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TAMIL NADU'S TRANSITION TO GREEN ENERGY: A LOOK AT CURRENT AND PLANNED RENEWABLE ENERGY INITIATIVES

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About CAG

CAG is a 37-year-old non-profit and non-political organisation that works towards protecting citizens' rights in consumer, civic and environmental issues and promoting good governance processes including transparency, accountability and participatory decision-making.

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Executive summary

Tamil Nadu is one of the leading states in India when it comes to renewable energy. Though the installed capacity of renewable energy is higher than non-renewable energy, it is not reflected in the overall electricity mix in the state. Unfortunately, the state still greatly depends on coal to generate electricity. Amid the recent announcement about the Tamil Nadu Climate Change Mission by the Government of Tamil Nadu, gradually reducing dependence on expensive and obsolete fossil fuel based power plants is essential if the state is to adapt to and mitigate climate change.

This report is prepared with two key objectives: (i) to understand the current and planned renewable energy initiatives in Tamil Nadu; (ii) to examine public perception of renewable energy in Tamil Nadu. Based on desk research, filing of RTI applications and consulting grey literature, this report has brought a few parameters that can inform the state's renewable energy initiatives. Primary quantitative data has been collected from 435 respondents from eight districts to measure the perception of renewable energy.

As of 2020-2021, the installed capacity of non-renewable sources of electricity generation was 16,219 MW. At the same time, renewables constituted 16,276 MW. Of the total installed capacity of renewables, wind energy alone contributes 52 per cent, and solar, hydro and biomass (including bagasse co-generation) constitute the remaining 48 per cent. Between 2011 and 2015, under the Chief Minister's Solar Powered Green House Scheme, 3,09,973 rural households benefited from a cumulative capacity of 25 MW. Based on the initiatives of GUIDANCE, the Government of Tamil Nadu's nodal agency for investment promotion, investments worth ₹35,828 crores were brought in from the renewable energy solution providers, and these investments were proposed to create employment for about 24,000 individuals. A dedicated green energy corridor is an essential prerequisite to improving distribution of renewable energy within the overall electricity mix. Under Phase-I of the green energy corridor, the Tamil Nadu Transmission Corporation Limited (TANTRANSCO) has completed 174 KM.

With regard to public perception of renewable energy, around 62 per cent of the respondents feel positive about renewable energy. Only about 11 per cent express negative feelings. As most of the population has a positive opinion of renewable energy, governments and civil societies should find it easier to promote the transition towards renewables at the macro and micro levels. Of the four renewables identified for this report, respondents preferred solar and wind over hydro and biomass.

1. Introduction

Energy is necessary to meet basic human needs such as cooking, lighting, health, comfort, space, mobility, communication and built infrastructure. Electricity, a form of energy, is essential to modern life. People use electricity for lighting, cooling, heating, refrigeration, and operating appliances, computers, electronics, machinery, and public transportation systems. Electricity is a secondary energy source from the transformation of other primary energy sources such as natural gas, coal, oil, nuclear power, solar, hydro, wind and biomass. Primary sources can be renewable or non-renewable. Amid climate change, governments are acting to improve renewable energy dependency. The following table gives an overview of primary renewable energy sources that help generate secondary energy, such as electricity, heat and transport fuels.

Electricity	Heat	Transport Fuels
Biomass: 1. Cofiring 2. Small scale combined heat and power, CHP (Gasification internal combustion engine) 3. Direct dedicated stoker & CHP 4. Small scale CHP (steam turbine) 5. Small scale CHP (organic Rankine cycle) **Solar Electricity:** 1. Concentrating solar power 2. Utility-scale PV (1-axis and fixed tilt) 3. Commercial rooftop PV 4. Residential rooftop PV **Geothermal Electricity:** 1. Condensing flash plant 2. Binary cycle plant **Hydropower:** All types **Ocean Electricity:** Tidal barrage **Wind Electricity:** 1. Onshore 2. Offshore	**Biomass Heat:** 1. Municipal solid waste based combined heat and power (CHP) 2. Anaerobic digestion-based CHP 3. Steam turbine CHP 4. Domestic pellet heating system **Solar Thermal Heat:** 1. Domestic hot water systems in China 2. Water and space heating **Geothermal Heat:** 1. Greenhouses 2. Uncovered aquaculture ponds 3. District heating 4. Geothermal heat pumps 5. Geothermal building heating	**Biofuels:** 1. Corn ethanol 2. Soy biodiesel 3. Wheat ethanol 4. Sugarcane ethanol 5. Palm oil biodiesel

Table 1: Overview of primary renewable energy sources | IPCC[1]

2. Renewable energy in climate change mitigation

Countries are at crossroads in taking measures to mitigate the impacts of climate change. As science continues to produce indisputable evidence of climate change, it is likely that the numbers of climate deniers is growing smaller. As this report is meant to bring out the current renewable energy pipeline in Tamil Nadu, this section aspires to highlight renewable energy transition as one of the prudent ways to mitigate climate change. Climate change is a global phenomenon; a single country, state, or local body aiming to achieve change might not produce the desired outcomes. But when all the 196 Parties to Paris Agreement take local actions, it can

[1] https://bit.ly/EHT_Renew

fructify their aspiration to limit global warming, preferably to 1.5°C, compared to pre-industrial levels (Lelieveld et al. 2019). Fossil fuels still constitute more than 50 per cent of the world's energy consumption. Therefore, the transition to renewable energy needs to happen faster, not just in power generation but also in transport, heating and cooling mechanisms to address the rise in global temperatures. By 2050, renewables could supply four-fifths of the world's electricity, according to the International Renewable Energy Agency (IRENA). This transition potentially cuts carbon emissions and helps to mitigate climate change. But to get there, innovation needs to be accelerated in business and technology (IRENA 2022). Thus, transitioning to renewable energy sources holds the key capability to displace greenhouse gas emissions (Owusu and Asumadu-Sarkodie 2016). Though securing the energy supply and controlling energy sector contribution to climate change are the two overriding problems of the energy sector for a sustainable future (Kaygusuz 2012), it seems to be achievable.

One of the major deterrents to the adaptation of renewable energy sources is the perceived high cost of transition, deployment and maintenance. However, several renewable sources, especially wind and solar energy have undergone remarkable growth and massive cost cuts over the past decade. Prices are declining rapidly and renewable energy is turning out to be gradually more competitive. Renewable energy is already cheaper than continuing to operate old, dirty and inefficient fossil fuel-fired or nuclear power plants. Solar and wind are becoming the lowest-cost electricity sources in India, even without subsidies. Comparing countries, the cost of solar in India has constantly been among the lowest in the world (NITI Aayog and Rocky Mountain Institute 2020).

Though climate change may potentially affect solar radiation and wind speed in coming years, the development of battery storage capabilities and exclusive green energy corridors may, to a great extent, help to subdue the adverse effect of climate change on solar radiation and wind speed. Reduced stream flow for hydropower, diminished sunlight and increasing temperature for solar, altered air density and wind speed pattern for wind power and changing yields for biomass crops (Brettman 2021) are the possible ways in which climate change can impact renewable energy sources. A study based on climate models demonstrated that Tamil Nadu shows promising wind potential. The study also reiterated that the maximum concentration of wind energy is in the Palghat pass area of Kerala and the Kanyakumari region in Tamil Nadu, followed by Gujarat (Anandh, Gopalakrishnan, and Mukhopadhyay 2022). Thus, Tamil Nadu has huge potential to sustain its leadership position in the wind energy sector. At the same time, we cannot ignore evidence generated on the impact of wind farms on biodiversity (Kumara et al. 2022). Therefore, researchers suggested critically evaluating animal diversity, especially the birds and their occupancy, seasonal movements, abundance of mammals and possible impact on them before placement of wind farm infrastructure. Under the global business and biodiversity programme, the International Union for Conservation of Nature (IUCN) has developed a guideline for solar and wind energy project developers to mitigate the biodiversity impacts of such infrastructure developments (Bennun et al. 2021).

Transitioning to renewable energy sources in a fair and inclusive manner requires addressing several key challenges, such as ensuring that vulnerable and marginalised communities are not left behind, creating new job opportunities, and promoting community ownership and participation in decision-making processes. Strategies to achieve this include prioritising community engagement and participation, investing in job training and support for displaced workers, ensuring equitable access to clean energy, promoting community ownership of renewable energy projects, and developing policies that prioritise equity and justice. By implementing these strategies, policymakers and stakeholders can help ensure that the transition to renewable energy sources is grounded in the needs and aspirations of local communities and promotes a more equitable and inclusive future.

With careful long-term planning, dependency towards 100% renewables is achievable as related technologies are developed as we progress. Governments, intergovernmental agencies, interested parties and individuals today look forward to achieving a sustainable future due to the opportunities created in recent decades. Against this backdrop, the present report seeks to facilitate policymakers to make informed decisions to promote renewable energy in the state.

3. Methodology

To understand the current and planned renewable energy initiatives, RTI applications were filed with relevant government ministries and departments. In addition to that, secondary data was collected from grey literature.[2] Further, to understand the public perception of renewable energy in Tamil Nadu, CAG surveyed[3] eight districts representing east, west, north and south zones, with two districts in each zone. Survey participants include a mixed group with varied socio-demographic characteristics such as gender, college students, working professionals, self-employed, rural, urban, etc. The perception survey[4] was conducted among 435 respondents from Chennai, Tirupattur, Salem, the Nilgiris, Madurai, Theni, Trichy, and Thiruvarur districts. Statistically, the sample is representative of Tamil Nadu. The survey captured the public perception of solar, wind, hydro and biomass energy, energy security future and climate change.

4. Findings

This section of the report presents a comprehensive analysis of the current renewable energy pipeline in Tamil Nadu. It covers various aspects of renewable energy, including solar energy (ground-mounted and rooftop), job creation in renewable sector, infrastructure development, investments, progress towards achieving Sustainable Development Goal 7, challenges and

[2] The term grey literature is used to describe a wide range of different information that is produced outside of traditional publishing and distribution channels.
[3] Perception survey questionnaire.
[4] Output of the data analysis.

solutions related to renewable energy integration, curtailment[5] of renewable energy, phasing out non-renewable energy sources, and public perception.

4.1 Current renewable energy installed and generation capacity of Tamil Nadu

Renewable energy in Tamil Nadu is generated from four sources: solar, wind, hydro, and biomass (including bagasse co-generation). Solar energy is generated through ground-mounted photovoltaic and roof-top photovoltaic. Most solar energy is generated by private players (The Hindu 2022). Wind energy generation started in Tamil Nadu in 1986, and is generated through wind farms primarily placed in the four wind passes, namely, Aralvaimozhi (Kanyakumari and Tirunelveli), Sengottai (Tirunelveli and Thoothukudi), Palghat (Coimbatore, Tirupur and Erode), and Cumbum (Dindigul and Theni) (TNENVIS 2020). Like solar, most of the wind energy is also generated by private players. Regarding hydro energy, until 2018-2019, TANGEDCO considered it as a non-renewable energy source along with thermal and gas. The Ministry of New and Renewable Energy (MNRE) termed hydro projects <25 MW as a renewable source in1999 (MNRE 2022). From 2019 onwards, the Ministry of Power declared that hydro projects >25 MW were also a renewable energy source (POWERMIN 2019). Therefore, from 2019-2020, hydro energy sources are considered renewables by TANGEDCO. Though TANGEDCO also considered hydro energy sources as non-renewable sources of energy till 2018-2019, for the purpose of this study, hydro energy is considered a renewable source of energy all through the years the report discusses. Biomass (including bagasse co-generation) is another form of renewable energy source, as identified by TANGEDCO. Biomass energy is produced through bagasse, coconut shells, coffee waste, cotton stalk, de-oiled cakes, groundnut shells, P. Juliflora, jute wastes, municipal solid waste, rice husk, sawdust, soya husk, straw, etc. (TNENVIS 2020).

[5] Curtailment is when an electricity generating system stops exporting power to the grid or temporarily shuts down, resulting in the waste of energy that could have been utilised.

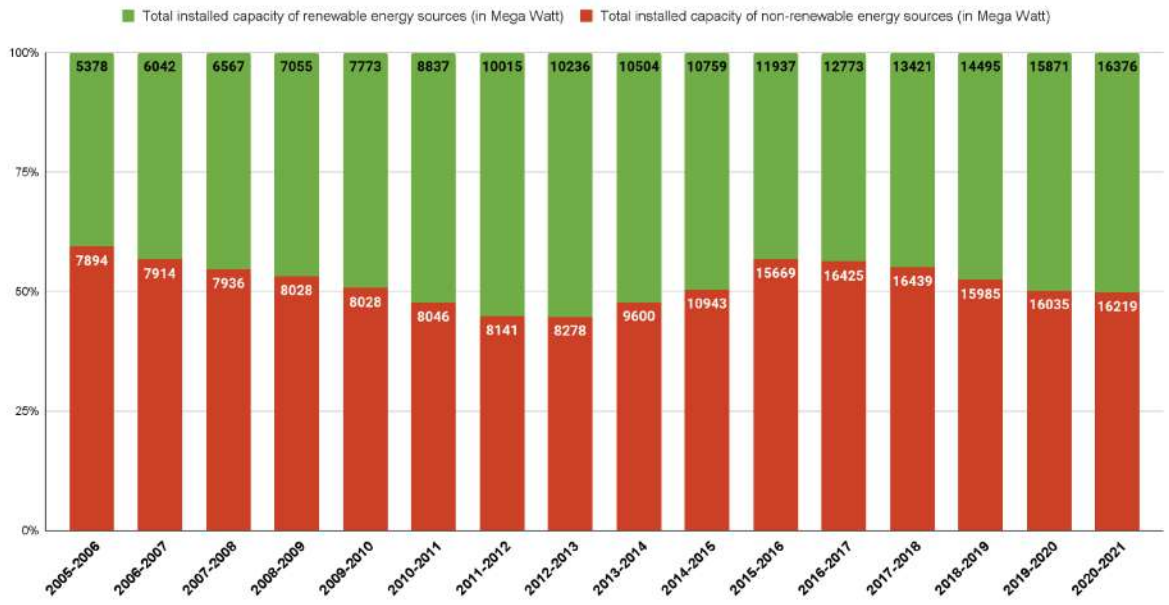

Figure 1: Installed capacity of renewable and non-renewable sources | TANGEDCO[6]

As of 2021, the current installed capacity of renewable energy is more than 50% when comparing non-renewable energy sources (see Figure 1). As per Auroville Consulting (2022), in Tamil Nadu, as of 2020, renewable energy accounts for only 22% of the total electricity generation, while coal power plants make up the majority with 75%. The possible reason for the lower percentage of renewable energy mix may mainly be due to curtailment resulting from the intermittent nature of renewables and the absence of dedicated green energy corridors.

Year	Hydro	Wind	Solar Power Plant	Solar Roof-top	Biomass power plant	Bagasse - Private	Bagasse - Cooperative	Total renewable energy added
Up to 2005-2006	2137.4	857.56	-	-	7.75	40	0	3042.71
2006-2007	46.75	577.91	-	-	17.5	22	0	664.16
2007-2008	2.5	381.08	-	-	26.5	115	0	525.08
2008-2009	0	430.98	-	-	36.7	20	0	487.68
2009-2010	0	602.03	-	-	27.5	88.8	0	718.33
2010-2011	4	997.4	5	-	6.95	50	0	1063.35
2011-2012	32.6	1083.46	10	-	25	27.5	0	1178.56
2012-2013	14.5	174.6	5	-	8.4	22	0	224.5
2013-2014	47	107.38	76.66	-	33.6	0	0	264.64

[6] https://bit.ly/3MG1nkD

2014-2015	4	186.25	46.25	7.3	19	0	0	262.8
2015-2016	19.5	158.85	956.502	32.8	0	0	18	1185.652
2016-2017	0	251.55	506.86	48.66	0	0	15	822.07
2017-2018	0	303.14	312	38.53	7.669	-19	4.5	646.839
2018-2019	7	315.72	638.62	54.59	27.925	0	33	1076.855
2019-2020	7	54.84	1275.875	40.83	0	0	0	1378.545
2020-2021	0	42.95	347.88	107.943	0	0	0	498.773
Total	**2322.25**	**8565.96**	**4180.647**	**330.653**	**265.594**	**620.4**	**90.5**	**16376.004**

Table 2: Year-wise capacity added to renewable energy sources (in MW) | TANGEDCO[7]

Based on the data presented in Table 2, wind energy alone contributes to 52 per cent of the installed capacity of renewables in Tamil Nadu. Solar, hydro and biomass constitute the remaining 48 per cent of installed capacity.

4.1.1 Solar energy (ground mounted and roof top solar)

Conventionally, solar energy is produced through ground-mounted and rooftop solar photovoltaic (PV) systems. For this report, ground-mounted systems are considered as solar power plants. The following data from TANGEDCO shows the yearly solar energy capacity (in MW) added to renewable energy.

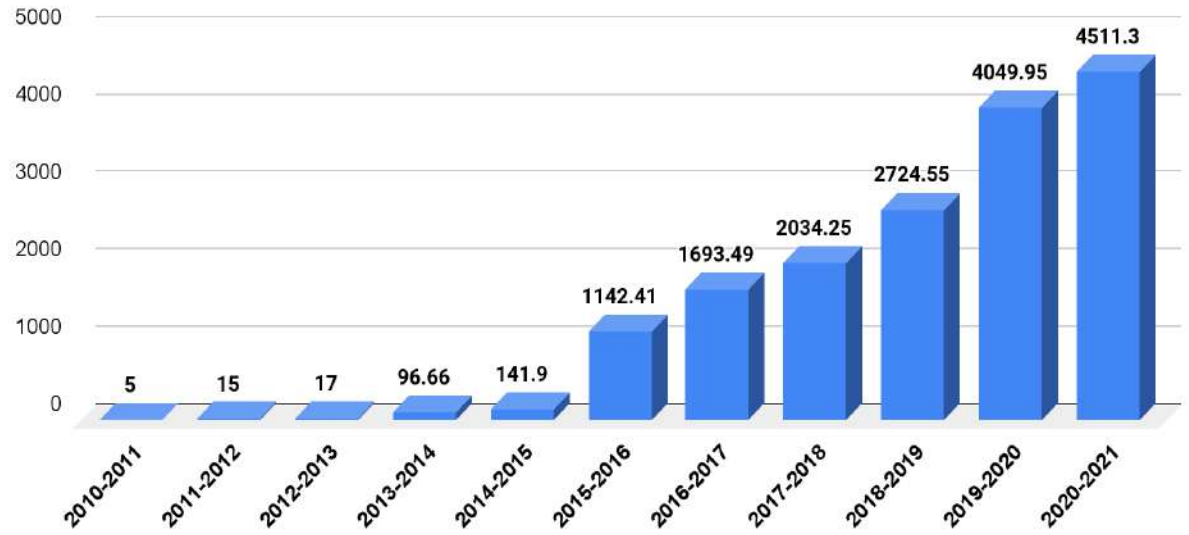

Figure 2: Solar energy installed capacity (in MW) | TANGEDCO[8]

[7] https://bit.ly/3MG1nkD
[8] https://bit.ly/3MG1nkD

Further, based on the RTI replies, between 2011 and 2015, under the Chief Minister's Solar Powered Green House Scheme, 3,09,973 rural households benefited from a cumulative capacity of 25 MW. The following table brings out district-wise beneficiaries except for Chennai.

Sl.No.	District	Number of households benefited
1	Ariyalur	5525
2	Coimbatore	8543
3	Cuddalore	11771
4	Dharmapuri	9143
5	Dindigul	11219
6	Erode	11252
7	Kancheepuram	11688
8	Kanyakumari	4687
9	Karur	5342
10	Krishnagiri	10778
11	Madurai	9597
12	Nagapattinam	10283
13	Namakkal	7964
14	Nilgiris	2685
15	Perambalur	3473
16	Pudukottai	10298
17	Ramanathapuram	7675
18	Salem	15516
19	Sivagangai	7081
20	Thanjavur	13072
21	Theni	4538
22	Tirunelveli	12221
23	Tiruppur	8921
24	Thiruvallur	11201
25	Thiruvannamalai	15907

26	Thoothukudi	7696
27	Tiruvarur	8281
28	Trichy	12123
29	Vellore	19388
30	Villupuram	22209
31	Virudhunagar	9896

Table 3: Chief Minister's solar-powered greenhouse scheme | TEDA[9]

4.1.2 Job creation in the renewable energy sector

Following the historical development in India's coal sector, and now with a shift towards ambitious decarbonisation, coal based employment is expected to decline by about 52 % between 2020 and 2050 (Sperfeld et al. 2021). The number of employees in the coal sector has already decreased considerably in past decades due to increasing mechanisation. In the coal-mining industry alone, approximately 105,000 jobs were lost due to automation between 2000 and 2015. This transition, however, needs to be efficiently managed politically and economically to mitigate adverse impacts on displaced workers and communities. Of the 35 lakh people projected to be employed in the Indian power sector by 2050, 32 lakhs can be employed in the renewable energy sector alone. Therefore, the renewable energy sector has the potential to employ five times more people by 2050 than the entire Indian fossil-fuel sector employs today. This is because renewable energy technologies tend to be more labour-intensive than non-renewable energy technologies. At the same time, distributed renewables such as small-scale hydro, roof-top solar and biomass create maximum employment for every MW of installed capacity. Roof-top solar employs 24.72 persons, small hydro employs 13.84 persons and biomass employs 16.24 persons for constructing and running a one-megawatt plant. Biomass and solar energy will be the major drivers of employment, with up to 2 million and 1.1 million employees, respectively, by 2050 (Jacobs et al. 2019).

To estimate the number of jobs created in Tamil Nadu in the renewable energy sector, RTI applications were filed with the MNRE and the Tamil Nadu Energy Department, whereas the respective public information officers do not hold job creation information data. Apart from creating new jobs in the renewable energy sector, developing a skilled workforce and reskilling the existing workforce is crucial. At the same time, skilling of such a workforce is projected to be the primary future challenge. According to the Nationally Determined Contributions (NDC) PLUS scenario,[10] India would require 1,43,000 skilled experts and approximately 4,10,000 semi-

[9] https://bit.ly/3MYiOhV

[10] Nationally determined contributions (NDCs) are at the heart of the Paris Agreement and the achievement of its long-term goals. NDCs embody efforts by each country to reduce national emissions and adapt to the impacts of climate change.

and low-skilled technicians in the solar sector. This number would increase to 2,50,000 skilled jobs and more than 8,50,000 semi- and low-skilled technicians under the REmap scenario.[11] Based on the RTI filed with the Tamil Nadu Skill Development Corporation, there is one solar green skill training provider each in Chennai and Ranipet districts. As of 2021, there are 34 individuals undergoing training in Chennai and 30 completed training on solar green skills in Ranipet[12]. Under the Green Skill Development Programme of the Ministry of Environment, Forest and Climate Change (MoEFCC), in 2021, 410 individuals received green skill training[13]. Research undertaken by Tyagi et al. (2022) suggests that governments should support rural skill development programs to bring the transition to renewable energy closer to communities. Additionally, updating green skilling curriculums through regular industrial engagement can help bridge the skill gap and ensure a timely supply of skilled workers. It is also important to reskill and upskill the existing workforce transitioning from non-renewable to renewable energy sectors to keep up with industry requirements. Tyagi et al. (2022) further stated that the COVID-19 pandemic has affected the Indian renewable energy sector, resulting in 48% fewer jobs created in FY21 compared to FY19. Only 6,400 new workers were added in FY21 compared to 12,400 in FY19. Moreover, the total workforce added in FY20 and FY21 combined (11,600) was 6% lower than in FY19 alone (12,400).

4.1.3 Renewable energy infrastructure under development

Most of the solar, wind and biomass energy infrastructure in Tamil Nadu is developed mainly by private players. Therefore, there is scant data to understand the renewable infrastructure under development in the state. By filing RTI applications, it was understood that two hydropower projects are under development in the Nilgiris, Namakkal and Trichy districts. In the Nilgiris district, Kundah pumped storage hydroelectric project with 500 MW with an installed capacity is under construction. Within the geographical extent of Namakkal and Trichy districts, a 20 MW Kollimalai Hydro Electric Project is under development[14]. The TANGEDCO has signed a memorandum of understanding with the Indian Renewable Energy Development Agency Ltd. (IREDA), a financing arm of MNRE for funding renewable and energy efficiency projects. Based on the signed MoU, Tamil Nadu plans to add 25,000 MW of new capacity in the next ten years to reduce power purchase costs and achieve self-sufficiency in meeting the state's energy needs. Of the total capacity, TANGEDCO is planning for 20,000 MW of solar power projects, with adequate battery storage, 3,000 MW of pumped storage hydroelectric projects, and 2,000 MW of gas-based power plants for efficient renewable integration. The loan required for the above projects is estimated at ₹1,32,500 crore (The Hindu Businessline 2021).

[11] REmap programme determines the potential for countries, regions and the world to scale up renewables. REmap assesses renewable energy potential assembled from the bottom up, starting with country analyses done in collaboration with country experts, and then aggregating these results to arrive at a global picture.
[12] https://bit.ly/3oyKOPI
[13] https://bit.ly/43aiOBb
[14] https://bit.ly/45DmEV8

Though the Tamil Nadu government is progressing to increase its renewable energy capacity, due to the COVID-19 pandemic, such progress was delayed during the FY 2020-21 and 2021-22. The renewable energy industry reported that there had been a supply chain disruption and a shortage of skilled manpower during the pandemic. It delayed the commissioning of projects and targets (Olabi et al. 2022; Lok Sabha Secretariat 2022).

4.1.4 Quantum of existing public and private investments in renewable energy

From the data received from MNRE, as on June 2022, solar projects of 5690.79 MW have been installed in Tamil Nadu. By keeping the normative cost of ₹4.5 crores per MW of solar infrastructure, an investment of around ₹25,608 crores has been made so far. Interestingly, as of FY 2020-2021, the total installed capacity of solar projects is 4511 MW (see Figure 2). Therefore, there was an increase of 1179 MW till mid-2022. According to Dash (2019), the standard cost of wind infrastructure is ₹6 crores per MW. Based on this, a total of ₹51,390 crores has been invested in Tamil Nadu for the 8565 MW of wind power. As of December 2022, the total installed wind energy capacity of Tamil Nadu is 8621 MW (IWPA 2022), which is an increase of 56 MW from FY 2020-2021. These can be considered an indicator of the progression and development of solar and wind energy infrastructure and investments in Tamil Nadu annually. With the help of GUIDANCE, the Government of Tamil Nadu's nodal agency for investment promotion and single window facilitation, investments have been attracted from wind energy machinery suppliers, original equipment manufacturers, and solar cell and photovoltaic module manufacturers.

Sl.No.	Name of the company	Products	Investments (in Rs. Crores)	Proposed Employment
1	WEG Industries	Wind turbine motors	650	650
2	Tata Power	Solar PV module and cells	3000	2000
3	Senvion Wind Technology Pvt. Ltd.	Wind blades and turbines	130	1400
4	Bonfiglioli S.P.A., Italy	Gearboxes to wind industry	400	250
5	JSW Renew Energy Two	Power generation	3000	100
6	Flender Drives	Wind turbine gearboxes	500	200
7	Eickhoff Wind Asia Pvt. Ltd.	Wind turbine gearboxes	410	525

8	SunEdison	Solar module and cells	1423	1907
9	TPI Composites - Expansion		300	1000
10	JSW Renew Energy	Wind farm	6000	2100
11	JSW Renewable Energy (Vijayanagar)	Wind farm	300	320
12	First Solar	Solar PV module and cells	4185	1076
13	Vivid Solaire Energy Pvt. Ltd	Wind farm	2000	600
14	Toshiba JSW Power Systems	500 MW to 1000 MW sub critical and supercritical steam turbines and generators	800	500
15	ReNew Power	Solar module and cells	1203	2000
16	Vikram Solar	PV solar 1 GW module & 500 MW cell units	5423	7542
17	Siemens - Expansion	Wind turbine gearboxes	225	125
18	Siemens Ltd.	Wind turbine gearboxes	23	340
19	Vestas Wind Energy Pvt. Ltd.	Wind turbines	626	500
20	AGS-Dindigul Renewable Energy Project	Solar energy power	4500	500
21	TPI Composites, USA	Wind blades	730	875
		Total	**35,828**	**24,510**

Table 4: Investments made in Tamil Nadu in the renewable energy sector | GUIDANCE[15]

In 2022, investments worth ₹35,828 crores were made in Tamil Nadu through GUIDANCE. These investments are proposed to create employment for about 24,000 individuals.

4.1.5 Progression to achieve SDG 7

[15] https://bit.ly/3MwDZGo

SDG 7 aimed to ensure access to affordable, reliable, sustainable and modern energy to all. Following are the global targets prescribed to achieve this goal by 2030.

> 7.1: Ensure universal access to affordable, reliable and modern energy services;
>
> 7.2: Increase substantially the share of renewable energy in the global energy mix;
>
> 7.3: Double the global rate of improvement in energy efficiency;
>
> 7.a: Enhance international cooperation to facilitate access to clean energy research and technology, including renewable energy, energy efficiency and advanced and cleaner fossil-fuel technology, and promote investment in energy infrastructure and clean energy technology;
>
> 7.b: Expand infrastructure and upgrade technology for supplying modern and sustainable energy services for all in developing countries, in particular least developed countries, small island developing States, and land-locked developing countries, in accordance with their respective programmes of support.

Whereas in Tamil Nadu, the state-specific indicators are identified below:

> 7.1.1a: Percentage of Households electrified in remote areas with solar grid
>
> 7.2.2: Renewable Purchase Obligation (RPO) achieved (%)
>
> 7.3.1.1: Reduction of Aggregate Technical & Commercial losses

Though national and state governments can localise the SDG targets based on their preference in line with universal targets, specific targets for Tamil Nadu do not capture the universal targets. For instance, no indicators were prescribed to track access to electricity and clean cooking solutions. Regarding doubling the progress on energy efficiency, Tamil Nadu only considers the transformation loss of electricity rather than promoting energy efficiency at the household level. Also, no indicators are prescribed to keep track of international collaboration in support of clean and renewable energy. Tamil Nadu Planning and Development Department (TNPDD) is the nodal department to track the SDG goals in Tamil Nadu. Therefore, TNPDD has developed an SDG monitoring platform.[16] During preparation of this report, the mentioned SDG monitoring platform on the state-specific indicators is not complete and up to date.

4.2 Renewable integration challenges and solutions

The earlier Tamil Nadu Solar Energy Policy 2012 aspired to have 3000 MW by 2015, but the state could only achieve 150.21 MW (Government of Tamil Nadu 2012). The 2019 policy then

[16] Sustainable Development Goals Monitoring Platform: https://tnsdg.tn.gov.in/

set a goal of 9000 MW of installed capacity, with 3600 MW coming from the consumer category, including rooftop solar (Government of Tamil Nadu 2019). However, as of 2020-2021, only 330.653 MW of capacity was added through rooftop solar, which is less than 1%. As of FY 2020-2021, Tamil Nadu has achieved just 4511 MW of installed capacity with regard to total solar energy (see Figure 2). Therefore, the state is struggling to implement the aspirations of the solar policies consecutively. To encourage the adoption of grid-connected rooftop solar (part of the consumer category solar), the Tamil Nadu Government, through Tamil Nadu Energy Development Agency (TEDA), offers a subsidy of Rs. 20,000 per kilowatts peak (kWp) and a 30% subsidy from the MNRE (TEDA 2014). However, according to Shekhar (2022), this scheme has not been successful due to poor implementation of the subsidy transfer.

Apart from the above, green energy corridors are considered crucial for integrating renewable energy into the electricity consumption mix. The green energy corridor project aims at synchronising electricity produced from renewable sources, such as solar and wind, with conventional power stations in the grid. Under Phase-I, Tamil Nadu Transmission Corporation Limited (TANTRANSCO) has completed 174 KM of green energy corridor.

Sl.No.	Name of the line	Name of the district	Green Energy Corridor Completed (in KMs) during phase I	
			Length Completed	To be completed
I	**SE/GCC/Madurai, Salem**			
1	400 KV DC line from Rasipalayam-Palavadi route length 189.510 KM	**Tiruppur**	34.591	-
		Erode	60.406	-
			16.35	-
		Salem	29.93	-
		Dharmapuri	48.23	-
		Total	**189.51**	
II	**SE/GCC/Madurai, Coimbatore**			
2	Ingur-Arasur (PGCIL 400 KV SS) 230 KV SC line on DC tower route length 54 KM	**Tiruppur**	35.767	-
		Erode	10.865	-
		Coimbatore	7.138	0.23
		Total	**53.77**	**0.23**
III	**SE/GCC/Coimbatore**			
3	Arasur (PGCIL 400KV SS)-Gobi 230 KV SC line on DC towers route length 47.917 KM	**Tiruppur**	24.419	-
		Erode	23.498	-
		Total	**47.917**	-
IV	**SE/GCC/Madurai**			
4	400 KV DC line from Kayathar to Thennampatty (Package-II)	**Tuticorin**	23.937	-

5	Kayathar 400 KV SS to Tuticorin Auto 230 KV DC line on DC towers length 56.582 KM		56.424	-
		Total	**80.361**	-
V	**SE/GCC/Madurai**			
6	Veeranam-Tirunelveli (PGCIL 400 KV SS) 230 KV SC line on DC towers (String in the exisiting free arm) length 30.948 KM	**Tirunelveli**	20.32	-
		Tenkasi	10.5	-
		Total	**30.82**	-
7	Veeranam-Kodikurichi 230 KV DC line on DC towers (Partly dismantling the exisiting 230 KN SC line) length 24.174 KM	**Tenkasi**	24.174	-
VI	**SE/GCC-II/Chennai & Trichy**			
8	Cuddalore-Veerampuram Acharapakkam & Purai 230 KV DC line on DC tower length 173.84 KM	**Cuddalore**	22.3	-
		Villupuram	58.45	-
		Kanchipuram	5.057	-
		Thiruvannamalai	13.813	-
		Chengalpet	74.441	-
		Total	**174.061**	**0.23**

Table 5: Status of green energy corridor in Tamil Nadu | TANTRANSCO[17]

Recently, TANTRANSCO signed an MoU with the KfW Development Bank (Germany) to implement phase two of the Green Energy Corridor. The Union government has approved ₹719.79 crores for the project in Tamil Nadu, including a grant of 33% from the MNRE, while 47% cost of the project will be funded by the loan from KfW and the remaining 20% as equity from TANTRANSCO. The tenders for this project are expected to be floated by December 2023. The state-owned power utility has planned to start the bidding process soon since it has signed an agreement with KfW. The work has been scheduled to be completed by 2025-2026. The proposed phase-2 green energy corridor will add 10,753 circuit kilometres of transmission lines and 27,546 mega-volt-amperes capacity of substations in seven states - Gujarat, Himachal Pradesh, Karnataka, Rajasthan, Tamil Nadu, and Uttar Pradesh (The New Indian Express 2022).

Though energy generated through solar and wind are intermittent, they are complementary energy sources. Solar generation peaks during the daytime, while wind power is high during twilight and at night. Similarly, wind could compensate during the monsoon when sunlight is weaker. A study conducted between 2012 and 2014 found that combining solar and wind energy in a hybrid system can reduce electricity production costs by half compared to when these two

[17] https://bit.ly/45No2of

energy sources are used independently. Additionally, this hybrid system can help reduce the intermittency of renewable energy (Kumar, Manoharan, and Rajkumar 2014). The Tamil Nadu government has yet to develop a policy framework for solar and wind hybrid systems. Thus, the state is missing a "golden opportunity" by not capitalising on the hybrid mode (Boopathi et al. 2016). In the present scenario, wind energy suppliers who want to add solar components to the existing facility need to obtain additional permissions, a burdensome and expensive process (Sridharan 2022). Though TEDA is responsible for promoting wind-solar hybrid systems, an RTI application filed on the number of such systems in Tamil Nadu, returned a response from TEDA as 'not applicable.'

4.2.1 Renewable energy curtailment

The level of curtailment reflects how effectively renewable energy is being integrated into the overall energy mix. High levels of curtailment indicate a lack of flexibility in the system, which prevents grid operators from fully utilising available renewable resources. Based on a report by the National Renewable Energy Laboratory, as of 2017, 4.3% of wind and solar energy is curtailed annually in Tamil Nadu. The state's renewable energy curtailment is relatively low from January through April but rises during the monsoon season, and this persists through November (Palchak et al. 2017). CAG has filed RTI applications requesting information on the curtailment of energy generated through renewable sources. In response to RTI request, State Load Despatch Centre (SLDC) of TANTRANSCO refused to provide information by citing a reason "the information sought does not involve larger public interest, the same could not be furnished as per clause 8(1)(d) of Right to Information Act, 2005." Clause 8(1)(d) reads as follows: "information including commercial confidence, trade secrets or intellectual property, the disclosure of which would harm the competitive position of a third party unless the competent authority is satisfied that larger public interest warrants the disclosure of such information." The first appeal filed to get the data is still pending with the RTI appellate authority. Therefore, this report consulted a few secondary data sources to learn more about renewable energy curtailments in the state. Recently wind energy generators in Tamil Nadu complained that SLDC and TANGEDCO are on major curtailment of power generated through renewable sources (Vijayakumar 2022). Legal battles are being fought between the renewable energy generators and TANGEDCO on alleged rampant and arbitrary curtailment of renewable energy (Appellate Tribunal for Electricity 2021). Therefore, curtailment is one of the critical issues requiring the government's immediate attention to promote the renewable energy mix by considering grid stabilisation as well.

4.2.2 Phase out non-renewable energy dependency

Tamil Nadu's electricity demand is expected to increase yearly, 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 the Government of

India targeting net zero carbon by 2070, Tamil Nadu will require a long-term strategy to reduce its emissions. During the Tamil Nadu Climate Change Mission launch, Chief Minister M. K. Stalin said that the state will achieve carbon net zero before 2070 (The Hindu 2023). This requires establishing sector-specific emission inventories, followed by sector-specific emission target setting. The power sector is deemed one of the easiest to decarbonise. Target setting is one of the first steps in implementing a decarbonisation strategy. Though the installed renewable energy capacity is more than 50%, the electricity generation from renewables is at just 22% compared to 75% from coal-based thermal power plants (Auroville Consulting 2022). This requires serious introspection on the challenges of integrating renewable energy into the power grids.

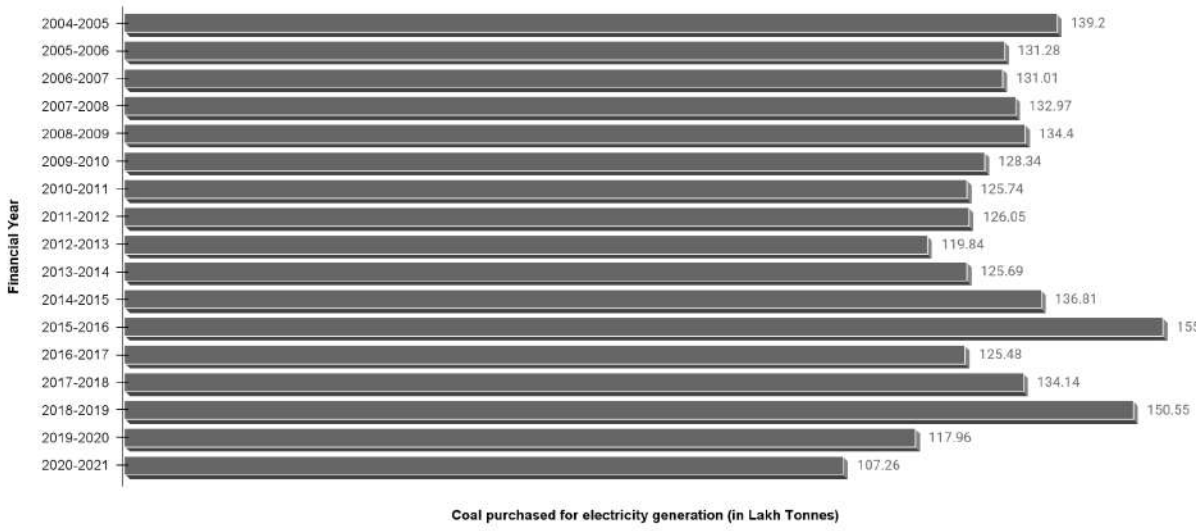

Figure 3: Financial year-wise coal purchased for electricity generation (in Lakh Tonnes) | TANGEDCO[18]

[18] https://bit.ly/45B3oaz

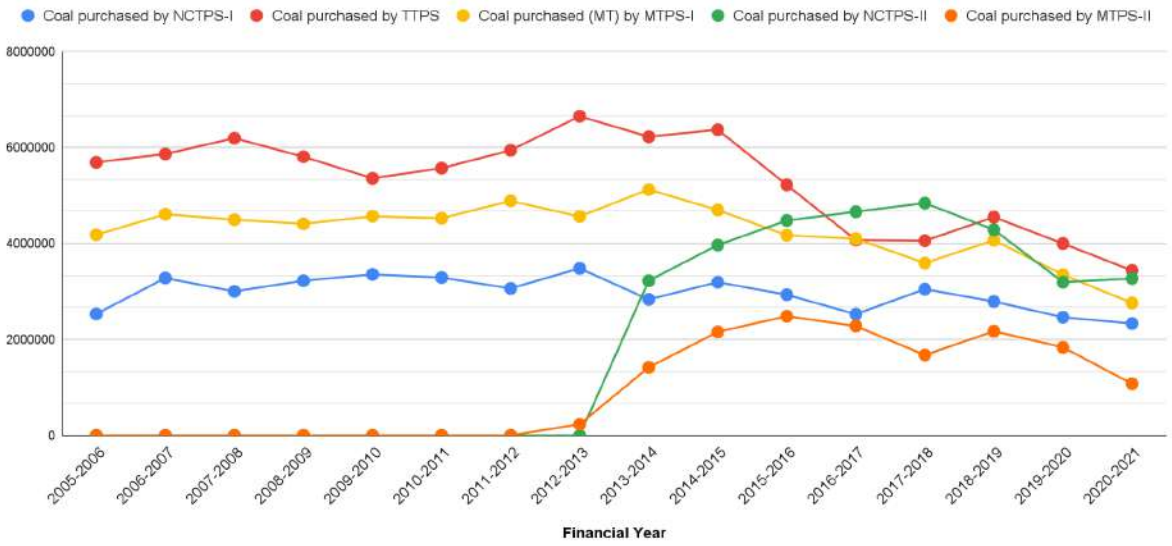

Figure 4: Coal purchased (in MT) by the five thermal power stations of TANGEDCO in Tamil Nadu | TANGEDCO[19]

There are five thermal power stations, namely, North Chennai Thermal Power Station I & II (NCTPS I & II), Tuticorin Thermal Power Station (TTPS) and Mettur Thermal Power Station I & II (MTPS I & II) owned by TANGEDCO. Coal is the primary fuel to run the thermal power station. Based on Figures 3 and 4 presented above, it is observed that FY 2020-2021 recorded the lowest coal purchase in the past 17 years. This reduction has also been reflected in the coal imported by all the five thermal power stations of TANGEDCO.

In addition to requesting data on coal utilisation, RTI applications were filed with five thermal power stations requesting annual CO2 emissions. Unfortunately, all five thermal power stations responded that they do not have a direct measuring instrument for CO2 emissions. At the same time, NLC India Limited shared CO2 emissions data. There are three thermal power stations: Neyveli Thermal Power Station I & II (NTPS I & II) and Neyveli New Thermal Power Station (NNTPS). As of 2021, NTPS-I was decommissioned, and NTPS-II and NNTPS emitted 1,15,96,110 and 36,77,974 metric tonnes of CO2, respectively.

[19] https://bit.ly/3MFRCTz

4.3 Perception of the public on renewable energy in Tamil Nadu

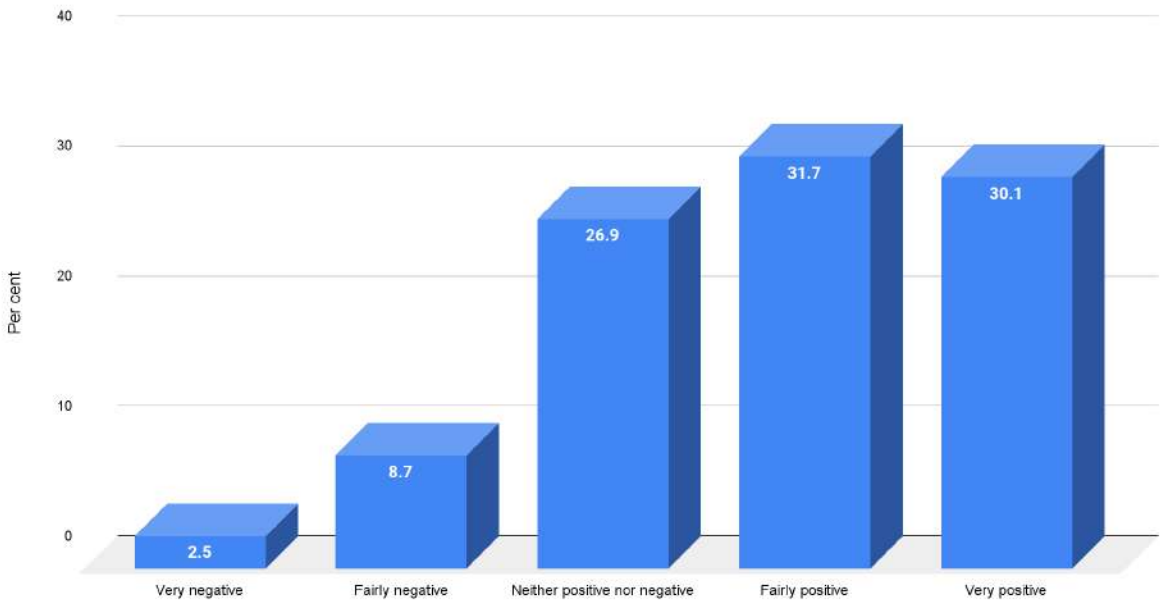

Figure 5: How do people in Tamil Nadu feel about renewable energy?

Around 62 per cent of respondents feel positively about renewable energy. Only about 11 per cent express negative feelings. As most of the population has a positive opinion on renewable energy, governments and civil societies should find it easier to potentially promote the transition towards renewables at macro and micro levels. Information, Education, Communication (IEC) is crucial in promoting a positive perception of renewable energy among the larger population. Through effective IEC, individuals can be informed about the benefits of renewable energy, how it works, and how to use it. This knowledge can encourage people to switch to renewable energy sources, which can help reduce greenhouse gas emissions and mitigate climate change. IEC campaigns can also help dispel myths and misconceptions about renewable energy and increase awareness about the various options available.

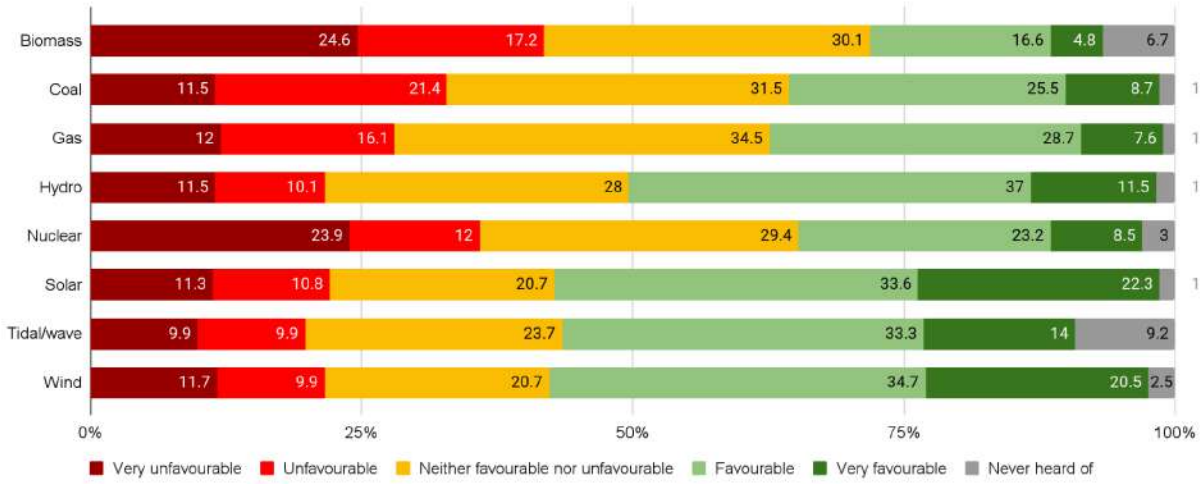

Figure 6: Overall opinions or impressions of energy source

Of the many sources for producing electricity, more respondents favour renewable energy sources such as solar, wind, tidal, and hydro than non-renewables. Of the non-renewables, nuclear (24%) and biomass (25%) based energy sources are considered very unfavourably.

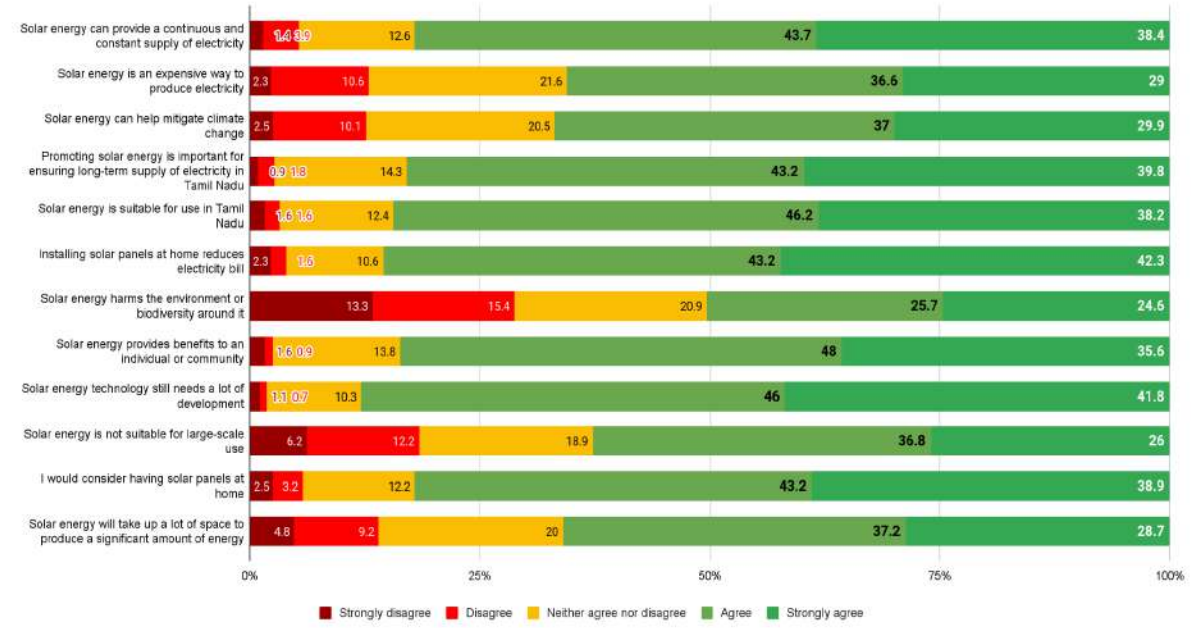

Figure 7: Perception of solar energy

Of the various opinions on the perception of solar energy, more than 80 per cent of the respondents stated that solar provides continuous and constant electricity, is suitable for Tamil

Nadu, benefits the community, but where technology still requires development. Significantly, 82 per cent of respondents were willing to install roof-top solar in their homes.

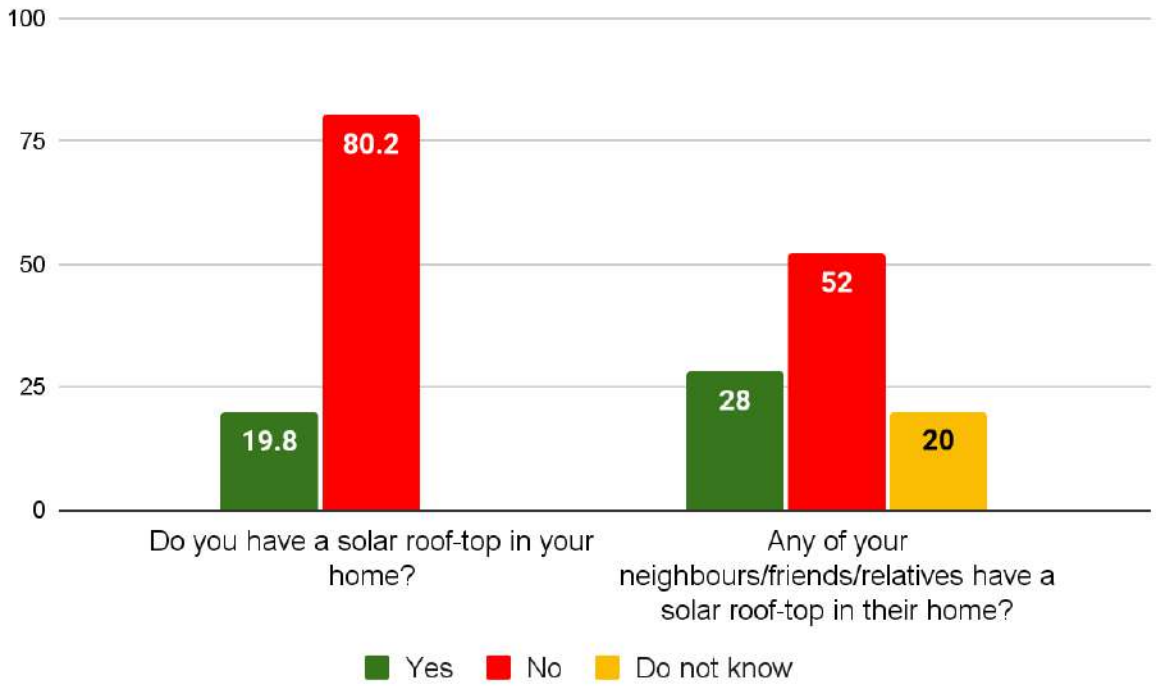

Figure 8: Solar roof-tops at household level

Corresponding to the general perception, 80 percent of the respondents said they do not have a rooftop solar in their home. Likewise, only 28 percent of their neighbours/friends/relatives have rooftop solar in their homes.

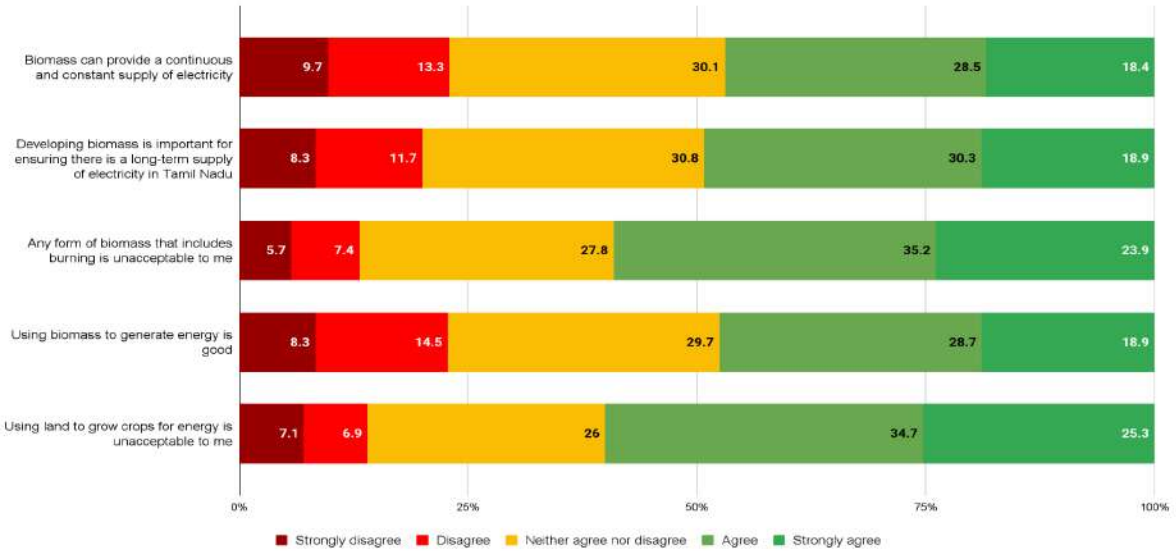

Figure 9: Perception of biomass

In line with the findings presented in Figure 6, sixty percent of respondents opined that it is unacceptable to use land for growing bioenergy crops like corn, sorghum and sugarcane for biomass energy production. Also, 59% expressed that any form of biomass that includes burning is unacceptable.

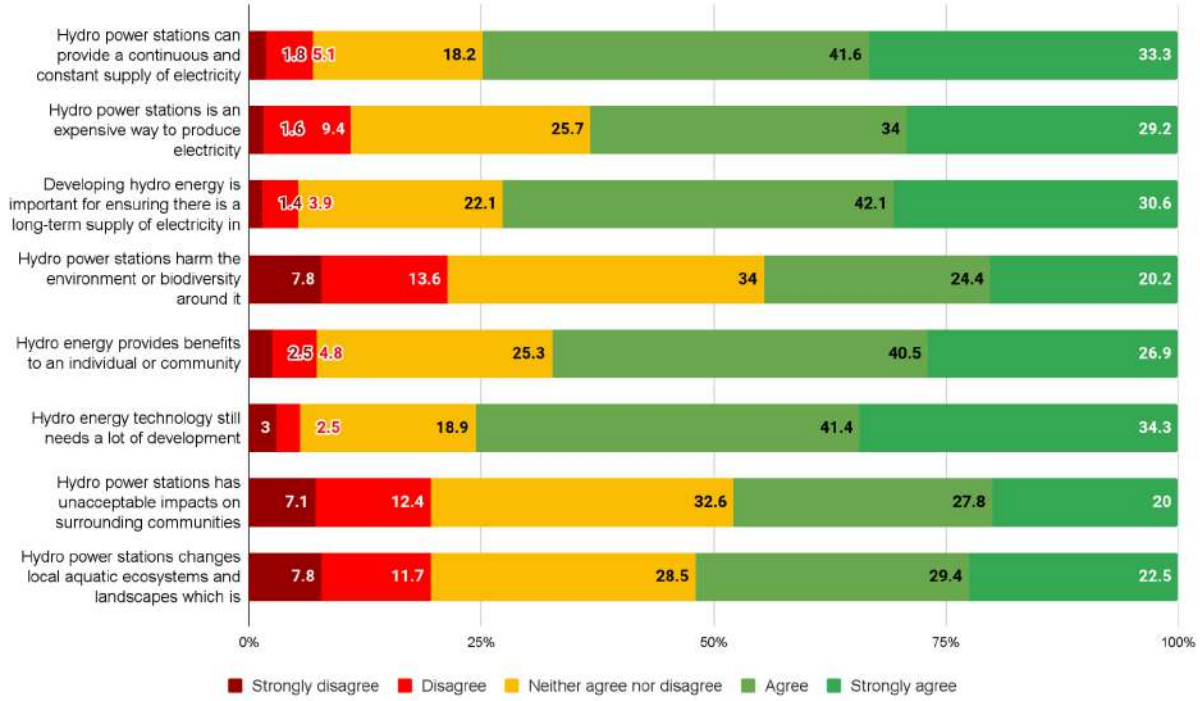

Figure 10: Perception of hydropower

About 75 per cent of the respondents stated that hydropower stations could provide a continuous and constant supply of electricity and that its technology needs a lot of development. Nearly half agreed that hydropower stations change local aquatic ecosystems and landscapes. Another 48% agreed it has unacceptable impacts on surrounding communities.

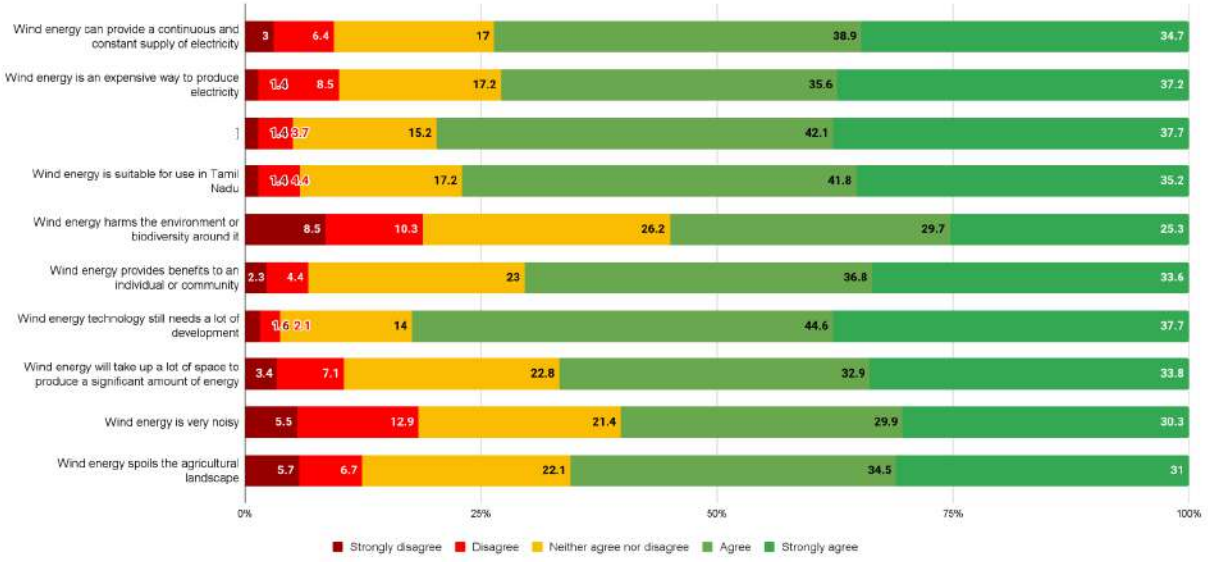

Figure 11: Perception of wind energy

Wind energy technology still needs a lot of development, stated 82%. This may be due to the perceived cost involved in creating wind energy infrastructure. Another 80% agreed that developing wind energy is important for ensuring long-term electricity supply in Tamil Nadu. Sixty-six per cent perceived that wind energy spoils the agricultural landscape. Of the four renewables, the respondents prefer wind and solar except for their concern about perceived harms to agriculture, environment and biodiversity.

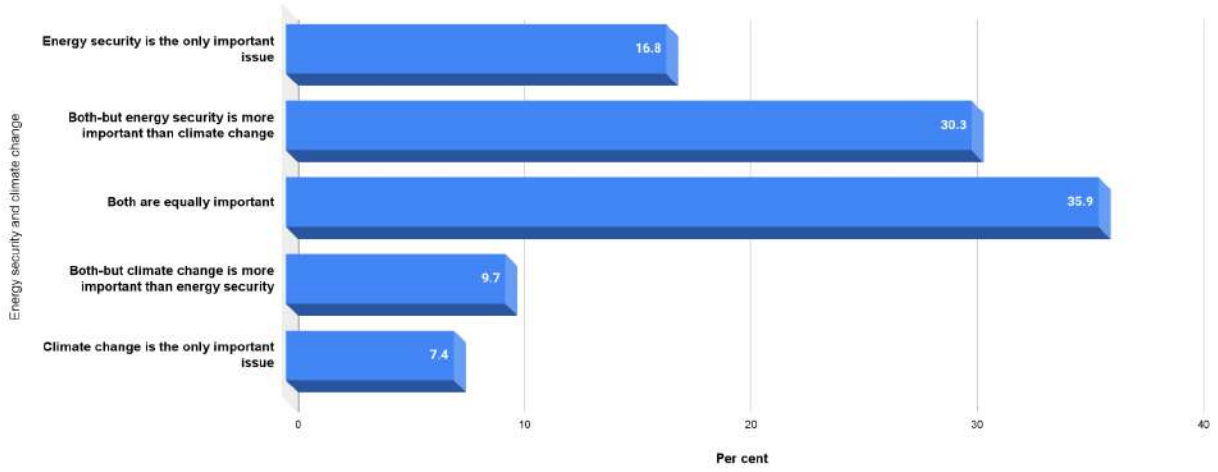

Figure 12: Public perception of energy security vs climate change

As discussed elsewhere, carbon emissions from the energy sector contribute more to climate change as we are hugely dependent on fossil fuels. Therefore, to understand respondents' preference towards energy security and climate change, they were asked about their preference between the two. Based on the results presented in Figure 12, although about 36 per cent perceive that both energy security and climate change are equally important, more than a quarter of them (30%) prefer energy security over climate change. Around 17 per cent think energy security is the only important issue they are concerned about. A very low percentage of respondents (7.4%) perceive climate change as the only issue more important to them than having energy security.

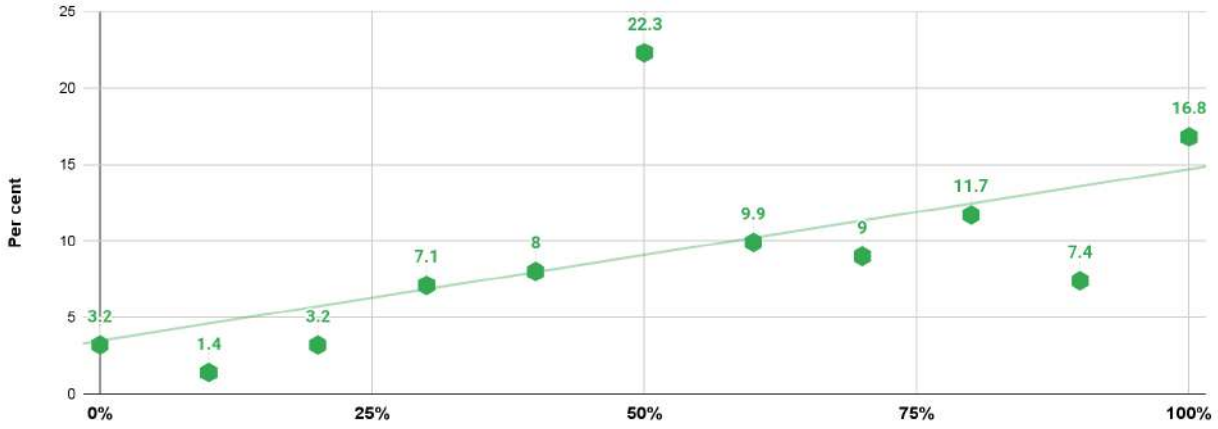

Figure 13: Public estimate of contribution of renewables to the energy mix in 20 years

The respondents were further asked about their perceived projection of renewable energy mix in the electricity sector in the next 20 years based on the prevailing political, technological and

economic factors of Tamil Nadu. Twenty-two per cent suggested that 50 per cent of the electricity will be from renewable energy. About 45 per cent perceive that renewable energy will contribute to 70 to 100% of electricity supply in Tamil Nadu. As of 2020, renewable energy constitutes only 22% of the electricity generation in the state (Auroville Consulting 2022).

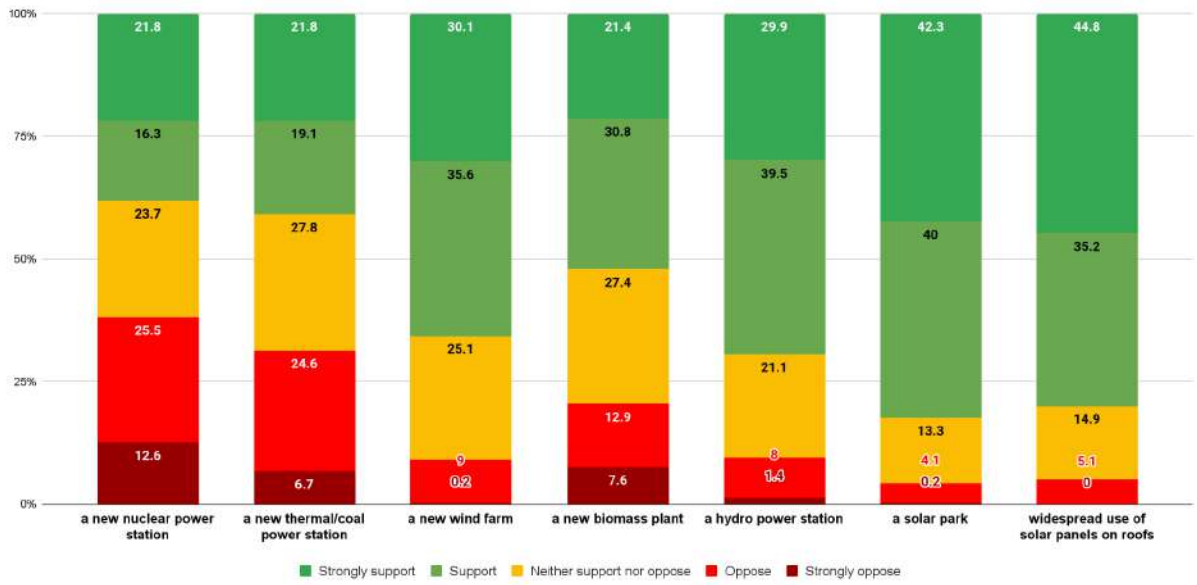

Figure 14: Public support for energy generation infrastructure in their area

The respondents were asked how much they support or oppose energy generation in their area (approximately within a five kilometre radius). As observed from Figure 14, a significant per cent of the respondents support solar parks (82%) and roof-top solar (80%). A considerable per cent of respondents oppose nuclear (38.1%), thermal (31.3%) and biomass (20.5%) plants in their area.

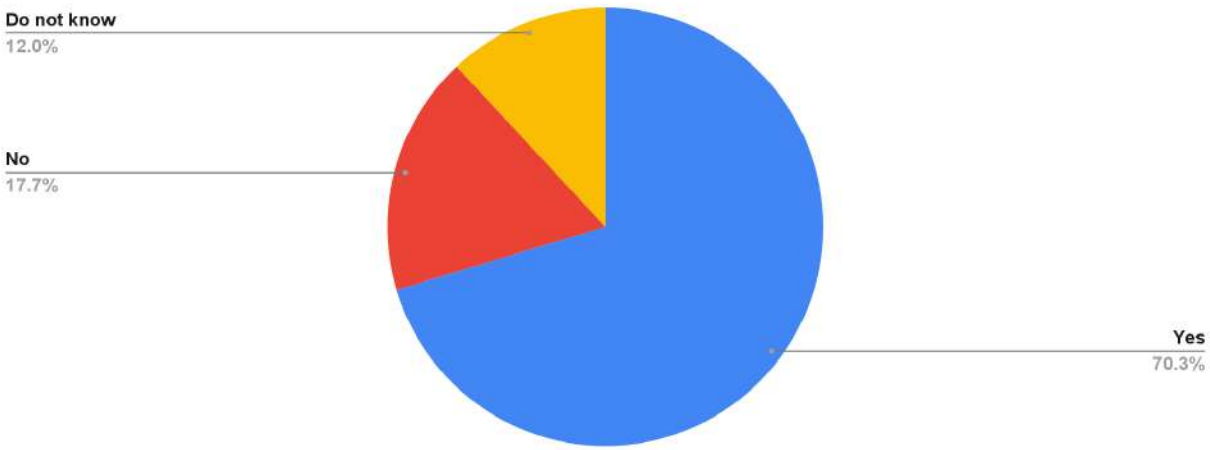

Figure 15: Public perception on whether the climate is changing or not?

The respondents were further asked about their perception on the reality of climate change. Interestingly, 70.3 per cent of the respondents think climate change is happening. A lower number (17.7%) believe climate change is not happening, and another 12 per cent are not aware whether it is happening or not.

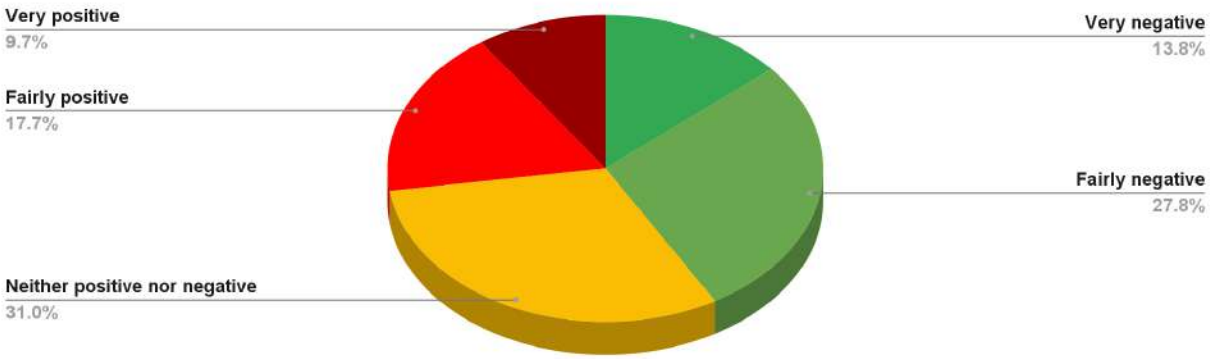

Figure 16: Public perception of climate change

Further to this, they were asked to state what they really think of climate change. Around 42 per cent of respondents feel climate change is a negative phenomenon. In comparison, the remaining 58 per cent of them are neither positive nor negative or positive about climate change. Many researchers (e.g., Johnston, 2020) reiterate that climate change literacy and science are necessary for developing policies and making decisions that will effectively combat climate change and its impacts. Therefore, the government should prioritise bringing climate change curriculum to schools and climate literacy among the public.

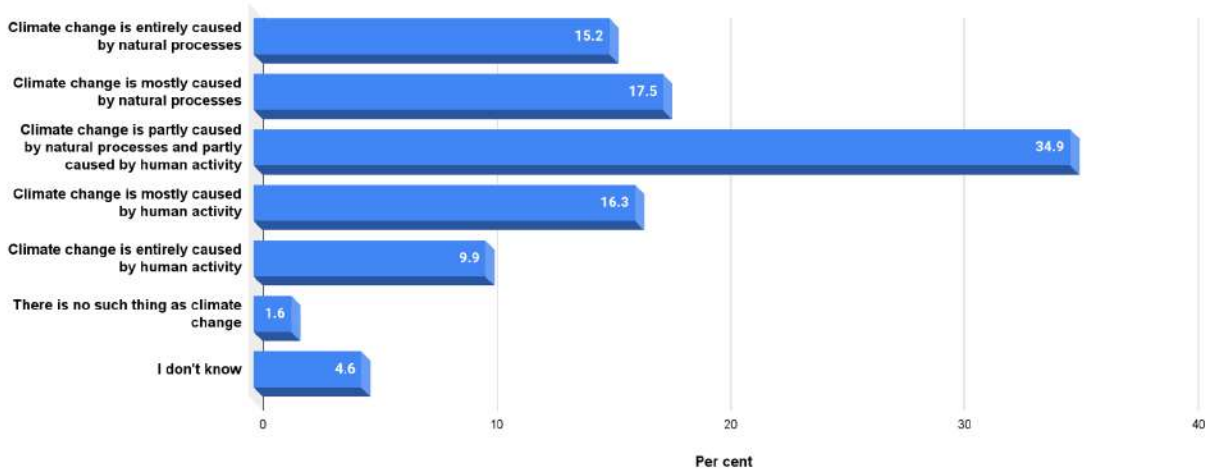

Figure 17: Public perception on the causes of climate change

Through their fourth and fifth assessment reports, the Intergovernmental Panel on Climate Change (IPCC) demonstrated that climate change is the result of human activity. Along this line, the survey results show that about 35 per cent of the respondents were of the opinion that natural processes and human activity partly cause climate change. Another 33 per cent believe that climate change is caused mostly or entirely due to natural processes. Only about a quarter of the respondents say climate change is caused mostly or entirely by human activity.

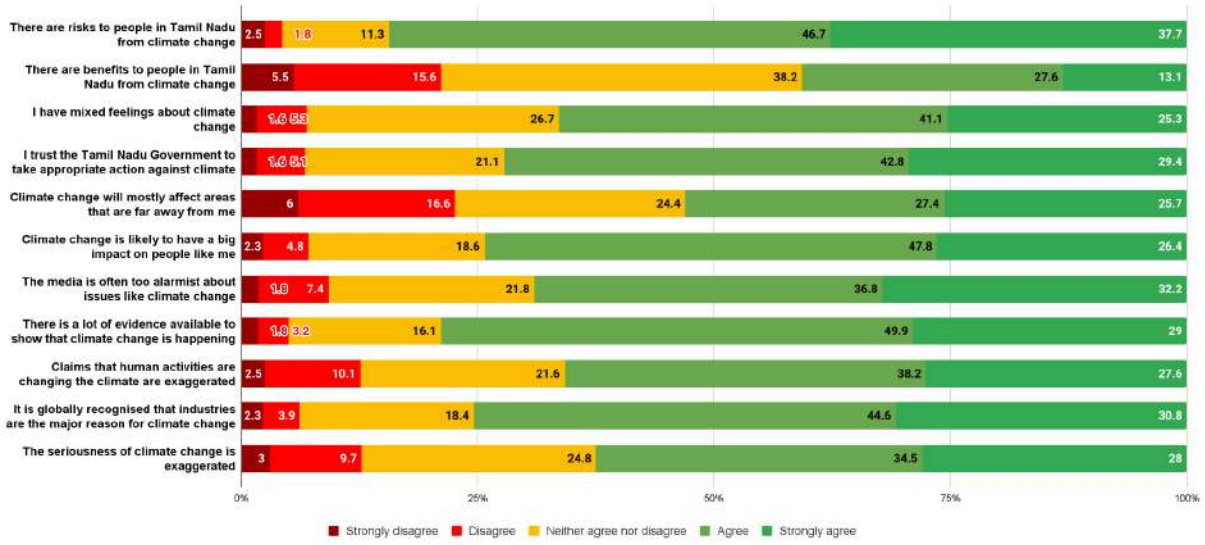

Figure 18: Perception of climate change and its effects on Tamil Nadu

Though only 42 per cent of the respondents feel negatively about climate change, concerning the perception of climate change, 84 per cent stated that there are risks to people in Tamil Nadu from climate change. Nearly 79 per cent of them agreed that much evidence is available to show that climate change is happening. Two-thirds of them agreed that industries are the primary reason for climate change. Most respondents (72%) trust that the Tamil Nadu Government will take appropriate action against climate change.

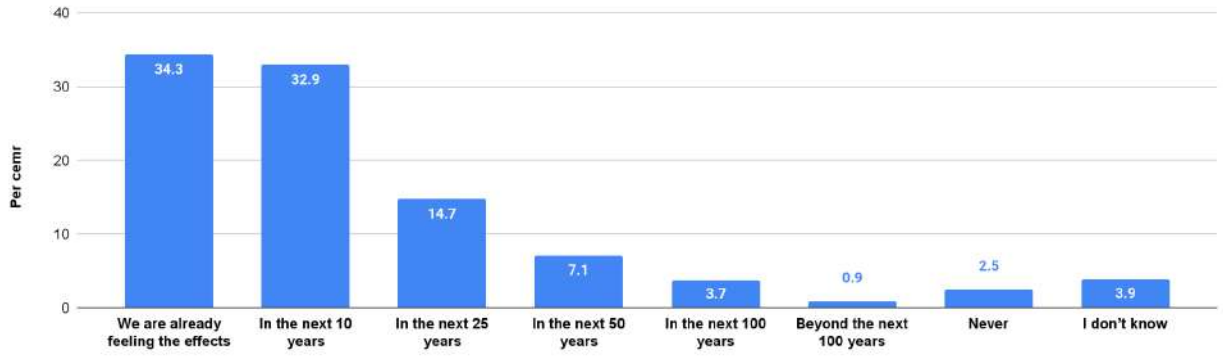

Figure 19: Public perception on when Tamil Nadu will start feeling the effects of climate change

The respondents were also asked when Tamil Nadu will start to feel the effects of climate change. Thirty-four per cent of them stated that we already feel the effect of climate change. About 33 per cent believed that the effect of climate change would be felt in the next ten years.

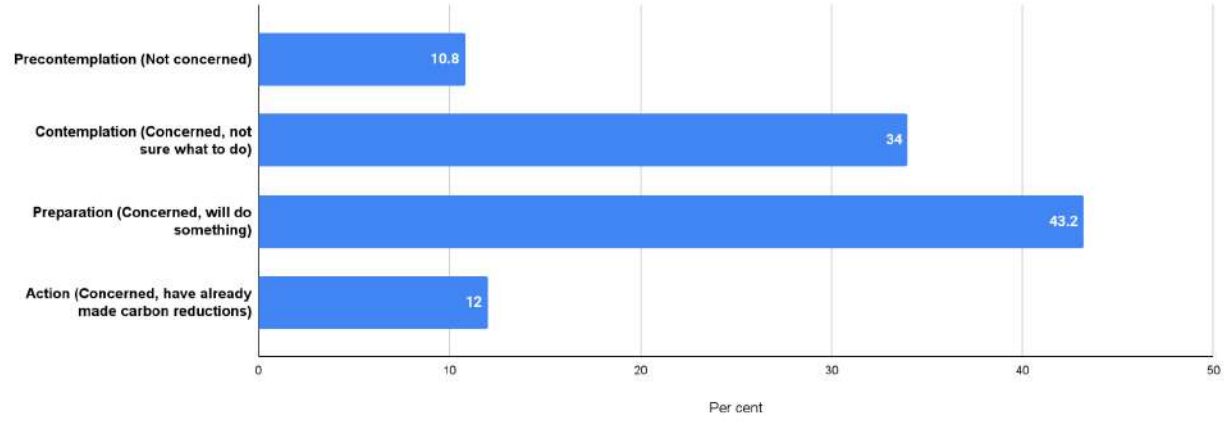

Figure 20: Position on stage of change to mitigate climate change

The Stages of Change is a widely used mechanism to measure human behaviour change. Though it was developed in the late 1970s by Prochaska and DiClemente to bring behaviour change among smokers,[20] this model has been adopted to bring in various other behavioural changes. This model has also been adopted to understand the behaviour change among people to initiate climate action and thus mitigate climate. Most of the respondents (43.2%) are in the preparation stage (they are concerned and will do something) to initiate climate action. Another 34 per cent are in the contemplation stage and about 11 per cent are not all concerned about climate action. A small per cent (12) stated that they are taking climate action.

5. Recommendations

Based on the inferences drawn out from this report, a few recommendations are formulated to increase the renewable energy mix in Tamil Nadu.

- Though the installed capacity of renewable energy is 50 per cent compared to non-renewables, the electricity generated through renewables is just 22 per cent of the total electricity mix. So as to increase the renewable energy mix, concerted efforts are needed to increase the green energy corridors to minimise curtailments.
- The existing data suggest that the state's roof-top solar coverage is deficient. The Government should implement measures to increase roof-top solar installation in households, government and private buildings. Thus dependency towards non-renewable electricity sources can come down.
- Green skill development programmes need to be scaled up in all the districts. Currently, Chennai and Ranipet district have solar green skill training providers. Various projections (e.g., NDC Plus and REmap) demonstrated that there would be a high demand for skilled, semi-skilled and low-skilled technicians in the renewable energy sector.
- The Tamil Nadu Energy Department, in collaboration with TANGEDCO and TEDA, needs to develop a one-stop centralised database solution for renewable energy in the state. Such a database should include data pertaining to renewable energy capacity and electricity generation, solar roof-tops (both on-grid and off-grid), government and private

[20] The Transtheoretical Model (also called the Stages of Change Model), developed by Prochaska and DiClemente in the late 1970s, evolved through studies examining the experiences of smokers who quit on their own with those requiring further treatment to understand why some people were capable of quitting on their own.

infrastructure development, public and private investments made towards the promotion and creation of renewable energy infrastructure, achievement towards realising SDG 7 and employment generation. This exercise may help to formulate inventories to track the progression of renewable energy in Tamil Nadu.

- Formulating a state policy on solar-wind hybridisation to minimise the intermittency nature of renewables. Such a hybridisation has the potential to reduce electricity production costs by half while those two energy sources produce energy independently.
- The state should prescribe informed and achievable targets in their policies for promoting renewable energy. The past overreaching ambitions have not been met as prescribed in the 2012 and 2019 Tamil Nadu Solar Energy Policy.
- TANGEDCO does not have a mechanism to quantify CO2 emissions from its thermal power stations. At the same time, NLC India Limited annually brings out CO2 emissions from its thermal power stations. Therefore, triangulating data points such as coal purchases, coal utilisation, electricity generation, CO2 emissions and waste generation from thermal power stations will help with social and environmental auditing.
- The renewable energy perception survey findings demonstrated that most of the public positively perceives renewable energy. Though 80 per cent of households do not have solar roof-tops, 82 per cent are willing to install them in their homes. Therefore, the government may aggressively promote solar roof-tops by addressing existing impediments relating to transferring subsidies for solar roof-top installation. Thus, electricity generation through solar roof-tops can substantially be increased.

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