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Renewable energy certificate mechanism in India: A preliminary assessment

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ABSTRACT

The Indian National Action Plan for Climate Change (NAPCC) envisages several measures to address global climate change. One of the important measures identified involves increasing the share of renewable energy in total electricity consumption in the country. This would mean NAPCC envisages renewable energy to constitute approximately 15% of the energy mix of India by 2020. To achieve the target set by the NAPCC, Indian Ministry of Power launched Renewable Energy Certificate (REC) mechanism in November 2010. However, participation in the REC markets is low and RECs have failed to attract significant investment so far.

In this study a preliminary attempt has been made to assess the performance of existing REC mechanism in India. After highlighting the salient features of the Indian renewable energy policy framework a brief description of renewable purchase obligation (RPO) and source specific RPOs for different states is discussed along with an overview of REC market in India to date.

The performance of Indian REC mechanism is evaluated by cost competiveness, decentralized distributed generation and renewable energy portfolio diversity and their effectiveness has also been measured on the basis of the available data. Although, it is difficult to make any conclusive remark on the success or failure of REC mechanism due to its short experience, this study examines the process to date to come out with some recommendations which can be used to fine tune the functioning of existing REC market in India. For instance, REC price bounds should be revised because it has been not explicitly supporting cost competiveness by offering 60.33% higher average price than the existing average feed-in tariff (FiT). It is also observed that state-wise contribution in registered capacity is skewed towards few states like Tamil Nadu (27%), Maharashtra (23%), and Uttar Pradesh (22%), which puts pressure on policy makers to restructure the existing REC mechanism.

Contents

1. Introduction

Energy security and climate change are both increasingly critical drivers affecting policies, regulations and investment in the energy sector [1–3]. Renewable energy (RE) plays an

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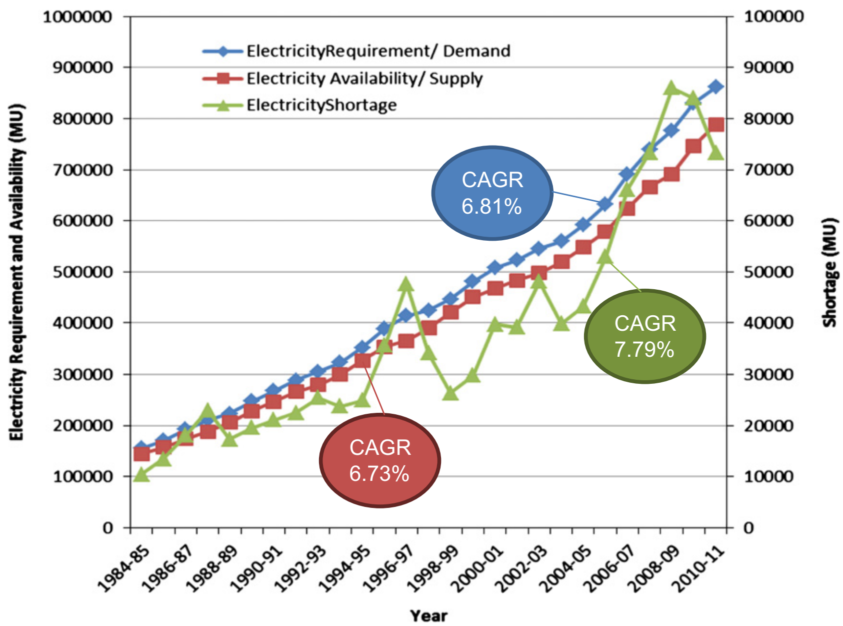

Fig. 1. Electricity supply and demand trend in India [25].

important role in contributing to the transition toward low-carbon development growth to reduce greenhouse gas emissions, enhancing technology diversification and hedging against fuel price volatility to increase supply adequacy, strengthening economic growth to promote industrial development and employment generation, and facilitating access to electricity to promote rural development and poverty reduction [4–6]. The global trends indicate a growing commitment to RE development from developed and developing countries in both the introduction of specific policy levers and investment flows [2,3]. The share of RE in global primary energy could increase from the current 17% to between 30% and 75%, and in some regions exceed 90%, by 2050 [7]. Over 50% of the existing RE capacity in the world is operating in developing nations [3]. In addition, about half the countries that have issued some type of RE promotion policy are now in the developing countries [8].

RE gained significance in India with growing concern for energy security [9]. It may be noted that approximately 70% of the total oil requirement in India is imported [10] and more than 56% coal thermal power generation is based on fast depleting coal reserves [11]. Energy self sufficiency has been identified as the major driver for RE in India with rising insecurity in relation to fluctuating oil prices [12,13]. Moreover, 70% of people burn biomass for meeting energy requirements for cooking and heating in the country [14–16]. Policies of the Central/State level government are direct and conscious efforts to break with the import dominant generation to environmentally benign, indigenous and sustainable form of generation. The cumulative installed capacity of electric power plants in India under utilities was 207,006 MW until August 2012 [11]. Out of this 56.9% is generating through coal, 9.1% by gas, 0.6% by oil and 2.3% from nuclear. The share of hydro is 19% followed by 12.1% through RE resources.

While countries around the world have been meeting their increasing industrial and domestic demands for electricity with increasing share of RE; the countries like India, where power shortage has been a consistent problem since decades (Fig. 1) still unable to devise policies to effectively overcome this problem [17–20]. In one of the worst instances of power outage around the world, more than 600 million people in 22 states across the northern, eastern and northeastern regions of India went without electricity for several hours in July 2012 [21–22], after three power supply grids collapsed in quick succession [23,24]. Fig. 1 also demonstrates the cumulative annual growth rate (CAGR) of supply, demand and shortage of electricity as 6.73%, 6.81% and 7.79%, respectively [25]. This shortfall seems to be distributed in some proportion across all the states and union territories, as shown in Fig. 2. For the financial year 2011, the highest peak electricity deficit is observed in Jammu & Kashmir (33.7%) followed by Bihar (22.5%).

India has come a long way since the inception of its RE program in 1981. With a total investment of over US$4 billion in 2010 alone [26], the country has emerged as one of the leading destinations for investors in RE [27]. Massive energy needs, a favorable regulatory framework and a vibrant private sector is helping India exploit its huge RE potential [27,28]. It has potential of more than 150 GW of RE [29], with 50% of this capacity existing in the small hydropower, biomass and wind segments and rest being in the solar, cogeneration, and waste-to-energy sectors. The Indian Ministry of New and Renewable Energy (MNRE) estimated the potential of solar and non-solar RE at 500,000 MW and 87,495.65 MW, respectively [30]. The detailed description of MNRE estimates for state-wise and source-wise potential of RE is presented in Table 1. These RE sources are widely distributed with wind, biomass, and small hydro power as the major contributors.

To overcome the problem of power shortage and to achieve the objective of sustainable development, India has been putting effort to streamline its plans to achieve ambitious RE targets [31]. The National Action Plan for Climate Change (NAPCC) of the Government of India has set the target of 5% RE purchase for FY 2009–10 [32]. Further, NAPCC envisages that such target will increase by 1% for next 10 years. This would mean NAPCC envisages RE to constitute approx. 15% of the energy mix of India. In addition, under the Jawaharlal Nehru National Solar Mission (JNNSM), ambitious targets of 20,000 MW of grid-connected solar power capacity, and 2000 MW of off-grid solar applications up to 2022 were decided [33]. To achieve the target set by the NAPCC, the Indian Ministry of Power (MoP) launched Renewable Energy Certificate (REC) Mechanism in November 2010. This concept seeks to address the mismatch between availability of RE sources and the requirement of the obligated entities to meet their RPO [34]. It is also expected to encourage the RE capacity addition in the States where there is potential for RE generation as the REC

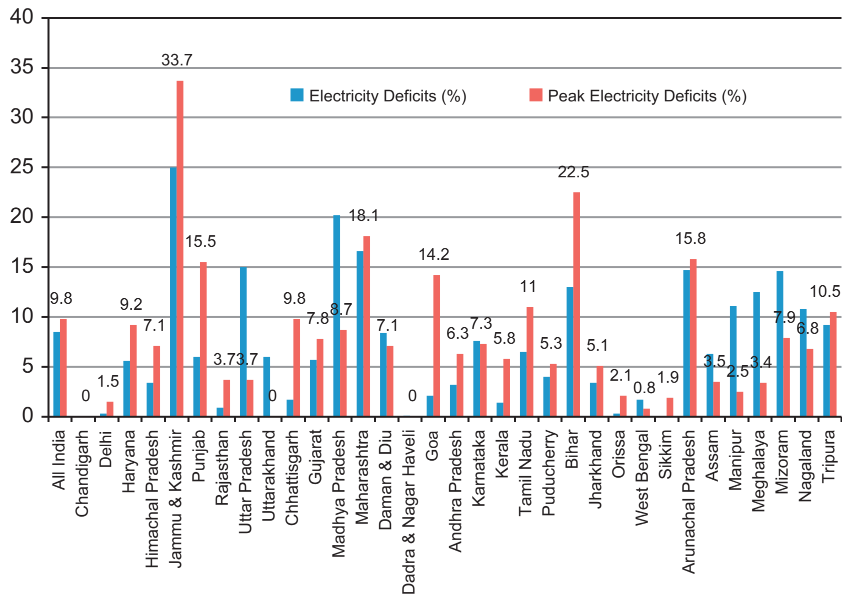

Fig. 2. Electricity deficits across different states and union territories for FY2011 [25].

Table 1
Renewable energy potential in India [30].

S. no.	State/union territory	Renewable energy potential (MW)				Total	(%) share of total potential
		Wind	Biomass	Bagasse cogeneration	Small hydro power		
1	Andhra Pradesh	5,394	150	300	560	6,404	7.32
2	Arunachal Pradesh	201	NA	NA	1,329	1,530	1.75
3	Assam	53	166	NA	239	457	0.52
4	Bihar	NA[a]	530	300	213	1,044	1.19
5	Chhattisgarh	23	221	NA	993	1,237	1.41
6	Goa	NA	16	NA	7	22	0.03
7	Gujarat	10,609	1,014	350	197	12,170	13.91
8	Haryana	NA	1,261	350	110	1,721	1.97
9	Himachal Pradesh	20	128	NA	2,268	2,416	2.76
10	Jammu & Kashmir	5,311	32	NA	1,418	6,761	7.73
11	Jharkhand	NA	67	NA	209	276	0.32
12	Karnataka	8,591	843	450	748	10,632	12.15
13	Kerala	790	762	NA	704	2,256	2.58
14	Madhya Pradesh	920	1,065	NA	804	2,789	3.19
15	Maharashtra	5,439	1,585	1250	733	9,007	10.29
16	Manipur	7	4	NA	109	120	0.14
17	Meghalaya	44	1	NA	230	275	0.31
18	Mizoram	0		NA	167	167	0.19
19	Nagaland	3	3	NA	189	195	0.22
20	Orissa	910	147	NA	295	1,353	1.55
21	Punjab	NA	2,675	300	393	3,368	3.85
22	Rajasthan	5,005	4,595	NA	57	9,657	11.04
23	Sikkim	98		NA	266	364	0.42
24	Tamil Nadu	5,374	863	450	660	7,347	8.40
25	Tripura	NA	NA	NA	47	47	0.05
26	Uttar Pradesh	137	1,478	1250	461	3,326	3.80
27	Uttaranchal	161	7	NA	1,577	1,745	1.99
28	West Bengal	22	368	NA	396	786	0.90
29	A&N Islands	2	NA	NA	7	9	0.01
30	Lakshadweep	16	NA	NA		16	0.02
	Total	**49,130**	**17,982**	**5000**	**15,384**	**87,496**	**100.00**

RE potential tabulated above excludes waste-to-energy, industrial waste and solar power generation potential.

[a] NA: not available.

framework seeks to create a national level market for such generators to recover their cost. The Central Electricity Regulatory Commission (CERC) of India has also notified REC Regulation in fulfillment of its mandate to promote renewable sources of energy and development of market in electricity.

"Goyal and Jha" [35] put forward the case for REC markets in India and discussed the advantages to having a market based system. However, few studies [36,37] have probed the effectiveness of design and assessed the performance of the few year-old REC markets with focus on cost competiveness only. Therefore, an attempt to assess the performance of existing REC mechanism in India has been made in this study. The effectiveness of REC mechanism is evaluated by cost competiveness, decentralized distributed generation and RE portfolio diversity with the help of available data. Due to complex and varying nature of data for each objective, in-spite of following any standard assessment method customized approach for each objective has been followed.

The paper is set out as follows. Section 2 provides some salient features of the Indian RE policy framework. A brief description of renewable purchase obligation (RPO) and source specific RPOs for different states are presented in Section 3, while Section 4 presents an overview of REC market in India to date. Performance of existing REC mechanism in India is analyzed in Section 5. Section 6 concludes.

2. Renewable Energy Policy of India

Indian government has enacted several policies to support the expansion of RE sector [38–41]. The capital subsidy policies are generally used during the initial stages to reduce capital cost of RE projects especially during the demonstration stage [20]. This, however, leads to excess capital costs and provides no incentive for cost reduction. Tax incentive policies provide accelerated depreciation related income tax benefits for investment in renewables and also income tax holidays for investment in RE based projects. The states also have created additional major policy initiatives to encourage private/foreign direct investment to tap energy from renewable sources of energy, including provisions of fiscal and financial incentives (e.g., 100% depreciation), simplification of procedures for private investment including single-window permit procurement, reduced number of required governmental authorizations and unrestricted levels of foreign direct investment in the ownership of renewable energy projects. More than 17 States of India have so far announced policies of inviting private sector participation and allowing wheeling, banking and buyback of electricity to attract private sector entrepreneurs in field of renewable generation. Some states are also awarding the projects based on competitive bidding process for the rate for purchase of electricity.

Since 2006-07, India is able to achieve 19 percent cumulative annual growth rate of RE capacity installation, as shown in Figure 3. (www.mnre.gov.in). Such an impressive growth could be attributed to many policies and regulative measures implemented by different government organizations during last few decades. This growth trajectory has got its momentum with the enactment of the Electricity Act (EA) 2003 which abolished all the earlier electricity related acts [42]. Section 3 (1) of EA 2003 considers National Electricity Policy, National Tariff policy and National Electricity Plan including optimal utilization of renewable sources of energy, while section 4 of EA 2003 advocates a national policy for stand-alone system based on renewable energy and other sources of energy for rural areas. In addition, section 61(h) of EA 2003 recommends appropriate commission which will consider promotion of co-generation and generation of electricity from RE while calculating tariff. Moreover, section 86(1) (e) also recommends concerned state commission to ensure grid connectivity for evacuation of all the electricity generated from renewable sources of energy and insists state regulatory bodies to fix a certain proportion of their electricity consumption through renewable energy sources.

National Electricity Policy (NEP) 2005 was formulated under section 3(1) of EA 2003. NEP stipulates the need for increasing the share of electricity from non-conventional sources and allows for the SERCs to establish a preferential tariff for electricity generated from renewable sources to enable them to be cost-competitive [43]. Section 5.12.3 of NEP encourages the development of cogeneration facilities and allows for SERCs to promote arrangements between co-generators and distribution companies interested in purchasing excess electricity through a competitive bidding process. Moreover, section 5.12 specifically highlights the importance of non-conventional source of energy as an environmental friendly way to produce electricity. It also mandates SERCs to increase the share of non-conventional sources with giving due importance to promotion of co-generation of electricity. To increase the penetration of electricity with increasing share of renewables, the Government of India, in compliance with section 3(1), notified the electricity tariff policy 2006 which in section 6.4(1) considers the purchase of a fix minimum percentage of electricity from non-conventional sources including co-generation at a preferential tariff determined by the appropriate state commission [44].

Similarly, in order to implement Sections 4 and 5 of the Electricity Act, 2003, the Government of India notified Rural Electrification Policy 2006. Under section 3.2 of this policy, villages where grid connectivity is not feasible, off grid or stand-alone system based on renewable technologies may be adopted. The central government has also launched Rajiv Gandhi Grameen Vidhyutikaran Yojana (RGGVY) in order to ensure 100% electrification of all un-electrified villages/hamlets. In order to harness the potential of locally available resource like biomass in rural India, Section 8.8 offers automatic approval for land use

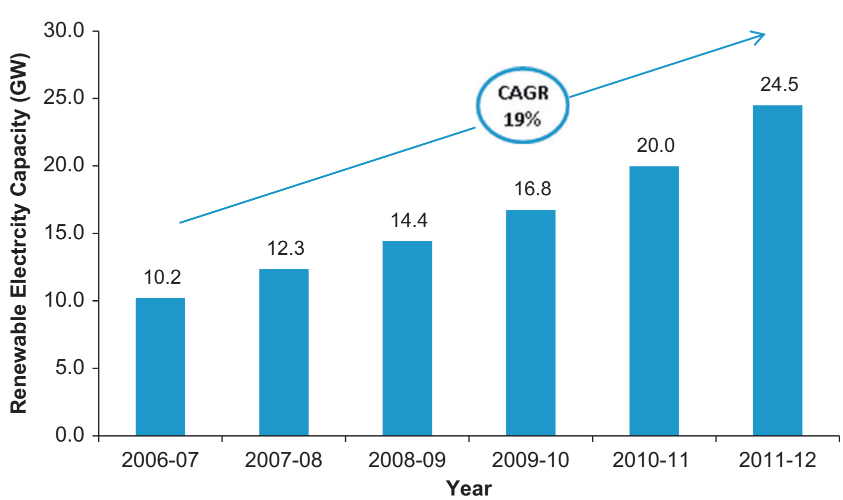

Fig. 3. Growth of renewable electricity installed capacity in India (GW).

change, pollution clearance and safety clearance etc. for a standalone system of upto 1 MW.

Further, Ministry of New and Renewable Energy (MNRE) provides generation based incentives (GBI) to power generated through RE sources. Fiscal incentives in the form of higher rates of depreciation, capital subsidies, income tax exemption, and financing support encourage investment in RE. Recently, the government has discontinued the tax benefit available in the form of accelerated depreciation (AD) for wind energy projects, from 1st April 2012. This is in line with the GBI provision announced in December 2009. The GBI scheme is applicable only for those power producers who do not avail benefits from accelerated depreciation under the income tax act. At present, MNRE provides the GBI of Rs. 0.50/kW h for a grid integrated project of more than 5 MW for a period of ten years.

The growing solar footprint in India is supported by policy push through the Jawaharlal Nehru National Solar Mission (JNNSM) and state policies. JNNSM was launched in 2010 which set the target of 20,000 MW grid connected and 2000 MW off grid solar power by 2022 [33]. Under this mission, provisions like concessional custom duty and excise duty exemption have been made for all the transactions related to solar power projects. In case of hydro power, the central government has approved new hydro power policy on 3rd January 2008 to extend different benefits to both private and public hydro power producers. The benefits like exemption from tariff based competitive bidding, facility of merchant sale up to 40% of the saleable energy, industrial training institute (ITI) at every project site to train project affected people etc. are considered under this new policy.

A national policy on bio-fuels was also introduced in order to promote a diversified portfolio of renewable energy. It has proposed a blending target of 20% for bio-diesel and bio-ethanol by 2017 [45]. Under this policy, National Bank of Agriculture and Rural Development (NABARD), Indian Renewable Energy Development Agency (IREDA), Small Industries Development Bank of India (SIDBI) and other financing agencies as well as commercial banks would be actively involved in financing of various activities related bio-fuel value chain. In another initiative, the Central govt. has also allowed FDI up to 100% equity investment in renewable energy based power generation plants through technological and financial collaborations.

3. Renewable purchase obligation (RPO) across Indian States

The policies framed under the Electricity Act 2003 [42], as also the NAPCC [32] provide a roadmap for increasing the share of RE in the total generation capacity in the country. However, RE sources are not evenly spread across different parts of the country. One of the key actions taken by the Indian government and regulatory bodies has been to introduce RPO in India [46,47]. India aims to derive 15% of its energy requirements from RE sources by the year 2020. RPO is one of the tools for implementing this ambitious goal. In this policy measure, SERCs determines the obligated entities, which generally includes distribution companies, captive consumers and any open access users. Then these SERCs fix a certain proportion of electricity consumption, as shown in Table 2, as RPO targets for the above mentioned obligated entities. In general, SERCs decide the RPO by taking into account the availability of resources and its impact on electricity tariffs. For example, RPO standards for the states of Himachal Pradesh, Uttarakhand and Tamil Nadu are over 10% due to high hydro and wind resource availability in these states. Similarly, states of Haryana, Goa, West Bengal, Jharkhand, Meghalaya, Punjab, and Tripura have RPO standard less than 5% due to low RE potential. With the launch of the REC market in 2011, many states have made meeting RPO targets mandatory and rolled out their ambitious plan for a more realistic renewable energy addition. In case of defaults or non-compliance, entities have to pay penalties, in general, at forbearance prices, which is an upper bound for REC price at any trading platform. As on January 2012, all states except Sikkim and Arunachal Pradesh have declared their RPO targets.

Most of the states have declared very short-term commitment towards RPOs either due to weak financial condition of their distribution companies or they are still in their experimental phase with this new policy. For example, eight states (Bihar, Chhattisgarh, Himachal Pradesh, Haryana, Karnataka, Madhya Pradesh, Uttar Pradesh and Tamil Nadu) have reduced their post-REC RPO targets, either due to under achievements in the previous years, or due to increasing financial burden on consumers. Moreover, Out of 27 states, 15 states have declared RPO target up to 3 years only. This may adversely hit the investment scenario of RE capacity addition in India. While few states have diversified their RPO portfolio by fixing RE source specific obligation, as shown in Table 3, others have chosen to specify a common RPO target. Under the influence of JNNSM and high solar insolation, state of Bihar, Chhattisgarh, Delhi, Gujarat, Jammu & Kashmir, Karnataka, Kerala, Maharashtra, Rajasthan, and Uttar Pradesh have declared RPO for solar electricity. The solar RPO ranges from 0.02% to 1%. The states have kept it low because of relatively higher production cost of solar electricity. For example, Gujarat has declared tariff Rs. 13/kW h and Rs. 3.57/kW h for solar and wind electricity, respectively. Though most of the states have sufficient biomass potential [48–53], Chhattisgarh is the only state which has declared RPO for it.

Table 2
RPOstandards across states.

State	RPO (%)					
	2010–2011	2011–2012	2012–2013	2013–2014	2014–2015	2015–2016
Andhra Pradesh[a]	5.00	5.00	5.00	5.00	5.00	5.00
Assam	1.40	2.80	4.20	5.60	7.00	
Bihar	1.50	2.50	4.00	4.50	5.00	
Chhattisgarh	5.00	5.25	5.75			
Delhi[a]	2.00	3.40	4.80	6.20	7.60	9.00
Gujarat	5.00	6.00	7.00			
Haryana	1.50	2.00	3.00			
Himachal Pradesh	10.01	10.01	10.25	10.25	10.25	10.25
Jammu & Kashmir	1.00	3.00	5.00			
Goa & UT	1.00	2.00	3.00			
Jharkhand	2.00	2.50	3.10			
Karnataka	0.25	0.25	7.25	7.25	7.25	7.25
Kerala	5.25	5.25	5.25	5.25	5.25	5.25
Madhya Pradesh	0.80	2.50	4.00	5.50	7.00	
Maharashtra	6.00	7.00	8.00	9.00	9.00	9.00
Manipur	2.00	3.00	5.00			
Meghalaya	0.50	0.75	1.00			
Mizoram	5.00	6.00	7.00			
Nagaland	6.00	7.00	8.00			
Orissa	5.00	5.00	5.50	6.00	6.50	7.00
Punjab	2.40	2.86	3.44	3.94	4.00	
Rajasthan	8.50	9.50	7.10	8.20		
Tamil Nadu	10.15	9.05				
Tripura	1.00	1.00	2.00			
Uttar Pradesh	4.00	5.00	6.00			
Uttarakhand	10.00	11.00				
West Bengal	2.00	3.00	4.00			

Source: http://www.recregistry.in.

[a] Final regulations are yet to be published in the official gazette of the state.

Table 3
Source specific RPOs for different states.

State	Source	RPO (%)						
		2010–2011	**2011–2012**	**2012–2013**	**2013–2014**	**2014–2015**	**2015–2016**	**2016–2017**
Bihar	Solar	0.25	0.25	0.25	0.50	0.75	1.00	1.25
Chhattisgarh	Biomass	3.75	3.75	3.75				
	Solar	0.25	0.25	0.50				
Delhi	Solar		0.1	0.15	0.20	0.25	0.30	0.35
Gujarat	Solar	0.25	0.50	1.00				
Jammu & Kashmir	Solar	0.02	0.10	0.25				
Karnataka	Solar	0.25						
Kerala	Solar	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Madhya Pradesh	Solar		0.40	0.60	0.80	1.00		
Maharashtra	Solar	0.25	0.25	0.25	0.50	0.50	0.50	
Rajasthan	Solar		0.50	0.75	1.00			
Uttar Pradesh	Solar	0.25	0.50	1.00				
West Bengal	Solar				0.25	0.30	0.40	0.50

Source: http://mnre.gov.in/file-manager/UserFiles/Solar%20RPO/state-wise-solar-RPO-targets.pdf accessed on 25/12/2012.

4. Overview of REC market in India to date

The REC mechanism is a market based instrument, to promote renewable sources of energy and development of market in electricity, leading to the sustainable development of the country [4,31,54]. REC mechanism has been designed to address the mismatch between availability of renewable electricity and the requirement of the obligated entities to meet their RPO by purchasing green attributes of RE remotely located in the form of REC [55,56]. To achieve cost competitiveness or grid parity, India, in-line with many other developed and developing countries, promotes the trade of green attributes of renewable electricity separately from its physical content [4,30]. This mechanism, in general, allows the development of the cost efficient RE sources at most efficient locations in a liberalized energy market [57–65]. The implementation issues as well as institutional framework for India have been discussed in detail by Singh [37,66] and MNRE [31]. As mentioned above, Goyal and Jha [35] discussed in detail the framework to promote RE through a framework which puts into place RPO mechanism. The framework includes setting of RPO targets, provisions for a surcharge levied upon non-compliance of RPO targets and also a mechanism to meet RPO through trading of certificates. The RE generator may sell electricity to the distribution company at an average power purchase cost (APPC) and associated RECs on a National Power Exchange. RECs can be purchased by a distribution company or other obligated entities towards meeting their RPO.

In India, RECs trading began in March 2011, on the platform of Indian Energy Exchange (IEX) and Power Exchange of India (PXI). Both the exchanges came into existence with the objective of performing day ahead and term ahead trading of electricity. The activities of the Exchange are regulated under Power Market Regulations (2010). In order to get registered and accredited in the exchanges, participants or RE producers approach their State Nodal Agencies (SNA's)[1] and state load dispatch centers (SLDC's)[2]. On the basis of reports issued by these SLDC's, National Load Dispatch Center (NLDC) issues RECs to registered market participants. The recent trend of REC trading dynamics is shown in Fig. 4. It may be noted that the REC trading volumes have been following natural trend of variability which is inherent to most of the RE sources. But the months like April 2012 and July 2012, where the gap between the sums of REC issued and closing balance and REC redeemed was apparently wide, need to be pointed out. This kind of market behavior brings excess volatility, which leads to the poor performance of price discovery mechanism. However, the recent increasing trend of REC issued (from May, 2012 to July, 2012), with the column touching new peak every month, is certainly a positive sign for Indian REC market.

Fig. 5 presents the status of RE development in India as of July 2012. It may be noted that the RE capacity registered (2965 MW) to the REC registry of India is only a small fraction (3.4%) of the estimated potential (see: Table 1), till July 2012. This might be the reason for volatile and inadequate supply of RECs. But in the long term, India has massive potential for capacity addition which may lead to huge increase in REC volume, depending on state-wise RPOs. This problem could also be addressed by redesigning the existing structure of REC market in order to increase the contribution from RE technologies which have huge potential but not much exploited, for example, solar and offshore wind. Though this will increase liquidity in the REC market, it will also pose a challenge for state and national level agencies, those are involved in REC issuance and redemption mechanism. However, the major RE technologies, except solar, have given good start with wind power as the highest (1664 MW) and small hydro power (SHP) as the lowest (152 MW) contributor.

There are literatures which advocate the tools like secondary market[3] (forward, future, hedging etc.) [67,68], banking of certificates [69,70] and price bounds/caps [71,72] to reduce the adverse effect of excess liquidity and volatility on prices. However, a price bound is the only tool which Indian REC market has used. And, it needs to be examined that up-to what extent investors' interest is safeguarded by fixing the forbearance price, i.e., upper bound and floor price, i.e., lower bound for REC prices. Table 4 provides the details about these prices in India. The price bounds are reduced for 2012–2015 due to learning effects [73–78] of emerging renewable energy technologies.

The concept of exchange came into existence in order to bring many buyers and sellers close to each other, through various real or virtual modes, and provide them a platform to negotiate over the price of a particular commodity. It is expected that REC mechanism explores the true price of green attribute of RE. And in case, when there is more than one exchange then, ideally, price of a commodity would be approximately same on all the exchanges due to arbitrage opportunity, under the assumption of no transaction cost and free movement. Figs. 6–7 depict the details about REC trading volume and price trends for IEX and PXI, respectively.

In order to draw some conclusions about their performance, parameters like coefficient of determination (R^2) and weighted average price of REC are calculated in this study. Table 5 presents a comparative analysis of REC prices at IEX and PXI. From Table 5, it is observed that REC price variation cannot be explained by any of the considered variables on individual basis. Moreover, even with a combination of two, where ratio of buy to sell bid is correlated with REC price, it is observed that buy to sell bid ratio explains only 31.4% and 10.5% of variations in REC price on IEX and PXI, respectively. It clearly demonstrates that REC market has not yet reached its market equilibrium.

[1] SNA accredits renewable energy producers and enforce RPO targets. At present there are 28 SNA's existing in India. These agencies function as per the guidelines of CERC and MNRE.

[2] SLDC monitors and accounts renewable energy injected into the grid on monthly basis.

[3] Secondary market provides a platform to trade derivatives whose underlying value is derived from the commodity traded on primary market. In this market, buyers and sellers sign a contract to exchange some pre specified commodities at some fixed time in future.

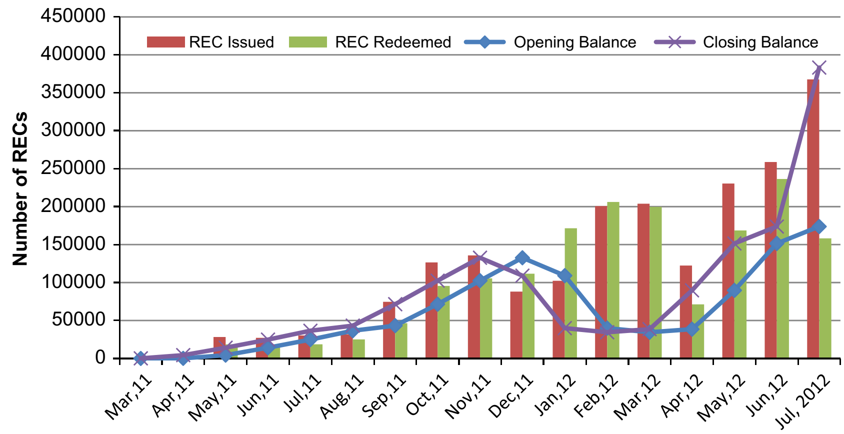

Fig. 4. REC accounting.

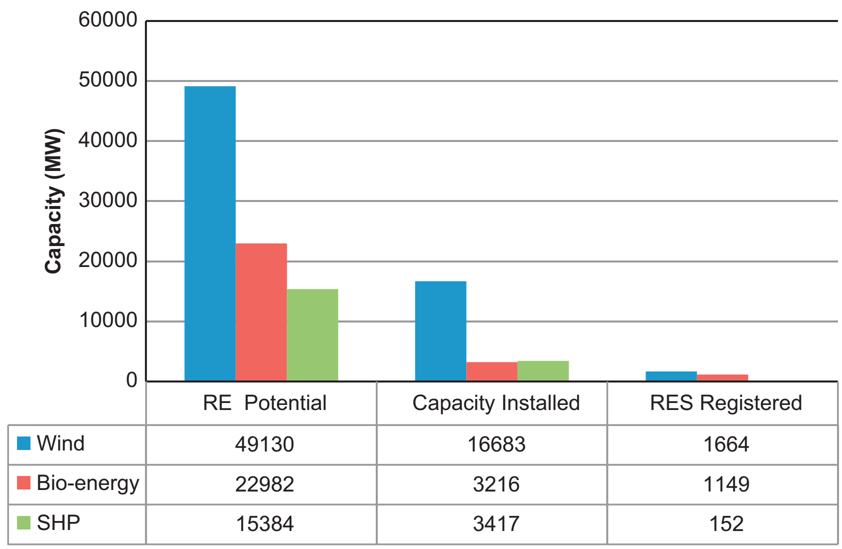

Fig. 5. Present status of RE development in India (as of July, 2012).

Table 4
Floor and forbearance prices for RECs (Rs.[a] /REC)[b].

	REC prices till 2011		REC prices for 2012–2015	
	Non-solar	Solar	Non-solar	Solar
Forbearance price	3900	17,000	3300	13,400
Floor price	1500	12,000	1500	9,300

[a] 1 USD = INR 54.5 as of Sep. 20, 2012.
[b] 1 REC = 1 MW h.

Table 6 also presents the comparative analysis of REC price at IEX and PXI. It describes the results of *t*-test and *F*-test. These statistical test shows that the difference between average REC prices is insignificant at 5% level of significance, with correlation coefficient as 0.975. Moreover, the difference between variances is also found insignificant at 5% level of significance. This kind of market behavior ensures a level playing field for all the producers and purchaser whether they are registered with IEX or PXI.

5. Performance of REC mechanism

The literature available on RE policy performance assessment used measures like RE penetration [36,63,79–81], CO_2 reduction [63], industry, innovation and employment [63,82–83], cost of RE [82–86], etc. In this section the performance of Indian REC mechanism is evaluated by proposing few parameters, which are generally considered as the measures of effectiveness for RE policies across the world. These are cost competiveness of promoted RE source, Decentralized Distribution of Generation (DDG), and RE portfolio diversity.

5.1. *Cost competitiveness*

The ultimate aim of promoting RE capacity building is to pass the available RE technologies through different learning phases[4] as early as possible to bring down its unit production cost [75,87–91]. This has led to massive investment in the form of REC price or premium for green attributes of electricity. Fig. 8 presents the REC price trend with cumulative premium paid by consumers. So far, no sign of consistent price decrease is very prominent in the existing trend (Fig. 8). But this might not happen due to price averaging/equilibrium effect. Therefore, the average of the trading ranges Rs 2629.4 per MW h is very close to calculated weighted average prices, Rs. 2619.6 per MW h and Rs. 2494.5 per MW h on IEX and PXE, respectively. Nevertheless, it

[4] It is also known as learning curve or experience curve.

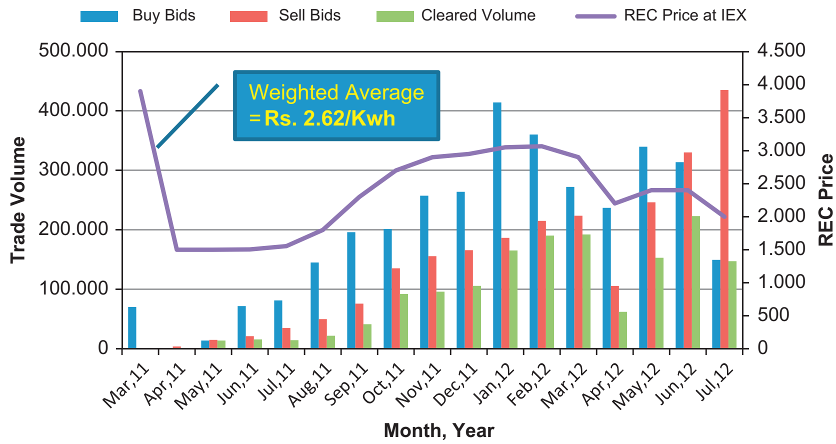

Fig. 6. REC trade at IEX.
Source: http://www.iexindia.com/Reports/RECData.aspx accessed on 03/08/2012.

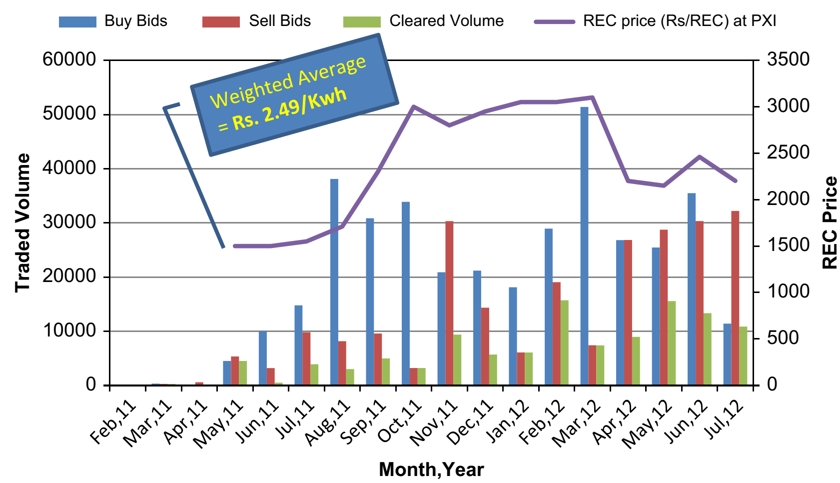

Fig. 7. REC trade at PXI.
Source: http://www.powerexindia.com/PXILReport/pages/RECMVPReport.aspx accessed on 03/08/2012.

Table 5
Comparative analysis of REC prices at IEX and PXI.

	IEX				PXI			
	Buy bid and REC price	Sell bid and REC price	Cumulative premium paid and REC price	Buy/sell bid and REC price	Buy bid and REC price	Sell bid and REC price	Cumulative premium paid and REC price	Buy/sell bid and REC price
Correlation Coeff. (R)	0.553	0.229	0.168	0.560	0.498	0.120	0.315	0.324
R^2	0.306	0.052	0.028	0.314	0.248	0.014	0.099	0.105
Weighted Average price	Rs. 2619.6 per MW h				Rs. 2494.5 per MW h			

may be considered as a sign of market stability for a short term experience. And the recent decline in average REC price could be attributed to decrease in regulated REC upper price bound.

It is observed that market is not performing well on the basis of cost competiveness. For example, Table 7 presents the comparative analysis of REC and FiT for wind based electricity from the Investors' view point. For different states, total cost under REC is higher than the state-wise preferential tariffs for wind based electricity (Table 7), when it considers average of weighted average prices for REC pricing. The average price paid was Rs. 5.74/kW h of RE electricity under REC regime while it was Rs. 3.58/kW h under existing FiT tariff. It means that approximately 60.33% higher price was paid in existing REC market mechanism. Similar kind of finding was reported by EC [85]. Though this scenario seems to be beneficial from capacity building point of view because it offers investors more earning potential, but it does not favor cost competiveness explicitly wherever levelised tariff [25] is less than the price paid under REC mechanism. This seeks the attention of policy makers to redesign the structure of existing REC mechanism.

While the influence of REC on retail tariff for customers was analyzed, it was found that it varies widely among the sample states because of wide differences in the anticipated demand [92] and the RPO obligation (Table 2), as shown in Table 8. Moreover, due to low magnitude of RPO, most of the sample states have marginal increase in cost with the exception in the states of Gujarat and Tamilnadu.

Moreover, in case of solar energy, solar REC market performance has been improving during last few months, as shown in Table 9. It has initially failed to generate enough market liquidity in spite of separate REC with higher price bounds. Though in the last few months, it has shown some activity but still due to large unmet demand, solar REC price has been hovering around the forbearance price (upper bound) of Rs. 13,400/REC. However, a recent notification by MNRE [93] which clarified state agencies for allowing use of solar REC to non-solar RPO if it is above its minimum prescribed limit may increase the liquidity of solar REC market which is expected to decrease the price of it.

5.2. Decentralized distribution of generation (DDG)

It is a well-known fact that RE sources like wind, solar, biomass, small hydro etc. are widely distributed across any geographical region. In order to harness the potential of these RE sources and to reduce the transmission and distribution losses (T&D), there is a need to promote decentralized distributed generation capacity of electricity as one of the major goals of any renewable energy development policy or programme. For example, MNRE is implementing the village electrification programme for providing financial support for electrification of those remote un-electrified census villages and un-electrified hamlets of electrified census villages where grid-extension is either not feasible or not cost effective and are not covered under Rajiv Gandhi Grameen Vidyutikaran Yojana [94,95]. Such villages are provided basic facilities for electricity/lighting through various RE sources. Small hydro power generation systems, biomass gasification based electricity generation systems, solar photovoltaic power plants, etc., in distributed power generation mode may be used depending upon the availability of resources for generation of required electricity.

In India, as shown in Table 10, it is observed that state-wise contribution in registered capacity under REC mechanism is skewed towards few states like Tamil Nadu (27%), Maharashtra (23%), and Uttar Pradesh (22%). Similarly, the state-wise contribution in number of REC projects developed is also skewed towards the states like Maharashtra (46%) and Tamil Nadu (27%), as shown in Table 10.

Moreover, when the state-wise distribution of registered capacity was compared to state-wise estimated potential, as shown in Table 9, it clearly demonstrates that though most of the states have RE potential, only few of them able to exploit it. There might be many reasons for their underperformance but the most common and detrimental is not fixing the penalty for under realization of RPO target. This was observed in the states like Madhya Pradesh, Karnataka, Rajasthan, Jammu & Kashmir etc. However, there is not even a single incidence where a state has enforced penalty clause. The level of the penalty could be looked upon as a degree of political willingness to follow the RE target. Moreover, it is also observed that few states like Gujarat, Tamil Nadu, Maharashtra, Uttar Pradesh etc. have come up with lot of innovative schemes and polices like excise duty exemption, tax holidays etc. to attract and incentivize investors to turn them into renewable energy producers while others not. Thus, growth RE sector would be contingent on facilitating a market for RE based

Table 6
Comparative analysis of REC price at IEX and PXI: results of *t*-test and *F*-test.

***t*-Test**: two-sample of REC prices with equal variances			**F-Test:** two-sample for variances	
	IEX	**PXI**	*F*	0.902
Mean	2,348.80	2,368.333	$P(F<=f)$ one-tail	0.424
Variance	329,656.74	365,611.809	*F* critical one-tail	0.403
Observations	15	15		
Pooled variance	347,634.28			
t Stat	−0.091			
$P(T<=t)$ two-tail	0.928			
t critical two-tail	2.048			
Pearson correlation	0.975			

Table 7
Comparative analysis of REC and FiT for wind power projects.

State	APPC[a]	REC weighted avg. price	GBI[b]	Total under REC	Existing preferential tariff	Profit over preferential tariff
Rajasthan	2.60	2.68	0.5	5.78	3.83	1.95
Gujarat	2.98	2.68	0.5	6.16	3.56	2.60
Maharashtra	2.62	2.68	0.5	5.80	3.50	2.30
Madhya Pradesh	2.09	2.68	0.5	5.27	4.00	1.27
Karnataka	2.66	2.68	0.5	5.84	3.70	2.14
Kerala	1.64	2.68	0.5	4.82	3.14	1.68
Tamilnadu	3.38	2.68	0.5	6.56	3.39	3.17
Andhra Pradesh	2.50	2.68	0.5	5.68	3.50	2.18
Average	**2.56**			**5.74**	**3.58**	**2.16**

Source: [25].

[a] Average Power Purchase Cost (APPC) for the year 2011–2012.
[b] GBI stands for generation based incentive.

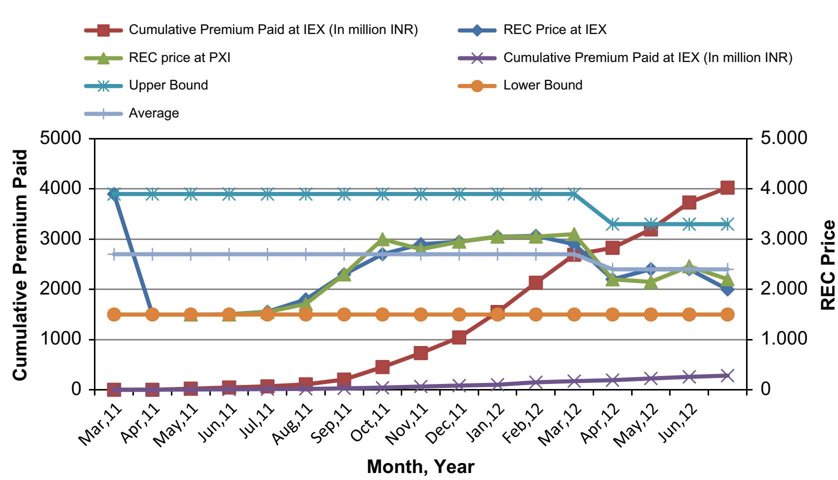

Fig. 8. REC price trend with cumulative premium paid consumers.

Table 8
Effect of REC on retail price of electricity for FY2011.

State	Anticipated electricity demand (MU)	REC demand (MU)	REC weighted avg. price (INR)	APPC (INR)	Total cost to distributor (INR)	Retail tariff (INR)[a]	Increase in retail cost (INR)
Rajasthan	49,095	4664.03	2.68	2.60	128,020.12	2.61	0.01
Gujarat	76,072	4564.32	2.68	2.98	225,325.26	2.96	−0.02
Maharashtra	124,632	8724.24	2.68	2.62	327,059.29	2.62	0.00
Madhya Pradesh	52,050	1301.25	2.68	2.09	109,552.24	2.10	0.01
Karnataka	52,751	131.88	2.68	2.66	140,320.30	2.66	0.00
Kerala	19,019	998.50	2.68	1.64	32,229.60	1.69	0.05
Tamilnadu	87,539	7922.28	2.68	3.38	290,336.22	3.32	−0.06
Andhra Pradesh	88,335	4416.75	2.68	2.50	221,632.52	2.51	0.01

[a] It ignores the transmission price differences between the states.

Table 9
Solar REC trading details from IEX.

Year	Month	Buy bids (REC)	Sell bids (REC)	Cleared volume (REC)	Cleared price (Rs/REC)	No. of participants
2011	February	11	–	–	–	1
	March	30,001	–	–	–	3
	April	–	–	–	–	–
	May	–	–	–	–	–
	June	–	–	–	–	–
	July	–	–	–	–	–
	August	1	–	–	–	1
	September	7	–	–	–	4
	October	1	–	–	–	1
	November	43	–	–	–	2
	December	495	–	–	–	0
2012	January	2,635	–	–	–	10
	February	582	–	–	–	9
	March	5,782	–	–	–	26
	April	289	–	–	–	9
	May	1,637	149	5	13,000	16
	June	9,489	541	336	12,750	17
	July	8,554	419	93	12,800	11
	August	1,728	310	129	12,850	13
	September	1,317	1,094	735	12,500	23
	October	1,263	864	820	12,680	19
	November	1,458	758	733	12,720	21

Source: http://www.iexindia.com/Reports/RECData.aspx, accessed on Dec.25, 2012.

Table 10
State wise distribution of REC projects in India.

S. no.	State	Renewable energy potential (MW)	Number of registered projects	Registered capacity under REC mechanism (MW)
1	Andhra Pradesh	6,404	0	0.00
2	Arunachal Pradesh	1,530	0	0.00
3	Assam	457	0	0.00
4	Bihar	1,044	0	0.00
5	Chhattisgarh	1,237	10	103.50
6	Goa	22	0	0.00
7	Gujarat	12,170	40	340.25
8	Haryana	1,721	3	8.50
9	Himachal Pradesh	2,416	6	47.50
10	Jammu & Kashmir	6,761	2	17.50
11	Jharkhand	276	0	0.00
12	Karnataka	10,632	8	101.60
13	Kerala	2,256	1	21.00
14	Madhya Pradesh	2,789	8	41.65
15	Maharashtra	9,007	254	683.75
16	Manipur	120	0	0.00
17	Meghalaya	275	0	0.00
18	Mizoram	167	0	0.00
19	Nagaland	195	0	0.00
20	Orissa	1,353	0	0.00
21	Punjab	3,368	2	46.00
22	Rajasthan	9,657	14	75.80
23	Sikkim	364	0	0.00
24	Tamil Nadu	7,347	150	802.16
25	Tripura	47	0	0.00
26	Uttar Pradesh	3,326	52	670.73
27	Uttaranchal	1,745	1	24.00
28	West Bengal	786	0	0.00

Source: https://www.recregistryindia.in/index.php/general/publics/registered_regens, accessed on July 30, 2012.

power; creation of demand through enforcing of RPO and creation of supply through assuring appropriate returns to investors.

5.3. RE portfolio diversity

On the lines of DDG, it is also expected that the RE portfolio should be diversified enough to hedge the risk of variable supply due to its dependence on weather. Fig. 9 demonstrates the percentage distribution of different RE sources in the portfolio of installed capacity, registered capacity and estimated RE potential. To assess the diversity of these portfolios, this study has devised a portfolio diversity index (PDI) which is based on the following assumptions:

1) The most diverse portfolio contains equal proportion of all constituents,
2) The contribution of every constituent should be greater than zero, and
3) The number of constituents should be equal while making any comparisons among portfolios

Using the above mentioned assumptions the portfolio diversity index (PDI) can be estimated as:

$$\mathrm{PDI}_k = \frac{P_1 \times P_2 \times P_3 \times \cdots \times P_n}{(1/n)^n} = \frac{\prod_{i=1}^{n} P_i}{(1/n)^n}$$

where P_i represents the proportion of ith RE source in a given portfolio ($P_i > 0$), n the number of energy sources and ($n = n_1 = n_2 = \cdots = n_k$) and k the number of portfolios compared with each other.

It may be noted that the PDI vary between 0 and 1. The portfolio diversity index calculated in this study using the above

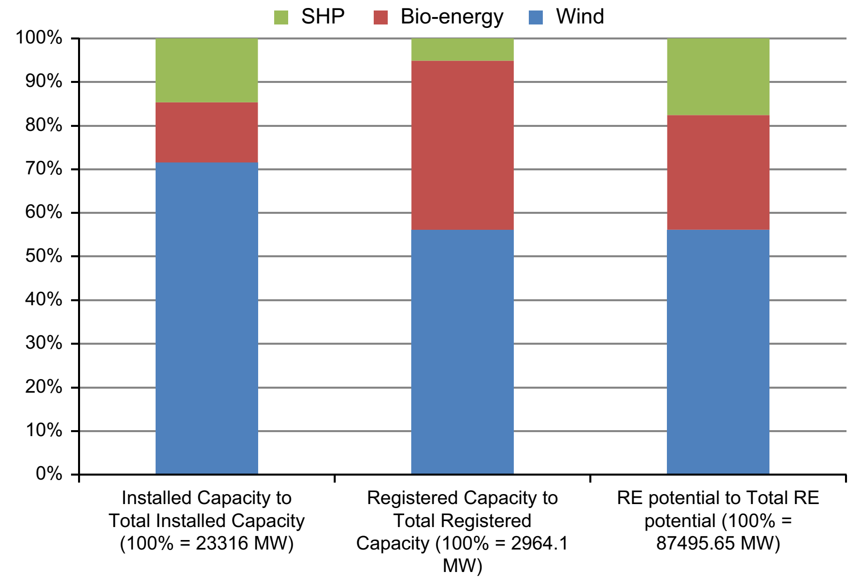

Fig. 9. Source-wise distribution of renewable under REC mechanism. To ensure uniformity in the portfolios, biomass and bio-fuel regeneration have been combined to get bio-energy share.

Table 11
Source wise distribution of REC registered electricity plants (in MW).

Renewable energy resource	No. of projects	Registered capacity (MW)	Avg. capacity (MW)	Max. capacity (MW)	Min. capacity (MW)	Range (MW)	Std. Dev. (MW)	Coeff. of variation (%)
Wind	418	1663.86	3.98	44.00	0.23	43.78	5.96	66.79
Biomass	51	520.02	10.20	34.00	1.20	32.80	6.52	156.45
Baggasse cogeneration	56	628.73	11.23	33.50	1.30	32.20	7.27	154.53
Small hydro	18	151.50	8.42	24.00	1.50	22.50	6.51	129.23
Solar PV	7	18.16	2.59	8.50	0.16	8.40	3.07	84.53

equation are estimated at 0.702, 0.393 and 0.301 for renewable energy potential, installed capacity and registered capacity portfolio, respectively. Significant differences across renewable energy potential and renewable energy installed or registered portfolios could be attributed to either REC and its trading platform design, or the differences in the state specific RE promotion policy design, or it could happen due to varying state specific need based on extent of electricity shortages. While analyzing the state wise and source wise distribution of REC registered capacity, it is observed that Indian REC market supports a wide range of average size of plant capacities, as shown in Table 11.

As shown in Table 11, the installed capacity of wind power varied from 0.225 MW to 44 MW with coefficient of variation (CV) as 66.79%. As wind energy is considered a relatively mature technology which is close to grid parity, this range or variation in capacity should be squeezed to reap the benefit of economy of scale in electricity production cost. The policy measures like increase in floor price or setting a minimum limit for plant size can resolve this issue up to a certain extent. Similarly, in case of biomass and baggasse cogeneration which have very limited estimated potential, installed capacity range varied from 1.2 MW to 34 MW and 1.3 MW to 33.5 MW respectively that should be reduced by supporting power plants which are based on some recently introduced most efficient technology and having a capacity above a minimum prescribed plant size for REC registration. Likewise, SHP, which also has a limited potential, power plant capacity range (22.5 MW) should be brought down to reduce the marginal cost of REC. Though REC registered capacity under solar technology is lowest (18.16 MW), it has highest potential among all RE technologies. In spite of separate REC, it could not get enough investors' attention due to relatively higher production cost, and due to ambiguity about states' RPO enforcement policy. Still due to reasonably high price bounds, the REC registered solar PV plant capacity ranges from 0.16 MW to 8.5 MW with as 84.33%. Thus, in case of all RE technologies, there is a need to develop a separate support mechanism for plants below a certain minimum size. In order to ensure good economy of scale this more or less similar kinds of attributes are observed with other RE sources as well.

6. Conclusion

A preliminary attempt has been made in this study to assess the performance of existing REC mechanism in India. After highlighting the salient features of the Indian RE policy framework a brief description of renewable purchase obligation (RPO) and source specific RPOs for different states is discussed along with an overview of REC market in India to date. The performance of REC mechanism in India is evaluated by cost competiveness, decentralized distributed generation and RE portfolio diversity whereas their effectiveness was measured based on available data.

While analyzing the geographical distribution of registered capacity, it is observed that state-wise contribution in registered capacity is skewed towards few states like Tamil Nadu (27%), Maharashtra (23%), and Uttar Pradesh (22%). Other states should review their policies on RPO, tax incentives etc. to increase their contribution in achieving the NAPCC target of 15% renewable electricity in national grid by 2020. At present, only a small fraction (3.4%) of estimated potential is registered under REC mechanism. This problem could also be addressed by redesigning the existing structure of REC market in order to increase the contribution from RE technologies which have huge potential but not much exploited, for example, solar and offshore wind. But the recent directives of MNRE on solar REC mechanism have been infusing some positive changes in this direction.

At this moment, it is difficult to make any conclusive remark on the success or failure of REC mechanism due to its short experience, this study examines the process to date to come out with some recommendations which can be used to fine tune the functioning of existing REC market in India. It is observed that in case of wind energy, which has maximum share (71.55%) in installed renewable energy capacity, RPO with REC policy has been not explicitly supporting cost competiveness by offering 60.33% higher average price than the existing average FiT. This could be attributed to poor price discovery mechanism of REC exchanges due to excess volatility and less liquidity. These problems may disappear in long term, if more liquidity is infused through larger shift of renewable energy producers from FiT to REC regime.

This study also demonstrates that the renewable energy portfolios developed under existing installed and registered capacity are less diverse than the renewable energy potential portfolio. This has been concluded based on the values of portfolio diversity index which are 0.702, 0.392, and 0.301 for renewable energy potential, installed and registered portfolio, respectively. Moreover, it is also observed that REC market supports a wide range of average renewable energy power plant size. For instance, in case of wind energy, it ranges from 0.225 MW to 44 MW. Thus, there is a need to develop a separate support mechanism for plants below a certain minimum size.

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