AurovilleConsulting

Pathways to Decarbonisation

Modelling Tamil Nadu's Power Sector Decarbonisation

NOVEMBER 2022

Sustainable Energy Transformation Series

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Acknowledgment

This publication forms part of the Sustainable Energy Transformation, Tamil Nadu (SET-TN) series of documents and activities. SET-TN aims to facilitate higher clean energy deployment in the State by working with all stakeholders to find sustainable and equitable solutions. SET-TN is a collaborative initiative by Auroville Consulting (AVC), Citizen Consumer and civic Action Group (CAG), and the World Resources Institute India (WRI).

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Abbreviations

B2DS	Beyond the 2 Degree Celsius Scenario
BAU	Business as Usual
CAGR	Compound Annual Growth Rate
CEA	Central Electricity Authority
CO2	Carbon Dioxide
COP26	Conference of Parties
EEP	Energy Efficiency Pathway
EPS	Energy Policy Scenario
ETP	Energy Technology Perspectives
IEA	International Energy Agency
INR	Indian National Rupee
IPCC	Intergovernmental Panel on Climate Change
IREDA	Indian Renewable Energy Development Agency Limited
kW	Kilowatt
kWh	Kilowatt-hour
LEAP	Low Emission Analysis Platform
MU	Million Units
MMT	Million Metric Tonnes
MW	Megawatt
NDC	Nationally Determined Contribution
NREL	National Renewable Energy Laboratory
PAM	Partial Adjustment Model
RE	Renewable Energy
SBT	Science Based Targets
SDA	Sectoral Decarbonisation Approach
SD	Standard Deviation
TN	Tamil Nadu
TANGEDCO	Tamil Nadu Generation and Distribution Company
TNERC	Tamil Nadu Electricity Regulatory Commission
UNFCC	United Nations Framework Convention on Climate Change

Executive Summary

Tamil Nadu's electricity demand is expected to increase year on year, and so are the sector's absolute carbon dioxide emissions. Considering India's commitments under the United Nations Framework Climate Change Convention, and the recent announcement of targeting net zero carbon by 2070 (UNFCC 2022), Tamil Nadu will require a long-term strategy to reduce its emissions. This may start with establishing sector-specific emission inventories, followed by sector-specific emission target setting.

The power sector is deemed to be one of the sectors easiest to decarbonise. One of the first steps for putting in place a decarbonisation strategy is target setting. This report assumes a net-zero carbon target for the Tamil Nadu power sector by 2050. It applies the Sectoral Decarbonisation Approach (SDA) of the Science Based Target (SBT) model to simulate decarbonisation pathways that are in line with the goals of the Paris agreement - limiting global warming well below 2°C above pre-industrial levels (ETP B2DS) and pursuing efforts to limit warming to 1.5°C (SBT 1.5°C) respectively.

Under the business as usual (BAU) scenario the cumulative CO2 emissions from the power sector of Tamil Nadu are projected to increase by 365% between 2020 to 2050.

The SBT 1.5°C pathway would require the state to generate 81% of its energy from carbon-free energy sources by 2030. For the ETP B2DS pathway, 57% of energy is required from carbon-free energy sources by 2030.

The Ministry of Power has released targets for the Renewable Energy Purchase Obligation (RPO) (Ministry of Power 2022). This mandates a state to source a minimum of 43% of its electricity from renewable energy sources by 2030. With this 43% share of renewable energy, the expected emission trajectory of the ETP B2DS pathway. Even if the emission reduction trajectory from the two SBT pathways seems ambitious, at least fulfilling the RPO would reduce the sector's absolute emissions considerably.

Other power sector planning scenario models by NREL (2021) and WRI (2022), which integrate recent renewable policy announcements such as the 20GW of solar energy capacity addition, show a significant emission reduction in the year 2030 in comparison with the Business as Usual (BAU) scenario.

The recently announced RPO targets by the Ministry of Power or the state-level solar energy targets put Tamil Nadu's power sector on a trajectory to decarbonisation pathway in line with the SBT. That is, the current trajectory aligns closer with the ETP B2DS pathway for 2030. if ambitions are stepped up a bit further, that is an addition of 38% of energy from renewable sources from the level of RPO, it could even embark on an SBT 1.5°C pathway.

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01

7%
of global CO2 emissions are from India

45%
of India's CO2 is from the power sector

76%
of electricity is from fossil fuels based in Tamil Nadu[1]

Introduction

After announcing a 2070 net zero target at the World Leaders Summit at COP26 in Glasgow in 2021, India will need to develop decarbonisation plans. And such a long-term low-carbon development strategy will need to be translated into sector-specific and state-level targets and action plans.

The power sector accounts for a major share of India's absolute CO2 emissions. In 2019, the power sector emitted 1,104 million tonnes of CO2 which constituted 45% of the total emissions (IEA 2019). India's coal-based power plants alone contributed to 2.40% of the global GHG emissions (CSE 2018).

With 7% of the total global CO2 emissions, India is ranked among the top contributing nations (see Figure 1). One of the reasons for this high share in global emissions is India's strong reliance on coal power. India's commitment under the COP21 agreement through its Nationally Determined Contribution (NDC) will require the energy system to gradually, but decisively, move away from fossil fuels, especially so from coal.

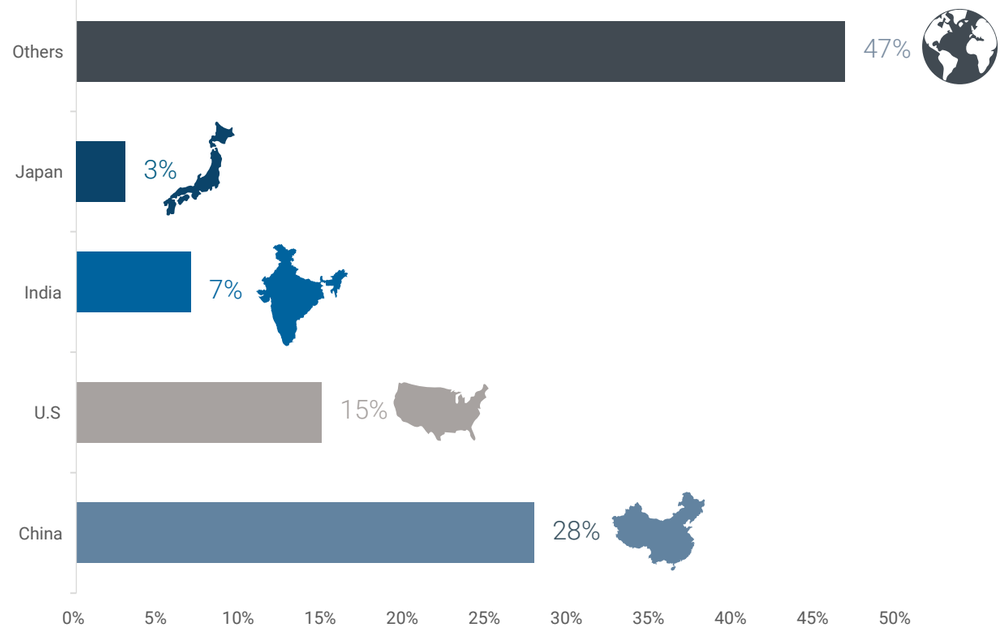
Tamil Nadu is one of the most industrialized states in India. Electricity generation in Tamil Nadu, like elsewhere in India, is still highly dependent on coal. The electricity generated from fossil fuel-based power plants contributed 76% of total electricity generation in 2020 (TANGEDCO 2022).

Decarbonising Tamil Nadu's power sector will require reducing the state's reliance on coal power, while accelerating the deployment of clean and emission-free energy sources, such as solar, wind, and hydro, at an unprecedented scale. With the steep drop in the cost of solar and wind energy over the last decade and the more recent technological advances in the energy storage system, the technical and economic barriers to an electricity grid that is powered by 100% renewable energy at a low cost have been overcome[2]. This makes the power sector one of the sectors that are deemed to be the easiest and fastest to decarbonise (Stanford 2021).

The objective of this paper is to model decarbonisation pathways for Tamil Nadu's power sector and to compare these pathways with the emission trajectory considering recent policy announcements made by the State Government.

[1]This is for the FY 2020-21.
[2]The central American country of Costa Rica produces 100% of its electricity from renewable energy resources (TCRN 2021).

Figure 1: Global share of CO2 emissions



Source: (MDPI 2021)

02

290 TWh
Energy demand
in 2020

75%
of primary energy
from fossil fuels

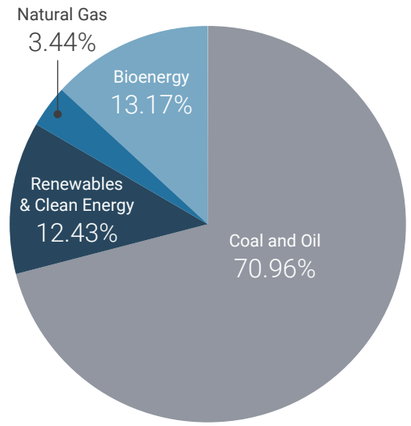
66%
of coal used for the
power sector

Energy Stats

In 2020, fossil fuels, with a 75% share, account for most of Tamil Nadu's primary energy sources (refer to Figure 2). In 2020 the total energy demand of Tamil Nadu was 290 TWh (TNSEC 2020). The transport and industry sectors combined accounted for 60% of the demand (refer to Figure 3).

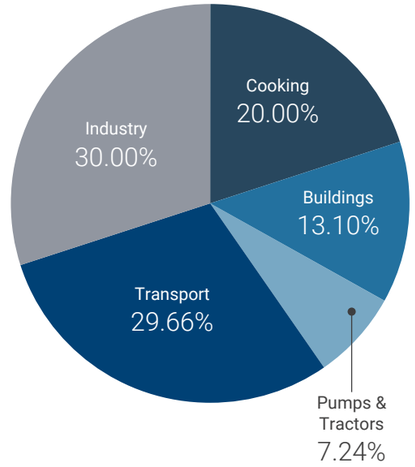
Of the total electricity generation in Tamil Nadu, renewable energy constitutes 22% while coal power plants constitute the lion's share with 75% (refer to Figure 4). Concerning the electricity demand, the industry and domestic sector combined account for 70% of the demand (refer to Figure 5). The electricity sector alone accounts for 66.37% of the total coal requirement in the state (see Figure 6). Relying on coal and petroleum products not only contributes to deteriorating air quality and greenhouse gas emissions, but it creates a dependence on imports to meet the State's energy needs. As much as 30% of the total coal requirement of Tamil Nadu comes from imports (Energy Department of Tamil Nadu 2022 & 2023). Therefore, decarbonising the power sector alone can reduce the state's dependency on coal considerably. To address the tripartite concerns of human health, global warming, and energy supply security a transition to renewable sources of energy is required.

Figure 2: Primary Energy Share 2020



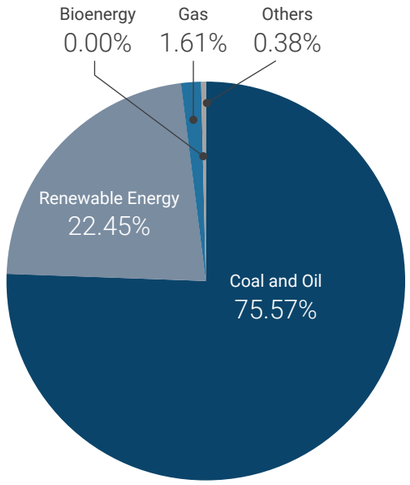
Sources: TNSEC (2020) TANGEDCO (2022)

Figure 3: Sector-wise primary energy demand 2020



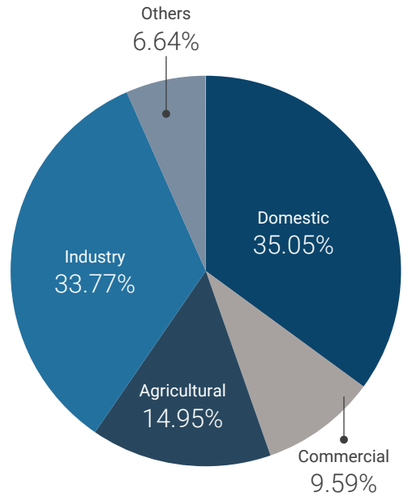
Sources: TNSEC (2020) TANGEDCO (2022)

Figure 4: Electricity Generation 2020



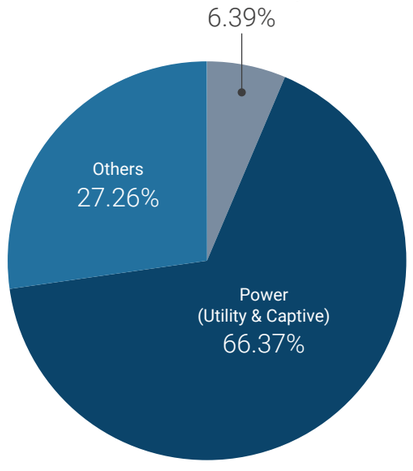
Sources: TNSEC (2020) TANGEDCO (2022)

Figure 5: Sector-wise electricity demand 2020s



Sources: TNSEC (2020) TANGEDCO (2022)

Figure 6: Industry-wide coal demand 2020



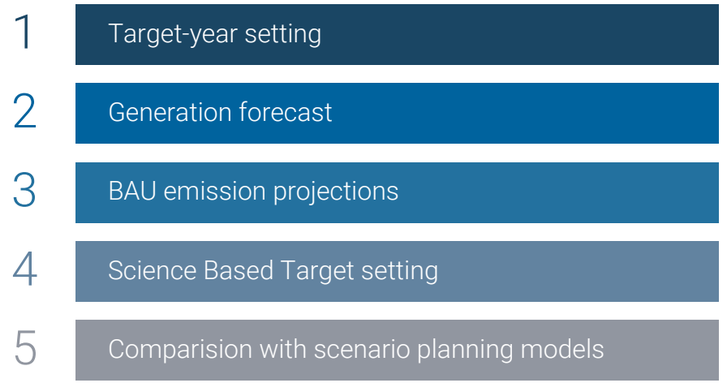
Sources: CEIC (2020), Energy Department of Tamil Nadu (2021), MOPONG (2019), Provisional Coal Statistics (2020), TANGEDCO (2022)

03

Methodology

The Sectoral Decarbonisation Approach (SDA) of the Science-Based target (SBT)[3] setting methodology has been used to model annual emission caps and an overall decarbonization pathway. Science-Based Targets (SBTs), which are built upon robust climate change mitigation scenarios developed by the Intergovernmental Panel on Climate Change (IPCC) and the International Energy Agency (IEA), set forth targets for decarbonisation. ETP B2DS and SBT 1.5°C are two pathways that are in line with the goals of the Paris agreement - limiting global warming well below 2°C above pre-industrial levels (ETP B2DS) and pursuing efforts to limit warming to 1.5°C (SBT 1.5°C) respectively. The methodological steps of this exercise are given below in an order:

Figure 7: Methodological steps



[3]The Science Based Targets (SBT) is a tool developed by the Science Based Targets initiative (SBTi), which drives ambitious climate action by enabling organizations to set science-based emissions reduction targets. The SBTi is a partnership between CDP, the United Nations Global Compact, World Resources Institute (WRI), and the Worldwide Fund for Nature (WWF).

3.1 Target-year setting

Setting a target year is the first step in developing a decarbonisation strategy for the power sector. This includes the extent of decarbonisation e.g., partial decarbonisation or full decarbonisation (zero carbon), and the year by which this will be achieved.

With 50% of its total installed power capacity from renewables (Energy Department of Tamil Nadu 2022), Tamil Nadu is an established renewable energy leader and has laid the foundation to decarbonise its power sector. Recent policy announcements, such as the planned capacity addition of 20 GW solar by the year 2030 is highlighting the state's long-term renewable energy ambitions. The time from 2020 to 2050 has been selected for this modeling exercise. 2020 has been set as the baseline year, and 2050[4] has been set as the year in which a zero-carbon grid will be achieved.

3.2 Generation forecasting

To estimate the total power generation in the State from 2020 to 2050 existing forecasts by various government and non-government organizations are compared. Most of these generation forecasts go up to the year 2030 only and needed to be extrapolated till the year 2050. A simple linear forecasting methodology for each was used to do so. The average CAGR of all the scenarios such as CEA (2021), NREL (2021), and WRI (2022) is used to forecast the generation.

3.3 BAU CO2 emissions projections

The historical emissions from 2010 to 2020, and the future emission till the year 2050 are estimated for the state's electricity sector. For emission forecasting, the emission intensity of Tamil Nadu is calculated based on the quantum of generation and the type of technology of the sources of electricity. This emission intensity is assumed to be constant till 2050 for the calculation of the BAU emissions in the state.

3.4 Science-Based Target (SBT) setting

ETP B2DS and SBT 1.5°C are two pathways that are in line with the goals of the Paris agreement. These two pathways will give two scenarios for decarbonisation. The output is emission targets in terms of absolute emissions as well as emission intensities from the base year (2020) to the target year (2050).

3.5. Comparison with scenario planning models

To conclude the analysis, the results from the SBT modelling are compared with existing scenario planning models by NREL (2021) and WRI (2022) for Tamil Nadu's power sector and the recently announced renewable energy purchase obligations by the Ministry of Power. The purpose of this comparative analysis is to estimate to what extent the current policy announcements and RPO obligations align with the results for the SBT model in terms of annual absolute carbon emissions.

[4]The target set here is based on the modelled pathways from the IPCC which aims to limit the warming to 1.5°C.

04

365%
increase in the generation between 2020 and 2050

8.17%
max annual compound growth rate in the generation

4.12%
min annual compound growth rate in generation

Generation Forecast

Generation forecasts for Tamil Nadu's power sector were available from multiple entities. Most of the available forecasts were made up to the year 2030 and had to be extrapolated till the year 2050 based on their CAGR. Comparing the existing generation forecasts, a significant variation in the compound annual growth rates (CAGR) of these forecasts can be found (refer to Table 1). Generation mix, if contained in any of these forecasts, was not considered for the forecast. The average CAGR of all the scenarios is 5.26%, which is used to forecast the generation from 2020 to 2050.

Table 1: Comparison of generation forecasts

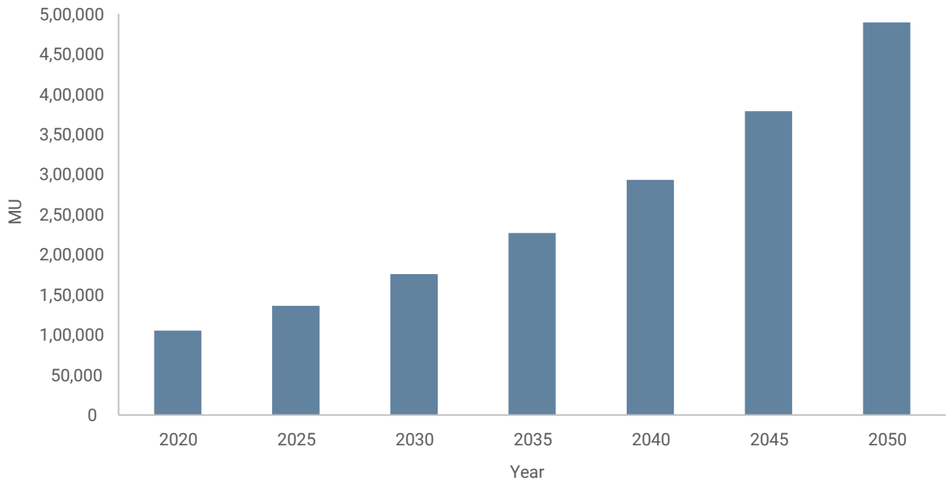
Organisation	Scenario Names	CAGR 2020 to 2050
WRI	LEAP	4.65%
	LEAP EPS	4.65%
	LEAP EEP	4.12%
NREL	NREL I	5.00%
	NREL II	8.17%
CEA[5]	PAM Baseline	5.19%
	PAM Optimistic	5.66%
	PAM Pessimistic	4.64%
Average		**5.26%**

Source: Ministry of Power (2022), NREL (2021), TANGEDCO (2022), WRI (2022)

The electricity generation of 105,146 MU in 2020 is forecast to increase 3.6 times to 489,395 MU by 2050 (refer to Figure 8).

[5]The CEA generation forecast utilized slightly different timelines, this have been adapted to this table.

Figure 8: Generation forecast 2020-2050



Source: Ministry of Power (2022), NREL (2021), TANGEDCO (2022), WRI (2022)

Table 2: Generation forecast

Year	Generation Forecast (MU)
2020	105,146
2025	135,864
2030	175,556
2035	226,843
2040	293,115
2045	378,747
2050	489,395

Source: Ministry of Power (2022), NREL (2021), TANGEDCO (2022), WRI (2022)

05

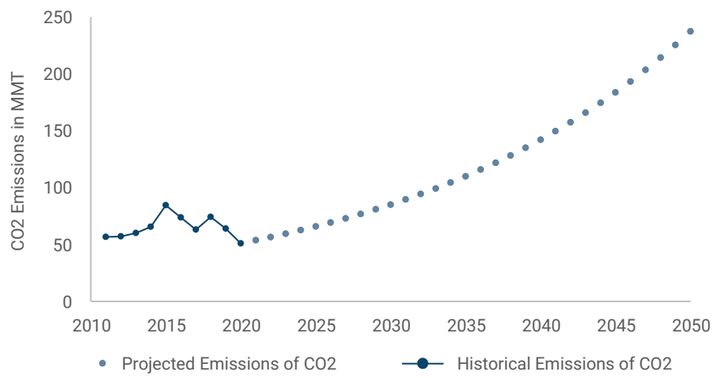
7%
decrease in CO2 emissions
between 2010 and 2020

365%
increase in CO2 emission
between 2020 and 2050 under
the BAU average growth scenario

Bau Emission Projections

The annual power sector-related CO2 emissions have decreased from 57.06 to 50.97 MMT/CO2 between 2011 and 2020[6]. This represents a 7% decrease. Under the BAU Scenario, CO2 emissions are expected to increase from 50.97 MMT in 2020 to 237.27 MMT in 2050, which is an increase of 365% (refer to Figure 9). The cumulative emissions between 2011 and 2050 are 4378.55 MMT (Refer to Figure 10). The contributors to this emission are coal, lignite, and gas power plants. Of which, power generated by lignite as fuel accounts for a share of more than 60% of CO2 emissions from 2010 to 2018 (refer to Figure 11).

Figure 9: Historical and BAU emission forecast 2010 to 2050



Source: TANGEDCO (2022), TANGEDCO (2022a), TNERC (2017)

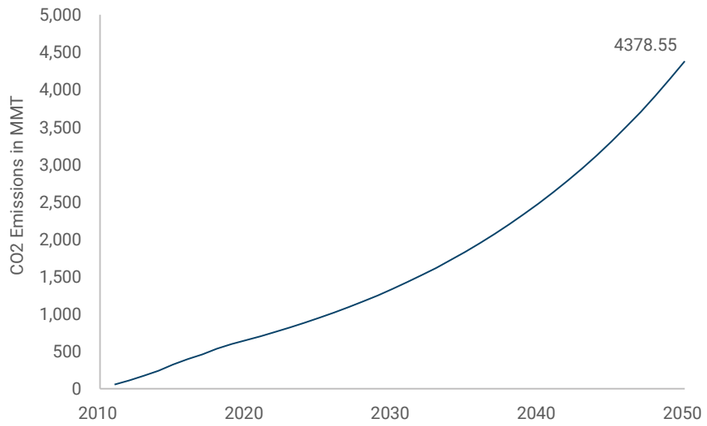
[6] Based on the historical emissions between the years 2011 and 2020, an emission factor for the state of Tamil Nadu is estimated. With this emission factor, future emissions from 2021 to 2050 are calculated.

Table 3: Annual absolute emission forecast BAU

Year	Emissions BAU (MMT CO2)
2020	50.98
2025	65.87
2030	85.11
2035	109.98
2040	142.11
2045	183.63
2050	237.27

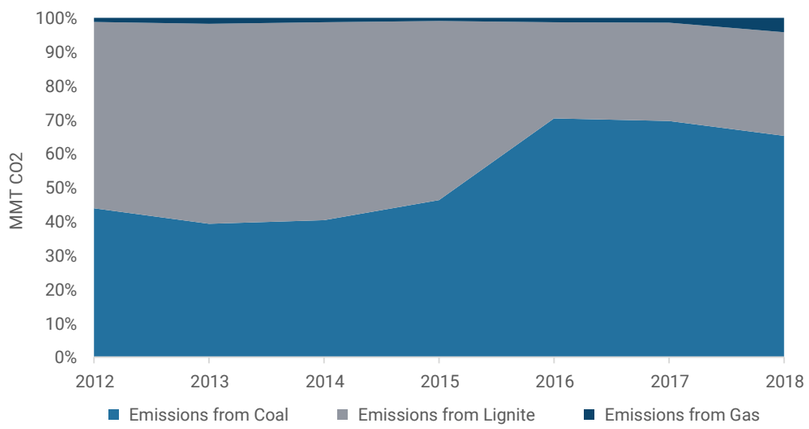
Source: TANGEDCO (2022), TANGEDCO (2022a), TNERC (2017)

Figure 10: Cumulative emissions



Source: TANGEDCO (2022), TANGEDCO (2022a), TNERC (2017)

Figure 11: Historical and BAU emission forecast 2010 to 2050



Source: TANGEDCO (2022), TANGEDCO (2022a), TNERC (2017)

06

72%
emission reduction by 2030 compared to BAU by following SBT 1.5°C

37%
reduction by 2030 compared to BAU by following ETP B2DS

3,324 MMT
of avoided cumulative emissions over BAU by following SBT 1.5°C

Science Based Target (SBT) Setting

ETP B2DS and SBT 1.5°C are two decarbonization pathways that are in line with the goals of the Paris agreement - limiting global warming well below 2°C above pre-industrial levels (ETP B2DS) and pursuing efforts to limit warming to 1.5°C (SBT 1.5°C) respectively. These two SBT pathways set a cap on the maximum carbon-dioxide emissions for every year up until 2050. The 'SBT 1.5°C' gives a pathway to limit global warming by 1.5°C which requires a 72% decrease in total emissions by 2030 and 100% by 2050. The 'ETP B2DS' gives a pathway to limit global warming well below 2°C which requires a 37% decrease in total emissions by 2030 and 100% by 2050. The SBT 1.5°C scenario is aggressive in the reduction of the emissions in comparison with 'ETP B2DS'. Also, the SBT 1.5°C scenario recommends reducing most of the emissions till 2030 after which it takes a less aggressive approach. The comparison of these two target-setting methods is given in Figure 12 and Figure 13.

Table 4: CO2 Emission targets (in terms of absolute emissions) estimated with the SBT 1.5°C and ETP B2DS method

Year	Emission Targets MMT CO2	
	SBT 1.5°C	ETP E2DS
2020	50.98	50.98
2025	32.56	42.18
2030	14.13	31.82
2035	8.71	21.29
2040	3.28	11.80
2045	1.70	3.49
2050	0.00	0.00

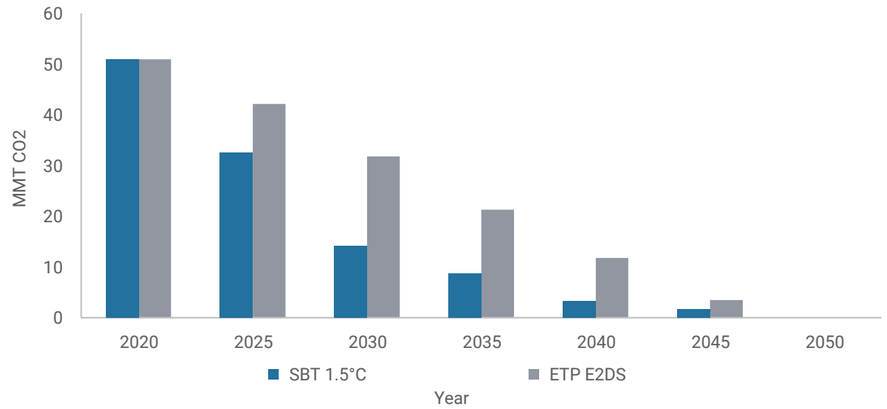
Source: TANGEDCO (2022), TANGEDCO (2022a), TNERC (2017)

Table 5: CO2 Emission targets (in terms of emission intensity) estimated with the SBT 1.5°C and ETP B2DS method

Year	Emission Targets (Kg CO2/kWh)	
	SBT 1.5°C	ETP E2DS
2020	0.48	0.48
2025	0.25	0.33
2030	0.09	0.21
2035	0.05	0.12
2040	0.01	0.06
2045	0.00	0.01
2050	0.00	0.00

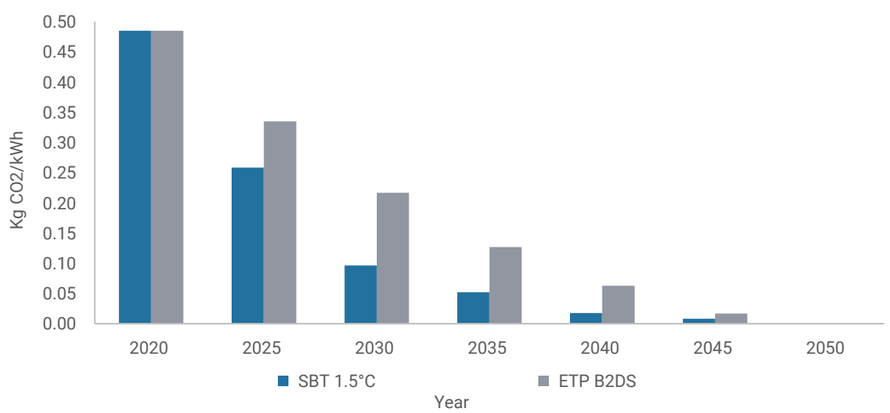
Source: SBT model

Figure 12: Absolute CO2 emission for SBT 1.5 and ETP B2DS B2DS.



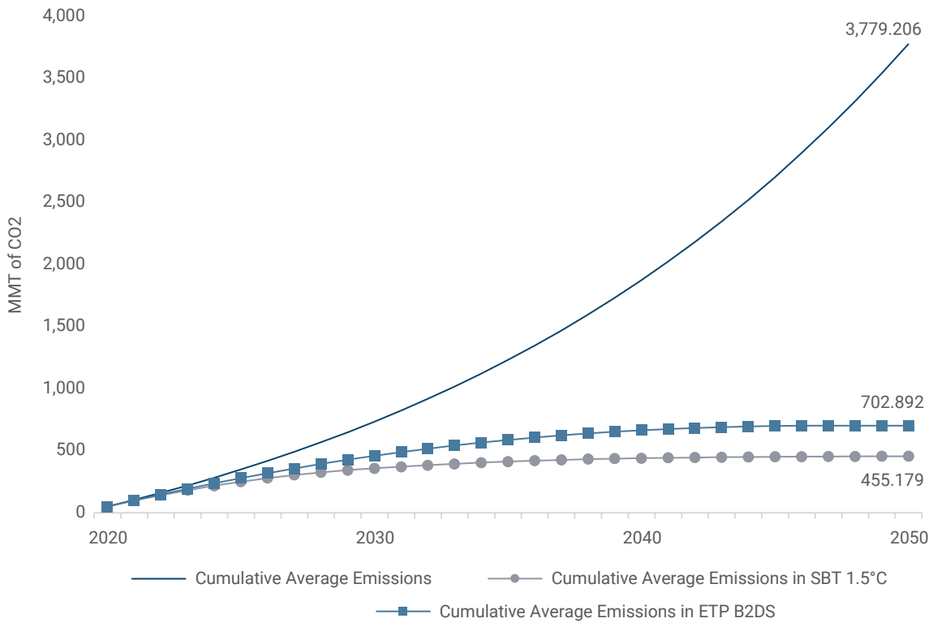
Source: SBT model

Figure 13: CO2 emission intensities for SBT 1.5°C and ETP B2DS.



Source: SBT model

Figure 14: Cumulative emissions in BAU, SBT 1.5°C, and ETP B2DS from the year 2020 to 2050



Source: SBT model

07

56%
higher CO2 emission under the RPO scenario as compared to SBT 1.5°C by 2030

17%
higher CO2 emission under the RPO scenario as compared to ETP B2DS by 2030

81%
of carbon-free energy generation is required to achieve the targets of SBT 1.5°C by 2030

Comparison with Scenario Planning Models

Numerous organizations undertook scenario planning exercises to forecast the future energy mix of Tamil Nadu's power sector. Scenarios planning models or simple generation forecasts that will be compared are outlined in Table 6 below:

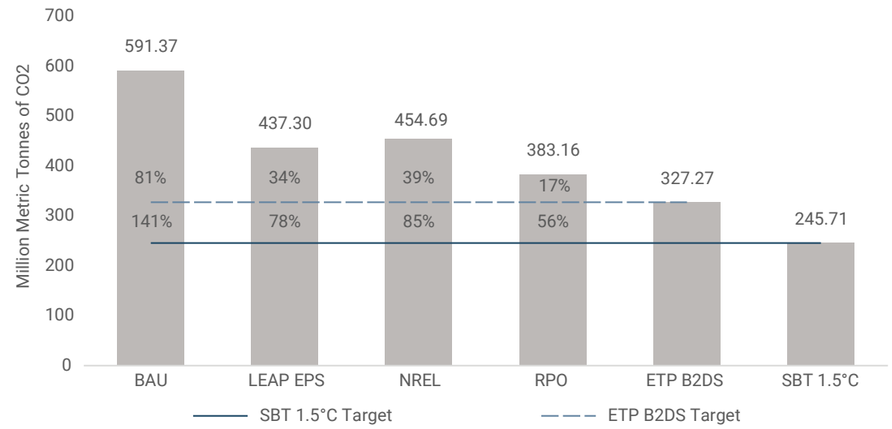
Table 6: Scenario Planning models and RPO obligations

Model	Assumptions
BAU	This model forecasts the generation, CO2 emissions, and energy mix based on the historical data from 2011 to 2020 from the stat book of TANGEDCO. This emission intensity is assumed to be constant from 2020 to 2050.
LEAP EPS By WRI	This model considers the Tamil Nadu target of incorporating 20GW of solar, 2 GW of gas, and 3 GW of hydro by 2030 based on the TN Government – IREDA agreement, 2021.
NREL	This model assumes that the share of total generation from coal decreases from 46% in 2020 to 35% in 2030 with an increasing share met by supercritical coal while the use of subcritical coal plants decline. The energy contributions from wind and solar increases from 46% in 2020 to 52% by 2030.
RPO	This model is based on the Renewable Energy Purchase Obligations set by the Ministry of Power – Government of India.

The estimated cumulative CO2 emissions from the year 2020 to 2030 of these scenario planning models are compared with the two SBTs - SBT 1.5°C and ETP B2DS. All scenario planning models fall short to meet the cumulative emission cap as per ETP B2DS and SBT 1.5°C. To meet the ETP B2DS emission cap, the BAU, LEAP EPS, NREL, and RPO models should reduce their emissions by 81%, 34%, 39%, and 17% respectively. (Figure 15).

To meet the SBT 1.5°C emission cap, the BAU, LEAP EPS; NREL, and RPO models should reduce their emissions by 141%, 78%, 85%, and 56% respectively.

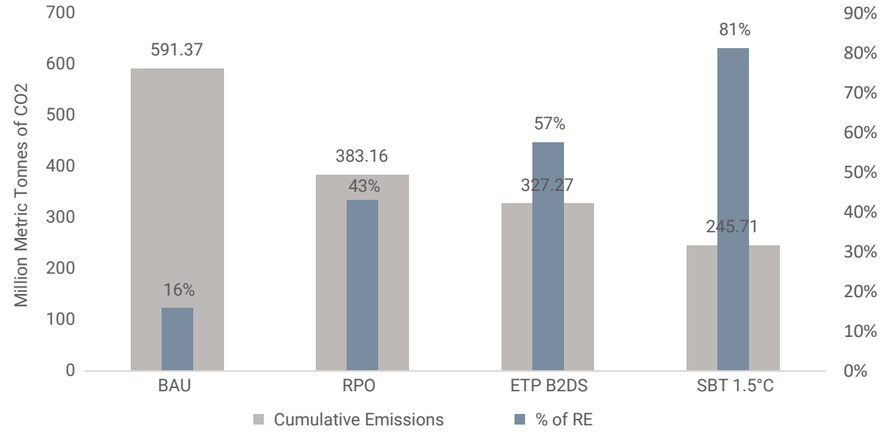
Figure 15: Cumulative CO2 emissions of various models such as the LEAP EPS, NREL, STAT Book, and RPO with the target on CO2 emissions from SBT 1.5°C and ETP B2DS.



Source: Ministry of Power (2022), NREL (2021), TANGEDCO (2022), TANGEDCO (2022a), TNERC (2017), WRI (2022)

The SBT methodology indicates that by 2030 the state will need to generate 57% to 81% of its energy from free carbon-free energy sources to align with the ETP B2DS and SBT 1.5°C pathways respectively. If the state fulfils the RPO, which is 43%[7] from renewable energy, the cumulative emissions will be closer to one of the SBT scenarios – ETP B2DS.

Figure 16: Comparison of cumulative emissions with the percentage of free carbon-free energy to be generated



Source: Ministry of Power (2022), NREL (2021), TANGEDCO (2022), TANGEDCO (2022a), TNERC (2017), WRI (2022)

[7] RPO includes hydro, solar and wind, where as a carbon-free energy includes energy generated from any technology that does not emit CO2

08

Conclusions

There is a need to outline a decarbonisation pathway and to set emission reduction targets for the state's power sector. The 'SBT 1.5°C' sets a target to limit global warming by 1.5°C which requires a 72% decrease in total emissions by 2030 and 100% by 2050. The 'ETP B2DS' sets a target to limit global warming well below 2°C which requires a 39% decrease in total emissions by 2030 and 100% by 2050. The SBT 1.5°C scenario is aggressive in the reduction of the emissions in comparison with the 'ETP B2DS'.

Utilizing the SBT methodology indicates that the state will have to generate 57% to 81% of its energy from carbon-free energy sources to align with the ETP B2DS and SBT 1.5°C pathways respectively. This would limit the cumulative CO2 emissions from 2020 to 2030 to 327.27 MMT of CO2 under the ETP B2DS pathway and to 245.71 MMT of CO2 under the SBT 1.5°C pathway. Under the Business as Usual (BAU) scenario, Tamil Nadu would accumulate 591.37 (MMT) of CO2 emissions from 2020 to 2030. This would exceed recommended cumulative emissions of the ETP B2DS pathway by 81% and SBT 1.5°C pathway by 141%.

Comparing the ETP B2DS and SBT 1.5°C pathways with existing scenario planning models and the recently announced RPO targets, it can be found that recent policy announcements and renewable energy targets, if met, have the potential to direct the state towards the ETP B2DS decarbonisation pathway.

If the renewable purchase obligation (RPO) is met by 2030, which is 43% of the total energy coming from renewable energy, the CO2 emissions of the state's electricity sector would be closer to the CO2 emission targets of the ETP B2DS scenario. At the top of fulfilling the RPO adding 14% of energy from renewable sources would meet the emission targets of ETP B2DS while adding 38% of energy from renewable sources would meet the aggressive emission targets of SBT 1.5°C.

09

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