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Techno-economic Evaluation of Grid Connected Solar Rooftop Projects in India

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Abstract—*The National Solar Mission (NSM) of Government of India (GoI) has revised its target of solar power generation capacity from 20 GW to 100 GW by year 2022; which categorically specifies 40 GW capacity for grid connected rooftop solar (RTS) systems. With the cumulative installed grid connected capacity of around 7 GW; GoI has announced state wise targets for grid connected RTS projects from year 2015-16 to 2021-22. Several states have been given the targets of more than 3 GW viz. Maharashtra, Uttar Pradesh, Tamil Nadu. Till date the cumulative installed capacity of grid connected RTS projects in India have been reported as 166 MWp by Ministry of New and Renewable Energy (MNRE). The grid connected RTS projects contain several technical and financial challenges due to its variance in capacity (few watts to MW range); hence its techno-commercial viability critically depends on the policy and regulatory framework. Presently, there are 25 states which have their specific policies or regulations for promoting RTS.*

In the present study an attempt has been made to present techno-economic viability of grid connected RTS projects in India taking in to account the locations, resource, technology, and available policy measures along with cost aspects. The state policies have been ranked based upon their targets, achievements, incentives etc. The technical assessment has been carried out for 37 representative locations (i.e. all states and UTs) of India using Meteonorm 7.0 database in PVsyst software via system sizing under the scalability from 10 kW, 100 kW, and 500 kW up to 1 MW covering all consumer categories. Further a financial model has been developed in order to evaluate levelized cost of electricity (LCOE) from RTS considering the benchmark capital cost of SECI and other sources of state electricity regulatory commissions. The study presents a straight forward approach for investors towards taking techno-economic decision to implement rooftop projects in the country.

1. INTRODUCTION

Electricity would play a pivotal for a developing country like India which currently stands at 130th position on the Human Development Index (HDI), 8.37% behind the developing countries average. On one hand, it has to meet growing energy demands of its vast population and on the other hand it has to also minimize GHG emissions in order to combat climate change. With its recent global agreement at COP 21, India intends to increase the share of renewables in the electricity mix from 14% currently to 40% by 2030 and hence reduce its emissions. The launch of International Solar Alliance by India and an ambitious solar target of 100 GW by 2022 clearly highlight India's commitment for large scale deployment of solar projects. Recently, the MNRE has approved development of 33 solar parks across 21 states with a cumulative capacity of 20 GW.

The GoI has set an ambitious target of 40 GW grid connected RTS capacity by 2022 with an expectation to grow at 86% per year. To achieve this target, it has to take measures to build awareness among consumers, improve financial health of utilities, develop skilled man force, reduce investors' risks and provide adequate finance by ensuring effective policies and regulations [1]. In November 2015, Ministry of Power (MoP), GoI has launched UDAY Ujwal DISCOM Assurance Yojana scheme to revive the utilities from their financial debt while Surya Mitra program by National Institute of Solar Energy (NISE) aims to train 50,000 personnel for installation and maintenance of solar projects by 2020.

The RTS in US contributes about 0.8% to the generation capacity with more than 3 GW installed capacity in California alone. Experts predict that China would add about 7 GW capacity RTS in 2016. In India, the installed capacity of grid connected RTS stands at 166 MW [2] which includes 39 MW installations from Solar Energy Corporation of India (SECI), 1.5 MW from Ministry of Railways and 11 MW from Public Sector Undertakings (PSUs) while the MNRE estimates the potential of solar RTS to be 124 GW. Recently, India has commissioned the world's largest RTS of 11.5 MW capacity in the state of Punjab. Still, there is ambiguity among investors regarding grid parity, long term economic viability of these projects and to choose the best business model for RTS installation at a particular location based upon state specific policies/regulations. The present study attempts to address such issues via sectoral assessment.

2. METHODOLOGY

In order to carry out the study at national level, a cumulative of thirty four representative locations have been selected across India which includes state capitals and union territories (UTs). Further the central and state specific policies/regulations applicable in the above selected locations have been reviewed and ranked for each targeted sector (not presented here). Thirdly, a detailed solar radiation resource assessment has been carried out for all the locations by comparing different resolution solar radiation databases namely Meteonorm 7.0, NASA and SWERA. The detailed approach has been explained in resource assessment section. Fourthly, CUF has been estimated based upon the GHI (Global Horizontal Irradiation) values and other technical parameters using PVsyst software which has been discussed in the energy yield assessment section. Finally, the financial evaluation section presents a model developed to calculate LCOE for different consumer categories which is followed by sections on results and discussion and way forward.

3. POLICY REVIEW

The rooftop policies in India are an amalgamation of central and state policies. The central policies provide benefits like CFA (Central Financial Assistance), AD (Accelerated Depreciation) while state policies provide additional incentives (exemption on varies duties like value added tax, entry tax etc.) and frame regulations, pass orders to promote the rooftop installations in India. Under NSM, GoI has allotted ₹5000 crore for grid connected RTS implementation during 12th five year plan. The central policy provides 30% subsidy on benchmark cost to domestic, institutional and social sectors and up to 70% for special category states for the same sectors while Govt. /PSUs are eligible to receive 15-20% subsidy.

No subsidies would be granted to commercial and industrial sectors. Contrary, GoI aims to install 20 GW RTS systems by 2022 through these sectors and has already fixed 597 MW (for FY 2016-17) target for its channel partners. Further, 0.4 GW capacity projects under these sectors would be supported by $625 million soft loans from World Bank which would be channelized through State Bank of India. Indian Renewable Energy Development Agency Ltd. (IREDA) also finances RTS projects of PSUs, state utilities and private companies with minimum 1000 kWp capacity at rates ranging from 9.9% to 10.75%. The owner of the RTS system under all categories can also avail 80% accelerated depreciation benefit in the first year of the installation under the central policy. The Solar Energy Corporation of India Ltd. (SECI) has been appointed as the implementing agency by MNRE for grid connected RTS projects in India. SECI has successful implemented 39 MW capacity projects under 4 phases and had also invited bids for selected states to utilize roofs of warehouses and Central Public Works Department (CPWD) under build own operate (BOO) and Renewable Energy Service Companies (RESCO) business models respectively[4].

The state policies/regulations have been reviewed and ranked based upon the rooftop policy/regulation/order issued, state specific roof top targets and respective achievements, state subsidy/incentives, specifications of grid integration, eligibility for Renewable Purchase Obligation (RPO) and Renewable Energy Certificate (REC) mechanism, metering mechanism and settlement of excess units supplied to the grid.

As on March 2016, out of 29, only 16 states have announced solar policy, while 8 states have grid connected roof top policy, 19 states have net metering regulations and only Haryana has passed orders to mandatory install RTS projects on all buildings. The MNRE has proposed yearly targets for 7 years up to 2022 for all states including UTs. However, only few states like Gujarat, Haryana, Himachal Pradesh, and Uttar Pradesh have considered them in their respective policies. The solar potential, energy consumption pattern and grid integration issues are state specific. Therefore, the MNRE should actively involve all stake holders (consumers, state nodal agencies & state utilities) in a state while setting up targets. Punjab leads the country with 26 MWp RTS installations, followed by Gujarat with 23 MWp and Chhattisgarh with 17 MWp. Besides, CFA from MNRE, the states of Gujarat, Tamil Nadu, Telangana and Uttarakhand have proposed additional subsidy on benchmark cost for domestic consumers while Delhi has proposed GBI (Generation Based Incentive) of Rs.2/kWh for all sectors. If realized, these schemes would substantially improve the techno economic viability of RTS projects particularly for domestic sector.

In 26 states, the RTS projects are eligible for meeting the RPO compliance of the state utilities. MNRE has requested the states to meet 8% solar RPO by 2022, which does not seem feasible observing the technical challenges of grid integration and current financial crisis faced by the state utilities. The Supreme Court favoring the enforcement of RPOs may productively contribute to the target to some extent. Also, REC framework was developed to eliminate the difference in RE potential of a state and the RPO of its obligated entities. The present condition of REC market is lethargic with over 17 million unsold RECs, as on May 2016.

In this context, it would be sensible for commercial and industrial consumers with RTS projects generating more than 100 MWh/year to utilize environmental attributes as RECs and sell the electricity component at APPC (Average Power Purchase Cost). Countries like US and Germany has successful adopted Feed in Tariff (FiT) mechanism in the past to ensure rapid deployment of RE projects. In India, only Rajasthan has opted for this policy mechanism, which raises risks to the techno economic viability of the project over its life, considering the rapid declining cost of PV modules.

Net metering mechanism is being emphasized by 19 states through their regulations while its operational ability is still arguable. Few states support both net as well gross metering mechanisms. In net metering, the solar power generated is consumed and excess units are supplied to the grid which is accounted by a bi-directional/net meter and generally settled at APPC. In gross metering, the entire power generated through RTS systems is injected to the grid which is accounted by a solar meter and settled at the applicable solar tariff while the consumer pays for the units consumed from grid at the applicable grid tariff. Taking into account, the long term challenges of integrating RE to the grid, net metering mechanism is favorable for India as it is easy for consumers to understand and state utilities to implement.

4. RESOURCE ASSESSMENT

The solar radiation resource assessment forms the backbone of detailed project report of any commercial scale project. In the present study, the following three different databases were analyzed viz;

- NASA satellite data
- SWERA satellite data
- Meteonorm 7.0 time series data

The yearly values of GHI provided by all the three databases were compared following the approach of Purohit and Purohit, 2015[3]. Since, Meteonorm 7.0 data is most widely recommended for commercial projects, it has considered as the base data for comparison. It has been observed that the mean percentage error (MPE) in yearly GHI values for NASA database varies from 0.4% to 18.9%, while the range is 0.5% to 15.8% for SWERA database. Among the 37 representative locations, Dehradun receives the highest annual GHI of 2156.1 kWh/m^2 while Itanagar receives the lowest annual GHI of 1392 kWh/m^2.

5. ENERGY YIELD ASSESSMENT

The energy yield assessment has been carried out for each selected representative location using Meteonorm 7.0 weather database. In order to size the rooftop solar PV system multi-crystalline technology has been found optimum. The solar PV module manufactured by Canadian Solar has been selected for energy yield estimation which is a TIER-1 manufacturer. For 10 kW capacity project string inverter of ABB is selected; however for higher capacity the central inverter of ABB are considered. The energy yield estimation has been carried out using PVsyst software under fixed axis (modules tilted equator facing and inclined near the latitude of the location) project design approach. The associated DC and AC losses have also been considered for assessment. The systems were sized for four different consumer categories: 10 kW (domestic), 100 kW (institutional), 500 kW (commercial) and 1000 kW (industrial). The annual capacity utilization factor (CUF) of the rooftop systems under all categories for all locations has been summarized in Table 1.

Table 1: Techno-economic analysis of grid connected RTS projects

Location	Annual GHI	Lat	Long	Residential (10 kW)		Institutional (100 kW)		Commercial (500 kW)		Industrial (1000 kW)	
	(kWh/ m^2)	(^{o}N)	(^{o}E)	CUF (%)	LCOE (□/kWh)	CUF (%)	LCOE (□/kWh)	CUF (%)	LCOE (□/kWh)	CUF (%)	LCOE (□/kWh)
Agartala*	1876.	23.8	91.3	19.01	2.86	18.18	2.99	18.56	6.99	18.85	6.88
Aizawl*	2037	23.7	92.7	20.40	2.67	20.63	2.64	20.84	6.23	21.98	5.90
Amravati	1796	16.5	80.5	16.77	5.81	17.23	5.66	17.59	7.38	18.59	6.98
Bengaluru	2024	13.0	77.6	19.04	5.12	19.54	4.99	19.94	6.51	21.08	6.15
Bhopal	1958	23.3	77.4	17.29	5.64	18.51	5.27	18.89	6.87	19.15	6.78
Bhubaneswar	1787	20.3	85.8	16.51	5.90	16.96	5.75	17.32	7.49	17.55	7.39
Chandigarh	1994	30.8	76.8	18.59	5.24	19.08	5.11	19.48	6.66	19.74	6.57
Chennai	1883	13.1	80.3	17.29	5.64	17.77	5.49	18.13	7.16	18.38	7.06
Daman	1920	20.4	72.9	18.79	5.19	18.14	5.37	18.52	7.01	18.77	6.91
Dehradun*	2156	30.3	78.0	20.20	2.69	20.72	2.63	21.15	6.13	21.44	6.05
Delhi	2144	28.6	77.2	21.04	4.63	20.91	4.66	20.74	6.26	21.03	6.17
Dispur*	1856	26.1	91.8	18.45	2.95	17.82	3.06	18.19	7.13	18.43	7.04
Gandhinagar	2037	23.2	72.7	19.78	4.93	19.10	5.10	19.49	6.66	19.76	6.57
Gangtok*	1601	27.3	88.6	16.50	3.30	15.91	3.42	16.25	7.98	16.46	7.88
Hyderabad	1947	17.4	78.5	18.99	5.13	18.34	5.31	18.71	6.93	18.97	6.84
Imphal*	1738	24.8	94.0	17.49	3.11	16.88	3.23	17.24	7.53	17.47	7.43
Itanagar*	1392	27.1	93.6	14.09	3.86	13.56	4.02	13.86	9.36	14.04	9.24
Jaipur	2093	26.9	75.8	20.40	4.78	19.71	4.95	20.11	6.45	20.39	6.36
Kavaratti*	1852	10.6	72.6	18.20	2.99	17.57	3.10	17.93	7.24	18.18	7.14
Kohima*	1699	25.7	94.1	17.37	3.13	16.76	3.25	17.12	7.58	17.35	7.48
Kolkata	1784	22.6	88.4	17.65	5.52	17.03	5.72	17.38	7.47	17.62	7.36
Lucknow	1886	26.8	80.9	18.62	5.23	17.97	5.42	18.34	7.07	18.59	6.98
Mumbai	1859	19.0	72.8	18.17	5.37	17.54	5.56	17.90	7.25	18.15	7.15
Panaji	1988	15.5	73.8	19.43	5.02	18.77	5.19	19.15	6.78	19.42	6.68
Patna	1729	25.6	85.1	17.09	5.70	16.49	5.91	16.83	7.71	17.06	7.61
Puducherry	1871	11.9	79.8	18.31	5.32	17.67	5.52	18.03	7.20	18.28	7.10

Port Blair*	1626	11.7	92.7	16.12	3.38	15.54	3.50	15.87	8.18	16.09	8.06
Raipur	1888	21.3	81.6	18.47	5.28	17.83	5.47	18.20	7.13	18.45	7.03
Ranchi	1936	23.4	85.3	19.17	5.08	18.51	5.27	18.89	6.87	19.15	6.78
Shillong*	1719	25.6	91.9	17.35	3.14	16.74	3.25	17.10	7.59	17.33	7.49
Shimla*	2023	31.1	77.2	20.66	2.64	19.96	2.73	20.38	6.37	20.65	6.28
Silvassa	1917	20.3	73.0	18.70	5.21	18.06	5.40	18.43	7.04	18.68	6.95
Srinagar*	2084	34.1	74.8	21.32	2.55	20.60	2.64	21.04	6.17	21.31	6.09
Trivandrum	1948	8.5	77.0	19.10	5.10	18.44	5.29	18.82	6.89	19.08	6.80

**(Locations under special category, eligible to claim 70% CFA for installations in domestic and institutional sectors)*

6. FINANCIAL EVALUATION

A financial model was developed to determine LCOE from RTS projects for different consumer categories based upon the latest benchmark cost of SECI, Gujarat Electricity Regulatory Commission (GERC) regulations [5], applicable state / central subsidies and accelerated depreciation benefits. Some of the key parameters considered; benchmark cost: ₹ 75,000/kW, operation & maintenance cost: ₹ 1,090/kW and discount rate: 11%.

7. RESULTS AND DISCUSSION

Table 1 depicts the CUF and LCOE values for different consumer categories across all representative locations. It has been observed that CUF varies from 21.32% to 14.09% for domestic consumers while the LCOE varies from ₹ 5.90/kWh to ₹ 2.55/kWh. Similarly, for institutional sector CUF varies from 20.91% to 13.56% and LCOE from ₹ 5.91/kWh to ₹ 2.63/kWh. Certainly, the techno economics of RTS projects in domestic and institutional sector would be an alluring investment for developers with these sectors achieving grid parity. The commercial and industrial sectors would gradually achieve grid parity. Based upon the policy ranking and techno economic evaluation of all the locations, Dehradun is recognized as the best location for RTS projects for all consumer categories.

8. WAY FORWARD

The above study has been conducted for only 34 locations in India which could be extended to other locations as well. An approach could be developed for financial analysis of business models catering to different consumer categories. Moreover, grid integration issues and its rectification measures could be worked out in detail.

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