Indian Progress in the Renewable Technologies: A Review on Present Status, Policies, and Barriers

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Abstract

The world's energy demand is growing and conventional sources are diminishing. Sustainable/renewable energy sources are gaining possibilities to come up with solutions to the long standing energy crisis, environmental problems, economic development and quality of life. By adopting renewable technologies in developing countries like India, effective steps are being taken towards clean mechanism and fortifying more sustainable future. From the past three decades there has been a strenuous pursuit to development, demonstration, application, production and research of renewable/sustainable technologies for use in distinct sectors. These efforts led to substantial improvement in renewable power generation. However, energy demand also increases largely in higher proportion to the production. It is observed that the current energy requirement is more than 1162 million units (MU) and the availability is 1138 MU leaving a shortage of 24 MU approximately. Hence, this paper focuses on discovering further availability of barren space for power generation from the renewable sources such as solar, wind, bio-energy and small hydro. The available unused potential of various energy sources in different states of India have been identified. The current status in market, policies, and various constraints of renewable technologies in India has also been summarized.

Key words

Renewable Energy, Market status, Policies, Barriers, Solutions

1. Introduction

Energy sources have been classified into a. Fossil fuels - coal, oil and natural gas, b. renewable energy resources and c. nuclear resources. According to Energy Information Administration of US report 2016, the present world energy consumption has been calculated as 550.4 exajoules [1]. Fig.1 shows the year wise distribution of various fuels. The contribution of fossil fuels has been estimated as 78.4%.

As per World Energy Forum prediction, the reserves of fossil fuels will be exhausted in less than another 10 decades. Energy demand increases by population growth. Energy sources play a vital role in fulfilling the need of population in the world. Electricity places an important role for economic growth, industrialization, urbanization and quality of life. Energy demand is proportional to economic growth. Fossil fuels are slender in quantity and their vast usage is associated with environmental retrogression. There are three major environmental issues; global warming, ozone layer depletion and acid rain [3]. The result has been an express growth in the amount of greenhouse gas emission into the atmosphere and a rise in fuel cost which are the main causes to look into the alternative sources.

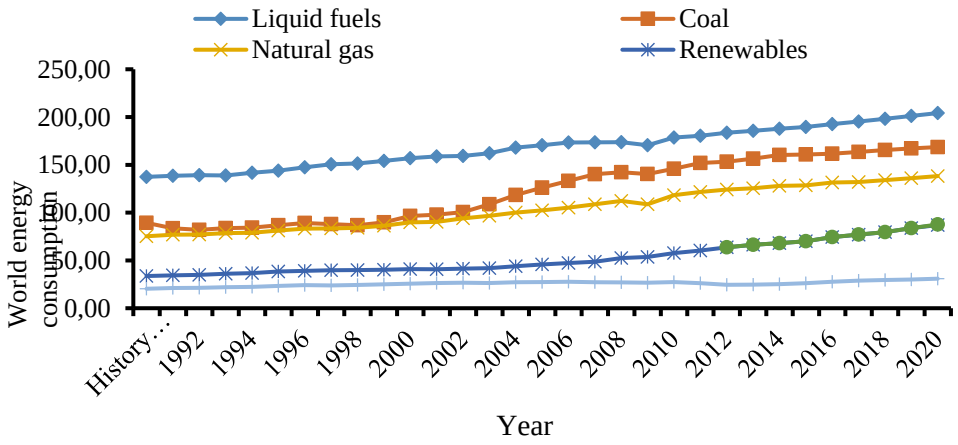

Fig. 1. World Energy consumption by fuel [2].

Renewable energy sources (RES) are sustainable/green energy sources and do not drain over time at a sensible cost that can be used without negative impacts. As per REN21's 2016 (Renewable Energy Policy Network for 21st century) report, renewables contributed 19.2 % to total energy consumption. Fig. 2 shows global renewable energy contribution by biomass, large hydro and other renewable sources (wind, solar, small hydro). Traditional biomass such as bio-gas, bio-diesel, ethanol etc. used for cooking and heating constitute 13.1 % and is growing moderately. Hydroelectricity generated amounts to 3.9 % and is growing steadily [4]. New renewable constitutes 2.2 % and having a swift evolvement in developed and developing countries. The global RES power generation capacity exceeds 1,700 GW and having a worldwide investment of $286 billion in 2015.

In developing countries like India, population is increasing at an annual rate of 1.2 %. As a result, energy demand increases drastically. As fossil fuels are limited, India faces the fuel shortage due to energy insecurity and elevation in fuel prices [5]. RES use indigenous resources that have the ability to provide cost effective energy with pollution free environment [6]. With these considerations, efforts have been taken through this paper to address the picture of renewable energy sources in India on global map in avail of these resources. Furthermore, the short-term and long term energy availability and the recommendation for future technological development to the research community have been addressed.

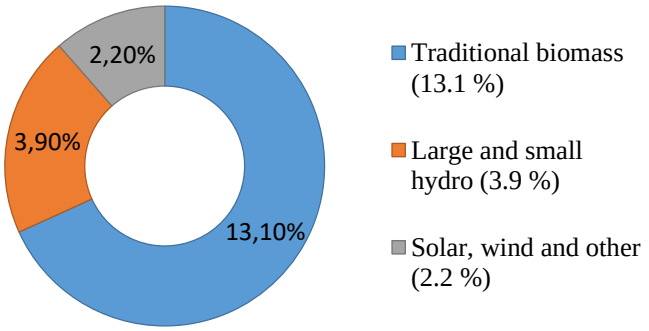

Fig. 2. Global renewable energy consumption

2. Geographical, Energy and Economical Status of India

2.1 Geographical and climate circumstances

India is the 7th largest country in the world with an area of 3,287,263 sq. km. including islands, mountains, coasts, wetland, deserts and plain. India has a total land border of 9,386.87 miles (15,106.7 km) and a coast line of 4,670.6 miles (7,516.6 km). The North frontier of India shares border with China, Bhutan and Nepal having a length of 3,488 km., 699 km., and 1,751 km. respectively. The North-East border with Myanmar is 1,643 km. In western border, Pakistan lies with 2,910 km. On the east, its border with Bangladesh is 4,076.9 km. [7]. India is enclosed by water from three sides – Bay of Bengal in the East, Indian Ocean in the South and Arabian Sea in the West. India surrounds 14,500 km. of navigable inland waterways. There are 12 major rivers with the total collecting area exceeds 2,528,000 sq. km. [8].

The combination of low lands and highlands incorporate the compound geography of India has a crucial effect on its climate. The annual temperature of the country depends upon the season that constitutes summer, rainy and winter seasons. The average temperature reaches 45° C in hot climate and 25° C in cold climate.

The average annual rainfall of the country is 1170 mm; but it varies from place to place. In some places like Rajasthan, the average annual rainfall is below 100 mm. and in other extreme, the average crosses to 10,000 mm. on Khasi hills and North East [9].

2.2 Economic and Energy status in India

India is the second densely populated country in the world having 1.326 billion citizenry as on year 2016 [10] and was identified an annual growth rate of 1.2 % [11]. An overview of the population and economic statistics of India is stated in Table 1.

Table1. Demographic and economic index of India [10-15]

Specifications	Year	Value
Citizenry in mid of the year (billions)	2016	1.326
Population growth rate (%)	2016	1.2
Urban population (%)	2016	32.4
Forest area (%)	2016	23.77
Gross Domestic Product (GDP) (trillions USD)[i]	2016	2.25
GDP per capita (USD)	2016	1,718.687
Primary energy production (BU)[ii]	2015	654.5
Electricity consumption per capita (kWh)[iii]	2015	746
Electricity generation per capita (kWh)	2015	1,010
CO_2 emission (Metric ton per capita)	2013	1.6

[i] USD - United States Dollars

[ii] BU - Billion Unit

[iii] kWh – Kilo Watt hour

Energy production is major factor that affects economic growth in India. India is the top third primary energy consumer and electricity producer in the world with a global share of 5.3 % and 4.8 % respectively [16]. The total primary energy consumption is from coal (54.5 %), crude oil (29.45 %), natural gas (7.7 %), hydroelectricity (5.0 %), nuclear energy (1.26 %) wind power, biomass electricity, solar power and small hydro (2.09 %) as per year 2013 [17]. India is the fourth top importer of net crude oil (163 MT in 2015) and having the refinery capacity of 4.561 million barrels per day. India places globally seventh in hydro power generation [18].

3. Renewable Energy Progress in India

India ranks fifth largest power generation capacity in the world with 305.554 GW and having an annual growth rate of 9.4 %. Thermal power is the major component generating a power of 212.568 GW, followed by hydro power of 42.968 GW, renewable energy sources of 44.236 GW and nuclear power of 4.296 GW [19]. Power generation in India is influenced mainly by fossil fuels and is followed by renewable energy resources. According to international data base, India generates a power of 305.554 GW during 2016. On the other hand, the nation consumes 938.82 TWh where the industrial sector has been identified to be the top consumer in large scale demand. This sector consumes 42.1 %, domestic sector 23.53 %, agriculture 18.45 %, commercial 8.77 %, traction 1.79 % and miscellaneous 5.37 % [20]. The electrical energy demand for 2015-2016 has anticipated a 2.1 % energy shortage with a peak shortage of 2.6 %.The annual energy requirement and availability is shown in Table 2 [21].

Table 2. Annual energy requirement and availability

Particulars	Energy (MU)	Peak (MW)
Requirement	1,162,423	156,862
Availability	1,138,346	152,754
Surplus(+)/Shortage(-)	-24,077	-4,108
Surplus(+)/Shortage(-) %	-2.1	-2.6

Electric power is one of the most censorious constituents of infrastructure essential for economic growth and welfare of nation. The existence and expansion of ample infrastructure is crucial for extended growth of Indian economy. Electricity demand in the country increased promptly and is predicted to upswing in the coming years. To move out of these circumstances, Indian government countersign renewable energy sources. India is the first country to lay out a ministry of non-conventional energy sources in early 1980's. Renewable energy in India is administrated by the Ministry of new and renewable energy (MNRE) excluding large hydro. Large hydro comes under the purview of the Ministry of power. Power generation from renewable rose from 7.8 % in 2008 to 14.1 % in mid of 2016. India's grid tied renewable capacity reached about 42.85 GW, striking the installed capacity of large hydro (42.78 GW) in April 2016 [22], [23]. Renewable energy sources (excluding large hydro) contributes 14.1 % to overall power generation, of which, more than 95 % was owned by private sector and rest by the public sector. Wind energy contributes 61.3 %, while solar constitute 18.0 %, bio-mass power 10.9 %, small hydro 9.6 %, waste to energy 0.3% in 2016 [23], [24] as shown in Fig. 3. During the last two decades, various renewable technologies have been exploited. Few achievements are stated along with its potentials in Table 3.

Table 3. Renewable energy in India at a glimpse [22] [23]

S. No.	Sector/System	Achievement (as on 31st August 2016) (MW)	Target 2022 (MW)
1	**Grid Interactive Power**		
	a. Wind power	27674.55	60,000
	b. Solar power	8083.17	100,000
	c. Small hydro power	4310.35	5,000
	d. Bio-power (Bio-mass and Bagasse co-generation)	4882.33	10,000 (Includes bio-power and waste to power)
	e. Waste to energy	115.08	
2	**OFF-Grid power**		
	a. Waste to power	161.39	
	b. Non-bagasse co-generation(biomass)	651.91	
	c. Biomass gasifiers (Including rural and Industrial)	184.19	
	d. Aero generators/Hybrid systems	2.79	
3	**Decentralized systems**		
	a. Solar PV systems	342.18	
	i Solar lanterns	999253 no's	
	ii Solar street lighting systems	2,21,121 no's (from 2011)	
	iii Solar home lighting systems	5,01,189 no's (from 2011)	
	iv Solar water pump (For drinking and agriculture)	30,256 no's	
	v Solar cookers (Box type and dish type)	14,11,930 no's	
4	**Village electrification**	11,308 villages/Hamlets (up to 2014)	

5	**Family Biogas Plant (lakhs)**	48.64

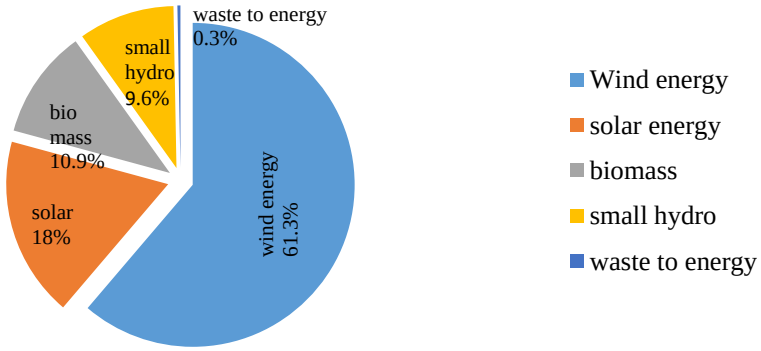

Fig. 3. Renewable energy share in India

3.1 Wind Energy

The wind is abundant, free, clean and worldwide renewable source of energy [25]. Wind energy is the focal point for world economy. It escalates easily and can be expanded rapidly. Denmark was the first country to generate electricity with use of wind in 1980's [26]. The global wind power installed capacity reached by 369,553 MW in 2015. The availability of wind varies from one place to another. Wind resources can be utilized mainly in areas where wind power density is at least 400 W/m^2 at 30 m above the ground [27]. Wind power development in India has been started in 1986. India has potential to generate 100000 MW [28]. India is placed the fourth largest wind energy hub in the world after China, USA and Germany [29] with total installed capacity of 28,082.95 MW till October 2016. Wind power ledger indicates that, nearly 8.6 % is the total installed power generation capacity in India and has generated 28,604 MU in the fiscal year 2015 – 2016.

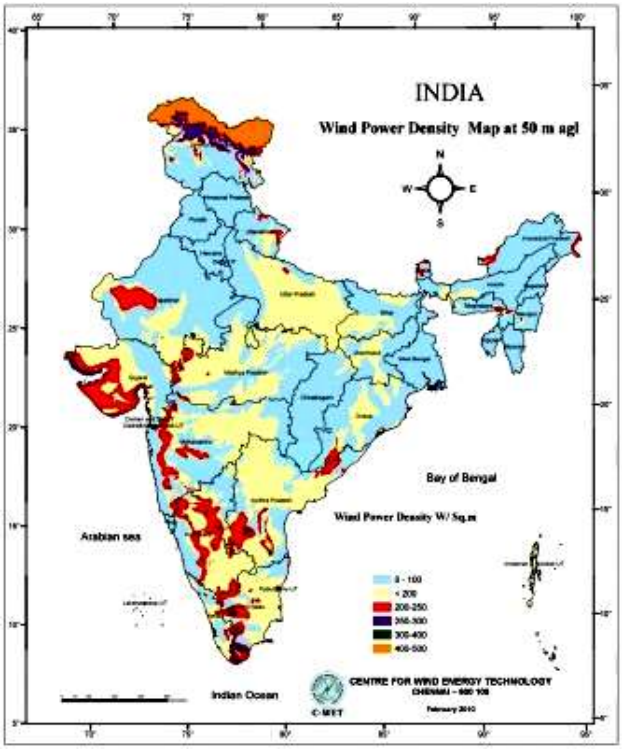

Fig. 4. Wind power density in India

Generally, the location of wind farm should be feasible in cost and should not have consequential effect on the regional environment regarding noise, visual and wild life collision [29]. As per regional wind farm planners, average wind speed map was classified as high suitable (2.6-3.0 m/s), medium suitable (1.9-2.2 m/s), low suitable (1.6-1.9 m/s) respectively [30]. 70 % of wind is available during May to September and concur with southwest monsoon duration. The wind power density is shown in Fig. 4 [31], [32]. Total wind power potential at 100 m above ground level is shown in Fig. 5 [33].

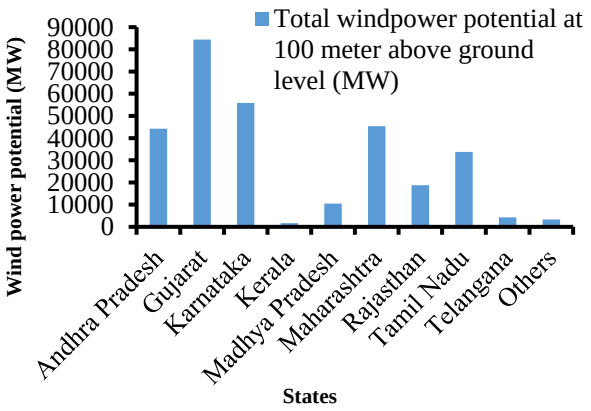

Fig. 5. Wind power potential at 100m above ground level (MW)

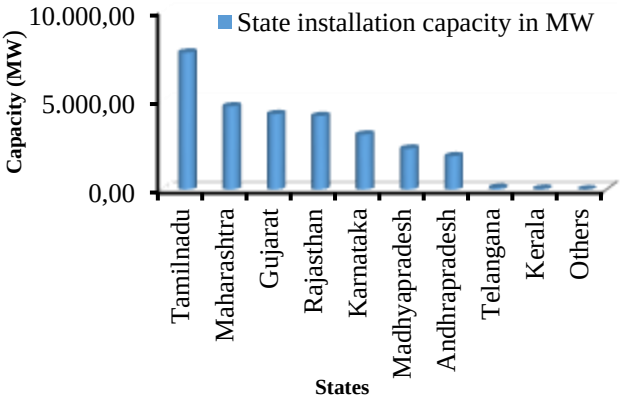

Fig. 6. Wind energy installation in states

Wind energy installations are growing in many states of India. The capacity of installed wind energy systems in states across India is shown in Fig. 6 [34]. The generation of electricity by wind during various months is shown in Fig. 7.

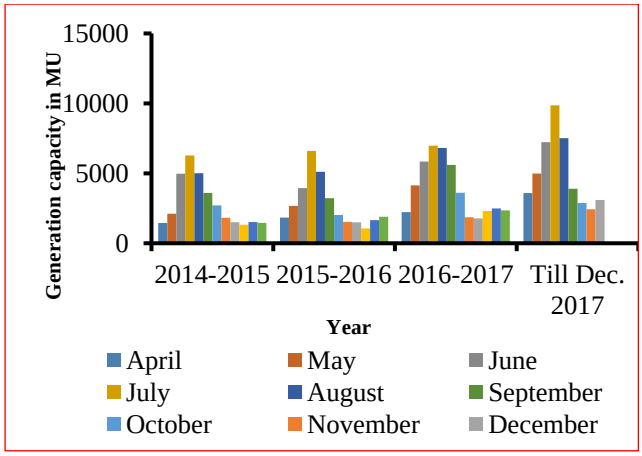

Fig. 7. Wind generation in million units (MU) [35]

3.2 Solar Energy

Solar energy is the most opulent energy in the world. Sun emits at the rate of 3.8×10^{23} kW, out of which around 1.8×10^{14} kW impeded by earth [36], [37]. The distribution and its intensity of solar irradiation are the two major factors to determine the efficiency of solar PV industry. In many countries, especially in developing countries, solar irradiation is inherent which makes beneficial usage. India recline in a sunniest region and it has about 250-300 sunniest days in a year. There is a huge potential of solar energy in India, given to enhance solar thermal and solar PV technologies. India receives 5000 trillion kWh per year solar energy incident and with a daily average of 4 to 7 kWh/m^2 depending on location [38]. As per Ministry of new and renewable energy (MNRE), Rajasthan and Northern Gujarat receives highest annual irradiation. Rajasthan receives an irradiation of 5.5-6.8 kWh

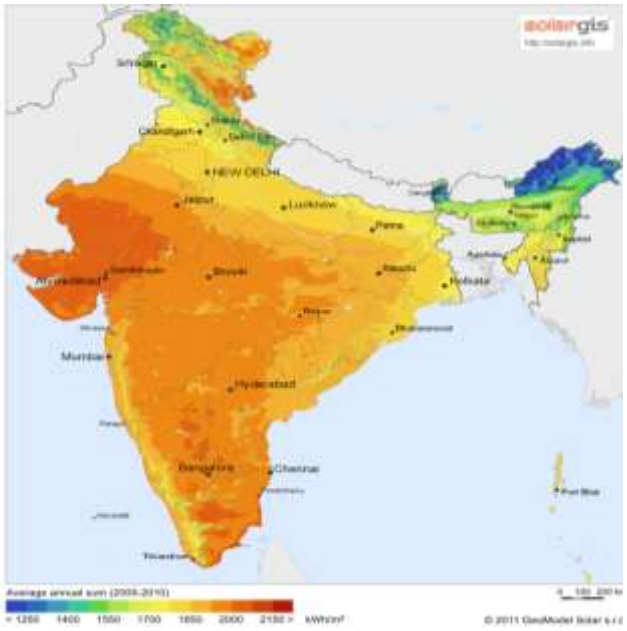

Fig. 8. Average annual solar irradiance [41]

and can be installed with a plant capacity of 35-50 MW in one square kilometre land area. Northern Gujarat (more than 5.5 kWh/m^2/day) and Northern India (some parts of Ladakh) receives highest and North Eastern parts receives the lowest [39], [40]. The average annual solar irradiance is shown in Fig.8.

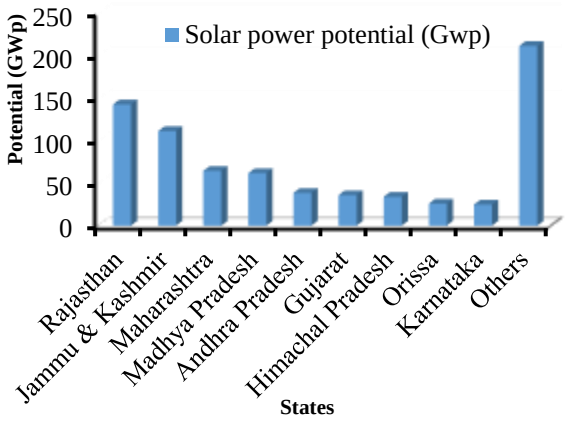

Fig. 9. State wise solar potential

India ranked one of the top countries in terms of solar electricity productions per watt installed; with an insolation of 1700 to 1900 kWhr/kWp [42]. India got a swift rise in use of solar energy. State wise solar power potential is shown in Fig. 9 [43].

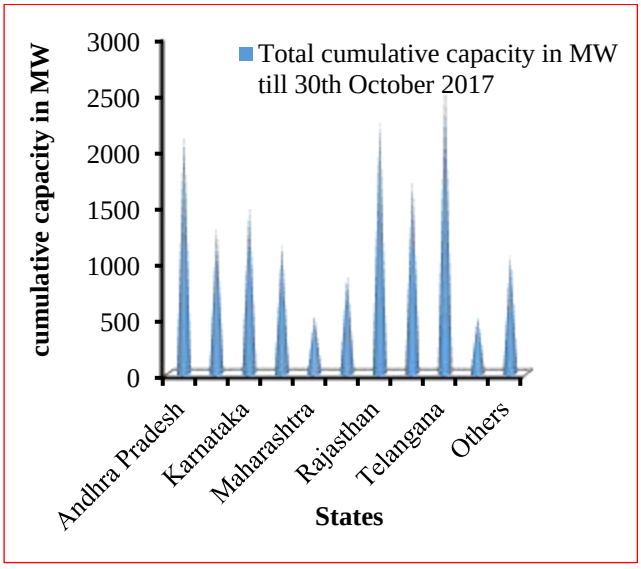

Fig. 10. State wise status of grid connected solar power projects [44]

As on October 2017, the total cumulative grid installed capacity is 15604.76 MW in India. Out of this, Telangana has the highest installed capacity of 2570.43 MW and Sikkim with the least capacity of 0.01 MW. The state wise grid connected solar power installation status till October 2017 is shown in Fig. 10. Monthly electricity generation through solar energy is shown in Fig. 11 for different years.

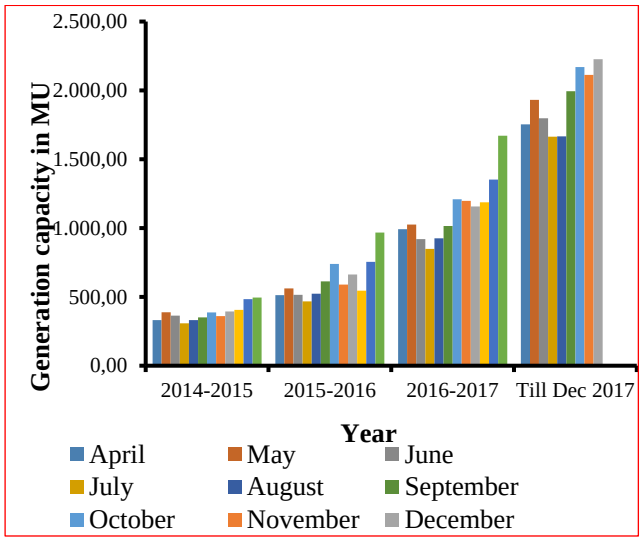

Fig. 11. Solar generation in MU [35]

3.3 Bio-Energy

Biomass is one of the dominant green energy sources and cleans our environment by maintaining carbon dioxide neutral. Biomass includes bagasse, coconut shells, coffee waste, cotton stalk, de-oiled cakes, groundnut shells, jute waste, rice husk, saw dust, straw etc. In India, 32 % of total energy is derived from the biomass [45]. The current availability of biomass in India has been calculated to about 500 million metric tonnes per year. The state wise bio-energy potential is shown in Fig. 12.

According to MNRE, it is expected that bio-mass can produce 73,000 MW of energy by 2032 [46]. There are different types of bio-energy such as Biomass (agri-waste and organic forest residue), Bio-pellets (strained and calcified form of biomass), Bio- Diesel (Fabricated from oil and fats), Bio-ethanol, Bio-oil, Bio-gas, waste to energy [47]. The month wise biomass and bagasse electricity generations are shown in Fig. 13, 14 respectively from 2014-2017 (till December)

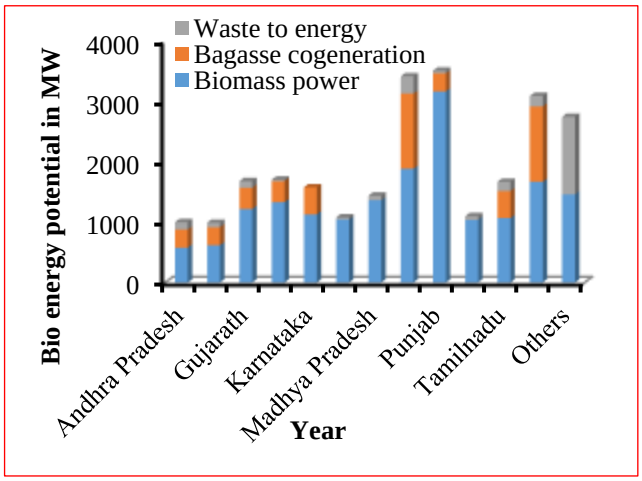

Fig. 12. State wise bio energy potential in MW [46]

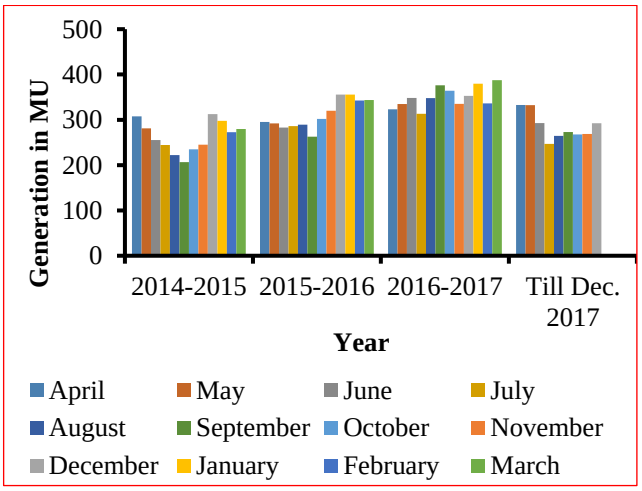

Fig. 13. Biomass generation in MU [35]

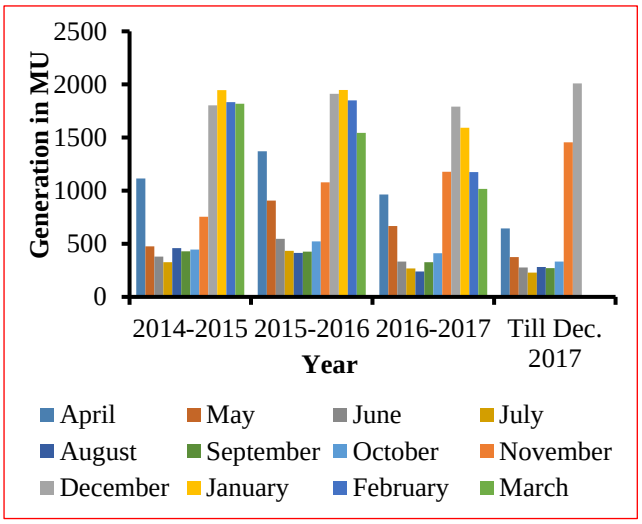

Fig. 14. Bagasse generation in MU [35]

3.4 Small Hydro Power (SHP)

Small hydro is the enlargement of hydroelectricity for industrial plant and mini community. The description of small hydro varies from country to country. For example, United States estimates plant size up to 100 MW considered as small hydro but in case of Sweden it is up to 1.5 MW. Table 6 shows the consideration for small hydro project installed in MW for various countries [48].

Table 6. Country wise consideration of installed capacity in MW for small hydro.

S. No.	Country	Consideration for small hydro installed capacity in (MW)
1	USA	5-100
2	Canada	<50
3	China	≤50
4	Brazil	≤30
5	India	≤25
6	EU linking directive	≤20

7	Norway	≤10
8	Sweden	≤1.5

Table 7. Categorization of SHP

S. No.	Class	Station capacity in kW
1	Micro Hydro	Up to 100
2	Mini Hydro	101 to 2000
3	Small Hydro	2001 to 25000

According to MNRE, small hydro capacity in India is ≤ 25 MW and is further classified into different types. The classification of small hydro is shown in Table 7.

MNRE found that there are 6,474 small hydro potential sites with an aggregate of 19,749.44 MW exist in India. The present installed capacity of SHP project is 3632.253 MW and by the end of 12th plan it aims to 7000 MW [49]. The monthly electricity generation from installed small hydro is shown in Fig. 15.

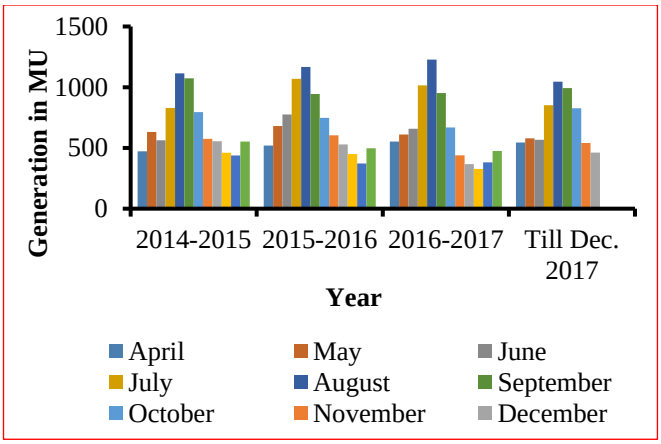

Fig. 15. Small hydro generation in MU [35]

4. Renewable Energy Market in India

The renewable energy market in India is the second most attractive market in the world. As per the end of year 2017, the total installed capacity is 62846.9 MW and with total generation of 78256.54 MU through different RES. Grid interactive renewable energy generation is shown in Fig. 16. The graph shown between installed capacity and generation.

4.1 Wind Energy Market

Wind market growth rely on various factors such as land, availability of wind resources, component manufacturing facility and producers, access to advanced technology, capacity utilization factor, skilled manpower, and supporting distribution infrastructure [50]. The majority of wind farms are located in Rajasthan, Madhya Pradesh, Maharashtra and Andhra Pradesh. As per REN 21 (Renewable energy policy network) global energy status report 2015, wind power producers have chosen 80 % mark down in first year of installation (tax based AD incentive) [51]. India's wind energy capacity is almost doubled by 2020 from 2015 (23,000 MW in June 2015), and expected to attract investments of Rs. 1,00,000 crore [52]. The important turbine suppliers in India were Gamesa, Suzlon, Inox, Regen and Wind World. Wind power producers can either choose for privileged tariffs distinct by the state regulatory ranging from Rs. 3.50 – 5.91 /kWh or get tradable renewable energy certificates (minimum price: Rs. 1,500 /MWh, maximum price Rs. 3,300 /MWh) along with wind power bought at the average power purchase cost (APPC) by the utility at Rs. 3.4/ kWh approximately for the fiscal year 2015 – 2016 [53].

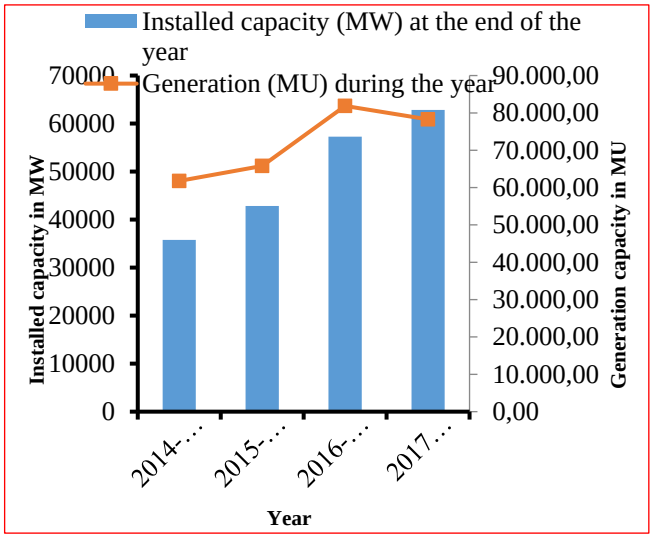

Fig. 16. Installed capacity Vs generation [35]

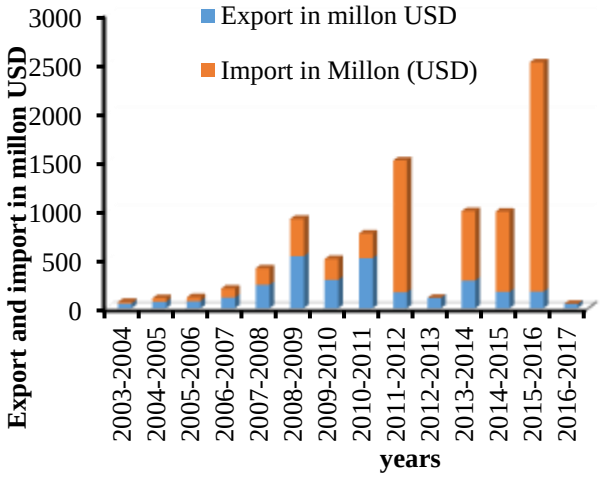

Fig. 17. Solar components market in India

4.2 Solar Energy Market

The Indian solar market has widen quickly and going to be one of the world's vast market by 2022. The Indian government has planned to install world's largest solar farm with a capacity of 750 MW in Madhya Pradesh. Rajasthan and Gujarat constitute 50 % of solar installed capacity in India [54]. India becomes fourth largest solar market in the world in 2016. Solar components trade in India is shown in Fig. 17 [54], [55].

4.3 Bio-energy market

India ranks second in bio-mass production. Projects counts in biomass gasification have been revealed on commercial basis. Around 500 million metric tonnes of biomass is available in a year. An industry of bio-mass energy production spellbinds the investments about Rs. 600 crores every year with generating capacity of 5000 million units' electricity and providing employment for 10 million manpower/year [56].

4.4 Small Hydro market

The station capacity of small hydro power projects are up to 25 MW with an estimated whole country potential of 20,000 MW. These projects are economically feasible and suitable to be managed by private sector. As on January 2015, there are 27 small hydro turbine fabricators having the capacity of 400 MW [57].

5. Renewable Energy Policies, Schemes and Incentives in India

According to union budget 2015 – 2016, India targets to fix 60 GW of wind energy and 100 GW of solar energy by 2022. Due to present sketch operation, renewable energy discern more lavish than fossil fuels [58]. Hence, to take part with fossil fuels renewable energy needs support from federal [59]. Table 8 shows the policies developed in India for sustainable technologies.

Table 8. Policies, Incentives and Schemes in India

Type of energy	Type of Policy	Description
WIND ENERGY [60] - [62]	**Central Government Policies**	
	Central Electricity Regulatory Commission	It involves return on equity, interest on working capital, loan capital, taxes, duties and depreciation.
	Accelerated Depreciation	This benefit permits to deduct 80 % from the value of equipment during first year and having tax benefits up to 10 years. Wind power producers who are under this benefit have to register and provide generation data to Indian Renewable Energy Development Agency (IREDA).
	Indirect tax benefits	This includes depletion in customs duty and concession on excise duty. Based on component these benefits vary from 5 – 25 % and components like aero generators, battery chargers, wind power electricity generators, water pumping wind mills are barring from excise duties.
	Generation based Incentives (GBI)	This scheme is applicable for independent wind producers those who are not profitable under accelerated depreciation benefits. For grid connected electricity, GBI is set at Rs. 0.50 /kWh from minimum of 4 years to maximum 10 years.
	Small wind energy and Hybrid system Programme	State nodal agencies have handled this program for small power requirements of users like farmers, individuals, NGO's etc.
	State government policies	Many states have transpired with wind energy policies to support wind energy production come up with a new step in wind energy trade. The state electricity regulatory commission has provided the revised tariff policy for renewable during the year. In accordance to this policy the tariff of Rs. 3.50 per unit for Andhra Pradesh, Gujarat, Maharashtra, Rs. 3.39 per unit for Tamilnadu, Rs. 3.40 per unit for Karnataka, Rs. 3.14 per unit for Kerala, Rs. 4.50 per unit for Rajasthan (Excluding Jaisalmer, Jhodhpur, Bermer having a tariff of Rs. 4.25 per unit).
SOLAR ENERGY [63] - [67]	Jawaharlal Nehru National Solar Mission (JNNSM)	This mission was established to elevate the use of solar energy and promote the unification of other renewable sources. The frame work is earmarked to fulfill solar energy utilization through NSM phases. Phase 1: (2010 – 2013). Utility grid power including roof top – 1000 to 2000 MW, Off grid solar applications - 200 MW, Solar collectors - 7 million sq. m. Phase 2: (2013 – 2017). Utility grid power including roof top - 4000 to 10000 MW, Off grid solar applications - 1000 MW, Solar collectors -15 million sq. m. Phase3: (2017 – 2022). Utility grid power including roof top - 20000 MW, off grid solar applications - 2000 MW, Solar collectors - 20 million

		sq. m.
	Tax incentives, subsidies and incentives under JNNSM	Capital subsidies, incentives and various tax assumptions are applicable for variable components under solar energy value chain. JNNSM nurtures the assemblies of imported solar module with free of import taxes. There are other benefits like GBI, 80 % accelerated depreciation tax benefits and some products made under MNRE specifications to utilize capital subsidiary benefits.
	Grid connected Renewable energy Policies	
	National Rural Electrification Policy 2006	There are assorted goals under this policy like rural electrification, quality, reliability at reasonable rates and minimal lifeline consumption.
	Rajiv Gandhi Gramin Vidhyut karanYojana (RGGVY)	This is carried out by rural electrification corporation for allowing bulk power purchase, rural electrification and organization of local distribution. Under this scheme, projects could be subsidized with 90 % capital subsidy and, households those who are under poverty line get 100 % capital subsidy as per kutir jyoti programme.
	OFF Grid renewable power policies	
	Remote village electrification Programme	This program covers all villages are not under RGGVY. The projects are permitted under central financial support and producers can posit in policy document format. There are 8722 villages and 2533 hamlets are approved under this scheme, in which 1705 villages and 946 hamlets are down the progress and rest have been completed.
	Special area demonstration project programme (SADP)	This scheme is being enact into 2 parts – illustration of renewable energy systems at renowned places like tourist destinations, educational institutions, heritage sites and Energy park scheme. There are 33 solar parks in 21 states and with a total capacity of 19900 MW.
	Energy efficient solar/green building programme	Under this scheme GRIHA (Green Rating for Integrated Habitat Assessment) rating system being upgraded. For GRIHA certification 117 projects with 4.98 million m^2 build up area out of which 81 projects with 3.32 million m^2 build up area from government sector have been registered. This GRIHA rating system has been executed and elevated by independent registered society called "Association for Development and Research in Sustainable Habitats" (ADaRSH).
	Development of solar cities programme	During the 11^{th} plan MNRE supported 60 cities to develop as "solar/Green cities". Minimum of 1 and maximum of 5 cities in a state to be developed under this scheme.
	Akshay Urja Programme	These shops are organized in each district to make patently obtainable to people and provide repair services to the products. This programme is handled by state nodal agencies with economical support interms of soft loans and recurring grant of maximum Rs. 2.40 lakhs for first two years of operation from ministry. 119 shops out of 294 have been organized by Aditya solar under this scheme.
	State government Policies	Rajasthan, Gujarat and Karnataka have their separate solar policy. In these states, power period sale is same i.e. 25 years but the tariff may vary. For Rajasthan and Karnataka, the tariff is based on competitive bidding. Tariff is fixed for Gujarat i.e. for PV Rs. 15/12 for the first 12 years and then Rs. 5.00/3.00 till 25 years. For thermal it is Rs. 10.00/9.00 and the rest it is Rs. 3.00.
BIO ENERGY [68] - [71]		
(a) Bio-mass Power	**National level policies**	
	Fiscal Incentives	According to IREDA 100 % accelerated depreciation has been declared in the first year for the equipments like fluidized bed boilers, condensing turbine, high efficiency boilers and waste heat recovery equipment. As per MNRE 80 % depreciation has given in first year for the following equipments like organic rankine cycle power system, vapor absorption refrigeration systems, small steam turbine.

	Income tax holiday	Under this scheme, ten years tax has been benefited.
	Custom and Excise duty	20 % concessional customs for the projects under 50 MW capacity and exempted excise duty for energy devices including raw materials, components and machinery.
	General Sales tax	Dispensation is available in certain states.
	State Policies	Under this policy, power wheeling charges, power banking charges, buy back rate, capital subsidy, third party sale have been subsidized.
(b) Bio-fuel (Bio-Diesel/ Bio- ethanol) [72]	National bio- diesel mission	This mission was brought up to look concern about bio-diesel and blooming of Jatrophacurcas as the raw material for bio-diesel production.
	Ethanol blending program	This plan involves a compulsory 5 % blend of ethanol procure from sugar molasses with petrol.
	National bio-fuel policy	This policy provides financial subsidies, grants and MSP (minimum support price) for non-edible oil seeds. The policy anticipates constitutional of a national bio-fuel fund.
(c) Waste to Energy		Get subsidized from excise duty, income tax, capital subsidy, interest rate on term loan, and loan installment payments.
SMALL HYDRO [73] - [75]		The MNRE has been given financial subsidy like commercial projects, renovation of old projects, micro hydel projects and R&D.

6. Obstacles Towards Renewable Energy Development in India

Although India has a top prospective of renewable energy development, only less percentage has been used. So, there are vast investment scopes to develop the use of RES but there are certain constraints that prevent its development in India [76] – [78].

6.1 Environmental and ecological constraints

Considering the meteorological conditions of India, solar and wind energy are sporadic due to irregular geographic distribution [79]. Solar panels are highly inclined by environmental conditions like sunlight intensity, murkiness and blustery weather [80], [81]. Due to large scale PV industry few tortuous effects are caused to nature. Birds and insects may be killed as they fly into solar beam [82]. In wind energy, noise and visual impact are the major civic health and society concerns [83], [84].

6.2 Institutional barriers

Renewable energy technologies desire well-built infrastructure expansion. Lack of infrastructure is one of the features of institutional barriers [85]. The problems associated to these barriers are roads, grid connectivity, communication and cost. Infrastructure refers not only physical facilities but also about essential equipments and utilities for power industries. There is no apparent allotment of authority between units performing at the intra (state) and inter (regional) level when it comes to the development of sustainable technologies [86]. Technically sound and tough management skilled people are needed in India. Schooling of local work force is offered in hands on training in local language, leads to long term issue [87]. There is a deficit in suitable assistance and technological assistance for operators that resist the growth of renewable energies [88]. There is a meagre co-ordination and co-operation exists between ministries, agencies and stack holders [89].

6.3 Technology barriers

Renewable technologies are in the growing stage in India. These technologies are at a price pitfall stage when compared with conventional energy technologies [90]. Insufficient proven reliability for the technology in India is the concern to endorse latest technologies [91]. Enormous populace of the end user of electricity in India lack easy access to information about latest technologies [92]. Lack of 'information and communication' can be one of the significant constraints to technology change encountered in an industry. There is a poor knowledge on technology and management [93]. Almost all renewable technologies are compound in nature [94].

6.4 Political and policy barriers

Ministerial transient, government involvement in national trades, deception and inadequate civil society are the major concerns in the acquisition of renewable technologies in India [95]. Sustainable energy technologies in India are yet in progressing phase and not having related policy statements for renewable energy. The policies have been furnished while and when important to make easier for development of certain technologies. Future plans for technology growth do not match up with present policies [96]. For example, Energy Conservation Act determines the initiation of the Bureau of Energy Efficiency (BEE), a permitted frame work under the ministry of power. BEE lively upgrades, governs, funds and scans energy conservation strives in the economy through energy reviews. It also has the permitted sovereignty to enact mandatory energy efficiency standards but has not done so far [97]. The principal barrier for wind is lack of dedication in off shore policies [98].

6.5 Budgetary constraints

By importing efficient technology from advanced and highly industrialized countries tend to be expensive in initial cost, may forbidden by the consumers adopting them [97], [99], [100]. Many producers allow retaining the initial cost low rather than reducing the operating costs [101]. Poor

credit availability is the major constraint to buy renewable technologies.

6.6 Market related barriers

Sustainable energy projects and firms are basically small. Hence, they have a handful of resources than large generation chains. They will have less sway negotiating terms, lack of participation in legislative proceedings with massive market players. Due to insufficient market base, size and policies in India private speculation is daunt [102], [103].

6.7 Other barriers

There are some other constraints like unavailability of solar data sheets, inexperienced customers, faith and beliefs, lack of public interest litigations, disposal of storage devices etc. [104], [105]. Land acquisition is a significant challenge in India [106].

7. Solutions for Renewable Energy Barriers [107]

To overcome these barriers some suggestions have been proposed.

a. Adopting general national policy instead of implementing policies for each technology.
b. The financial schemes should be helpful for small investors by providing fiscal incentives.
c. Encouragement for the progress of research and development programs, training programmes and improvement of technology with public-private cooperation.
d. Generalization and simplification of procedures for contractors which make simple to begin new projects.

8. Future Scope

The enormous use of RE depends on progress on related technologies [108] and incentive policies. Enhancement of technology is highly relying on fund to that particular R&D. Stable investment policy to be enhanced [109]. Hybrid system can be possible using different RES to supply electricity even without interaction with the grid [110], [111]. Cost can be minimized through proper equipment sizing and load matching [112]. A storage system is additionally required in this case [113] - [115]. Improvements in battery technology allow high energy density battery which lasts long [116]. Grid connected roof top solar electric power generation system allows stable voltage at the AC bus which require no storage [117], [118]. Subsidies and incentives are being provided to roof-top system [119]. This aid enables the utilization of unused space in the roof top of building/house [120] - [122]. Roof-top solar systems can be installed in almost all the states of India [123] mentioned in Fig. 10. Small hydro systems respond faster than large hydro for dynamic changes in the local electrical loads. Considering the advantages, these projects in large number shall be set up in hilly areas of India. However, the livelihood of the local population largely depends on the mainstream water [124]. Therefore, care must be taken prior to installation of such projects in those areas which disturb the local ecosystem as well as the nearby environment.

9. Conclusion

Economic growth, energy security and environmental protection led development and promotion of renewable energy sources in India. Accordingly, increased focus is being laid on the deployment of renewable power that is likely to account for around 5 % in the electricity-mix by 2032. In view of this, a review of the potential, progress and various barriers of renewable energy in India have been presented. Various renewable sources such as wind, solar, bio and small hydro energies illustrating the potential in various states and progress (raise in installation capacity and generation capacity) in different years have been discussed. The states in India that have enormous potential to generate energy from renewable sources such as solar and wind have been identified. Residential solar and wind electric energy systems have the flexibility that it can be generated and utilized at the same load centre. Transmission losses are greatly reduced in this case. Further, introduction of net metering with RE sources will enhance the monetary benefits of the consumers. However, an optimal capacity of the RE source, power converter technology and power extraction algorithms is the challenge that a power engineer encounters with. Alternate fuels such as bio-fuels have been proposed to be progressively used for hybrid vehicles used in transport applications. Finally, renewable energy provides extensive benefits and can contribute significantly in the national energy mix and it is expected that the share of renewable energy in the total generation capacity will increase in future.

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