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Progress of renewable energy in India

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Abstract. Energy holds key to economic growth and prosperity of India. Currently, India has very high-energy import dependence, especially in the case of crude oil (80%) and natural gas (40%). Even coal import has been increasing over the years. Considering India's population growth, emphasis on manufacturing, production, and service industry, energy consumption is bound to increase. More fossil energy consumption means greater dependence on energy import leading to widening trade deficit and current account deficit. Therefore, exploitation of indigenous renewable energy production is necessary. The paper reviews the progress and growth of renewable energy production, distribution, and consumption in India. The paper highlights some of the enablers of renewable energy in India. The authors discuss the opportunities and challenges of increasing share of renewable energy to reduce energy import and address issues of energy security in India. The findings suggest that India is ready for a quantum leap in renewable production by 2022.

Keywords: renewable energy; tariff; investment; policy

1. Introduction

Energy holds key to economic growth and prosperity of India. Currently, India has very high-energy import dependence, close to 80% of crude oil and 40 % of natural gas imported in India. Domestic shortage of coal is widening and the estimated shortage is in the range of 185-265 million tonnes by 2016/17 (Das 2014). One of the consequences of shortage in domestic supply is increase in coal import. Overall, increasing energy import dependence recognized as a bigger concern from energy security point of view (Kar and Sinha 2014, MNRE 2011).

More fossil energy consumption means greater dependence on energy import leading to widening trade deficit and current account deficit. There is an emergent need to address the primary energy demand-supply issues. In our view complete exploration and harness of domestic and sustainable sources of energy is not only desirable but also necessary to address energy security challenges in India. Although the importance of renewable energy (RE) sources in the transition to a sustainable energy base was recognized in the early 1970s (MNRE 2011) but actual achievement has been less than expectations. As of September 30, 2014, a cumulative of 33.8 Giga Watt (GW) of renewable installation including off-grid/captive renewable capacity installation

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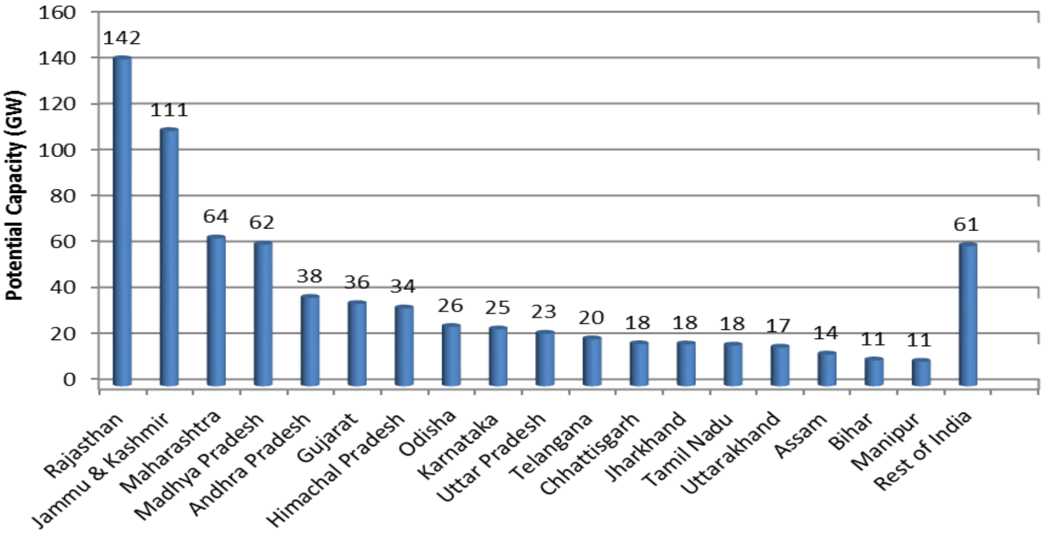

Fig. 1 Solar potential in leading states in India

Source: Prepared by authors based on MNRE 2014b.

(MNRE 2014) was available in India. At the end of September 2014, the share of renewable capacity was just over 13% (CEA 2014) from the total cumulative installed capacity from all sources of about 254 GW. However, the future of renewable market in India looks bright. By 2022, the Government targets to achieve a cumulative installed capacity of over 175GW from renewable sources only.

The paper reviews progress of renewable energy in India. In addition, some of the enablers of renewable energy identified and discussed. Further, opportunities for renewable growth, challenges faced, and ways to overcome challenges discussed. In the concluding section, the paper summarises the findings and lays down direction for future research.

2. Status of renewable energy in India

To inform the readers about progress and development of renewable energy in the country the current section devotes to discuss RE potential and actual progress made so far. This section focuses on leading sources of RE like solar, wind, small hydro, and biomass energy.

2.1 Solar

India has an estimated potential of about 749 GW (MNRE 2014b) of solar energy to be harnessed for reducing energy poverty in the country. In terms of solar energy potential Rajasthan leads the table with 142 GW followed by Jammu and Kashmir (111GW).

Fig. 1 presents top 18 states with solar potential in India. India has increased its target for solar power generation capacity to 100 gigawatts by 2022 (Vidya 2015), from the current capacity of less than 3GW. Recently government received commitment of 166GW of RE installation from

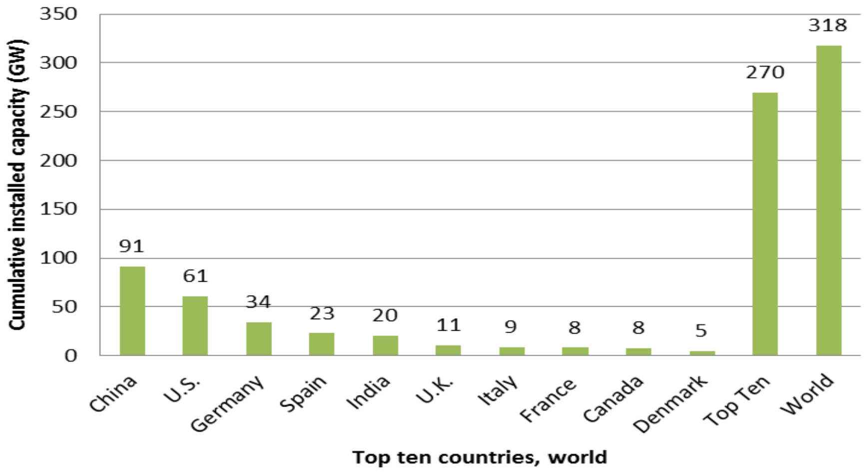

Fig. 2 Cumulative wind installed capacity by the end of 2013
Source: Kar and Sharma (2015).

various companies (RE-Invest 2015). The power minister recently admitted in an open forum that not all commitments may translate to reality but the Government could achieve the target of 100GW by 2022 (Goyal 2015).

The current Government has shown clear intent and internal motivation to increase share of solar power and reduce carbon footprint. The government has notified to set up at least 25 solar parks each with a capacity of 500 MW and above with a target of over 20,000 MW of solar power installed capacity in a span of 5 years from 2014-15 to 2018-19; with an estimated Central Financial Assistance (CFA) of Rs.4050.00 crore (MNRE 2014c).

In budget 2014-15, government made a budgetary allocation of Rs. 5000 million to be provided for Ultra Mega Solar Power Projects in Rajasthan, Gujarat, Tamil Nadu, Andhra Pradesh and Laddakh. In addition, the government earmarked a budgetary support of Rs. 4000 million for a scheme for solar power driven agricultural pump sets and water pumping stations. Additional support of Rs. 1000 million provided for the development of one MW Solar Parks on the banks of canals.

India's commitment to renewable energy started to attract domestic and foreign investors. According to Thierry Lepercq-the head of Solairedirect cost of producing solar power in India is "significantly less expensive" than many parts of the world (Vidya 2015). Comparatively low cost of solar power production could be a driving factor in terms of attracting global investors to India. Recently, SunEdison's solar technology and Adani Energy entered into an agreement to start a joint venture (JV) company to explore and exploit solar potential in the country. SunEdison's solar technology expertise with Adani's experience in creation of infrastructure, the JV will be able to transform the region into a solar production powerhouse (PTI 2015). With an investment of about $4 billion, the JV can create 4,500 direct jobs and over 15,000 indirect jobs.

2.2 Wind

Until 2007, India with a wind-installed capacity of 7,845 MW was the leading wind power installation in Asia. By the end of 2008, China overtook India with a massive capacity addition of

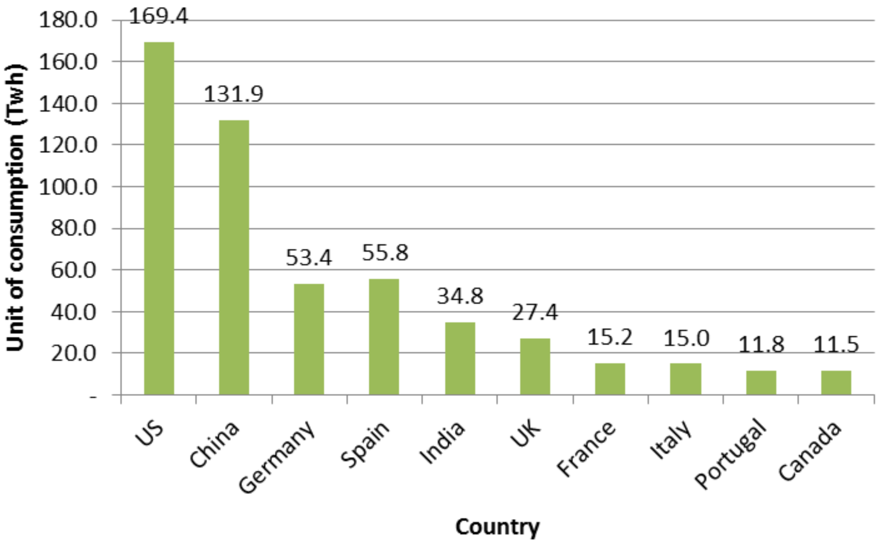

Fig. 3 Top wind power consuming countries in 2013
Source: BP Statistical Review (2014).

Table 1 Wind potential (MW) in India

States	at 80 meter	at 50 meter
Gujarat	35071	10609
Andhra Pradesh	14497	5394
Tamil Nadu	14152	5374
Karnataka	13593	8591
Maharashtra	5961	5439
Jammu & Kashmir	5685	5311
Rajasthan	5050	5005
Madhya Pradesh	2931	920
Odisha	1384	910
Uttar Pradesh	1260	137
Kerala	837	790
Uttarakhand	534	161
Total in leading states	100955	48641
Rest of India	1833	489
Total in India	102788	49130

Source: National Institute of Wind Energy, India.

6.1GW which is almost same as the cumulative capacity addition by India until 2006 (6.2 GW) (Kar and Sharma 2015). India ranked fifth amongst the wind producers (Fig. 2) and consumers in 2013 (Fig. 3). Currently India has a wind potential of 102 GW at 80 meter height and 49 GW at 50 meter height (Table 1). As of March 31, 2015 about 23.44 GW of wind turbines installed in the country and the Government targets to achieve a cumulative installed capacity of 60 GW by 2022. It is heartening to note that the domestic wind turbine manufacturing industry is getting globally

Table 2 Prevailing capex and capacity utilization factor in leading Indian states

State / UT		State / UT		State / UT	
Andhra Pradesh	Capex: Rs.57.5 million/MW CUF: Normative 23%	Gujarat	Capex: Rs.60.6 million/MW CUF: 24%	Madhya Pradesh	Capex: Rs.59.6 million/MW CUF: 20%
Karnataka	Capex: Rs.56 million/MW CUF: 26.5%	Kerala	Capex: Rs.57.5 million/MW CUF: 25%	Maharashtra	Capex: Rs.58.5 million/MW CUF: 22-32%
Rajasthan	Capex: Rs.56.5 million/MWs CUF: 20-21%	Tamil Nadu	Capex: Rs.57.5 million/MW CUF: 27.15%	Uttarakhand	Capex: Rs.51.5/MW CUF: 20-32%

Source: Compiled from Kar and Sharma (2015) and SERC tariff orders.

competitive. The domestic wind turbine manufacturers have started manufacturing bigger wind turbines (Kar and Sharma 2015a) leading to higher efficiency. Out of 33 domestic wind turbine producers, about 20 of them producing turbines bigger than 1500 kW and the biggest model is 2625 kW (NIWE 2015). It is evident from the fact that the current all India average CUF is above 20% (see Table 2) compared to 15% in 1994-95 (Rajsekhar *et al*. 1999).

The Government is striving hard to achieve the ambitious target. In the recent Re-investment-15 summit, 19 power producers committed 45GW of wind installation in the country (RE-Invest 2015).

Wind technology is one of the matured renewable technologies. Today, wind power is leading renewable source in the world and India. There is constant endeavour to increase share of wind energy in countries like China, the USA, Germany, Spain, and India. The general trend in turbine design has been to increase the height of the tower, the length of the blades and the power capacity (IEA 2013). Since 2008, the share of gearless or direct-drive turbines has increased from 12% to 20%.

Wind is getting increasingly competitive in countries where conventional generation costs are high. According to the IEA (2013) in Australia, Chile, Mexico, New Zealand, Turkey and South Africa also onshore wind power competing or close to competing with new coal- or gas-fired plants. In the near future, renewable energy like wind may achieve competitive grid parity in India. Tamil Nadu already achieved the most competitive wind tariff in India (Kar and Sharma 2015).

The emergence of rotors designed for lower wind speeds, having even smaller specific power, with high masts and long blades in relation to generator size-and even higher capacity utilization factor (CUF) may boost competitive wind energy production in India. Higher CUF may bring down capital expenditure (capex) and tariff (Sharma *et al*. 2012). Table 2 presents prevailing capex and CUF in leading wind producing states in India.

2.3 Small hydro

In India, the estimated small hydro power (SHP) potential is around 20 GW. Most of the potential is in Himalayan States as river-based projects and in other states on irrigation canals. By the end of March, 2015 about 4055 MW of small hydro power installed in India, which is about 20% of the estimated potential. The small hydro projects developed under three categories: micro (=<100 kw), mini (101-2000 kw), and small (2001-2500 kw). By the end of January, 2015 about

27-equipment manufacturers of Small Hydro Power Turbine registered with the MNRE.

Sharma, Tiwari, and Sood (2013) argue that SHP continues to be the most efficient, reliable, clean, and largely carbon-free, and represents a flexible peak-load technology way to generate electricity. So, producers are showing greater interest in substantial development of SHP potential (Benkovic *et al*. 2013, Sharma *et al.* 2013). SHP developments can improve regional economic developments within the country and reduce energy import dependency. Affordable and 24×7 supply of electricity holds key to industrial development. States with rich hydro resources can produce affordable electricity and ensure timely supply of green electricity for industrial development.

Khan (2015) points out that most of the SHP projects are economically viable and the viability depends on many factors like site conditions, size of the SHP project, evacuation and transmission facilities, grid connectivity, and initial capital expenditure. However, long gestation periods and high interest rates prolong the payback period-which is true for other renewable projects too. The Government is committed to facilitate timely completion of projects, ensure grid connectivity, and making funds available at lower interest rate to enhance viability of SHP.

The SHP programme is now essentially private investment driven. However, the Central Government provides incentives to the developers from private, co-operative, joint and government sector to install SHP projects across the country. The central assistance for North Eastern region, Jammu & Kashmir, Himachal Pradesh, and Uttarakhand stands at Rs.15 million/MW with a ceiling of Rs.50 million for the projects in the category of 0.1-25 MW. For the other states, the central financial assistance is Rs.10 million/MW with a ceiling of Rs.50 million per project.

2.4 Biomass

Biomass offers a potentially ideal source of fuel for cleaner power generation and the support of sustainable development in developing countries (Hart and Rajora 2009). The primary barrier to biomass power generation is the ability to obtain adequate supply of biomass at an economical price. However, in India, a plenty of biomass available and the current availability of biomass in India is about 500 million metric tones per year and there is a potential to generate 18GW of power from biomass. In addition to above potential, about 5GW of power generation is possible through bagasse-based cogeneration in the country's 550 sugar mills.

Due to shortage or lack of electricity supply, most of the rural households use wood as biomass for cooking and heating (Singh and Setiawan 2013). The Government had taken several initiatives to change traditional way of using biomass and popularise efficient use of biomass. Some of the large-scale initiatives intended at individual household include National Biogas and Manure Management Program (1981) and the National Biomass Cookstoves Initiative (2009) resulted in 4.82 million family biogas plants installed by the end of March 2015.

Many other programs launched to promote grid interactive power from biomass resulted in 1.4 GW of installed capacity by the end of March 2015. Similarly, initiatives for Bagasse Cogeneration (3 GW) and Biomass (non-bagasse) Cogeneration (592 MW) had shown encouraging results. Singh and Gu (2010) point out that lower costs and higher conversion efficiency are the major reasons for biomass conversion to energy in India. In addition to the above-discussed points, incentives like capital subsidy offered by the Government helps growth of biomass energy. For example, Biomass Gasifier for industries (MNRE 2010) offered capital subsidies: Rs.2.0 lakh / 300 KWth for thermal applications, Rs.2.5 lakh / 100 KWe (for electrical

Table 3 Generic tariff determined by CERC for biomass power projects in India

	Levellised fixed cost		Variable cost		Applicable tariff rate		ADB (if availed)		ADB adjusted net levellised tariff	
	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15
	Rs./kWh	Rs./kWh	Rs./kWh	Rs./kWh	Rs./kWh	Rs./kWh	Rs./kWh	Rs./kWh	Rs./kWh	Rs./kWh
Andhra Pradesh	2.21	2.44	3.34	3.82	5.55	6.26	0.14	0.13	5.41	6.13
Haryana	2.25	2.49	3.8	4.35	6.05	6.84	0.14	0.13	5.91	6.71
Maharashtra	2.26	2.5	3.89	4.45	6.15	6.95	0.14	0.13	6.01	6.82
Punjab	2.27	2.51	3.98	4.55	6.25	7.06	0.14	0.13	6.11	6.93
Rajasthan	2.2	2.44	3.32	3.8	5.52	6.24	0.14	0.13	5.38	6.11
Tamil Nadu	2.2	2.44	3.29	3.76	5.49	6.2	0.14	0.13	5.35	6.07
Uttar Pradesh	2.21	2.45	3.4	3.89	5.61	6.34	0.14	0.13	5.47	6.21
Others	2.23	2.47	3.57	4.09	5.8	6.56	0.14	0.13	5.66	6.43

Source: CERC (2013), CERC (2014)

applications through dual fuel engines), Rs.10.00 lakhs / 100 Kwe for 100% producer gas engines with gasifier system, Rs. 8.00 lakhs / 100 Kwe for 100% producer gas engine alone.

Growth of power generation from biomass depends on various factors like price of biomass, government policy to attract investment and tariff of power generated from biomass power projects. The Central Electricity Regulatory Commission (CERC) determined attractive generic tariff for the biomass power projects (Table3) in India.

Kumar *et al*. (2015) suggest that electricity generated from biomass serving as one of the best solutions to shortage or lack of electricity in rural India. We believe energy from biomass can ensure supply security at low price leading to socio-economic inclusion of rural households.

3. Enablers of renewable growth in India

This section discusses some of the enablers of renewable growth in India. Of course, there are very many factors but we focus on factors like commitment of the Government, policy initiatives, regulatory measures, environmental concerns, and international collaborations.

3.1 Commitment of the government

Government of India is extremely passionate and committed to reduce carbon emission. The government at all possible levels have shown clear intent to reduce impact on environment. Constantly efforts made for building the capacities of cities to improve mobility with lower CO_2 emissions. The current prime minister of India gives special emphasis on zero effect on environment. Globally low carbon strategies deployed as climate negotiation tool (Tilburg *et al*. 2011) and adoption of such a strategy by India is necessary.

The Government recently reset solar and wind target of 100GW and 60 GW respectively by 2022. To enable greater participation of the Central Public Sector Undertaking/Government of India Organizations-a special scheme launched with central assistance of up to Rs.10 million/MW for viability gap funding for installation. The above scheme targets to achieve installed solar power

Table 4 Central assistance for domestic and commercial installation of solar systems in India

	Central assistance	Benchmark cost
Solar Water Heaters (ETC)	Domestic: Rs. 2550/- per sq.mt. Or 30% of cost whichever is less; Commercial: Rs.2400/-per sq.mt. or 30% of cost whichever is less	Rs.8,500/- per sq.mt.for domestic, Rs.8,000/- per sq.mt for commercial
Solar Water Heaters (FPC)	Domestic: Rs. 3300/- per sq.mt. Or 30% of cost whichever is less, Commercial: Rs. 3000/- per sq.mt. or 30% of cost whichever is less	Rs.11000/- per sq.mt.for domestic, Rs.10,000/- per sq.mt.for commercial
Solar Concentrator (manual tracking	Rs. 2100/- per sq.mt. or 30% of cost whichever is less	Rs.7000/- per sq.mt.
Solar Concentrator (single axis tracking)	Rs.5400/- per sq.mt. or 30% of cost whichever is less	Rs.18000/- per sq.mt.
Solar P.V. systems (with Battery bank) applicable to Solar Street light	30% of cost 1)300 Wp to 1 kWp 2)> 1 kWp to 10 kWp 3)> 10 kWp to 100 kWp	1) Rs.210/- per watt 2) Rs.190/- per watt 3) Rs.170/- per watt
Solar P.V. systems (without battery bank) applicable to Solar street light	30% of cost 1) Upto 100 kWp 2) > 100 kWp to 500 kWp	1)Rs.100/- per watt 2)Rs.90/- per watt
Aerogenerators/Wind-Solar Hybrid Systems	a) Rs.1.5/- Lakhs per kW for Govt./Public/Charitable, R&D, academic and other non-profit making institution. b) Rs.1/- Lakhs per kW for other beneficiaries not covered under (a) i.e. Individuals and private/corporate sector will come under this.	Rs.2.5 lakhs per KW
Community Solar Cooker	It can cook for 35 to 40 persons. MNRE subsidy of 30% cost subject to a maximum of Rs.15, 000/- per cooker is available for rural areas.	Rs.50,000/-
Dish Solar Cookers	It can cook food for 10 to 15 people. MNRE subsidy of 30% cost subject to a maximum of Rs.1500/- per cooker is available for rural areas.	Rs.7000/-
Solar Steam Cooker	It can cook twice a day for 10,000 persons. MNRE provides subsidy of 50% of ex-works cost of the system.	Rs.55/- lakhs

Source: http://kredlinfo.in/Solaroffgrid/mnre%20CFA-revised%20(1)_3.pdf

of 1000MW by 2016-17 (MNRE, 2015a). With intent to promote domestic manufacturing of solar cells and modules, the scheme has a mandatory provision to procure cells and modules from domestic manufacturers.

The central government provides financial incentives for domestic and commercial customers to install renewable systems. Table 4 presents financial assistance provided by the central government for installation of solar systems for domestic, commercial, and agricultural use.

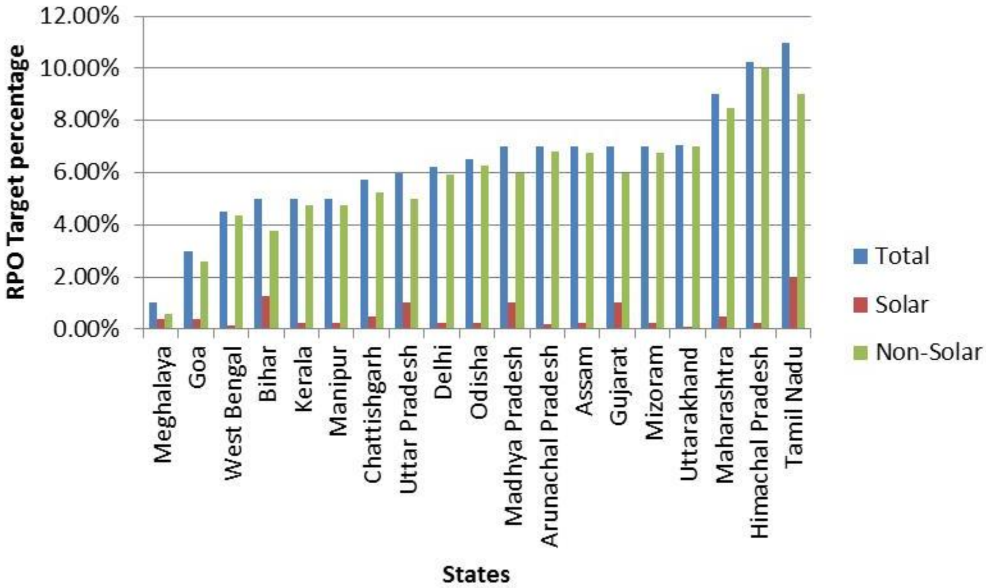

Fig. 4 Target of renewable purchase obligations in India, 2014-15
Source: Based on Kar and Sharma (2015, 2015a)

3.2 Policy initiatives

Renewable energy is a very important component of total energy mix in India. Government at the centre constantly takes various strategic policy initiatives to increase share of renewable energy to reduce dependence on energy import and ensure energy security (Kar and Sinha 2014). In the Electricity Act 2003, there is a special clause to promote production and distribution renewable energy in India. As per the Electricity Act 2003 and amendments thereafter, the appropriate commissions are empowered to promote co-generation and generation of electricity from renewable sources. In addition, the State Electricity Regulatory Commissions (SERCs) are empowered to determine renewable tariff for a company producing in a single state. Whereas the Central Electricity Regulatory Commission (CERC) is empowered to determine tariff for the Central Government companies and companies producing power in more than one state. To ensure appropriate level of renewable energy production in the states, the SERCs are empowered to set the renewable purchase obligation (RPO) limits in the respective states. Fig. 4 presents targets for RPO in various states in India for the period of 2014-15. Past RPO achievement record suggest that most of the states are lagging behind the RPO target, except couple of states like Tamil Nadu and Himachal Pradesh.

To address mismatch between availability of RE resources in states and the requirement of obligated entities to meet the RPOs, the Government introduced Renewable Energy Certificate (REC)-a tradable instrument- that is equivalent to 1MWh. As RPOs classified as Solar and Non-solar, RECs can be traded as Solar and Non-solar. Current floor price and forbearance price for non-solar REC is Rs.1500/ and Rs.3300/ respectively. Whereas the solar REC has a floor price of Rs.9300/ and forbearance price of Rs.13400/ (REC Registry, n.d). Despite availability of REC mechanism achieving RPO target remains a concern.

Table 5 Generic renewable tariff determined by CERC in India

	Levellised total tariff		ADB (if availed)		ADB adjusted net levellised tariff	
	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15
Particular	Rs./kWh		Rs./kWh		Rs./kWh	
Wind power project						
Wind Zone -1 (CUF 20%)	6.29	6.34	0.34	0.49	5.95	6
Wind Zone -2 (CUF 22%)	5.72	5.76	0.31	0.45	5.41	5.45
Wind Zone -3 (CUF 25%)	5.03	5.07	0.28	0.39	4.75	4.79
Wind Zone -4 (CUF 30%)	4.19	4.23	0.23	0.33	3.96	4
Wind Zone -5 (CUF 32%)	3.93	3.96	0.22	0.31	3.71	3.74
Small hydro power project						
HP, Uttarakhand and NE States (Below 5MW)	4.38	4.46	0.36	0.36	4.02	4.1
HP, Uttarakhand and NE States (5MW to 25 MW)	3.75	3.8	0.32	0.33	3.43	3.47
Other States (Below 5 MW)	5.16	5.25	0.42	0.43	4.74	4.82
Other States (5 MW to 25 MW)	4.4	4.47	0.38	0.39	4.02	4.08
Solar project						
Solar PV	8.75	7.72	0.88	0.77	7.87	6.95
Solar Thermal	11.9	11.88	1.21	1.23	10.69	10.65

Source: CERC (2013) and CERC (2014)

There are several policy initiatives designed and implemented for promotion renewable energy in India. Some of the notable policy instruments for promotion of RE include: tax incentives, feed in tariff (FiTs), accelerated depreciation benefit (ADB), capital subsidies, Renewable Energy Certificates (RECs), and generation based incentives (GBI) (USAID 2013, Kar and Sharma 2015a). The policy initiatives like ADB, GBI, and RECs targeted to increase actual production of renewable energy. Certainly, the ADB and GBI have significant impact on renewable energy generation but the REC needs more refinement. Other policy initiatives like direct equipment subsidies and rebates, net metering, investment tax credits, preferential tariff and feed-in tariff, grid-access, banking, wheeling, third party sales, and renewable purchase obligations are designed to improve renewable production, distribution, and consumption (Kar and Sharma 2015a). In a recent study, Polzin *et al*. (2015) find public policy measures directly affects the risk and return structure of RE projects. In India, the statutory provision in the Electricity Act 2003, for promotion of renewable energy encourages most of states with renewable potential to develop special renewable energy policy to attract investment and exploit the potential. Most of the states have already developed renewable specific policies to optimize their energy potential.

3.3 Strong regulatory measures

In India, legal frameworks sought a balance between the federal legislation and the state legislation (IRENA 2012). Largely a fine balance between the federal and the state regulatory

Table 6 Prevailing renewable tariff (Rs./kWh) in India

	Wind tariff	Solar (PV) tariff	Solar thermal tariff	Solar (PV) rooftop tariff	Biomass	Small hydro (<5 MW)
Andhra Pradesh	₹ 4.70	₹ 6.49	-	-	₹ 4.82	-
Tamil Nadu	₹ 3.39	₹ 7.01	₹ 11.03	-		
Karnataka	₹ 4.20	₹ 8.40	₹ 10.92	₹ 9.56	₹ 5.54	-
Kerala	₹ 4.77	-	-	-	-	-
Gujarat	₹ 4.23	₹ 9.63	₹ 11.55	-	₹ 3.52	-
Maharashtra	₹ 3.91	₹ 7.95	-	₹ 8.45	₹ 6.63	₹ 5.06
Madhya Pradesh	₹ 5.92	₹ 12.65	₹ 11.26	₹ 15.49	-	₹ 6.12
Rajasthan	₹ 5.57	₹ 7.50	₹ 11.67	₹ 7.50	₹ 6.10	-
Uttarakhand	₹ 5.00	₹ 11.10	₹ 13.30	₹ 9.20	₹ 4.84	₹ 4.22

Source: http://www.mperc.nic.in/170513-SMP-19-2013.pdf; KERC Order S/03/1 (Oct.10, 2013); UERC notification (April 15, 2013); KSERC Order dt. Aug.4, 2010, TNERC order 4, Sept.12, 2014; RERC Order Dt. Aug. 21, 2014; MERC order Suo-moto dt. July 7, 2014.

developments has been evident. Various mechanisms developed by the regulators and the government to strengthen the regulatory environment for effective implementation of the renewable policy framework in the country. The Central Electricity Regulatory Commission (CERC) and State Electricity Regulatory Commission (SERC) are important regulatory bodies responsible for developing relevant regulations and operating guidelines for renewable energy producers and distributors. The CERC has been empowered to determine tariff of generating companies owned or controlled by the Central Government (The Electricity Act 2003, 79 (a)); and if such generating companies enter into or otherwise have a composite scheme for generation and sale of electricity in more than one State (The Electricity Act 2003, 79 (b)). Table 5 presents generic tariff determined by the CERC for wind, small hydro, and solar projects generating electricity in India.

The SERCs are empowered to determine tariff of renewable producers in their respective states except the cases where CERC is empowered to determine tariff. Table 6 presents prevailing renewable tariff determined by SERCs of some of the India states.

3.4 Rising environmental concerns

India is currently the fourth largest greenhouse gas (GHG) emitter in the world, with its transport sector being the second largest contributor of CO_2 emissions. Carbon dioxide from fossil fuel combustion and cement production is the largest contributor to total greenhouse gas (GHG) emissions. The UNEP report (2014) projects the global emissions to reach 59 Gt CO_{2e} per year by 2020 and 87 Gt CO_{2e} per year by 2050. Such steep upward trajectories are consistent with global average temperature levels that are around 4℃ warmer in the year 2100 than the period 1850–1900. Above level of temperature rise can have serious consequences for a country like India. It is to be noted that GHG emissions from electricity use occur during the generation of the electricity from fossil fuel based power plants have aggravated the problem of high carbon dioxide (CO2) emissions in India (Ramachandra *et al*. 2015).

There are rising global concerns over carbon dioxide emissions budgets, greenhouse gas emissions, and temperature limits. Indian government has been seriously contemplating on climate

Table 7 Collaborations of MNRE with foreign countries/organizations

Organization/country	Purpose	Year
The Department of Energy of the USA	Cooperation in the Development of Bio-fuels.	9-Feb-09
The Ministry of Climate and Energy, Government of the Kingdom of the Denmark.	New and Renewable Energy cooperation	6-Feb-08
Government of the Republic of South Africa, Government of the Federative Republic of Brazil	Cooperation in Wind Resources.	17-Oct-07
The Republic of Cuba	Cooperation in renewable energy	24-May-07
The Republic of Iceland.	New and Renewable Energy cooperation	9-Oct-07
The department of Resources, Energy & Tourism, Government of Australia.	Research, development, investment, and industry collaboration in the field of renewable energy	5-Feb-10
The University of Saskatchewan, Canada	Indo-Canadian Renewable Energy Cooperation.	28-Mar-08
The Ministry for Environment, Land and Sea of Italy.	New and Renewable Energy cooperation	15-Feb-07
The Secretariat of Energy of the United Mexican States.	New and Renewable Energy cooperation	17-Apr-08
Republic of the Philippines	Enhanced Cooperation in the Field of Renewable Energy.	5-Oct-07
The Kingdom of Thailand	Enhanced Cooperation in the field of Renewable Energy.	26-Jun-07
The National Energy Commission, Republic of Chile.	Cooperation in the Field of New and Renewable Energy	17-Mar-09
The Government of Scotland	Renewable Energy Cooperation	14-Oct-09
Tourism and Trade of the Kingdom of Spain	Cooperation in the field of Renewable Energy.	NA
The National Renewable Energy Laboratory, United States Department of Energy.	Cooperation in the area of solar energy	23-Nov-09
The Ministry of Enterprise, Energy and Communications of Sweden.	Development of clean, affordable, and sustainable energy	19-Apr-10
The Government of Malaysia on Cooperation in Renewable Energy	Cooperation in the field of Renewable Energy.	7-Nov-12
Fraunhofer Institute fur Solare Energiesystems (ISE), Germany	Cooperate in various areas of Solar, Hydrogen, and Fuel cells	11-Apr-13
The Government of Unites States of America	Cooperation in New and Renewable Energy to Facilitate Clean Energy Access	29-Jan-14
The Ministry of Economic Affairs Agriculture and Innovation of the Netherlands	Cooperation in Renewable Energy	28-Apr-14
Japan Bank for International Cooperation	Promoting New and Renewable Energy	1-Sep-14
The Ministry of Employment and the Economy of the Govt. of Finland	To encourage and promote bilateral cooperation on new and renewable energy issues	15-Oct-14

Source: http://mnre.gov.in/schemes/support-programmes/international-cooperation-3/

change and taking various visible measures to protect environment and maintain high growth. Like the predecessors, the current government at the centre is highly committed to green growth and development. Considering severe environmental implications, India should seriously explore and exploit renewable sources of energy to meet the energy requirements (Kar and Sharma 2015, Kar and Sharma 2015a, Kar and Sinha 2014, Ramachandra *et al.* 2015). To reduce CHG footprint special emphasis should be given to the sectors like electricity generation, transport, domestic, commercial, and industrial (Ramachandra *et al*. 2015).

3.5 Cooperation and collaboration

Lv and Spigarelli (2015) indicate that cooperation and collaboration has helped integration of Chinese and European renewable markets. Further, they suggest tailoring investment promotion policies or cooperation initiatives to enhance mutual benefits. Important benefits of cooperation and collaboration include new technology development and sharing, sharing of cost, and market development. Reboredo (2015) suggests for that greater international cooperation to push more sustainable development globally. India already established collaborations with many countries and organizations for promoting New and Renewable Energy (Table 7). These collaborations and cooperation include exchange of ideas, transfer of knowledge, joint development of technology, transfer of technology on commercial basis, and ensuring investment in the areas of renewable and sustainable energy. We can infer that international cooperation and collaborations could be a big driving factor for renewable growth in India. Cooperation and collaborations could address issues like easy access to innovative technology and faster commercialization of renewable technology in India.

4. Challenges to renewable growth

Some of the prominent challenges often considered as barriers to renewable growth in India are low performance of renewable plants, especially in case of wind with lower capacity utilization factor of 18-32%, economic viability of wind projects, lack of evacuation infrastructure, high grid imbalance, and intermittency (Kar and Sharma 2015).

Similar kind of challenges, especially in terms of economic viability and low efficiency are common in case of solar technology. For instance, while determining tariff Rajasthan Electricity Regulatory Commission (RERC) considered capacity utilization factor (CUF) of 20% and 23% for solar PV and solar thermal plants respectively for projects applicable during 2014-15 (RERC 2014). Current CUF for small hydro ranges from 45% in Hamachal Pradesh, Uttarakhand, and North Eastern states to 30% in other states (CERC 2014).

Research conducted by Singh and Singh (2014), NRDC (2014); Kar and Sharma (2015) and Reuters (2015) suggest that unavailability of land acts as a barrier to growth of renewable technology in India.

Renewable projects often considered risky with scope for long-term but slow return resulting in lack of interest from the investors. In India, the mainstream financial institutions have been reluctant to take risks in lending due to a long history of poor recovery of loans due to falling returns, the high costs of servicing in these dispersed and low-volume markets like renewable energy (Deloitte 2015).

Risks associated with financing renewable energy projects include but are not limited to market risk, credit risk, liquidity risk, operational risk and political risk (Lee and Zhong 2015). Market risk and credit risk can be easily quantified and hedged while liquidity risk, operational risk and political risk cannot. Furthermore, access to finance proves to be one of the biggest barriers to renewable developments in India (Kar and Sharma 2015, Luthra *et al*. 2015, Deloitte 2015). In addition, high initial capital cost for renewable technologies (Hirmer and Cruickshank 2014, Lee and Zhong 2015) leads to higher amount of investment for same capacity compared to conventional technologies (Beck and Martinot 2004). Often higher capital cost results in higher unit cost of production, which acts as an inhibiting factor for adoption and purchase by the consumer.

The above discussed challenges are not permanent in nature, so could be could be addressed. The following section discusses the ways to address of the challenges and streamline renewable growth to achieve ambitious target by 2022.

5. Addressing challenges

Removal of barriers like economic viability is feasible by offering suitable incentives and setting attractive tariff structure. To address the issues of economic viability Sharma *et al*. (2012) suggest to design, develop technologically superior and cost efficient wind turbines to reduce unit cost of wind power in India. The government is planning to launch a repowering scheme, which could address improving efficiency of existing wind farms with low CUF in the country.

Suitable development of storage technologies can address concerns linked to intermittency and grid imbalance. Some recent studies in the field of storage technologies (Mohammod-Rozali *et al*. 2013, Pan *et al*. 2014, Xiu *et al*. 2014) suggest that life of the battery and storage is improving along with economic viability. According to the work by Ayodele and Ogunjuyigbe (2015), hybridization of storage technologies is a potential solution to intermittency.

To reduce risk and enhance renewable project viability the Government is already offering capital subsidies, viability gap funding (for solar projects), generation-based incentives, and tax benefits. Such incentives are effective but not adequate to meet the financial requirements for the renewable sector. Considering the current renewable investment pattern in India, an estimated additional investment of about $180 billion needed by 2022. The above investment excludes evacuation and transmission infrastructure developments. For better utilization of renewable resources, the Government is planning to have a green energy corridor with a capital outlay of around INR 425 billion (USD 6.964 billion (MNRE 2015b). This initiative is intended increasing accessibility to renewable power in the country.

It is pertinent to highlight that during 2004-13, the renewable sector in India attracted a cumulative investment of $56 billion (BEF 2014) which is slightly lower than China’s investment in 2013 alone. To attract an addition investment to the tune of $180 billion is an incredible task for the government. Therefore, the government is constantly working on creating suitable investment climate, ensuring investment security, and launching innovative financing models. One of the important renewable financing models is development of renewable infrastructure bond market for better access to fund. Lee and Zhong (2015) suggest hybrid bond for financing renewable projects. The finance minister did announce tax-free infrastructure bond but did not announce special renewable infrastructure bond. We suggest creating special tax-free renewable infrastructure bond to push investment in this sector. To push rooftop installation government may allow income tax deduction for a part or total investment made in the rooftop projects.

To facilitate growth of renewable investment, the government created the National Clean Energy Fund (NCEF), funds from CSR activities and tax-free donations will be important sources of funding renewable project during the 12th Plan period and thereafter. The government is in the process of facilitating easy access to debt financing, access to foreign investment, and equity market. During the RE-INVEST 2015, 14 companies from seven countries have given their Green Energy Commitments for 58 GW installations. Similarly, 22 PSUs for 18 GW, 257 private limited companies for 190 GW and the Railways for 5 GW have submitted their commitments for renewable energy. About 27 banks submitted their commitments for financing 72 GW renewable energy projects (MNRE 2015c). As per the advice of Ministry of Finance (2014), Government of India the commercial banks have initiated steps for including financing of rooftop solar PVs as a part of the home loan/home improvement loan.

6. Discussion

India's policy choices could shape its ability to diversify its energy mix and increase the renewable energy share in the short-term and long-term. It is quite understandable that a set of comprehensive and implementable renewable policy at the centre and customized renewable policy framework at the state government level could push the growth of renewable energy in India. The Government of India is highly committed to increase budgetary support for research, development, and demonstration of renewable technologies (Maithani 2011).

The Government incentivises the producers and consumers for greater adoption of renewable technologies. To boost adoption of clean and green energy like solar the central government declared 48 cities as solar cities. The 'Solar City' initiative already received Rs.48 million financial assistance from the total sanction amount of Rs. 217 million. The above initiative aims developing eight cities as 'Model Solar Cities' and so far, Nagpur, Chandigarh, Gandhinagar and Mysore have been identified/ sanctioned (MNRE 2015d) for the purpose.

Ensuring policy implementation demands more proactive involvement of the regulatory bodies (Kar and Sharma 2015, IEC 2015). Higher investments in risky renewable projects demand well directed fiscal and monetary incentive schemes. Government promises the investors and power producers to create investor friendly renewable market. The government is not only willing but also committed to create easily accessible financing models including developing innovative financial instrument (Goyal 2015). Government is quite open to explore all possible options including pension fund to invest in the renewable sector. Green manufacturing, distribution, and consumption are clearly high on the Government agenda. This would certainly help the renewable sector by raising economies of scale and scope for renewable energy industry. Higher demand for renewables would lead to demand for local equipment manufacturing. Indigenous manufacturing may bring down cost of renewable equipment and finally reduce price of renewable energy.

Beck and Martinot (2004) advocates adoption of private entrepreneurship to drive of renewable energy penetration in rural areas. Entrepreneurship in the field of renewable energy, especially in solar, biomass, small and hydro could push penetration and adoption of renewable energy to the desired level. Of course, the government is determined to support the entrepreneurs with feasibility studies, business planning, viability gap funding, training, and marketing. Especially products like solar cooker, solar lantern, solar lighting, and many other renewable technology based products need better distribution and marketing infrastructure for higher penetration in rural market. Addition of new distribution and marketing channels like internet, self-help groups, tie-up with

Indian post, and fair price shops could enhance access to green energy products. Government's intention to train 50000 youth to educate, market, and service renewable products would certainly improve penetration level across India.

One more area, which demands significant level of attention and commitment from all stakeholders, is education for renewable energy and energy conservation. The Government should push to make renewable energy as a compulsory part of academic curricula in school, colleges, and universities across the country. Such a move not only can improve awareness but also enhance acceptability of renewable energy in country.

7. Conclusions

The Government seriously acknowledges the need for pushing generation, transmission, and consumption of renewable energy in the country. The vigour, intent, and commitment level of the Government is evident. The recent revised renewable target of 175 GW by 2022 looks far fetching but international experience; especially the cases of China and the US suggest that it is very much achievable. Along with the Government, policymakers, regulators, and citizens need to believe that the target is realistic. Recent renewable developments send encouraging signals to massive development for the future. Amongst the renewable technologies wind is the most matured technology and largest contributor to the Indian renewable sector. However, Solar has immense potential and bound grow faster than wind. Off course, SHP, biomass, and other renewable technologies expected to supplement solar and wind.

The renewable sector facing challenges like low efficiency, lack of long-term financing, high initial capex, high interest rate, low return, grid connectivity, land availability, and many more. The Government and its agencies are constantly trying to create investor friendly environment by offering necessary fiscal and monetary incentives. To increase share of renewable energy massive renewable initiatives like developing Solar City, Solar Park, Large Scale Solar Power Plants, Solar rooftop, repowering of existing wind farms, and many more have been taken. The Government need to continue offering generation based incentives and capital subsidy schemes to keep the sector attractive for the producers On the other hand, creating awareness, interest, desire, and action for green products at the consumer should be given equal importance.

However, lot of ground to cover to achieve the ambitious target of 175 GW by 2022, especially in the areas of technology development, commercialization, financing, and training and development.

Scope of RE is very wide and it is difficult to cover all aspects with equal emphasis. Therefore, some of the areas that demand further research include efficiency improvement, especially in solar and wind, competitiveness of the domestic component manufacturing industry, improving grid connectivity, and financing renewable projects. Serious research needed to explore, identify, and implement suitable financial instruments to fund the risky renewable projects in India.

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