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# Rural Electrification through Renewable Energy Sources- An Overview of Challenges and Prospects

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**Abstract***: Energy security and sustainable development are prime issues these days in developed as well as in developing countries. Decentralized Renewable Energy (DCRE) generation of electricity is expected to become more important in the future electricity generation system. This paper explores the various challenges faced in the process of rural electrification in India. It also highlights the alternatives available including usage of renewable energy towards decentralized electrification and policy recommendations for the use of renewable energy technologies. There are complex socio-economic issues that are hindering the growth of renewables in rural India, especially in off-grid villages. What should be the approach for maximum penetration of renewables in remote villages in India? How can renewable devices be made affordable for active use? How can local participation in such initiatives be increased? How can private participation be encouraged? These are the key issues that the Indian government is trying to address.*

***Key Words: Renewable energy, rural electrification, sustainable energy, solar, wind energy.***

## 1 Introduction

It is now well recognized that electric power is a key driver of economic growth and prosperity. But access to electric power remains a distant dream for majority of the poor living in developing countries. Still after 100 years of Edison's statement that "we will make electricity so cheap that only rich will burn candle" we still have 1.6-2 billion people who do not have access to electricity and 2.5 billion people still depend on traditional biomass for their domestic energy need. It is thought-provoking fact that the majority of these people are living in the developing world [1,2]. The global electricity generation is projected to increase at an annual rate of 2.4% between the years 2004 and 2030, and will reach 30.36 trillion kWh in year 2030". At present the global electricity generation is around 21 trillion kWh [3].

Globally the present electricity generation has been centered to the coal thermal power stations. Instead, the renewable energy in a decentralized manner has provided access to electricity to 1.6-2 billion people, who are living in remote areas and the villages that are not connected to the central grid. Even if connected to the central grid but does not have a reliable electricity supply. [1]

India has one of the fastest growing economies in the world and ranked 6$^{th}$ place in the worldwide consumer of energy. About, 40 % of the total energy is in rural areas, in which domestic sector constitutes major energy demand and its consumption accounts for 60 % of energy used. [4]
Energy crisis in India is the result of the fact that the major share of India's rural population is energy poor. Due to income poverty people find it difficult to access to modern energy services and this has resulted in energy poverty. The root causes for lack of access to modern energy are unaffordability due to poverty and inaccessibility due to inadequate infrastructure [5].

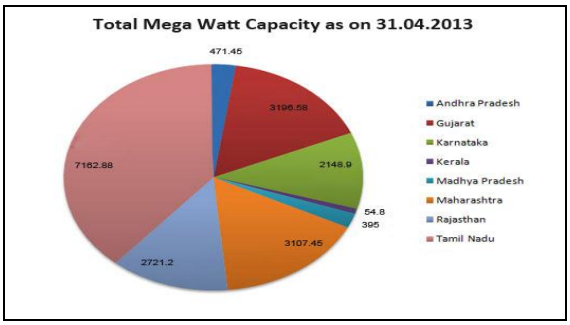


**Fig 1.** Installed Power Capacity in 2013. [6]

India has got a very high potential in the RE but still the total share of renewable in India's electricity sector is low around 6-8%. Fig.1 shows the installed power as on 2013 in India. According to the estimates, RE could meet about 60% of India's total electricity supply by 2050 in a planned phased manner. But to make this happen in reality a change in the government spending pattern, concrete policy support for renewable in electricity sector is expected [7,8].

"Power for all by 2012", was the stated goal of the Government of India to ensure that each and every household of India (both urban and remote rural) had access to affordable power supply by 2012. However, to this day one-third of rural households and 6% urban households are still unelectrified [9].

Currently most of the energy needs in the country are met through fossil fuels. Coal, gas, and diesel -fired power plants account for 66% of the country's total electricity-generating capacity [10]. The contribution of renewable energy is as low as 12% in the overall energy mix (total overall installed capacity as on 30 April 2012 was 201.6 GW) [11]. Fig. 2 indicates the percentage of renewable in total energy consumption.

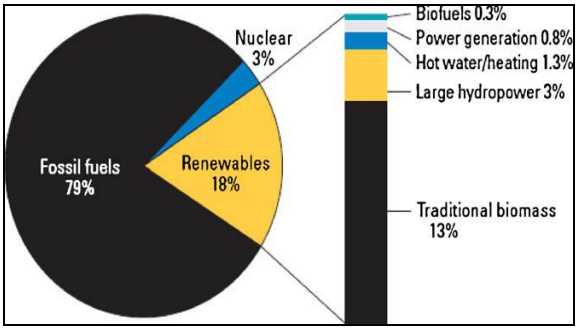


**Fig 2.** Percentage of renewables in total consumption [12]

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## 2. Problem Statement in Indian Context

The broad goals of RE as set out in the draft REP (Rural Electrification Policy-2012), referred to as AARQA goals, are as follows: Accessibility, Availability, Reliability, Quality and Affordability [13]. The government of India has an ambitious target of providing electricity to everyone. The Electricity Act (EA) 2003, Integrated Energy Policy (IEP) of the government of India aims to electrify all the villages and around 23.4 million un-electrified households that are Below Poverty Line (BPL) providing up to 90% subsidy under the various schemes launched by the government. Out of these 140 000 villages around 18 000 villages are in the category of remote villages that are inaccessible through the central grid for electrification. [14]. However, the villages that are electrified through the central grid often get low quality electricity supply, mainly ridden by blackouts.

### 2.1 Electricity Scenario in Karnataka

Karnataka is one of the industrialized states in India and depends mainly on hydroelectricity. Exponential growth in population coupled with mechanization of agriculture, industrial growth and acute rainfall shortage resulted in a serious power crisis in recent years. This necessitated the promotion of alternative sources of energy like solar, wind, micro Hydel plants etc. About 100 to 200 MW of electricity can be generated from wind, 225 MW from potential micro hydel sites, 1000 MW from biomass process and solar energy has unlimited possibilities. [16]. Apart from increasing its generation, the state has been procuring power from short-term sources and through energy exchanges in order to minimize power shortages. Despite all of this, it is still not able to fulfill energy demand. From Table 1 it is clear that energy deficit and peak power deficit are highest for the state of Karnataka among southern states of India even though it has good share of renewables in total installed capacity.

**Table 1**. Power Scenario of Southern Indian States. [15]

| Parameters - 2012 | AP | Karnataka | Kerala | TN |
|---|---|---|---|---|
| Energy deficits (%) | 7.2 | **11.2** | 2.1 | 10.5 |
| Peak power deficits(%) | 14.8 | **18.9** | 5.1 | 17.5 |
| % of private sector in total installed capacity | 24.5 | **33.8** | 5.1 | 47.6 |
| % of renewable energy in total installed capacity | 5.5 | **23.8** | 4.25 | 41.7 |

AP- Andhra Pradesh, TN- Tamil Nadu

Fig. 3 and Fig. 4 illustrate the power supply and peak demand in the state of Karnataka for the year 2011-12. It has been observed that energy demand during 2006-2012 grew at 8% while the supply grew only by 6%, leading to constantly increasing energy deficits.

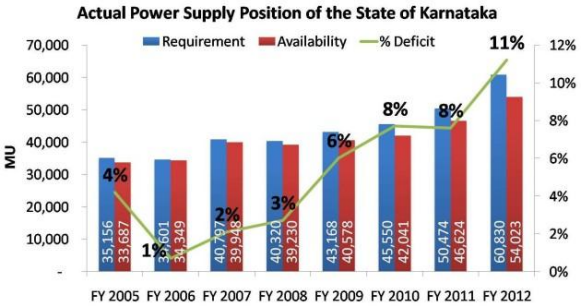


**Fig 3**. Power supply position

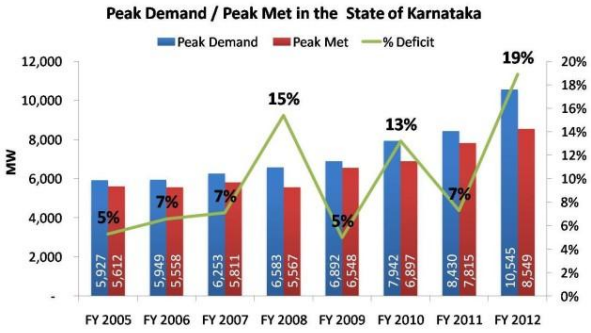


**Fig 4.** Peak demand [Source: Akshya Urja, June 2013]

The demand for energy shot up by almost 21%, while supply grew only by 16% over the last one year. The energy deficit has increased from 2.1% in 2006-07 to as high as 11.2% in 2011-12. [17].

### 2.2 Karnataka Renewable Energy Policy

Building on its current strengths and a capacity of 24 Megawatts, Karnataka intends to establish a dynamic renewable sector with emphasis on different forms of generation-wind, mini hydro, bio mass, cogeneration and solar. The energy consumption in the State is anticipated to be around 64,000 MU per annum by 2015. [15]. At present, renewable energy sources contribute to about 4600 MU of energy per annum (11.5%) out of the total 40,000 MU available from various installed capacities. To achieve a 20% share, the renewable energy sources are required to contribute 12,800 MU by 2014. This necessitates a renewable energy capacity addition of 6600 MW by 2014. A clear–cut policy is, therefore, essential to regulate and ensure speedy development of renewable energy. In view of the present electricity shortage and of the debate on prioritization of the distribution of electricity in Karnataka, it is the hour of need to initiate massive movement for renewable energy projects in a decentralized manner for rural electrification. **Hence the objective of this study is to investigate the present scenario of renewable energy sources, their prospects, their contribution towards rural electrification and the challenges that need to be overcome.**

### 2.3 Renewable Energy Technologies

There is a significant opportunity for Renewable Energy Technologies (RETs) in India. Renewable energy provides a

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promising solution not only in meeting the ever increasing demand of energy but also in mitigating the adverse environmental effects. It is essential to tackle the energy crisis through judicious utilization of abundant RE resources, such as wind, biomass, solar, etc as these sources are going to become the long-term solution for future energy needs. Amongst the various renewable energy sources like wind, solar, geothermal, tidal etc, wind energy is a promising source not only at the global level but also at the domestic level. It is one of the fastest developing RETs across the globe including India and is an alternative clean energy source compared to fossil fuel, which pollute the lower layer of the atmosphere. Wind energy not only offers a power source that completely avoids the emission of carbon dioxide, the main green house gas (GHG), but also produces none of the other pollutants associated with either fossil fuel or nuclear generation. [17]

### 2.4 Decentralized Power Generation Technologies

Decentralized electricity generation means "An electric power source connected directly to the distribution network or on the customer side of the meter". The size of the power plant may vary from Micro-DG (below 5 kW), small DG (5 kW to 5 MW), medium DG (5- 50 MW), and large DG (50-300 MW). [9]. Under decentralised energy generation system, electricity needs of local people are met from a power station located in the villages, based on locally available 'raw material'—biomass, solar, wind or mini hydro. [18]. Table 2. depicts different usage forms of renewable energy.

**Table 2.** RE sources and their usage [19, 20]

| Energy source | Energy conversion and usage options |
|---|---|
| Hydropower | Power generation |
| Modern biomass | Heat and power generation, pyrolysis, gasification, digestion, transesterification. |
| Geothermal | Urban heating, power generation, hydrothermal, hot dry rock |
| Solar | Solar home system, solar dryers, solar cookers |
| Direct solar | Photovoltaic, thermal power generation, water heaters |
| Wind | Power generation, wind generators, windmills, water pumps |
| Wave | Numerous designs |
| Tidal | Barrage, tidal stream |

Following are some options decentralised generation:

- Biomass based heat and power projects and gasifiers for rural and industrial energy applications
- Watermills/micro hydro projects – for meeting electricity requirement of remote villages
- Small Wind Energy & Hybrid Systems - for mechanical and electrical applications, mainly where grid electricity is not available.
- Solar PV Roof-top Systems for abatement of diesel for power generation in urban areas [21]

## 3. Renewable Energy Prospects in India

India is considered one of the most promising countries for wind power development in the world. With 1019051 MW (MNRE 2013) of installed capacity (as on 31 Dec 2013), India's rank in harnessing wind energy is fifth in the world after the USA, China, Germany and Spain. As is clear from Fig. 5, more than 95 per cent of the nation's wind energy potential is concentrated in five states—**Tamil Nadu, Andhra Pradesh, Karnataka, Maharashtra and Gujarat.** India is also endowed with abundant of solar radiation. The country receives solar radiation equivalent to more than 5,000 trillion kWh/year, which is far more than its total annual energy requirement. Even 0.1% of the land area of the identified solar hot spots (1897.55km2) could deliver nearly 146 GW of SPV based electricity (379billionunits (kWh) considering 2600 sunshine hours annually). [21].

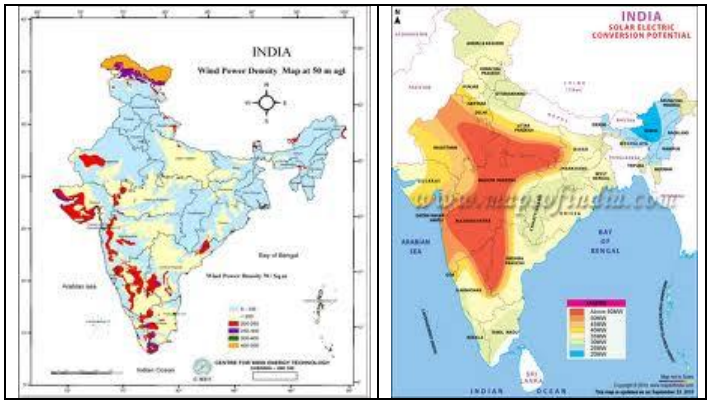


**Fig. 5**. Wind and Solar Energy Maps of India (MNRE)

India is committed towards increasing the share of renewable power in the electricity mix to 15 per cent by the year 2020. The National Solar Mission targeting 20,000 MW grid solar Power, 2,000 MW of off-grid capacity including 20 million solar lighting systems and 20 million square meters solar thermal collector area by 2022 is under implementation. [22]

### 3.1 Benefits Of Renewable Energy

To be able to provide adequate electricity to its population, India needs to 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. Renewable energy is well positioned to play a critical role in addressing this growing energy demand for the following reasons:

• **India has the natural resources.** India has abundant, untapped renewable energy resources, including a large land mass that receives among the highest solar irradiation in the world, a long coastline and high wind velocities, significant annual production of biomass, and numerous rivers and waterways that have potential for hydropower.

• **Renewable energy provides a buffer against energy security concerns.** India's use of its indigenous renewable resources will reduce its dependence on imported, expensive fossil fuels.

• **Renewable energy offers a hedge against fossil fuel price hikes and volatility.** Increased competition for limited fossil

resources is projected to push prices up, while increased deployment of renewable technologies pushes prices down in line with technology improvements and economies of scale. For example, oil prices in 2030 are projected to be 46% higher than in 2010 while the investment costs for photovoltaic (PV) systems are expected to decrease to less than half of their 2007 levels over the same time period.

• **Off-grid renewable power can meet demand in un-served rural areas.** As a distributed and scalable resource, renewable energy technologies are well suited to meet the need for power in remote areas that lack grid and road infrastructure.

• **Renewable energy can be supplied to both urban and rural poor.** Renewable energy technologies offer the possibility of providing electricity services to the energy poor while addressing India's greenhouse gas (GHG) concerns and goals.

• **Renewable energy can support attainment of India' climate change goals.** Through its National Action Plan on Climate Change (NAPCC) and through its recently announced carbon intensity goal, India has made a commitment to addressing its carbon emissions.

• **India aims to be a global leader in renewable energy.** India's intention to play a leadership role in the emergent global green economy is driving investment in renewable energy technologies. Recognizing the magnitude of the potential demand for renewable energy, India is attracting significant investment in renewable energy.

## 4 Government Policies

The Government of India has enacted several policies to support the expansion of renewable energy. These include:

• Electricity Act 2003: Mandates that each State Electricity Regulatory Commission (SERC) establish minimum renewable power purchases; allows for the Central Electricity Regulatory Commission (CERC) to set a preferential tariff for electricity generated from renewable energy technologies.

• National Electricity Policy 2005: Allows SERCs to establish preferential tariffs for electricity generated from renewable sources.

• National Tariff Policy 2006: Mandates that each SERC specify a renewable purchase obligation (RPO) with distribution companies in a time-bound manner with purchases to be made through a competitive bidding process.

• Rajiv Gandhi Grameen Vidyutikaran Yojana (RGGVY) 2005: Supports extension of electricity to all rural and below poverty line households through a 90% subsidy of capital equipment costs for renewable and non-renewable energy systems.

• Eleventh Plan 2007–2012: Establishes a target that 10% of power generating capacity shall be from renewable sources by 2012 (a goal that has already been reached); [23]

### 4.1 Government Initiatives for Rural Electrification.

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, wind and SPV power plants. [24]

#### 4.1.1 Rural electrification under Minimum Needs Program (MNP):

This program has been launched during 5th five year plan; rural electrification was added as one of the component in this program. The area which was proposed to electrify under this program were remote and difficult villages with low load potential. [25].

**4.1.2 Pradhan Mantri Gramodayan Yojana (PMGY):** This scheme was launched in 2000-2001 and the component of rural electrification was added in the later part of 2001-2002. Under this scheme grant were issued by central government to the state governments on a normal pattern of the government of India, which includes 30% grant and 70% loan for states.

**4.1.3 Kutir Jyoti Scheme (KJC):** This program was launched in 1988-89. The aim of this program was to provide single point light connection to households that are below poverty line. Under this scheme about 6 million households were connected to electricity in 15 years [26].

**4.1.4 Accelerated Rural Electrification Program (AREP):** AREP was launched in 2003-2004 and was restricted to the electrification of non-electrified villages/electrification of hamlets/tribal villages and electrification of households in the villages through conventional and non-conventional source of energy.

**4.1.5 Accelerated Electrification of one hundred villages and 10 million households:** This scheme was introduced by the government of India in 2004-05. 40% capital subsidy was provided for rural electrification projects and balance amount as a soft term loan through Rural Electrification Corporation (REC). This scheme is now merged in Rajiv Gandhi Gramin Vidyutikaran Yojna (RGGVY) (MoP).

**4.1.6 Rajiv Gandhi Grameen Vidyutikaran Yojana (RGGVY):** RGGVY has been launched in April 2005 to achieve National Common Minimum Program objective, to provide electricity to all households within four years (MoP). The objectives of this program are;

1. To achieve 100% electrification of all villages and habitations in India
2. To provide electricity access to all households
3. To provide free-of-cost electricity to BPL households

Under the RGGVY scheme, 45602 villages have been electrified and 25087 villages electrified intensively between April 2005 and January 2008. [25].

## 5 Rural Electrification via Renewable Energy

At the end of 10th five year plan of the government of India renewable energy sources succeeded to meet only 1% of rural energy need; therefore, in the subsequent plan i.e. $11^{th}$ five year plan, there are two programs introduced based on

renewable energy. Namely, Remote Village Renewable Energy Program (RVREP) and Grid-connected Village Renewable Energy Program (GVREP).

Some of the challenges faced during rural electrification are listed below.

a. Incomplete coverage
b. Faulty definition/Incomplete Data
c. Low demand, low consumption and shift in focus
d. Long and cumbersome procedures
e. Financially un-viable.
f. Active Participation by Local Bodies
g. Lack of measures for capacity enhancement
h. Over-emphasis on grid rural electrification

Rural electrification has been financially non viable, has reached the limits of its success and has become a large financial burden on electric utilities. However, the policy makers in the country have, over the years, considered that

electric supply from the grid as a symbol of progress and consequently have laid over emphasis on it in the planning process. In contrast to the developed countries, in a developing country like India, with its large rural population and the much higher levels of poverty, the provision of grid electricity is economically unviable.

**5.1 Recommendations:** The following are the recommendations based on the above analysis. [18]

a. Increasing promotion of use of Renewables
b. Set up effective institutions to deal with problems.
c. Government commitment and dealing with the political dimension.
d. Establishment of clear planning criteria for rural electrification.
e. Subsides for grid expansion capital costs.
f. Charging the right price for electricity.
g. Lowering the barriers to obtaining a supply.
h. Benefits of community involvement.
i. Reducing construction and operating costs.
j. Reducing Transmission and Distribution (T&D) losses

### 5.2 Impact of rural electrification

Recent studies of rural electrification indicate the following broad consensus concerning the impact of electrification in the rural areas. [27]

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 those 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

In recent years attention has risen regarding the issue of rural access to electricity supply and regarding the relation between energy (electricity) and poverty. Following are some of the issues identified for implementation of decentralized renewable energy [26]

1) Need for a robust business model
2) Assured supply of raw material
3) Technological issues
4) Economic viability
5) Less conducive government policies for decentralized renewable electricity projects
6) Social issues such as public perception, active involvement of local government

It is clear that decentralized generation is an important option to provide electricity in rural areas in India. But before this dream can be realized, a number of sticky issues relating to policy, technology, regulation, financing and institutional matters, need to be sorted out.

## 6 Conclusion

Rural electricity access in India is currently inadequate for needs of the rural population, and there is observed and revealed willingness to pay for better electricity supply. The Indian government is pursuing large scale initiatives towards greater access mainly through grid expansion. Renewable energy distributed generation projects, if widely replicated, can ease the burden on both electricity supply shortfalls and reduce the urgency of costly grid extension. Needless to say, "renewables" will have a big role to play in meeting rural electrification targets in the country. Grid connection will not be a viable option for at least 20 per cent of the unelectrified villages, which will have to opt for renewable energy solutions. There are signs of the attitude changing. Be it the policy-backed fine-tunings or the new programs launched by the government, the RE-based remote village electrification drive is certainly poised for better times. A policy paradigm shift is needed to make electrification integral to all rural development plans. Technology has shown the way to lighting up rural India, now it is only an enabling policy environment that can ensure that the lights do not go off. A strategy involving pilot projects, tracking of costs and dissemination of information is likely to result in the growth of DCRE in India's power needs.

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