DISCOM Decarbonization Strategies – A Future Outlook of Tamil Nadu DISCOM (TNPDCL – Tamil Nadu Power Distribution Corporation Limited)

Author Lists & Affiliations: Anandajit Goswami (Lead & Corresponding Author, Research Fellow, ACPET), Prodyut Mukherjee (Co-Author, Founder, En-genuity), Ranjit Chandra Vallabhaneni (Co-Author, Founder, En-genuity), Renuka Sane (Co-Author, Managing Director, Trust Bridge)

Reviewed by Mr. Vaibhav Chaudhary, Director, ACPET, Shri Rakesh Kacker (Honorary Advisor, ACPET) and Proof Read by Ms. Alpana Shekhar (JRA, ACPET)

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Abstract

The transition of India to move towards a Net Zero Goal by 2070 will only be possible when the Distribution Companies (DISCOMs) procure power from renewable energy sources and decarbonise such power procurement with a minimum cost implication. Even though the AT&C (Aggregate Technical & Commercial) losses of the DISCOM Sector have reduced in the last year, there is a long way to go in terms of the Decarbonization Strategies and Investment Pathways of DISCOMs for the future by focusing on hybrid solutions.

With this background, the policy brief presents a futuristic scenario of decarbonization strategies of TNPDCL (Tamil Nadu DISCOM) and the possible investment pathways and requirements of reaching the decarbonization goal and targets in a cost optimization framework. Multiple futuristic scenarios are considered in terms of thermal and renewable energy tariff comparisons, round-the-clock [1](RTC) scenarios, shifting of industrial consumers, and availability of gas-based and offshore wind options to come up with future decarbonization strategies for TNPDCL. The policy brief is informed by a modelling framework developed by ACPET and its partners En-genuity and Trust Bridge, to suggest possible policy directions for transparent policy-making for DISCOM Decarbonization of Future in India.

The policy brief concludes that TNPDCL can easily decarbonize 45% of its portfolio, but going beyond 85% will not be financially attractive, and a minimum of 15% power from thermal sources will be needed in the long term. To achieve these decarbonization targets, a rise in the renewable energy installed capacity of 3.3 times might happen in Tamil Nadu with a rise of investment of 3.5 times. This would entail an additional investment need of at least INR 297 billion to INR 320 billion in the long term within the time horizon of 2030 – 2040. If the state intends to make such investments, then it must work out the possible sources of financing to meet these investment needs through taxation, new investment finance, loans, grants, scheme-based transfers, etc.

[1] Round The Clock electricity availability will entail that the solar energy availability of the day can be used at night when it is not available through storage options. Round-the-clock (RTC) power, as the name suggests, entails that power supply is available **24×7**, throughout the year. In the case of renewables, owing to resource intermittency it is difficult, preventing assured RTC power supply from standalone solar and wind power plants.

Alternatively, if private sector investment is sought to develop this capacity, then a conducive policy and regulatory framework should be put in place. More importantly, innovative power procurement models and power purchase agreements (PPA) need to be designed and adopted, which would encourage private sector investments in RE capacity addition.

KEYWORDS:

- DISCOM Intelligence,
- Decarbonisation,
- Cost Minimization,
- Hybrid Solutions,
- Investment Pathways

Introduction

The DISCOM sector of India has been undergoing a stressed situation with looming losses. The state-level DISCOMs have been contributing more to these growing losses. More than INR 84,000 crore bailout has been undertaken by the State Governments of India. This has happened despite a reduction of the Aggregate Technical & Commercial (AT&C) losses from a high of 30.47% (in FY2007) to 15.79% (in FY2023). Even at the improved level of 15.79% (2023) loss, the excess AT&C loss costs around Rs 0.21 per unit of energy (kilowatt-hours or kWh) sold by the DISCOMs. This creates the need for reforms within the DISCOM sector of India so that it can financially sustain itself for a longer time, as continuous subsidy provision is not an option for the sector anymore. Additionally, DISCOMs have been given a target of achieving a renewable purchase obligation (RPO) of 43% by 2030 (Table 1).

Table 1: RPO Trajectory of DISCOM

Year	Wind RPO	HPO	Other RPO	Total RPO
2024 - 25	2.46%	1.08%	26.37%	29.91%
2025-26	3.36%	1.48%	28.17%	33.01%
2026-27	4.29%	1.80%	29.86%	35.95%
2027-28	5.23%	2.15%	31.43%	38.81%
2028-29	6.16%	2.51%	32.69%	41.36%
2029-30	6.94%	2.82%	33.57%	43.33%

Source:
Renewable_Purchase_Obligation_and_Energy_Storage_Obligation_Trajectory_till_2029_30.pdf

Hence, the DISCOMs are now under a double pressure of achieving a decarbonisation pathway as well as attain financial sustainability for which they will need financial support or new forms of financial re-engineering. Hence it is important to create innovative clean energy transition financing solutions for the DISCOMs of India to stick to the RPO trajectory which has been provided to them by the Government of India.

Often, it is being suggested that where grid based electricity provision is not cost effective for the DISCOMs, decentralised energy solutions through solar micro grids can be used as a complementary provision for electricity provision. In various aspirational districts of India already such DRE provisions are being worked out with innovative models like pay-as-you-go and rooftop leasing making renewables more accessible through blended financing, and tariff discovery. Moreover, impact investing and crowdsourcing are also bridging clean energy funding gaps and democratizing participation in sustainable projects. In many cases, carbon financing and climate-linked debt swaps may also have the potential to unlock critical funds required to balance grid based electricity provision with off grid DRE solutions where it is not viable to provide grid based electricity. Within such a context, decarbonization pathways of DISCOMs have to be worked out in a least cost optimal way. In this policy brief, such an attempt is being made through a range of scenario analysis conducted for the TNPDCL.

Is Hybrid Renewable Energy or Hybrid RE a solution for Tamil Nadu DISCOM?

This leads us to one of the crucial questions: whether hybrid renewable energy is a potential solution for a DISCOM like TNPDCL. Such a hybrid solution for TNPDCL will entail a combination of solar and wind along with energy storage to provide improved supply. In these contexts, RE supply may focus on higher availability during the peak hours with minimum annual and monthly availability during the peak period. Round-the-clock (RTC) options are also considered to be some of the possible options with minimum time slot availability and minimum annual availability during peak periods. They are thought through as a solution as often the hybrid solutions are seen to be oversized to meet the supply conditions which generates surplus energy. Moreover, the variation in demand is more than 50%, and power is procured on a long-term basis through the power procurement agreements. Hence, within the DISCOM sector, developers need to focus on hybrid configurations while paying less attention to the quality of supply with an additional mismatch between the generation profile and the varying load curves of the range of consumers. Within such a context, the supply and procurement profile of TNPDCL in 2022-23 is shown in Table 2 below.

Table 2: Total energy procurement by TNPDCL (2022-23)[2]

	Energy Purchased (MUs)	Cost (INR Crore)	Average Cost (INR/kWh)
Own Generation	28,504	19,384	6.80
Thermal	20,715 (72%)		
Gas	1,634 (5%)		
Hydro	6,152 (21%)		
Wind	3 (2%)		
Central Generation Stations	40,781.87	19,432.84	4.77
Thermal	30,403.57 (74%)		
Nuclear	10,378.30 (26%)		
IPP	2,148.77	1,904.84	8.86
Renewables (Solar & Wind)	11,077.79 (10%)	4,280.41	3.86
Others	20,814.58 (20%)	17,754	8.53
Total	**1,03,326.77**	**62,756.09**	**6.07**

Source: Authors' Estimates based on TNPDCL Data

Table 2 shows that in Tamil Nadu, on the supply side, from the self generation and central generation stations, 72% and 74% of the power is coming from thermal sources. Hydro is contributing to 21% of the generation, Gas is contributing to 5% of the generation, and Solar and wind is contributing to 12% of the generation considering the Own Generation and Other Sources. Nuclear is contributing to 26% of the generation mix from the Central Generation Stations.

[2] Source – TNERC's Approval of True Up of TNPDCLTNPDCL for FY 2022-23 dt Aug 13, 2024 (https://www.tnerc.tn.gov.in/Orders/files/TO-MP%20No%201140820240436.pdf)

The state has a contracted electricity demand of 38 GW, out of which there is an envisaged capacity of 23 GW of renewables, which can further rise to 28 GW in the long run post-2030. The peak electricity demand of last year was 20 GW[3]. Out of the 38 GW electricity demand, 13.5 GW is expected to come from coal-based thermal power plants, 11.4 GW is expected to come from wind projects, 5.6 GW from solar projects, 2.3 GW from hydro, 1.4 GW from nuclear, and the rest of the 3.1 GW is supposed to come from biomass and other resources. Hence, 23.8 GW capacity is envisaged to come from renewables, which includes close to half of it from solar and wind. The large contracted capacities from wind and solar reflect Tamil Nadu's significant renewable energy potential and TNPDCL's efforts to increase clean energy procurement. However, coal still forms a major portion of the contracted capacity to ensure reliable baseload power supply, as shown in Table 3.

Table 3: Contracted capacities from various sources in MW[4]

	Thermal					Low Carbon				Total
	Coal	Lignite	Gas	Diesel	Sub -Total	Hydro	Solar & Wind	Nuc- -lear	Sub -Total	
Own Generation	4,320	0	524	0	4,844	2,178	123	0	2,201	7,145
Private Sector	3,225	250	503	212	4,190	0	18,652	0	18,652	22,841
Central Generation Stations	2,500	3,390	0	0	5,890	0	232	2,440	2,672	8,562
Total	**10,045**	**3,640**	**1,027**	**212**	**14,924**	**2,178**	**19,007**	**2,440**	**24,425**	**38,548**

Source: Authors' Estimates based on TNPDCL Data

It is quite encouraging to note that more than 63% of the contracted capacity, i.e., 24 GW. GW, in the states, is from RE and clean sources. However, in terms of the supply of energy, the share of RE and clean sources is only 26.72% (which includes nuclear, hydro, wind, solar, and biomass). This is due to the variable and intermittent generation of RE. While the supply side presents this scenario for Tamil

3 https://www.thehindubusinessline.com/news/national/tamil-nadus-energy-demand-touches-new-peak-of-20000-mw/article68045662.ece

4 Source – TNERC's Approval of True Up of TNPDCL for FY 2022-23 dt Aug 13, 2024 (https://www.tnerc.tn.gov.in/Orders/files/TO-MP%20No%201140820240436.pdf)

Nadu, the demand side reveals a contrasting picture, where an inevitable mismatch between demand and supply occurs.

Demand Scenario

The average consumer load in 2022-23 was 11.79 GW. The average demand of 4.47 GW has been further sliced into 15-minutes intervals to understand the detailed pattern of the electricity demand. However, it should be noted that the spread of this data is uniform and unbiased, and hence, the inferences/ conclusions drawn from this data can be extrapolated to the whole state.

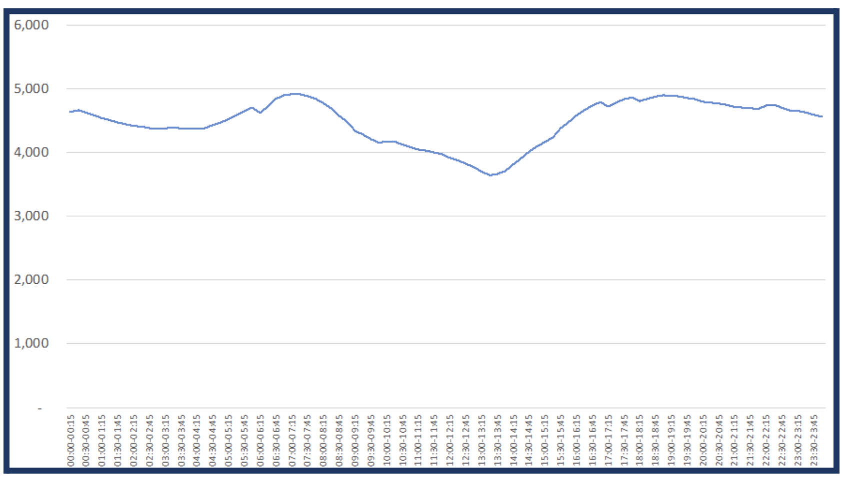

Figure 1: Load Curve of Tamil Nadu

Disaggregating the 4.47 GW average demand curve into time slots, one gets the demand curve for the state, which is shown in Figure 1. From the curve, one can observe that there are two peaks and one trough; the peaks occur in the morning and evening, and the trough occurs in the afternoon. The maximum demand (during the peaks) crosses 6.46 GW, and the minimum demand drops down to 1.42 GW MW during the trough. The total energy consumption at these demand levels is 39,182 MU.

Table 4: Time slot ranges and demand levels

Load (MW)	Timeslots (no.)	%	Cumulative %
> 6,000	868	2.5%	2.5%
5,000 to 6,000	7,930	22.6%	25.1%
4,473 to 5,000	9,366	26.7%	51.8%
4,000 to 4,473	8,484	24.2%	76.1%
3,000 to 4,000	6,136	17.5%	93.6%
2,000 to 3,000	2,094	6.0%	99.5%
1,000 to 2,000	161	0.5%	100%
Total	**35,040**		

Source: Authors' Estimates based on TNPDCL Data

Table 4 shows that in about 76% of the time slots, the demand ranges between 4 GW and 4.4 GW. Demand overshoots 6 GW in only 2.5% of time slots and is in the range of 1 GW to 2 GW in only 6.5% of the time slots. This nature of the demand curve indicates that power procurement can be designed to match most of the time slots, leaving flexible sources of power to meet the peaks. RE-based RTC is one such solution. This is illustrated in the following example.

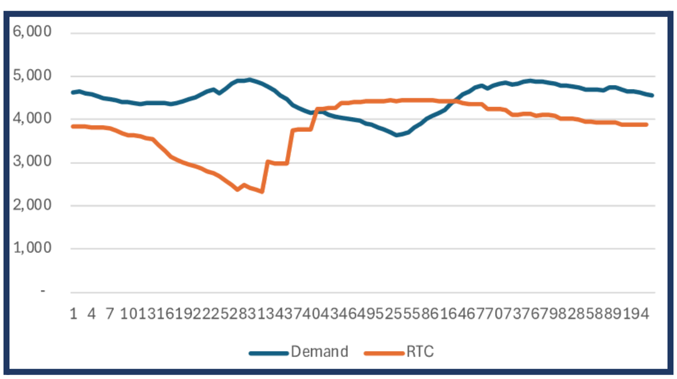

Figure 2: Indian Railways Demand Curve vs RTC Supply Profile

RE-based RTC is a system designed to provide continuous electricity using RE sources like solar, wind, and hydro, combined with energy storage solutions such as batteries or pumped hydro projects **(**Figure 2 – A Case Study Example).

The goal is to ensure a reliable and stable power supply that always meets demand, even when renewable sources are intermittent. The key benefits include a reduction in reliance on fossil fuels, leading to lower GHG emissions. Over time, RE can be cheaper than traditional fossil fuel-based power, and this has been demonstrated in India. In addition, the tariff for RE-based electricity is generally fixed over a PPA duration of 20–25 years, leading to better control and predictability of costs. Steady supply from RTC projects also enhances grid stability and reduces the risk of power outages. Considering these benefits, Indian Railways, through Railway Energy Management Company Limited (REMCL), floated a tender for 100% RE-based RTC procurement in 2021-22 for 1 GW (RTC-1). The final awarded capacity was 900 MW, in which L1 was INR 3.99/kWh and H1 was INR 4.27. The next tender that REMCL floated in 2022-23 was for 750 MW, in which L1 and H1 were INR 4.25/kWh and 4.43/kWh, respectively. In both these tenders, the key features were:

- Annual availability of 85%
- 100% RE-based supply
- BESS and Pumped Hydro for balancing power

Analysis of the bids received showed that the winners' typical configuration was 1.5x solar, 2x wind, and 0.35x PHP of their bid capacity.

With this background context, this policy brief highlights the results of a simulation model which aims to show a direction towards the DISCOM Decarbonization Strategies of Tamil Nadu complemented by the future investment needs to implement such a DISCOM decarbonisation by moving towards renewable energy-based procurement planning.

Approach and Methodology

Exhibit A: Methodological Framework

The broad facets of the approach and methodology of the 'Least Cost Optimisation and Minimisation' based simulation model are as follows (Figure 3*):

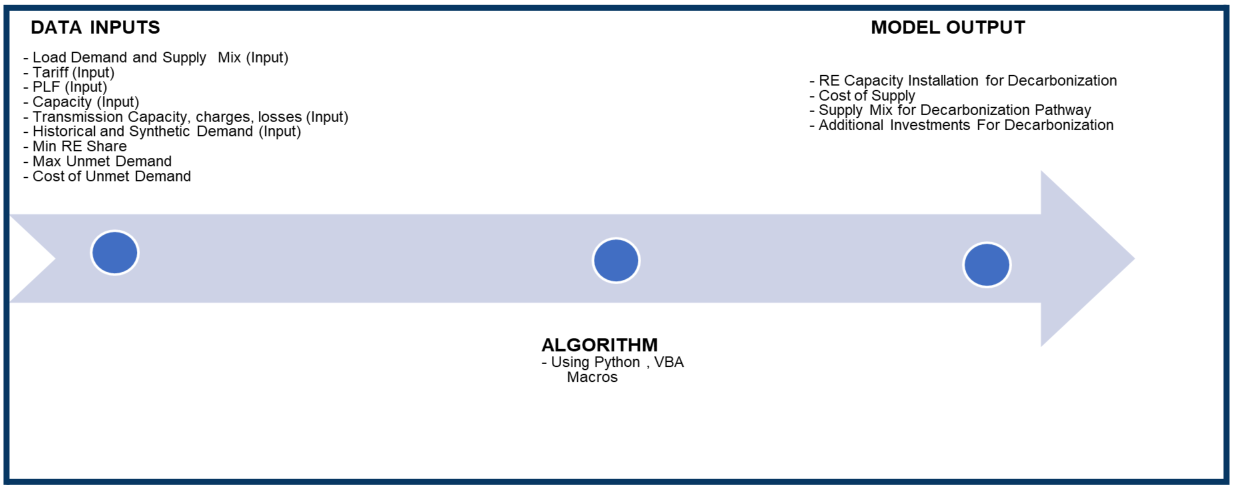

Exhibit B : Modelling Framework

The modelling framework followed for the analysis is shown below:

Model Constraints

cost, technology (constraint), power quality (constraint),

minimum RE share (> = constraint),

cost of unmet demand (<= constraint),

maximum unmet demand (<= constraint), need for balancing power within the model (<= constraint)

interstate transmission possibilities (<= constraint), in consonance with the demand and supply

Model Outcome

To create a decarbonisation strategy through a Intelligence Based Procurement Planning enabling a policy roadmap of decarbonisation for future

Based on the above modeling framework, the results and outputs of the model were as follows:

- Landed Cost for the year
- Supply and Demand Profiles
- Supply in Million Units (along with break up)
- Cost of Supply in INR Crore (along with break up)
- Average cost in INR/ kWh (along with break up)
- Additional capacities for given multiple years
- Supply in Million Units for optimized portfolio
- Cost of Supply in INR Crore for optimized portfolio
- Average Cost in INR/kWh for optimized portfolio

Hypothesis

Based on the above modelling framework and analysis, this policy brief has tested the following hypothesis:

"Hybridized RE solutions designed based on demand curves of Tamil Nadu DISCOMs can:

- Increase large-scale adoption of RE by the DISCOMs with better RE-based energy solutions.
- Act as the preferred supply option for meeting base loads.
- Act as a major strategy for meeting India's Net Zero by 2070 target and can help in understanding the clean energy transition financing needs.
- Can impact Renewable Energy Mix or Procurement Scenario of the future under
- Offshore Wind

- Availability of Electricity from other states through the reduction of transmission losses
- Availability of storage-based options
- Availability of gas-based supply"

To test the above hypothesis, the following scenarios were further considered:

Scenario	Description	Thermal Tariff	RTC Tariff
Scenario 1	Base Case	Fixed Tariff – INR 1.0/kWh to INR 2.5 kWh (with an increment of INR 0.5/kWh) Variable Tariff – INR 1.5 to 5.0 /kWh (with an increment of INR 0.5/kWh)	32wq
WSA	Supply of RE RTC from within the State / waiver of CTU (Power Procurement from other states)		
Scenario 3	Reduction in demand by 1000 MW due to Migration of Industrial Consumers		
Scenario 4	Supply of 1000 MW Offshore Wind		

Scenario 5	Climate Vulnerability and Its Impact on Peak Demand and Decarbonization of DISCOM		

The objective is to - understand the potential of RE penetration in the supply mix for Tamil Nadu DISCOM. Understand the additional financing needs to enhance the renewable supply. Understand the potential RE penetration in the supply mix by including the following constraints.

Results, Findings and Policy Directions

Scenario 1 – At a thermally fixed cost of 1.5 INR/kWh, a variable cost of INR 3.5 /kWh and an additional 2.9 GW RTC will be required by 2030, leading to a 52% renewable supply mix, 38% from thermal and the rest 10% from the exchange. If the additional amount increases to 4.5 GW, the renewable energy mix will increase to 77%, with 13% thermal and 10% from exchange. The additional investment that will be required to reach this renewable energy mix will be from INR 297 billion to INR 320 billion. However, the renewable supply mix can never increase more than 80% (upper bound). This will be because of the following:

- Flexibility of the thermal generation: thermal offers flexibility of supply and timeslots in which RTC is not able to meet the demand; thermal comes forward to meet the shortfall, despite its tariff being higher.
- Fixed cost of transmission: transmission cost is another reason, which contributes to the continuance of thermal beyond the RTC tariff. This is because transmission charges are at the MW level and not on energy (MU) terms. In a sense, it acts like a fixed cost.

Hence, a dependency of 15% - 20% thermal-based generation is going to stay even in the most optimistic scenario of decarbonization for the DISCOMs. In such a situation, for a 3.3 times increase in new renewable share, an additional investment rise of 3.5 times will happen.

Result 1:

As the share of RE, which makes the RTC supply, in the portfolio of the DISCOM increases from 49% to 85%, the rise in the weighted average cost of power increases very mildly from INR 6.35 /kWh to INR 6.79/kWh. However, beyond 85%, the weighted average cost of power jumps up by two times and reaches to more than INR 12/kWh.

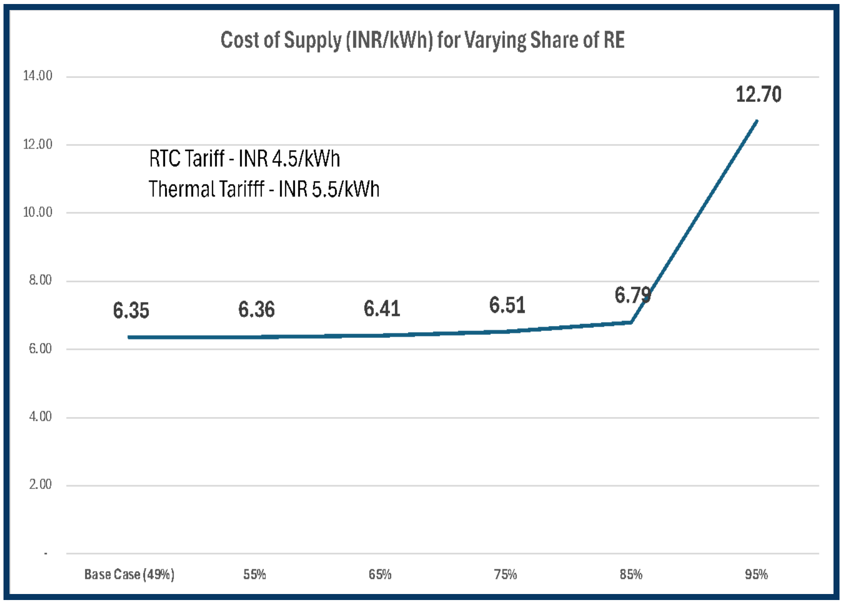

Figure 3: Rising Cost of Renewables

This also proves the reason for not increasing the renewable energy portfolio mix beyond 85% for the State of Tamil Nadu.

Installed capacity and investment required:

Our model indicates the investment required for the envisaged installed capacity creation of the state of Tamil Nadu to chart out its decarbonization pathway (Table 6).

Table 6 highlights that for a rise in the installed capacity from 45% to 65%, the investment required is less than two times. This sets out the possibility of a scale economy setting in beyond the renewable energy portfolio mix of 45% whose upper bound is to be fixed at 85%.

Table 6: Investment requirement

RE Share (%)	For 4.47 GW			For 11.80 GW (Extrapolated)		
	Contracted Capacity	Installed Capacity	Investment (INR Crore)	Contracted Capacity	Installed Capacity	Investment (INR Crore)
45%	2,749	8,890	49,530	6,705	23,468	1,30,750
55%	3,120	10,917	60,821	8,234	28,818	1,60,555
65%	3,729	13,052	72,716	9,844	34,454	1,91,956
75%	2,940	15,404	85,820	11,618	40,662	2,26,548
85%	5,368	18,788	1,04,676	14,171	49,597	2,76,326

Source: ACPET Model Estimates to be added

Key Takeaways and Next Steps

Our analysis in this policy brief highlights certain actions that need to be taken by Tamil Nadu if it wants to decarbonise its electricity sector. RE-based RTC, either in its current form or with modifications, is the most appropriate supply option that DISCOMs and large electricity consumers should adopt. This is because only solar or wind, the two RE sources that offer the largest potential in India, have intermittency built into their generation profiles, which needs to be addressed either by using energy storage (BESS or PHP) or using thermal power. As per the latest policy released by the State Government 14 GW capacity of pumped storage projects have been identified and 1 GW capacity of battery storage projects have been identified for the future[5].

Until such time energy storage costs come down and become financially attractive, DISCOMs need to rely on thermal power to meet the demand shortfalls, even with RTC procurements. The following key takeaways emerged from the study.

- RE-based RTC at INR 4.5/ kWh can compete with thermal energy at INR 5.5/ kWh.
- Counterintuitively, higher fixed costs lead to a higher share of thermal energy in the power portfolio. This is due to the stickiness of thermal energy, as explained earlier
- Thermal energy will be needed and will continue to be a key component of the power portfolio in the near to medium term despite its higher costs. This is because DISCOMs need to meet their demand curves – not meeting means load shedding – and to do that on a real-time basis, thermal power would be required. Thermal power plants can be ramped up or down quickly to offset the intermittency of RE generation.
- Till such time energy storage costs come down, thermal power plants would be acting as balancing sources of power
- Tamil Nadu would need about 28,818 MW installed capacity to increase the share of RE to 55% of their energy requirement at an 11.80 GW average load
- There is a need to understand the impact of climate variability on electricity demand and how RE can help address DISCOM challenges in meeting demand at cheaper costs.

Climate Variability and Electricity Demand

An analysis of the impact of climate variability over the DISCOM-specific electricity demand for TNPDCL shows that when the temperature increases by 1%, the cooling electricity demand of the DISCOM consumers increases by 2.3%.

[5] PressReader.com - Digital Newspaper & Magazine Subscriptions

Electricity demand is determined largely by regional climate conditions and seasonal characteristics, apart from socio-economic and demographic factors. In the Indian city context, POSCO in 2016 observed for Delhi that consumer electricity demand for DISCOMs decreases as one moves from cold temperatures to "pleasant" conditions and then increases again at higher temperatures.

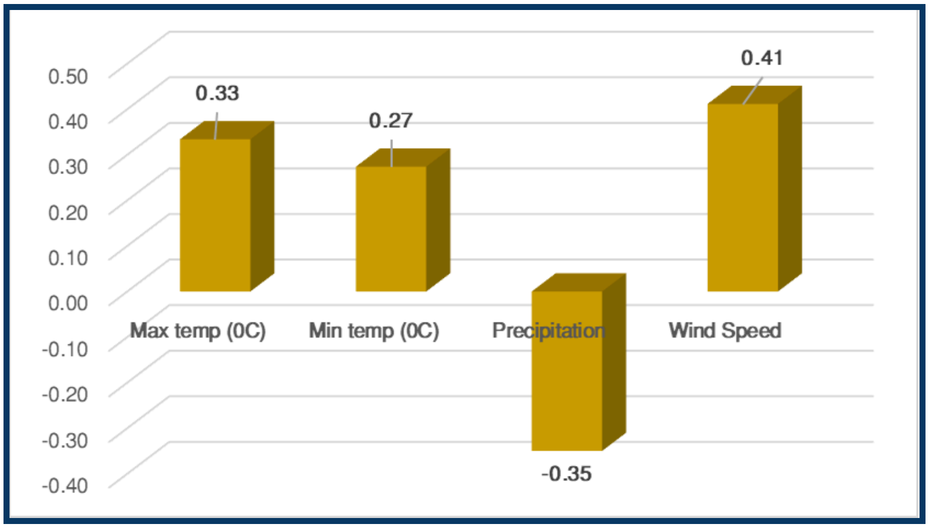

Figure 4: Sensitivity of Electricity Demand to Climate Parameters of Tamil Nadu

Taking the Tamil Nadu DISCOM case, an analysis of demand data, temperature (maximum and minimum), precipitation and wind speed January 2020 to March 2024, reveal that there is positive correlation between electricity demand and maximum temperature, minimum temperature and wind speed, but a negative correlation with precipitation. There is a need to analyse this data over longer periods, define and capture variability, consider climatic events, assess granular electricity demand (15 min interval). Further, preparation of scenario analysis needs to be done considering disruptive technologies like EVs and solar rooftops for the future.

Based on the above analysis of this policy brief, this brief comes up with the following actionable recommendations for DISCOM Decarbonisation of TNPDCL through a data-driven DISCOM Intelligence model:

- RE RTC @ INR 4.5/kWh can compete with thermal energy at INR 5.5 kWh

- Higher fixed costs will lead to the consideration of a higher share of thermal, beyond 85% of the renewable energy mix
- Thermal would be needed despite higher costs. The dependence on thermal will be around 15% - 20% even in the long term, as meeting the DISCOM electricity demand on real-time basis would need thermal to address the intermittency of demand and RE generation
- Tamil Nadu would need about 28.81 GW of installed capacity to increase the share of RE to 55% of their energy requirement at an 11.80 GW average load
- There is a need to understand the impact of climate variability on electricity demand and how RE (Renewable Energy) can help address DISCOM challenges in meeting demand at cheaper costs with climate variability and the introduction of disruptive technologies and EV
- RE RTC can be pursued as base load generators
- Existing RE capacities can be used along with ESS (Energy Storage Based Supply Options) to make their supply more stable
- Additional capacities can be procured through RE RTC or other customized RE solutions
- All new loads can be met through RE RTC while using thermal for addressing intermittency
- RE solutions can replace the thermal plants at the end of their life cycle
- There is a need to analyse data over longer periods, define and capture variability, consider climatic events, and assess granular electricity demand (15 min intervals) through a DISCOM Intelligence Model, based on AI ML Applications
- A regulatory and Policy Framework must be built to create Deep Decarbonisation for Tamil Nadu DISCOM

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