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Decentralised renewable energy: Scope, relevance and applications in the Indian context

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ABSTRACT

Presently used centralised energy planning model ignores energy needs of rural areas and poor and has also led to environmental degradation, whereas decentralised energy planning model is in the interest of efficient utilisation of resources. Energy planning at the village level is the bottom limit of the application of decentralised planning principle. The individual villages are the smallest social units where the energy consumption occurs. Renewable energy is energy derived from sources that are being replaced by nature, such as water, wind, solar or biomass. Renewable sources are essentially non-polluting if applied correctly. The paper presents a review of the important decentralised renewable energy options, related case studies of successful deployment of renewable energy technologies in India and resulting lessons learnt. Case studies discussed in the present work show the feasibility of decentralised energy options for the residential and small scale applications in a village or a cluster of villages. The paper also details the different initiatives taken by the government of India to promote decentralised energy production in India. It is found that the small scale power generation systems based on the renewable energy sources are more efficient and cost effective. Thus the focus should be on the small scale renewable energy technologies that can be implemented locally by communities and small scale producers, but can make a significant overall contribution towards the national energy supply.

Introduction

The current pattern of commercial energy-oriented development, particularly focused on fossil fuels and centralised electricity generation, has resulted in inequities, external debt and environmental degradation. For example, large proportions (approximately 80%) of rural population and urban poor continue to depend on low quality energy sources and inefficient devices, leading to low quality of life. The current status is largely a result of adoption of centralised energy planning, which ignored energy needs of the rural areas and poor, and thus led to environmental degradation due to fossil fuel consumption and forest degradation. As suggested by Reddy and Subramanian (1980) and Ravindranath and Hall (1995), decentralised energy planning is one of the options to meet the rural and small scale energy needs in a reliable, affordable and environmentally sustainable way. Among different energy forms, power generation provides the largest opportunity for promoting Renewable Energy (RE). The focus in this case is on small/medium sized plants ranging from about 10 kW to 50 MW. The main advantages are substantially lower capital outlay, lower risks, shorter gestation periods and proximity to load centres. The main objective is to assure reliable and quality power.

In this paper, a review of the potential for decentralised power generation, attempts made in India to implement such systems, case studies of successful implementations and policy support to draw lessons for the future are presented.

Decentralised energy: an Indian perspective

India has nearly 600,000 villages and has a large potential for Decentralised Energy (DE) systems (Ravindranath and Hall, 1995). Officially, over 500,000 of India's 600,000 villages are “deemed” to be “electrified”: defined as a minimum of 10% of households being connected to power supply (Reddy, 1999). Only 44% of India's 138 million rural households use electricity for lighting — a particularly efficient and desirable application of power, the remaining 55% still use kerosene — a grossly inefficient source, which is increasingly becoming expensive too (Ravindranath et al., 2004). This also affects

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rural industries, with negative impact on employment generation and income (Reddy and Subramanian, 1980; Burrough, 1986; Ravindranath et al., 2000).

During the past last quarter of the century, a significant thrust has been given to the development, trial and induction of a variety of RE technologies for use in different sectors (Goldemberg and Johansson, 1995; Ravindranath et al., 1994). The Government of India is keen on increasing the share of RE in India's installed power generation capacity by an additional 10% or 12,000 MW by 2012. In effect, around one tenth of the 120,000 MW expansion in energy generation capacity planned for India by the Central Electricity Authority (CEA) for the 11th plan (2007–2012) is expected to come from the RE sector. Within the long-term vision, policy seeks to set out the major application areas and short term targets for the period up to the end of 11th Five Year Plan, 2012. The major application areas are decentralised energy supply for agriculture, industry, commercial and household sector in rural and urban areas and grid quality power generation and supply.

Further, the government of India is also planning to decentralise the management of the electricity delivery system in rural and semi-urban areas to the users. While several pilot-scale models are being designed and implemented in India to showcase the viability of distributed generation schemes, this would not be sufficient to mainstream them in the national planning process unless a clear framework and road-map containing technical, financial, implementation and regulatory-related aspects are developed. The Draft Renewable Energy Policy, Rural Electricity Supply Technologies Mission and the Electricity Bill 2001 are good starting points. However, a national policy on distributed generation that comprehensively takes into account the nature of diverse rural situations is needed. Such a policy should look at appropriate Renewable Energy (RE) and Distributed Generation (DG) technologies for providing electricity access; the necessary institutional and financial arrangements for facilitating the same; the extent to which reforms and restructuring could impact DG in rural areas, and finally, the linkages of all of the above with the economic and social development of rural communities (Chaurey et al., 2002).

The draft New and Renewable Energy Policy (NREP) Statement 2005 has been in the making for some time now. Although, the Statement attempts to set a strategic vision for new and renewable energy in the country, it does not purport to be a blueprint that would be pursued during the next 20 years and beyond. It, however, proposes a direction to deliver positive changes in both the short and longer terms. Through the NREP Statement, priorities have been proposed, which would be reflective of the aims of national energy security and energy independence. In doing so, the role of renewable energy has been placed in its proper perspective vis-à-vis those of competing sources, whether conventional or nuclear. It has been recognised that current deployment has tended more towards replacement of coal rather than oil. The priority of the country, however, has to be to develop substitutes for liquid, gaseous and solid fossil fuels, in that order. The NREP Statement proposes a policy direction that would facilitate a realignment of our deployment priorities. Further, it has also been recognised that renewable energy development in the country has somewhat lagged behind deployment. Consequently, the country remains a net importer of new and renewable energy systems/devices although in biomass gasification it has attained a leadership position. The NREP Statement proposes a policy direction for making the new and renewable energy sector a net foreign exchange earner by 2021–22.

Renewable energy technologies for decentralised power generation in India

Following sections briefly present the case studies of different RE based decentralised power generation systems and summarise the lessons learnt for moving ahead. The technologies considered are bioenergy, solar power, wind and hydro.

Table 1
Summary of Gosaba Island biomass electrification

Plant capacity	5 × 100 kW
Cost of installation (total)	Rs. 9.5 million
Subsidy	100%
Distance from grid	39 km
Monthly expenditure (November 2003)	Rs. 45,000
Monthly revenue (November 2003)	Rs. 46,000
No of consumers	1150 HH
Operation hours	16 h (9:00 am to 1:00 am next day)
Tariff Structure	Rs. 5.6/kWh (US$0.12) for domestic
	Rs. 6.75/kWh (US$0.15) for commercial
	Rs. 8/kWh (US$0.18) for industrial
Specific fuel consumption	90 cm3 diesel + 850–900 g of wood/kWh
Cost of fuel	Rs. 35 (US$0.78)/40 kg half dry wood
Consumption of diesel	0.13 l/kWh
Consumption of biomass	900 g of dry fuel/kWh
Area under plantation	100 ha
Expected yield	10/t/ha/annum
Indirect employment	84
Beneficiaries(direct + indirect)	1100
Year of installation	1997

http://www.plants.uwa.edu.au/home/research/research_centres/ergo/.

Bioenergy

Bioenergy refers to renewable energy resources derived from organic matter, such as forest residues, agricultural crops and wastes, wood and wood wastes that are capable of being converted to modern energy carriers. The extraction of energy from biomass is split into three distinct categories, solid biomass, biogas, and liquid biofuels. Solid biomass includes the use of trees, crop residues, household or industrial residues for direct combustion to provide heat. Biogas is obtained by anaerobically digesting organic material such as cattle waste and leaf biomass to produce the combustible gas methane. The other kind of fuel is liquid biofuels, which are used in place of petroleum derived liquid fuels, are obtained by processing plants, plant seeds or fruits of different types like sugarcane, oilseeds or nuts using various chemical or physical processes. Pressing or fermentation is used to produce oils or ethanol from industrial or commercial residues such as biogases or from energy crops grown specifically for this purpose (Bhat et al., 2001).

Currently, biomass accounts for around 30% of the national primary energy consumption. Under the optimistic scenario, use of three times the present amount of biomass is considered to be a possible development by 2050, if effective measures were to be adopted. The contribution of crop-residue and cattle waste is likely to remain constant at the 2001–02 level. The additional estimated bio-energy use by 2050 and beyond would be derived from wastelands. India has implemented the biogas programme mainly for cooking and to a small extent for decentralised power whereas the major focus is on biomass gasifiers for power generation. In this review, the focus is on case studies of biomass power generation at decentralised level.

Case studies: biomass power

West Bengal: Gosaba Island rural electrification. About three million people inhabit the Delta Region of Sunderbans, West Bengal State. Two million of them do not have access to electricity. A 500 kW gasifier was installed in Gosaba Island off the Sundarbans, West Bengal, for electrification of five villages comprising more than 10,000 people. Gosaba Island is located south of 24-Parganas district at a distance of 115 km from Kolkata. After an initial survey of the area, the West Bengal Renewable Energy Development Agency (WBREDA) decided to set up a 500 kW gasifier-based power plant along with an energy plantation (to meet fuel wood needs without affecting agricultural lands) in 100 ha of wasteland and a rural energy cooperative for regular operation of the power plant. The 500 kW

Table 2
Operation cost per unit electricity comparison for water supply system of Odanthurai Panchayat, Tamil Nadu State

	With grid power	With gasifier system
Electricity	Rs. 4.5/kWh	Rs. 0.45/kWh
Labour cost	Rs. 0.45	Rs. 0.66
Maintenance cost	Rs. 0.07	Rs. 0.28
Total	Rs. 5.02	Rs. 1.39

http://www.plants.uwa.edu.au/home/research/research_centres/ergo/.

(5 × 100 kW) biomass gasifier dual fuel power generation system (70% biomass + 30% diesel) was installed in June, 1997. The system had only 16 customers when the operation started because people did not believe that it really works. The island developed dramatically since the installation of power station with many commercial establishments (shops, hotels, etc.) attracting even people from nearby islands for shopping. The project is 100% funded by the government since this is a pilot project but owned and operated by Gosaba Rural Energy Cooperative. The cooperative organizes 75 ha of energy plantation. Biomass fuel is supplied by both the farmers and the plantation. The details of plant operation are summarised in the Table 1.

Gosaba gasifier has shown the technical feasibility of a medium sized (500 kW) multi-village decentralised biomass power system and its management.

Tamil Nadu: gasifier installations at Odanthurai Panchayat. Ankur Scientific, which is a leading gasifier manufacturer (67% share of total gasifier installations), installed 60 gasifier systems in Tamil Nadu State in one year during 2004. Of the 60 systems, 57 were of 9 kW capacity. In one such case, Odanthurai Panchayat (Panchayat is a general term of village cooperatives in India) installed a 9 kW biomass gasifier power generation system to substitute the grid electricity usage for pumping drinking water supply. The biomass gasifier system saves about 70% of pumping cost compared to using grid electricity (Table 2). This Panchayat also has other renewable energy projects such as solar street lighting and biogas production using human and domestic animal waste. The biogas system is connected to each house for cooking purpose. This has resulted in people hardly using firewood. Panchayat purchases waste wood from a saw mill in the village at very low price of Rs. 0.3/kg (US$6.7/t) as fuel for the gasifier. The low price is mainly the result of low demand for wood in the village.

Though, the grid electricity tariff of Rs. 4.5/kWh (US$0.10) is considered inexpensive, it is not preferred because gasifier installation saves large amount of cost of the water supply system.

Karnataka: Hosahalli and Hanumanthanagara villages. This case presents the experiment of the Centre for Sustainable Technologies (CST), Indian Institute of Science, Bangalore, India to demonstrate and disseminate biomass-based electricity generation systems in non-electrified villages. Hosahalli and Hanumanthanagara are located in the semi-arid Tumkur district of Karnataka State. The population, of 220 and 300 respectively, is dominated by the farming community of whom over 80% have agricultural lands. The main source of drinking water was a bore well and the collection of water involved enormous drudgery. There was no assured irrigation water supply. Main supply was from a small irrigation pond, which was dependent on the rainfall. A 20 kW capacity biomass gasifier (see Table 3) developed by CST has been installed in each village. These gasifiers have an efficiency of around 23% and are connected to a diesel engine to run on dual fuel (coupled to a generator). A diesel replacement of 85 to 90% was achieved in field conditions. Woody biomass is obtained from social forestry plantation grown for meeting village biomass needs. Its specific fuel consumption per unit of electricity generation is around 1.25 kg/kWh. The investment cost for the 20 kW biomass gasifier power generation units was Rs. 850,000 while the investment cost for services such as irrigation, drinking water, flour mill, and electrical wiring of all homes was Rs. 650,000. The total investment cost for power generation and provision of services was about Rs. 1,500,000 for each village. The operation and maintenance cost was about Rs. 3.34/kWh at a full load of nearly 20 kW (Ravindranath et al., 2004). Electricity was provided for home-lighting, street lighting, pumping drinking and irrigation water, and operation of a flour mill. These services were provided during fixed hours agreed to by the village community. Electricity was generated and provided for over 90% of the days. The main responsibility for managing the system was with the Village Management Committee. The functions are: supervision of the operation of the system, protection of the forest and equipment, insurance of the payment for the services, ensure compliance to agreement reached, day-to-day decision-making, monitoring of income and expenditure. Local trained operators were responsible for operation and maintenance, collection of charges, wood supply and recording basic data on performance. CST provided technology support, organized major repair and replacement and undertook monitoring of the system. Village community received the benefits of quality lighting, safe drinking water supply, flour milling and irrigation water supply and sharing arrangements.

Impacts and lessons learnt

Benefits of biomass-based distributed generation (DG) systems accrue by changing from a remote, centralised service that uses imported and indigenous fuels, to building a localised system based on modular technology that uses indigenous fuels. Decentralised power that uses biomass can avoid T&D losses, include a participatory project development process, and increase rural employment based on an indigenous resource. The modularity associated with DG systems offers consumers a number of benefits such as: (a) a degree of energy independence, (b) opportunities for local control to improve security of supply, (c) equal or better power quality, and (d) a cleaner environment. The decentralised power generation systems based on biomass, implemented in India, have shown the technical and operational feasibility as well as acceptance by the local communities. However, economic viability of biomass-power systems is yet to be demonstrated in India.

Solar power

Photovoltaic (PV) cells transform sunlight into electricity, storing it in batteries for later use. Solar Photovoltaic (SPV) systems are most commonly used for stand-alone applications and are commercially available with capacities ranging between below one kW to one MW.

Table 3
Status of village electrification Hosahalli and Hanumanthanagar Karnataka, India

Location	Capacity	Running from when?	Purpose/services	Operation hours	Biomass	Comment
Hosahalli, Karnataka, India	25 kVA — DG set with 50 kg/h gasifier	1987 — with 5 kW system; 1998 — 25 kW system	Lighting, drinking water, grinding machine, Irrigation irrigation water	1200–1500 per annum with irrigation 4000 h	Pieces from a different species of forest residues	Operational
Hanumanthanagara, Karnataka, India	25 kVA — DG set with 25 kg/h gasifier	1994+	Lighting, drinking water, grinding machine, Irrigation irrigation water	1200–1500	Pieces from differentspecies of forest residues	Operational

http://cgpl.iisc.ernet.in/.

It requires minimum maintenance and is well suited for remote locations. Due to its geographical position near the equator and high levels of sunshine all year-round, PV systems are a cost-effective means of making power available to remote users in India. This has now been demonstrated by a number of projects that are now being integrated in rural electrification programmes in different parts of India.

Case studies: solar power plants

West Bengal: Sundarban region. Providing power and drinking water facility to the large population in the isolated islands of the Sundarban region in West Bengal had been a perpetual problem in the past, as it was not practically possible to link the islands with the mainland power grid. The Ministry of New and Renewable Energy (MNRE), through the West Bengal Renewable Energy Development Agency (WBREDA), came forward, way back in 1996 to solve this problem in two major islands of the Sundarban region i.e., Sagar Island and Moushuni Island.

Sagar Island is a large island with an area of around 300 sq km spread over 43 villages and a population of over 160,000, situated 110 km south of Kolkata. The main hardship of the people had been non-availability of electricity. Till 1996, only a few diesel generating sets of aggregate capacity of 300 kW were in service to provide electricity to some selected 400 consumers for a few hours in the evening. The operation and maintenance requirements of these generators were quite high and at the same time causing adverse environmental pollution. The year 1996 changed the situation for the better when MNRE identified Sundarban Region as one of the high focus areas under its SPV programme and started providing necessary funds to WBREDA for setting up of SPV power plants there. The first 26 kWp SPV plant was commissioned in Kamalpur village in Sagar Island with only 19 consumers in February, 1996. Subsequently many such power plants with aggregate SPV capacity of 300 kWp are operational in Sagar Island serving around 2000 families. Today, hospital services, water supply, etc. are being served through solar energy to some extent. The solar generated electricity constitutes more than 50% of the total electricity consumed in Sagar Island.

Moushuni, another large island in Sundarban region, has earned the distinction of having India's largest stand-alone SPV power plant with installed capacity of 55 kWp, commissioned in April, 2001. It is located at Bagdanga village under Namkhana block in south 24 Parganas district. Already about 250 different categories of consumers are being served with the three phase, grid-quality power from this power plant. This benefit will be extended further to another 200 families in near future, for which new distribution lines are being laid. Power is being supplied through 5 km overhead distribution system network for duration of 6 h in the evening. The Ministry has sanctioned another project for setting up a 100 kWp power plant in Baliara village on the other part of the Moushuni Island. With the commissioning of this power plant, an additional 700 families are expected to benefit directly, and thus the socio-economic developmental process will get the desired fillip in the entire Moushuni Island.

The SPV power plants in Sagar and Moushuni islands are being run on commercial mode through the local rural cooperatives formed by the beneficiaries themselves under the aegis of WBREDA, catering to both the domestic and commercial needs for 5–6 h in the evening daily. The distinguishing feature of the SPV Programme at both Sagar and Moushuni islands is the integration of power and water supply systems in these projects. Around 700 families are getting the twin benefits of such integrated power and water supply systems at present in the twin Islands of Sagar and Moushuni. This novel and unique venture has opened up a new vista and provides immense opportunities for catering to the two basic needs of electricity and water together, for the dispersed population of the isolated and remote habitats having no alternate or traditional energy sources, in a meaningful way.

Orissa: Salepada Power Plant. Salepada is a small hamlet of the Gatibeda revenue village in Sunabeda Gram Panchayat of Komna block in the state of Orissa. A total of 40 households are located in the village, with a total population of 206 inhabitants. Salepada possesses sufficient shadow free open space and receives adequate solar insolation for about 300 days a year. A 2 kW size SPV plant was established. Under the project, 85 home lights were installed, along with 8 lights for street illumination. Each home received one 9 W CFL (compact fluorescent lamp) for illumination purposes. Moreover, for community use, five extra points including a TV point and 8 street lights of 11 W each were provided. A 2 kW PV power plant can easily cater to the total load of 0.944 kWp. Illumination for 5 h per day, 5 p.m.–11 p.m., had been fixed. The installation of SPV power plant was under the aegis of UNDP-DESI (United Nations Development Program - Decentralised Energy Systems India) for demonstration of power generation through renewable energy. Salepada is an example of community action coupled with the participation and involvement of the community at every step.

Kerala: Mundanmudy village. The solar lighting system in Mundanmudy village of Idukki district in Kerala, the largest installation of its kind in the world, has changed the life-style of the local people. Hundreds of houses (393 precisely) lined one after the other with bright solar panels in the village are quite impressive. Mundanmudy village is located at an elevation of 1500–2000 m near a reserved forest, with no access to the electrical grid. The connection only reaches the foothills, and even here due to the transmission losses, the light in the last few houses only glimmer. Till 1997, the entire population depended on kerosene lamps. But with the introduction of solar lighting system, the lighting dreams of the village have come true.

Uttaranchal: remote villages and hamlets. The government of Uttaranchal State prepared plans for electrification of all villages in the State by the end of 2007. All remote villages would be electrified through non-conventional energy sources. The state has a good mini-hydroelectric potential and solar radiation in this region is also very good. The remote villages can therefore be electrified through Solar Household Systems (SHS). The selection of villages for electrification is done by Uttaranchal Renewable Energy Development Agency after obtaining “No Objection Certificate” from Uttaranchal Power Corporation Ltd.

Impacts and lessons learnt

People claimed to have benefited not only from the social point of view but also from the point of view of income generating activities. Vocational training for self-employment has been initiated. After sunset, the presence of light permits other activities such as sewing and handicrafts. Sewing machines are already in use for training the youth and women for income generating activities. In fact more such activities are on the way. Table 4 gives a brief overview of SPV and their benefits to the households in Sagar Island in West Bengal.

Other renewables

Micro-hydro and wind are the other renewables with large potential for decentralised power generation in India. According to the Central Electricity Authority (CEA), the economically exploitable hydro potential in India has been assessed at 84,044 MW at 60% load factor which corresponds to an approximate installed capacity of 150,000 MW from 845 schemes. Assuming that even if 50% of this potential was to be harnessed by 2050, the total hydro installed capacity could be around 100,000 MW by then (including around

Table 4
Frequency distribution of sample households by type of benefits derived for getting power from SPV Plant in the Year 2000

Type of benefits	Percentage of households with SPV connection					
	Centres					All
	Ka	Kh	Mr	Gb	Mg	
Availability for longer period for study	67	80	28	54	30	47
Saving of time for cooking	56	80	17	48	13	38
Movement at night	6	4	8	29	0	9
Entertainment	17	28	39	13	8	21
Time for household work at night	6	48	22	10	2	17
Physical comfort	6	24	17	10	53	25
Doing of agriculture work at night	28	24	3	3	13	12
Availability for longer period for trade and business	17	4	75	35	68	46
Increase in income for extended hours of work	22	16	83	58	35	46

Notes. (1) Name of the centres in an island called 'Sagar Dweep' in West Bengal, India: Ka (Kamalpur); Kh (Khasmahal); Mr (Mrityunjoy Nagar); Gb (Gayen Bazar); Mg (Mahendragang).
(2) The study, based on a sample survey, conducted in an island called 'Sagar Dweep' in West Bengal, India (Chakrabarti and Chakrabarti, 2002).

25,000 MW already installed). There are a large number of perennial streams with adequate discharges in the hilly regions and the Himalayan region of India, which can be harnessed for generation of small hydropower. Smaller capacity hydropower development schemes, especially the "Run-of-river" schemes have certain advantages over other hydroelectric schemes with larger capacities. In India the potential of small hydro power is estimated to be about 10,000 MW.

Wind power potential in India has so far been assessed at 45,000 MW with 1% land required for wind power generation in potential areas. Assuming a capacity utilisation factor of 25%, the identified potential can generate electricity equivalent to around 100 TWh per annum. It has been assumed that with better resource assessment and further increase in conversion efficiencies, the identified potential can generate around 117 TWh by 2051–52. Wind turbines extract energy from moving air and enable an electric generator to produce electricity. These comprise the rotor (blade), the electrical generator, a speed control system and a tower. These can be used in a distributed generation in a hybrid mode with solar or other technologies. Research on adaptation of wind turbines for remote and stand-alone applications is receiving increasingly greater attention and hybrid power systems using 1–50 kW wind turbines are being developed for generating electricity off the grid. Wind turbines are also being used as grid connected distributed resources. In many parts of India, small wind systems (from 50 to 300 kW) provide energy for village electrification, water pumping, battery charging, small industrial uses, etc. In India, however, the use of wind as an energy source is at a preliminary stage for decentralised energy generation. Some of small decentralised hydroelectric and wind energy generating systems have been discussed later.

Case studies: other renewable sources

There is a long history of small hydro projects in India. The following two examples are illustrative.

West Bengal: Jaldhaka Hydroelectric Power Station. Jaldhaka hydroelectric power station, situated in West Bengal's Darjeeling district near Bhutan border, started operation with 2 × 9 MW generating units during the year 1967 and 3rd unit capacity 9 MW commissioned in the year 1972. This power station had been commissioned with additional 2 × 4 MW generating units in the year 1983.

West Bengal: Rammam Hydroelectric Project. Ramman hydroelectric project (4 × 12.75 MW), a major hydro power project of West Bengal State Electricity Board, is a run-of-river scheme and located about 140 km from Siliguri in the hilly district of Darjeeling, West Bengal. Subsequently the 1st unit was commissioned in September, 1995. The performance of Rammam hydroelectric Project, had achieved a commendable success since its commissioning. This project was planned to utilise the water resources of the river Rammam as well as the river Lodhoma, a tributory to the river Rammam. Due to financial and other constraints the discharge of Lodhoma river could not be utilised since commissioning while the project is being operated with the diversion of the discharge of river Rammam only.

Wind power and integrated wind biomass gasifier diesel system in Sagar Island. As mentioned above, Sagar Island is among the largest islands in the Sunderbans region of West Bengal. The people of the island have been getting electricity from a 500 kW diesel plant and 50 kW solar PV power plants. Considering the rapid growth in the demand of electricity on the island, WBREDA proposed to install an additional 500 kW of new generating capacity based on wind turbines. The wind turbines and the diesel generator would work in an integrated manner through a controller that would enable utilisation of wind energy whenever the wind resource is available. People will get electricity at lesser cost and also from an energy source that is environmental friendly. The power supply using wind energy is also expected to improve the social and economic life of the people as other renewable energy sources.

At the same time it would demonstrate a new technology for harnessing renewable energy to be managed by a local cooperative of consumers. Sagar island wind diesel hybrid system is first of its kind in Asia. Presently, two units of 50 kW each are generating electricity for supply into the local grid and has been providing electricity to 861 households and commercial establishments at the island during the evening hours from July 2002. When completed, there would be ten (10) units of 50 kW each, which along with 500 kW of biomass gasifier would supply electricity to the people in the island. This project is expected to lead to social and economic development of the island, where electricity till some years ago, was a distant dream.

The first phase of the wind diesel hybrid electricity system comprising of two diesel engines and two units of 50 kW each of wind turbines was installed in July 2002. The number of consumers since then has increased from 33 to 861 during this period. Two wind electric generators coupled with two diesel generators meet the resultant increase in load (from 12 kW to 140 kW). Electricity supply is provided for six hours. During the period of October to February electricity is supplied from 5 PM to 11 PM and from 6 PM to midnight from March to September.

Jammu and Kashmir: Hybrid Power System in Ladakh region. Ladakh is a remote region located in the Himalayas with very low population density. Small scattered loads and good availability of renewable energy resources like hydro, solar, wind and geo-thermal, makes the region ideal for renewable energy based decentralised power generation. At present hydro and solar energy play an important role in power generation and rural electrification in Ladakh. Hydroelectricity from small hydroelectric plants (installed capacity 8.5 MW) accounts for about 60% of the total electricity generation. About 7000 solar PV Domestic Lighting Systems provide electricity for lighting to about 25% of the households in Ladakh.

Impacts and lessons learnt

There is limited information on the performance, costs and impacts of wind, micro-hydro and SPV systems in India, These renewable and hybrid power projects have proved to be an effective environment-friendly way of producing electricity, and a viable alternative to electricity generated by thermal, large hydro and nuclear routes. They have benefited land owners, who had no means to irrigate and cultivate their otherwise barren land. Ample employment opportunities have been created for manufacture, installation, operation and maintenance of wind turbines, micro-hydro and hybrid systems. The above stated experiences have proved beyond doubt that such technologies not only deliver much-needed electricity, but also provide employment to a large number of people, and pave the way for economic prosperity. Hybrid systems combine two or more energy conversion devices, or two or more fuels that when integrated, overcome limitations inherent in either. These systems have been found to be very useful for meeting water pumping and small power requirements in decentralised mode in rural and remote windy areas of the country, which are unelectrified or have intermittent electric supply. Such hybrid units offer greater reliability, especially for remote applications such as land-based while at the same time attempting to minimize the use of the diesel fuel.

Cost of decentralised energy options

Comparison of costs and its implications

Decentralised energy technologies based on local resource availability can be a viable alternative to rural electrification in India through the extension of the main grid. This paper compares the cost of grid electricity to the end-user and with the cost of electricity from decentralised energy systems considering factors like the specific distances from the grid, the level of demand and the load factor conditions under which using decentralised energy systems for rural India makes economic sense. These factors are explained below:

- The specific distances from the grid;
- The level of demand; and
- The load factor conditions.

Thus an attempt has been made to identify the specific conditions under which different decentralised energy technologies become cost-effective. Sinha and Kandpal (1991) compared the cost of grid-supplied electricity with the cost of supplying electricity through decentralised energy technologies to different kind of villages in India (like for a single, isolated village and a cluster of villages or 'scheme'). Sinha and Kandpal (1991) incorporated the site-specific nature of cost by empirically establishing a generalised cost function for the distribution network; this exercise was carried out for three distances: 5, 15 and 25 km from the 33 kV grids. It was assumed that the load factors calculated for are representative of the load-factor range in rural areas of India. Table 5 summaries the generating system cost of delivered power by distance (km) from 33 kV grid point and Table 6 gives broad view of cost of delivered power by distance (km) from 33 kV grid point.

Thus it can be concluded that for small and isolated villages with low load factors, decentralised energy technologies make economic sense. The specific load factor conditions as well as the distance from the grid at which some of these decentralised technologies become economically viable without resorting to debatable accounting and pricing assumptions of grid electricity.

Table 5
Cost of delivered power in a remote village in the year 1999

Generating system	Cost of delivered power by distance (km) from 33 kV grid point (in Rs.)				
	5	10	15	20	25
Thermal station	9.39	14.38	20.27	25.71	31.15
Diesel generator	14.12	19.56	25.00	30.44	35.88
Solar PV	26.10	26.10	26.10	26.10	26.10

Notes. Cost of delivered power is the sum of generation cost of power supplied at bus and distribution cost including cost for line loss. The line loss as a percentage of production has been taken as 40 for thermal system, 21 for diesel based system and 0 for SPV system. Source: Chakrabarti and Chakrabarti (2002).

Table 6
Distance-wise cost of delivered power for different power generating systems for the years 2005 and 2010

Sources of power generation	Cost of delivered power by distance (km) from 33 kV grid point (in Rs.)				
	5	10	15	20	25
For 2005					
Thermal station	9.55	14.69	19.64	25.45	29.69
Diesel generator	14.85	19.90	24.94	30.75	34.99
Solar PV	15.38	15.18	15.18	15.18	15.18
For 2010					
Thermal station	9.76	14.45	19.15	23.83	28.59
Diesel generator	15.76	20.43	25.15	29.83	34.54
Solar PV	9.67	9.67	9.67	9.67	9.67

Source: Chakrabarti and Chakrabarti (2002).

Conclusion

Decentralised power plants address some of the major issues faced by the Indian power sector. For a large and dispersed rural country, decentralised power generation systems, wherein electricity is generated at consumer end and thereby avoiding transmission and distribution costs, offers a better solution. The renewable energy technologies in India relate to small and micro hydro, wind turbines, combustion and gasification of biomass, solar photovoltaic and hybrid systems. However, most of the decentralised plants are based on wind power, hydroelectricity and biomass gasification.

Some case studies of distributed renewable energy sources implemented in India are been discussed in the paper. The small scale power systems are likely to be more efficient and cost affective. Decentralisation of electricity generation provides a new economy. Employment availability will be greater once renewable energy is mainstreamed in the economy. There is a large potential for growth in renewable energy industry. Promotion of renewable technology through decentralisation will expedite the use of cleaner forms of energy production.

It can be concluded that village level decentralised planning approach has been attempted on a small scale for isolated projects for meeting one or two energy needs of the villages. Though India has made considerable progress in implementing technologies based on renewable sources of energy, the decentralised energy technology applications are still few. The actual examples of decentralised energy options are very few, despite MNES making numerous efforts to promote spread of these systems. The energy-environment technology packages are rarely used at local, block and district level energy planning. Dedicated efforts are needed to ensure meeting all the energy needs through decentralised renewable energy options. Thus it is necessary to develop criteria and identify environmental factors that need to be incorporated during decentralised energy planning.

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