International Journal of Enhanced Research in Science, Technology & Engineering
ISSN: 2319-7463, Vol. 9 Issue 4, April-2020, Impact Factor: 6.754

Renewable Energy Sources and their Prospects in India: An overview

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ABSTRACT

India has more than 1.35 billion people out of which around 70% lives in rural areas. Population is increasing on a daily basis and with the progressive increase in population the demand for energy is also increasing. Today the need of the hour is to rely more on the renewable energy sources instead of the conventional energy sources. It has long been debated that the continuous use of the conventional energy sources is detrimental to the environment in the sense that it is resulting in global climate change and also these energy sources can easily get exhausted in the near future. Although a lot of developments and progress have been made in this sector but in order to reach the zenith, the concept of utilisation and development should be undertaken in such a manner that the entire country becomes a hub for renewable energy mantra. The opportunities in the field of renewable power are immense and with proper initiative a lot of ground-breaking and transformational changes can be manifested.A more firm basis needs to be provided on wind and solar energy because of their efficient production in the country. Important renewable energy sources and their prospects in India are mainly overviewed in this paper.

Keywords: Conventional energy, renewable energy, prospects, climate change, India.

1. INTRODUCTION

India is a developing nation and has a population of more than 1.35 billion. Around 70% of the population still lives in the rural areas and the energy requirement of India will be almost double by 2040. The energy crisis has been a long debated issue in India. Energy and development are inter-related. There is a growing concern that the world's reliance on energy from non-renewable fossil fuels is not sustainable. Our dependence on fossil fuels puts us at risk of disturbances in energy supply due to changing political, climatic and international relations.The continuous useof these fossil fuels has ultimately resulted in increased greenhouse gas emissions which are the primary cause behind global warming. As per the Paris Accord on Climate Change, India has made a pledge that by 2030, 40% of India's installed power generation capacity shall be from non-fossil fuel sources [1].Considering all these, renewable energy sources can be of utmost importance. Renewable energy can be defined as any form of energy from solar,geophysical or biological sources that is replenished by natural processes at a rate that equals or exceeds the rate of use [2]. In broad sense renewable energy can be categorized into solar energy, wind energy, biomass energy, hydro energy, geothermal energy and tidal energy etc. To maintain the speed of economic growth with the reduction of greenhouse gas emission, India must decrease its dependency on the conventional energy sources and move towards the renewable energy sources.Bioenergy and solar energy could be the essential parts to realise the renewable energy potential of India. Various forms of biofuel could account for 62% of the total final renewable energy by 2030 in India. In addition solar,wind and hydro power can contribute 16%,!4% and 7% respectively in the renewable energy front in India by 2030 [3].It is also estimated that India could have over million jobs in solar energy and around 2 lakhs in wind energy alone by 2022. India has already set a target of 175GW installed renewable energy capacity including 100 GW of solar,60GW of wind,10GW of biomass and 5 GW of small hydropowers by 2022. As per the solar energy market outlook--2026, the global solar energy market has been valued at $52.5 billion in 2018 and is projected to reach $223.3 billion by 2026. There are several advantages of renewable energy compared to its non-renewable counterpart. Renewable energy is environment friendly in the sense that itdoes not emit any poisonous gases or noxious fumes into the environment.Other advantages of the renewable energy sources are reduce dependency on imported fuels, reduce conflicts related to mining and helps in limiting the use of available fossil fuels and stabilising global energy prices etc.

Besides, higher renewable energy uptake will have several benefits and more particularly on air pollution and climate change related savings. Reducing energy related CO2 emission by 750 megatonnes per year India can save USD 13-63 billion per year [3]. Proper exploitation of renewable energy technologies can lower the demand for coal and oil products between 17-23% in India by 2030. India being an active player in the fight of climate change the country should give major emphasis on the production of clean and renewable energy. Reducing the use of traditional biomass in cooking itself will have significant impact for reducing indoor airpollution. Improvement in energy efficiency and sustainable energy production through the renewable energy resources should be the priorities for the country.

Considering the enormous prospects of renewable energy sources in India more initiatives in different parts of the country is needed to make India as clean and sustainable energy production hub in future. Although, India has set a target of 175GW installed renewable energy capacity including 100GW of solar, 60 GW of wind,10GW of biomass and 5GW of small hydropower by 2022 [3].The capacity created in India's renewable energy sector has begun to slacken. According to Mercom India research Solar capacity installations in the country is at 25,000 megawatts (MW), or one-fourth of the 2022 target of 100,000 MW and as of July 2018, Indian Wind Turbine Manufacturers Association pegged operating wind capacity at 34,393 MW, or about 57% of the 60,000 MW target set by the government for the five-year period. But the continuous initiatives of the Govt. of India with the involvement of more private partners it may be possible to achieve the targets. The total installed renewable capacity as of 31st December 2018 in India is shown in the Fig -1. The important renewable energy sources and their prospects in India are reviewed in brief.

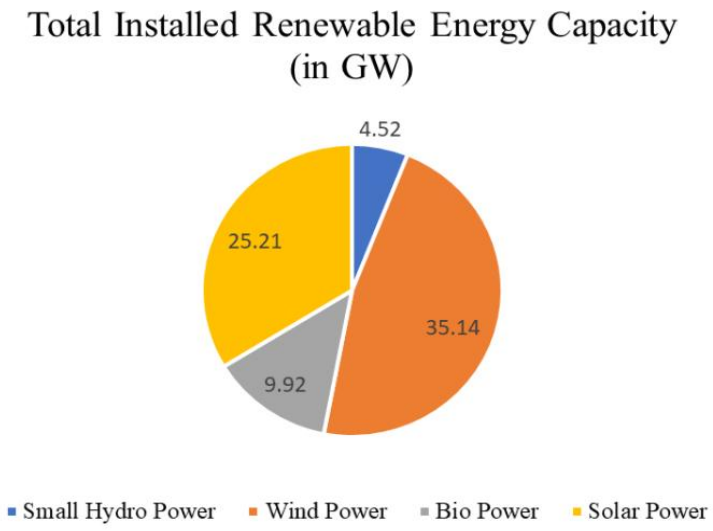

Fig. 1: Total installed renewable energy capacity in India till December 2018 (Source: MNRE, Govt. of India)

2. RENEWABLE ENERGY SOURCES

Solar energy: Solar Energy is the energy obtained by capturing heat and light from the sun either directly by using solar photovoltaics (SPV) and indirectly using concentrated solar power(CSP) or by using a combination of both.International EnergyAgency (IEA) forecastedthat within 2050, the SPV and CSP will constitute about 16% and 11% respectively of thetotalelectricityconsumptionintheworld [4].A report ofthe IEA,2017 also stated that solar energy has become the world's fastest – growing source of power. Among the various renewable energy sources the solar energy potential is the highest in India and it is occupying the 5thGlobal position for solar energy production.The opportunities and challenges for installation of solar tower technology in Indian contexthas been reported earlier [5,6].The challenges in the policy implementation of grid-associated, off- grid and rooftop applications of solar power generation have also been highlighted [7]. Despite the challenges there are many opportunities and solar energy can be put to great use as it is a source of energy which is readily available. The geographical location of India is beneficial for generation of solar energy. Moreover, it is a tropical country and most parts receive sufficient amount of sunlight throughout the year. TheaveragesolarinsolationreceivedinIndiaisapproximately 200MW/km-squarewithanaverage250–300sunnydayinayear.About 5,000 trillion kWh per year energy is incident over India's land area. However, the solar radiation varies geographically in India. Annual radiation of solar energy is the highest in northern region, especially in the North-Eastern Region and Ladakh of the country (Fig.2). Data analysis showed that nearly 58% of the geographical area potentially represents the solar hotspots in India with more than 5 kWh/m^2/day of annual average Global insolation [8].

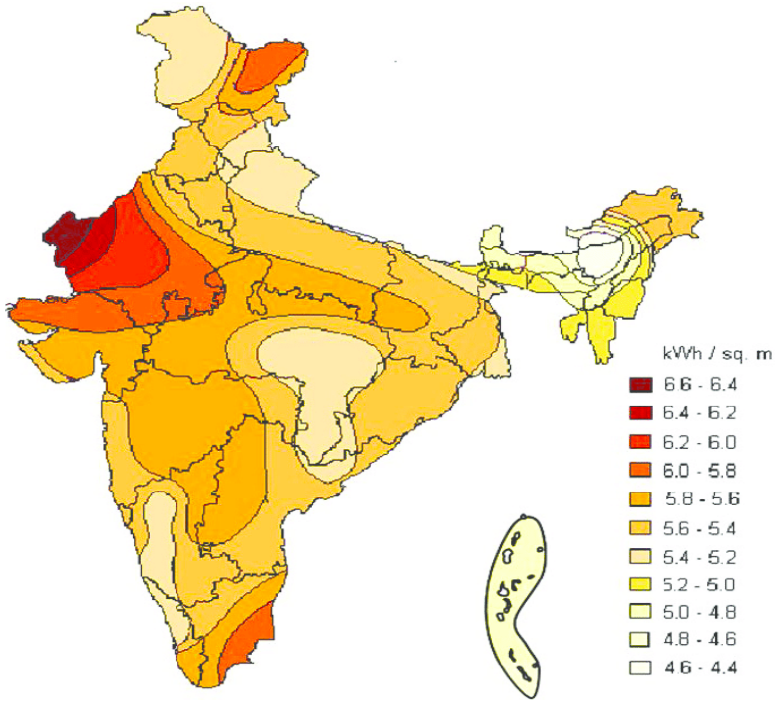

Fig.2: Insolatiom map of India showing average daily solar radiation in units of kWh/m

(Source: http://www.cercind.gov.in)

Considering the potentiality of the solar energy, the Jawaharlal Nehru National Solar Mission (JNNSM) launched by the Govt. of India is targeting 20,000 MW of solar energy power by 2022[9]. The state of Gujarat pioneering in solar power policy aims at 1,000 MW of solar energy generation and Rs. 130 billion solar power plan was unveiled in July 2009, which projected to produce 20 GW of solar power by 2020 [9].At present, the Thar region in Rajasthan is home to some of the best solar projects of the country, generating close to 2,100 GW power [10]. Solar energy has several advantages in the sense that it is in-exhaustible and does not cause any atmospheric pollution. Moreover, the cost of installing solar panels is decreasing so the demand is increasing.

It is heartening to note that the dedicated Ministry of New and Renewable Energy (MNRE), Govt. of India has undertaken a scheme to develop Ultra Mega Renewable Energy Power Parks (UMREPPs) under the existing Solar Park Scheme. Besides, the progress in the solar power sector in India is consistently encouraging and some the milestones are given below.

Milestones in the field of Solar Energy in India

- 2010 – 25.1 MW electricity produced through solar energy
- 2011 – 468.3 MW electricity produced through solar energy
- 2015 – 4229.36 MW electricity produced through solar energy
- 2017 – 10,000 MW electricity produced
- 2022 – 1,00,000 MW electricity to be produced.

Compared to other renewable energy sources the cumulative achievements in the solar power sector is higher in India as per the recent report of the press information bureau [11]. The cumulative achievement in the solar power sector from 2014 to 2018 showed 9.237 % increase in the solar power sector whereas the change in the wind power sector is only 1.663% (table 1). Besides, India is targeting 100GW energy from the solar power by 2022.India is also having an advantage because of theInternational Solar Alliance (ISA) , the first International intergovernmental organization in which India and several other countries have already signed framework agreement.

Table 1: The changes in renewable energy sectors in terms of cumulative achievements in India [11]

Sector	Cumulative achievement in MW as on 31.3.2014	Cumulative achievement in MW as on 31.3.2018	% Change
Solar Power	2631.90	24312.58	9.237
Wind Power	21042.57	34986.35	1.663
Bio Power	8041.63	9545.91	1.187
Small Hydropower	3803.74	4506.95	1.185

Solar energy sector is fast growing because of its innumerable applications and lot of innovations in terms of efficiency in energy production and cost reduction has been made in the recent past. Energy efficient and cost effective materials are being developed, solar panels are become lighter, more flexible and applicable everywhere.With proper adoption of newer technologies and with their effective implementation a lot can be done in the field of solar energy in India.Post harvest losses of agricultural products are a serious concern in most places of India. With the aim to reduce the post harvest losses anindirect solar dryer for drying agricultural products was designed, fabricated and its performance was evaluated [12]. The dryer has been designed indigenously using locally available materials and it was cost effective. Such type of cost effective indigenously developed solar dryer may be immensely useful for the rural farmers of India.Similarly solar powered water pumping systems have proved to be cost-efficient and reliable alternative of diesel and manually operated pumps and are raising agricultural productivity levels all over the world [13]. Additionally, solar powered pumps have proved to be an efficient and environment friendly way of meeting the domestic and commercial needs of the people living in remote areas [14].Recently we have developed a low-cost solar powered water pump (below US$50) for meeting the irrigation and household needs of the people of KohDambang, Cambodia [15]. Sinceirrigation is a major constraint in the cultivation for most of the rural farmers, cost effective solar pump can be the viable option for them to enhance the productivity of the agricultural sector.

Wind Energy: Wind energy is the process to generate electricity by using flowing wind or air in the earth's atmosphere.Wind turbines are used to convert the kinetic energy of flowing wind or air into mechanical energy and to electricity. The capacity to generate the required amount of power from flowing wind would depend upon its characteristics which include the mean wind speed, wind speed distribution, turbulence, long term fluctuation, distribution of wind direction and wind shear. Wind turbines can be classed into Horizontal axis wind turbine (HAWT) and Vertical axis wind turbine (VAWT). Wind energy has emerged as the biggest source of renewable power not only in India but all throughout the world, because similar to solar, wind is an inexhaustible and non-polluting source of energy.There is a rapid increase in cumulative global capacity of windpower reaching 651GW at the end of 2019 [16]. China is leading in windpower installed capacity and accounts for 35% of the world's total windpower capacity [17]. Although India has the second largest wind market in Asia after China, but it is occupying the 4th global position in the wind power installed capacity. As of June 2018 the installed capacity of wind power in India was 34GW and the target by 2020 is 60GW on the other hand the China which is occupying the Global 1st position is forecasting to have 250GW of wind power installed capacity by 2020. Studies have shown that various states of India have a promising potential for the development of offshore wind power and the various advantages of offshore wind have been reported earlier [18].The offshore potential of wind energy in India has been identified to about 350GW with 7600 Km coastline of the country [19]. However, generating power from wind is concentrated mostly in the south, west and northern regions of India with Tamil Nadu having the highest installed capacity in the country. The progress of cumulative installed wind power capacity in the North Eastern States is very slow.

The development of wind power in India began in the early 1990's and has significantly increased in the last few years due to the extensive effort taken by the government for the development of renewable energy production sector owing the global concern on climate change . India can progress further in wind energy sector with the focus on adoption of newer technologies, involvement of more domestic manufacturing units, financial support and policy.

Hydro energy: Hydro energy is one of the leading renewable energy resources recognized globally for electricity generation. About 71% of all renewable electricity is coming from hydropower at the end of 2015 and the undeveloped potential of the hydropower is approximately 10000TWh/y globally [19]. It is also estimated that 99% of the world's electricity storage capacity is in the form of hydropower [19].Many developed countries like USA, Japan, Norway and France etc have harnessed more than 80% of their hydropower potential. China has already installed hydropower capacity of about 342GW [20] and the global total hydropower installed capacity has already reached about 1271GW [21]. Hydropower is one of the oldest sources of energy for producing mechanical and electrical power. Hydropower is the most mature, reliable and cost-effective renewable power generation technology available [22]. Growing energy

demand and concern for carbon emission is making hydropower development more favourable [23].India is the 7th largest producers of hydropower in the world and the Govt. of India has also drafted a new hydropower policy for 2018-20 to boost the sector. As per the report of MNRE, Govt. of India,the country has installed a total capacity of 4.5GW of grid connected small hydropower as on October 2018 and anticipated to have 5GW small hydropower by 2022.Many states of India like Himachal Pradesh, Uttarakhand and all the North Eastern (NE) states have tremendous potential to generate hydropower. The Himalyan states, other plain states like Punjab, Maharashtra, Karnataka and Andhra Pradesh are producing hydropower. The NE states of India have tremendous potentiality in hydropower sector because of high rainfall, perennial waterfalls, mighty river Brahmaputra and its tributaries. Despite this the region is lagging behind to explore the potentialities of hydropower. The North Eastern Electric Power Corporation (NEEPCO) is playing the major role in the hydropower sector in the NE region, but more investment and participation of private players are important to harness more from the hydropower in the region. Although certain inherent factors such as environmental and forest issues, rehabilitation of peoples and change of river basin are impediment but the issues can be sorted out for the greater interest of the society.

In a hydro-electric power station, the falling water is used to turnthe turbines. Through magnetic induction, the generator converts the mechanical energy of turbines to electricity. The flow rate of water is an important technical term which comes into consideration while dealing with hydropower. The turbines employed in hydro-electric power stations can be classified as impulse turbines, reaction turbines and mixed turbines. The techno-economic viability of hydroelectric projects depends on geology, topography, hydrology and accessibility to project area. Lot of technology innovations in hydropower particularly in turbine development, hydropower control and storage technologies etc which need to be further explore for effective and sustainable use of the hydropower in India. The environmental impact assessment is also essential to address.

Bio energy: Bioenergy is broadly defined as the type of energy, which is produced from organic matter (biomass) derived from plants or animals. Sources of biomass include agricultural crops, animal and plant wastes, algae, wood and organic residential/ industrial waste. Biomass and biomass wastes are carbon-neutral widely available, which can be utilized toproduce renewable power / gas with the potential to provide significant employment in the rural areas of India.The bioenergy demand in India rises by around 11% over the projection period to 2040[24].The power generation based on biomass will rise by more than five-times to reach around 120 TWh in 2040[24]. In 2015, about 474 TWh (2%) of global electricity generation was derived from biomass resources [25].Considering fuel properties (e.g. heating value), and feedstock-to-energy conversiontechnologyindicated that the global potential for bioenergy by 2050 would be 1,135 EJ, ifall sources were considered [26].Different types of potential traditional biomass are agricultural residues, which includes harvesting residue and food waste, animal's dung,forest products or woody biomass etc. The potential of lignocellulosic biomass for bio-energy production in India have been evaluated for the past decades with inclusion of updated technologies [27]. Biomass availability in India is estimated to be around 915 million metric ton which includes both agricultural and forestry and wasteland residues, the power potential of which is estimated at 33,292 MW [24].The gross residue availability in India from the cultivation of different grains, oilseeds, fibers and sugarcane is estimated to be 877Mt per year by 2030 [28]. The current availability of biomass as per MNRE ,Govt. of India is about 500 Mt per year.In India, 97.19 Mt of rice straw is produced every year, and around 23% of it is left unutilized. Mostly these are burnt in fields which emit greenhouse gases hazardous to human and ecosystem health [24]. Rice straw can be alternatively used as feedstock for clean energy.The gross residue availability in India from the cultivation of different grains, oilseeds, fibres and sugarcane is estimated at 680 Mt for 2010-11 and 877 Mt for 2030–31 respectively [28]. As per the Ministry of New and Renewable energy, the current availability of biomass in India is estimated at about 500 Mt per year.

Sugarcane is one of the most promising agricultural sources of biomass energy in the world and India is the 2nd largest sugarcane-producer in the world, after Brazil [29]. Bagasse,the fibrous residue left over after milling of the sugarcane is one of the potential sources of biomass energy. For every 100 tons of sugarcane crushed, a sugar factory produces nearly 30 tons of wet Bagasse and cogeneration of bagasse is one of the most attractive and successful energy projects in many parts of the world.Bagasse has already emerged as a lucrative feedstock for bio-ethanol production. Earlier, bagasse was used mainly as a fuel to power the sugarcane production facilities but a disadvantage of using bagasse as a fuel is that it emits some pollutants into the atmosphere. With innovative approachhigh-efficiency bagasse cogeneration now become an attractive technology both in terms of its potential to produce carbon neutral electricity as well as its economic benefits to the sugar sector. In the present scenario, India' is having more than 525 working sugar mills which crush around 240 million tonnes of sugarcane per year and generate 80 million tons of wet bagasse (50% moisture).India has around 206 cogeneration units with a cumulative installed exportable capacity of 3,123 MW (peak season). As per the report of MNRE, Govt of India, the country has potentiality of power generation through Bagasse co-generation is about 3500 MWand the potentiality in some of the state like Maharashtra alone is 1250 MW.

India is having the largest livestock population, as per the latest Livestock Census, Govt of India, the total livestock population is 536 million, out of which over 300 million are cattle and buffalo. Cow dung primarily a potential source of biogas. A cow can produce about 5 Kg dung per dayand 25 kg of fresh dung gives 5 kg of dry dung which would generate $1m^3$of biogas [30]. Considering the huge cattle population of the country there is tremendous potentiality to

promote biogas production. A prototype biodigester using cow dung mixed with house hold waste was developed in Melbourne, Australia and applicability of such biodigester in India particularly in urban settings can be explored to recycle the huge solid waste generated by the urban households[31].The potentiality of biogas and its integration into the energy systems in India has also been elaborated [32].The algal biomass from various sources have been reported from India to have potential for design of a bio refinery to harvest bioenergy and other value added products.As per the report of the Ministry of Foreign Affairs of Denmark office at New Delhi, India, about 18 GW of energy from biomass India can harness. More than 70% of the country's population depends on biomass for their energy needs. India has 5+ GW capacity biomass powered plants, 83% being grid connected while the remaining 17% are off-grid plants.A total capacity of 9.54 GW off grid connected bio-power has been installed in the country as on October 2018 against a target of 10 GW bio-power by 2022. This includes 8.73 GW from bagasse cogeneration, 0.68 GW from non-bagasse cogeneration and 0.13 GW from waste to energy [11].

Tidal energy: Naturally tides are form due to interaction of the gravity of the sun, earth and moon. The rise and fall of the tides creates potential energy. Besides, the flows of water current due to flood and ebb create kinetic energy. Both these forms of energy can be converted to mechanical energy by the use of tidal turbines and then to electricity [33]. Worldwide the tidal resources are huge and largely untapped. The tidal energy resource at the global level is estimated to be 3TW [33].Different types of tidal turbines are used and there are several technologies for developing tidal energy. Recently, it was estimated that India is having a tidal energy of 8000 MW according to a study conducted by IIT, Madras. This includes about 7000 MW in the Gulf of Cambay in Gujarat, 1200 MW in the Gulf of Kutch and 100 MW in the Gangetic delta in the Sunderbans region of West Bengal. Across the globe there has been a concerted effort to harness the energy from tidal power. The tidal power is unique because it can be predictable, it provides clean energy and the energy can be generated both at day and night. .The concept of conversion of tidal power is very ancient and tide mills have been used for long by many developed countries. There are different methods like barrage, fences and tidal farm etc for harnessing tidal power.The largest tidal barrage in the world is the Sihwa lake tidal power station in South Korea built in 2011 [34]. Although there are barriers in harnessing the tidal power, India can invest and have a policy in harnessing the tidal power to reduce the effect of global warming and climate change.

Geothermal energy: Geothermal energy is one of the potential alternative sources of energy available in the form of heat energy in the earth's interior. Right from the inception of the civilisation, people from all over the world have been using geothermal energy in the form of hot springs for different purposes like bathing and washing of clothes. It is well established by now that the geothermal energy has huge potential to contribute towards meeting the increasing demand of energy. The challenges in development of geothermal energy in India have been highlighted recently [35]. The study and exploration of different geothermal fields in India was carried by the Geological Survey of India (GSI) since 1970. Currently there are 350 potential geothermal locations of capacity more than 10,000 MW have been identified in India. Some of these major geothermal energy sites in India are :- Tattapani in Chhattisgarh, Puga in Jammu & Kashmir, Cambay Graben in Gujarat, Manikaran in Himachal Pradesh, Surajkund in Jharkhand and Chhumathang in Jammu & Kashmir. Despite the potentiality and exploration drilling in places of India, geothermal plant is yet to be installed in India. The main constraints are insufficient data on deep level exploration and reservoir parameters. Besides, there is scarcity of machinery to conduct deeper level drilling and inadequate finance [35]. Since, geothermal energy is enormous underused heat and power resource that is clean and reliable, MNRE, Govt. Of India may take up sustainable projects to expand the renewable energy sources and increase the clean energy production in the country.

3. CONCLUSION

The energy consumption in India is increasing day by day and is expected to follow a similar trend in the coming years. India is widely dependant on non-renewable energy sources with coal being the major contributor. With the current energy demand and abundant availability of renewable energy sources, it is seen thatthese energy sources can be easily harnessed if properly planned. There are several opportunities to promote the renewable energy in India and the country has more strength than weakness. But adequate finance, proper planning and policy needed. Besides technological innovations to harness the renewable energy efficiently in a cost effective manner with more indigenous manufacturing units, India can be at the forefront in near future.

4. REFERENCES

[1]. PIB, " Renewable energy sector makes rapid strides in 2019",Press Information Bureau, Ministry of Renewable Energy, Govt. of India, New Delhi,2020.
[2]. A. Verbruggen, W.W. Moomaw, J.Nyboer, " Climate symbols and prefixes" , In IPCC special report on renewable energy sources and climate change mitigation, Edenhofer et al. Cambridge Unversity Press, Cambridge, U.K. 2011.
[3]. D. Gielen, K. Chawla, and A. Ghosh, "Renewable energy prospects for India. Technical report".2017 https://www.researchgate.net/publication/316688462.

[4]. International Energy Agency (IEA),"Technology Roadmap: Solar Photovoltaic Energy", 2018. http://www.iea.org/publications
[5]. S.V. Gopalakrishnan, N.C.Venkatesh and N.S. Suresh, "Challenges and opportunities for Solar power technology in India". Renew. Sustain. Energy. Rev.vol.45,pp.698–709,February 2015
[6]. S.Dawn ,P.K.Tiwari, A.K. Goswami and M.K. Mishra, M.K. Mishra, "Recent developments of solar energy in India: Perspectives, strategies and future goals". Renew. Sustain. Energy. Rev. vol.62 pp.215–235, Sept 2016.
[7]. K. Kapoor, K.K. Pandey, A.K. Jain and A. Nandan, "Evolution of solar energy in India: a review". Renew. Sustain.Energy.Rev. Vol.40, pp75–87 December 2014.
[8]. T.V. Ramachandra, R. Jain and G. Krishnadas, "Hotspots of solar potential in India."Renewable and Sustainable Energy Rev. vol. 15, pp. 3178-3186, January2011.
[9]. B.R. Singh and O.Singh, ",Future Scope of Solar Energy in India". Proceedings of International Seminar on Sources of Planet Energy, Environmental & Disaster Science: Challenges and Strategies,2016. *h*ttps://www.researchgate.net/publication/308302825
[10]. K. Kohli, "Climate Accord and credibility to the country' ambitious 100 GW target for 2022". J.Sci. and Energ.Res.vol.4,pp.48-51, February 2017.
[11]. Press Information Bureau, Government of India, Ministry of New and Renewable Energy, New Delhi,2018.
[12]. K. Bharadwaz, D. Barman, D. Bhowmik and Z. Ahmed, "Design fabrication and performance evaluation of an indirect solar dryer for drying agricultural products".Int. Res. J.Eng..Techn. vol. 4 ,pp. 1684-1692, July 2017.
[13]. B.Eker, "Solar powered water pumping systems". Trakia Journal of Sciences, vol.3, pp 7-11.Jan 2005.
[14]. I.Akhubaizi, "Solar Water Pump" International Journal of Engineering Research and Application .vol 7, pp 01-05.July 2017.
[15]. K.Bharadwaz, A.Misra, A.V.Bangaru, P.Kotoky, M.K. Lakkam and B. Kusumanchi, "Design of low cost solar powered water pump for Koh Dambang village, Cambodia". Int. J. Ren. .Energy Tech .in press
[16]. WEC, "World energy scenerios: exploring innovation pathways to 2040". World Energy Council, September 2019.https://www.worldenergy.org
[17]. S.K. Kar and A.Sharma, "Wind power developments in India". Renew Sustain Energy Rev.vol.48 pp264–275 Aug 2015.
[18]. M. Singh, "Offshore wind energy-potential for India", Tencon IEEE Region 10 Conference, pp2624-2627, November 2016.
[19]. WEC, "World energy resources, The Grand transition Summary report, United Kingdom.2016.v
[20]. Y. Li, P. Ji, and J.Yang, "The status quo analysis and policy suggestions on promoting China ′s hydropower development". Renew Sustain Energy Rev. Vol.51,pp.1071–1079,2015
[21]. S.S.Agarwal and M.L.Kansal,''Importance of hydropower for energy sustenance in India". Water and Energy Inter.vol.61,pp.61-73 May 2018
[22]. A. Brown, S. Müller and Z. Dobrotková, "Renewable energy markets and prospects by technology", International Energy Agency (IEA)/OECD, Paris,2011.
[23]. P. Saxena, and A. Kumar, " Hydropower development in India". IGHSM, IITR, pp1-6. Oct.21-23, 2010.
[24]. S.K. Ghosh,"Biomass and Bio-waste Supply Chain Sustainability for Bio-energy and Bio-fuel Production" Procedia Environ. Sci. vol.31, pp. 31 – 39 December 2016.
[25]. IEA,"Bioenergy and Biofuels" 2017.https://www.iea.org/topics/renewables/bioenergy/.
[26]. A. Anukam, S. Mamphweli, P. Reddy,E. Meyer and O. Okoh, " Pre-processing of sugarcane bagasse for gasification in a downdraft biomass gasifier system: acomprehensive review". Renew. Sustain. Energy Rev. Vol. 66, pp.775-801 December 2016.
[27]. P.M.Bhavik, R. Bakshi and G.D.Yadav,"Ethanol from Indian agro-industrial lignocellulosic biomass: an emergy evaluation" Clean Tech. Environ. Policy vol.18,pp.2625-2634 August 2016.
[28]. P. Purohit and S.Dhar,"Promoting low carbon transport in India, Biofuel Roadmap for India", UNEP DTU Partnership, DTU Management Engineering, Technical University of Denmark, Denmark, November 2015.
[29]. FAOSTAT, "Crop Data",2017.http://www.fao.org/faostat/en/#data/QC.
[30]. T.V. Ramachandra, "Geographical information system approach for regional biogas potential assessment". Research J. Environ. Sci. vol. 2, pp170-184,March 2008.
[31]. K. Bharadwaz, S. Loona, N. Mundada, K.Shah and A. Baral, "Design of all season household biodigester" unpublished.
[32]. A.K. Rupnar, S.Jain and N.L. Panwar,"Biogas in India: Potential and Integration into Present Energy Systems". Int. J. Curr. Microbiol. App.Sci. vol.7,pp. 2175-2186,July 2018.
[33]. IRENA, "Tidal energy technology brief". International Renewable Energy Agency, Abu Dhabi, June 2014. https://www.irena.org
[34]. M. Ahmad, J.G.M. Jassan, H.M.M. Chy and G.M. Mahenoon," Renewable Energy Potentials along the Bay of Bengal due to Tidal Water Level Variation". MATEC Web of Conferences 147, January 2018. https://doi.org/10.1051/matecconf/201814705008
[35]. P. B. Sarolkar, "Challenges in Development of Geothermal Energy in India",Proceedings World Geothermal Congress, Iceland, April 26 – May 2, 2020.