Tax-Cum-Subsidy Scenario (CTS)

As already discussed in the section under scenario descriptions, in this scenario the revenue generation from participation in the global carbon market is recycled back to the energy system, with the revenue flow back to the sectors being in proportion to their share in emission reductions. This ensures the sustainability of the regime involving participation in global environmental interventions and enhances competitiveness. For the renewable energy sector, the contribution from undertaking emission mitigation activities is recycled back to lower the investment costs of the technologies. The subsidisation of investment costs of the technologies by revenue from the carbon market alters their trajectories (see Figure 7 and Table 3). A low mitigation plus subsidy scenario increases the renewable energy penetration by near about one-fifth in the next 15 years, and has a one-third rise in renewable energy capacity over baseline by 2025. In the long-term (2035), there is a 40 percent higher penetration over baseline. Results reveal that stricter mitigation targets with higher revenue being recycled back to the renewable energy sector increases the penetration further. There is a 60 percent rise in capacity over baseline in a medium mitigation scenario by 2015, and a one and a three-quarters capacity rise by 2025. In this scenario, the renewable capacity more than doubles over baseline in the long-term (2035).

Figure 7: Renewable Energy Capacity Trajectories in CTS

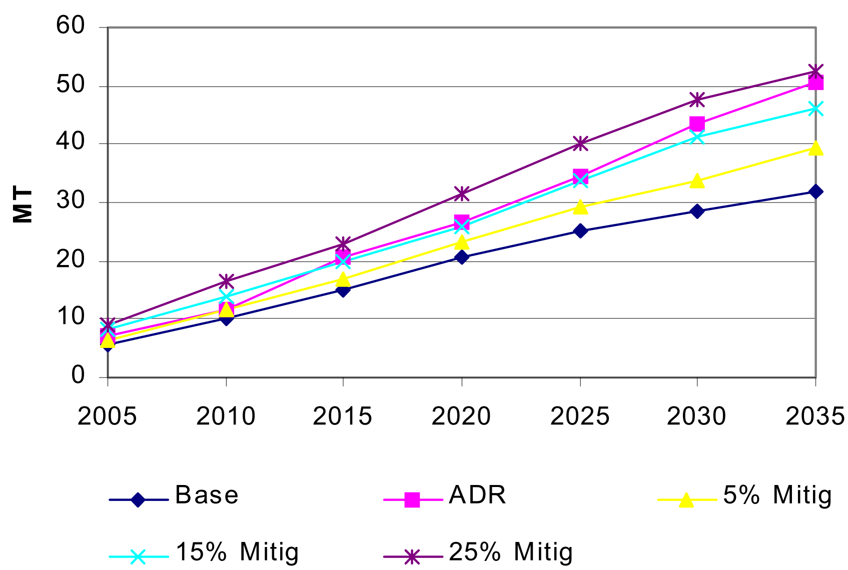


A strong mitigation scenario with revenue recycling leads to a doubling over baseline capacity as early as 2015. Subsidisation of the investment costs gives a large push for renewable energy penetration early on, that improves their competitiveness via learning by doing and accelerates their penetration in later periods. The capacities are two and a half times and three times the baseline capacities by 2025 and 2035 respectively. Compared to mitigation scenarios without revenue recycling, a weak mitigation scenario with revenue recycling achieves around 3 to 10 percent higher penetration in technologies, with penetration increasing over time. Under medium and strong mitigation scenarios with revenue recycling, the capacity increases range between 10 to 20 percent over pure mitigation scenarios.

Biomass Fuel Supply

For the commercialisation of biomass energy supply, it is necessary to ensure a continued and reliable supply of the fuel. At present, a market for biomass fuel does not exist. The transaction costs in setting up of a market for biomass fuel are high. There are high costs involved in the development of dedicated bioenergy plantations in wasteland as well as agricultural land, building transportation network for biomass fuels and setting up of institutional arrangements for supply and marketing of the product. Internalisation of these transaction costs will increase the biomass fuel price and thereby alter the competitiveness of the technology. Future scenarios for biomass usage need to take into account these issues. Within the next decade under baseline, biomass fuel requirements increase seven times over the present level (see Figure 8) for more than eight-fold increase in biomass based generation capacity.

Figure 8: Biomass Fuel Requirements across Scenarios



By 2020, there is a fifteen-fold rise in biomass fuel requirements under baseline, and a more than twenty times increase by 2035

Assuming an average land productivity of 6t/ha/yr, technological advancements leading to higher efficiencies and greater capacity utilisation levels of biomass conversion technologies bring down land requirements per unit of installed capacity from close to 1 Mha per GW progressively to 0.6 Mha per GW in the next 35 years. Table 9 shows the biomass based generation capacities and the corresponding land requirements for biomass fuel supply across different scenarios. Commercialisation of biomass technologies will require about two and a half million hectare of land within the next 15 years to supply 15 MT of biomass for meeting the requirements of 3 GW of generation capacity. The medium-term (2025) land requirements are close to four million hectares with average land productivity of 6 t/ha/yr. With biomass requirement of close to 30 MT by 2035 in the baseline, land requirement comes close to 5 million hectares. Global climate change interventions significantly alter the biomass fuel requirements. Carbon mitigation of close to thirteen and a half million tonnes by 2015 requires setting up of 5 GW of generation capacity for which the fuel supply needs of 20 MT of fuelwood will be grown from more than three million hectares of land. 25 MT of mitigation in next 15 years by biomass technologies has a generation capacity requirement of 6 GW. While there is only a quarter rise in biomass generation capacity in the long-term (2035) under a weak mitigation scenario, the generation capacity rise is close to 60 percent in medium mitigation and 80 percent in strong mitigation scenario respectively with land requirements for fuelwood cultivation reaching close to 8 million hectares.

Table 9: Biomass Generation Capacities and Land Requirements

Scenarios		2015	2025	2035
Baseline	Biomass generation capacity (GW)	3.4	6.3	8.7
	Land requirement (Mha)	2.5	4.2	5.3
ADR	Biomass generation capacity (GW)	5.6	11.2	15.7
	Land requirement (Mha)	4	6.6	10
GEI 5 percent Mitigation	Biomass generation capacity (GW)	3.9	7.5	10.9
	Land requirement (Mha)	2.8	4.8	6.6
15 percent Mitigation	Biomass generation capacity (GW)	4.9	9.6	14.1
	Land requirement (Mha)	3.4	5.7	7.7
25 percent Mitigation	Biomass generation capacity (GW)	6.1	12.3	16
	Land requirement (Mha)	3.9	6.5	8

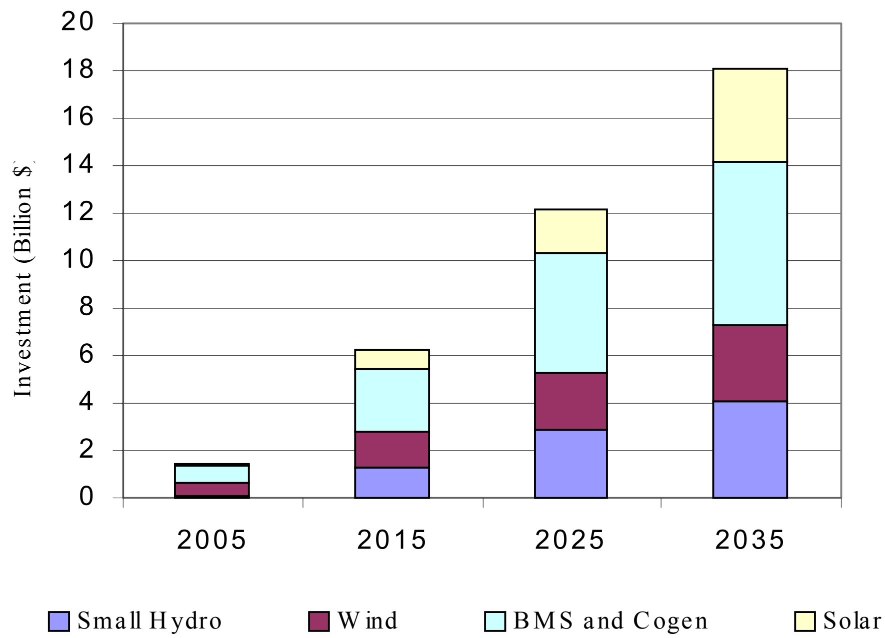
It is interesting to note that the biomass fuel requirements under ADR scenario follow closely the trajectory under medium mitigation scenario in the next 25 years, while by 2035 the fuel requirements reach close to that observed under a strong mitigation scenario.

A shift in the perspective with respect to biomass energy strategies will be necessary to treat biomass as a competitive and modern energy supply source by reorientation of technology policy and integration of biomass policy with development and environment policy. Sustained supply of biomass will require enhanced production of energy crops where some of the critical issues related to land availability, restoration of degraded land by dedicated biomass plantations, enhancing productivity through technological interventions, competition for land requirement vis-à-vis foodgrain production and integration with afforestation programmes will need to be addressed. The present subsidy given to fossil fuels affects the penetration of biomass energy. Other important issues are setting up mechanisms for biomass collection, storage and transportation for ensuring continued and reliable supply; information dissemination programmes to promote usage and technology transfer; international co-operation in technology transfer and financing of biomass projects; pricing of the fuel; institutional development involving community participation and role of public and private agencies; formation of farmers' co-operatives; and integration with regional development programmes.

Investments in Renewable Energy Technologies (RETs)

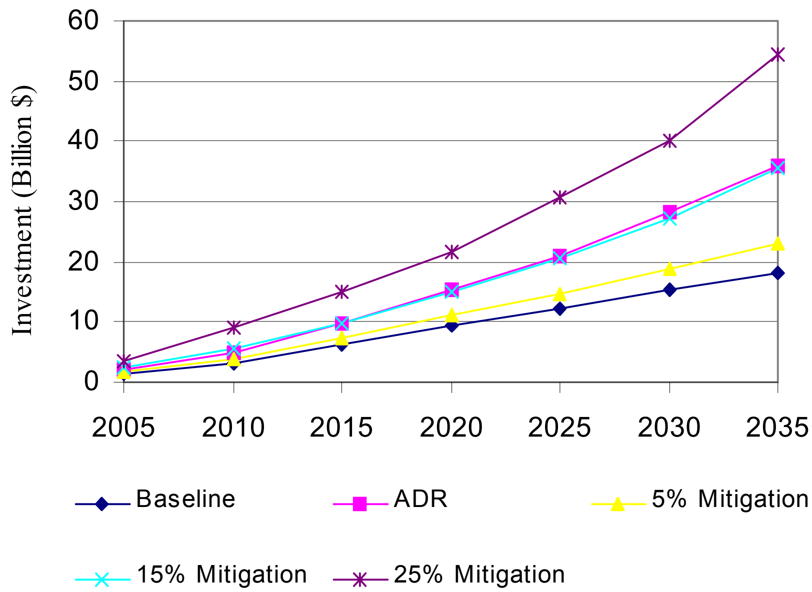
In the baseline scenario, renewable energy investment requirements in the next decade reach around 3 billion $ and crosses 6 billion $ by 2015 (see Figure 9). The growth rate in investments is faster in early years, due to large capacity additions and high investment costs of the technologies. Till around 2015, the average annual growth rate in investment is around 5 percent, but slows down in later years to less than one percent. Among renewable technologies, wind technologies have close to one-third share in the total renewable sector investments within the next decade. Wind energy investments reach a billion $ by 2010, and double in the following ten years. By 2035, investments in wind have a one-fifth share in the total renewable sector investments, reaching more than 3 billion $. Over the entire time horizon from 2000 to 2035, biomass and cogeneration technologies have the largest share in investment, maintaining a 40 to 50 percent share. Increasing commercialisation and growing competitiveness of these technologies leading to their large-scale deployment lead to growing investments in these. Within the next decade, investments in these reach more than one and a half billion $. The medium-term (2025) and long-term (2035) cumulative investment requirements in these technologies are close to 5 billion and 7 billion $ respectively. Cumulative investments in solar technologies are more than a billion $ in the next two decades, with a 13 percent share in the total renewable energy investments. Higher penetration of solar technologies in later time periods due to declining costs via learning experiences, technology R&D and transfer and removal of trade barriers for freer import of components result in investments reaching 4 billion $ by 2035, i.e. one-fifth share in the total investments. Investments in small hydro reach more than a million dollars by 2015. It maintains a one-fifth share in the total renewable energy investments in power sector. By 2025, investment requirements are 3 billion $ and are a billion more in the following decade by 2035.

Figure 9: Cumulative Investment in Renewable Energy Technologies in Baseline (Billion $)



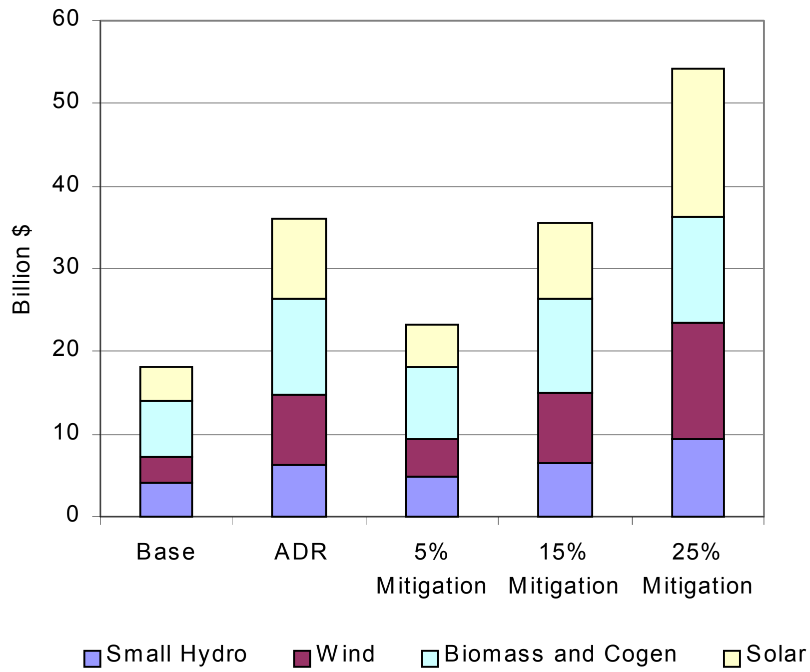
A strong emissions control regime for sulphur under local environmental interventions lead to only about 10 percent rise in the wind power investments by 2025 and almost double the investments by 2035, as compared to baseline. Cumulative investments in Solar PV technology under this scenario are about one and a half times the baseline value by 2035. Global environmental interventions for the control of carbon emissions result in technological interventions on both the demand and supply side of the energy system. The demand side technological interventions take place early on as compared to supply side interventions. These demand side interventions such as irrigation pumpset improvements in the agricultural sector reduce the electricity demand and slows down the investment requirements for additional capacity set up. Within the power sector, the investments in renewable energy technologies keep increasing with stricter mitigation requirements due to their rising share in the overall power sector capacities. Close to 17 MT of carbon mitigation by renewables (while following a 5 percent cumulative mitigation trajectory over 35 years) by 2015 would entail an investment requirement of the order of 7 billion US$ while adding around 8 GW of RET capacity between 2000 and 2015 (see Figure 10). Under stronger mitigation trajectories, the cumulative investment requirements till 2015 could be of the order of 10 to 15 billion $ for achieving around 45 MT and 90 MT of cumulative mitigation respectively over the same period. It is interesting to observe that following an overall mitigation target of 15 percent over baseline emissions in the next 35 years requires investments in renewable energy technologies similar to that under the ADR scenario (see Figure 11).

Figure 10: Cumulative Investments in RETs across Scenarios



For a strong mitigation scenario, close to 25 GW of renewable energy capacity in the next two decades with more than 150 MT of mitigation potential has an investment requirement of 20 billion $. A 50 percent reduction in mitigation in the same period brings down the investment to 15 billion $. For renewable energy technologies to mitigate more than 100 MT of carbon by 2035, 20 billion $ of investment is needed for setting up of 30 GW of renewable energy capacity. Two and a half times this mitigation amount over 2000 to 2035 almost doubles the investment requirements. Under a strong intervention scenario with 530 MT of mitigation from renewable technologies alone in the power sector, investment requirements reach 50 billion $ with an aggregate RET capacity higher than 60 GW by 2035. Interventions under the ADR scenario for setting up of 12 GW capacity by 2015, have an aggregate investment requirement of 10 billion $, i.e. more than one and a half times baseline investments. Continuing the thrust on renewable energy penetration adds another 10 GW capacity between 2015 and 2025 requiring 11 billion $ investments. Acceleration in capacity increase between 2025 and 2035 increases investment needs to 15 billion $.

Figure 11: Cumulative Investment in Renewable Technologies (2000-2035) (Billion $)



Under strong carbon mitigation regimes, solar and wind technologies increase their investment shares to one-third and a quarter respectively compared to other scenarios. Biomass and cogeneration technologies have the highest share in cumulative investments in baseline. Even under ADR scenario, they have more than one-third share in total investments. Across all scenarios, small hydro investment share remains at around one-fifth of the total (see Figure 11).

It is interesting to compare the relative share of the renewable energy technologies to carbon mitigation vis-à-vis their investment share across different mitigation scenarios (Figure 12 and Figure 13).

Figure 12: Technology shares in Cumulative Investment (2000-2035)

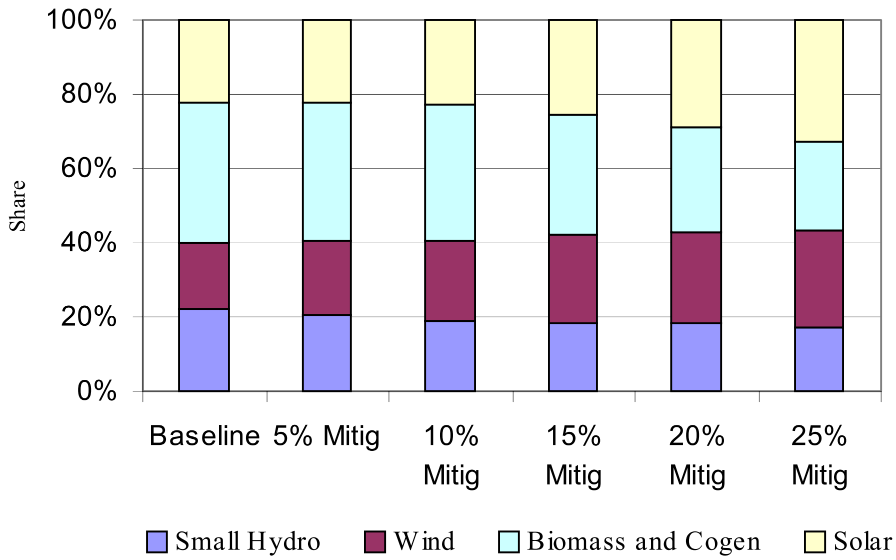
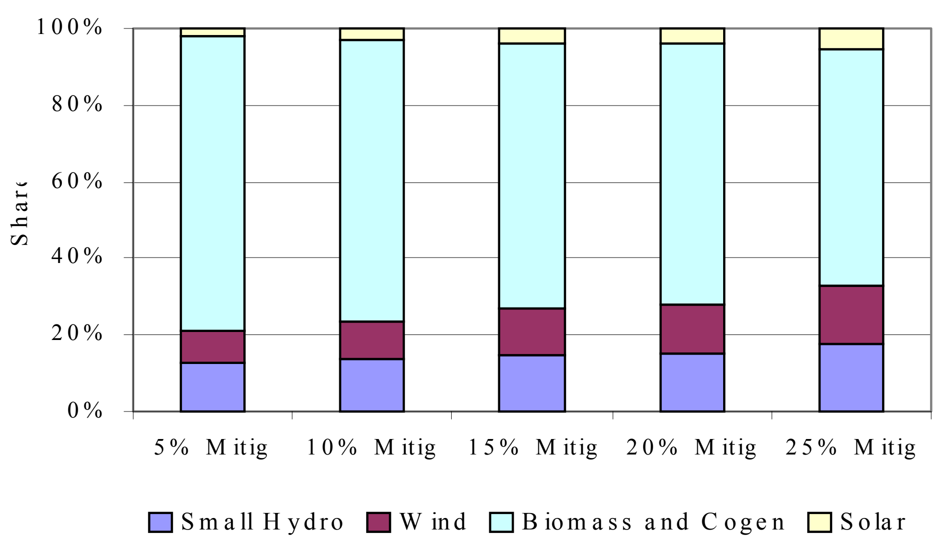


Figure 13: Technology shares in Cumulative Mitigation (2000-2035)

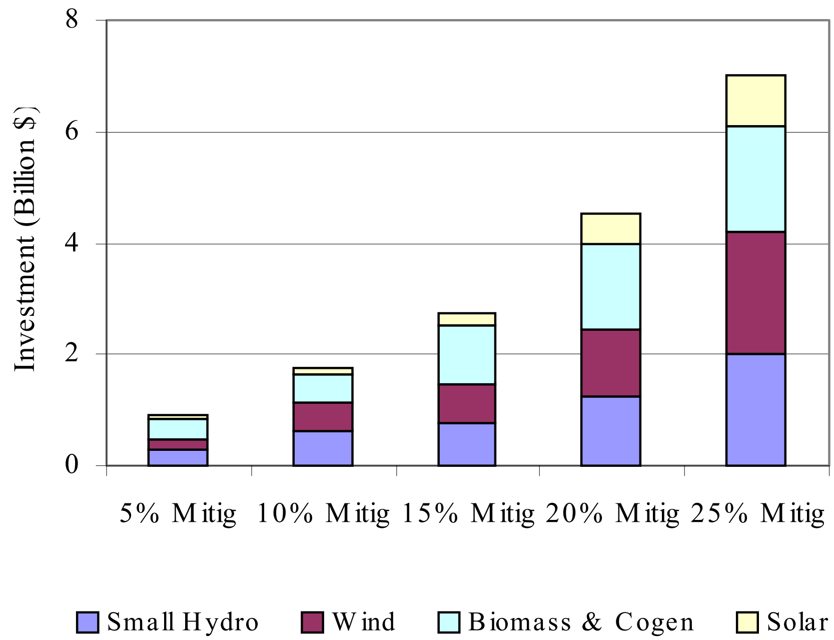


Biomass and cogeneration technologies have a very large share in the total mitigation ranging between 60 to 80 percent, but relatively lower share in investments ranging between a quarter to 40 percent of the total. These two technologies have the lowest investment costs among all renewable energy technologies, while contributing highest in mitigation. Contrast this with solar technologies that have only a 3 to 6 percent share in mitigation, while their share in investments are relatively much higher ranging between one-fifth to a third of the total. Small hydro on the other hand has almost equivalent shares in mitigation and investments. Wind power having high investment costs and low capacity utilisation has a 10 to 15 percent share in mitigation, while having 20 to 25 percent share in investments.

Investment Potential in RETs under Clean Development Mechanism (CDM)

The contribution of RETs to carbon mitigation offer investment opportunities in these technologies through mechanisms such as Clean Development Mechanism (CDM) under the functioning of a global carbon market (see Figure 14). Depending upon the mitigation trajectory followed, the CDM investment potential for the period 2000-2012 ranges between 1 to 7 billion $. Following the *additionality* criteria under the Kyoto Protocol, a 6.5 MT of carbon mitigation over baseline emissions between 2000-2012 under a 5 percent cumulative mitigation scenario entail a CDM investment potential of 1 billion $. A mitigation of 60 MT of carbon over the next 12 years has an investment potential of 7 billion $. Biomass and cogeneration technologies have the highest share in CDM investment (30 to 40 percent share) under low to medium mitigation scenario (5 to 15 percent mitigation scenarios) as they offer a large and relatively cheap potential that can be easily exploited compared to other RETs. The investment in these technologies can range between less than half a billion dollars to more than two billion dollars across mitigation scenarios. Stricter mitigation requirements (20 to 25 percent cumulative mitigation), necessitate high investments in technologies such as wind and solar and their share rises under 20 and 25 percent mitigation scenarios. Close to 50 MT of mitigation by RETs over 2000-2012, has an investment potential of more than a billion for wind alone. Around 60 MT of mitigation target doubles the investment potential in wind to more than 2 billion dollars.

Figure 14: Investment Potential in RETs under CDM (Billion $)



Under this scenario, investment potential in solar technologies reach about a billion dollar that has a 13 percent share in the total RET investment potential. Small hydro maintains close to one-third share in investments across all mitigation scenarios.

<u>Carbon Tax-Cum-Subsidy Scenario (CTS)</u>

The net contribution from renewables under participation in a global carbon market has already been discussed in the previous sections. The recycling of this contribution to subsidize the investment costs of the renewable energy technologies further enhances their penetration. Under a weak mitigation scenario, contribution from power sector RETs is less than 1 percent of the aggregate investment requirements in these technologies for the short (2015) and medium term (2025). Only in the long-term does the aggregate contribution form around 1 percent of the investment requirements. But for a medium mitigation scenario (15percent cumulative mitigation over baseline in 35 years), the net contribution is about 2 percent of the investment requirements by 2015 and close to 6 percent by 2035. Net contribution under strong mitigation scenario forms a substantially higher percentage of the investments approximating 3 percent by 2015, 6 percent by 2025 and 12 percent by 2035. The entire net contribution amount is recycled back to the sector to lower the investment costs of the technologies. This brings down the aggregate investment requirements in RETs as compared to that in pure mitigation cases (see Table 10).

Table 10: Cumulative Investment requirements and reductions* in Investments under CTS (Billion $)

Scenarios	2015	2025	2035
5percent Mitigation + Subsidy			
Investment	7.19	14.6	23.2
Reduction in Investment*	0.1	0.5	0.9
15percent Mitigation + Subsidy			
Investment	9.7	20.2	33
Reduction in Investment	0.8	2.1	7
25percent Mitigation + Subsidy			
Investment	14.6	28.2	44.8
Reduction in Investment	3	5.9	17

* The reduction estimation is with respect to the investment requirements in pure mitigation scenarios without revenue recycling.

Recycling of the net contribution from mitigating about 100 MT of carbon over a period of next 35 years can lead to close to a billion $ saving in investments. There is a potential to save close to a billion dollars by 2015, if the contribution from 45 MT of mitigation during the same period is recycled. In the short-term, if India were to mitigate about 90 MT of carbon by RETs alone in the power sector by 2015, the saving in investment is as high as 3 billion dollars. The medium-term (2025) savings in investment range between half a billion to 6 billion dollars for mitigation of 50 to 250 MT of carbon respectively. Long-term reductions in investments are quite substantial. There is an investment saving of about 7 billion dollars by recycling of the contribution from close to 300 MT of carbon mitigation over 2000-2035, while for a billion tonne of carbon mitigation over the same period the investment saving is 17 billion dollars.

Electricity Cost Linkages with Carbon Market

Global environmental interventions change the relative competitiveness of renewable energy technologies with respect to fossil fuel technologies (see Table 11). Under a weak mitigation scenario with cumulative emission reduction of 5 percent over baseline in a period of 35 years, electricity generation cost from conventional Sub-critical Pulverised Coal (PC) technology rises by 10 percent in 2025 and 20 percent in 2035 as compared to baseline. The corresponding generation cost increases for natural gas based CCGT (Combined cycle Gas Turbine) technology are 5 percent and 10 percent respectively. In this scenario, biomass and small hydro emerge competitive with conventional coal technologies in the long-term (2035).

Table 11: Levelised* Electricity Generation Costs in Mitigation Scenarios (cents/kWh)

Scenarios	Technologies	2015	2025	2035
Baseline	Sub-cr PC	4.43	4.40	4.38
	CCGT	4.53	4.40	4.36
Weak Mitigation	Sub-cr PC	4.53	4.85	5.21
	CCGT	4.47	4.64	4.87
Medium Mitigation	Sub-cr PC	5.06	5.57	6.72
	CCGT	4.77	5.06	5.72
Strong Mitigation	Sub-cr PC	5.64	6.74	8.66
	CCGT	5.11	5.72	6.83
All Scenarios	Small Hydro	5.11	5.11	5.11
	Wind	6.66	6.66	6.66
	Biomass	5.09	5.09	5.09
	Solar PV	27.13	27.13	27.13

* Levelised electricity cost represents the life cycle cost of generating a unit of electricity and includes for a technology all relevant costs like investment, fuel cost, operations and maintenance. The technological characteristics for levelised cost estimation are the same as given in Shukla P.R., Ghosh Debyani, Chandler William, Logan Jeffrey. *Developing Countries and Global Climate Change. Electric Power Options in India.* Prepared for the Pew Centre on Global Climate Change, Battelle, Advanced International Studies Unit, Washington, USA. October, 1999.

A medium mitigation scenario with 15 percent cumulative emission reduction increases electricity costs from conventional coal technologies by as much as 15 percent in 2015 by adding less than a cent to the electricity cost. In the same scenario, the increase is by 25 percent in 2025 and 50 percent by 2035. Natural gas based technologies have corresponding increases of 8, 15 and 35 percent respectively. In this scenario, small hydro and biomass emerge competitive with conventional coal technologies in the next 15 years, while wind is competitive only in the long-term. The generation costs from fossil fuel based technologies are significantly altered over a short period of time under strong mitigation requirements (25percent cumulative mitigation over baseline in a period of 35 years). Coal based generation costs increase by more than a quarter in the next 15 years by adding around 1.3 cents to the electricity cost, becomes one and a half times by 2025 and almost doubles by 2035 as compared to baseline generation costs. Increases in costs from natural gas based technologies are lower at 15, 30 and 55percent over the next 15, 25 and 35 years respectively. In a strong mitigation regime, the generation costs from biomass and small hydro are lower compared to conventional coal and gas technologies as early as 2015, and wind emerges competitive with conventional coal technologies by 2025. Generation costs from Solar PV remain four to six times the costs from conventional fossil fuel technologies across all scenarios.

The recycling of contribution, from participation in a global carbon market, to subsidise the investment costs of renewables further improves their competitiveness as compared to pure mitigation scenarios. Under global carbon price expectations of about 50$/T of C, recycling of the contribution from renewables brings down the electricity generation costs from these technologies by 2 to 3 percent. In a strong mitigation scenario, the reduction in generation costs range between 5 percent in 2025 to 10 percent in 2035.

V BARRIERS IN RENEWABLE ENERGY DEVELOPMENT

Despite the cost reductions achieved over recent years, the largest barrier to greater renewable energy use is its high cost. Intermittent electricity generation characteristics from renewable resources like wind and solar, result in their low reliability in meeting power demand, especially during peak periods. These technologies need to be supported by effective back-up power supply options, which increases cost. There are additional issues related to grid connection and costs of transmission. Lack of full cost pricing when determining the cost of competing energy supplies also hinders the development of renewable energy since the cost of environmental impacts are usually not included in energy prices. Renewable energy development is impeded under conditions of electricity markets undergoing transition when high discount rates and competition on short-term electricity prices within a regulatory framework disadvantage projects with high capital costs but low running costs, such as renewable electricity systems. In addition to cost-related barriers, non-cost barriers also inhibit the greater use of renewable energy. This is particularly the case with the imperfect flow of information and the lack of integrated planning procedures and guidelines. The barriers for the penetration of renewable energy technologies are broadly classified as a) Economic and Technological barriers b) Market-related barriers and c) Institutional barriers

Table 12 shows the barriers associated with penetration of different renewable energy categories.

Economic and Technological

Investment costs: This relates to the current high levels of capital cost of renewable energy technologies based on new technologies, low volume production and current manufacturing practices.

Technology Maturity-level: Renewable energy technologies such as solar have not attained technological maturity and are still in the developmental stages.

Table 12 Barriers in Renewable Energy Development

Small Hydro Power

Economic & Technological	Market related	Institutional
➢ High Investment costs ➢ Remote and dispersed availability of potential ➢ Demand/supply mismatch ➢ Intermittent supply of water; sharing for irrigation- need for back-up technologies raises costs ➢ Varied Peak Coincidence factor depending on water availability ➢ Power off-take problems due to Grid instabilities ➢ Inadequate maintenance & servicing infrastructure ➢ Unstable grid leads to power off-take problems	➢ Setting up of competitive wholesale electricity market and spot-market creation affect competitiveness ➢ High risk perception of private investor to serve rural market and set up decentralised applications ➢ High charges in wheeling contracts due to intermittent generation characteristics in an electricity market ➢ High investment requirements make it unattractive under high discount rate and low payback periods ➢ Subsidy on fossil fuels and irrational electricity tariff structure hinder development ➢ Non-internalisation of socio-environmental externalities in energy pricing and irrational tariff structure for electricity affect competitiveness	➢ Lack of information, training and awareness programmes ➢ Lack of clear guidelines in project specifications ➢ Long-term un-sustainability of programmes based on fiscal and financial incentives. ➢ Low of R&D investment ➢ Non-uniform and unstable policies across states ➢ Non-inclusion in the regulatory framework ➢ Inadequate allocation from state plans and low priority for utilities to take up projects ➢ Not integrated in power sector reforms ➢ Lack of co-ordination between planning and implementing agencies ➢ Marketing infrastructure- lack of consumer service orientation and inadequate sales and services networks ➢ Difficulties in availability of finance ➢ Demonstration projects have low replicability that hinders adoption ➢ Low level of capacity building and non-mobilisation of community participation ➢ Lack of orientation towards providing energy services for decentralised and rural applications

Wind Power

Economic & Technological	Market related	Institutional
➢ High Investment costs ➢ Dispersed nature of potential- difficulties in tapping wind energy resource. ➢ Peak Coincidence factor may be low, depending on wind availability. This leads to problems in matching wind availability with load duration curve ➢ Low capacity utilisation of wind technology ➢ Need for back-up technologies due to intermittent nature raises costs ➢ Power off-take problems due to Grid instabilities ➢ High reactive power requirements for start-up	➢ Setting up of competitive wholesale electricity market and spot-market creation affect competitiveness due to intermittent nature of generation from wind ➢ Higher charges imposition under wheeling contracts on intermittent generators based on wind ➢ Fluctuating generation costs create problems in cost recovery under fixed power purchase terms ➢ Subsidy on fossil fuels and irrational electricity tariff structure hinder development ➢ Non-internalisation of socio-environmental externalities in energy pricing and irrational electricity tariff affect competitiveness	➢ Non-availability of infrastructure such as land and access to T&D networks ➢ Lack of clear guidelines in project specifications ➢ Long-term un-sustainability of programmes based on fiscal and financial incentives ➢ Not integrated in power sector reforms ➢ Low of R&D investment ➢ Non-uniform and unstable policies across states deters investors ➢ Non-inclusion in the regulatory framework ➢ Inadequate allocation from state plans and low priority for utilities to take up projects ➢ Lack of co-ordination between planning and implementing agencies ➢ Marketing infrastructure- lack of consumer service orientation and inadequate sales and services networks ➢ Lack of orientation towards providing energy services

Biomass and Cogeneration Power

Economic & Technological	Market related	Institutional
➢ Inconsistencies in nature of biomass fuel lead to difficulties in conversion ➢ Uncertainties in technological performance ➢ Technical barriers in upgradation of existing sugar mills for cogeneration, synchronisation and feeding electricity to grid ➢ Intermittent fuel supply for cogeneration, need for supplementary fuels ➢ Channelling of sugarcane bagasse for alternative uses like paper production ➢ Power off-take problems due to Grid instabilities ➢ Inadequate maintenance & servicing infrastructure ➢ Large fund requirements in setting up of biomass fuel (fuel wood) market for afforestation programmes, harvesting and transportation of the fuel.	➢ With reforms, extension of supply network and better grid operations affect decentralised applications- especially for biomass gasifiers ➢ Non-existence of biomass fuel market leads to unreliable fuel supply ➢ High transaction costs in setting up of biomass fuel market will raise fuel prices and affect competitiveness of the technology ➢ Unbundling of utilities reduces incentives for distributed generation applications. ➢ For cogeneration, market for surplus power from sugar mills not ensured ➢ Utilities unwilling to purchase power from sugar mills that operate only seasonally ➢ Non-remunerative tariff for power export from sugar mills ➢ Subsidy on fossil fuels and irrational electricity tariff structure hinder development ➢ Non-internalisation of socio-environmental externalities in energy pricing ➢ For commercialisation of biomass technologies for centralised power generation, difficulties in marketing and pricing of forest products pose challenges for Fuel wood market creation.	➢ Barriers in obtaining land for biomass cultivation for large scale applications- competition with foodgrain production ➢ Lack of information, training and awareness programmes ➢ Lack of clear guidelines in project specifications ➢ Low of R&D investment ➢ Non-uniform and unstable policies across states ➢ Non-inclusion in the regulatory framework ➢ Inadequate allocation from state plans and low priority for utilities to take up projects ➢ Not integrated in power sector reforms ➢ Lack of co-ordination between planning and implementing agencies ➢ Misallocation of incentives- e.g. investment subsidy for biomass gasifiers led solely to procurement of subsidized diesel engine pumpsets ➢ Marketing infrastructure- lack of consumer service orientation and inadequate sales and services networks ➢ Lack of orientation towards providing energy services for decentralised and rural applications ➢ Difficulties in availability of finance ➢ Demonstration projects have low replicability that hinders adoption ➢ Lack of successful and replicable business models

Solar Power

Economic & Technological	Market related	Institutional
➢ Very high Investment costs ➢ Low level of technological maturity ➢ Non-standardisation of technologies leading to low level of reliability ➢ Uncertain technological track record ➢ Need for storage/backup technologies for supply during night-time raises costs ➢ Low Peak Coincidence factor ➢ Inadequate maintenance & servicing skills	➢ High-risk perception of the private investor towards technology adoption due to high costs and uncertainties related to serving rural markets. ➢ Large pre-investment risks associated with the costs of marketing, contracting and information collection ➢ Trade barriers imposed by high import duties for PV modules. ➢ Lack of established market for solar power deters commercialisation. ➢ Setting up of competitive wholesale electricity market and spot-market creation affect competitiveness due to high costs and intermittent nature of supply ➢ With reforms, extension of supply network and better grid operation affect decentralised applications ➢ Under reforms, imposition of higher charges under wheeling contracts on intermittent generators based on solar affect competitiveness adversely. ➢ Unbundling of utilities reduces incentives for distributed generation applications. ➢ Investment unattractive under high discount rate and low payback periods ➢ Subsidy on fossil fuels and irrational electricity tariff structure hinder development ➢ Non-internalisation of socio-environmental externalities in energy pricing and irrational electricity tariffs affect competitiveness	➢ Lack of information, training and awareness programmes ➢ Lack of clear guidelines in project specifications ➢ Long-term un-sustainability of programmes based on fiscal and financial incentives. ➢ Low of R&D investment ➢ Non-uniform and unstable policies across states deters investors ➢ Non-inclusion in the regulatory framework ➢ Inadequate allocation from state plans and low priority for utilities to take up projects ➢ Not integrated in power sector reforms ➢ Lack of co-ordination between planning and implementing agencies ➢ High transaction costs involved in technology commercialisation ➢ Technology dissemination difficult due to inadequate marketing infrastructure such as- lack of consumer service orientation and sales and services networks ➢ Lack of orientation towards providing energy services for decentralised and rural applications ➢ Difficulties in availability of finance and providing micro-credit access, especially for rural areas ➢ Demonstration projects have low replicability that hinders adoption ➢ Lack of successful and replicable business models

Technology Standards and Reliability: For most of the renewable energy technologies, technical standards not very well established. Technologies such as Solar PV have low reliability with uneven technical quality.

Technology Upgradation: In the case of cogeneration, there are technical barriers in upgrading of existing sugar mills, setting up of cogeneration facilities and supply of grid electricity.

Resource Availability: The scale of operation of wind and solar technologies is constrained by matching supply with load duration curve, leading to very low Plant Load Factors (PLFs) with a very high percentage of unused capacity. For ensuring reliable power supply, back-up power supply sources need to be set up, which increase the overall costs. In the case of cogeneration, seasonal operation of sugar mills leads to intermittent power supply from cogeneration projects and therefore utilities are unwilling to buy power from these units.

Location of Supply Sources: Renewable energy sources such as small hydro are very often located in remote, dispersed and inaccessible areas that necessitate high investment requirements in T&D for power supply.

Demand/Supply Match: High potential of renewable energy supply sources exist in areas with low level of demand due to developmental and socio-economic patterns. This supply-demand mismatch coupled with the problems in transfer of power from such regions leads to a very large share of the potential remaining unexploited.

Fuel diversity for biomass: There is a large diversity in biomass fuel supply and devices are specifically designed to handle these. The lack of adherence to fuel specifications in the case of biomass gasifiers by the consumers leads to operational problems of the technologies.

Peak Coincidence Factors: Low peak coincidence factors for renewable energy technologies, especially for wind and solar, make them unreliable sources for power supply during the peak periods.

Grid Stability: Unstable electricity grids and their low reliability in operation create problems in power off-take from renewable.

Reactive power requirements: Wind energy penetration is restricted by high reactive power requirements for start-up of operations, that necessitate drawing of power from the state grid.

Maintenance and Servicing Infrastructure: Inadequate servicing and maintenance of equipments along with low reliability in operations lead to very low customer confidence and hampers technology adoption.

Market-related

Market Reforms: There are possibilities that market reforms adversely affect the penetration of certain renewable energy technologies. The reforms measures leading to setting up of an electricity market with competitive and reliable power supply, better grid operations and extension of the supply networks, lower transmission and distribution losses, tariff rationalization and elimination of subsidies and grants may bring down the penetration of renewables.

Competitive Wholesale market and Spot market creation: The creation of 'spot' markets for wholesale power (i.e., markets for bulk power to be delivered immediately) will be particularly unfavourable to renewables like wind and solar which are available only intermittently, since spot markets will have a preference for generators that can provide reliable power supply at all times. Wholesale competition in bulk power markets may adversely affect renewables as spot markets will find it difficult to finance and develop renewable energy based generation projects with high investment costs. Spot markets operate on the basis of short-term operating costs and weaken the incentives to invest in distributed renewables for which the cost recovery takes place over a long period of time.

Privatisation: Increasing private participation as part of market reforms policies can increase the cost of capital and make the high initial investment in renewable energy technologies unattractive. Privatisation is also likely to dampen interest in serving rural markets where renewables have a comparative advantage. Shareholders may require higher rates to justify investments in rural markets, which are inherently perceived to be more risky.

Discount rate and Payback period requirements: Investments in renewable energy technologies are not attractive under high discount rates and short payback period requirements. Under such conditions, generation options that have relatively lower capital costs, shorter gestation periods, high efficiency and availability are preferred- none of which fit into the characteristics of renewable energy technologies except to a certain extent for biomass based generation.

Restructuring and Unbundling: Restructuring and unbundling under market reforms may reduce incentives for distributed generation. In the unbundled utility, the investment decision for distributed generation will be taken most likely by the distribution company who may not be able to clearly perceive the avoided costs in upstream generation, transmission and distribution by investing in distributed generation. This may thereby reduce the scope of renewable energy applications in distributed generation.

Wheeling Contracts: The intermittent generation characteristics of renewable energy technologies and their site-specific nature may place the renewable energy developers in an unfavourable position regarding structuring of contracts for power transmission as compared to non-renewable energy developers. Renewable energy developers may not have equal access to transmission capacity. Intermittent generators may be required to pay higher charges per kWh than their dispatchable competitors to transmit power, with transmission charges being based on the rated capacity of the generator or the actual generation during peak periods. The site-specific nature of the renewables may be a drawback under some transmission pricing schemes where the rates are based on the distance.

Fuel Market for Biomass: For biomass-based technologies, the barriers are unsustainable biomass supply and non-existence of a fuel market, unreliable supply of biomass and frequent price fluctuations. Coupled with this are the difficulties in setting up of a fuel transportation network due to the transportation difficulties of biomass.

Trade Practices: Restrictive trade practices and imposition of trade barriers obstructs the import of advanced technologies and adversely affects their competitiveness. For example, high import duties on PV modules result in much higher prices than the international level and leads to very high costs in the system.

Energy and Electricity Pricing: Distortions in the pricing of different energy forms and an irrational tariff structure for electricity do not provide incentives for investment in generation capacity. Internalization of externalities and full cost pricing of energy have in many cases possibilities of placing renewable energy in a favourable position as compared to fossil-fuel based energy supply sources. Difficulties in estimation of socio-environmental costs for various alternate energy supply sources for full cost pricing of energy thereby restricts renewable energy development.

Transaction Costs: Due to non-existence of market for renewable energy, high transaction costs are involved in commercialization of technologies.

Power Purchase Structure: With the power purchase agreement structured at utilities buying power at fixed rates from generators, there may not be sufficient incentives for power generation from renewable sources with fluctuating cost.

Risk Perception: High-risk perception in adoption of most renewable energy technologies arises due to uncertainties regarding technology performance and low level of information and awareness surrounding these technologies. This is especially valid for renewable energy technologies like solar with a low level of technological maturity

Institutional

Information, Training and Awareness Programmes: Lack of trained personnel for training, demonstration, maintenance and operations along with inadequate awareness and information programmes for technology dissemination impedes renewable energy penetration. Information regarding renewable energy projects is not easily available, which dissuades further investments in RETs.

Regulatory Forums and Processes: The increased accountability of public expenditure may hinder push for renewables through financial incentives like grants, subsidies, soft-loans, etc. Non-incorporation of renewable energy issues in the regulatory policy and lack of awareness among regulators further restrict technology penetration. Renewable energy projects are also adversely affected by frequent and inconsistent regulatory proceedings across states.

Policy Regime: Unstable and non-uniform policy regime across states and between the centre and the states with no clear policies for third party sale, wheeling, banking and buy-back of power lower investor confidence in renewable energy projects.

Private Participation: Lack of well-defined policies for private participation and delays in clearances and allotments for private sector projects hinders private participation in renewable energy projects.

Plan Allocation and Prioritization: Inadequate allocation from state plans for renewable energy and low priority for the State Electricity Boards to take up Renewable energy projects impede their progress.

Co-ordination Issues: In the existing institutional arrangements, lack of co-ordination between planning and implementing agencies delays and restricts the progress in renewable energy development.

Nature of Incentives: The government push policy for penetration of renewables, driven by fiscal and financial incentives, is unsustainable. This is seen especially in the case of wind energy where lowering and removal of incentives led to almost capacity stagnation.

Allocation of Incentives: Due to lack of clear policy guidelines, the incentives provided by the government are often misallocated. For example, in the case of biomass gasifiers, the government granted an investment subsidy for the purchase of gasifiers, which led to the procurement of systems solely for the purpose of getting the subsidized diesel engine pumpsets or the diesel engine gensets.

Marketing Infrastructure: Lack of consumer service orientation in terms of technology features and sales and service requirements and barriers in setting up of marketing infrastructure with promotion campaigns, after-sales service infrastructure, quality control measures, etc. for most of the renewable energy technologies restrict their penetration.

Availability of Finance: For the development of renewable energy technologies, there are barriers in obtaining competitive forms of finance due to lack of familiarity and awareness of these technologies, high-risk perception, and uncertainties regarding resource assessment

Financial Networks: A limited network of Financial Institutions to provide micro-credit access in rural decentralized regions crucially restricts the penetration of renewable energy technologies. Institutions like the Industrial Development Bank of India (IDBI) do not have provisions to supply micro-credit to local bodies through a network of nationalized banks having a wide rural reach.

Nature of Financial support: The provision of financial support to renewable energy technologies is restricted to the investment cost of the technology. The lack of financial support for working capital requirements hinders operating and maintenance of the equipments as well as setting up consumer service infrastructure.

Project Structuring: Intermittent fuel supply for cogeneration projects requires supplementary fuels for continuous power supply. Quite often, the supplementary fuel may be a fossil fuel like coal, oil or gas. Under the existing institutional arrangements, such a project using a combination of fuels may not qualify for IREDA's requirements for a renewable energy project.

Business models: Lack of successful and replicable business models hinders renewable energy technology adoption. This stems from the fact that most of the renewable energy projects lack sustainable commercial arrangements among the various participants.

Infrastructure Availability: Non-availability of infrastructure such as land and transmission and distribution networks in potential sites of renewable energy supply leads to low exploitation of their potential. This is especially valid for wind energy projects.

Community Participation and Capacity Building: Community participation and local capacity building are restricted to just a few demonstration projects. Only private commercial participation is allowed and there is no law for involvement of individuals, committees and communities. This greatly restricts renewable energy development for decentralized applications in remote areas.

Networking with Local Organizations: There is insufficient networking with local organizations for flow of credit with the result that most of the credit flows to the corporate sector whose primary motivation is taking advantage of the financial incentives. This has disabled renewable energy promotion at the local level.

Rural sector Delivery Mechanisms: The lack of appropriate initiatives for rural sector delivery mechanisms hinders providing energy services using renewable energy for decentralized and rural applications.

VI CONCLUSIONS AND POLICY RECOMMENDATIONS

The renewable energy programme has been in existence for more than three decades, but a market for renewable energy technologies still does not exist. Though a manufacturing base has been set up and an infrastructure created to support RET design, development, testing and deployment, commercial demand for these technologies still remains low.

Some key issues related to faster diffusion of RETs are a strong need to improve reliability of technologies and introduce consumer-desired features (in terms of services and financial commitments) in the design and sales package. Renewable energy strategy needs to be integrated with liberalization of energy markets and withdrawal of direct government interventions in energy sector. Renewable energy deployment could be enhanced from *'energy services'* delivery perspective. Incorporation of renewable energy strategy into development programmes will promote its decentralised applications. Renewable energy strategy should form a part of energy sector regulatory framework.. Public-private role in renewable energy development needs to be redefined. The government policies should encourage more private participation and industry collaboration in R&D for rapid commercialization of RETs and in market infrastructure development. Most renewables still have a significant way to go before they are competitive with fossil technologies, especially for power generation purposes. This will demand intense further RD&D efforts. However, at present many renewables are in a classic chicken and egg situation - financiers and manufacturers are reluctant to invest the capital needed to reduce costs when demand is low and uncertain, but demand stays low because potential economies of scale cannot be realised at low levels of production. Renewables need to gain the confidence of developers, customers, planners and financiers. This can be done by renewables establishing a strong track record, performing to expectations, and improving their competitive position relative to conventional fuels.

Future targets set for renewable energy penetration needs to be integrated with overall energy sector and power sector targets. Within renewables, the overall target needs to be desegregated into targets for individual RETs. The baseline scenario projections should be based on past trends and most likely future developments. Specific interventions need to be clearly outlined for achieving penetrations beyond baseline projections, as shown in the analysis under results of different scenarios. At present, MNES has projected a 10,000 MW renewable energy capacity by 2012 for which our analysis results indicate that investment requirements would approximate 8 billion $. Looking into the past performance and likely future developments under baseline, it is unlikely that such investment requirements would be mobilised unless some specific interventions take place. Our analysis results for baseline project around 8,000 MW renewable capacity by 2015 and a 15,000 MW capacity by 2020. Results also indicate that the 10,000 MW capacity target set for renewable energy by 2012 match very closely with the projections for Accelerated Deployment of Renewables (ADR) and medium mitigation sub-scenario as part of Global Environmental Intervention (GEI). Under such scenarios, renewables constitute about 6 percent of the total power generation capacity. Some specific interventions and policy measures related to renewable energy penetration are outlined in Table 13 and Table 14. ADR scenario presumes interventions based on such measures beyond those incorporated in baseline. Mobilisation of large investment requirements under ADR necessitates increasing levels of private participation and international collaborations. An average 25$/T of C price offers around 15 MT of cumulative carbon mitigation potential by 2015 from renewable energy in the power sector (medium mitigation scenario in our analysis). This leads to renewable capacity achievements close to MNES targets by 2012. Analysis in this paper indicates that India's participation in a global carbon market for 15 MT mitigation target offers an investment potential of about 3 billion $ under the Clean Development Mechanism (CDM) or any other alternative mechanisms that may come into effect for participation of developing countries in global climate change interventions. Under this scenario, the CDM investment potential forms a substantial 40 percent of the total investment requirements with a net earning potential of close to 150 million $ from renewable energy CDM projects in the power sector.

Most renewables still have a significant way to go before they are competitive with fossil technologies, especially for power generation purposes. This will demand intense further RD&D efforts. However, at present many renewables are in a classic chicken and egg situation - financiers and manufacturers are reluctant to invest the capital needed to reduce costs when demand is low and uncertain, but demand stays low because potential economies of scale cannot be realised at low levels of production. Renewables need to gain the confidence of developers, customers, planners and financiers. This can be done by renewables establishing a strong track record, performing to expectations, and improving their competitive position relative to conventional fuels. We discuss some specific policy issues linked to renewable energy development with recommendations for future strategies and measures (see Table 13 and Table 14 for summary of key measures).

Learning Investments in Technologies: In the case of renewable energy technologies that are near-commercial stage, 'learning by doing' will help in lowering of costs in accordance with the *'experience curve effect'* and aid in commercialization of the technology. The experience curve effect for Solar PV shows that for each doubling of cumulative sales, the production cost has declined by about 20 percent (IEA, 2001). Learning investments in niche markets for these technologies will catalyse development of sustainable commercial renewable energy market and

provide incentives to reach cost competitiveness. An issue in this context is tapping funds from venture capital sources for the development of Renewable Energy Technologies (RETs) needs.

International R&D and Technology Transfer: International co-operation in R&D, setting up of technology transfer mechanisms to accelerate technology transfers between developed and developing countries and promotion of North-South and South-South co-operation will aid in technology cost reductions.

Technological Leap-Frogging: Promotion of technological innovation and deployment and adoption of new renewable energy technologies in developing countries will provide leapfrogging opportunities and facilitate technology penetration.

Manufacturing Capabilities: Development of advanced indigenous manufacturing capabilities, especially for technologies like Solar PV for silicon wafer manufacturing and transition to multifuel and integrated gasification combined cycle technologies for biomass based power generation will promote the deployment of RETs.

Table 13 Overall Policy Recommendations

Economic & Technological

- Encourage learning investments in technologies that reduce costs and improve performance.
- Promote international co-operation in R&D and technology transfer mechanisms
- Set up of advanced indigenous manufacturing capabilities
- Leapfrogging opportunities- Promote technological innovation and adoption of RETs
- Enact codes, set standards and certifications for fixing technology prices and ensure service reliability
- Promote RE applications in distributed generation, especially for Solar PV
- Develop hybrid technologies for decentralized energy system with a combination of two or more technologies for greater reliability. This is especially valid for technologies such as solar and wind that have low peak capability.
- Emphasize overall system optimization and integrated resource planning by utilities, with renewables integrated in the merit-order dispatch, and taking into account environmental considerations.

Market related

- Develop energy market incorporating full cost pricing of energy forms and life cycle cost analysis of technologies that benefits renewables. Internalisation of socio-environmental externalities in the pricing of energy services will enhance competitiveness of renewables.
- Promote investment in renewables for decentralized and rural energy markets by providing Energy Service orientation of utilities
- Promote RE applications in distributed generation during unbundling of utilities.
- Enhance competitiveness of RETs in decentralized energy system applications in energy sector deregulation process.
- Adopt Net-metering schemes by incorporating avoidance costs for T&D in the electricity supply price from renewables.
- Reforms in electricity transmission and distribution (T&D) with grid expansion needs to integrate decentralised electricity generation at the local level into the national grid by a network of local and state grids.
- Develop Market Based Instruments (MBIs) such as Green Pricing Schemes for renewable electricity with tradable renewable energy certificates
- Liberalize trade with elimination of trade barriers for technology transfer (e.g. high import duty on Solar PV modules)
- Structure Power Purchase Agreements (PPAs) for renewable electricity supply that are cost covering, bankable and replicable for mobilizing private investment in RE Projects.
- Structure instruments such as the *Green Power Price Insurance* to reduce risk borne by the developers and marketers of green power

Institutional

- Set up Renewable Energy Portfolio with a mix of technologies for meeting multiple objectives
- Rationalize targets set up by different departments such as Ministry of Power and MNES and formulate an integrated energy sector policy.
- Integrate renewable energy strategy with that of the entire energy system.
- Set targets for meeting a certain percentage of future energy requirements from renewables.
- The overall energy sector policy should have a distinct decentralized energy development component in which renewables play a significant role.
- Integrate renewable energy policies with power sector reforms.
- Renewables should be included in the Electricity Bill and incorporated in the regulatory proceedings/mechanisms at the centre and states.
- Need awareness building among regulators regarding renewable energy strategy.
- Set up uniform and stable policy regime across states with respect to renewable energy.
- Formulate decentralized energy policy with a bottom-up approach of institutional networks.
- Encourage public-private partnerships in RE development.
- Encourage private entrepreneurship and risk-taking; formulate insurance mechanisms for renewables as part of insurance framework for energy sector.
- Set up consumer awareness and information programmes and ensure a strong service presence.
- Increase resource allocation for technology R&D. Attract private investment in R&D and integrate with technology commercialization activities. The R&D activities should be integrated with the market deployment of advanced technologies and industry participation and co-operation should be increased in such activities.
- Integrate Renewable energy policy with poverty alleviation and rural development programmes

Table 14 Recommendations for Technology categories

Small Hydro

- Integrate Small Hydro power development with regional development plans, especially for stand-alone systems
- Thrust on decentralised power generation from stand-alone small hydro sources occurring in remote hilly areas, as a part of rural electrification and poverty alleviation programmes
- Integrate development of canal-based systems with irrigation projects for better water management
- Policies should encourage more private participation by speeding up clearances of private power projects, de-license power generation from small hydro and provide investment support.
- For stand-alone systems, place thrust on up gradation programme of water mills.
- Adopt a bottom-up approach for technology dissemination. Set up demonstration, training and awareness programmes for community empowerment and local capacity building. Involve local bodies in the decision-making process for purchase of equipments, supply of power and fixing of costs.
- Provide funding access from banks such as National Bank for Agriculture and Rural Development (NABARD)
- Management of canal-based systems, integrated with irrigation projects, can be handed over to farmers' co-operatives.

Wind

- Undertake measures for better operation and maintenance of wind power systems and better technological performance leading to improved capacity utilization.
- Integrate wind power supply option with those from other conventional sources in utility's planning and include wind in utility's unit commitment approach.
- Allocate more resources for technology R&D.
- Disseminate learning experiences in 'international best practices'.
- Ensure grid stability for reliable power off-take and better capacity utilisation of technologies.
- Enter into some agreement with state utilities for drawing high reactive power during start-up operation of windmills.
- Establish uniform and stable policy regime across states so that private investors are not deterred regarding third-party sale, fixing of tariffs, wheeling and banking of power.
- Interventions for environmental sustainability enhance wind power penetration. Redefine baseline projections and develop preparedness plans for accelerated penetration under global climate regime.

Biomass and Cogeneration

- For accelerated penetration of cogeneration projects- set up uniform and stable policies across states regarding third-party sale, fixing of tariffs and wheeling and banking of power.
- Provide investment and technical support for upgradation of existing sugar mills for setting up cogeneration facilities.
- Ensure grid stability for power off-take from biomass and cogeneration projects.
- Ensure continuous power supply from sugar mills to utilities by using supplementary fuels at the time of non-operation of sugar mills.
- Enhance R&D in advanced biomass conversion technologies such as integrated cycle conversion technologies.
- Develop advanced manufacturing capabilities for biomass conversion technologies for transition from demonstration and pilot-plant stages to commercial stage.
- Reorient policy towards treating biomass as a competitive and modern energy supply source.
- Conduct information dissemination programmes to enhance utilisation and promote biomass usage.
- Undertake measures for setting up of dedicated energy plantations and integrate this with wasteland development programmes.
- Set up fuelwood market for ensuring a continuous and reliable supply of biomass fuel. The fuelwood market development should be a part of the overall system for harvesting, transportation, marketing and pricing of forest products.
- Provide incentives for private participation in setting up biomass energy plantations.

- Programme for development of biomass energy for centralised power generation can be combined with the programme for development of biomass fuels for transportation.
- Set up biomass energy development as part of area development, poverty alleviation, and rural employment generation programmes.
- Empower local communities for biomass energy projects and undertake capacity building programmes. Set up farmers' co-operatives in catchment areas for management of plantations.
- Integrate biomass policy with environment and development policy.
- Set up biomass energy development as part of area development, poverty alleviation, and rural employment generation programmes.

Solar

- Integrate solar power programmes with regional development and rural electrification programmes. Focus on niche applications for decentralised power generation.
- Encourage private participation and foreign investment in solar.
- Disseminate learning experiences from international best practices.
- Improve technology performance and reliability by standardization of equipments and adopt quality control measures.
- Facilitate technology transfer by removal of trade barriers such as high import duty on PV modules.
- Develop sustainable business plans for ensuring replicability of demonstration projects.
- Invest in market infrastructure development- set up strong sales and services infrastructure and conduct consumer awareness campaigns.
- Mobilise community participation in decentralised system development by local capacity building, training and awareness building programmes, and assistance in income generation schemes as part of their economic and social welfare.
- Set up sustainable financial arrangements with a network for micro-credit access. Local financiers should be encouraged to assume part of the credit risk to ensure post project sustainability and replication. Encourage small private dealers to work with local micro-finance organizations or partner with large credit firms.

Standard Setting: In order to ensure service reliability and generate customer confidence, standards need to be set for renewable energy technologies. This is also essential for fixing of technology prices.

Distributed Generation: RETs can be promoted for distributed generation opportunities, which are small modular electricity source within the distribution system as part of actions taken to meet the overall objective of providing access to a wider population. This can play a thrust on the promotion of SPVs under the Distributed Utility Concept.

Promotion of Hybrid and Storage Technologies: For decentralized energy systems and off-grid electricity generation from renewables, development of an integrated renewable energy system with a combination of say solar and biomass or any other combination involving two or more technologies can act as a reliable power source.

Overall System Optimization and Integrated Resource Planning (IRP): Renewables may be placed in an advantageous position under conditions of Integrated Resource Planning by an electric utility where there is a thrust on overall system optimization, rather than on plant optimization only. This takes into account supply and demand side constraints and environmental planning considerations. The integration of renewables in the merit-order dispatch of utilities will play a crucial role in safeguarding renewables.

Market-related

Commercialization: Commercialization driven by market reforms leading to improved management, cost accounting and cost recovery may increase the utilities interest in choosing the least-cost approach to expanding services on a life-cycle basis. The key driving forces for a utility are cost recovery, removal of subsidies and more accurate price signals, better information on cost of service and more attention to the environmental implications of investment choices. Renewables will be benefited in the distributed market when utilities are required to supply power on a least cost basis to isolated rural areas where small renewable energy sources offer lower cost solutions then the cost of supplying grid power.

Restructuring and Unbundling: Decisions to invest in renewable energy applications for distributed generation will be favourable in the context of restructuring and unbundling in the electricity sector. The decision to invest in renewable energy for distributed generation will be guided by cost-effectiveness factors in locations where marginal costs for providing service are very high due to network constraints and under conditions where service must be extended to consumers with low load who are far from the grid and there are sharp local peak demands which lead to the inefficient use of distribution assets.

Energy Sector Deregulation: Market reforms will enhance open regulatory forums and processes in the energy sector, which may lead to contests on public outlays on conventional energy supply, including subsidy elements, high transmission and distribution losses and large investment requirements in extending low voltage grids to a wide area. This may enhance the competitiveness of renewable energy technologies, especially in areas where grid construction is difficult and promote decentralized energy systems.

Energy Service Orientation: Market reforms emphasizing on consumer service orientation will lead to a shift from delivery of energy products to providing energy services. In this context, renewables can play an important role in delivery of reliable decentralized energy services along with an efficient marketing and sales and distribution network for instilling consumer confidence.

Fuel Supply and Market Development: Establishing fuel-supply contracts for biomass projects and market development of biomass fuels are extremely critical for the development, commercialization and development of biomass based renewable energy technologies, especially for centralized electricity generation. The long-term sustainability of biomass-based projects will depend upon setting up of a biomass supply market, sustainable biomass plantations, transportation networks for biomass supply and establishing biomass banks.

Full-cost Pricing of Energy forms and Life-cycle Cost Analysis: Measures such as full cost pricing of energy forms, internalization of costs of socio-environmental externalities, reduction in price distortions in substitutable energy forms, electricity tariff rationalization and life-cycle cost analysis for selection of alternate technologies have potential to enhance renewable energy penetration. The removal of pricing distortions in various energy forms will enhance the competitiveness of renewable energy technologies. The distortions range from direct subsidies to conventional energy forms to a more general failure to reflect the socio-environmental costs. Measures for removal of distortions can range from simple direct measures for subsidy removal to indirect measures to reflect the full cost of energy. Some of these include proxy measures such as environmental regulations, incorporation of instruments such as tradable quotas and permits, cess on fossil fuel based energy supply and application of energy and carbon tax. Full value pricing for renewable electricity will need to incorporate various economic, social and environmental benefits generated by renewable energy technologies. Some of these include benefits arising due to the modularity and flexibility of the technology, avoidance in transmission and distribution investment and system losses in renewable energy applications for decentralized power applications, social benefits of rural electrification and increasing employment opportunities. The adoption of *Net-Metering Schemes,* as has been done in other countries, incorporating the avoidance costs for transmission and distribution in the electricity supply price from renewables will prove to be particularly useful. Charging a higher price for energy supply from renewables as compared to supply from conventional fossil fuel technologies based on avoided costs will be critical for enhancing technology competitiveness in a deregulated energy market.

Time-Of-Use (TOU) Electricity Pricing: The role of renewable energy for electricity supply under conditions of imposition of TOU tariff for electricity involves various issues. For renewable energy supply sources like wind and solar- resource availability, demand-supply matching and the peak-coincidence factors of these technologies need to be considered. This would require prediction of wind availability. If the wind availability regime is found to have a high peak coincidence in certain regions, wind may be a useful source for meeting peak power requirements. Peaking in the load duration curve in India occurs in the evening due to lighting load and therefore using solar for meeting peak power demand will entail investment in costly storage technologies. Using renewable energy for meeting peak power demand has been successful in some countries. For example in California, the availability of sunshine coincided with the peak demand occurrence during the day. Solar electricity supply therefore met the peak power demand with a tariff structure of about $2/kWh during peak period vis-à-vis 3 cents/kWh during off-peak periods, that justified the high electricity supply cost using these technologies.

Developing Market Based Instruments (MBIs): Setting up of “Green Pricing Schemes” with tradable renewable energy certificates and trading in “green credits” can serve as effective MBIs for renewable energy penetration. Under such schemes, consumers (residential, but sometimes commercial/industrial) can opt to pay more for renewable electricity. Some of the countries have been very successful in the development of this instrument. For example, the Netherlands has two green pricing schemes, each run by a different distribution company, and these are very popular despite the cost of "green" electricity being up to 25percent more expensive than normal electricity.

Trade Liberalization: Reforms in trade practices with elimination of high import duty on certain equipments such as Solar PV components and elimination of unfair taxation will enhance the competitiveness of renewable energy technologies. Policies and mechanisms to attract foreign investments in renewable energy projects will promote technology transfer.

Power Purchase Agreements (PPA) Structuring: For attracting private participation in renewable energy projects and to ensure their sustainability and replicability, it is extremely crucial to structure appropriate PPAs between the generators and the power suppliers. This can include provisions such as premium rates for projects whose environmental performance exceeds national standards, payment terms that do not discriminate against renewable energy projects with high initial cost but comparable life-cycle costs with generation from other sources, and assignment of risks and liabilities associated with future environmental controls between power suppliers and purchasers.

In this context, there are interesting lessons to be learnt from California's experience in developing Solar Thermal technology. The key success factors behind California's solar plant experience were the structuring of cost-covering, bankable and replicable PPAs that mobilized private investment. The California Energy Commissions lead to the development of standardized contracts with guaranteed price for power purchase by the utility and tax credits for investments in renewable energy supply based on the assumptions of escalating marginal fuel prices for a period of 10 years in a 30-year contract. Under this scheme, it was easy to obtain financing from banks against these PPAs for a long time period of about 30 years. This triggered investments in this technology and lead to substantial cost reductions by learning through scale economies.

Buy-Back Rates: The structuring of the tariff that independent power producers obtain for sales of electricity to the grid and the regulations governing these rates are a critical area influencing development of renewable electricity markets. A differential rate is applied to renewable and non-renewable electricity. In this context, various schemes have been followed in other countries some of which include- providing a guaranteed market for renewables-based electricity at the utility's "avoided cost", guaranteed premium rates for renewable electricity through schemes such as the *Electricity Feed Law* (*EFL)* in Germany and *Non-Fossil Fuel Obligation (NFFO)* in UK. The NFFO is currently being wound up.

Renewable Energy Certificates Trading: An effective means of promoting renewable energy development will be adoption of Renewable Energy Credit Schemes. Under this scheme, tradable renewable energy credits can be set up between suppliers under obligation for each supplier to meet a certain percentage of their electricity supply from renewable sources. This will have an equal impact on all utilities and provide incentives to utilities to bring down the costs of renewables. The critical issue here is methods of ensuring compliance by the utilities.

Green Pricing: Under the green pricing scheme, consumers (residential, but sometimes commercial/industrial) can opt to pay more for renewable electricity, applicable almost always at a local, rather than national level. This scheme has been set up in other countries, and in some the degree of interest shown by consumers is such that some of these schemes have been oversubscribed. For example, the Netherlands has two green pricing schemes, each run by a different distribution company, and these are very popular despite the cost of "green" electricity being up to 25percent more expensive than normal electricity. Issues related to the functioning of such schemes are nature of utilisation of the revenue from the premium placed on renewable electricity, objectives behind electricity companies setting up such schemes (setting up such schemes to appear "green", are they just satisfying consumer demand or are they receiving consumers' help to become green and competitive), and environmental implications.

Green Power Price Insurance: This instrument has the potential to stimulate the market for renewable energy development at a low and acceptable level of financial risk by reducing the risk borne by the developers and the marketers of green power. It can address the asymmetry between the long-term purchase commitments required by renewable energy developers to obtain financing and the customers' interest in signing only short-term purchase contracts. It assumes that consumers are willing to pay a price premium for green power. Under this scheme, the green marketer who purchases power from the generators and sells it to the consumers would take out a price insurance policy before it entered into a power purchase agreement, and the insurance would apply to the power purchased under that agreement. The insurance would in part bear the risk of decline in the green premium that consumers pay over conventional energy. The risk arises due to future uncertainties regarding the future demand for green power and the decline in the costs of renewable energy technologies. This instrument offers a strong possibility of encouraging the growth of green power in a cost-effective way.

Institutional

Renewable Energy Portfolio: There are variations in the suitability of different renewable energy technologies in meeting specific objectives such as meeting minimum rural energy needs, and supply of decentralized and grid power. The creation of a renewable energy portfolio with an appropriate mix of technologies for meeting multiple objectives can lead to overall optimization in the long-term and enable trading in renewable energy certificates. The renewable energy portfolio should also formulate differential strategies for renewable energy categories- commercial, emerging and future technologies. Setting up of Renewable Portfolio Standard (RPS) will require that a certain percentage of the power sold in a jurisdiction be generated from renewable sources. For providing a thrust on market development and convergence promotion of technologies like wind and biomass, a policy regime that requires distribution utilities to buy a certain percentage of their electricity from renewable sources, priced at a premium, may be effective. This extra cost is passed through to the consumers by a levy on the electricity prices.

Target Setting: The presence of a centralised plan and/or target and regulatory requirements for specifying the amount of renewable energy use by the utilities can encourage increased renewable use through information and awareness programmes, setting up of financing mechanisms, and co-ordination of public and private decision making on renewable energy. It can involve capacity allocation to a range of technology clusters (based on near commercial, emerging and future technologies) over a period of 10 to 15 years. In Brazil, for example, Concession Contracts are signed by the utilities and the regulatory requirements necessitate minimum investment targets by the utilities to undertake programmes and R&D activities using at least one percent of the annual revenue related to energy efficiency, energy conservation and technological developments. The present Draft Renewable energy policy sets a target for providing 10 percent share of renewables in the additional power capacity set up till 2012.

Decentralized System Development: This involves formulation of a decentralized energy policy with specific tasks to be completed in time-bound manner and integration with power sector reforms and decentralized electricity supply. The decentralized energy policy formulation needs to be harmonized with institution building at the local decentralized level, e.g. formation of a Renewable Energy Development Agency at the district level in integration with District Energy Development Committees that function under Regional Energy Centres. For certain renewable energy projects such as biomass, the local planning and implementation of project can be carried out by farmers' co-operatives. Dissemination of small hydro technologies can involve setting up of community-based run-of-the-river hydel projects. Setting up of Build-Operate-Own-Transfer (BOOT) schemes for decentralized power generation can involve setting up of a cluster of local companies that form a single entity, which in turn enters into a joint venture with a foreign partner.

In Bangladesh, the success story of Grameen Shakti's renewable energy programme offers interesting lessons for renewable energy development based on decentralized system development and community participation. This non-governmental organization was created in 1996 to popularize renewable energy in rural Bangladesh. The programme for promotion and development of renewable energy sources (solar, wind and biomass energy) and renewable energy supply to the rural households has been integrated with poverty alleviation and environment protection programmes. The objective has been to deliver cost effective energy services at affordable price to non-electrified areas with wide dissemination of technologies among villagers in remote rural areas. The organization has played a crucial role in local capacity building, training and awareness building programmes, assistance in income generation schemes, providing micro-credit facilities to the villagers, and their economic and social well-being. The Chinese experience can provide learnings in integrating decentralized electricity generation at the local levels into the national grid by a network of local and state grids. Biomass based cogeneration offers high potential for this kind of combination.

Integration with Rural Electrification Strategy: A policy thrust on rural electrification needs to be integrated with renewable energy development strategy. According to estimates, about 18000 remotely accessible villages are yet to be electrified and large proportion of the villages having electricity connections are plagued with extremely unreliable power supply situation. The Draft Renewable Energy Policy sets a target for providing electricity to 25 percent of the 18,000 un-electrified villages using renewable energy.

Regulatory Issues: Renewable energy issues need to be clearly outlined in the regulatory framework for the entire energy system, and especially for power sector. Various issues need to be discussed in this context. Promotion of renewable energy may need decentralized regulatory powers and promotion of local level regulation in accordance with decentralization policy for renewable energy development. Under reforms, regulators can grant the new private owner a long-term concession for the right to distribute electricity to a defined geographical area that includes both urban and rural consumers along with structuring of appropriate incentives for private participation: There can be specification of some fundamental rural electrification requirements in the bidding process and the bid evaluation criteria can incorporate business plans for serving off-grid areas in a least-cost manner. A compulsory share of renewable energy in Retail Supply/Monopoly Bulk Purchase of electricity can be associated with price capping by the regulators along with issues related to preferential purchase price for renewable energy. A requirement by regulators for utilities to file Integrated Resource Planning (IRP) along with investment and power purchase plans will provide incentives to utilities to undertake demand-side investments that reduce system costs. This can promote RET deployment for decentralized applications. Regulatory Commissions can allow voluntary purchase and pricing of *'Green Power'* under market reform conditions. Full-cost pricing of different energy forms initiated under open regulatory forums and processes have enhanced renewable energy penetration possibilities. Formulation of policies such as 'Universal Access' or 'Life-line Supply' will expand opportunities for renewables based electricity supply in niche markets, promote distributed generation and enhance the role of renewables in delivery of reliable energy services to niche markets. Setting up of balanced long-term cost recovering regulatory mechanisms is extremely critical for the development of RETs. This would imply distribution of the risk and sharing among a number of players such as multilaterals, banks, financial institutions, export credit agencies, private parties and other players. Last but not the least, there is a need for awareness building among regulators regarding the role of renewable energy technologies.

Structuring of Financing Mechanisms: The policy regime needs to provide assistance and incentives to financial institutions for setting up innovative and sustainable financing mechanisms with sufficient investment flow to the renewable energy sector. There is a need to provide financing for working capital requirements for setting up of marketing and sales-service infrastructure, ensuring service reliability and better operation and maintenance of equipments. A crucial issue here is the setting up of network of micro-credit schemes with rural banks at the local decentralized level. Centralised financial institutions need to have a provision for distributing finances to local nationalized banks, which in turn provide credit to local bodies. Strong rural network financing schemes need to be built that are sustainable and involve community participation. Policy framework should involve private participation in these activities. The choice from among a set of financing options like individual sales, lease-hire, concessions and others depends upon various criteria such as stage of technological development and technological complexity, market size and type, type of technology, etc The present financing mechanisms cater only to investment requirements.

Business Model Setting: Spread of renewable energy programmes necessitates setting up of sustainable and replicable business models having a set of well-defined structure and functions. For renewable energy based conversion technologies that are available *'off-shelf',* there is a need for thrust on business model replication rather than on technology demonstration programmes. The dissemination of learning experiences and replicability of successful models will facilitate technology penetration and ensure the sustainability of renewable energy projects through market mechanisms. Mechanisms to encourage private risk-taking and entrepreneurship should be coupled with the development of attractive business opportunities.
An example in this context would be learnings from the success story of SELCO (Solar Electric Lighting Company), set up with the primary objective of providing energy services through promotion of SPV systems in rural areas (Ramana P.V, 1998b). SELCO entered into

collaboration with a rural development bank, Malaprabha Grameen Bank (MGB) that had a long experience in micro credit operations. The bank provided loans to cover the cost of the device and identified credit-worthy consumers. SELCO performed the task of an energy service company by setting up of training, awareness and demonstration programmes and providing service to the consumers. Rural sub-branches were set up for facilitating after-sales service, and regular collection of loan instalments with consumers being provided with performance guarantees. Under this programme, there was widespread dissemination of Solar Home Systems (SHS). The key success factors were networking with a well-established rural bank, creation of local and decentralised infrastructure and institutions, capacity building, wide community participation, participation of local bodies such as review committees and societies and consumer service orientation.

International Co-operation: This can involve setting up of an institutional mechanism for sharing of 'international best practices' and experiences, dissemination of learning experiences, assistance in training and capacity building programmes, learnings from policy experiences of other countries, setting up of Joint Implementation schemes, information and awareness building programmes, providing training and capacity building at a decentralized level with participation of local authorities. Mechanisms should be set up for enterprise level co-operation at the national and international levels for dissemination of learning experiences and support provision.

Nature of Policies: Renewable energy development policies should be integrated with national developmental policies and it must be ensured that the targets set and the measures undertaken for promotion of RETs are in line with the overall developmental priorities. Policies for *'Universal Access'* or *'Life-Line Supply'* of electricity will expand opportunities for electricity supply to 'niche' markets and promote decentralized applications of renewable energy. A set of uniform and consistent policies for renewable energy promotion and development need to be set up across states and integrated with central policies and targets. Private risk-taking and entrepreneurship should be encouraged. The policies should clearly outline issues related to guaranteed purchase, third-party sales, wheeling and banking of power and other issues. There is a need to ensure stability of the policy regime over a period of time.

Project Integration: Certain renewable energy projects such as small hydro need to be integrated with water management and flood control works.

Legislative Issues: The renewable energy policies and plans along with the targets set need to be clearly outlined in the various legislative procedures. For example, provisions for renewable energy can be included in the new Electricity Bill, specifying the targets set for supplying a minimum quantity of the total energy requirements from renewable energy. Policies for increased scope for decentralized electricity generation and de-licensing of generation will provide an impetus to renewable energy development.

Project Information: Transparency and details in reporting of projects is very essential for attracting private participants to invest in renewable energy projects. Database availability on some of the projects already undertaken along with balance sheet statements and profit and loss account with easy access to investors and other stakeholders will go a long way in boosting investor confidence.

Networking: Setting up of an institutional network is essential for sustaining and developing renewable energy programmes. Some of the participants would involve policy makers, project developers, investors, banks and financial institutions, researchers, NGOs, local community representatives, utilities and other stakeholders. Within the government, there should be involvement of various government ministries and departments that are related to agriculture, rural development, tribal affairs, environment and forests, water management, technology research and development, finance and external affairs, among others.

Voluntary Actions and Agreements: Voluntary actions and agreements can range from formalised and binding negotiated targets to more informal approaches aimed at encouraging renewable energy. These are increasingly being used in a number of countries as part of the mix of measures in place to promote renewable energy. The range of voluntary actions can be extremely diverse, with emphasis on increased information and/or co-ordination of the parties involved, as well as more formal or binding agreements (such as the requirement on the Dutch electricity companies to produce 3 percent of electricity from renewable sources by 2000).

Bibliography

ADB (Asian Development Bank), (1993). *Proceedings of the Training Workshop on Environmental Issues Related to Electric Power Generation Projects in India*. March 1993. Jaipur, India.

Agarwal, Anil, (1996). *Pay-offs to progress.* Down to Earth, October 15, New Delhi, India.

Ahuja D.R. (1990). Research Needs for Improving Biofuel Burning Cookstove Technologies. *Natural Resources Forum*. 14. 125-34.

ASCI (Administrative Staff College of India), (1998). *India: Environmental Issues in the Power Sector.* Andhra Pradesh Case study. Volume III: Coal model. April. Hyderabad, India.

Audinet, Pierre, Shukla, P. R. and Grare, Frederic, (2000). Editors. *India's Energy: Essays on sustainable development*. Manohar Publishers and Distributors, New Delhi, India.

Banerjee, Nandini and Taplin,.Roslyn., (1998). *Climate change, electricity generation and environmental sustainability: India and the Ganges Region.* Energy Policy,26(13).

Berger, C., Haurie, A., and Loulou, R., (1987). *Modelling Long Range Energy Technology Choices: The MARKAL Approach,* Report, GERAD, Montreal, Canada.

Biswas, D. (Ed), (2000). *Parivesh Newsletter: June*. Central Pollution Control Board, Ministry of Environment and Forests, Government of India, New Delhi.

Bose, Kumar Deb, (1999).“International Trade in Emission of Greenhouse Gases - Costly Bargain for Developing Countries”, Economic and Political Weekly.

Brown S. (1996). Mitigation Potential of Carbon Dioxide Emissions by Management of Forests in Asia. *AMBIO*. Vol. 25 No. 4. 273-278.

Brown S., Sathaye J., Cannel M. and Kauppi P. (1996). Management of Forests for Mitigation of Greenhouse Gas Emissions. *IPCC (WG II) Report: Climate Change 1995*. Chapter 24. Cambridge University Press. 772-797.

CEA (Central Electricity Authority), (1999). *Perspective transmission Plan 2011-2012,* New Delhi, India.

CEA (Central Electricity Authority), (1997). *Fourth National Power Plan 1997-2012*. Ministry of Energy, New Delhi, India.

CERI and TERI, (1995). *Planning for the Indian Power Sector: Environmental and Development Considerations.* 1995. Canadian Energy Research Institute, Calgary, Canada; and Tata Energy Research Institute, New Delhi, India.

CMIE (Center for Monitoring Indian Economy), (2000). *India's Energy Sector*. Mumbai, India.

CMIE (Center for Monitoring Indian Economy), (1999). *India's Energy Sector*. Mumbai, India.

DoE (Department of Energy), (May 1996). *Inventory of Technologies, Methods and Practices for Reducing Emissions of Greenhoues Gases,* Technical Appendix to Climate Change 1995: Impacts, Adaptations and Mitigation of Climate Change: Scientfic Technical Analyses. Published for the Intergovernmental Panel on Climate Change by United States Department of Energy.

Down to Earth, (2000). *Power to the People*; November 30, 2000, Vol.9, No.13, New Delhi, India.

Down to Earth, (1999). ***Gone with the Wind*** June 30, Volume 8, No.3, New Delhi, India.

Dutta S, I H Rehman, P Malhotra and P V Ramana (1997). *Biogas – The Indian NGO Experience*. Action for Food Production and Tata Energy Research Institute, New Delhi.

Dwivedi B N and O N Kaul (1997). Forest as biomass energy source in India. (In) P V Ramana and S N Srinivas (eds). *Biomass Energy Systems*. British Council Division, New Delhi; Tata Energy Research Institute, New Delhi.
Economic Survey (1991 to 2000), Ministry of Finance, Government of India, New Delhi.
Edmonds, J. and Barns, D.W., (1992). Factors Affecting the Long-term Cost of Global Fossil Fuel CO_2 Emissions Reductions. *International Journal of Global Energy Issues* 4(3): 140-166.
Edmonds, J. and Reilly, J., (1983). A long-term energy-economic model of carbon dioxide release from fossil fuel use, *Energy Economics*, April: 74-88.
Edmonds, Jae and Clarke, J. F., (1998). *The global energy technology strategy*: Project review. Battelle, Washington D. C., USA.
ERM (Environmental Resources Management), (1997). *Renewable Energy in India: A Special Study.* July, New Delhi, India.
ESMAP (Energy Sector Management Associate Programme), (1998). *India Environmental Issues in the Power Sector, Report No. 205/98.* The World Bank, June, Washington D.C., USA
FAO (1995). *Forest Resources Assessment 1990: Global Synthesis*. FAO Forestry Paper 124. Rome.
Fishbone, L. G. and Abilock, H. (1981). *MARKAL, A linear programming model for energy system analysis: Technical description of the BNL version*. International Journal of Energy Research, 5, 353-375.
Fisher-Vanden, K A; Shukla, P R; Edmonds, J. A., Kim, S. H. and Pitcher, H. M., (1997). *Carbon taxes and India*, Energy Economics, Vol.: 19 Iss: 3 Date: Jul. 289-325
Flavin Christopher, Dunn Seth. *Climate of Opportunity: Renewable Energy after Kyoto*. Issue Brief, July 1998, No.11. Renewable Energy Policy Project (REPP), Washington, USA.
Goel, R.S. and Srivastava, R.N., (1997). *Environmental concerns and prospects of hydro power development in India,* in Pradeep Chaturbedi (Ed), Sustainable Energy supply in Asia, Concept Publishing Company, New Delhi.
Goldemberg, Jose, (1998). *Leapfrog Energy Technologies.* Energy Policy,26(10), 729-741.
Goldstein, G. A., (1994). *PC-MARKAL and the MARKAL Users Support System (MUSS)*, Biomedical and Environmental Assessment Group. Brookhaven National Laboratory, New York.
Grubb M J (1990), *The Cinderella Options: A Study of Modernized Renewable Energy Technologies,* Part 1: A Technical Assessment, *Energy Policy* 18(6):525-542.
Grubler Arnulf, Nakicenovie Nebojsa and Victor G David (1999). "Dynamics of Energy Technologies and Global Change", Energy Policy
Guha, M. K., (1999). *The US utility perspective on technology transfer through the CDM*. Presented in the Workshop on 'Development and Financing of Climate Change Partnership Projects', Organized on December 9-10 by Indian Institute of Management, Ahmedabad, India.
Hall D.O. (1991). *Biomass Energy*. Energy Policy. Vol. 19 No. 8. 711-737.
Hirsh Richard F., Serchuk Adam H. (2001). Power Switch: *Will the Restructured Electric Utility Help the Environment?* Renewable Energy Policy Project (REPP), Washington, USA.
Houghton R.A. (1996). Converting Terrestrial Ecosystems from Sources to Sinks of Carbon. *AMBIO*. Vol. 25 No. 4. 267-272.
IEA (2001), *The Evolving Renewable Energy Market.* IEA/OECD Publication, Paris, France.

IEA (1997a), *Energy Technologies for the 21st Century*, International Energy Agency, Paris, France.
IEA (1997b), *Energy Technology and R&D*, International Energy Agency, Paris, France.
IEA (1997c), *Key Issues in Developing Renewables,* International Energy Agency, Paris, France.
IPCC (Inter Governmental Panel on Climate Change), (1997). *Inventory of Technologies, Methods, and Practices for Reducing Emissions of Greenhouse Gases*, (technical appendix to climate change 1995).
IREDA (2000). *Renewable Energy Financing Guidelines,* Indian Renewable Energy Development Agency, New Delhi.
Jackson Tim, Oliver Mark (2000). *The viability of solar photovoltaics*, Energy Policy, 28 (2000), 983-988.
Jagdeesh A., (2000). *Wind energy development in Tamil Nadu and Andhra Pradesh, India Instituitional dynamics and barriers,* Energy Policy, 28 (2000), 157-168.
Johansson, T.B., Kelly, H., Reddy, A.K.N and Williams, R.H., (1993). Renewable Fuels and Electricity for a Growing World Economy - Defining and Achieving the Potential, *in Renewable Energy- Sources of Fuels and Electricity - Johansson T.B, Kelly H, Reddy A.K.N and Williams R.H (Eds.)*, Island Press, Washington D.C., U.S.A.
Kainuma, M., Matsuoka, Y. and Morita, T., (1997). The AIM Model and Simulations, *AIM Interim Paper*, National Institute for Environmental Studies, Tsukuba, Japan.
Kanudia, A., (1996). *Energy-Environment Policy and Technology Selection: Modelling and Analysis for India*. Doctoral Dissertation, Indian Institute of Management, Ahmedabad, India.
Kaufman Steven L (1999). *Calculating, Monitoring and Evaluating Green House Gas Benefits from Solar Heating Systems in Developing Countries.* Sunrise Technologies Consulting. Arlington, MA, April 30, 1999.
Kaya Y. (1990). *Impact of Carbon Dioxide Emission Control on GNP Growth: Interpretation of Proposed Scenarios.* Paper presented to the IPPCC Energy and Industry Subgroup, Response Strategies Working Group, Paris, France.
Koch Hans Jorgen (2000). *The Potential of Renewables and Distributed Energy Technologies in Energy Supply.* WEC/IEA International. Symposium on Renewable Energy Development, China, 23-25 May.
Kozloff Keith (1998). *Impact of Power sector Reform on Bulk and Distributed Markets for Renewable Energy.* http://www.repp.org
Kuznets S.S. (1958). *Six Lectures on Economic Growth*. Free Press, New York, NY, USA
Loiter, M. Jeffrey and Norberg-Bohm, Vicki, (1999) *Technology Policy and Renewable Energy : Public Roles in the Development of New Energy Technologies,* Energy Policy.
Loulou, R, Shukla, P R, and Kanudia, A. (1997), *Energy and Environment Strategies for a Sustainable Future: Analysis with the Indian MARKAL Model*, Allied Publishers, New Delhi.
Mc Veigh James, Burtraw Dallas, Darmstadter Joel, Palmer Karen. *Winner, Loser or Innocent Victim: Has Renewable Energy preformed as expected?* Renewable Energy Policy Project (REPP), Research Report No.7, May 1999, Washington, USA.
McGowan F (1991), *Controlling the Greenhouse Effect - The Role of Renewables, Energy Policy*, March, p 110-118.
Means Robert C. *Evaluation of a Proposal for Green Power Price Insurance.* Renewable Energy Policy Project (REPP), Special Report, May 1999, Washington, USA.

Miller D., Hope C., *Learning to lend for off-grid solar power: policy lessons from World Bank loans to India, Indonesia and Sri Lanka;* Energy Policy 28(2000) 87-105.
MNES (2001). *Annual Report 2000-2001.* Ministry of Non-conventional Energy Sources, New Delhi.
MNES (2000). *Annual Report 1999-2000.* Ministry of Non-conventional Energy Sources, New Delhi
Morita T, Kainuma M, Harasawa H, and Kai K., (1996). *A Guide to The AIM/ENDUSE Model - Technology Selection Program with Linear Programming*, AIM Interim Paper, Japan.
Morita, T, Kainuma, M, Harasawa, H, Kai, K, Kun, L D, and Matsuoka, Y. (1994). Asian-Pacific Integrated Model for Evaluating Policy Options to Reduce Greenhouse Gas Emissions and Global Warming Impacts, *AIM Interim Paper*, National Institute for Environmental Studies, Tsukuba, Japan.
Munasinghe, M., (1991). *Sustainable Energy Options for Developing Countries,* World Energy Council Journal 1, December, 69-87.
Naidu, B S K (1996). *Indian scenario of renewable energy for sustainable development*, Energy Policy, 24(6), 575-581.
OECD/IEA, (1998). *Penetration of Renewable Energy in the Electricity Sector.* Annex I Expert Group on the UNFCCC, Working Paper No.15. Paris, France.
Pearson, Peter J. G., (1996). Fouquet, Roger, *Energy efficiency, economic efficiency and future CO2 emissions from the developing world*, Energy Journal, 17(4) 135-160.
Rajsekhar, B., Fan Hulle, F., and Jansen J.C, (1999). *Indian Wind Energy Programme : Performance and Future Directions,* Energy Policy, New Delhi : Tata Energy Research Institute.
Ramana P V (1991). *Biogas Programme in India – A Status Report. TERI Information Digest on Energy* 1(3):1-12.
Ramana P V and Joshi V (1997). *Use of biomass fuels in India - trends and issues.* (In) P V Ramana (ed). *Rural and renewable energy: perspective from developing countries*. Tata Energy Research Institute, New Delhi.
Ramana, P.V. and Shukla P.R., (1998a). Climate Change Policies and Long-Term Rural Energy Trends in India, in Climate Change Mitigation: Shaping the Indian Startegy- PR. Shukla ed., Allied Publishers, New Delhi, India
Ramana, P.V. (1998b). *As if Institutions Matter*: An Assessment of Renewable Energy Technologies in Rural India. University of Twente, Netherlands.
Ravindranath N.H. and Hall D.O. (1995). Biomass Energy and Environment- A Developing Country Perspective from India. *Oxford University Press*. Oxford.
SAR (1996). Second Assessment report of IPCC. *Climate Change 1995: The Science of Climate Change*. Cambridge.
Shukla, P. R.; Pierre, Audinet and Grare, Frederic (2000). (Eds.). *India's Energy*: Essays on Sustainable Development. Manohar Publication. New Delhi.
Shukla, P. R.; Ghosh, D.; Chandler, W. and Logan J. (1999a). *Developing Countries and Global Climate Change: Electric Power Options in India.* Prepared for the Pew Centre on Global Climate Change, Arlington, US.
Shukla, P. R and Pandey, R. (1999b), *Energy and Emissions Projections for Indian Industries using AIM\ENDUSE Model*, in Energy and Emissions Studies using AIM Model - Eds. T. Morita, Y. Matsuoka and M. Kainuma, Springer-Verlag Publications, Forthcoming.

Shukla, P. R. (1998), Implications of Global and Local Environment Policies on Biomass Energy Demand: A Long-term Analysis for India, *Proceedings of Expert Workshop on Biomass Energy: Data, Analysis and Trends*, International Energy Agency (IEA) Paris, March 23-24.
Shukla, P. R. (1997a), *Biomass Energy Future for India*, Proceedings of International Workshop on Science and Technology for a Modern Biomass Civilization, Rio de Janeiro, Brazil, Sept. 8-9.
Shukla, P. R. (1997b), *Penetration of Renewable Energy Technologies in India: Assessment of Future Trajectories and Macro Policies,* in Renewable and Rural Energy Policy Perspective in Developing Countries, Ed. P. Venkat Ramana, Tata Energy Research Institute, New Delhi.
Shukla, P. R. (1997c), *Biomass Energy in India: Policies and Prospects,* Proceedings of Workshop on Biomass Energy: Key Issues and Priority Needs, International Energy Agency (IEA), Paris, February 3-5.
Shukla, P. R., Edmonds, Fisher-Vanden, K.A., J.A., Kim, S.H. and Pitcher, H.M. (1997d). *Carbon Taxes and India*. Energy Economics, Elsevier Science B.V, May.
Shukla P R (1996). *The Modelling of Policy Options for Greenhouse Gas Mitigation in India,* Ambio 25(4):240-248.
Shukla, P. R.; Deo, P. and Modak, S. (1991). *Decentralised Energy Planning: Methodology and Case Studies*. Oxford & IBH Publishers, New Delhi.
Sinha C S (1992). *Renewable Energy Programs in India: A Brief Review of Experiences and Prospects*. Natural Resources Forum 16(4):305-314.
Sinha C S (1993). *Renewable Energy programs in India: Some Recent Developments*. Natural Resources Forum 18(4):213-224.
Smith K.S. (1987). *Biofuels, Air Pollution, and Health*, Plenum Publishers, New York.
SRES (2000). *Special Report on Emissions Scenarios.* Inter-governmental Panel on Climate Change, Cambridge University Press, Cambridge, USA.
TEDDY (1999/2000). *TERI Energy Data Directory and Yearbook.* Tata Energy Research Institute, New Delhi, India.
TERI (1997a). *Evaluation of the Wind Pump Program.* Report submitted to the Ministry of Non-conventional Energy Sources. Tata Energy Research Institute, New Delhi.
TERI (1997b). *Rural and Renewable Energy: Perspectives from Developing Countries*. Tata Energy Research Institute, New Delhi, India.
TERI (1989). *Evaluation of National Programme on Improved Chulhas in West Bengal, Rajasthan and Tamil Nadu.* Report submitted to the Department of Non-conventional Energy Sources, New Delhi.
TOI (Times of India), (2000). *12,000 MW of renewable energy planned.* The Times of India (Ahmedabad), 23 May, India.
UNFCCC (1997), *Kyoto Protocol to the United Nations Framework Convention on Climate Change*, United Nations, New York.
USAID/India's Greenhouse Gas Pollution Prevention (GEP) Project. *Cane Cogen India.* A quarterly newsletter of the GEP Project (ABC Component), India, with support from USAID, ISNN 0972-0855 Vol II, Jan 1999.
WGEP (1979), *Report of the Working Group on Energy Policy,* Planning Commission India, New Delhi.
Workshop Proceedings. Workshop on *Policies to Accelerate Renewable Energy Market Deployment,* 18-20 February, 2001: Ashoka Hotel, New Delhi.

WRI (World Resources Institute), (1998). World Resources 1998-99, A guide to Global Environment. A joint publication by the WRI, UNEP, UNDP, and World Bank, Oxford University Press, New York, USA.

YES (1998). *Yearbook of Energy-Environment Statistics*. Bharat Information Technology Services, New Delhi, India.