सत्यमेव जयते

Techno-Economic Analysis of Renewable Energy-Round the Clock (RE-RTC) Supply for Achieving India's 500 GW Non-Fossil Fuel Based Capacity Target by 2030

केविप्रा
cea

GOVERNMENT OF INDIA
MINISTRY OF POWER
CENTRAL ELECTRICITY AUTHORITY

घनश्याम प्रसाद
अध्यक्ष तथा पदेन सचिव भारत सरकार
GHANSHYAM PRASAD
Chairperson & Ex-officio Secretary
To the Government Of India

सत्यमेव जयते

75 आज़ादी का अमृत महोत्सव

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FOREWORD

India's energy landscape is undergoing a transformative journey, marked by a steadfast commitment to sustainability and energy security in response to the global shift towards clean and green energy sources. The transition is not merely based on a shift in power generation sources, but accompanied by new and innovative power supply solution (i.e. hybrid, RTC, RE-RTC etc.) which necessitates a paradigm change of the energy supply contracts. India is actively pursuing a diverse and inclusive energy mix that prioritizes the development of solar and wind energy, promotion of advanced storage solutions etc., keeping in view the objective of enhancing energy security, decarbonizing the power sector, ensuring viability of power sector and adoption of consumer centric approach.

The government of INDIA's target of achieving 500 GW of capacity from non-fossil sources by 2030 is a step towards addressing its energy security, climate change, and economic development challenges. There is a growing need for balancing the variation in the renewable power supply with storage, to provide a steady power supply 24*7 in the grid to meet the demand reliably. India is emphasizing energy storage technologies in addition to promoting RE hybrid projects besides mandating flexible operation of coal-based generation, precise forecasting & scheduling, demand side management and integrating RE projects at different locations through national grid.

Renewable Energy based Round the Clock (RE-RTC) supply has the potential of achieving dual benefits of providing reliable, flexible, dispatchable power while simultaneously reducing the impact of greenhouse emission.

I appreciate the efforts put in by Member (Planning), CEA and his team of officers from Integrated Resource Planning Division, CEA, in bringing out this report, which I believe will help the Policy Makers, RE developers and Distribution Utilities in understanding the scope and functioning of RE-RTC which is expected to play a major role in Indian Power Sector.

(Ghanshyam Prasad)

A Balan
Member (Planning)
Central Electricity Authority
& Ex-officio Additional Secretary
to Government of India

PREFACE

India's announcement of achieving net zero emissions by 2070 and to meet fifty percent of its electricity requirements from non -fossil energy sources by 2030 is a hugely significant moment for the global fight against climate change. This requires significant RE sources (Solar, Wind) addition over the years which poses further challenges of variability and intermittency associated with such sources.

The report titled "Techno-Economic Analysis of Renewable Energy-Round the Clock (RE-RTC) Supply for Achieving India's 500 GW Non-Fossil Fuel Based Capacity Target by 2030" has been prepared by carrying out detailed modelling Studies to explore the possibility of designing a FDRE (Flexible Dispatchable Renewable Energy) sources by combining Solar, Wind and storage system.

A State-of-the-art sophisticated generation expansion planning model has been used to carry out the studies to determine optimal combination of Solar, Wind, and storge system for designing RE-RTC based on the RE profile and Demand requirement. The study explores the diversity factor across the RE profile and the possible ways to utilize it.

I convey my sincere thanks to Smt Ammi Ruhama Toppo, Chief Engineer and the officers of Integrated Resource Planning division, CEA for successfully carrying out a comprehensive study and coming up with this report which will give the reader a holistic idea and understanding of RE-RTC and its possible impact on the Indian Power Sector.

(A Balan)

Ammi Ruhama Toppo
Chief Engineer
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ACKNOWLEDGEMENT

The preparation of report titled "Techno-Economic Analysis of Renewable Energy-Round the Clock (RE-RTC) Supply for Achieving India's 500 GW Non-Fossil Fuel Based Capacity Target by 2030" would not have been possible without the expert guidance of Chairperson, CEA and Member (Planning) CEA.

I am thankful to various stakeholders in the power sector who have given their valuable suggestions and words of encouragement towards finalization of the report.

I am also thankful to the dedicated team of Integrated Resources Planning division, CEA for their tireless efforts in carrying out studies and preparing this report. The specific contribution made by following officers of IRP division is well appreciated and acknowledged with thanks: -

1. Mr. Apoorva Anand Deputy Director
2. Ms. Jyotsana Kapoor Deputy Director
3. Mr. Girija Sankar Pati Assistant Director

(Ammi Ruhama Toppo)

Contents

EXECUTIVE SUMMARY

India has set an ambitious target of achieving 500 GW of non-fossil Fuel based capacity by 2030, majority of which will be from renewable sources such as Solar and Wind. These sources provide a challenge for grid operation due to variability & intermittent nature of supply. There is a growing need for balancing the variation in the Renewable power supply with storage to provide a steady power supply 24*7 in to grid to meet the demand of DISCOMS. RE-RTC (Renewable Energy-Round the Clock) is a form of supply that combine storage system such as battery energy Storage system or PSP with Solar, Wind or Hydro to meet a demand at a desired availability and cost. Round the Clock (RTC) supply has gained prominence in recent years due to various benefit it provides; Reliable supply of Power, Combination of Solar and wind with complimentary profile, reducing the Green Housing Gas (GHG) emission etc. This paper presents a techno-economic analysis of different combination of RE-RTC based on generation profile of Renewable Sources and Storage Solutions, Investment cost and demand profile etc. The study explores combination of RE sources for RE-RTC to meet the requirement of different consumers with different demand profile. With Reduction of Cost of Storage technologies, it is expected that RE-RTC will become cost competitive with other standalone renewable technologies and the dependence on fossil fuel sources may be reduced in the future. Overall, achieving RE-RTC is a critical goal for reducing greenhouse gas emissions and ensuring a sustainable energy future. While there are still technological and economic challenges to overcome, continued investment and innovation in renewable energy systems can help accelerate progress towards this goal

1.0 INTRODUCTION

With the objective to provide RTC power to the DISCOMs through renewable energy sources complemented with storage and facilitating the scale up of renewable capacity addition and achieve economies of scale along with fulfilment of RPO requirement of the obligated entities, RE RTC (renewable Energy Round the Clock Supply) is being considered as a viable option. The concept of Green Hydrogen is gaining popularity and RE RTC power supply can be reliable energy source for green hydrogen production to realize its huge potential in decarbonisation.

Recently the Ministry of Power has published Guidelines for Tariff Based Competitive Bidding Process for Procurement of Firm and Dispatchable Power from Grid Connected Renewable Energy Power Projects with Energy Storage Systems dated 09th June 2023. These Guidelines are being issued under section 63 of the Indian Electricity Act,2003 to enable procurement of Firm and Dispatch able RE power by Distribution licensees from grid-connected Renewable Energy (RE) power projects, with Energy Storage through tariff based competitive bidding. Firm and Dispatch able RE power means supply of electricity to match the demand profile of consumer (Distribution companies, Open access consumers etc.).

The objective of guidelines is as follows:

(a). To provide firm and dispatchable power to the DISCOMs from renewable energy sources;

(b). To promote renewable capacity deployment and fulfilment of Renewable Purchase Obligation (RPO)/ Storage Power obligations (SPO)requirement of DISCOMs;

(c). To provide a transparent, fair, standardized procurement framework based on open competitive bidding with appropriate risk-sharing between various stakeholders to enable procurement of power at competitive prices in consumer interest, improve bankability of projects and ensure reasonable returns to the investors; and

(d). To provide for a framework for the inter-state/ intra-state, long-term, sale-purchase of power as a further measure to de risk the sector.

In October 2019, the Solar Energy Corporation of India (SECI) issued the first-ever RTC tender for 400MW (RTC-1). The following March, another SECI 5,000MW RE-plus-thermal (RTC-2) tender was announced (the capacity was reduced to 2,500MW in December 2020). In May 2020, for the RTC-1 auction set the lowest bid (L1) tariff discovered for the first year of the power purchase agreement (PPA) was at Rs2.9/kWh (3% annual escalation for first 15 years). Similarly, for RTC-2 auction conducted in October 2021, the L1 tariff discovered was Rs 3.01/kWh.

The key differences of RTC-1 & RTC-2 can be summarized below:

Tender Attribute	**SECI RE 400 MW (RTC-1)**	**SECI RE 2500 MW (RTC-2)**
Tariff Structure	Scalable with annual escalation	Part fixed, part variable Scalable only for fuel and transport part
Required Power Supply Profile	Annual CUF- 80% Monthly CUF-70%	Annual CUF- 85%
Peak Hour Duration	Not defined	4 Hours
Penalty Provision in case of shortfall	300% of the PPA tariff for the shortfall in energy terms	400% of the applicable tariff payable during the year for the corresponding shortfall in energy terms

Source: SECI Tender Document

Both RTC-1 & RTC-2 tenders imposed annual and monthly CUF constraints in terms of energy however RTC as a product in the true sense needs to ensure availability at block level (15 min). This results in significant storage requirement as well as oversizing the capacity which leads to higher levelized tariff.

The Ministry of power in Oct, 2023 notified the Year wise Renewable Purchase Obligation up to 2029-30 starting from 2024-25 for all electricity distribution licensee and other designated consumers, open access and captive consumers. The notification mandates the minimum share of consumption of electricity to be procured form renewable energy sources. The RPO requirement of these utilities can be met by procurement of standalone sources such as Solar, Wind, Hydro or through combination of one or more sources (i.e. hybrid, RTC). Compared to stand alone sources, the RE-RTC provides higher reliability and greater flexibility. With the global trend of reduction in investment costs of Solar, Wind, BSES and other form of storage projects, the per unit cost of generation is likely to further reduce.

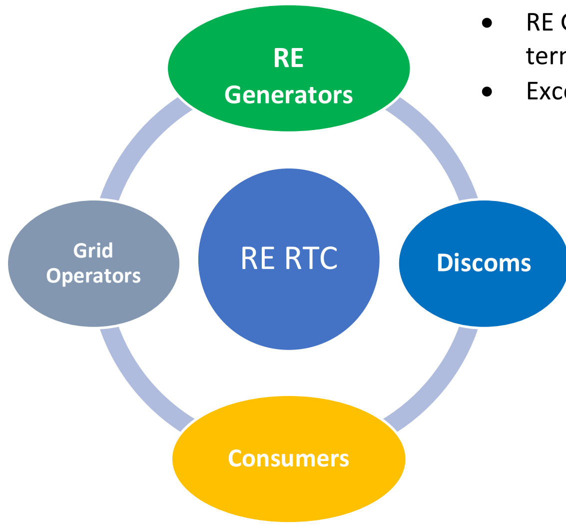
As per Rule 16 of the Electricity (Amendment) Rules, notified in December 2022, ministry of power has already issued guidelines in June 2023 for assessment of resource adequacy during the generation planning stage and operational planning stage. Due to uncertainty and intermittency associated with Solar and wind resources, the distribution utilities need to procure additional firm capacities to meet the variation in demand, RE Sources, outage of conventional sources.RE RTC in this regard proves to be more reliable and efficient when compared to plain vanilla Solar/Wind generation to fulfil resource adequacy requirement of the utility.

1.1 Benefits of RE RTC

RE RTC proves to be beneficial at all levels of the electricity value chain. The following exhibit depicts the same.

- Reduces intermittency, Generator risk
- RE Generators can make Long-term PPA based on Availability
- Excess Generation can be traded

- Reduces the impact of intermittency of RE generation on Grid
- Helps grid operator in Scheduling as available firm capacity
- Peaking support available during peak demand hours



- RPO Target
- Variable cost of Coal plants can be minimized.
- Peaking Support
- Reduced dependence on Power Exchange and associated volatility

- Helpful for C&I and open access consumers to reduce their tariff in future

Additionally, RE RTC can also help in achieving

1. Reduction of greenhouse gas emission
2. Adoption grid scale Pump Storage project (PSP) & Battery Energy Storage System (BESS)
3. Leveraging Diversity in demand pattern and RE profile of Utilities
4. An alternative sustainable firm source of Power as compared to Coal and Gas and other conventional Sources

Based on the above analysis it is evident that RE RTC is the way forward for achieving the Govt of India's target of achieving 500 GW of installed capacity from nonfossil sources by 2030 and achieving net zero emission by 2070. However, RE RTC is in a nascent stage of development in the country. To promote wide scale adoption of RE RTC, the developers need to understand the requirement of Utilities based on their demand pattern and RE profile. Similarly, awareness among the policy makers and regulators needs to be created regarding the benefits and impact of RE RTC in the Indian Power sector.

Central Electricity Authority has carried out a study to asses various scenarios wherein RE generation viz. solar and wind generation sources across different region/states of the country may be combined with storage capacity to provide RE-RTC power at a certain availability and load profile at least cost. The study ensures optimal utilization of resources while facilitating reduction in curtailment. The study considers state specific solar and wind profile. Investment and O&M costs of Solar, Wind and Storage (BESS and PSP) have been sourced from National Electricity Plan (2022-32).

1.2 Objective of Study:

The study aims to determine

- The optimal Solar, Wind & Storage Requirement to meet RE RTC demand based on demand pattern and RE profile
- The per unit cost of Generation
- The total Investment cost requirement
- The impact of diversity and state/regional variation of demand pattern and RE Profile on RE RTC

The studies were carried out using generation expansion planning model namely ORDENA. ORDENA is a mixed integer linear optimization program that minimizes the net present value of investment and operating costs subject to several constraints. Hourly Solar and Wind Profile various states based on actual generation has been considered in the model. The model optimizes total investment required to meet the energy and peak demand based on the demand profile.

1.3 Assumptions:

State specific hourly solar and wind profile have been considered for the study. The CUF and cost considered for various sources based on the location is given below in Table 1 and Table 2.

Table 1

Source	Annual CUF (%)
Gujarat Wind	26.67
Karnataka Wind	30.61
Maharashtra Wind	26.83
Tamil Nadu Wind	29.15
Madhya Pradesh Solar	20.78
Maharashtra Solar	20.74
Tamil Nadu Solar	20.71
Telangana Solar	20.78
Gujarat Solar	19.9

Battery Energy Storage System (BESS) and Pump Storage Plant (PSP) have been considered to provide storage for the RE RTC power. The PSP & BESS investment cost and operational characteristics considered are given below in table 2.

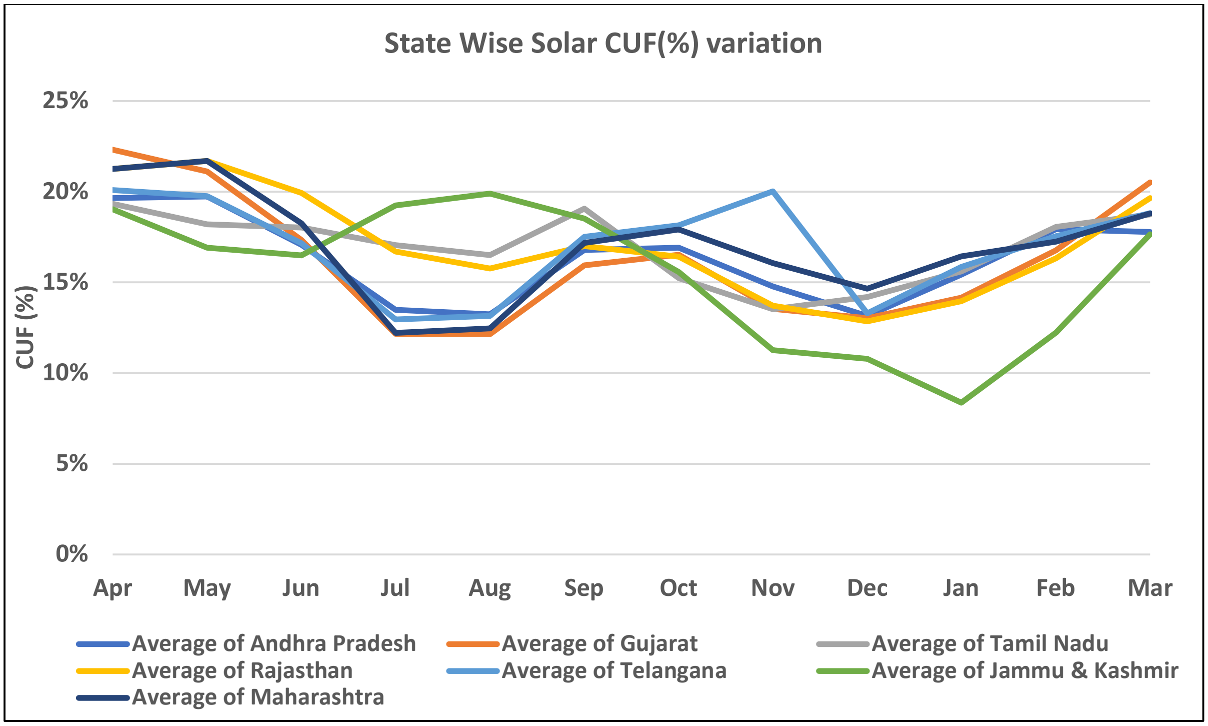
Table 2

Name of Technology	Cost of Investment (Rs/MW) *
Solar	4.5 Cr
Wind	6 Cr
Hydro	8-10 Cr
PSP (6 hours)	4-6 Cr
Battery (5 Hour Storage)	8 Cr

*All prices Considered are at 2022-23 price level.

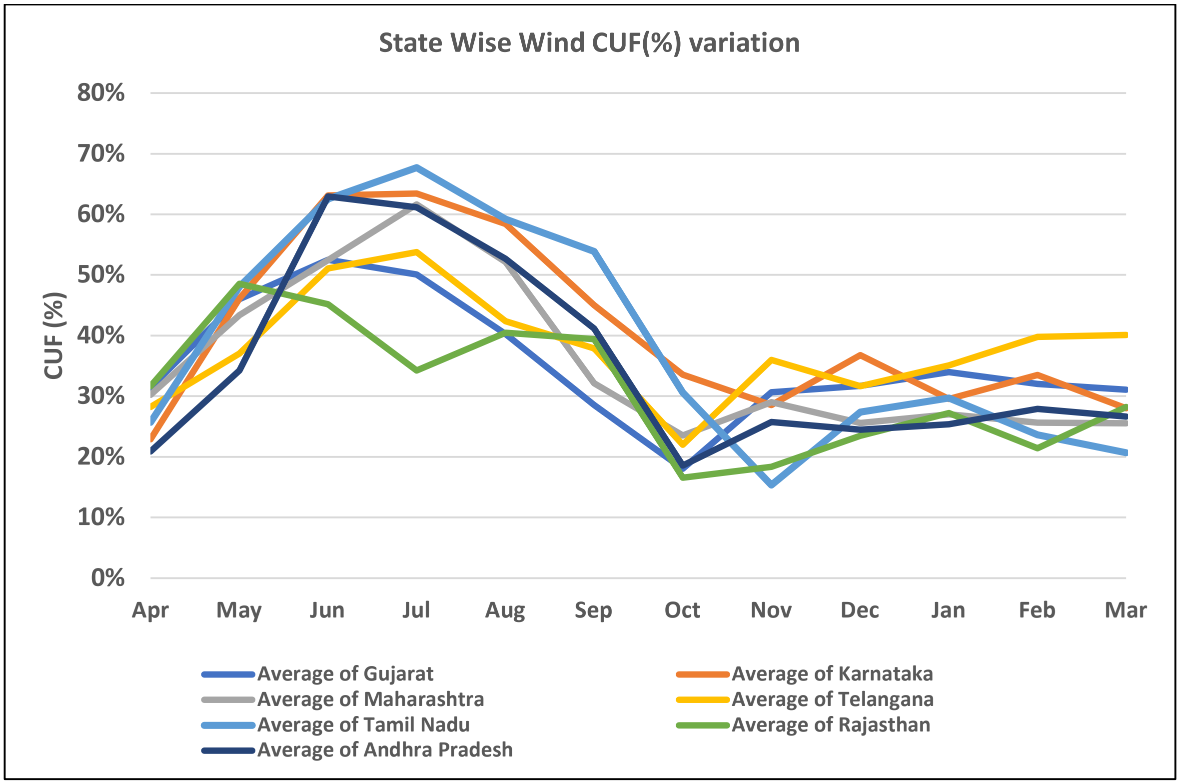
The monthly variation in Solar availability (%) for various states is shown in Exhibit 1. It may be observed that solar generation varies across seasons in the country, with lower available insolation during monsoon and winter months.

Exhibit 1



The monthly variation in wind generation of various states is shown in Exhibit 2. It may be observed that wind generation is highly seasonal and varies significantly across different states.

Exhibit 2



1.4 Cases considered for the study

The demand pattern of Utilities plays a significant role in determining the generation capacity mix. The demand pattern may require peaking requirement at different instances of the day based on various factors including agricultural load pattern, weather, temperature among others. So, the requirement of RE RTC power may vary from one state to state and based on the requirement of the end user the RE RTC product needs to be customized.

Based on the demand pattern analysis, the requirement of RE RTC from consumer point of view can be one or a combination of the possibilities below.

a. **RE RTC as an alternate source of expensive coal or gas generating station**. These expensive coal and gas generating station may be utilized during the peak demand season but scarcely utilized during lean period. By replacing these expensive coal and gas generating station from the portfolio, distribution utilities may reduce their fixed cost burden while simultaneously ensuring the availability of equivalent amount of RE RTC product to meet their requirement during peak demand period.

b. **Morning & Evening Peak (diurnal variation):** The demand pattern of a no of utilities have been analysed and it was observed that morning and evening peak requirement is significant during some period of the year. The RE RTC can be customized for these utilities to cater to this demand. This will reduce the dependency on the energy exchange to meet this demand.

c. **C&I Customer:** In 2021-22, the C&I consumers constituted 36.2 % of the total power demand in the country, amounting to approximately 412.9 BU. This is expected to grow at a CAGR of 8.2% with an estimated demand of 775.3 BU by 2030 (Source: *20th EPS, CEA*). C&I consumers have shown a strong interest in transitioning to RE recently in light of the dual benefits of savings and sustainability. Currently, grid tariffs in India for most C&I consumers exceed INR 7.00/kWh while RE prices have dropped precipitously in the last few years.RE power has proved highly competitive in the current scenario. Furthermore, many large C&I consumers have internal green mandates and the transition to RE procurement enables them to meet these targets. In light of these interest shown by C&I customers a typical demand pattern has been considered to be met fully from RE RTC product. This will enable them to label their produce as green which will make them competitive in the foreign market.

d. **State Specific RE RTC:** State specific RE RTC can be customized based on the RE profile of RE rich states (i.e. Gujarat, Tamil Nadu, Karnataka, Maharashtra, Rajasthan etc.). This will help the respective RE generators to develop the product accordingly.
e. **RE RTC with annual & monthly availability:** Existing RE RTC product in the market (RTC-1, & RTC-2) ensures availability on an annual and monthly basis. Similar product has been customized for specific RE rich states based on the available RE pattern.

Hourly demand profiles considered for the study as shown in Exhibit 3 include:

1. Flat Demand profile of 100 MW at every instant of time.
2. Morning & Evening 100% Peak support & 90/80/70/50% availability during other period (as defined by the consumers)
3. Double shift load profile (8 AM-10 PM) for C&I consumer.
4. Flat Demand profile of 100 MW with Specific State Solar & wind profile based RE RTC.
5. C&I consumers with state specific Solar and wind Profile
6. RE RTC with annual availability of 80%, 90% and 95%

The load profiles are based on the prevalent requirement of various consumer (DISCOMS, Industry, service sector, Open access consumers) etc. the demand patterns are shown in exhibit 3 (a), (b), (c) below:

Exhibit 3a

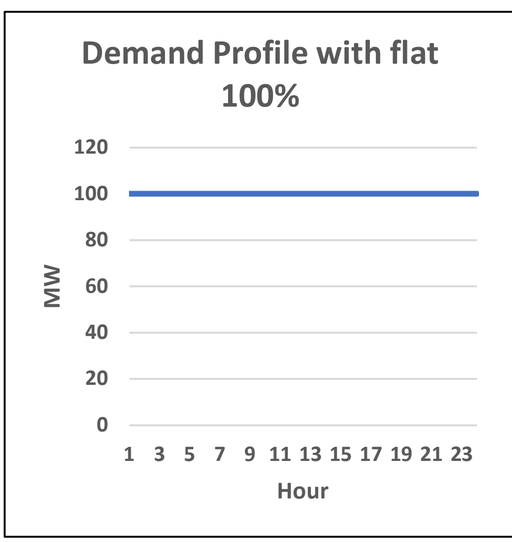


Exhibit 3b

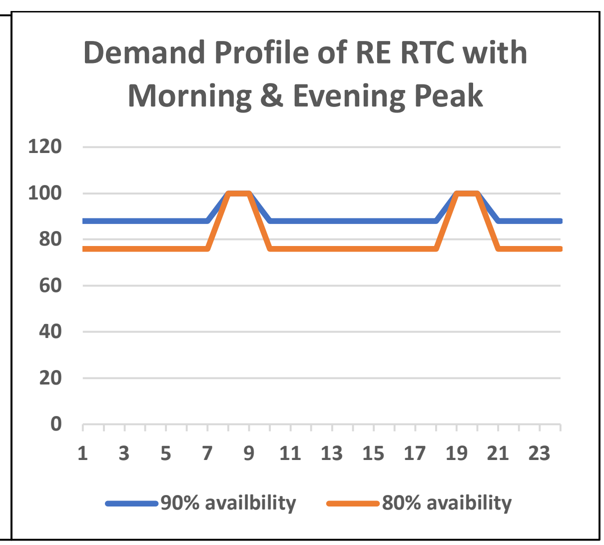
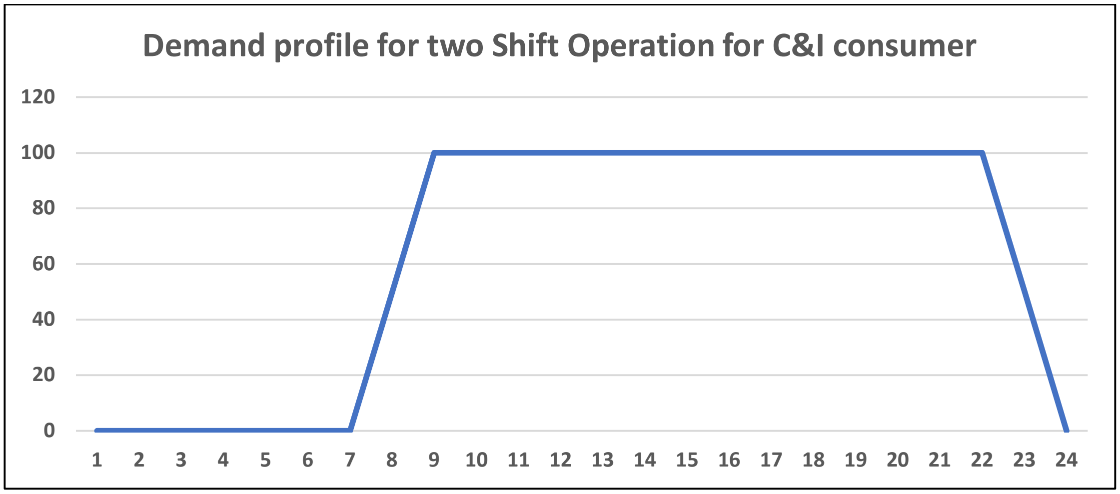


Exhibit 3c


Demand profile for two Shift Operation for C&I consumer
120
100
80
60
40
20
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24

2.0 Result Analysis

Use Case 1: RE RTC at 100% availability (Flat Demand profile)

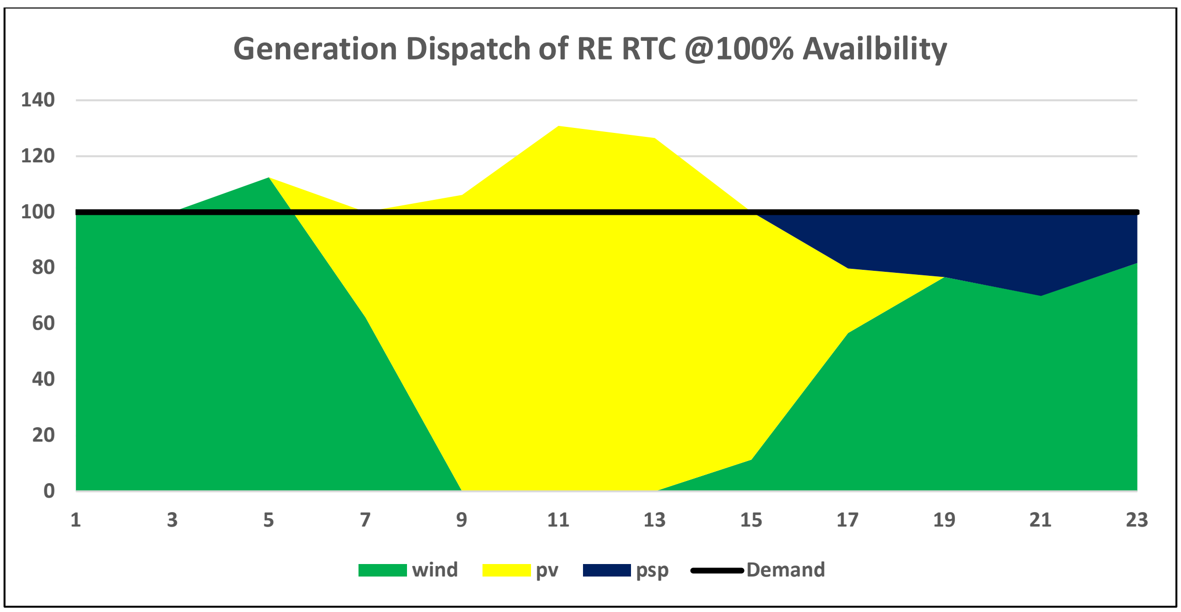
A case study for a flat demand profile of 100 MW from RE RTC has been modelled. The Capacity requirement and per unit cost is shown in table 3. A typical demand profile for RE RTC is shown in Exhibit 3a. The dispatch for a typical day is shown in Exhibit 4.

Table 3

Source	Installed capacity in MW
Gujarat WIND	55
Karnataka WIND	147
Maharashtra WIND	52
Tamil Nadu WIND	116
Telangana SOLAR	184
PSP (6 Hours Storage)	67
Energy (in MWh)	876000
Per unit Cost (Rs/kWh)	4.95

The result represents the ideal case for power procurement leveraging the diversity and complementarity of solar and wind generation from different states. However, the power procurement from the relevant states strictly adhering to the quantum of capacity obtained as per the results may be practically challenging.

Exhibit 4



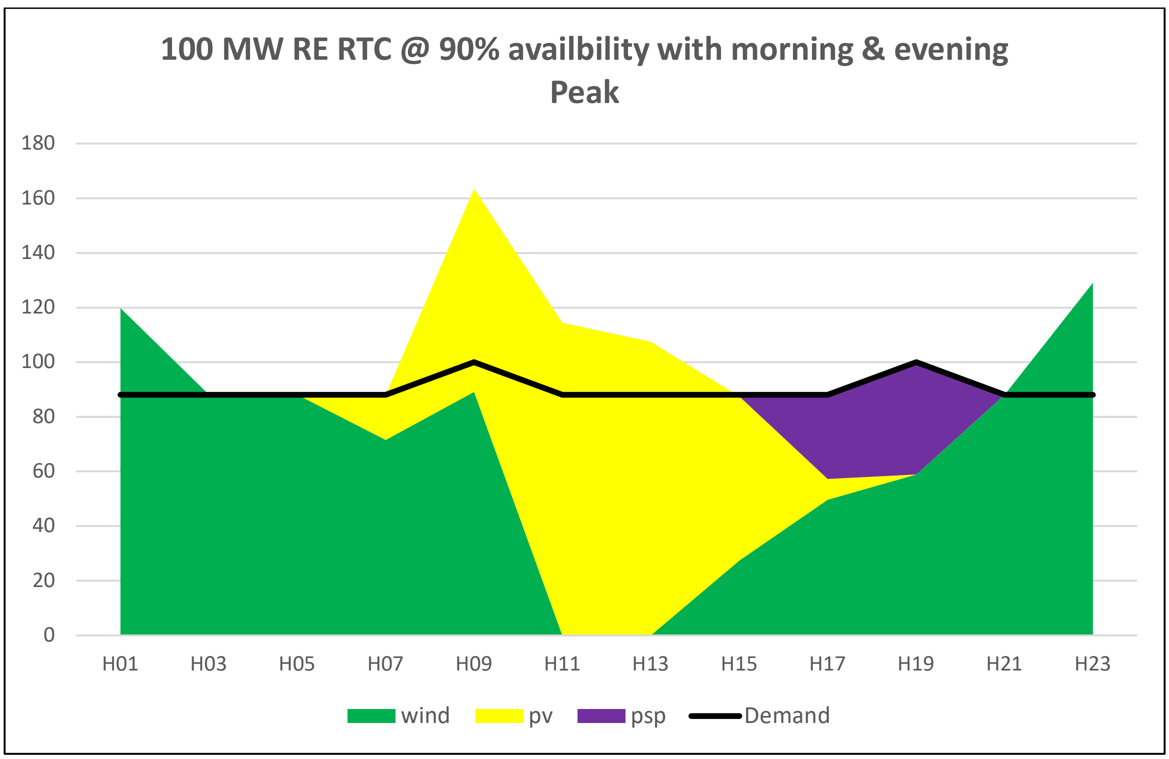
Case 2: Case Study for 100 MW RE RTC @90% Daily availability with 2 Hours Morning & Evening Peak Support

In case of RE RTC demand of 100 MW @90% of daily availability with 2hours of Morning and evening peak support, the capacity requirement and cost analysis are shown in Table 4. The demand profile is shown in Exhibit 3(b). A typical day dispatch for the RE RTC is shown in Exhibit 5.

Table 4

Source	IC(MW)
Gujarat Wind	45
Karnataka Wind	134
Tamil Nadu Wind	149
Telangana Solar	170
PSP (6 Hours)	64
Energy In MWh	786240
Per Unit Cost of Generation (Rs/kWh)	4.97

Exhibit 5



Similarly, different RE RTC constructs with daily availability varying from 50% to 90% to provide morning and evening peak support has been analysed and the corresponding variation in RE capacity requirement (MW) and per unit cost of generation (Rs/kWh) for different constructs is shown in Exhibit 6 & Exhibit 7 respectively.

Exhibit 6

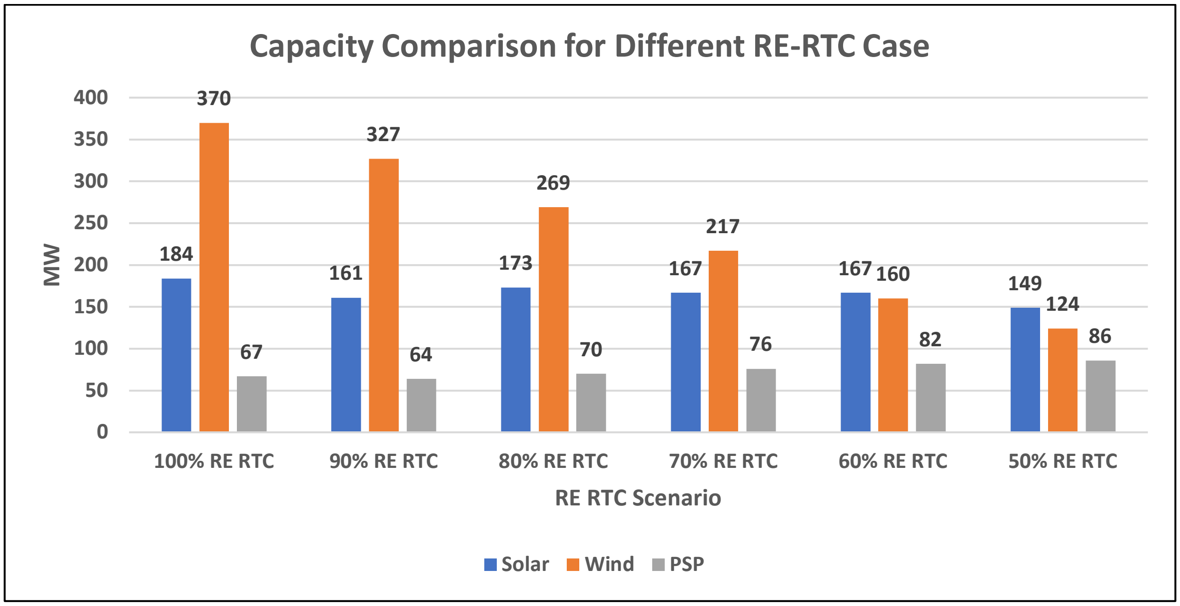
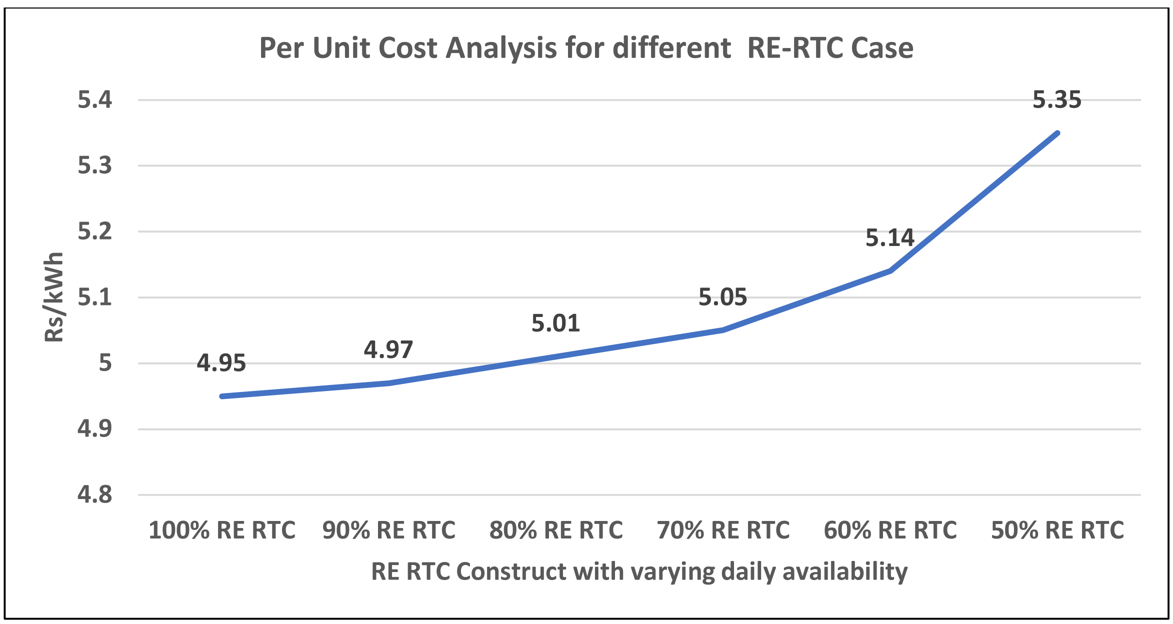


Exhibit 7



It can be observed from Exhibit 6 as hourly load requirement is increased from 50% to 100% availability; the wind capacity requirement increases while solar capacity is increased marginally. This is owing to the fact that the solar generation is available only during certain hours of the day while wind is available throughout the day. Similarly, the storage requirement also increases from 100% to 50 % RE RTC scenario because of morning and evening peak requirement.

Since in 100% RE RTC scenario, the energy supplied is higher, although the investment cost is highest, the per unit cost of generation is lowest. This cost increases as we move down to 50% RE RTC scenario as although the total investment cost decreases, the per unit cost of generation increases with improvement in RE availability. This anomaly occurs due to utilization of higher PSP capacity in latter (50%) which contributes towards meeting the morning and evening peak demand.

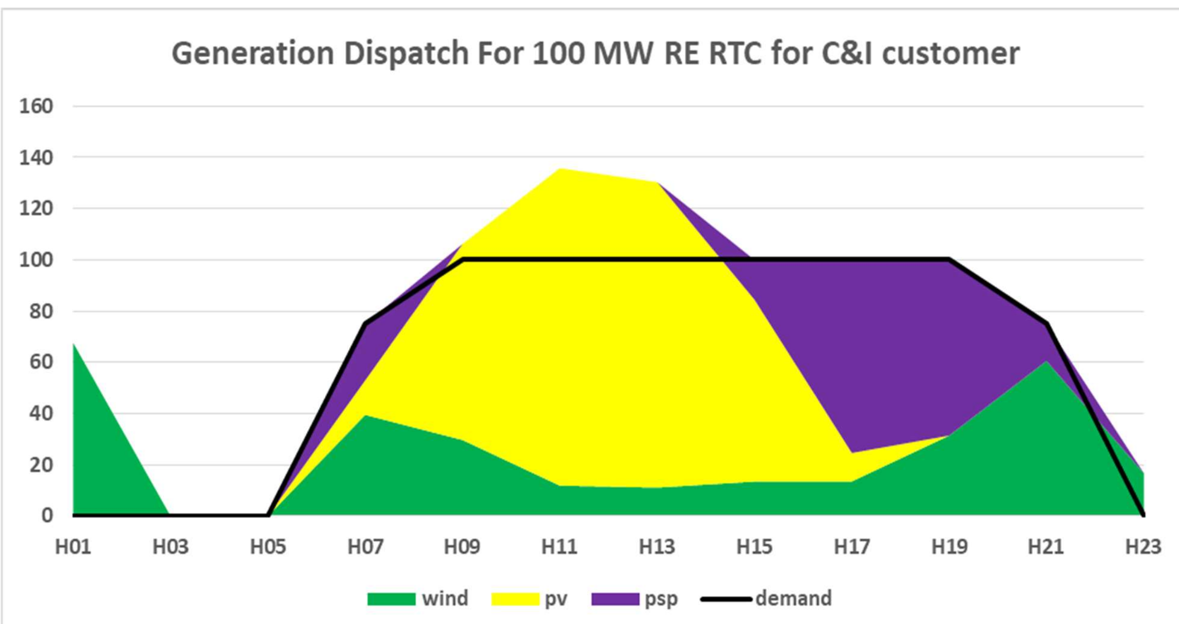
Case 3: 100 MW RE RTC suited for C&I customers

A case study for a 100 MW from RE RTC for C&I customers has been modelled. The Capacity requirement and per unit cost is shown in Table 5. The demand pattern for C&I customer with two shift operation is shown in exhibit 3(c). The dispatch for a typical day is shown in Exhibit 8.

Table 5

Source	IC(MW)
Maharashtra Solar	189
Gujarat Wind	41
Karnataka Wind	78
Tamil Nadu Wind	34
PSP (6 Hours)	84
Energy in MWh	546000
Per Unit cost of generation in (Rs/kWh)	5.102

Exhibit 8



Case 4: 100 MW RE RTC with State Specific Solar & Wind Profile

Gujarat

A case study for a 100 MW from RE RTC (flat profile as shown in Exhibit 3a) for State RE profile (Solar & Wind) of Gujarat has been considered. The Capacity requirement and per unit cost is shown in Table 6.

Table 6

Source	Capacity in MW
Solar	323
Wind	398
PSP (6 Hour)	113
Energy in MWh	876000
Per Unit Cost (Rs/kWh)	6.41

Tamil Nadu

A case study for a 100 MW from RE RTC for State RE profile (Solar & Wind) of Tamil Nadu has been considered. The Capacity requirement and per unit cost is shown in Table 7.

Table 7

Source	Capacity in MW
Solar	500
Wind	303
PSP (6 Hour)	235
Energy in MWh	876000
Per Unit Cost (Rs/kWh)	7.57

Maharashtra

A case study for a 100 MW from RE RTC for State RE profile (Solar & Wind) of Maharashtra has been considered. The Capacity requirement and per unit cost is shown in Table 8.

Table 8

Source	Capacity in MW
Solar	290
Wind	347
PSP (6 Hour)	120
Energy in MWh	876000
Per Unit Cost (Rs/kWh)	5.81

Rajasthan Solar & Gujarat Wind

A case study for 100 MW RE RTC with Rajasthan Solar & Gujarat Wind has been considered. The capacity requirement and per unit cost is shown in Table 9.

Table 9

Source	Capacity in MW
Rajasthan Solar	466
Gujarat Wind	212
PSP (6 Hour)	199
Energy in MWh	876000

Per Unit Cost (Rs/kWh)	6.30

Telangana Solar & Tamil Nadu Wind

A case study for 100 MW RE RTC with Telangana Solar & Tamil Nadu Wind has been considered. The capacity requirement and per unit cost is shown in Table 10.

Table 10

Source	Capacity in MW
Telangana Solar	500
Tamil Nadu Wind	166
PSP (6 Hour)	222
Energy in MWh	876000
Per Unit Cost (Rs/kWh)	6.26

Case 5: 100 MW RE RTC for C&I customers with State Specific Solar & Wind Profile

Gujarat

A case study for a 100 MW from RE RTC for C&I customers of Gujarat state (profile as shown in Exhibit 3c) with RE profile (Solar & Wind) of Gujarat has been considered. The Capacity requirement and per unit cost is shown in Table 11.

Table 11

Source	Capacity in MW
Solar	390
Wind	80
PSP (6 Hour)	98
Energy in MWh	546000
Per Unit Cost (Rs/kWh)	6.29

Maharashtra

A case study for a 100 MW from RE RTC for C&I customers of Maharashtra state (profile as shown in Exhibit 3c) with RE profile (Solar & Wind) of Maharashtra has been considered. The Capacity requirement and per unit cost is shown in Table 12.

Table 12

Source	Capacity in MW
Solar	309
Wind	93
Storage (6 Hour)	100

Energy in MWh	546000
Per Unit Cost (Rs/kWh)	5.65

Tamil Nadu

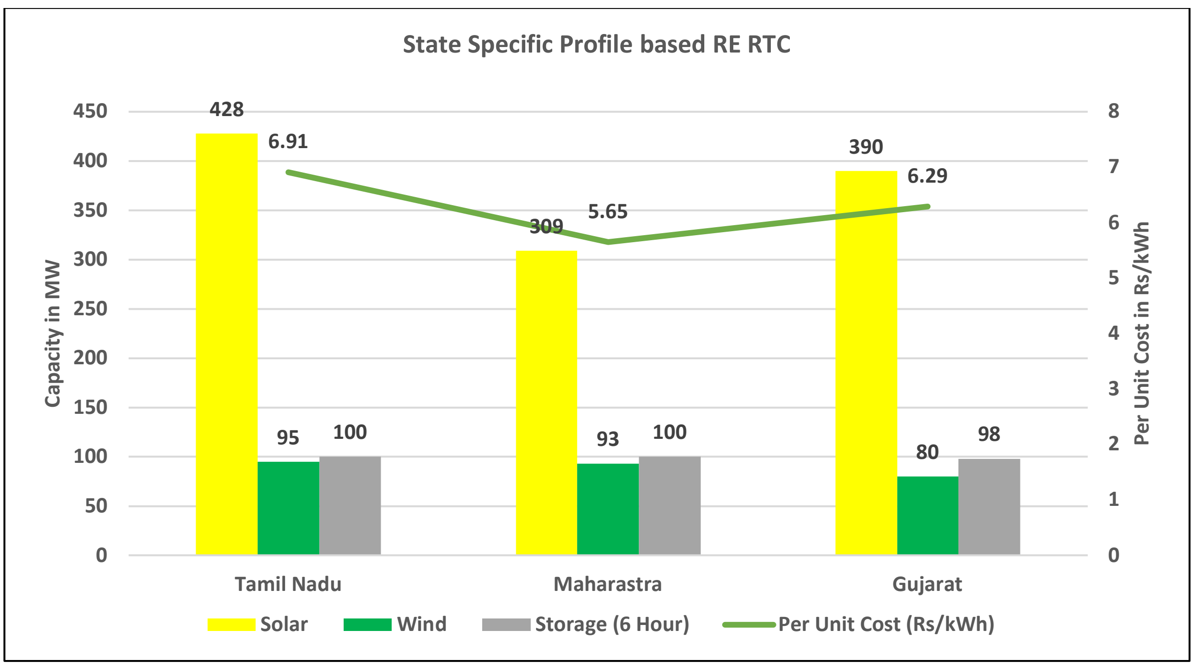
A case study for a 100 MW from RE RTC for C&I customers of Tamil Nadu state (profile as shown in Exhibit 3c) with RE profile (Solar & Wind) of Tamil Nadu has been considered. The Capacity requirement and per unit cost is shown in Table 13.

Table 13

Source	Capacity in MW
Solar	428
Wind	95
Storage (6 Hour)	100
Energy in MWh	546000
Per Unit Cost (Rs/kWh)	6.91

The comparison of State specific Profile is summarized below in Exhibit 9

Exhibit 9



Case 6: RE RTC with Annual availability 80%/85%/90%/95%

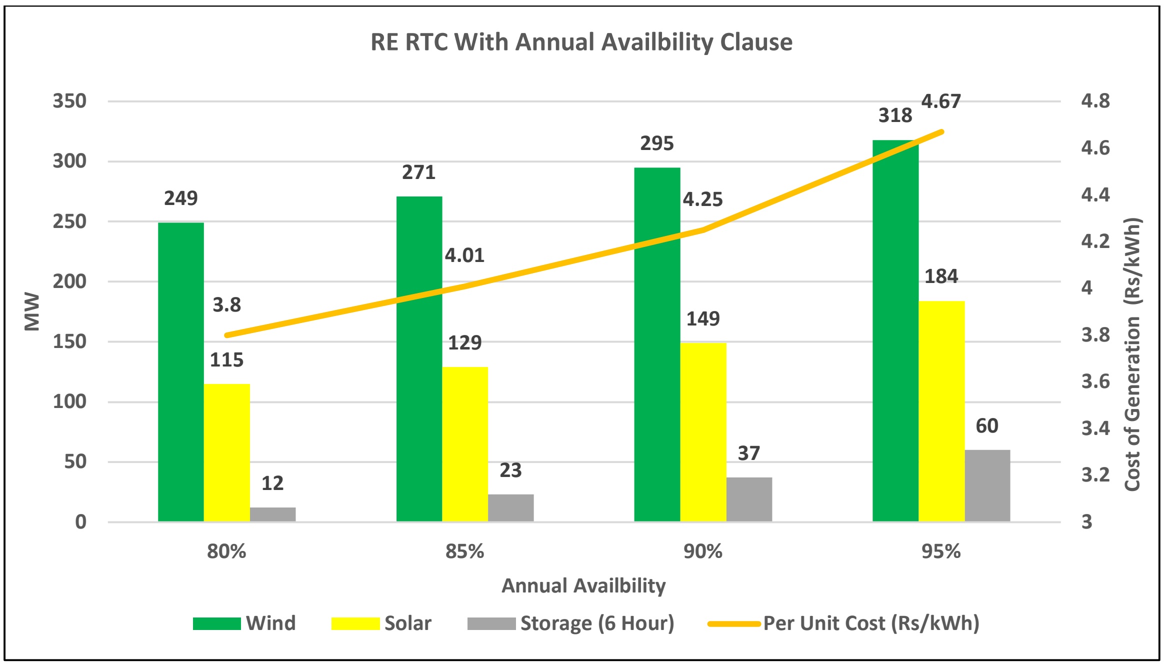
A case study for a 100 MW RE RTC with annual availability varying in the range of 80-95% was considered for customers with the combination of Gujarat Solar and Maharashtra Wind. The Capacity requirement and per unit cost is shown in Table 14.

Table 14

Source	80%	85%	90%	95%
Wind	249	271	295	318
Solar	115	129	149	184
Storage (6 Hour)	12	23	37	60
Per Unit Cost (Rs/kWh)	3.80	4.01	4.25	4.67

The Capacity requirement and per unit cost requirement is shown in exhibit 10.

Exhibit 10

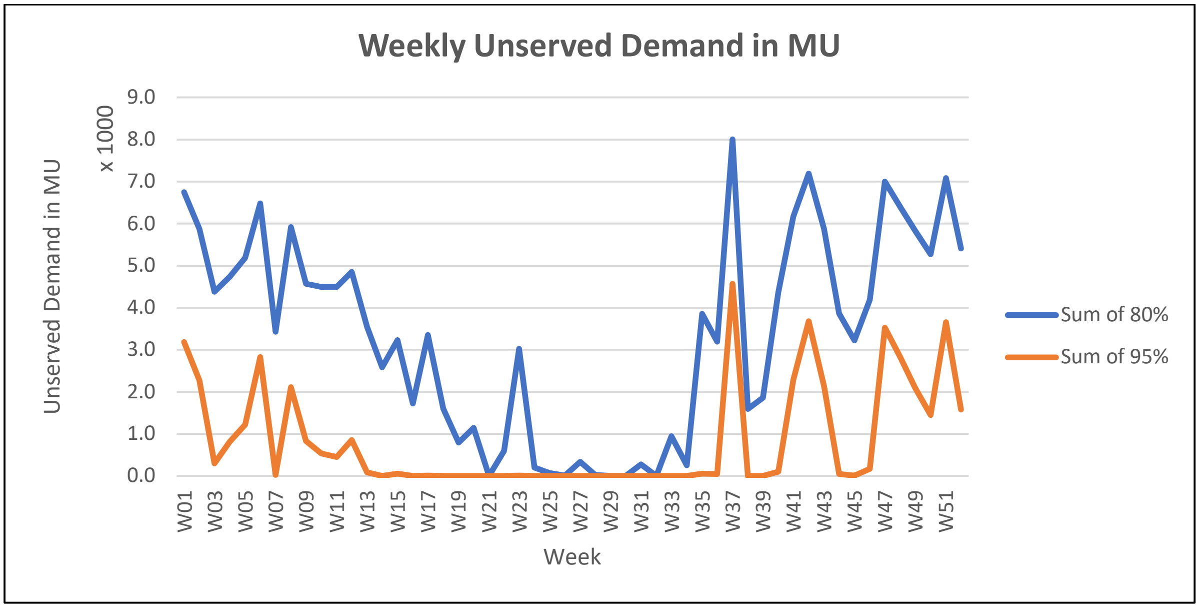


It can be noted that:

a. With higher annual available requirement, the capacity and storage requirement increase significantly. This corresponds to higher investment requirement and higher per unit cost of generation.
b. Comparison of annual availability of RE-RTC vs conventional sources with similar availability is difficult as for conventional sources the availability can be managed by planning the annual maintenance of the plant as per the requirement of utilities, while the availability of RE-RTC is solely dependent on the weather patterns and is subject to higher degree of seasonality across the year.
c. The present cost of generation of new coal plants is around 5-6 Rs/Unit with an annual escalation of 1-2% of fuel cost. Compared to this, RE-RTC presents an alternate green solution to meet the demand which is economically viable. The cost of RE-RTC is expected to decrease further which will make it more competitive to the conventional fossil generation source.

The comparison of Unserved demand pattern of 95% vs 80% annual availability is shown in Exhibit 11. It can be observed that the during high wind season of Aug-Sept, the RE-RTC is able to supply reliable power during every instance of time. However, during lean wind period, the Unserved demand is observed during few hours of the day. The unserved pattern is similar in both cases.

Exhibit 11



The summary sheet of all the case scenarios discussed above is summarized below.

Summary Table

Case 1- Case study for RE RTC at 100% availability (Flat Demand profile)						
States	Solar (MW)		Wind (MW)		Storage (6-hour) (MW)	Per unit Cost (Rs/kWh)
States	Telangana	184	Gujarat	55	67	4.95
			Karnataka	147		
			Maharashtra	52		
			Tamil Nadu	116		
Case 2- Case Study for 100 MW RE RTC @90% Daily availability with 2 Hours Morning & Evening Peak Support						
States	Telangana	170	Gujarat	45	64	4.97
			Karnataka	134		
			Tamil Nadu	149		
Case 3-Case Study for 100 MW RE RTC for C&I customers						
States	Maharashtra	189	Gujarat	41	84	5.10
			Karnataka	78		
			Tamil Nadu	34		
Case 4: Case Study for 100 MW RE RTC with State Specific Solar & Wind Profile						
Gujarat	323		398		113	6.41
Tamil Nadu	500		303		235	7.57
Maharashtra	290		347		120	5.81
Rajasthan solar and Gujarat Wind	Rajasthan	466	Gujarat	212	199	6.3
Telangana solar and Tamil Nadu Wind	Telangana	500	Tamil Nadu	166	222	6.26
Case 5: Case Study for 100 MW RE RTC for C&I customers with State Specific Solar & Wind Profile						
Gujarat	390		80		98	6.29
Maharashtra	309		93		100	5.65
Tamil Nadu	428		95		100	6.91

Case 6: Case Study for 100 MW RE RTC for customers with State Specific Solar & Wind Profile (Gujarat Solar, Maharashtra Wind) (Annual Availability 80/85/90/95%)				
Annual Availability	Solar (MW)	Wind (MW)	Storage (6 Hours) (MW)	Per unit Cost (Rs/kWh)
80%	115	249	12	3.80
85%	129	271	23	4.01
90%	149	295	37	4.27
95%	184	318	60	4.67

3.0 Challenges, opportunities and way forward for RE RTC

The electricity distribution companies – the main beneficiaries of these RE RTC product are pushing for these newer types of tenders that match their demand profiles more closely and shift the responsibility of balancing intermittent renewables onto the independent power producers (IPPs). It is expected that price will continue to decrease further owing to the projected global trend of decrease in the CAPEX cost of Solar, Wind, and Battery energy storage system. However, developers of RE-RTC are facing a number of challenges few of which are given below.

3.1 Challenges

Aggregating multiple Solar and wind generators

The optimized solution provided by the model shows that the least cost solution for a given RE RTC product may be obtained by combining solar and wind project from multiple projects spanning multiple states. This however poses a challenge in terms of arranging long term PPAs with multiple generators, obtaining transmission access at multiple location, setting up remote control centers for real time control etc. For a large scale RE RTC product obtaining a Single location for Solar or wind project may pose a serious challenge for RTC product developers.

Variation of Demand pattern and RE profile

The demand pattern of various discoms have been undergoing a significant transformation owing to various Govt of INDIA policy intervention such as SAUBHAGYA scheme, agricultural feeder segregation, TOD mechanism, promotion of green hydrogen & solar roof top and due to change in consumer behaviour such as cooling demand, electric vehicle. Owing to these rapid changes, the RTC product designed for the present demand pattern might not be suitable 3-5 years later. The Developer needs to anticipate this likely change in demand pattern and adapt its RE RTC constructs.

Similarly, the RE generation particularly wind, experiences significant disturbances due to intermittency associated with it. The Developer also need to take into account this variation of RE generation while designing RE RTC. Aggregating multiple solar and wind generators across multiple geographical location will reduce the variation and ensure greater reliability and availability.

Financing RE RTC projects

This can be challenging due to higher upfront costs, technology risks, and longer payback periods associated with energy storage systems. The high cost of energy storage system will increase the overall cost of the product making it unviable at present. However, Pump storage-based energy storage solution can be utilized to reduce the system cost owing to longer life time compared to Battery energy storage system.

3.2 Opportunities:

- With reduction of Storage Cost, RE RTC will become cost effective compared to other conventional sources. This will ensure that more and more developer will participate in the bidding process and the discovered tariff is further expected to decrease as per the global trend.
- Push towards Renewable Energy Capacity Addition will further enhance the importance of RE RTC in the Indian Power Scenario which was earlier dominated by Conventional sources such as Coal, gas etc. Govt of INDIA's push towards Renewable energy through RPO (Renewable Purchase Obligation) will ensure more and more utilities will add RE RTC to their portfolio to meet their growing energy requirement while simultaneously fulfilling RPO obligation.
- RTC products are typically designed with significant overcapacity to ensure reliable supply even during lean RE generation period. During excess RE generation period the excess energy can be auctioned in the power market or through bilateral agreement. This will not provide additional revenue to the Developer but also ensure the effective utilization of resources.
- Combining Solar and wind power with Hydro Power particularly Run of the River or small storage capacity will result in reduction of tariff. The Storage capacity of hydro power plant can be utilized to provide quick ramp up/down in addition to provide some energy requirement. This will ensure the viability of some hydro power projects where the tariff has already shoot up due to delay in the project implementation
- Compared to standalone Solar and Wind generators, hybrid projects such as RE RTC provide greater reliability and flexibility to the grid operator. This also shifts the responsibility of maintaining the grid stability from grid operator to RE RTC developers as it is responsible for maintaining reliable supply of power with suitable compensation for non-compliance.

3.3 Way forward:

- Research and development for fast adoption of storage technology should be taken up on war footing. Government can provide VGF (Viability Gap funding) for green hydrogen as storage projects in the initial period to promote RE RTC and ensure sufficient demand for such product via creating a common platform for all the stake holders to enhance awareness and utility of such products.

- Development of Policy and Regulatory Framework for wide implementation of RE RTC. Similar to RPO trajectory for standalone Solar, Wind, and other RE source, govt can mandate a certain portion of energy demand to be met through RE RTC. This will create a large-scale opportunity for Product developers and attract investments.

- With improvement in forecasting of renewable profile, the excess energy available can be auctioned in the Day ahead and real time market. This will ensure cheaper power is available in the exchange which will further reduce the volatility in the market.

3.4 Conclusion

- **RE RTC** is a promising power supply option for meeting different kind of load /demand requirements from end consumers like distribution utilities, industries, commercial setup etc. It can facilitate RPO fulfilment by the utilities and mitigate the challenges associated with RE generation intermittency by providing reliable supply.

- **The ideal case** of RE RTC procurement exploits the diversity in RE generation profile across states and provides the most optimized power procurement option. However, power procurement in such a fashion may be practically challenging.
- Storage capacity may play an important role in realizing the objective of RE RTC power. In this regard, PSP offers a competitive and affordable option for storing energy compared to BESS which is an expensive option presently. However, with decreasing trend of prices of BESS, it may become competitive option to facilitate RE RTC supply. This will also give a boost to Government of India 's initiative to promote PSP as a Storage option.
- It can be observed that 100 % RE RTC case is most economical and provides maximum reliability. However, the capacity requirement is highest in that case. RE RTC may be customized as per requirement of customer based on the Solar, Wind profile and demand requirement
- It was analysed that power procurement from different states leverages the diversity in generation profile and results in higher utilization RE capacities which results in lower per unit generation cost. This also reduces the risk of uncertainty in generation due to abrupt change in weather pattern and minimizes the generator risk.