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Scope of Decentralized Power Generation using Renewable Energy Resources at Global Level-A Review & Survey at a Glance

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Now-a-days renewable energy sources like biomass, biogas, wind turbines, solar photovoltaic, and micro-hydro are widely used in standalone as well as hybrid power generating systems of different combinations with diesel generator as per the load demand & availability of the resources. Different results of various case studies were reviewed where optimization of the systems was done with the help of several software. As per the availability of biomass, solar radiation and wind speed in the villages, power potential was also estimated that could satisfy the load demand of the particular village which comprises of their basic domestic needs as well as some agricultural demands like irrigations etc. Performance of these hybrid systems compared on the basis of some parameters like Cost of Energy (COE), Net Present cost (NPC), Levelised Cost of energy (LCOE), levelised unit electricity cost (LUEC), per unit electricity cost (PUEC) and life cycle cost (LCC) with respect to grid connected systems and extension of grid. For analysis of importance and potential of decentralized power generation using these renewable energy resources, electricity generation in past and growing today with future scenario are demonstrated at the global, India & state of Rajasthan level and compared with conventional sources also.

Keywords: Cost of Energy, Net Present Cost, Levelised Cost Of Energy, Levelised Unit Electricity Cost, Per Unit Electricity Cost, Life Cycle Cost

1. Introduction

Renewable energy is naturally replenished on a human timescale, such as sunlight, wind, rain, tides, waves, and geothermal heat. It is often provides energy in four important areas: electricity generation, air and water heating/cooling, transportation, and rural (off-grid) energy services. Renewable energy resources exist over wide geographical areas, in contrast to other energy sources, which are concentrated in a limited number of countries. Moving into the time of recorded history, the primary sources of traditional renewable energy were human labour, animal power, water power, wind, in grain crushing windmills, and firewood, a traditional biomass. In the 1860s and '70s there were already fears that civilization would run out of fossil fuels and the need was felt for a better source [1].

Decentralised electricity production unlike the centralized electricity production, as the name suggests, produces electricity close to where it will be used, rather than at a large plant elsewhere and sent through the national grid. This local generation reduces transmission losses and has lowers carbon emissions. Security of supply is increased nationally as customers don't have to share the supply or rely on large and remote power stations. Long term decentralised energy can offer more competitive prices than traditional energy. While initial installation costs may be higher, a special decentralised energy tariff creates more stable pricing. The economic development of a society is directly proportional to the energy consumption and the efficiency of energy use. However, the electrification of the villages from the main grid in remote areas usually leads to large investment and losses associated with the transmission and distribution network [2]. Depending upon the topography of the area, energy resources potential available, and type of energy need, demand and socio-economic status of remote areas, the energy models can be developed and optimized in order to suit the needs of the area [3]. The remote villages are proposed to be provided with electricity supply from renewable energy-based decentralised generation options such as small hydro, biomass gasifier, photovoltaic, wind energy conversion systems, hybrid systems, etc [4]. The major application areas are decentralised energy supply for agriculture, industry, commercial and household sector in rural and urban areas. 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 [5]. In a developing country like India, the majority of the population lives in remote rural areas with no utility grid and this seems to be the main obstacle to overall development [6]. It is therefore important to realize the potential of renewable energy based technologies in decentralised power generation and green house gases (GHG) emission reduction in developed countries and their role in promoting sustainable rural development in developing countries.

Table 1 represents the total power generated across the world per year from 1990 to 2015. It shows that the demand for electricity continuously increased per year and risen from 11,854 TWh in 1990 to 23,950 TWh in 2015. The power generation was almost become two times hence it can be concluded that there is a great need of electricity for global development. Figure 1 is the graphical representation of total power generated per year across the world.

Table 1: Global Electricity Generation (TWh) [7]

Year	Electricity Generation (TWh)	Year	Electricity Generation (TWh)	Year	Electricity Generation (TWh)
1990	11,854	1999	14,774	2008	20,263
1991	12,134	2000	15,477	2009	20,204
1992	12,244	2001	15,593	2010	21,515
1993	12,536	2002	16,203	2011	22,212
1994	12,840	2003	16,781	2012	22,709
1995	13,285	2004	17,570	2013	23,375
1996	13,718	2005	18,333	2014	23,765
1997	14,009	2006	19,040	2015	23,950
1998	14,370	2007	19,874	----	----

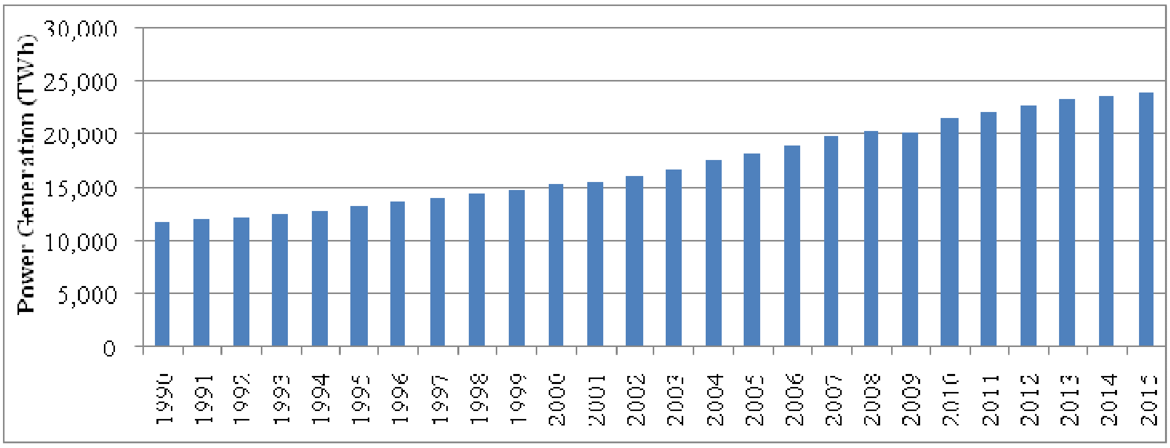

Figure 1: Variation in annual power generation at global level [7]

Table 2 shows the percentage of the renewable sources used in production of electricity across the world from 1990 to 2015. This shows that renewable sources hold a large portion in power generation. Per year the contribution goes on increasing but a drop is encountered during starting of 21st century. Figure 2 is the graphical representation of contribution of renewable sources in electricity production around the world.

Table 2: Contribution of Renewable Sources in Global Electricity Generation [7]

Year	Contribution (%)	Year	Contribution (%)	Year	Contribution (%)
1990	19.9	1999	19.4	2008	19.1
1991	19.9	2000	19.1	2009	19.9
1992	19.9	2001	18.6	2010	20.2
1993	20.4	2002	18.5	2011	20.6
1994	20.2	2003	18.1	2012	21.5
1995	20.5	2004	18.5	2013	22.2
1996	20.2	2005	18.6	2014	22.8
1997	20.1	2006	18.8	2015	23.4
1998	19.8	2007	18.5	----	----

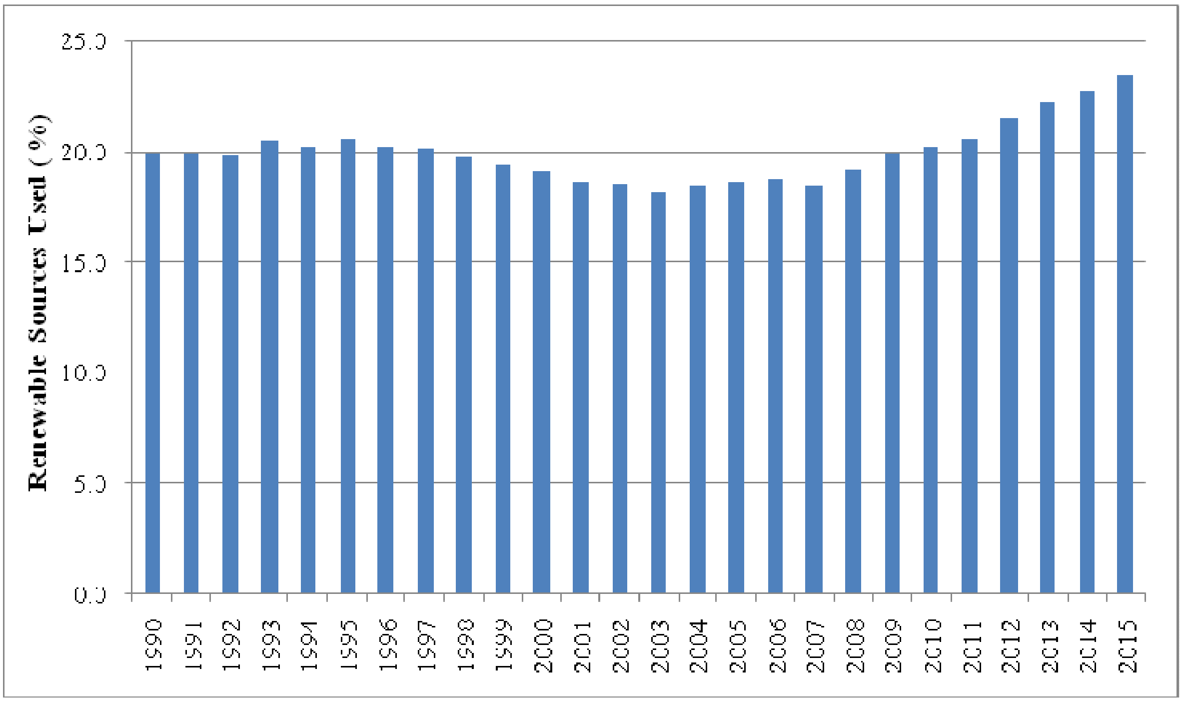

Figure 2: Contribution of renewable resources in electricity generation at global level [7]

Table 3 shows the combined contribution of solar energy and wind energy in the generation of electricity around the world. It can be seen from figure 3 that earlier their contribution was very less i.e. only 0.4% and it remained constant till 2000, but the use of wind and solar energy increased exponentially in the forthcoming years and increased to 4.9% till 2015.

Table 3: Contribution of Wind and Solar Energy in Global Electricity Generation [7]

Year	Contribution (%)	Year	Contribution (%)	Year	Contribution (%)
1990	0.4	1999	0.5	2008	1.5
1991	0.4	2000	0.6	2009	1.8
1992	0.4	2001	0.6	2010	2.1
1993	0.4	2002	0.7	2011	2.6
1994	0.4	2003	0.7	2012	3.1
1995	0.4	2004	0.9	2013	3.7
1996	0.4	2005	1.0	2014	4.1
1997	0.4	2006	1.1	2015	4.9
1998	0.4	2007	1.2	----	----

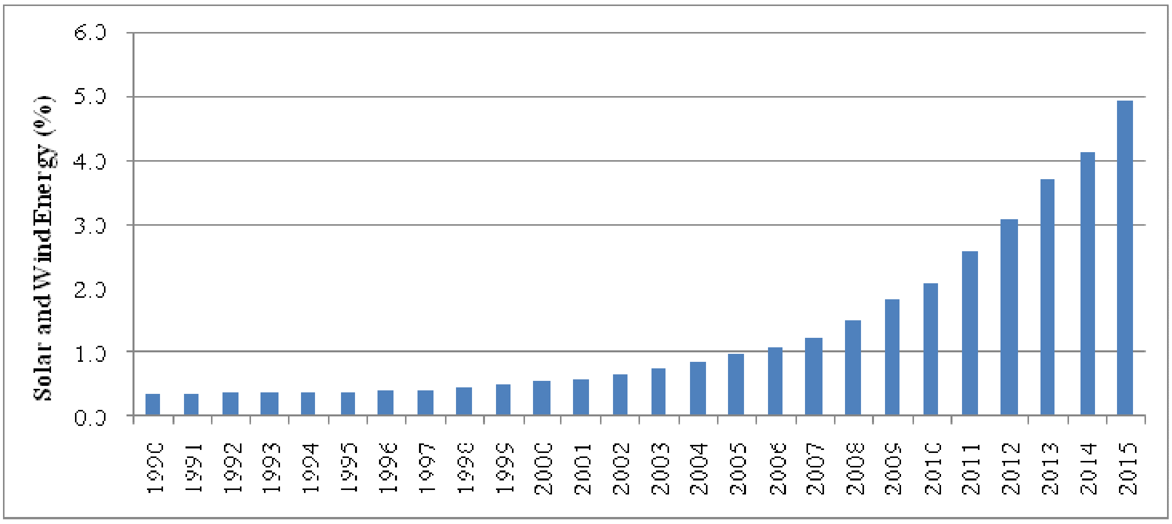

Figure 3: Combined contributions of wind and solar energy in global electricity generation [7]

2. Literature Review

Many Researchers have been discussed different type of technologies for decentralized power generation using renewable energy system and analyzed different results of various case studies using simulations by software moreover compared with grid connected system. An Integrated Renewable Energy Resource (IRES) model of Micro Hydro Power (MHP) - 15.88%, Photo Voltaic (PV) - 2.77%, Wind - 1.89%, Biomass - 79.46% is proposed for Jaunpur block of Uttaranchal state of India where total load estimated load is 808 MWh/yr and total available resources are 807 MWh/yr. The model is optimized using Linear, Interactive, and Discrete Optimizer (LINDO) software version 6.10. The Cost Of Energy (COE) found to be Rs 3.11 per unit for Effective Power Delivery Factor (EPDF) ranging from 1.0 to 0.75, and results are verified using Toolkit for Oracl (TORA) software version 1.00 [3]. A review of decentralised renewable energy options i.e. bio-energy, solar power, wind and hydro along with related case studies of successful deployment energy technologies in India is presented. It is found that tariff structure of Gosaba's Island with biomass electrification is Rs. 5.6/kWh for domestic, Rs. 6.75/kWh for commercial and Rs. 8.00/kWh for industries. COE for water supply system of Odanthurai Panchayat, Tamil Nadu is Rs. 5.02/kWh with grid power which is comparatively higher with gasifier system as Rs. 1.39/kWh. A 20 kW biomass gasifier, having efficiency around 23% is installed in a dual fuel mode (coupled to generator) in Hosahalli and Hamumanthanagara villages of Karnataka, India. It is found that diesel replacement of 85% to 90% is achieved in field conditions, total investment cost for power generation and provision of services is about Rs. 1,500,000 for each village and operation & maintenance (O&M) cost is about Rs. 3.34/kWh at full load [5]. IRES is proposed for seven-uneletrified villages of Almora district in Uttarakhand, India to satisfy their electrical and cooking needs by using Hybrid Optimization Model for Electrical Renewable (HOMER). The model is optimized using LINGO software. MHP-Biomass-Biogas-Energy Plantation-Wind-SPV hybrid system results to be the best with total cost of Rs 19.44 lacs for 0.95 Energy Index Ratio (EIR) and COE is Rs 3.36/KWh [6]. Different combinations of hybrid system comprising of wind, PV, Diesel Generator (DG) and batteries are analysed to determine the optimum size of system suitable to fulfil the requirements of 50 kWh/day primary load with 11 kW peak load for 50 households of three remote sites located at Cox's Bazar, Sylhet and Dinajpur areas of Bangladesh using HOMER. It is found that most economical is PV–DG–Battery hybrid system with COE 25.4 Tk/kWh (1 USD=68.5 Taka) and CO_2 emission is decreased by 40% [8]. A pre-feasibility test of Wind-PV-Battery hybrid system is carried out for Chittagong in the east-southern part of Bangladesh by using HOMER. Data for solar radiation is collected from meteorological parameters like sunshine duration and cloud cover, and data for availability of wind energy and speed are actually calculated. Net Present Cost (NPC) is found to be $391,492 and COE $0.47 / kWh with annual electricity production of 89,151 kW, which is 25.4 % in excess and it also reduces emission of CO_2 by about 25 ton per year [9]. Comparison of COE is carried out between decentralised system using hydrogen-based fuel cell and a grid connected system with the help of HOMER, for a rural primary health centre located at Mamandur in Tamil Nadu, India. COE is found to be between seven times and less than half that of conventional energy i.e. from $431,518 to $27,943, and the break-even distance is between 43.8 km to a negative distance for varying ranges of input component costs [10]. A hybrid system of MHP-Biomass-Biogas-Wind-SPV is optimized using HOMER for dense forest areas of Uttarakhand state in India. The average COE found to be Rs 6.80 and Rs 6.40 per kWh for reliability values of 0.999 EIR and 0.99 EIR, respectively [11]. COE is compared of PV-DG-Battery hybrid system with a system providing power by only a generator in northern part of Nigeria by using HOMER. Basic parameters are considered like annual mean global solar radiation of 6.00 kWh/m^2/day, annual real interest rate of 3% and diesel price of $1.1/L. It is found that the COE is reduced and varies in the range from $0.348 to $0.378 per kWh, earlier which was $0.417–$0.423 per kWh [12]. COE is compared for an IRES in optimal combination of 20 kW PV-Array, 30 kW Small Hydropower, 10 kW Bio Diesel Generator, 40 Batteries, 20 kW inverter and a 20 kW rectifier and grid connected system for Palari village of Chhattisgarh, India by HOMER. It is found that the total NPC, capital cost and the COE are $673,147, $238,000 and $0.420/kWh, respectively, and COE from grid extension is $0.44/kWh which is comparatively high [13]. Innovation in off-grid technologies are analyzed in Nepal and Afghanistan considering mini grid with micro hydro technology and Levelized Cost of Electricity (LCOE) of various technological pathways are compared which came out to be $0.28 to $0.35/kWh and $0.25 to $0.30/kWh for 25kW and 50kW respectively in Nepal, whereas it is higher in Afghanistan i.e. $0.50 to $0.67/kWh and $0.34 to $0.47/kWh for the same ratings respectively [14]. The villages of Madhya Pradesh, India are electrified after categorizing the total 83 villages into five categories based upon the availability of the resources in particular location and Per Unit Electricity Cost (PUEC) is found to be varying from Rs. 4.7 to 21.3/KWh. Minimum PUEC varies from Rs. 4.7 to 5.7/KWh for biogas based technology and maximum PUEC varies from Rs 16.1 to 21.3/kWh for PV based technology [2]. The SWEG having 3.2 kW capacity projects are most attractive both in terms of unit capital cost of wind turbine as well as Levelised Unit Electricity Cost (LUEC) considering the financial performance and power requirement of different geographical regions (19 locations) of India, where annual mean wind speed varies from 3.35 to 7.08 m/s. LUEC found to be in the range of Rs. 27.96 to 12.77/kWh and in niche remote locations, SWEG projects could be financially attractive as compared to PV power projects or DG sets, if a capital subsidy of about 20% is provided [15]. The financial viability of Dual Fuel Bio Gas Power Project (DF-BGPP) and 100% producer gas (HPG) mode is obtained in terms of initial capital cost and unit capital cost. It is found that both projects are costlier compared to projects of 5 kW and 10 kW diesel generator set based power generators, but a 40 kW HPG-BGPP is financially attractive to DG set project at a diesel price of Rs. 34.70/litre as LUEC estimated in the range of Rs. 11.89 to 20.34/kWh as compared to Rs 26.00/kWh for grid extension to a distance of 5 Km [4]. Out of 1,50,000MW hydro potential, only about 17.8% is exploited so far which contributes about 24.8% for the total power generating installed capacity and about 5.48% of total hydropower generating capacity by 453 small hydropower (SHP) projects in India. UCE supplied by MHP projects of 40kW capacity in Arunachal Pradesh is estimated in the range of Rs. 4.56/kWh to Rs. 4.92/kWh for a Plant Load Factor (PLF) of 40% whereas total cost of MHP projects in remote and inaccessible areas found in the range of Rs. 1, 24,310 to Rs. 2,33,335 per kW including the cost of power evacuation and distribution system [16]. A comparison of solar photovoltaic, biomass gasifier based power generation system with conventional grid on the basis of Life Cycle Cost (LCC) is carried out. It is found that LCC for biomass gasification lies between Rs 2.72 to Rs 5.48/kWh and for photovoltaic between Rs 16.89 to Rs 15.99/kWh with Economical Distance Limit (EDL) for the biomass gasifier system of 25 kW capacity is 10.5 km with 6 h of daily operation and for photovoltaic system it is 35 km in same conditions [17]. A domestic type Solar-Wind hybrid system is implemented for providing energy to a portion of home. Alternator of wind turbine provides a continuous output of 29 V and 250mA for continuous wind blow with some minor disturbances. If wind speed falls below a critical value and generated voltage comes less than 24 V then control system takes out the turbine from the system. The highest power output from the panel is obtained when battery is charged and load is engaged to the system. Current rises to 3.2 A and voltage up to 32 V. The current and voltage values from the solar panels for the daylight make a peak, at 10:25am [18]. A spatial assessment of crop residue biomass is carried out in Sonitpur district of Assam, India. 16 different types of crop residues identified in the district contributing about 0.17 million tonnes of crop residue biomass which have 17 MW power potential, with rice crop as dominant residue. Highest individual potential of 71.86 kW is observed in the village Charaibari [19]. Global warming is accepted as the greatest threat of the time to the environment due to emission of Green House Gases (GHG) and need of industries. Decentralized generation of electricity by palm oil based biomass is studied which is followed by study of palm oil production across the world, It is concluded that Malaysia, Indonesia, Thailand and Nigeria have great potential to generate decentralized electricity from palm oil biomass and further research is required to find out the optimal palm oil biomass which produces minimum waste and valuable by-products [20]. Decentralized Power generation potential is investigated from surplus rice straw among 1,117 villages within nine development blocks of Lakhimpur district of Assam, India. Linear Imaging and Self Scanning Sensor (LISS) III satellite images of Indian Remote sensing Satellite (IRS-P6 series, also known as RESOURCESAT-1), are used to map rice croplands. As a result 51.5 thousand tonnes (equivalent to 788 TJ) surplus rice straw is available having a potential to generate 5 MW at continuous generation with 20% overall conversion efficiency. Estimated power potential among the development blocks lies between 294 to 927 kW, with highest power potential at village level of 43 kW

[21]. A test for feasible hybrid system is carried out for Kutubudia Island in south coast of Bangladesh using HOMER. It is found that wind–PV–diesel hybrid system is feasible with annual capacity of shortage of 0% and wind-diesel hybrid system for 5%. Consumption of diesel and emission of GHG are reduced by 50% and 44% respectively [22]. Three different projects for decentralized electricity generation are analysed which are installed in three communities of Peru i.e. El Alumbre, Campo Alegre and Alto Peru. These projects are using only wind energy, hybrid of PV-Wind, individual equipment and micro grids. They are compared on both the technical and social aspects which results in a conclusion that hybrid system design is more complex than a stand-alone wind systems and planning of single home design are simpler than planning for micro grid. Indoor air pollution is reduced which accounts in reduction of smoke and decrease in eye and respiratory disease [23]. A case study is performed in eleven villages of Chhattisgarh, India to analyse the socio-economic effects of village electrification by solar power. As a result on an average children studied 41 minutes more in the evenings, dinner cooking started about 36 minutes later i.e. time is spending in other necessary work and monthly kerosene use decreased by 2 litres [24]. Jawaharlal Nehru National Solar Mission (JNNSM), a government run scheme is being discussed which aims at installing 20,000 MW of solar power generation capacity by 2022. This scheme targets both the grid connected and distributed power generation systems with a total investment of about 91,684 crore in next 20 years. It is funded by a mixture of debt and equity, and promoter's equity contribution is 20% and unexpectedly winners of this scheme are some unknown firms who have bid so low that make the returns negative for investors according to the renewable energy ministry officials (MNRE) [25]. A serious concern is raised about the present conditions of availability of electricity in the rural areas of the developing countries. Challenges linking to the implementation of decentralized systems in several difficult conditions along with the research needed to overcome them are discussed. It is expected that about 16% of world population will remain without reliable access to electricity if ongoing efforts for electrification of villages are not intensified [26]. Separated, uncoordinated, and integrated relations between grid and off-grid electrification are analysed in India. Explicit integration is the most effective because it prevents coordination failure. Sagar Dweep Island in the Sundarbans in West Bengal is the best example as off-grid rural electrification project based on solar photovoltaic is successfully installed and recently this island is witness of grid extension as an alternative. Also a field visit to Shahjahanpur district of Uttar Pradesh which is recently electrified by grid extension resulted into an interest in off-grid electrification business because even basic needs were not fulfilled due to unreliable supply of power [27].

3. Objectives

The main objective of this paper is to assess the potential of renewable energy sources in state of Rajasthan, India with primary motivation of exploring and evaluating different feasible options for designing single resource based as well as hybrid systems based on renewable energy to meet the electricity demand of villages and analyzing their cost effectiveness. The hybrid system may be of different types based on availability of the resources.

In the next section we will discuss about the power generation in India with the main focus on Rajasthan. Total amount of power generated per year with different modes of generation will be discussed along with renewable sources of energy.

4. Electricity Scenario In India

It is seen from table 4 that total power generated in the year 1990 was 293 TWh which increased drastically to 1,368 TWh in 2015 which is almost 4.5 times of the prior. It can be said that various methods of power generation were employed during this time period to satisfy the increasing demand of power.

Table 4: Electricity Generation in India (TWh) [7]

Year	Electricity Generation (TWh)	Year	Electricity Generation (TWh)	Year	Electricity Generation (TWh)
1990	293	1999	546	2008	848
1991	319	2000	570	2009	917
1992	337	2001	588	2010	979
1993	361	2002	611	2011	1,075
1994	391	2003	651	2012	1,123
1995	424	2004	684	2013	1,193
1996	443	2005	716	2014	1,295
1997	473	2006	774	2015	1,368
1998	504	2007	824	----	----

Table 5 shows the combined contribution of solar energy and wind energy in the power generation in India from the year 1990 to 2015. This shows that their use was almost negligible during 90's but as the demand for power increased in the upcoming years, the contribution of renewable sources also increased because of their advantages.

Table 6 shows the total installed capacity of different sources in India as on 31st Jan 2017. It can be seen that both conventional and non-conventional sources of energy are used for electricity generation. Even now more than 50% of the total power is produced by coal and 2% by nuclear. Different renewable sources are also represented along with their installed capacity in figure 4.

Table 5: Contribution of Wind and Solar Energy for Electricity Generation in India [7]

Year	Contribution (%)	Year	Contribution (%)	Year	Contribution (%)
1990	0.0	1999	0.3	2008	1.6
1991	0.0	2000	0.3	2009	2.1
1992	0.0	2001	0.4	2010	2.0
1993	0.0	2002	0.4	2011	2.4
1994	0.1	2003	0.6	2012	2.9
1995	0.1	2004	0.7	2013	3.1
1996	0.2	2005	0.9	2014	3.2
1997	0.2	2006	1.3	2015	3.6
1998	0.2	2007	1.4	----	----

Table 6: Installed capacity in India as on 31 January 2017 [28]

Source	Installed capacity (MW)	Contribution (%)
Coal	188,487.88	59.9
Large Hydro	44,189.43	14.0
Small Hydro	4,333.86	1.4
Wind Power	28,700.44	9.1
Bio mass	7,971.02	2.5
Solar Power	9,012.69	2.9
Gas	25,329.38	8.1
Nuclear	5,780.00	1.8
Diesel	837.63	0.3

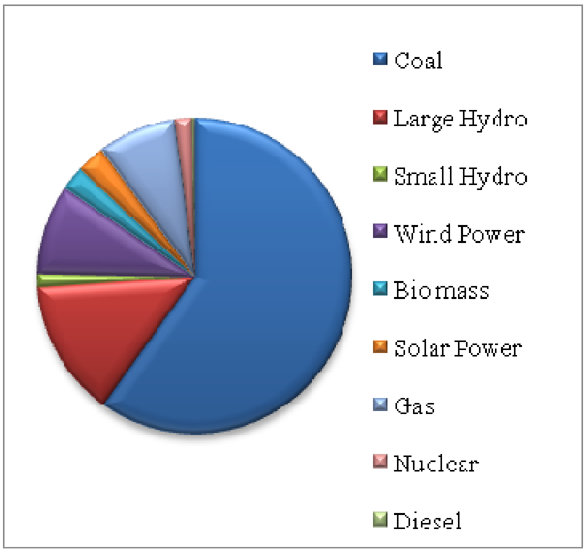

Figure 4: Installed capacity in India [28]

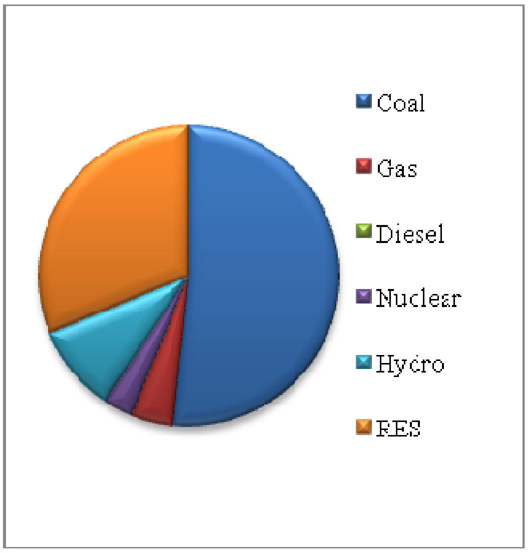

Figure 5: Installed capacity in the state of Rajasthan [28]

Table 7 shows the total installed capacity of different sources in state of Rajasthan, India as on 31st January 2017. Here also both conventional and non-conventional sources of energy are used for electricity generation. And approximately 50% of the total power is produced by coal and 3% by nuclear. Contribution of renewable is 31%. All these data are depicted graphically in figure 5.

Table 7: Installed capacity in Rajasthan, India [28]

Source	Installed capacity (MW)	Contribution (%)
Coal	9,400.72	51.63
Gas	825.03	4.53
Diesel	0.00	0.00
Nuclear	573.00	3.15
Hydro	1,729.49	9.50
RES	5,677.46	31.18

Table 8 shows the total installed capacity of different renewable sources in state of Rajasthan, India as on 31st March 2015. Here it is seen that among different renewable sources, solar and wind energy are mostly employed because of their maximum availability in Rajasthan. Solar energy contributes 71% of the total power produced by renewable sources; this is represented graphically in figure 6.

Table 8: Installed capacity of Renewable in the state of Rajasthan, India [29, 30]

Source	Installed capacity (MW)	Contribution (%)
Solar	9,820.00	71
Wind	3,866.00	28
Biomass	111.30	1
Hydro	23.85	0

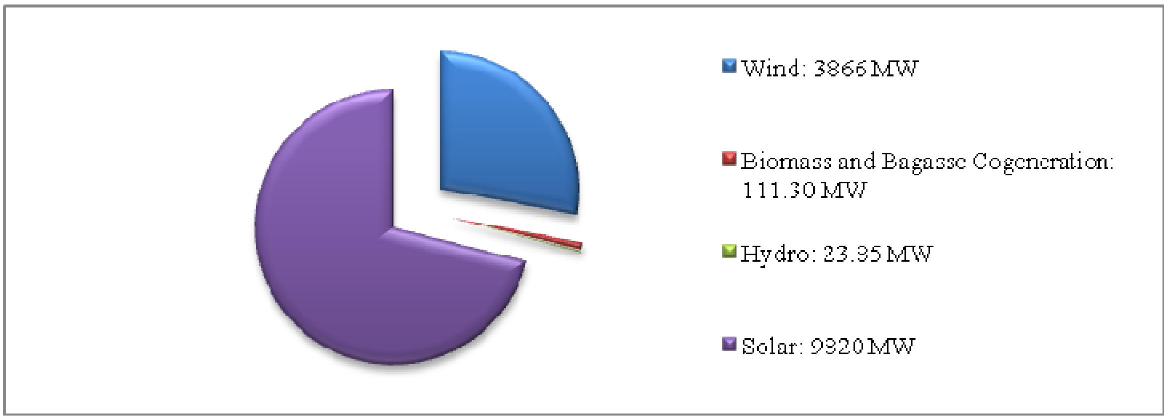

Figure 6: Installed capacity of Renewable in the state of Rajasthan [29, 30]

5. Survey Data of Un-Electrified Villages in India

Table 9 represents the total number of un-electrified villages in different states and union territories of India as on 30th April 2016. There are many states like Andhra Pradesh, Goa, Gujarat, Haryana, Kerala, Maharashtra, Punjab, Sikkim, Tamil Nadu and Telangana where there are no un-electrified villages. Among 7 union territories of India, 6 do not have any un-electrified village except Andaman & Nicobar Islands where 55 villages are un-electrified. Odisha have maximum number of un-electrified villages i.e. 2,175 followed by Assam with 1,832 and Jharkhand with 1,719 un-electrified villages. Rajasthan has 291 villages which are not yet electrified. Total 10,958 villages are there in India which has not been electrified till now.

Table 9: Number of un-electrified villages in India [31]

S. No.	State	No. of un-electrified villages
1	Andhra Pradesh	0
2	Arunachal Pradesh	1,326
3	Assam	1,832
4	Bihar	958
5	Chhattisgarh	660
6	Goa	0
7	Gujarat	0
8	Haryana	0
9	Himachal Pradesh	32

10	Jammu and Kashmir	107
11	Jharkhand	1,719
12	Karnataka	39
13	Kerala	0
14	Madhya Pradesh	232
15	Maharashtra	0
16	Manipur	192
17	Meghalaya	911
18	Mizoram	42
19	Nagaland	82
20	Odisha	2,175
21	Punjab	0
22	Rajasthan	291
23	Sikkim	0
24	Tamil Nadu	0
25	Telangana	0
26	Tripura	17
27	Uttar Pradesh	198
28	Uttarakhand	76
29	West Bengal	14
	Total (States)	**10,903**
	Union Territory	
1	Andaman and Nicobar Islands	55
2	Chandigarh	0
3	Dadra and Nagar Haveli	0
4	Daman and Diu	0
5	National Capital Territory of Delhi	0
6	Lakshadweep	0
7	Pondicherry	0
	Total (UT's)	**55**
	Grand Total	**10,958**

Table 10 shows the total number of villages to be electrified under Rajiv Gandhi Grameen Vidyutikaran Yojana (RGGVY) - 12th plan, Deen Dayal Upadhyaya Gram Jyoti Yojana (DDUGJY) and villages to be electrified in off-grid manner, in different districts of Rajasthan. Districts like Jaipur, Ajmer, Sikar, Jhunjhunu, Rajsamand, Doongarpur, Jolore, Jodhpur and Nagaur do not have any un-electrified village. Maximum 126 villages are un-electrified in Jaiselmer followed by 94 in Udaipur and 43 in Jodhpur.

Table 10: Number of Un-electrified and De-electrified villages taken for electrification [32]

S. No	District	RGGVY (12th Plan) sanctioned on 27.09.13	DDUGJY sanctioned on 06.08.15	Village proposed to be electrified by off grid	Total
1	Alwar	0	0	9	9
2	Baran	1	0	30	31
3	Bharatpur	0	0	4	4
4	Bundi	1	0	1	2
5	Dausa	0	0	1	1
6	Dholpur	0	9	1	10
7	Jaipur	0	0	0	0
8	Jhalawar	0	0	6	6
9	Karauli	0	0	10	10

10	Kota	0	0	1	1
11	S.Madhopur	2	0	12	14
12	Tonk	0	0	2	2
	Total	**4**	**9**	**77**	**90**
Ajmer Discom					
1	Udaipur	0	78	16	94
2	Chittorgarh	5	0	1	6
3	Pratapgarh	21	0	2	23
4	Banswara	0	2	2	4
5	Ajmer	0	0	0	0
6	Sikar	1	0	0	1
7	Jhunjhunu	0	0	0	0
8	Rajsamand	0	0	0	0
9	Bhilwara	3	0	1	4
10	Nagaur	5	0	1	6
11	Doongarpur	6	0	0	6
	Total	**41**	**80**	**23**	**144**
Jodhpur Discom					
1	Barmer	0	13	21	34
2	Bikaner	22	0	2	24
3	Jaiselmer	115	0	11	126
4	Jolore	0	0	0	0
5	Ganganagar	4	0	4	8
6	Hanumangarh	0	2	6	8
7	Sirohi	1	0	0	1
8	Pali	7	0	4	11
9	Jodhpur	43	0	0	43
10	Churu	2	0	4	6
11	Nagaur (P.S.Ladnu)	0	0	0	0
	Total	**194**	**15**	**52**	**261**
	Grand Total	**239**	**104**	**152**	**495**

6. Conclusion

The following concluding remarks are obtained from the review and survey:

- A large potential of renewable resources are available in India due to which off grid electrification is much preferred for electrification of remote areas where grid extension is not possible because of economical constraints.
- For solar PV the COE lies between $0.348 to $0.378/kWh, for wind energy COE came out to be $ 0.35/KWh, for biomass as fuel LUEC lies from Rs. 20.34 to 11.89/kWh, for micro hydro power LCOE found between $0.28 to $0.35/kWh. Minimum COE was Rs. 1.39/kWh for gasifier system installed for water supply system of Odanthurai Panchayat, Tamil Nadu, India.
- Installation cost of decentralised systems was high as compared to grid systems and found Rs 19.44 lacs for 0.95 Energy Index Ratio (EIR) corresponding to a hybrid system of MHP-biomass-biogas-wind-SPV.
- When hybrid system of MHP-Solar-Wind-Biomass was used then COE came out to be Rs 3.11pu. It is seen that the output power by renewable resources is economical in terms of cost, availability and reliability.
- India is very much enriched by all forms of renewable resources with variety in different states hence there is a lots of scope of power generation by renewable

sources especially in the state of Rajasthan on the basis of resource feasibility and climate conditions.

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