Status of Rural Electrification in India, Energy Scenario and People's Perception of Renewable Energy Technologies

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ABSTRACT

Energy is at the heart of most critical economic, environmental and developmental issues facing the world today. Clean, efficient, affordable and reliable energy services are indispensable for global prosperity. Several local and global factors, including climate change, population increase and future energy security are the driving factors to the desire for universal access to renewable energy technologies. Social attitudes and lack of knowledge and awareness are major challenges to overcome, to successfully introduce low carbon technologies as a sustainable alternative to more traditional means of energy provision. This article presents a review of the status of rural electrification in India and decentralized renewable energy technology options. The work details different initiatives taken by the government of India for electrification of villages and steps taken to promote decentralized energy generation technologies. The study includes the results of a rural energy survey conducted in a typical village in the Indian state of Karnataka. It highlights the opportunities and attitudes of the rural communities towards sustainable modern energy services and the technologies used to deliver them. Results from the survey show that there is interest among the people in using sustainable or renewable technologies for energy provision. The findings suggest that, while selecting a fuel source, the most influencing factors are cost, reliability and ease of use. These factors score higher than environmental benefits and safety issues; hence, the focus should be on creating awareness among rural people about decentralized renewable energy technologies. These can be implemented locally by communities,

making a significant overall contribution towards the national energy supply and environment protection.

Keywords: Rural electrification, renewable energy, reliability, cost, environment, safety.

INTRODUCTION

The International Energy Agency (IEA 2011) gives the following universal definition of the term "energy access": "a household having reliable and affordable access to clean cooking facilities, a first connection to electricity and then an increasing level of electricity consumption over time to reach the regional average." More than 1.3 billion people in the world do not have access to electricity, while 2.7 billion do not have access to clean cooking energies according to IEA. With almost 40% of the global population still lacking access to clean cooking energies, the challenge is daunting. Further, energy access is predominantly a rural problem. Out of 1.3 billion, 1.1 billion (or 85%) lacking electricity access are in rural areas. Similarly, out of 2.7 billion, more than 2.2 billion (or 81%) lacking clean cooking energy access reside in rural areas [IEA 2011]. More than 95% of these people are either in sub-Saharan Africa or developing Asia, and 84% are in rural areas. [Meghan 2012]

There is a clear relationship between poverty and access to electricity. Poverty levels increase the more remote and inaccessible the communities are, while costs for electrification increase due to transport and maintenance. Literature and practical experiences show that improved access to energy services is one of the main steps to the fulfillment of the millennium development goals [Alex Zhand 2009]. Almost universally, communities with no access to modern energy services identify lighting, cooking, heating and clean drinking water as their main needs for improved living conditions. Lighting, for brighter and cleaner indoor conditions, for reading, studying and socializing usually ranks at the top of the wish list of people without access to electric light. In the view of the poorest of the poor, living in remote mountain communities, electricity, even for minimal lighting services, is one of the most desired energy services.

The lack of access to energy services in rural communities in developing countries restricts educational opportunities, leads to negative public health and environmental impacts, and inhibits economic growth. Inadequate access to sustainable forms of energy in developing countries has devastating public health and environmental effects and threatens global energy security. Sustainable provision of energy services to rural communities can alleviate these negative impacts, and encourage development and education. [Meghan 2012]. Developing countries in particular need to expand access to reliable and modern energy services if they are to reduce poverty and improve the health of their citizens, while at the same time increasing productivity, enhancing competitiveness and promoting economic growth.

The UN Advisory Group on Energy and Climate Change (UNAGECC, 2010) calls on the United Nations system and its member states to commit themselves to two complementary goals: 1) Ensure universal access to modern energy services by 2030. The global community should aim to provide access for the 2-3 billion people excluded from modern energy services, to a basic minimum threshold of modern energy services for both consumption and productive uses. 2) Reduce global energy intensity by 40 percent by 2030 [Blenkinsopp 2013]. According to the International Energy Agency (IEA), "individuals' access to electricity is one of the most clear and undistorted indications of a country's energy poverty status." The IEA further breaks down energy access into incremental levels of 1) basic human needs, 2) productive uses, and 3) modern society needs. "Basic human needs" is the level that is used for forecasts of costs for universal energy access. This includes "electricity for lighting, health, education, communication and community services" and "modern fuels and technologies for cooking and heating" (IEA, 2009).

With about 1.3 billion people in the world (or about 1 in 5) without access to electricity in 2010 the challenge of providing reliable and cost-effective services remains one of the major global challenges facing the world in this century [Bhattacharyya 2012]. Although grid extension still remains the preferred mode of rural electrification, extension of the central electricity grid to geographically remote and sparsely populated areas can either be financially unviable or practically infeasible. More people today do not enjoy the luxury of having light in their homes in the developing world than the world's population in Edison's time. [Alex Zhand 2009]. Access to clean, easy and affordable energy is an important factor to achieve development and is considered as crucial for sustainable development and poverty reduction [Takada 2007].

Energy is a major input for socio-economic development. Fossil fuels are expected to fuel economic development for a majority of the world population during the next two decades. However, during the period 2020-50, fossil fuels are likely to reach their maximum potential, and their price will become higher than renewable energy options because of increasingly constrained production and availability. Therefore, renewables are expected to play a key role in accelerating development and sustainable growth in the next century. Since the use of renewables would be extensive by the year 2020-21, there is a need to develop a model for the effective use of renewables in India [Iniyan 2003]. To be able to provide adequate electricity to its population, India needs to more than double its current installed capacity to over 300 GW by 2017. Also, India's demand for oil in 2015 is expected to be 41% higher than in 2007 and almost 150% higher in 2030—needed primarily to feed a growing transportation sector [NREL-2010]. Renewable energy is well positioned to play a critical role in addressing this growing energy demand.

Electricity Market in India

The generation capacity in India (2012-13) is 225 GW, broken down thusly: 153 GW, 68 percent, thermal (including 132 GW from coal); 39.6 GW from hydro; 27.5 GW from other renewables; and 4.8 GW from nuclear [Deb Chattopadhyay-2014]. Despite a significant growth in capacity over the years, especially that of wind and solar in recent years, supply has perpetually lagged behind demand. As a result, in the 2012/13 financial year the country faced a peak and energy shortage of 9 and 8.7 percent, respectively. The sourcewise installed capacity of India as of March 2014 is shown in Figure 1.

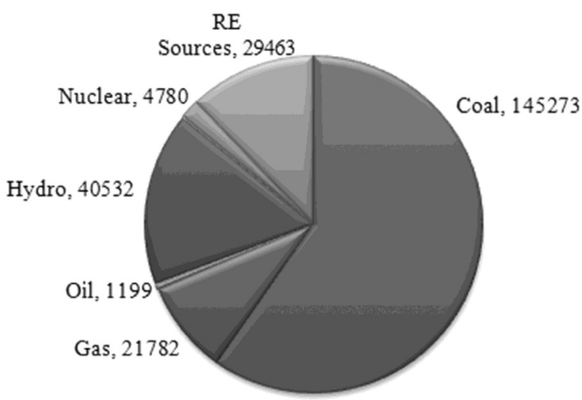

Figure 1. Sourcewise installed power capacity—India as of March 2014 [GREEN-2014]

Though cities and urban conglomerates in some developing countries have seen rapid rise in per capita consumption, semi-urban and rural areas still remain in darkness. There are vast disparities and inequities in access to electric power. For most of their power and energy needs, people in rural areas remain dependent on conventional sources such as firewood for cooking and kerosene for lighting. Even in villages that are "electrified" (connected to a grid or a centralized distribution system), supplies are erratic and of extremely poor quality. Access also is limited. In many "electrified" villages, all village residents do not have access to electricity. [Dinesh Sharma-2007]

The present electricity generation has been centered in the coal thermal power stations. Over 90% of dark households are concentrated in rural India. Expanding energy access to poor families and communities is a complex development challenge, particularly in rural areas. There are limitations to the expansion of the electricity grid as well as supply of electricity through the grid. Diesel and kerosene, neither of which is a sustainable solution, are being used to fill the gap. [Akshay Urja-2013]. The presently used centralized energy planning model ignores energy needs of rural areas and the poor, and has also led to environmental degradation, whereas the decentralized energy planning model is in the interest of efficient utilization of resources. Energy planning at the village level is the bottom limit of the application of the decentralized planning principle [Hiremath 2009]. The individual villages are the smallest social units where energy consumption occurs. Harvesting renewable energy in a decentralized manner is one of the options to meet rural and small-scale energy needs in a reliable, affordable and environmentally sustainable way.

The broad aim of the twelfth plan 2012-2017 w.r.t. environment and sustainability sector is:

- Increase green cover (as measured by satellite imagery) by 1 million hectares every year during the Twelfth Plan.
- Add 30,000 MW of renewable energy capacity in the Twelfth Plan.

Generally, 90% of the energy needs of the poor originate from heating and cooking demands whereas electricity is used for lighting and entertainment. The disparity in the energy consumption mix and quantity consumed can be quite significant between urban and rural consumers. For example, based on NSSO-2012 data for Indian households, rural consumers rely heavily on firewood (and other solid biomass), whereas urban consumers use electricity and LPG. This disparity is graphically shown in Figure 2.

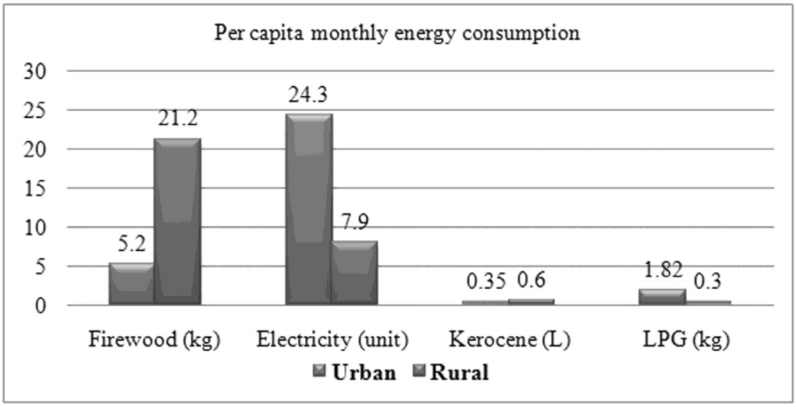

Figure 2. Energy use disparity between urban and rural India [NSSO-MOSPI-2012]

The current pattern of commercial energy-oriented development, particularly focused on fossil fuels and centralized electricity generation, has resulted in inequities, external debt and environmental degradation. Large proportions (approximately 80%) of the rural population and urban poor continue to depend on low quality energy sources and inefficient devices, leading to a low quality of life [Hiremath 2009]. The current status is largely a result of adoption of centralized energy planning, which ignored energy needs of the rural areas and the poor, and thus led to environmental degradation due to fossil fuel consumption and forest degradation.

India has made considerable progress in electricity generation after independence. Installed capacities have grown many times, mainly through conventional routes of power generation. But the demand for power continues to outstrip supplies, as the economy grows. The result is substantial peak and energy shortages all over the country. In addition, India has huge transmission and distribution losses to the tune of 40% [Nouni-2008]. So, universal access to electricity remains a pipedream for most Indians, particularly in rural areas.

Energy Scenario in Rural India

The pace of rural electrification over much of the developing world is painfully slow. In many African and South Asian countries, it is even lower than rural population growth. (Barnes-2005). The government declares a village electrified "if electricity is being used within its revenue area for any purpose whatsoever." So, if just one light bulb glows in a village for even one hour a day, the village is counted as electrified. As per the 2011 census, 72.2% of the people in India live in villages and 43% of rural households still use kerosene to light their houses compared to 6-7% in urban areas [Censusindia]. As of 31st March 2014 there are still 21,318 villages (4%) which have no access to electricity. (REC 2012-13). Realizing this fallacy after more than half a century of power production, the government of India set in motion an exercise to change the definition of village electrification. [GREEN-2014].

Rural Electrification in India

Over 85% of rural India is still using firewood, crop residue, or cow dung as its primary source of fuel for cooking. One of the major reasons lies in the location of the villages themselves which are often remote. Renewable energy becomes a very suitable candidate in these case as it requires less time to set up in rural areas [Kanase Patil- 2010]. In recent years, from an environmental point of view, the renewable energy resources are being looked at as unlimited, inexhaustible, friendly and sustainable. As per Rural Electric Corporation annual report 2012-13, 44,171 villages were electrified during 2012-13. The total number of villages that have been electrified stands at 692,770. The year-wise electrification of villages is shown in Figure 3.

According to Bhattacharyya [2006], the energization of irrigation pumpsets was for a long time the principal aim of rural electrification. Consequently, the level of electrification was not measured as a percentage of electrified households but in the extension of electricity lines to a particular area expressed by the percentage of electrified villages. A village was assumed to be connected if a transformer was placed in it. Although official estimates indicate that close to 96% of Indian villages are electrified, fewer than 50% of households actually consume electricity [Kemmler 2007]. Until recently, the main policy has been to extend the grid to villages in rural areas to emphasize productive uses for agriculture. Today, there is a new emphasis on making sure rural households have access to and adopt electricity. [GREEN 2014] The number of pumpsets energized has risen from 8,207,482 to 10,252,441 by the end of 2013 as indicated in Figure 4.

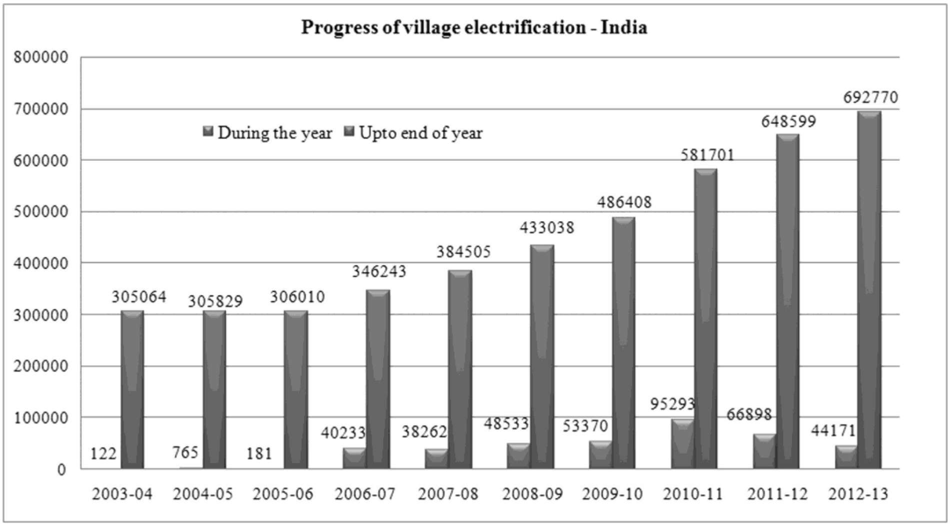

Figure 3. Year-wise progress of electrified villages until the end of 2012-13 [REC 2013]

The significance of access to easy and reliable electricity in rural parts of India has been recognized very early. However, the target of rural electrification is still incompletely met. Some of the factors causing most concern are lack of willingness of state utilities to develop the electricity

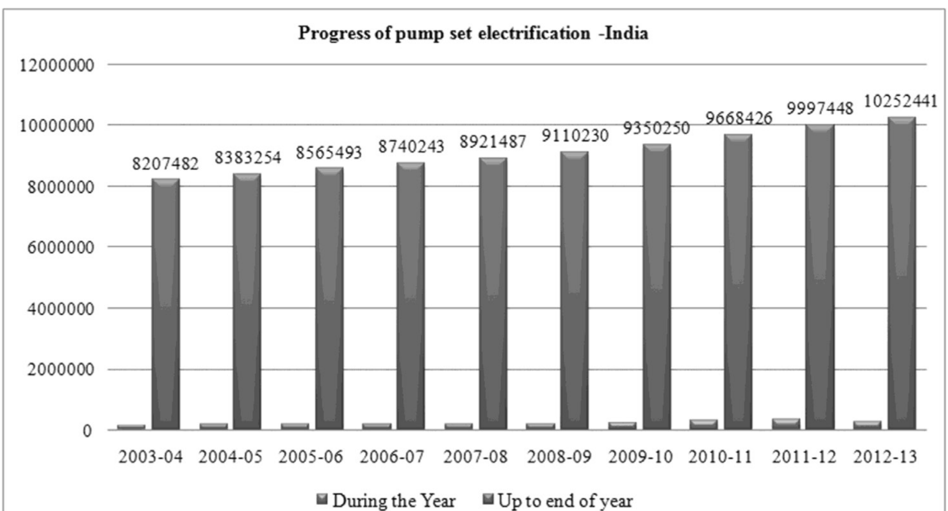

Figure 4. Year-wise progress of pumpset electrification till the end of 2012-13 [REC 2013]

infrastructure in rural areas, transmission and distribution losses, low revenue collection efficiency, and highly subsidized consumers [Anand 2009]. According to section 6 of the Electricity Act 2003, the government of India decided to electrify all villages that were not yet electrified. It is thought that conventional as well as renewable energy will be used to achieve this objective; renewable energy sources would be used in a decentralized manner where conventional grid connectivity is not possible. The application of decentralized renewable energy for electricity provision and rural electrification has shown good results.

Figure 5 shows the percentage increase in energy access among the urban and rural populations of India between 2004-05 and 2010-11. The hike in energy access with respect to LPG and electricity is marginal as far as urban populace is considered where as the percentage increase is substantial for rural populace. The reasons for less usage of LP gas in the rural sector include cost, easily available firewood and unreliable supply.

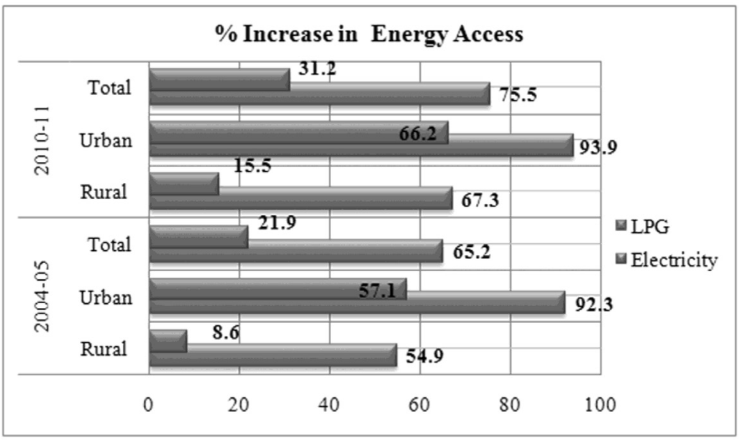

Figure 5. Percentage increase in energy access [Twelfth Plan]

Indian Energy Scenario: Share of Renewables

Until March 2014, India has been able to achieve only 12.95% of its renewable energy potential. The untapped market potential for overall renewable energy in India is 216,918.39 MW which shows huge growth potential for renewable energy [Nouni 2007]. As of March 31, 2014, the total installed capacity from renewable energy, both grid-interactive and off-grid/captive power, was 32,270 MW. Thus the untapped market potential for overall renewable energy in India is 215,922 MW

[Green-2014]. India's Ministry of New & Renewable Energy (MNRE) has set a target of achieving overall renewable energy installed capacity of 41,400 MW by 2017. The total renewable energy potential from various sources in India is 249,188 MW. Table 1 shows the total installed capacity of renewables in India

Table 1. Installed capacity of renewables: India, March 2014 [Source: GREEN-2014]

Sector	Potential (MW)	Installed Capacity (MW)	% Achieved
Wind Energy	102772	21136.2	20.57
Solar Energy	100000	2647	2.65
Small Hydro Power (SHP)	20000	3816.91	19.08
Biomass	17536	1914.5	10.92
Bagasse Cogeneration	5000	2648.4	52.97
Waste to Energy(W to E)	3880	106.6	2.75
Total	249188	32269.6	12.95

Government Initiatives for Rural Electrification.

In India, the principal actors in the rural electrification process are the state electricity boards (SEBs). They are responsible for power generation, transmission and distribution, and they own the intra-state lines, whereas the overall planning, policy, and financial reviews are conducted by both the Ministry of Power (MOP) and the Central Electricity Authority (CEA). As of March 2014 there are still 21,318 villages which have no access to electricity. Realizing this fallacy after more than a half century of power production in independent India, the government set in motion an exercise to change the definition of village electrification.

As per the new definition, a village would be declared as electrified, if:

- Basic infrastructure such as distribution transformer and distribution lines are provided and electricity is provided to public places like schools, panchayat offices, health centers, dispensaries, community centers, etc.
- The number of households electrified should be at least 10% of the total number of households in the village [MOP]

The government of India has enacted several policies to support the expansion of renewable energy. These include: Electricity Act 2003, National Electricity Policy 2005, National Tariff Policy 2006, Rajiv Gandhi Grameen Vidyutikaran Yojana (RGGVY) 2005, and many schemes under Eleventh Plan 2007-2012 and Twelfth Plan 2012-2017. Other programs include:

- Rural electrification under Minimum Needs Program (MNP)
- Pradhan Mantri Gramodayan Yojana (PMGY)
- Kutir Jyoti Scheme (KJC)
- Accelerated Rural Electrification Program (AREP) [MOP].

The village electrification program mandates that rural households receive electricity not only for domestic lighting, but also for productive applications such as water pumping for irrigation, community applications, and health care. Accordingly, MNRE proposes to deploy decentralized electricity generation technologies including biomass gasification, small hydro, and wind and SPV power plants. [Anand 2009]

Rajiv Gandhi Grameen Vidyutikaran Yojana (RGGVY) was launched in April 2005 by merging all ongoing schemes. Under the program, a 90% grant is provided by the government of India and 10% as a loan by Rural Electric Corporation (REC) to the state governments. REC is the nodal agency for the program. It aims at:

- Electrifying all villages and habitations as per new definition
- Providing access to electricity to all rural households
- Providing electricity connection to Below Poverty Line (BPL) families free of charge

Impact of Rural Electrification

Recent studies of rural electrification indicate the following broad consensus concerning the impact of electrification in the rural areas [Kamalapur 2012].

A. Quantifiable benefits: cost saving and increased productivity
   1. Industrial and commercial uses of electricity
   2. Household uses of electricity—lighting, cooking, etc.
   3. Agricultural uses of electricity—water pumping

B. Benefits that are difficult to quantify
   1. Modernization, dynamism and attitude changes
   2. Quality of life, community services and participation
   3. Income distribution and social equity
   4. Employment creations

Advantages of a decentralized system without grid connectivity are reductions in distribution losses because electricity need not be transmitted for a long distance. Therefore, decentralized energy with a large contribution of renewable sources in rural areas could be a sensible option.

Issues of Electricity Sector in India

Centralized conventional electricity generation with grid network has some issues that hinder the Indian electricity sector from achieving the 100% rural electrification target. The important issue is that the state utilities had shown no interest in electrifying the rural areas because there is not much economic gain (in terms of monetary value) for state utilities; therefore there is utterly no consistency of supply of electricity in rural areas. Kalra et al (2007), author of India's infrastructure report, mentioned that state utilities' heavy losses over the years had direct implication for the poor implementation of rural electrification programs in India.

In India the electricity sector has always been confined to centralized electricity planning with a large component of thermal power generation from fossil fuels mainly dominated by coal. However, this centralized planning has not been able to balance demand and supply. This centralized electricity generation has resulted in inequities, external debate, and environmental degradation, which can be seen from the fact that still nearby 70% of Indian population live in rural areas and around 40% of total population lives without any modern energy services (Kaundinya 2009). This situation occurred mainly because of the adoption of centralized energy planning; it snubbed electricity demand of rural poor community (Hiremath 2009).

Alternative energy sources, including a variety of renewable energy sources, provide another route for energy security, especially in the longer run. However, its quantitative potential over the next 10 years is small at present, though it is expected to expand to 50,000 MW by the end of the Twelfth Plan. The costs of these sources are also much higher though they are falling. Of special interest, this is a potentially profitable area for further research.

Survey to Assess Rural Energy Consumption Pattern and Community Perception Towards Renewable Energy Sources

A survey was performed to build a comprehensive picture of local/community energy requirements and attitudes towards renewable energy technologies for sustainable energy provision. The questionnaire

included information on
1. Household pattern of energy consumption (current energy use),
2. People view on renewable energy.

The survey was carried out in the form of a questionnaire-based interview, and answers were recorded. The work was carried out during in the month of June, 2014, in the village of Habbanatti and Kusmalli located in Khanapur Taluq of Belgaum district of the Indian state of Karnataka. Karnataka has significant potential for the expanded use of various renewable energy technologies. (MOSPI 2012). Depending on respondents' willingness to participate, households in the village were selected randomly. The main aim of the survey was to study the energy use pattern, awareness and attitude towards renewable energy technologies, and to determine the barriers for their adoption.

The village Habbanatti (15°64′32″N 75°52′33″E) and Kusamalli (15°42′53″N 74°23′3″E) of Karnataka have been selected for the present study. These villages are located at 16 and 26 km from Belgaum town. Habbanatti village is a typical rural settlement with groups of houses scattered over small segments. The major activities of the population are agriculture and livestock rearing. About 56.8% of the people are illiterate. Kusmalli village is similar to Habbanatti but located on the main road and is relatively bigger. The major activities of the population are agriculture, and some work in cooperative dairy farming. The standard of living of these people is that of a typical rural settlement. The major populace engages in agriculture during the rainy season, and during off season they move to neighboring states for masonry and other labor jobs. The main features of the village are given in Table 2.

Table 2. Main features of the selected villages for survey.

Features	Habbanatti	Kusmalli
Population	632	887
Male	312	475
Female	320	412
No. of households	139	182
Average household size	4.5	4.8
Literates	340 (53.8%)	504 (56.8%)
Illiterates	292 (46.2%)	383 (43.2%)
Cultivators	185	286
Agricultural labors	109	109
Household industry	01	02
Source: District statistics and census dept. Belgaum, www.censusindia.gov.in		

Village Energy Scenario

The energy scenario of these villages is typical of an average Indian village, with firewood, agri-waste and dung being the major and most important sources of energy. Kerosene is mainly used for domestic lighting in few houses, even in electrified households, because electricity supply is irregular, insufficient and uncertain. Apart from firewood, biogas is used for cooking in few households of Habbanatti with no one using LP gas as there is no supply. In Kusmalli village around 25% use LP gas for cooking, the rest completely dependent on easily and freely available firewood/biomass. Grid electricity is sometimes available only late at night or during the day for agricultural purposes. Hence, to maintain the regularity in electricity supply for domestic use for at least 6 hours a day, renewable energy sources can be considered.

Highlights of the Survey

a) The survey was used to examine the energy usage pattern of rural communities and their perception towards renewable energy technologies and low carbon energy sources.

b) The major factors that influence the choice of selecting a fuel are reliability, cost availability and ease of use with cost and reliability being the major barriers.

c) Most of the people surveyed believe in the use of alternative sources of energy despite lack of awareness of technology and their usage.

d) For the adoption of renewable energy technologies the influential factors are assessing the needs of the community by improving long-term viability and creating awareness among the people.

e) Factors like safety and environment degradation are of least importance with cost being the most influential driver for change. People do care about these factors when cost is not a barrier for adoption of a new setup.

SURVEY RESULTS AND ANALYSIS

Fuels for Household Activities

Household Lighting Fuels

The primary and alternative energy resources used for household lighting are shown in Table 3. All respondents identified electricity as their main energy resource for household lighting, identifying that the main reasons for this selection were that it was easy to use or readily available. Interestingly, all of the respondents also made use of an alternative supply, with candles being the most popular alterative (55%), followed by kerosene (30%), and locally available batteries (others, 13%) and firewood (2%). Some of them have recently begun using batteries which are cheaply available in nearby towns. Since most of the populace goes for labor work, the lighting is basically necessary during early morning and evening hours.

Table 3. Primary and alternative energy resources used for household lighting

Main energy resource used for lighting (Among respondents who chose electricity)		
Alternative fuels used for household lighting	Kerosene	30
	Firewood/biomass	02
	Candles	55
	Others	13

During the survey, many respondents expressed their dissatisfaction with their source of energy. So it was important to identify why they were unhappy. Forty percent of respondents indicated that using electricity is a bit expensive. Another issue with regard to cost is that the rural populace expects complete subsidy on electricity, but government cannot afford it as it is already burdened with electricity shortage and is borrowing power from neighboring states at a very high cost.

Table 4 shows the reasons for unhappiness with the selected fuel among the respondents who chose electricity as a primary energy source for household lighting. Fifty-five percent of respondents also indicated that they were unhappy with this fuel because according to them it is not reliable. This (unreliability) is an interesting issue; the Western world and developed countries consider electricity to be one of the most reliable sources of energy. With this background, it becomes clear as to why there is a choice to rely on two types of energy sources for the lighting of homes in rural India. The high costs associated with using electricity along with the reliability issues force the villagers to have a secondary option.

Household Cooking Fuels

Almost all respondents indicated that their main fuels used for cooking were either a combination of firewood/biomass (70%) or biogas

Table 4. Reasons for unhappiness with main fuels used for household lighting

Main energy resource used for lighting (Among respondents who chose electricity)		
Reasons for unhappiness with current/selected fuel	Unreliable	55
	Expensive	40
	Others	05

(25%). In the Kusamalli village, 25% used LP gas for cooking whereas, in Habbanatti village, LP gas supply is not available. In addition, 95% of respondents indicated that they also made use of alternative sources. These results are summarized in Table 5.

Table 5 shows that the most popular fuels used for household cooking are a combination of firewood and biogas or LP gas, as 90% of respondents indicated they utilize both as either their primary or alternative fuel. It is interesting to note that when a supply of LP gas is available, people tend to use firewood as a secondary fuel. This is because LP gas is a clean-burning fuel and is easy to use, compared to firewood, without producing any smoke.

Table 5. Primary and alternative energy resources used for household cooking

Primary	Secondary	Respondents that selected combination (%)*
Firewood/biomass	Biogas	25
Firewood/biomass	Kerosene	70
Firewood/biomass	None	05
Biogas	Firewood	75
Biogas	Kerosene	25
Biogas	None	00
Firewood/biomass	LP Gas	00
LP Gas	Firewood	80
LP Gas	Kerosene	10
LP Gas	Biogas	10
LP Gas	None	00
* Respondents are allowed to choose as many secondary sources as they used.		

The statistics for selecting a fuel source for household cooking, as indicated by the respondents, is shown in Table 6. The main reason for the selection of firewood/biomass was its low cost (100%) followed by familiarity (80%) and ease of availability (75%). None of the villagers indicated that firewood was easy to use, which was conversely the main reason for the selection of biogas as fuel (95%). The remaining 50% choose biogas because it is easily available. Many believe LP gas is an expensive fuel, but at the same time 95% choose it as easy to use. It is a familiar fuel to the respondents in the village where its supply is available.

Table 6. Reasons for selecting the main fuel used for household cooking

Main energy resource used for household cooking				
Respondents that chose →		Firewood /biomass (%)	Biogas (%)	LP Gas (%)
Reasons for selected fuel used	Cheap supply	100	50	05
	Easily available	75	50	30
	Easy to use	00	95	95
	Familiar fuel	80	10	20

The factors influential for selecting a particular fuel for household cooking are depicted in Table 7. Most respondents were unhappy with firewood because it is "smoky" (90%) and "takes too long to burn" (50%). "Expensive" (80%) and "unreliable" (40%) were the reasons given by respondents for being unhappy with LP gas as a fuel for cooking. The level of smoke produced by firewood/biomass is an identified health risk and is a valid concern of the respondents. The average distribution of particulates arising from biomass in Indian households is 2000 μg m^{-3} (Smith, 2000) which is far in excess of the 150 μg m^{-3} level set by the US Environmental Protection Agency. In such human-inhabited places, localized pollution can occur during peak cooking times. This results in acute respiratory infections among women.

Table 7. Reasons for unhappiness with main fuels used for household cooking

Main energy resource used for household cooking				
	Respondents that chose →	Firewood /biomass (%)	Biogas (%)	LPG (%)
Reasons for unhappiness with the selected fuel	Expensive	00	10	90
	Smoky	90	00	00
	Unreliable	05	25	50
	Takes too long to burn	50	00	00
	Others	10	00	00

Reducing this level of pollution by using renewable energy technologies (RET) would have benefits in terms of health as well as modern energy services [Blenkinsopp 2013]. The results for the most popular fuels used for household cooking and the reasons why these fuels were used and why respondents are unhappy with them help explain why firewood or biomass and biogas are the two most popular fuels and why each is also the main alternative fuel of choice to use in place of the other. The expense associated with using LP gas compared to the low cost of using firewood or biomass might mean that when the LP gas supply becomes too expensive or disrupted, users shift to the cheaper, more familiar firewood or biomass.

Overall Use of Fuels in Homes

Fossil fuels were used by 90% of respondents as either their primary or alternative fuel for cooking. The figure is slightly higher for fuels used for lighting where 100% of the respondents made use of electricity derived from fossil fuel sources. None of the respondents indicated that they were happy with the fuels they currently used primarily for household cooking or lighting, citing reasons mainly centered on ease of use, cost and reliability (Tables 4 and 7).

The results highlight that "availability" is an important factor when selecting fuels for household tasks. In addition, availability was the only reason selected as an influencing factor across all fuels used in household lighting and cooking. Accessibility has been highlighted by several studies (Reddy and Painuly, 2004) as a major barrier for modern energy access and in particular to the uptake of RETs. These technologies have however been shown to lend themselves to being used as decentralized energy resources (Hiremath et al 2009). This can remove some of the accessibility barriers as the energy generation can be put at the heart of the community.

These technologies (RET) can be installed close to the point of demand. This reduces the costs relating to energy transport and distribution to the end user. Cost and easy of use were also important factors for choosing particular fuels; however, these reasons were never stated simultaneously for selecting a fuel. The explanation for this is that the ease of using a specific fuel is offset by increased cost. This is why all the respondents who used firewood or biomass for cooking indicated that the reason for using this fuel was that it was cheap. However, none of them gave "easy to use" as a reason. By contrast, none of the respondents who selected electricity or LP gas indicated "cheap" as a reason for choosing this fuel, but "easy to use" was by far the most significant influencing factor.

From these results it can be reasoned that there is a direct relationship between the cost of a fuel and its ease of use. Of these two factors, ease of use is the more significant in terms of what is desired by the user. The results indicate that people appear willing to pay more for an energy resource which is easy to use, such as electricity or LP gas, despite the expense which is the reason for their dissatisfaction when using them (Tables 4 and 7). Cost is still however an important factor when considering fuel selection, because although people desire a fuel that is easy to use, they may be unable to afford those that are available. This is most likely the case with the respondents who primarily use firewood or biomass for cooking, as all of them indicated that they selected this resource because it was cheap, not because it was easy to use (Table 6). This, in conjunction with the fact that the majority of these respondents (80.0%) indicated that they also make use of LP gas or biogas as a secondary fuel, supports the idea that if cost were removed as a factor, the majority of respondents would prefer a fuel that is easy to use.

Perception and Attitude towards Renewable Energy

Lack of Awareness and Understanding

In Table 8, respondents were able to identify several renewable energy sources from a given list. The most recognized potential energy source was solar panels (80%), with wind turbines (70%), hydroelectricity (65%) and biodiesel (40%) also being widely recognized. An overview of the renewable technologies was given to the respondents before they indicated which they believe would be of most benefit to their household or village as a means of energy provision. All the respondents indicated that they believe the use of solar panels (100.0%) would provide the most benefits. Biogas (80%) and hydroelectricity (60.0%) were also considered to be beneficial sources of energy.

Table 8. Recognition of most beneficial and renewable means of energy generation.

Energy Source	Renewable means of energy generation (%)	Most beneficial energy source (%)
Biodiesel	30	20
Bio-digesters (biogas)	80	80
Geothermal	05	00
Hydroelectricity	70	60
Solar panels	80	100
Wind turbines	70	40
Tidal energy	05	00

Lack of knowledge is the primary barrier to the adoption of any new technology. Lack of technical knowledge and awareness in RETs has been identified as a potential barrier to their uptake (Reddy and Painuly, 2004). Despite the results in Table 8, 75.0% of respondents indicated they had no preference towards one energy source over another. Twenty-five percent, however, identified solar power as their preferred source. Despite a lack of distinct preference towards any one particular energy supply, all of the respondents believe that rural communities, such as their own, should be provided with renewable or sustainable alternative energy supplies.

Figure 6 shows the respondent's preference for alternative energy sources. Seventy-eight percent of respondents indicated alternative energy sources should be used over current energy supplies. Several studies (Painuly, 2001) have highlighted acceptance as an important factor in the implementation of renewable technologies. Without the acceptance, the likelihood of a successful project is slim. This can further damage the perception of new technologies, resulting in additional hindrances to future projects. By incorporating public participation into planning decisions, and by educating the target population on the long- and short-term benefits, these projects could be successful in terms of their acceptance and implementation.

Cost as a Barrier to Implementation

Respondents were asked a series of questions to see how cost affected their choice to shift from their current energy supply to an

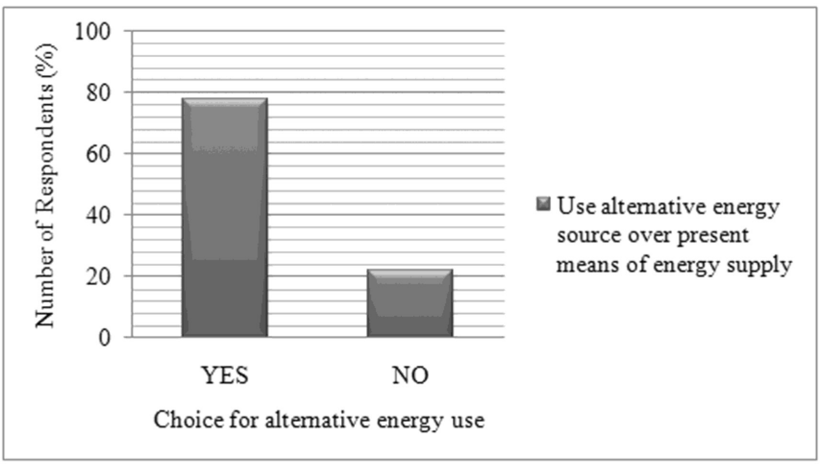

Figure 6. Preference for alternative energy sources

alternative low carbon one, despite any benefits that could be gained by shifting. If the costs remained the same but they knew it would be helping protect the local environment, 84% respondents indicated that they would be willing to shift. Respondents' inclination to shift towards renewable energy sources is shown in Figure 7.

Of the respondents who indicated they would shift to help protect the local environment when the price stayed the same (Figure 7), 25% would still shift when the price was slightly higher, whereas 75% no longer would shift.

If shifting meant a safer and more reliable supply at the same cost, 100.0% of the respondents indicated that they would be willing to shift. This is shown in Figure 8. This highlights that there is a will to change and an acceptance of the need to change to RETs in the future. However, if shifting supply meant paying slightly more, 84% of respondents indicated that they would not, even if it helped protect the local environment.

From the data discussed above, it becomes clear that cost is the biggest barrier to implementation of RETs in rural Indian villages. To ascertain what factors would influence a respondent's choice to contribute to the setup costs of a renewable or sustainable energy supply, each was asked if they would contribute if it meant either a cheaper supply, more reliable supply, or a safer supply. The response is summarized in Figure 9.

One hundred percent of respondents said they would contribute to the setup costs if it ultimately meant having a cheaper supply. For a safer supply, 66.7% would contribute, and 75.0% would contribute for a more

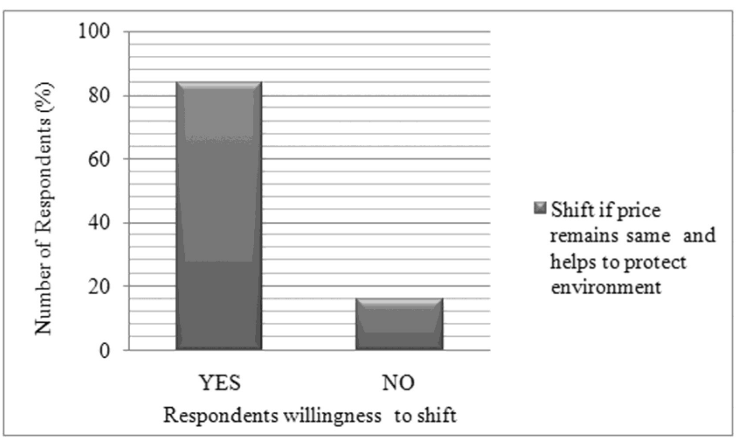

Figure 7. Preference to shift to alternative fuel (cost & environment)

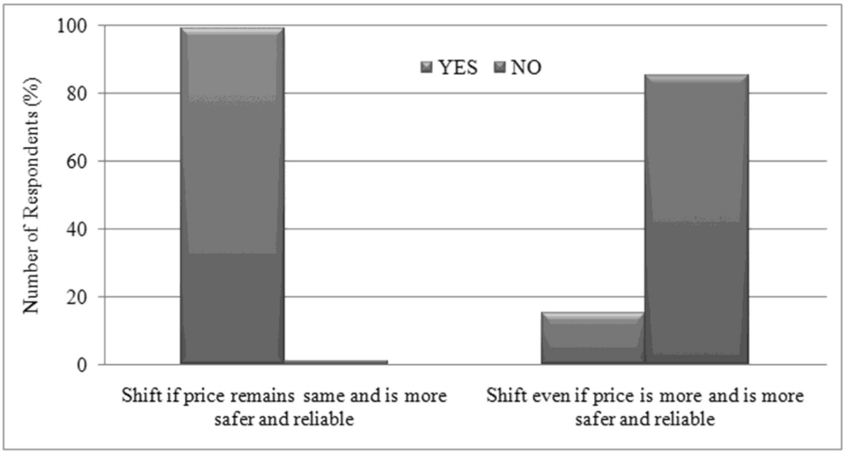

Figure 8. Preference to shift to alternative fuel (cost, safety and reliability)

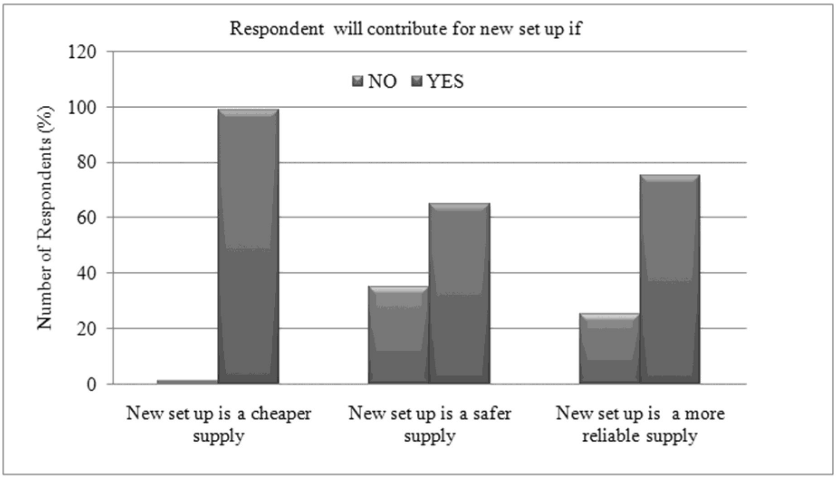

Figure 9. Factors affecting respondent's willingness to pay

reliable supply. All of the respondents who indicated that they would pay slightly more for a safer and more reliable supply also said they would contribute to the setup costs for these two benefits. This indicates that out of reliability and safety, the latter is of least significance to respondents, because when given the option, respondents were willing to contribute a one-time payment for improved reliability even though they would not pay long-term for it, but they would not do the same for improved safety.

Figure 10 shows the daily load consumption of the entire surveyed village of Habbanatti. The daily load curve is typical of an Indian village where maximum consumption occurs during evening hours. Most of this is required for entertainment and lighting loads and partly for other activities. The load curve is almost flat during mid-day when most of the occupants will be outside for daily earning.

Figure 11 indicates monthly energy consumption per family of the village. It can be observed that biomass/firewood constitutes the major part of energy consumption as it is being used for both cooking and heating requirement by majority of the people. The other reason for

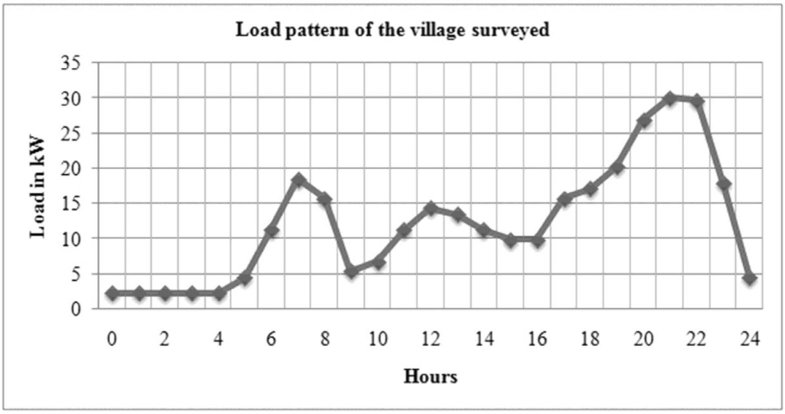

Figure 10. Daily load pattern of the Habbanatti village

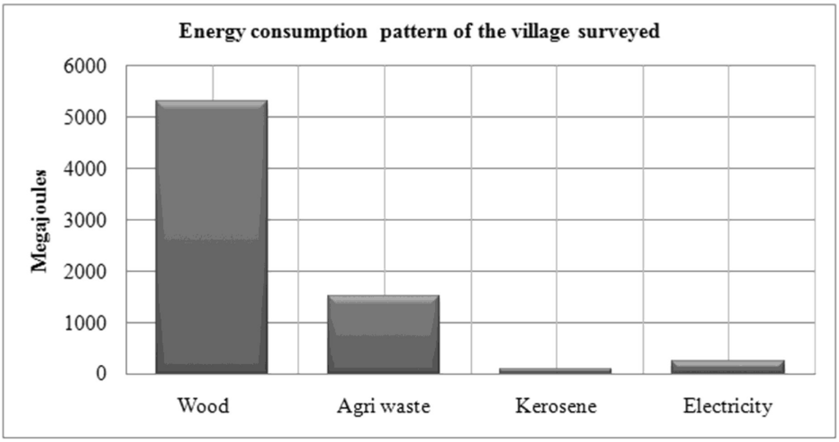

Figure 11. Monthly energy consumption per family

large usage is easy availability of firewood nearby for which they need not have to pay. But the level of smoke produced by firewood/biomass is an identified health risk and is a valid concern of the respondents. As a result, acute respiratory infections are now the largest single disease category in India (IEA, 2007).

Summary of Renewable Energy Technologies

Cost is the principal factor to influence a respondent's choice to shift to an alternative renewable supply or contribute towards its setup. The benefits of shifting, such as reduced environmental impacts and reliability and safety, are insufficient to persuade a respondent to shift to an alternative source. When cost is not a factor, when the energy resource price stays the same, respondents are more likely to be swayed to shift by these benefits. The desire for reducing the long-term costs of energy provision were shown by the fact that 100% of respondents were willing to contribute to setup costs of a supply if it ultimately led to cheaper supply.

Reliability was also shown to be an important factor that influenced a respondent's decision to shift to an alternative energy supply or contribute towards setup costs. It is a property that is desired in an energy supply, much like ease of use. Although reliability is not as significant as cost, respondents were more likely to pay to access an energy supply with this characteristic. This indicates that respondents were considering the long-term benefits over the short-term costs when selecting an energy supply. Because a reliable energy supply would reduce the need for alternatives, reducing energy expenditure and combining that with an affordable supply will increase disposable income which could be used to improve other areas of daily life.

The high costs associated with RETs are a major barrier to their successful implementation. While respondents indicated that cost was important to them, it did not significantly restrict their selection of electricity (an identified expensive source of energy).

The need to improve infrastructure in many developing countries adds additional costs to RET projects. These costs may well be passed onto the consumer and can lead to problems of uptake when they start to exceed those of more conventional energy provision. This is reflected in the survey results where the costs of different energy resources are shown to play a significant role in the selection of and extent to which a fuel is used. Increased uncertainties and a lack of confidence can contribute to increased project costs and threaten the long-term viability of a project (Painuly, 2001). It has been noted in some studies that it is difficult to attract funding from financial and private investors as they are often reluctant to provide funding for small-scale projects that are associated with risk (Reddy and Painuly, 2004). This can therefore make it almost impossible for people on low incomes to invest in RETs.

Benefits of Rural Household Energy Use

There are many benefits of rural electrification which may be either economic or social. Lower cost and expanded use of lighting, radio and TV are benefits that increase in household consumer surplus from rural electrification. Time savings for household chores, can also be considered a benefit which can be diverted for educational purpose. [ESMAP 2002]

With regard to rural electrification in India, the other benefits associated with improved lighting are the ability to irrigate with electric pumpsets and complementary returns to education. The availability of electricity appears to markedly accelerate the rate at which household incomes rise with years of schooling [Barnes 2005]. This can then be translated into substantial increases in the potential for increased farm and nonfarm income, when improved education is coupled with electricity availability. A premium should be placed on utilization of renewable energy. These technologies are scalable, require relatively low capital, are environmentally sustainable, and often have less complicated supply chain requirements. The cost of many of these technologies has decreased significantly over the last several decades. [Michael 2003]

Impacts of Lack of Access to Modern Energy Services

Public Health: Of the 3 billion people who use traditional fuels like charcoal for household energy, 1.5 million die each year from the high particulate air pollution created by these fuels in poorly ventilated spaces [Meghan 2012]. For example, the negative impacts of kerosene lamps for lighting are the release of toxins during combustion, contribution to upper respiratory disease, and safety concerns such as fire hazards and accidental ingestion. Household energy is itself a basic human need and is central to the satisfaction of basic nutrition and health needs (UNDP 2000). Household energy drives activities such as cooking and heating, pumping technologies for irrigation systems, and water and sanitation services. Thus, access to household energy is a precursor to the provision of all essential infrastructure services.

Local and National Development: The lack of access to household energy and associated infrastructure inhibits economic growth and development in developing countries. Energy infrastructure is often a prerequisite for income- generating activities, increasing productivity and education. Further, the increased demand for energy to fuel development and support continued population growth threatens global energy security.

Education: The negative impacts of reliance on fuels such as wood, charcoal and kerosene include inhibiting educational and social activities. In contrast to kerosene, renewable distributed energy micro-generation technologies for lighting have demonstrated positive impacts on health, the environment, and education (Zahnd and Kimber, 2009). However, their widespread sustainable use is often limited because of high cost, unsustainable supply chains, and lack of technically proficient human resources to support their installation and maintenance. [Meghan 2012]

Inequalities: There are large inequities associated with the global distribution of energy. The richest 20% of the world's population uses 55% of primary energy, while the poorest 20% uses only 5 percent. [UNDP-2010]. There are inequities in access between the rich/poor and rural/urban populations in developing countries. Not surprisingly, there is unequal access to energy services in rural populations versus urban populations. (Barnes 2005)

Environmental: Energy use patterns can be linked directly to environmental challenges, such as urban and indoor air pollution, acidification, and global warming. Arguably, unsustainable energy consumption is the single largest contributing factor to global detrimental environmental impacts. Providing modern energy services through decentralized renewable energy, particularly to the rural poor, can positively redirect the ecological and social factors that contribute to climate change. [Meghan 2012]

CONCLUSONS

Energy plays a significant role in humans' lives, and it is a key input for meeting basic needs and for achieving social and economic

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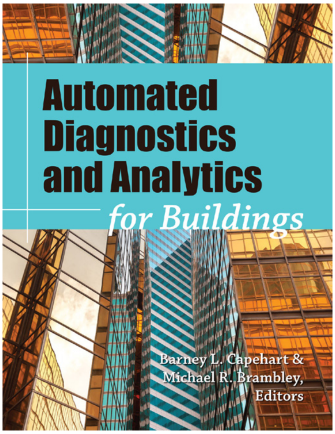

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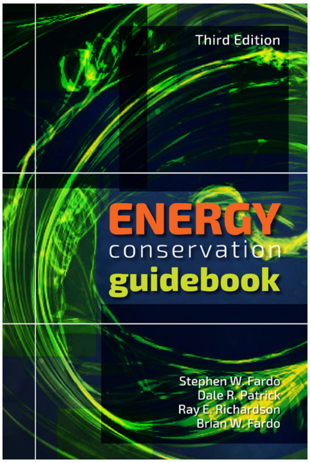

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development goals that include among others, fuel for cooking, heating, and lighting in households. Rural electrification must be analyzed within an integrated framework that includes rural energy, the broader power, and the overall economy. Recognition of the dynamic nature of rural electrification is an important key to successful implementation.

Rural electrification programs can undoubtedly face major obstacles. The low population densities in rural areas result in high capital and operating costs for electricity companies. Well-planned, carefully targeted, and effectively implemented rural electrification programs provide enormous benefits to rural people. There are major opportunities for increasing the pace and widening the scope of rural electrification. There is not one proper way to do rural electrification, but there is an underlying set of principles that needs to be followed to have successful programs. The institutional framework, load forecasting, design and planning of networks, operation and maintenance practices, methods of financing, assessment of socio-economic benefits and costs, and other aspects must be tailored to the growth of rural loads and the grid that serves them. Continued attention must be paid to financing and maintaining the level of services to electricity consumers in the scheme area over a long period of time, as load growth continues.

The study has elaborated on an initial analysis of the socio-economic factors that affect the development of sustainable or renewable energy projects in small rural communities in India. The results showed that there is interest in using sustainable or renewable energy sources over traditional or conventional methods. This however must come in the form of an affordable, reliable and easy-to-use energy resource, because these characteristics were highlighted by respondents as the most influential parameters for change. The need to invest heavily in technical expertise and infrastructure, particularly in rural areas, can deter investors, often leaving them isolated from sustainable development. However, by evaluating the needs and attitudes of target communities, many barriers can be overcome by using the appropriate energy resource for their needs, and by communicating with stake- holders from an early point.

Individual household bio-digesters to produce biogas would probably be collectively too expensive to install across a village. But a shared scheme where the whole community input into the development of a bio digester with the capacity to serve the needs of the population while requiring fewer skilled maintenance personnel would appear to be more appropriate. A key factor that can influence the future of renewable energy technologies is the development of a market and services. Long-term penetration of renewable energy in the industrial and power sector depends on the cost of delivered energy as well as reliability of technologies.

There are schemes available from the Ministry of New and Renewable Energy to subsidize the training of skilled workers. This would have to be coupled with educational schemes to highlight the benefits of this technology. From a civil society perspective, organizations, particularly those which work with partner institutions having a base in rural areas and communities, need to ensure that greater time is spent in creating models and systems for decentralized energy that can be replicated. Furthermore, with climate change also becoming a very serious issue that needs to be addressed on a war footing, India has the opportunity to revamp its energy policies and embark on a pathway which ensures fair and equitable energy to all, ensures inclusive growth and a speedier eradication of poverty while at the same time reducing the country's growing carbon emissions.

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