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RAMANATHAPURAM

DISTRICT DECARBONISATION ACTION PLAN

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RAMANATHAPURAM

DISTRICT DECARBONISATION ACTION PLAN

“Tamil Nadu has always led the nation in showing how growth and responsibility can go hand in hand. We are steadily building on our actions toward becoming a Net-Zero economy well before 2070. These District Decarbonisation Action Plans take this commitment deeper by bringing climate action closer to the people, to our villages, towns, and industries. When every district and every citizen joins hands, Tamil Nadu will demonstrate how sustainability can take root in local action and collective responsibility.”

Thiru M.K.Stalin

Honourable Chief Minister of Tamil Nadu

“For Tamil Nadu, economic progress and environmental care go hand in hand and they are central to how we plan and govern. These District Decarbonisation Action Plans reflect our commitment to ensuring that development also builds climate resilience. They will guide each district to grow responsibly, aligning prosperity with the health of our land, air, and water. This is how we see the future of Tamil Nadu where fiscal discipline, environmental stewardship, and people’s well-being move forward together.”

Thiru Thangam Thennarsu

Honourable Minister for Finance,
Environment and Climate Change, Tamil Nadu

“The District Decarbonisation Action Plans strengthen Tamil Nadu’s commitment to integrating climate priorities into development planning. They bring together policy, people, and business to act on shared goals of resilience and sustainability. This approach reflects our focus on turning data and collaboration into practical outcomes that safeguard our environment and support inclusive growth. This is where the strength of Tamil Nadu truly lies, in turning science and policy into action that uplifts people and protects nature.”

Tmt. Supriya Sahu, I.A.S.

Additional Chief Secretary to Government, Environment, Climate Change & Forest Department, Tamil Nadu

"The District Decarbonisation Action Plans reflect Tamil Nadu's participatory and bottom-up approach to climate action. They combine data, local experience, and cross-sector coordination to help districts plan and act with clarity. Through collaboration between departments, industries, and communities, TNGCC is working to ensure that every local effort contributes meaningfully to the state's long-term climate goals."

Thiru A.R. Rahul Nadh, I.A.S.

Director, Department of Environment and Climate Change, Tamil Nadu

CONTENT

List of Abbreviations

2W	Two-Wheeler
3W	Three-Wheeler
4W	Four-Wheeler
AES	Aggressive Effort Scenario
AFOLU	Agriculture, Forestry and Other Land Use
AMRUT	Atal Mission for Rejuvenation and Urban Transformation
ANR	Assisted Natural Regeneration
AWD	Alternate Wetting and Drying
BAU	Business as Usual
BFS	Blast Furnace Slag
BLDC	Brushless Direct Current
BOD	Biochemical Oxygen Demand
BPKP	Bharatiya Prakritik Krishi Paddhati
BUR	Biennial Update Report
CCTV	Closed Circuit Television
CCU	Carbon Capture and Utilization
CFL	Compact Fluorescent Lamp
CGWB	Central Ground Water Board
CH4	Methane
CMMKMKS	Chief Minister’s Manniyur Kaathu Mannuyir Kappom Scheme
CO2	Carbon Dioxide
COD	Chemical Oxygen Demand
COP	Conference of Parties
CPP	Captive Power Plant
DEWAT	Decentralised Wastewater Treatment
DFCs	Dedicated Freight Corridors
DJF	December-January-February
ECBC	Energy Conservation Building Code
EP	Energy Productivity
EV	Electric Vehicle
FAME	Faster Adoption and Manufacturing of Hybrid and Electric Vehicles
FO	Furnace Oil
FOG	Fats Oils and Grease
GDP	Gross Domestic Product

GHG	Greenhouse Gas
GIM	Green India Mission
GJ	GigaJoule
GOBARdhan	Galvanising Organic Bio-Agro Resources Dhan
GRIHA	Green Rating for Integrated Habitat Assessment
GWh	Gigawatt Hour
HGV	Heavy Goods Vehicles
HSD	High Speed Diesel
HT	High Tension
ICM	Indian Carbon Market
IEA	International Energy Agency
INCCA	Indian Network on Climate Change Assessment
IPCC	Intergovernmental Panel on Climate change
IPPU	Industrial Processes and Product Use
IRES	India Residential Energy Survey
JJM	Jal Jeevan Mission
KAVIADP	Kalaignarin All Village Integrated Agriculture Development Programme
KNMT	Kalaignarin Nagarpura Mempattu Thittam
ktCO2e	Kiloton Carbon Dioxide equivalent
LED	Light Emitting Diode
LPA	Local Planning Area
LPG	Liquified Petroleum Gas
LT	Low Tension
LULUCF	Land Use, Land Use Change and Forestry
MAM	March-April-May
MES	Moderate Effort Scenario
mbgl	Meters Below Ground Level
MLD	Million Litres per Day
MMM	Multi Model Mean
MORTH	Ministry of Road Transport and Highways
MTEE	Market Transformation for Energy Efficiency
MTPA	Million Tonnes per Annum
MW	Mega Watt
N2O	Nitrous Oxide
NADP	National Agriculture Development Programme
NAP	National Afforestation Programme
NAPCC	National Action Plan on Climate Change
NATCOM	National Communications

NBP	National Bio Energy Programme
NDC	Nationally Determined Contributions
NDDP	Net District Domestic Product
NEMMP	National Electric Mobility Mission Plan
NFHS	National Family Health Survey
NGT	National Green Tribunal
NMSA	National Mission for Sustainable Agriculture
NSM	National Solar Mission
OCEMS	Online Continuous Emission/Effluent Monitoring System
ODF+	Open Defecation Free
PAT	Perform Achieve and Trade
PJ	Peta Joule
PLF	Plant Load Factor
PM-KUSUM	Pradhan Mantri Kisan Urja Suraksha evam Utthaan Mahabhiyan
PMKSY	Pradhan Mantri Krishi Sinchayee Yojana
PNG	Piped Natural Gas
PV	Photovoltaic
RCP	Representative Concentration Pathways
RPO	Renewable Purchase Obligation
SBM	Swachh Bharat Mission
SCM	Smart Cities Mission
SEEP	Super Efficient Equipment Programme
SRI	System of Rice Intensification
STP	Sewage Treatment Plant
SWM	Solid Waste Management
TANSEED	Tamil Nadu Startup Seed Grant Fund
TANSIM	Tamil Nadu Startup and Innovation Mission
TNGCC	Tamil Nadu Green Climate Company
TNPCB	Tamil Nadu Pollution Control Board
TPD	Tonnes per Day
TSS	Total Suspended Solids
UGD	Underground Drainage
ULBs	Urban Local Bodies
ZLD	Zero Liquid Discharge

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Preamble

The District Decarbonisation Action Plan for Ramanathapuram has been developed with the overarching vision of enabling a low-carbon, climate-resilient, and economically inclusive future for the district. Anchored in scientific analysis, district-level energy modelling, and long-term climate projections, the plan outlines detailed sectoral strategies, emission trajectories, and actionable interventions tailored to Ramanathapuram's specific socio-economic and ecological context.

Situated along the southeastern coast of Tamil Nadu, Ramanathapuram is defined by its expansive coastline, vibrant fishing economy, and deep cultural and ecological heritage. At the same time, the district faces unique vulnerabilities stemming from rising temperatures, recurrent flooding, and increasing pressure on natural resources.

While some interventions—such as electrification of fishing fleets, transition to clean cooking fuels, and improved waste management—may entail short-term costs or disruptions, their long-term impacts are expected to be transformative. For instance, replacing diesel-powered fishing boats with electric alternatives can reduce operational costs, cut emissions, and improve air quality, contributing to both economic and environmental resilience.

A key pillar of the plan is nature-based carbon removal, leveraging Ramanathapuram's coastal and terrestrial ecosystems. Restoration and expansion of mangroves, seagrass, and seaweed habitats, alongside agroforestry on fallow lands, offer significant sequestration potential while enhancing livelihoods, land productivity, and community resilience.

The Action Plan cautions against a business-as-usual approach, which may seem economically viable in the near term but will likely accelerate ecosystem degradation, heighten climate risks, and erode the district's development gains. Instead, it advocates a forward-looking strategy—balancing technological decarbonisation with ecosystem restoration and climate adaptation.

By aligning sustainability with inclusive development, the plan sets a course for Ramanathapuram to not only meet Tamil Nadu's carbon neutrality goals but also become a model coastal district in climate leadership and just transition.

This report provides a comprehensive decarbonisation and climate action plan of Ramanathapuram, highlighting the need for climate resilience and decarbonisation in the district in a clear and accessible manner. It outlines ready to implement projects for near term, sectoral interventions with their abatement/sequestration potential, and a decadal implementation roadmap.

Executive Summary

Ramanathapuram is a coastal district in south-eastern Tamil Nadu, spanning 4,069 sq. km with a population of ~13.5 lakh (Census 2011). It is defined by a 276 km coastline, vibrant fishing economy, significant pilgrimage and heritage tourism, and unique coastal and marine biodiversity, including five Ramsar sites and multiple sanctuaries. The district's economy is shaped by marine fisheries, agriculture, MSMEs, and renewable energy production, with solar capacity exceeding 1.1 GW. Its geographical diversity—from sandy plains to rich coastal ecosystems—underpins both its livelihoods and its vulnerability to climate risks.

The district also forms a key part of the Gulf of Mannar Biosphere Reserve, one of India's first marine biosphere reserves, renowned for its rich coral reefs, seagrass meadows, and diverse marine life. This protected area not only sustains fisheries and coastal livelihoods but also serves as a vital carbon sink and a natural barrier against coastal erosion and extreme weather.

The district experiences a dry tropical climate with rising temperatures and erratic rainfall trends. Historical data (1951–2020) and climate projections under RCP8.5 indicate a temperature increase of up to 3.5°C and monsoonal rainfall increases of 33–82% (southwest) and 17–43% (northeast) by 2090. These shifts heighten vulnerability to high temperatures and floods, particularly in low-lying and coastal regions.

Dr. Tejaswini Eregowda

Low Carbon and Resilient Pathways for Ramanathapuram

As climate risks intensify energy demand, addressing emissions in alignment with broader climate goals would be essential for Ramanathapuram.

In 2022, the district's GHG emissions were estimated at ~1999 ktCO_2e, with energy sector contributing 62% (1,247 ktCO_2e), AFOLU 34% (674 ktCO_2e), and waste 4% (78 ktCO_2e). Overall, key emission sources include public electricity generation (559 ktCO_2e), rice cultivation (248 ktCO_2e), road transport (224 ktCO_2e), and fisheries (119 ktCO_2e).

The pathways explore three emission scenarios for Ramanathapuram through 2050: Business as Usual (BAU) representing the reference scenario, and two overarching decarbonisation scenarios namely, Moderate Effort Scenario (MES), and Aggressive Effort Scenario (AES)

Under the Business-as-Usual (BAU) scenario, gross GHG emissions are projected to decline to 1,746 ktCO_2e by 2050. This reduction is driven primarily by the planned retirement of the gas-based public electricity generation units and the organic uptake of electric vehicles under current policy trajectories. Energy sector emissions under BAU are expected to fall from 1,247 ktCO_2e in 2022 to approximately 664 ktCO_2e by 2050, while the IPPU sector emissions are expected to remain unchanged at 0.03 ktCO_2e. Emissions from the AFOLU sector are projected to increase from 674 ktCO2e in 2022 to 1006 ktCO_2e by 2050 and waste sector emissions are anticipated to marginally reduce to 76 ktCO_2e.

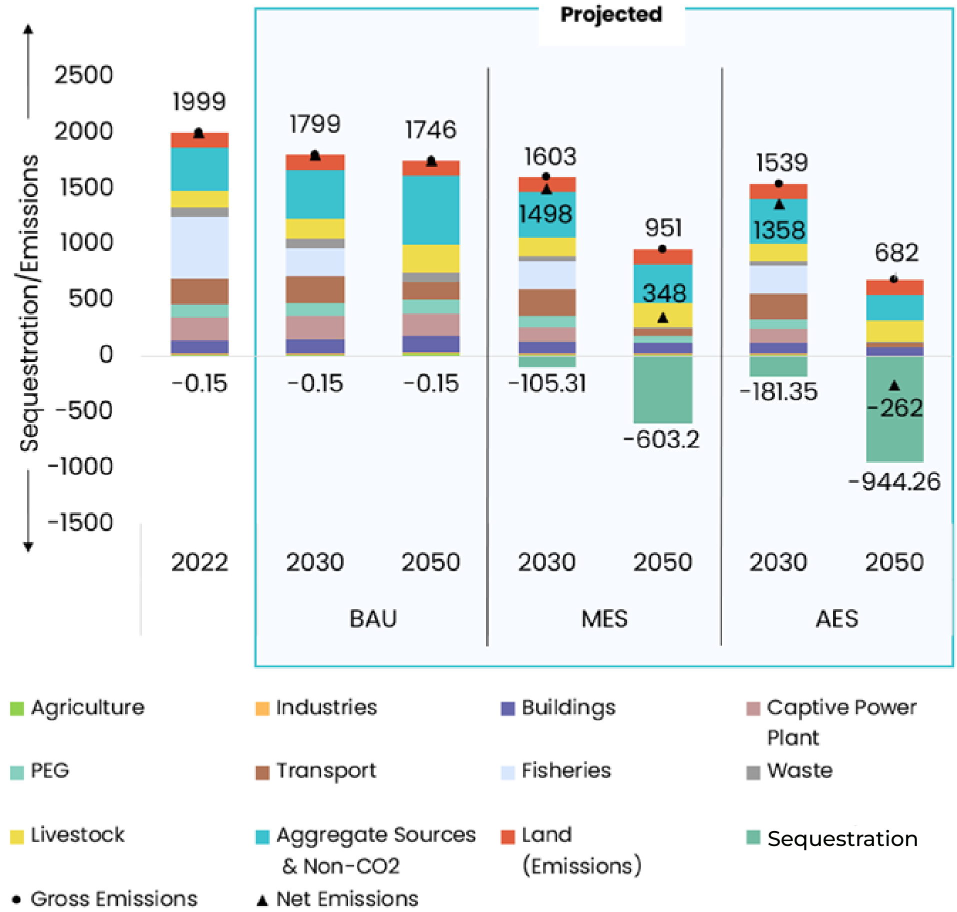


Figure ES1: GHG emissions (in ktCO2) in Ramanathapuram in 2022 (actual), 2030 and 2050 (projections) under BAU, MES and AES

The **Aggressive Effort Scenario (AES)** achieves **net-negative emissions of 262 ktCO_2e by 2050** through a combination of deep mitigation and large-scale sequestration. Mitigation measures include complete electrification of ~3,300 mechanised and motorised fishing vessels, 100% electrification of two, three, and four-wheelers and high-capacity goods vehicles, electrification of agricultural pumps and machinery, phasing out fossil-based captive power, and widespread adoption of electric cooking solutions. These reduce gross emissions to **~682 ktCO_2e by 2050** (a 61% drop from 2022 levels).

The AES also incorporates extensive nature-based carbon removal measures. It is proposed that 40 to 50 percent of the district's available barren, fallow, and cultivable-waste land be converted to social and agroforestry. Agroforestry in 99597 hectares of barren/fallow land could potentially sequester 876 ktCO_2e/year annually by 2050. Further, other blue-carbon interventions include the restoration of ~304 hectares of mangroves, expansion of seagrass meadows and seaweed cultivation by 2000 hectares, and seaweed cultivation in 2000 hectares, combined with respective sequestration potentials of 28 ktCO_2e, 26.4 ktCO_2e. In addition, enhancement of forest carbon stock density is projected to further sequester 13 ktCO_2e. Collectively, these interventions are expected to achieve approximately 944 ktCO_2e of annual sequestration by 2050, exceeding the district's residual emissions and enabling a net-negative emissions outcome.

Through a coordinated strategy combining targeted sectoral mitigation measures, accelerated deployment of renewable energy, and extensive ecosystem restoration for carbon sequestration, Ramanathapuram is projected to achieve carbon neutrality by 2047, positioning the district as a model for low-carbon, climate-resilient development in Tamil Nadu's coastal regions.

Implementable Projects in Near Term

Ramanathapuram's decarbonisation plan presents an integrated pathway of mitigation, resilience, and development. It provides a replicable framework for other vulnerable districts in India striving to meet subnational climate targets while advancing livelihoods and ecological stability. This plan can be implemented in a phase-wise manner – focusing on the main convertible projects with high impact in short to near run to commence the implementation, to be further built upon in medium and long run.

Key projects with higher scope of conversion in short to near term are provided below:

1. **Sustainable Tourism through Electric Vehicles and Electric Cookstoves:** Emissions from the tourism sector in Ramanathapuram are majorly derived from transport, commercial and waste segments. By adding new or electrifying public buses and replacing stock of diesel run cookstoves with electric cookstoves, as much as 6 ktCO_2e and 14 ktCO_2e can be abated respectively in a short run, which is 1% of the gross emissions in 2030.

Interventions	Departments	Expected Cost (Rs. Crores)	Available Finance
Electrification of 100 (~10% of the stock) public buses by 2030	Ramanathapuram Regional Transport Office and State Transport Department	180[1]	Rs. 20.6 Crore available under PM E-DRIVE[2] with a supplementing Rs. 0.8 Crore under TN EV Policy 2023[3] Furthermore, the Rs. 70 Crore allocation made by SPCB to TN Transport Corporation[4] can be explored.
Adoption of 37,000 electric cookstoves	Tamil Nadu Generation and Distribution Corporation Limited (TANGEDCO)	7	Potential of Rs. 0.9 lakh electric cookstoves under National Efficient Cooking Program (NECP) which provides cookstoves at a low cost (35% concession)

Electrifying ~600 public buses by 2050 will extend the abatement to ~30 ktCO_2e by 2050. Similarly, replacement of 0.72 lakh diesel run cookstoves with electric cookstoves could abate another ~30 ktCO_2e in the long run.

Particularly in Rameswaram, which is one of the most famous pilgrim destinations and accounts for 90% of Ramanathapuram's total tourist count, tourism is an essential economic driver while also resulting in emissions since transport, food and lodging are yet fossil-fuel reliant. By electrifying ~15,000 2W, ~4,000 3W, ~3000 4W and ~85 buses and heavy goods vehicles in Rameswaram, 30.8 ktCO_2e of emissions can be abated. An additional 5.7 ktCO_2e of emissions can be abated through electric cooking and bio-methanation.

2. **Electrification of Fishing Boats:** Ramanathapuram's 274 km of coastline houses 179 fishing villages, accounting for 78.8 MT of marine and 4.8 MT of inland fish production. Emissions from fishing emerge due to diesel consumption in fishing boats. As much as 35 ktCO_2e can be abated by 2030 through electrification of 900 fishing boats, negating ~2% of the gross GHG emissions. Additionally, solar cold storage systems and other technologies can be explored for decarbonising the value chain of the fishing industry.

Short Term Interventions	Departments	Expected Cost (Rs. Crores)
Electrification of 900 mechanised and motorised fishing vessels by 2030	Fisheries Department	26

Through subsequent electrification of mechanised and country craft fishing boats and motorised fishing vessels by 2050, the abatement potential will rise to 125 ktCO_2e.

3. **RE Installation to Abate Scope 2 Emissions:** Electrification across fishing, transport, buildings, and agriculture sectors, as suggested in this action plan, would triple the electricity demand—from 1000 GWh in 2022 to 2,893 GWh by 2050. Coupled with timely retirement of PEG units, this demand increase could create a supply lacunae and emissions, if energy is sourced from outside. By integrating an additional 0.7 GW of renewable energy capacity over and above the existing 1.05 GW, both the supply shortfalls and 816 ktCO_2e of associated Scope 2 emissions can be abated. Integrating solar power generation with existing salt pan operations for dual land use and clean energy production could also be explored in the district. Achieving this requires conducting a potential assessment to gauge the scope at earliest.

Interventions	Departments	Expected Cost (Rs. Crores)
Potential assessment by 2030, followed by installation of 0.7 GW of RE capacity (in addition to existing RE capacity of 1.05 GW)	TN Energy Development Agency (TEDA) and State Energy Department	5,500

4. **Agro/Social Forestry in fallow and barren lands:** Ramanathapuram district has sizable stretches of fallow and underutilized lands. These lands offer significant potential for agro and social forestry interventions. By implementing targeted programs of social forests, agro forests, and horticulture plantations with native species, an annual carbon sequestration potential of 137 ktCO_2e can be leveraged, offsetting gross emissions by 7.61% by 2030, apart from supporting soil conservation, rural livelihoods, and improving overall biodiversity of the region. The initiative will contribute to improving the district's green cover, reduce heat stress, and create long-term resilience against climate change.

Short Term Interventions	Departments	Expected Cost (Rs. Crores)	Policies/Funding Schemes
Social and agro forestry in 249 sq.km of barren/ fallow lands by 2030	Forest Department, Municipal Administration Department, Horticulture Department	349	Sub-Mission on Agro Forestry (SMAF), Green Tamil Nadu Mission, Green India Mission, State Compensatory Afforestation Fund Management and Planning Authority Fund (CAMPA), Trees Outside Forests in India initiative by MoEFCC and Government of Tamil Nadu

Further, expanding agro/social forestry over an additional 747 sq. km has the potential to mitigate 876 ktCO_2e by 2050, offsetting gross emissions by 50.20%.

5. **Restoration of mangroves and enhancing seagrass meadows and seaweed cultivation:** Ramanathapuram district, located along the Gulf of Mannar, has ecologically significant stretches of mangroves and seagrass meadows. Enhancing these blue carbon ecosystems provide immense potential for carbon sequestration while offering critical co-benefits such as shoreline protection, improved fishery productivity, and enhanced biodiversity. By 2030, enhancing seaweed and seagrass ecosystems by 4 sq. km has the potential to sequester 5.3 ktCO_2e annually, offsetting gross emissions by 0.29%, while restoring 61 ha of mangrove forests can sequester an additional 5.6 ktCO_2e annually, offsetting gross emissions by 0.31%.

Short Term Interventions	Departments	Expected Cost (Rs. Crores)	Policies/Funding Schemes
• Enhancement of seaweed and seagrass both by 4 sq.km by 2030 • Restoring 61 ha of mangrove forests by 2030	Forest Department , Department of Fisheries, Department of Environment & Climate Change, Tamil Nadu State Wetland Authority	61	Green Tamil Nadu Mission, National Adaptation Fund on Climate Change (NAFCC), Blue Carbon Initiative (potential integration), State Coastal Zone Management Authority Programmes, CSR initiatives in coastal ecosystem management

Further, expanding seaweed and seagrass over an additional 16 sq. km has the potential to mitigate 26.4 ktCO_2e by 2050, offsetting gross emissions by 1.51%. Restoration of an additional 243 ha of Mangroves has the potential to mitigate 28 ktCO_2e by 2050, offsetting gross emissions by 1.60%.

6. **Enhancing Domestic Wastewater Treatment:** To overcome the risk of untreated discharge, the proposed intervention aims to achieve 100% treatment of domestic wastewater by 2040, thereby reducing projected GHG emissions from 61 ktCO_2e under BAU to 13 ktCO_2e annually. Beyond climate benefits, effective wastewater management will significantly improve public health by reducing the spread of waterborne diseases, ensuring cleaner water sources, and creating a healthier living environment for communities.

Emission Reduction Potential: **~48 ktCO_2e/year by 2040, mitigating gross emissions by 2.89%**

Short Term Interventions	Departments	Expected Cost (Rs. Crores)	Policies/Funding Schemes
Urban and Rural Wastewater Management by 2040: • Urban: Centralised treatment capacity of ≈ 72 MLD by 2040 • Rural: 1,70,704 households connected to septic tanks and 38 FSTPs for sludge treatment • Advanced DEWATS for campuses > 2500 m², resorts, restaurants etc	Forest Department , Department of Fisheries, Department of Environment & Climate Change, Tamil Nadu State Wetland Authority	294	Government initiated with possibilities for gap funding through private, CSR, Swachh Bharat Mission, Tamil Nadu Urban Development Project. Namakku Namae Thittam, Kalaignar Nagarpura Mempattu Thittam

7. **Shifting from synthetic nitrogenous fertilisers to nano urea and organic fertilisers:** Shifting from synthetic nitrogenous fertilisers to organic farming and nano urea substitution aims to reduce nitrous oxide (N_2O) emissions from agriculture. This transition enhances nutrient-use efficiency, lowers the environmental footprint, and promotes soil health, thereby contributing to sustainable farming systems.

Emission Reduction Potential: **~ 25 $ktCO_2e$/year by 2030, mitigating gross emissions by 1.40%**

Short Term Interventions	Departments	Expected Cost (Rs. Crores)	Policies/Funding Schemes
• 15% agriculture area transitioned to organic farming • 30% of urea requirement met through nano urea	Horticulture Department, Environment and Climate Change Department, Agriculture Department	85	Farmer driven with possibilities of Government funds and subsidies under various listed schemes such as National Mission for Sustainable Agriculture, Chief Minister's Manniyur Kaathu Mannuyir Kappom Scheme (CM MK MKS), National Mission on Natural farming

Further, transitioning 75% of agricultural land to organic farming and meeting 15% of urea demand with nano urea by 2050 could mitigate 207 $ktCO_2e$ annually by 2050, mitigating gross emissions by 11.83%.

Financial incentives and allocations made available under AMRUT 2.0, Swachh Bharat Mission, Tamil Nadu Industrial Policy 2021, PM KUSUM, National Mission for Sustainable Agriculture, Pradhan Mantri Krishi Sinchayee Yojana, Green India Mission, Green Tamil Nadu Mission and other such policies/ schemes can further support the implementation of the decarbonisation plan.

KEY SECTORAL INSIGHTS

The developed pathways focus on key emitting categories, exploring a range of distinct interventions aimed at reducing emissions while ensuring that the transition aligns with ongoing programmes and schemes at both the state and central levels. The pathways explore three emission scenarios for Ramanathapuram through 2050: Business as Usual (BAU), Moderate Effort Scenario (MES), and Aggressive Effort Scenario (AES). (Figure ES2)

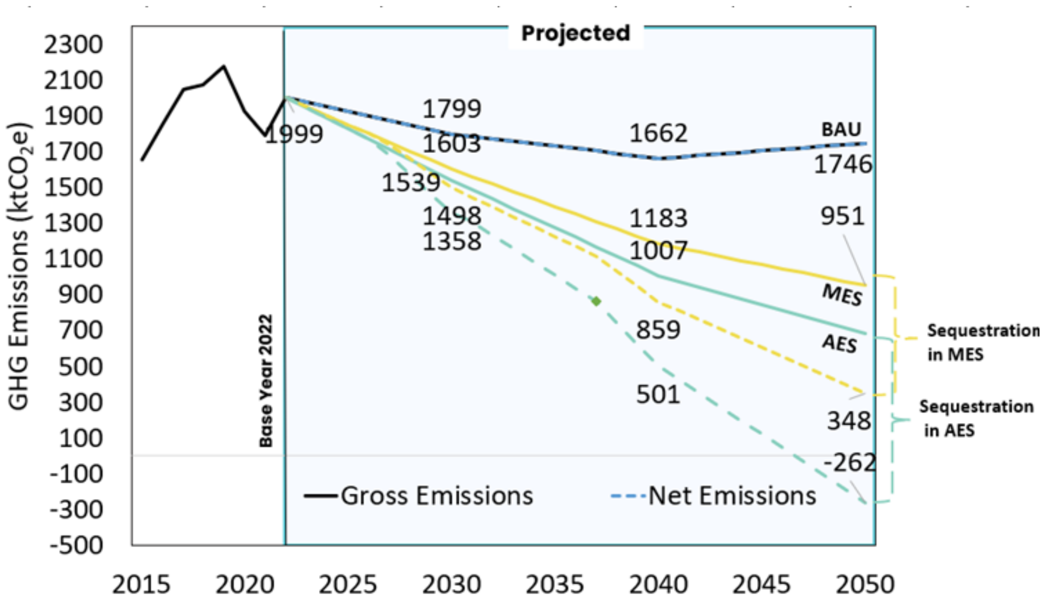


Figure ES2: Actual emissions till 2022 and projections by 2050 under BAU, MES and AES scenario, in Ramanathapuram, in $ktCO_2e$

Emissions are projected to decline from 1999 $ktCO_2e$ to 1746 $ktCO_2e$ under business as usual scenario due to planned retirement of the gas-based public electricity generation units and adoption of electric vehicles. This abatement can be further accelerated through aggressive sectoral decarbonisation strategies as mentioned in this plan – enabling Ramanathapuram to attain carbon neutrality by 2047 and net-negative emissions by 2050. The key messages emerging from the plan are:

A structured decarbonisation of the fishing industry will play a major role in Ramanathapuram's carbon neutrality

Fishing is a major livelihood generating sector in Ramanathapuram, but it relies heavily on diesel as a fuel for operating boats and other fishing equipment, which drove 119 $ktCO_2e$ of GHG emissions in 2022. This is further projected to increase to 125 $ktCO_2e$ in 2050 due to sectoral growth. By electrifying all existing ~3300 mechanized and marginally fishing boats by 2050, ~38 kt of diesel and ~125 $ktCO_2$ of sectoral emissions could be reduced annually.

Electrification of transport, clean cooking, and proper waste management among other interventions could help the district curtail emissions from its tourism sector

Transportation fleet in Ramanathapuram is predicted to expand as tourism in the district grows – boosting transport activities. This fleet is currently run on fossil fuels. Current market dynamics and policies are expected to promote higher adoption of electric vehicles, reducing emissions from road transport from 224 $ktCO_2e$ in 2022 to 155 $ktCO_2e$ in 2050. Further, 100% penetration of EVs in new sales of 2W, 3W, 4W and buses and 80% penetration in new sales of Heavy Good Vehicles (trucks, trolleys) could curtail up to 76% of remaining emissions in 2050.

Behavioural interventions can abate emissions over and above the projected abatement. A shift in transportation mode from 4W cars to public buses by one-tenth commuters in Ramanathapuram can lead to an additional abatement in the transport sector. of ~13.2 ktCO_2e of GHG emissions by 2050. This would also avoid the need for ~6100 four-wheelers on the road, replacing it with an addition of ~280 buses. Non-motorized transport, smart traffic systems and other interventions as listed in detail in this report could supplement these efforts.

Cooking in Ramanathapuram's residential and commercial sector has historically been dominated by LPG, meeting 94% of sectoral energy demand. With growth in population, emissions from cooking are predicted to increase from 97 ktCO_2e in 2022 to 116 ktCO_2e by 2050. Policy shifts promoting conversion of LPG cylinder usage to PNG, and adoption of electric cook stoves – increasing their penetration from 4 per 100 HH in 2022 to at least 28 in 100 HH in 2050 will reduce emissions to 70 ktCO_2e by 2050. Further, biomass pellets processed from palm tree residues could also be used for clean cooking and for heating fuel in buildings.

Waste in Ramanathapuram accounts for 4% of total economy-wide emissions, with domestic wastewater contributing the largest share (77%), followed by solid waste (15%) and industrial wastewater (8%). Emissions from the waste sector are expected to remain almost constant, from 78 ktCO_2e in 2022 to 76 ktCO_2e in 2050. Through waste avoidance, community-based composting, waste reuse/recovery and other waste management interventions, 57 ktCO_2e can be abated. Adoption of Zero Liquid Discharge processes by the industries and sludge waste treatment can further curtail 5 ktCO_2e by 2050.

Electrification across sectors will nearly triple the electricity demand by 2050. Additional renewable energy sources could be harnessed to meet this demand.

Ramanathapuram is an electricity-surplus district, with a total electricity generation of 2,483 GWh and electricity consumption, including captive power plants, amounting to 1000 GWh in 2022. Scope 2 emissions are solely attributed to gas-based public electricity generation units. Due to their high variable costs and a typical economic lifetime of 25 years, these gas plants are expected to fully retire by 2033. Further electrification across fishing, transport, agriculture, building and other sectors is also expected to increase electricity demand from current levels to approximately 2893 GWh by 2050 – (Figure ES3) Procurement of electricity to meet the district's demand will result in 816 ktCO_2e of potential Scope 2 emissions.

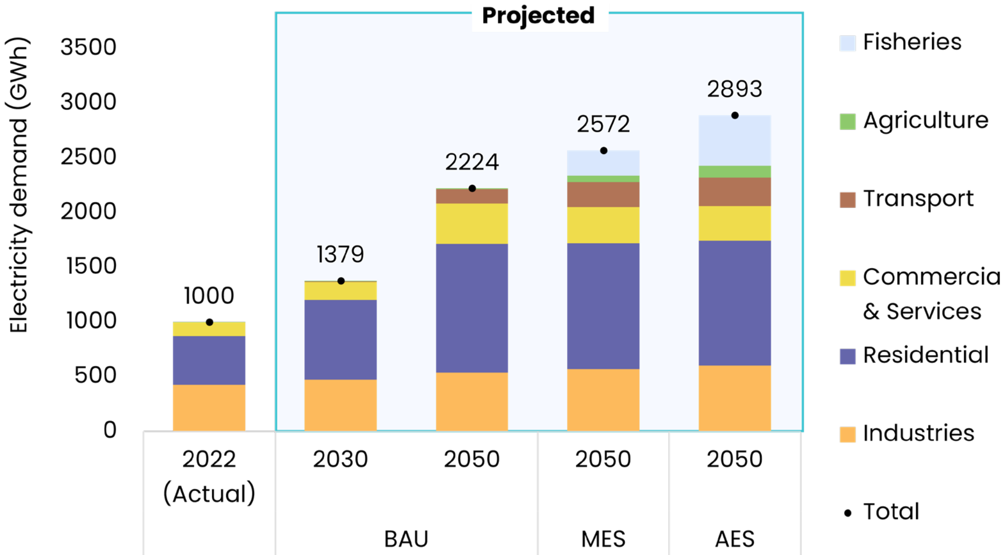


Figure ES3: Sector-wise electricity demand, across scenarios, in GWh

Deep electrification of fisheries and agriculture sector will drive increase in electricity demand in the decarbonisation scenario.

By installing an additional RE capacity of at least 0.7 GW, supplementing the existing RE capacity of 1.05 GW, the district will not only meet this demand but in doing so, also abate the potential Scope 2 emissions. Rameswaram, a water-locked municipality, also has an offshore wind potential of 1 GW (at 100 m agl). Further assessments of utility-scale solar, rooftop solar, onshore wind, and biomass could contribute to maintaining Ramanathapuram's status as an electricity-surplus district in 2050.

In the 'Solar PV Potential of India: Ground Mounted' assessment report published in September 2025, the National Institute of Solar Energy (NISE) has estimated a potential of ground-mounted solar capacity of 9.7 GW in the Ramanathapuram district. This potential assessment is based on a dynamic land use modeling that identify 10% of total wasteland with high irradiance and adequate grid access as feasible site for deployment of ground mounted solar in the State. Realising this potential in medium to long term will make the district carbon neutral from electricity standpoint, and support the state's vision of achieving net zero by 2070.

Deep electrification and energy efficiency initiatives lead to reduction of final energy consumption, making them key drivers of a sustainable energy future

Implementing energy efficiency measures, deep electrification (particularly in industry and transport), and fuel switching from LPG to PNG in the AES 2050 scenario reduces total energy demand to roughly 13 PJ—about a 23% drop compared to BAU 2050. This shift is driven by higher EV adoption in transport (replacing gasoline and diesel vehicles) and electric furnaces in industry (replacing fossil-fueled processes), which together reduce fuel consumption and improve overall system efficiency. Electricity's share in final energy jumps significantly—from around 7.6 PJ in BAU 2050 to over 11.2 PJ in the AES scenario—while the contribution from fossil fuels such as diesel, gasoline, coal, and bitumen declines. Likewise, the substitution of LPG with PNG in residential and commercial applications not only curbs direct emissions but also lowers primary energy use due to PNG's cleaner combustion characteristics and potential for more efficient distribution. (Figure ES4)

Temperature control in the building sector i.e., setting the AC to 24–26°C can supplement sectoral abatement. A conservative increase in the temperature setting by 2°C from 24°C to 26°C could reduce electricity demand by approximately 57 GWh, saving ~40 $ktCO_2e$ (Scope 2) emissions. Additionally, smart lighting solutions can prevent 40% of lighting electricity usage or 17 GWh in Ramanathapuram district. Additionally, promoting the implementation of cool roofs can contribute to lowering cooling energy demand in buildings and advancing overall energy efficiency goals

Decarbonising the non-energy sector would drive to carbon neutrality and potential carbon negative future

As of 2022, total non-energy emissions in Ramanathapuram stood at 752 $ktCO_2e$ (~37% of total emissions), primarily led by aggregate sources and non-CO_2 emission sources on land (52%, 389 $ktCO_2e$), which includes emissions from rice cultivation (33%, 248 $ktCO_2e$), agriculture soil (18%, 138 $ktCO_2e$) and biomass burning in cropland (0.4%, 3 $ktCO_2e$), followed by livestock (20%, 147 $ktCO_2e$), land (18%, 138 $ktCO_2e$) and waste sector (10%, 78 $ktCO_2e$). In BAU, the total non-energy emissions are projected to increase by 331 $ktCO_2e$ to 1005 $ktCO_2e$ (~58% of total emissions) by 2050, significantly increasing the sectoral contribution to the total emissions. The emissions from aggregate sources alone are projected to increase by 221 $ktCO_2e$ with predominant contributions from agriculture soil (137 $ktCO_2e$) and rice cultivation (84 $ktCO_2e$).

Around half of the projected non-energy emissions in 2050 can be abated by adoption of sustainable agriculture practices and targeted interventions in livestock management

Replacing synthetic fertilisers and urea with organic fertiliser and nano urea, and increasing the percentage of multiple aeration in the rice cultivated area would help to reduce the emissions

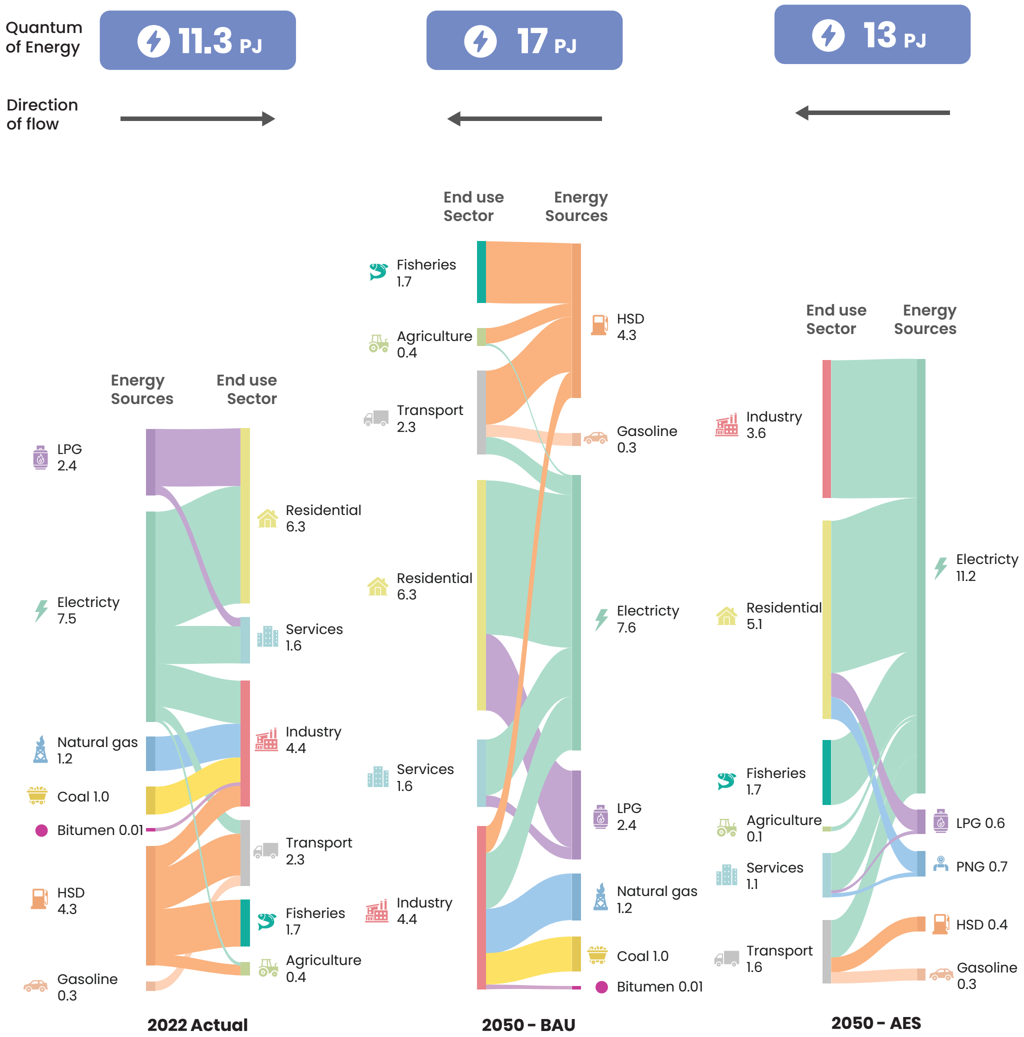


Figure ES4: Fuel to sector linkages in Ramanathapuram, in PJ

Electricity can replace fossil fuels across sectors by 2050, aligned with the decarbonisation plan

from the agriculture sector. Under AES, transitioning 75% of agriculture area to organic fertiliser and increasing the multiple aeration for rice cultivation from 20% to 77%, will reduce 206 ktCO_2e and 177 ktCO_2e of emissions respectively, by 2050. Similarly, through introduction of balanced rationing (90% of livestock), improved methanogen inhibiting feed supplements (75% of livestock) and manure management practices, 71 ktCO_2e of emissions from livestock category, arising from methane, can be abated by 2050. Additionally, efficient waste management through centralised treatment for urban, septic tanks for rural and fecal sludge treatment plants at Firka level, zero liquid discharge, composting organic waste, reuse etc. can abate 62 ktCO_2e by 2050 from the largely static waste sector.

In addition to the emission reduction interventions the rich coastal ecosystem of Ramanathapuram provides immense opportunity for land and blue carbon sequestration

Restoring mangroves, implementing agroforestry practices, increasing carbon stock density, and enhancing seagrass and seaweed ecosystems have the potential to sequester up to 944 ktCO_2e annually by 2050. About 73% of this can be achieved by monitoring and removing encroachments of forest lands and dedicating current barren, fallow and non-cultivable lands to social and agroforestry, with a special focus on community and village forests for enhanced local participation. Restoration of degraded coastal and inland areas, such as expanding mangrove cover along the 276 km coastline, could further offer co-benefits like biodiversity preservation and coastal protection (Figure ES5). This aligns with and can overtime benefit from support under other State initiatives, including the

Marine Resource Foundation that has been announced in the TN State Budget 2025-26 with an initial funding of Rs. 50 crore to focus on mangrove forest conservation and sustainable marine resource management.[5]

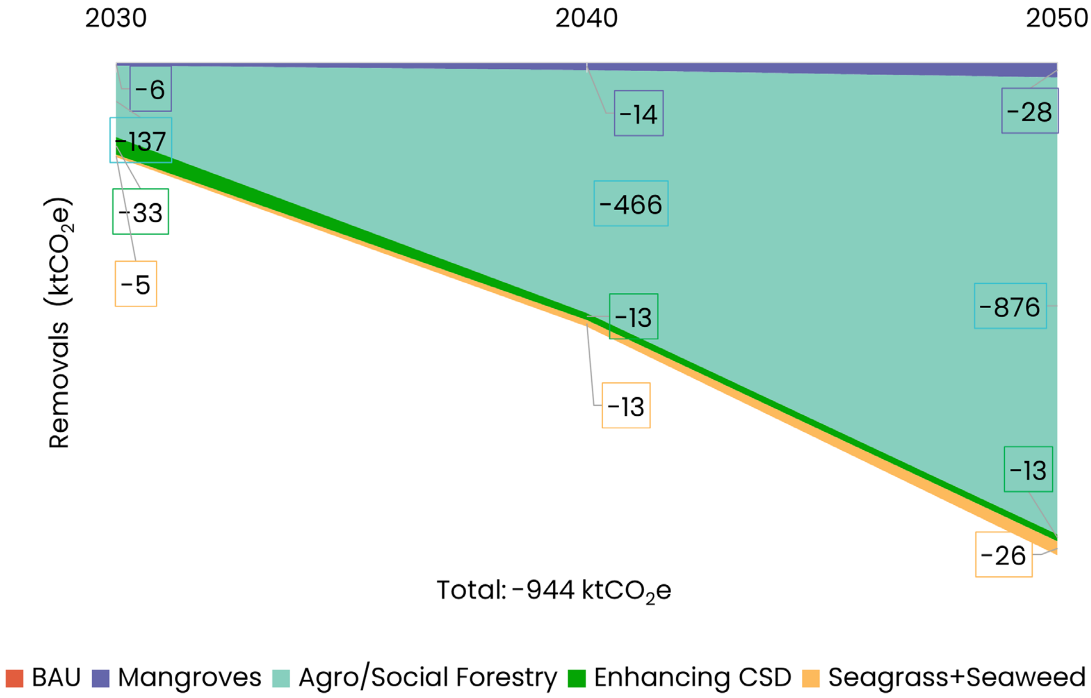


Figure ES5: Carbon sequestration potential under aggressive effort scenario (AES), by 2050, in $ktCO_2e$

Ramanathapuram's decarbonisation strategy emphasises renewable energy adoption, electrification of key sectors, preservation and enhancement of natural carbon sinks. By implementing these measures, the district can surpass its climate goals, achieve net-negative emissions, and contribute significantly to Tamil Nadu's and India's carbon neutrality targets while enhancing resilience against climate impacts.

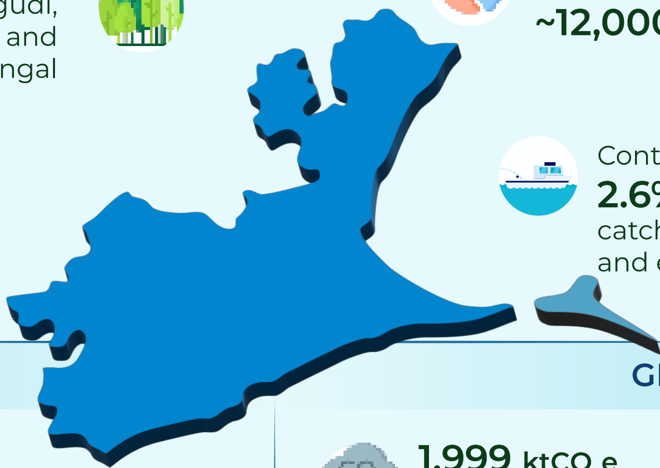
Why Transform Ramanathapuram into a Carbon Neutral and Climate Resilient Hub?

Credits: Pamban Bridge in Ramanathapuram; Source: Ramanathapuram District Administration

DISTRICT HIGHLIGHTS

5 Ramsar Sites - Gulf of Mannar Biosphere Reserve and 4 Bird Sanctuaries: Chitrangudi, Kanjirankulam, Sakkarakottai and Therthangal

Wetlands cover **18.05%** of the district's geographic area (highest in Tamil Nadu)



GDDP: **49.8%** by service sector, 30.65% by industries with **~12,000** MSMEs

Contributes **14%** of TN & **2.6%** of India's marine fish catch - vital for livelihoods and exports

CLIMATE PROFILE

976 mm
Annual rainfall

22.77°C to 34.7°C
Annual temperature range

0.9°C to 3.5°C
Projected increase in maximum summer temperature by 2090

33% - 82%
Rise in SW monsoon rainfall by 2090

17% - 43%
Rise in NE monsoon rainfall by 2090

GHG EMISSIONS (2022)

1,999 ktCO$_2$e
Gross and net emissions are same since carbon sequestration is negligible

Key Contributors
(% of Gross Emissions)

28% Public Electricity Generation

11% Road Transport

10% Captive Power Plants

26% Non-CO$_2$ emissions (paddy cultivation, livestock and agriculture soils)

6% Fisheries

TRANSFORMATION POTENTIAL

Potential to be carbon neutral by 2047

Rameswaram as **eco-spiritual & carbon neutral hub** - attracting global recognition

1,064 ktCO₂e
Annual mitigation potential by 2050 across interventions

(-944) ktCO₂e
Annual sequestration by 2050

Blended Finance and Community-Ownership Models, to sustain low carbon interventions

Gulf of Mannar: Preserving ecosystems, sustaining resilient livelihoods.

Low-Carbon Interventions and Ecosystem-Livelihood Co-benefits

Blue-Green Ecosystem

-944 $ktCO_2e$*

Intervention

- Enhance the carbon stock density of the existing forest
- Agroforestry in waste/fallow lands
- Restoration of mangroves, seagrass and seaweed

Resilience & Co-benefits

- Strengthens coastal climate resilience and heat resilience.
- Enable sustainable fishing and climate-resilent agriculture
- Enhances water security and water salinity management

Economics and Livelihood Improvement

- Promotes ecotourism and green entrepreneurships
- Strengthens fishers livelihood through value- added product development.
- Expands access to climate insurance, farmers's institution, market access
- Support livelihood opportunities for women and youth
- Improves energy access.

Sustainable Tourism

87 $ktCO_2e$*

Intervention

- Addition of 600 electric public buses, 6,000 electric 3Ws (autos) and 48,000 electric 4Ws (taxis) by 2050
- Adoption of 72,000 electric cookstoves in hotels/restaurants by 2050
- Low Carbon Eco-Spiritual Corridor-connecting Rameswaram Temple to Dhanushkodi and other hotspots using electric buses and shaded pathways for non-motorized transport.

Resilience & Co-benefits

- Reduced indoor and outdoor pollution
- Improved air quality
- Better energy access

Economics and Livelihood Improvement

- Decent working conditions
- Enhanced access to affordable and shared mobility

Sustainable Fisheries

125 $ktCO_2e$*

Intervention

Electrification of ~3300 mechanised and motorised fishing vessels by 2050

Resilience & Co-benefits

- Zero exhaust emissions→cleaner coastal air and water
- No diesel spills, safer marine ecosystems

Economics and Livelihood Improvement

- Resilience to fuel price shocks
- Improved efficiency and operational performance
- Community ownership of solutions

NMT: Non-motorised Transport; PBS: Public Bike Sharing

*Denotes mitigation potential

What Does Climate-Resilient Development Deliver?

- Stronger community adaptive capacity
- Climate-resilient communities with reduced risks from heat, drought, extreme weather and enhanced thermal comfort
- Smarter water management (restoration, recharge, efficiency, reuse, reduced salinity)
- Climate-informed planning, governance, and disaster readiness
- Conservation and restoration of ecosystems, supporting tourism
- Climate-informed planning, governance, and disaster readiness
- Bankable green projects, access to climate finance, green jobs, and livelihood security

RAMANATHAPURAM
Path to Decarbonisation

Ramanathapuram has the potential to become carbon neutral by 2047, and achieve a net negative of ~262 ktCO_2e by 2050 – all the while transforming itself into a sustainable tourism hub. Some key interventions that could support this through sectoral decarbonisation and enhancement of the district's sequestration potential are as follows:

Total Emissions (2022): 1,999 ktCO_2e

- **Annual Growth in Emissions (2005 to 2022) : 3.9%**
- **Per Capita Emissions (2022): 1.40 tonnes CO_2e per capita**
- **Emission Intensity Reduction in 2022 w.r.t 2005: 66%**

Electrification of INDUSTRIES

AMP: 226 ktCO_2e (12.94% of gross emissions)

- Replace existing **~87 MW** fossil-fuel-based Captive Power Plants (CPPs) with equivalent renewable energy capacity of **~156 MW** (solar, wind and GH2) by 2050
  AMP: 209 ktCO_2e
- Replacement of HSD by biodiesel in diesel generators for backup supply/renewable-based backup supply support
  AMP: 17 ktCO_2e
- Explore electrification of heating processes in industries to reduce fossil fuel consumption (Furnace Oil, HSD, etc.)

Electrification of TRANSPORT

AMP: 118 ktCO_2e (6.76% of gross emissions)

- Promote 100% penetration of electric vehicles in **2W, 3W, 4W** and buses, and **80%** penetration of heavy goods vehicles (trucks, trolleys) in new sales by 2050
- Install ~400 charging stations and development of other allied clean mobility and sustainable transport in Ramanathapuram by 2050

Stock of EVs in 2050

e - 2W	e - 3W	e - 4W
~1.8 lakh	**6,000**	**0.48 lakh**

e - buses	e - Heavy Goods Vehicles (HGVs)
600	**500**

Electrification of Fishing Boats

AMP: 125 ktCO_2e (7.16% of gross emissions)

- Electrify **~3,300 mechanised and motorised fishing** vessels by 2050

CARBON SEQUESTRATION

ASP: 944 ktCO_2e (54.08% of gross emissions)

- Repurposing **996** ha of barren/fallow lands to horticulture, agro/social forestry
  ASP: 876 ktCO_2e/yr
- Enhance Carbon Stock Density by 5.5% from the existing **~82.25 tCO_2/ha to 86.25 t/ha** through reforestation/ afforestation and sustainable forest management
  ASP: 13.36 ktCO_2e/yr
- Restoring 304 ha of mangrove forests **ASP: 28 ktCO_2e/yr**
- Enhancement of seagrass and seaweed by 20 sq km
  ASP: 26 ktCO_2e/yr

*AMP stands for Annual Mitigation Potential
**ASP stands for Annual Sequestration Potential

Scope 2 denote indirect GHG emissions from purchase of energy (electricity, heat, steam etc).

AGRICULTURE

AMP: 477 ktCO_2e (27.32% of gross emissions)

Electrify 1,400 tractors and tillers with EVs by 2050 **AMP: 5 ktCO_2e**

Convert 5,837 diesel pumpsets to solar pumps by 2050 **AMP: 16 ktCO_2e**

90% balanced rationing and **75% methanogen** inhibiting feed additives for livestock and 90% manure management through biogas plantsby 2050 **AMP: 71 ktCO_2e**

Increase multiple aeration water regime from **20% to 77%** for rice cultivation by 2050 **AMP: 178 ktCO_2e**

Replace synthetic nitrogen fertiliser and urea with **75% organic** fertiliser and **25% nano-urea** **AMP: 207 ktCO_2e**

39 mini weather monitoring stations (rainfall and temperature)

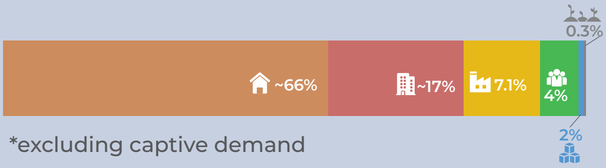
Capacity building to promote sustainable modernisation

ELECTRICITY

AMP: 816 ktCO_2e (Scope 2)

Electricity Generation: **~2,497 MU (2023-24),** about **71%** of which is driven by solar power, followed by gas turbines at **~29%**.

Electricity consumption: **625 MU** (2023-24) Led primarily by:



*excluding captive demand

PEG Units – that contribute **28% (559 ktCO_2e)** of gross emissions – are expected to retire by 2033 as per their economic lifecycle, fully abating the related emissions.

Electricity demand is expected to nearly triple from **1,000 GWh** in **2022 to 2,893 GWh** by **2050** under AES

A holistic assessment for setting up an additional RE capacity of at least **0.7 GW** (including solar plants on existing salt pans), supplementing the existing RE capacity of **1.05 GW,** could meet future electricity demand while abating Scope **2 emissions**

WASTE

AMP: 61 ktCO_2e (3.53% of gross emissions)

(Scope 2) 5 ktCO_2e

Improved wastewater treatment by 2040 **AMP: 48 ktCO_2e**
Urban: **71 MLD** centralised sewage treatment and **100% UGD connection**
Rural: Twin pit septic tanks for **1.7 lakh households** and **38 FSTPs** at Firka level

Install **1 MW** of waste-to-energy plant, requiring ~30 tons of waste per day, by 203 **AMP: 5 ktCO_2e**

Setting up of ETPs and a continuous treated effluent monitoring system for **4 MLD industrial wastewater** by 2050, and strict adherence to zero liquid discharge **AMP: 5 ktCO_2e**

100% segregation at source and processing of municipal solid waste with zero landfilling through **38 rural and 8 urban recycling centres** and **8 urban composting** units **AMP: 8 ktCO_2e**

BUILDINGS (Residential, Commercial and Services)

AMP: 57 ktCO_2e (3.26% of gross emissions)

(Scope 2) 136 ktCO_2e

Scope 1

Transition from LPG to PNG, and gradual adoption of **~0.72 lakh electric cook stoves** by 2050 **AMP: 29 ktCO_2e**

Install a biogas plant of ~15,000 m^3/day capacity by 2050 **AMP: 28 ktCO_2e**

Scope 2

Adopt **~4 lakh 3-5 star ACs and 4.2 lakh refrigeration units,** primarily by 2040. **AMP: 106 ktCO_2e**

Add **7.3 lakh** LED bulbs, **5.76 lakh** BLDC fans, and **0.5 lakh** LED street lights by 2030 **AMP: 30 ktCO_2e**

Domestic sector (434 MU) Commercial sector (108 MU) Industrial sector (44 MU)
Miscellaneous (14 MU) Agriculture (2 MU) Public works (23 MU)

1 Context, Methodology, and Scenario Framework

At the 26th Conference of Parties (COP26) in November 2021, India made a bold commitment to achieving net-zero greenhouse gas emissions by 2070. This signalled its strong resolve to decarbonise its economy and combat climate change. While this ambitious pledge marks a significant milestone in India's journey toward sustainable development and reflects the country's determination to play a leading role in global efforts to reduce carbon emissions, the role of sub-national entities is essential in realising this vision. As India advances its national decarbonisation plan, active participation from states and regions is critical to achieving a carbon-neutral and resilient future.

Tamil Nadu has emerged as a pioneer in climate action, demonstrating leadership through various initiatives aimed at mitigating carbon emissions. The Tamil Nadu Green Climate Company (TNGCC), established by the Government of Tamil Nadu, to promote renewable energy, sustainable infrastructure, climate-resilient agriculture, forest conservation, and climate adaptation strategies is one such key initiative that follows a dual approach of pursuing carbon neutrality at the state-level while formulating bottom-up strategies to decarbonise specific districts. In line with this strategy, Ramanathapuram has been identified as a key district for targeted decarbonisation efforts.

In support of this initiative, the Vasudha Foundation, in collaboration with TNGCC, has developed decarbonisation strategies for Ramanathapuram with a specific focus on the Rameswaram Local Planning Area (LPA). This report offers a detailed analysis of the district's current and historical GHG emissions, energy landscape, and projected future energy trajectory, while presenting an all-encompassing plan to decarbonise sectors across various scenarios

Methodology

A robust methodology has been adopted to derive decarbonisation pathways for Ramanthapuram. This encompasses the following:

Climate Variability Analysis and Projections	Historical climate data and climate models under RCP 4.5 and RCP 8.5 scenarios have been used to project future changes in temperature and rainfall. The projections show changes in rainfall, temperatures, and heatwaves.
Historical GHG Emission Inventory	To determine the historical Greenhouse Gas (GHG) emissions of the district, the methodology outlined by the Intergovernmental Panel on Climate Change (IPCC) for GHG emission inventory has been adopted . This approach typically involves collating data from various sectors contributing to emissions, such as energy, agriculture, forestry, and waste, and applying emission factors and activity data to calculate overall GHG emissions.
Energy Sector and Other Sectors Demand and Emissions Projection	A bottom-up energy system model has been used, which projects energy demand and emissions from 2022 to 2050 in five-year intervals. The model tracks the transformation of primary energy to meet end-user energy demand across sectors, such as residential, services, agriculture, transportation, and industry. Emissions from rice cultivation, fertiliser use, wastewater, and solid waste were also projected, along with assessing the potential for carbon sequestration from forestry. The model utilises inputs from the district statistical handbook, census data and electricity feed. The district's historical GHG emissions were estimated using the IPCC methodology, which involves collecting sectoral data (energy, agriculture, forestry, and waste) and applying relevant emission factors and activity data to calculate total emissions.
Sectoral GHG Emissions Abatement and Sequestration Potential Assessment	Strategies to minimise emissions and maximise sequestration through afforestation and other interventions have been devised, customised to the sector and its potential for abatement/sequestration.

Scenario Framework

The scenarios analysed in this study have been designed keeping in view the different operational and technological parameters. These parameters vary depending on system-level efficiency, fuel switching, behavioural changes, improving existing forest cover, waste management practices, land utilisation, etc. The studied scenarios in this report are:

1. Business as Usual (BAU)

The BAU scenario projects demand and supply growth based on current policies and historical trends. In this scenario, improvements in energy efficiency, fuel switching, and sequestration remain constant at current levels. Electrification is limited to road transport, with no changes in cooking fuel use or waste management practices. This scenario will be used as the reference scenario upon which the decarbonisation scenarios are built.

2. Moderate Effort Scenario (MES)

MES illustrates the extent to which current national policies and announced state government targets can achieve emissions abatement (i.e. India's NDC). This scenario makes relatively moderate assumptions on various sectoral emission abatement interventions. For non-energy sectors, the scenario outlines a practically feasible approach with moderate decarbonisation targets for categories such as waste treatment and fertilisers, along with exploring the scope for enhancing existing carbon sequestration in the district.

3. Aggresive Effort Scenario (AES)

AES outlines an aggressive strategy to achieve decarbonisation of the district by 2050, prioritising energy security and substantial emission reductions. It emphasises widespread electrification, implementing energy efficiency measures, promoting behavioural changes, and adopting robust strategies for waste management, optimising fertiliser usage, and enhancing carbon sequestration through afforestation and sustainable land-use practices. A full electrification of the tractors and tillers, fishing fleet and backup supply, among other sectors, and enhanced electrification of cooking (30%) is proposed.

Table 1: Assumptions considered under this study

Sector	Sub-Sector disaggregation	Demand Driver	Scenario		
			BAU	MES	AES
Agriculture (Energy)	Irrigation	Annual increase in water consumption* and fuel demand	•2022 shares of electrified, diesel, and solar pump sets remain unchanged through 2050. •Fossil fuel-based tractors and tillers in operation will be retained until 2050.	Conversion of 100% of diesel pumpsets to off-grid solar pumps by 2030	
	Residential Appliances & Lighting			Electrifying 50% of tractors and tillers by 2050	Electrifying 100% tractors and tillers by 2050
Buildings (Residential, Commercial, and Cooking)	Residential Appliances & Lighting	GSDP growth leading to higher spending capacities, Higher temperature led space cooling needs	•Current level of EE is to continue till 2050 •Stock out of conventional lighting by 2030	3-star appliances to cut down energy demand by 7-8% by 2050	5-star appliances to cut down energy demand by 11-12% by 2050
	Cookstoves	GSDP growth, population growth	LPG as a major fuel for cookstoves, only 6% cookstoves will be electrified by 2050	Shift in composition to LPG (50%), PNG (30%) and electricity (20%)	Shift in composition to electricity (30%), PNG (40%) and LPG (30%)
	Commercial Buildings, Public Lighting, Miscellaneous Services	Commercial Development in the District, leading to increase in electricity and fuel consumption	Electricity consumption in commercial buildings and public lighting to increase by 2.5% and 3% respectively by 2050	•Replacement of street lights with LED by 2030 •50% electrification for backup supply through commercial DG sets, and solarisation of commercial buildings by 2050	•Replacement of street lights with LED by 2030 •100% electrification for backup supply through commercial DG sets, and solarisation of commercial buildings by 2050

Transport	Road Vehicles	Annual growth in vehicle demand*	•100% EV share in new sales of 2W, 3W and 4W by 2050 •20% and 65% EV share in new sales of heavy goods vehicles (trucks, trolleys etc.) and uses in new sales by 2050	•100% electrification of 2W, 3W, 4W and buses •50% electrification of HGVs	•100% electrification of 2W, 3W, 4W and buses •80% electrification of HGVs
Fisheries	Fishing boats and vessels	Fuel consumed by fishing boats and fishing vessels	Current number of boats and vessels' emission rates from fuel consumption is expected to continue till 2050	Electrification of 50% of the fishing boats and fishing vessels by 2050.	Electrification of 100% of the fishing boats and fishing vessels by 2050
Industry	Textile, spinning and others	Annual industrial growth* leading to increased energy demand	Current growth and emission rates from fuel consumption are expected to continue till 2050	Electrification of current heating processes (boilers)	
Waste	Solid waste disposal	Per capita waste generation growth	Current growth	0% solid waste sent to landfills/ dumpsites by 2030	
	Industrial wastewater	Annual industrial growth	Wastewater generation in 2050 is expected to remain at the current levels.	60% treatment by 2050	80% treatment by 2050
	Domestic wastewater	Increase in population	Current growth	100% treatment by 2050	100% treatment by 2040

Carbon Sequestration			Existing sequestration to be the same till 2050	• Repurposing 30% of barren/fallow lands (219383 ha) to horticulture, agro/ social forestry • Enhancing Carbon Stock Density by 3% from existing ~82.25 t/h to 84.76 t/ ha • Restoration of 57 Ha of mangroves • Enhance seagrass stretch by 10 sq.km • Enhance seaweed stretch by 10 sq.km	• Repurposing 45% of barren/ fallow (219383ha) to horticulture, agro/ social forestry • Enhancing Carbon stock Density by 5.5% from existing ~82.25 t/ha to 86.76 t/ha • Restoration of 114 Ha of mangroves • Enhance seagrass stretch by 20 sq.km • Enhance seaweed stretch by 20 sq.km
Agriculture Non-Energy	Agriculture soils	Increase in net sown area and fertiliser demand to enhance productivity	Current growth	• Substituting nitrogen fertiliser and urea with 50% organic fertiliser and 50% nano-urea by 2050	• Substituting nitrogen fertiliser and urea with 75% organic fertiliser and 25% nano-urea by 2050
	Rice cultivation	Increase in net sown area	Current growth	• Increase in multiple aeration water regime from 20% to 60% for rice cultivation by 2050	• Increase multiple aeration water regime 20% to 77% for rice cultivation by 2050
	Livestock	Increase in livestock population	Current growth	• 60% Balanced rationing, 45% methanogen inhibiting feed additive and 60% manure management by 2050	• 90% Balanced rationing, 75% methanogen inhibiting feed additive and 90% manure management by 2050.

*Historical growth rates are assumed to continue

Results from the various assessments conducted, with decarbonisation strategies and pathways, are provided in the subsequent chapters of this report.

2. District Profile

Ramanathapuram, also known as Ramnad or Mugavai, is one of the oldest districts in Tamil Nadu, located in the state's southeast corner. It was formed on March 15, 1985. The original Ramanathapuram district was split into three parts, and is known for its difficult geographical terrain, resulting in drought, lower agricultural productivity, and eventually lower urbanisation than the state average. The nature of the land is mostly flat and sandy. Its extensive coastline, stretching about 276 kilometres, comprises a quarter of Tamil Nadu's entire coastline.

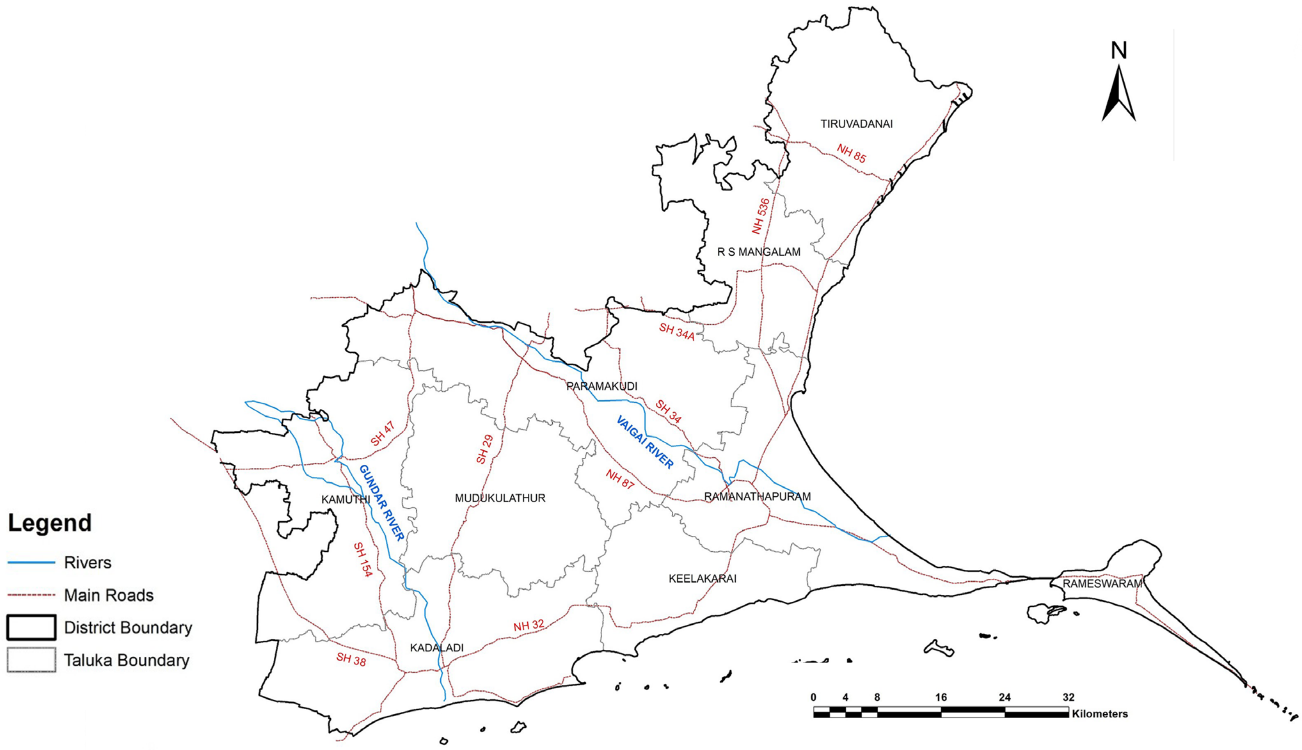


Figure 2.1: Geographical map of Ramanathapuram district
Source: authors' analysis

Demography[6]

According to the 2011 census, the district recorded a literacy rate of 80.72 percent, with male literacy at 87.81 percent and female literacy at 73.52 percent, indicating a gender gap that still requires attention despite overall educational improvements. The decadal population growth rate was 13.96 percent between 2001 and 2011, consistent with the demographic trends in other semi-arid and drought-prone districts of Tamil Nadu.

Table 2.1: Important demographic indicators of the district (census 2011)

Total Population (census 2011)	Population Density (number of people/sq.km.)	Urban Population (absolute, % of total)	Rural population (absolute, % of total)	Sex ratio (for 1000 males)
13,53,445	331	4,10,635 (30.34%)	9,42,810 (69.66%)	983

Topography and Climate

The district experiences high temperatures throughout the year and has a dry, hot climate with an annual average temperature ranging from 22.7°C to 34.7°C. The average annual rainfall in 2022–23 was 712.9 mm, lower than the normal 817.8 mm. Rainfall is mostly concentrated in the northeast monsoon season. The district's rivers Vaigai, Gundar, Kirudhumal, Virusuli, and Malataru, are mostly non-perennial and contribute minimally to irrigation.

Water Resources

Physiographically, the entire district is a plain terrain. The major part of the district falls in the Gundar-Vaigai river basin. The drainage pattern, in general, is dendritic. All the rivers are seasonal and carry substantial flows during the monsoon period.[7] In 2021-22, the pre-monsoon water level in the district ranged from 2 to 5 meters below ground level (mbgl), while the post-monsoon water level ranged from 0 to 2 mbgl.[8]

Current Scenario in Ramanathapuram

1. Land and Other Natural Resource

The land use pattern in Ramanathapuram district is primarily agricultural, with substantial areas also occupied by forests, barren lands, and coastal ecosystems. The district's terrain is mostly flat and sandy, with black soil widely distributed across all blocks. Coastal alluvial soils dominate the blocks of Ramanathapuram, Kadaladi, Thiruvadanai, and Mudukulathur, while red sandy soils are found in parts of Mudukulathur, Kamuthi, and Kadaladi. These varied soil types influence the cropping pattern and productivity of the region.

Ramanathapuram has a total geographical area of ~4,089 sq km. About 45 percent of land in the district is covered under net sown area. Another 22 percent of the area is classified as other fallow land, i.e., land which is temporarily out of cultivation for a period of not less than one year and not more than five years, and 21 percent is put to non-agricultural use, which also includes 45.56 sq.km of social forests. The remaining geographical area comprises of cultivable wasteland (7%), current fallow (2%), forest (1%), land under miscellaneous tree crops not included in net sown area (~1%), and permanent pastures and other grazing areas (<1%).[9] (refer to Figure 2.2.)

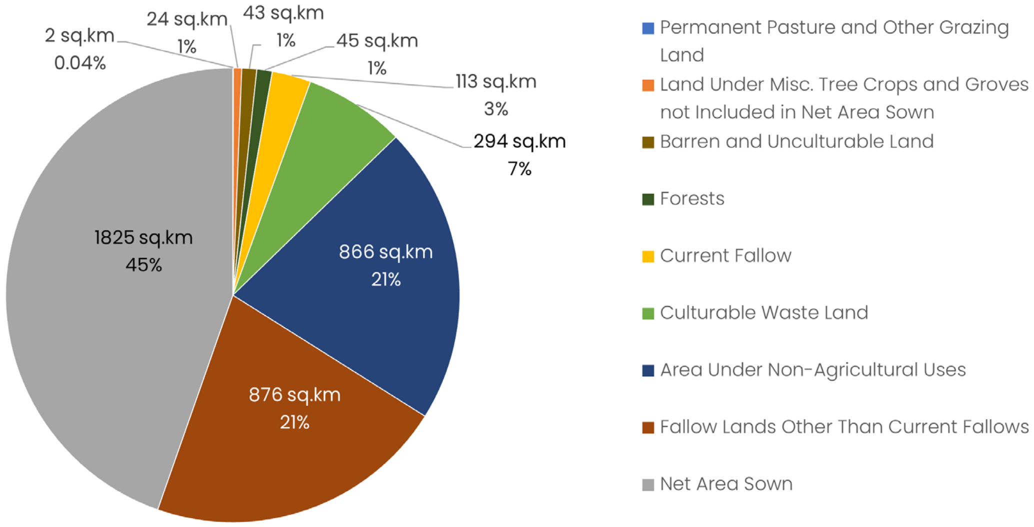


Figure 2.2 Category-wise land use in Ramanathapuram, in sq.km (2023-24)

Over the years, the demand for land for agriculture and industrialisation has increased in Ramanathapuram, which has resulted in shrinking of the area under other categories. A comparison of land use in the district in 2023 against 2013 shows this changing pattern. (Figure 2.3 and Table 2.2)

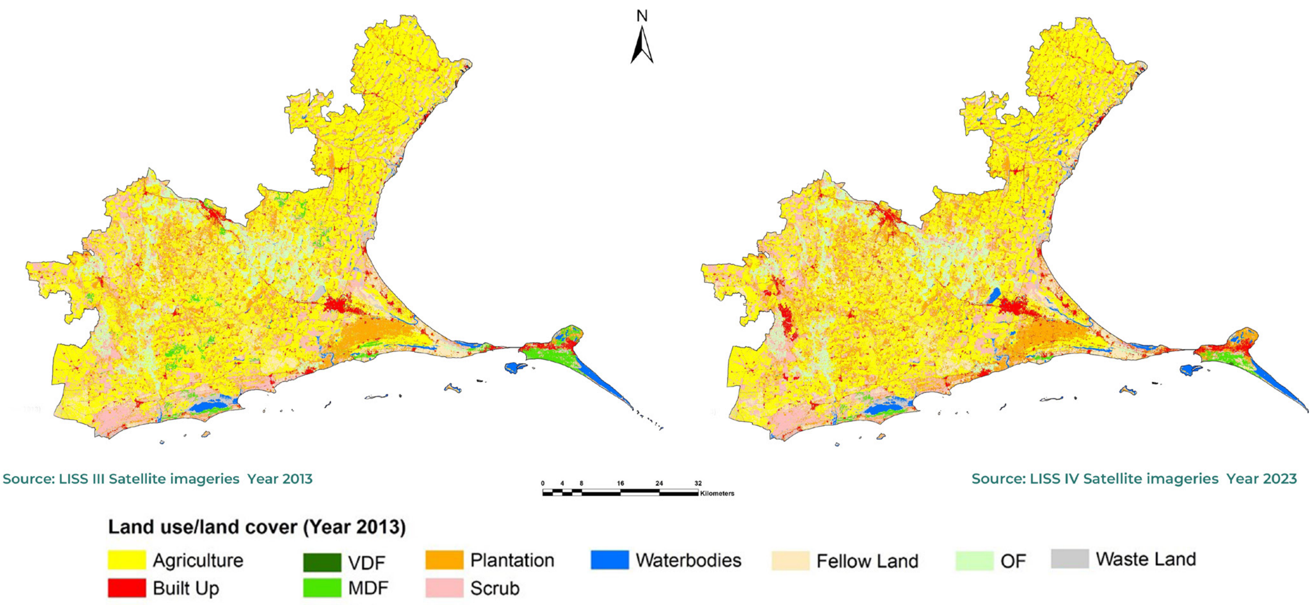


Figure 2.3 Land use change pattern in Ramanathapuram district between 2013 and 2023 (in sq.km)

Table 2.2: Land use change pattern in Ramanathapuram between 2013 and 2023[10]

Year	Agriculture	Built up Land	Fallow Land	Very Dense Forest	Moderate Dense Forest	Open Forest	Plantation	Scrubland	Waste Land	Water Bodies
2013	1,844.01	120.25	393.11	0	88.47	240.41	570.54	666.58	113.51	72.35
2023	1,777.88	167.9	390.38	0	30.95	229.16	653.23	681.4	90.99	87.34
Change (%)	-3.58	39.63	-0.69	0	-65.02	-4.68	14.49	2.22	-19.84	20.72

Build-up land in Ramanathapuram, i.e., land covered with buildings (roofed structures), paved surfaces (roads, parking lots, etc.), commercial and industrial sites (ports, landfills, quarries and runways) have increased by ~40 percent in the past decade. There has also been a 21 percent increase in water bodies in the districts. While the area under plantation has increased by ~14 percent, area under moderate and moderately dense forest has reduced drastically by ~65 percent between 2013 and 2023.

1.1 Wetlands and Biodiversity

As much as 18.05 percent of the total land area of Ramanathapuram constitutes wetlands, which is also 8.18 percent of the total wetlands of Tamil Nadu.[11] These wetlands, located in the globally recognised biodiversity hotspots such as Kanjirankulam and Chitragudi sanctuaries, are often overlooked ecosystems.

The district has five bird sanctuaries and five Ramsar sites, and encompasses two ecoregions: South Palk Bay and Gulf of Mannar Marine National Park. Further, the region is recognised as one of the richest marine biodiversity hotspots in India, supporting a diverse array of ecosystems, including mangrove forests, coral reefs, rocky shore, sandy beaches, seagrass meadows, and seaweed ecosystems. Over 4,223 species of flora and fauna, with 117 species of corals, 158 species of arthropods, 856 species of molluscs, and an estimated 1,182 species of fish were reported in this region. It also harbours the largest shallow-water coral reefs in India, including the rare black coral and several threatened reef-building corals.

2. Economy

The fishing industry is the main income source for the local economy, providing livelihoods for many and contributing significantly to foreign exchange through the export of premium varieties of sea fish. Additionally, the district is known for its handicrafts, including toys, bags, and mats made from palm leaves, which are widely sold across the state. Other major occupations include agriculture, Palmyrah tapping, and small-scale trades and businesses.

Ramanathapuram's economy for 2022-23 showed a GDDP at constant price of ₹1,552,898 lakh contributing 1.1% to Tamil Nadu's respective state-level figures. The service sector was the dominant economic engine, accounting for 58.57% of the district's GVA, followed by construction(16.92%), manufacturing(11.38%), and agriculture (11.34%). This highlights a notable imbalance where, despite 44.55 percent of the population being engaged in agriculture, these primary sectors contribute a disproportionately small percentage to the overall economy.

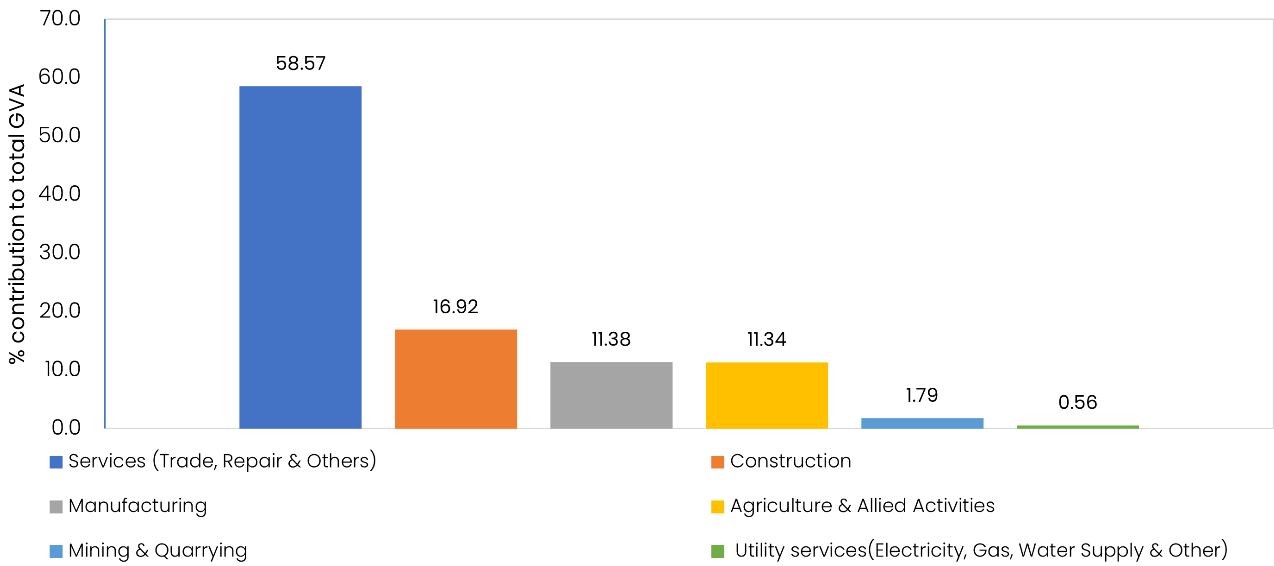


Figure 2.4: Sectoral contribution in GVA of the Ramanathapuram district for 2022-23

Source: Tamil Nadu Department of Economics and Statistics

2.1 Transport & Other Infrastructure

Road Connectivity

The district of Ramanathapuram has a road length (as of 2022-23) of 1,778 kms including all national highways, state highways and other roads. It is in the south-east side of Tamil Nadu and connected by NH 49 to Madurai from Rameswaram. The East Coast Road is the major coastal road in the east of Tamil Nadu, which connects the state capital Chennai and Ramanathapuram. This road also connects Ramanathapuram with Pondicherry, Tuticorin and Kanyakumari. The district has one bus terminus.[12]

Railway Connectivity

Ramanathapuram is around 518 KM away from Chennai, capital of Tamil Nadu. Ramanathapuram has a railway station and is well connected to the major cities of the country via the express/passenger trains. There are 8 railway stations situated across the district.

2.2 Industry

Industries in Ramanathapuram have historically been underdeveloped but are gradually evolving due to dedicated policies for the promotion of industries, especially Micro, Small and Medium Enterprises (MSMEs). As of 2022-23 the district has a total of 4,403 MSMEs as per Udyam Aadhaar/ Udyam Registration, which is only 0.5 percent of the total MSMEs in Tamil Nadu.[13] About 86 percent of these MSMEs were micro enterprises, including local businesses, followed by small enterprises at 13.35 percent and a mere 9 medium enterprises.

Four Small Industries Development Corporation (SIDCO) Industrial Estates have been set up by the SIDCO in Sivaganga as designated industrial areas to support agro-processing, textiles, food processing, automotive components and packaging-based MSMEs. In addition, Tamil Nadu in its State Budget 2025-26 has announced the establishment of one more SIDCO industrial estate in Thanichyam in Ramanathapuram along with other industry promotion initiatives, such as the setting up of essential infrastructure, a common facility centre for promoting electric line materials in the district.

Tourism Industry

Rameswaram is a renowned pilgrimage tourist destination in South India. The other key attractions in the district include its connection to the Ramayana, Dr Abdul Kalam Memorial Hall, Pamban Bridge, Devipatnam, Thirupullani, Thiruuttrakosamangai, and Erwadi. As of 2020 reports, a total of 30 lakh tourists visited the district, of which 1,985 were foreign tourists. Considering the tourism focus of the district, many of the existing enterprises are also service-based vis-à-vis manufacturing or processing enterprises.

Fishing Industry

The fishing industry is the main source of income for the local economy, providing livelihoods for many. Ramanathapuram's marine fish production was 78,810 tonnes, with 179 marine fishing villages, making fishing a vital source of employment and foreign exchange. The district is also known for its palm leaf handicrafts, palm-based products, and Mundu chillies.

2.3 Agriculture

Agriculture is the backbone of Ramanathapuram's economy. About 45 percent of land in the district is used for agricultural purposes, and a majority of inhabitants are engaged in agricultural activities. The major food grain crops cultivated are paddy, cholam, cumbu, ragi, and blackgram.[14] Tanks are the major source of irrigation in the district, accounting for the irrigation of 657.3 sq km of the net sown area in 2023-24. Groundwater sources (tubewell and dug well) are another important means of irrigation, irrigating 117.9 sq km in the same year.

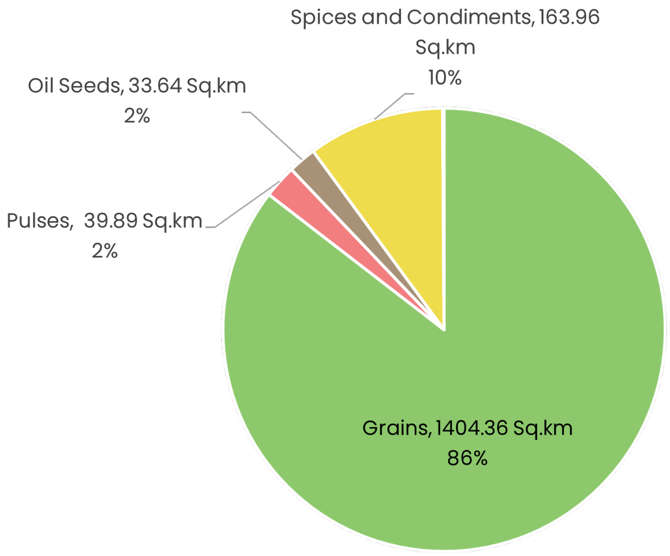


Figure 2.5 Area under crops produced in the district in 2022-23 (area in Sq. Km)[15]

2.4 Power Sector

The total installed power capacity in Ramanathapuram stands at 1304.3 megawatts (MW) as of 2023-24. The Valantharavai Combined Cycle Gas Power Plant and the Valuthur Gas Turbine Power Station in the district hold a combined capacity of 175.4 MW. In addition to these gas power plants; the district has a significant solar power capacity of 1,123.3 MW and a wind power installed capacity of 5.6 MW.[16]

In 2023-24, total electricity generation stood at 2497 MU in the Ramanathapuram district. Solar power contributed the most at 1,777 MU (71%), followed by the gas turbine at 716 MU (28.7%) and the wind turbine at 5 MU (0.3%). In the same year, the total electricity consumption was 625 MU. The domestic sector was the largest consumer at 434 MU, representing 69% of the total electricity consumption in the district. The commercial sector followed with a consumption of 108.35 MU, constituting 17% of the total. The electricity consumption in the industry sector was 44.13 MU, while the agricultural sector utilised 2 MU. The remaining 37 MU was consumed by miscellaneous activities within the district.

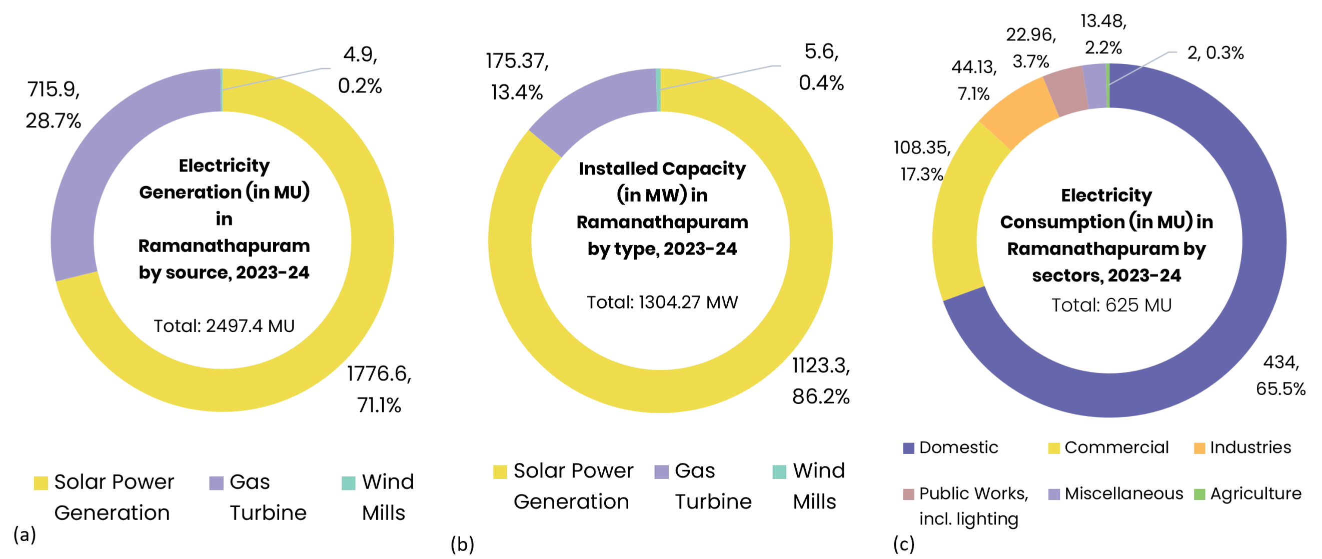


Figure 2.6[17] (a) Source-wise installed capacity, in MegaWatts, year 2023-24
(b) Source-wise electricity Generation, in MegaWatts, year 2023-24
(c) Sectoral electricity consumption, in million units, year 2023-24

3. Waste Management

Ramanathapuram district comprises 11 Urban Local Bodies (ULBs), including 4 municipalities and 7 town panchayats. Of these, 9 ULBs have been declared Open Defecation Free (ODF+), indicating improved sanitation standards across the region. The district has a well-established waste management system, with 9 solid waste treatment facilities and one construction and demolition (C&D) waste plant.[18] In terms of wastewater management, an operational Sewage Treatment Plant (STP) with a capacity of 8.19 million litres per day (MLD)[19] is located in Ramanathapuram, and an additional 4 MLD STP is in the trial phase in Rameswaram.

Door-to-door waste collection is implemented across all 219 ULB wards, achieving 100 percent coverage. Source segregation is practised in 216 wards. In 2023, the total waste processed from the 11 ULBs was approximately 109 tonnes per day (TPD), comprising around 26 TPD of wet waste and 83 TPD of domestic hazardous waste.

3. Climate Vulnerability, Climate Variability and Projections

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The district of Ramanathapuram has a tropical climate with dry, hot weather conditions throughout the year except during the northeast monsoon season in November and December. The mean maximum summer temperatures (March-April-May) range from 32°C to 36°C, with May being the hottest month. The winter temperature (December-January-February) ranges from 19°C to 22°C, with January being the coldest month. Maximum rainfall occurs during the north-east monsoon period (October to December)[20] with a mean rainfall of 468 mm (1951-2020). In the southwest monsoon season (June through September), the mean rainfall is around 216 mm.

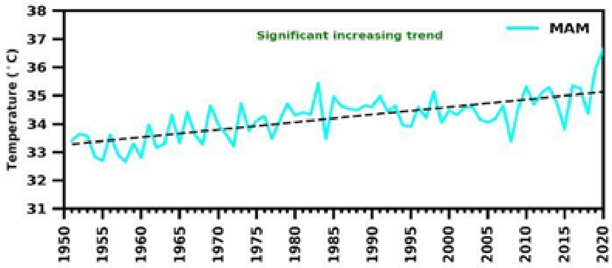
This chapter focuses on historical climate information (1986-2005) and projects climate for a future period using global climate models. Precipitation and temperature are used as the key climate variables for this analysis. The simulations of precipitation and temperature have been used for 1986 to 2005 (historical period) while projections have been considered over four different epochs 2021-2040 (2030s), 2041-2060 (2050s), 2061-2080 (2070s) and 2081-2100 (2090s) under medium (RCP4.5) and high (RCP8.5) emission scenarios.[21] Key findings from the analysis are provided below.

3.1 Temperature

3.1.1 Variability

Maximum Temperature

- The variability in maximum temperature in the summer months (March-April-May) show a significant increasing trend, which has further accelerated in the last decade (Figure 3.1).
- The mean percentage of warm days shows a significant increasing trend (Figure 3.2) in the district.



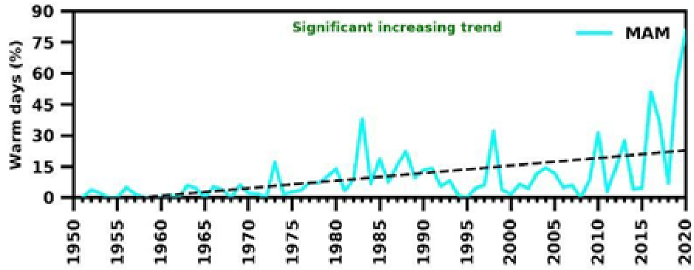
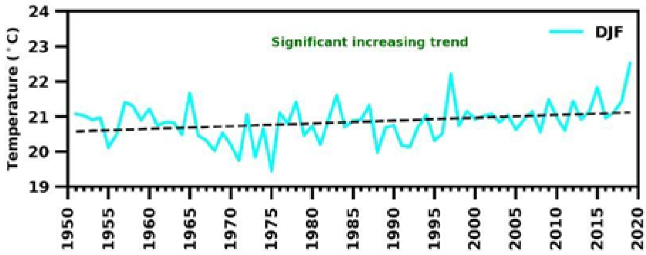


Figure 3.1:Inter annual variability of maximum temperature (deg.C) over Ramanathapuram for 1951-2020

Figure 3.2: Inter annual variability of warm days over Ramanathapuram for 1951-2020

Minimum Temperature

- The year-to-year variability in minimum temperature in the winter months (December-January-February) indicates a significant increase from 1951 to 2020 (Figure 3.3).
- The mean percentage of cold days has decreased in recent decades (Figure 3.4).



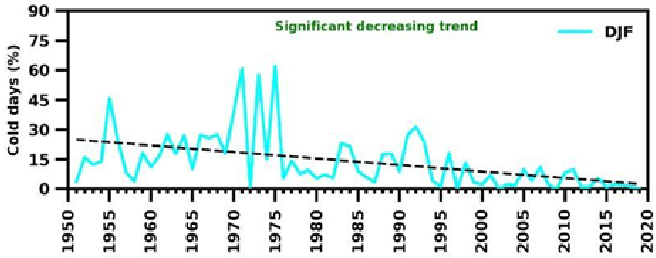


Figure 3.3: Inter annual variability of minimum temperature (deg.C) over Ramanathapuram for 1951-2020

Figure 3.4: Inter annual variability of cold days over Ramanathapuram for 1951-2020

3.1.2 Projections

Analysis has been carried out for projected changes in maximum and minimum temperatures on a monthly scale during the summertime (MAM) and wintertime (DJF), respectively.

Maximum Temperature

- The projections show that the maximum temperatures may increase by 0.7°C-1.8°C under RCP4.5 and 0.9°C-3.5°C under RCP8.5 from historical maximum temperature of 33.9°C in the district (Figure 3.5).
- The percentage of warm days is projected to increase by the end of the century compared to the present climate (Figure 3.6).

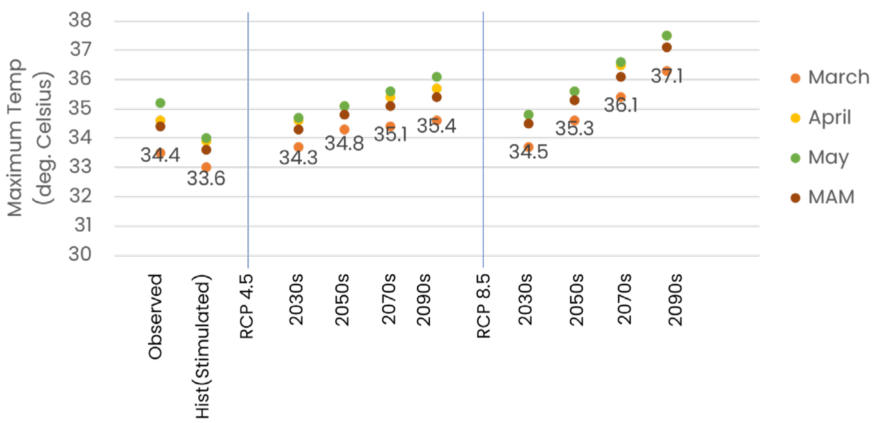


Figure 3.5: Observed, simulated, and projected monthly and seasonal max. temp, Ramanathapuram

(the changes in maximum temperature is based on MAM, which is observed to be 33.6°C under historical estimates, 34.3–35.4°C under RCP4.5, and 34.5–37.1°C under RCP8.5)

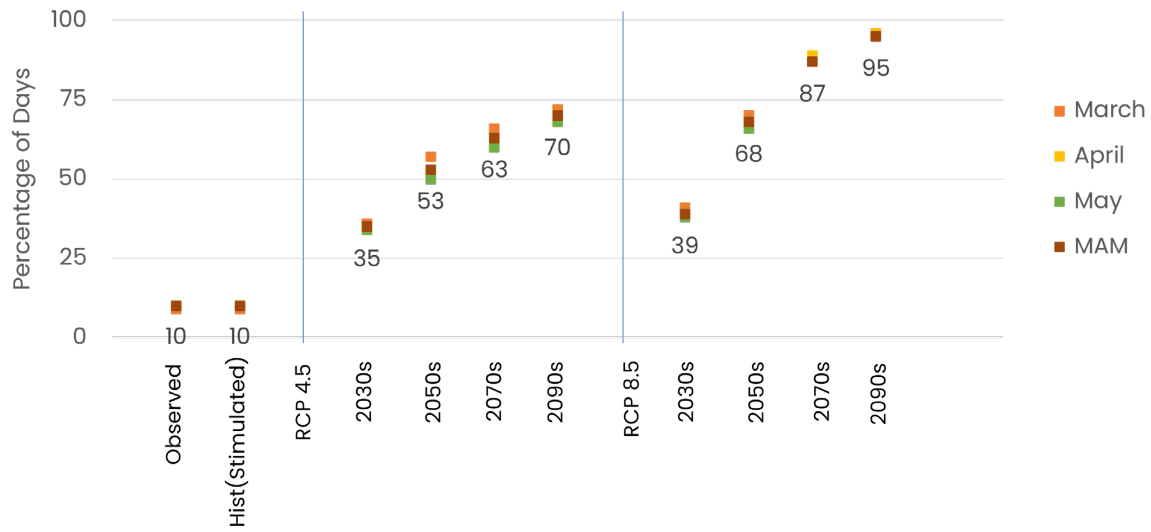


Figure 3.6: Observed, simulated, and projected percentage of warm days, Ramanathapuram district

- The Heat Wave Duration Index (HWDI)[22] is expected to increase by 0-9 days per season in RCP8.5 by the end of the 21st century (Figure 3.7).
- The Heat Wave Frequency Index (HWFI) [23] is also expected to increase in the range of 18-45 days in RCP4.5, and the intensity is more pronounced in RCP8.5, projected to increase in the range of 18-78 days towards the end of the century (Figure 3.7).

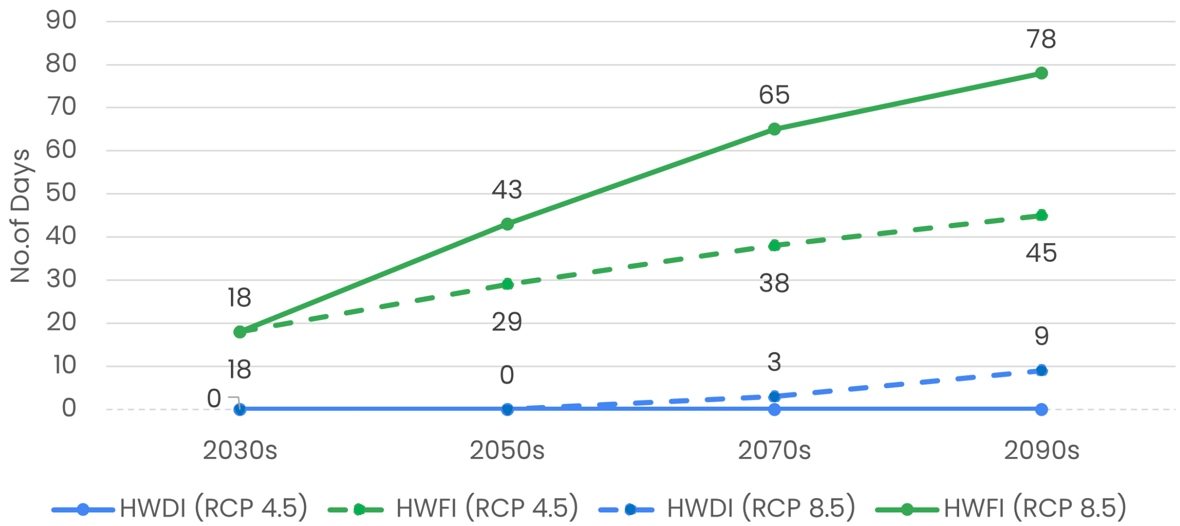


Figure 3.7: Simulated and projected seasonal temperature extremes, Ramanathapuram district

Minimum Temperature

- Minimum temperatures in the winter season (December-January-February) are projected to increase by 0.7°C-1.6°C under RCP4.5 and 0.8°C-3.3°C under RCP8.5 emission scenarios (Figure 3.8).
- This projected warming trend is accompanied by a decrease in the percentage of cold days across all periods (Figure 3.9).

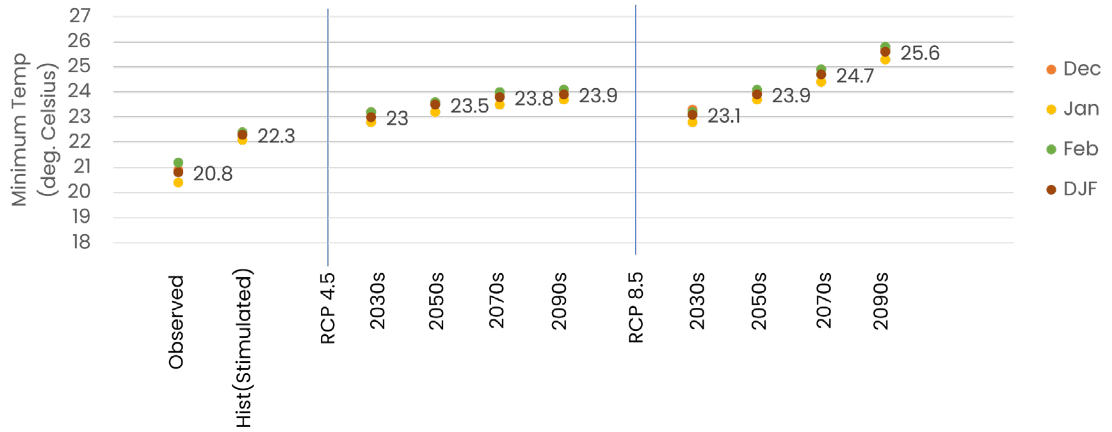


Figure 3.8: Observed, simulated, and projected monthly and seasonal min. temp, Ramanathapuram district (The change in minimum temperature is based on DJF, which is observed to be 22.3 °C under historical estimates, 23 °C-23.9°C under RCP 4.,5 and 23.1°C-25.6°C under RCP 8.5)

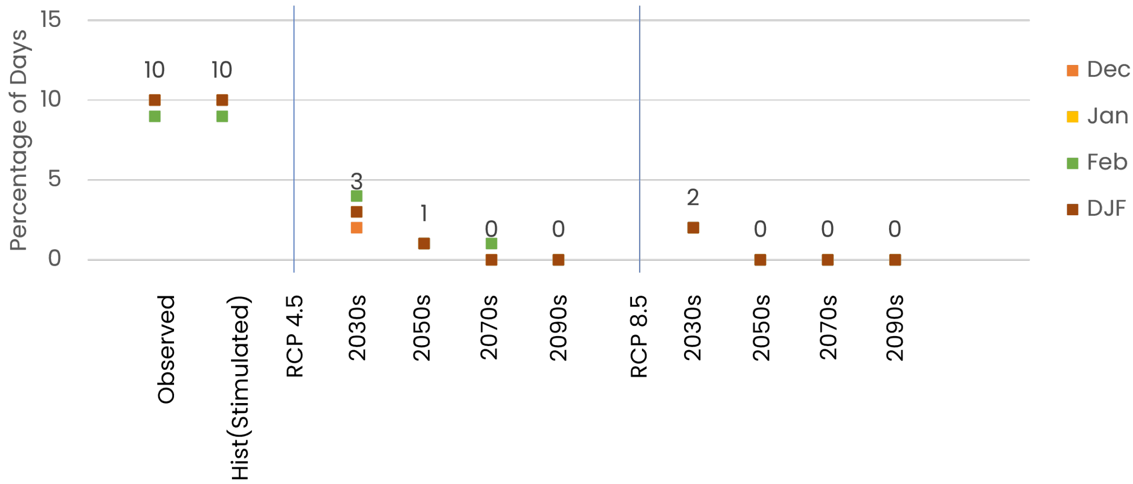


Figure 3.9: Observed, simulated, and projected percentage of cold days, Ramanathapuram

3.2 Precipitation

3.2.1 Variability

Southwest Monsoon

- The rainfall shows no significant trend for the June-July-August-September period (Figure 3.10).
- The number of rainy days does not show a significant trend for the period (Figure 3.11).

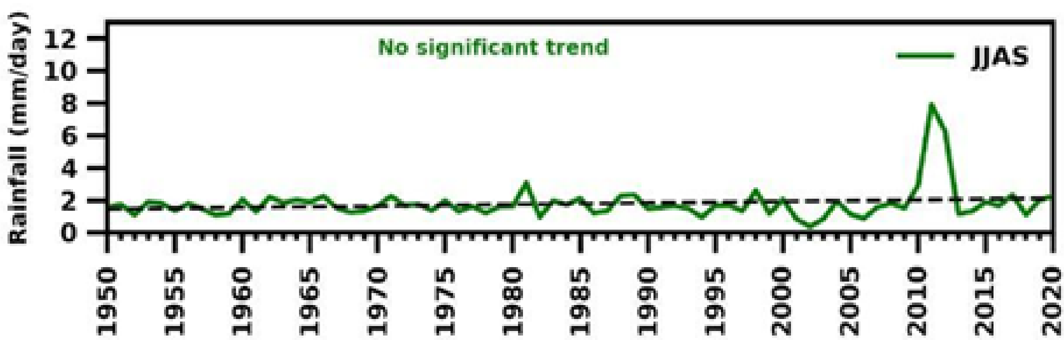


Figure 3.10: Inter annual variability of southwest monsoon rainfall (mm/day) over Ramanathapuram from 1951-2020

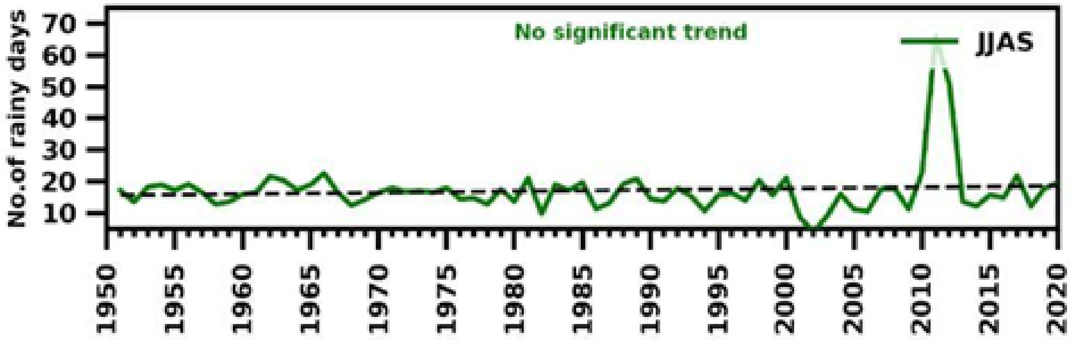


Figure 3.11: Inter annual variability of southwest monsoon rainy days (days) over Ramanathapuram from 1951-2020

Northeast Monsoon

- The rainfall shows no significant trend for the October-November-December period (Figure 3.12).
- It is observed that the variability in rainy days is higher in October and November. A decreasing trend is observed in October and the entire northeast monsoon season (Figure 3.13).

https://web.archive.org/web/20161029085654/http://www.panoramio.com/photo/97623384

Figure 3.12: Inter annual variability of northeast monsoon rainfall (mm/day) over Ramanathapuram for 1951-2020

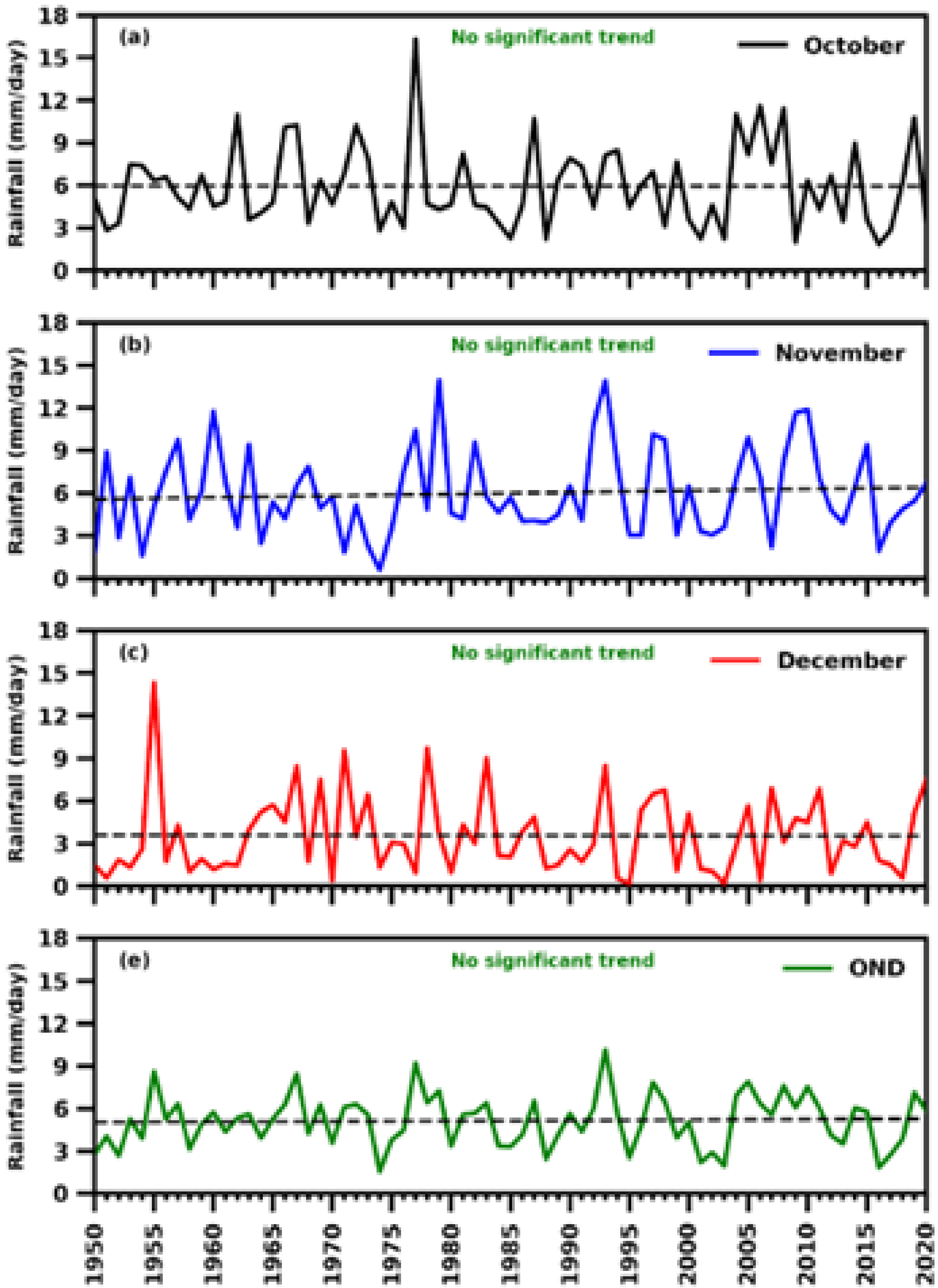
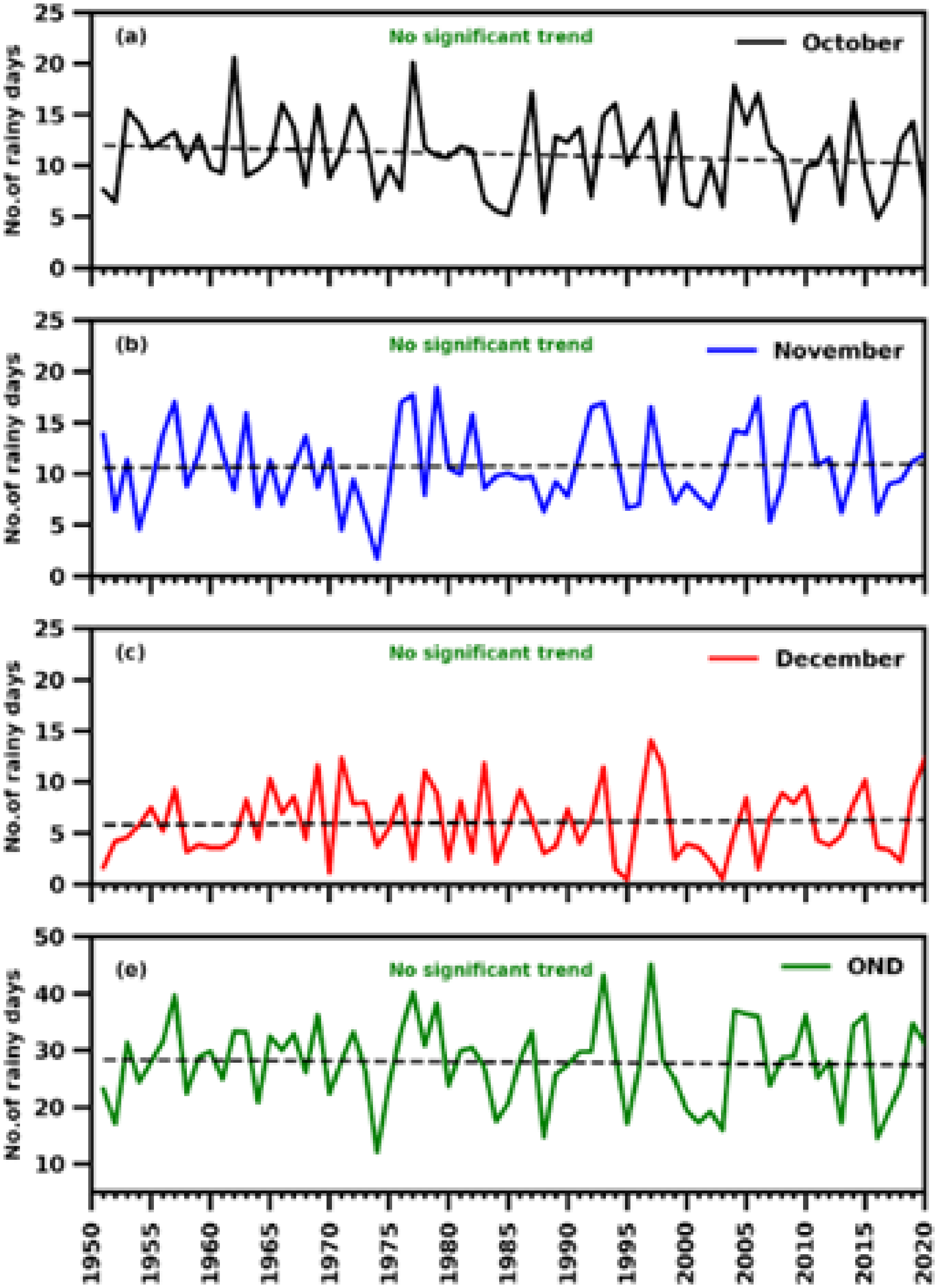


Figure 3.13: Interannual variability of northeast monsoons over Ramanathapuram from 1951-2020



3.2.2 Projections

Southwest Monsoon

- During the southwest monsoon period, the precipitation may increase between 39 percent to 55 percent under RCP 4.5 and 33 percent to 82 percent under RCP 8.5 emission scenarios (Figure 3.14).
- The number of rainy days is projected to increase mainly during July and August in the southwest monsoon season under both RCP4.5 and RCP8.5 emission scenarios (Table 3.1).

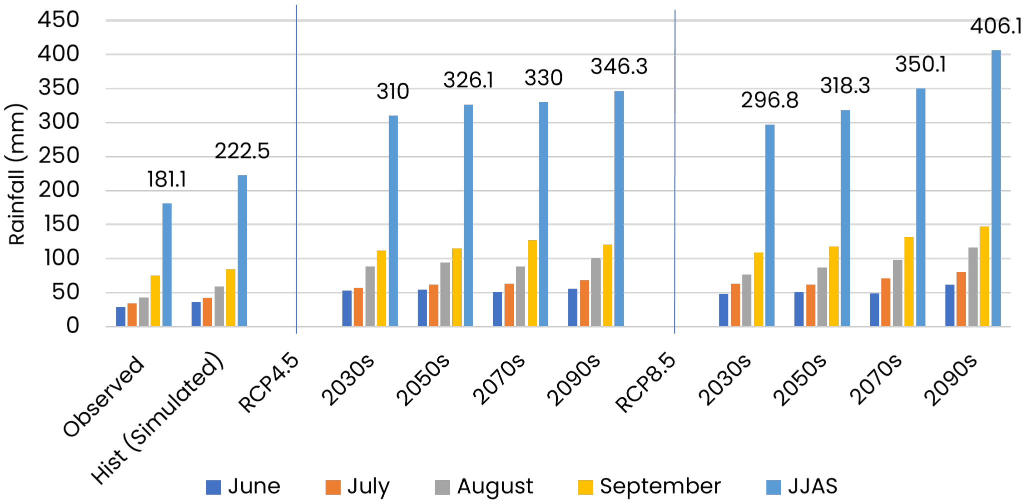


Figure 3.14: Observed (1986-2005), simulated (1986-2005) and projected mean monthly and southwest monsoon rainfall (mm) for Ramanathapuram district

Table 3.1: Observed (1986-2005), simulated (1986-2005) and projected mean monthly and southwest rainy days (rainfall >2.5 mm) for Ramanathapuram district

Obs.	Hist. (Simulated)	RCP 4.5	2030s	2050s	2070s	2090s	RCP 8.5	2030s	2050s	2070s	2090s
15	20		24	25	25	26		23	24	25	27

- There is a slight decrease in the number of consecutive dry days during the southwest monsoon season under RCP4.5 and RCP8.5 (Figure 3.15).
- The 1-day highest rainfall during the southwest monsoon season increases from 54 mm to 58 mm under the RCP4.5 and from 52 mm to 69 mm under the RCP8.5 scenarios (Figure 3.16).
- The 5-day cumulative highest precipitation during the southwest monsoon is also projected to increase from 89 mm to 96 mm under the RCP4.5 and from 83mm to 114mm under the RCP8.5 scenarios (Figure 3.16).

Northeast Monsoon

- The precipitation during the northeast monsoon is also projected to increase in the range of 5 percent to 22 percent under RCP4.5 and 17 percent to 43 percent under RCP8.5 emissions scenarios (Figure 3.17).
- The rainy days for this season are projected to increase by the end of the century under both RCP4.5 and RCP8.5 scenarios (Table 3.2).

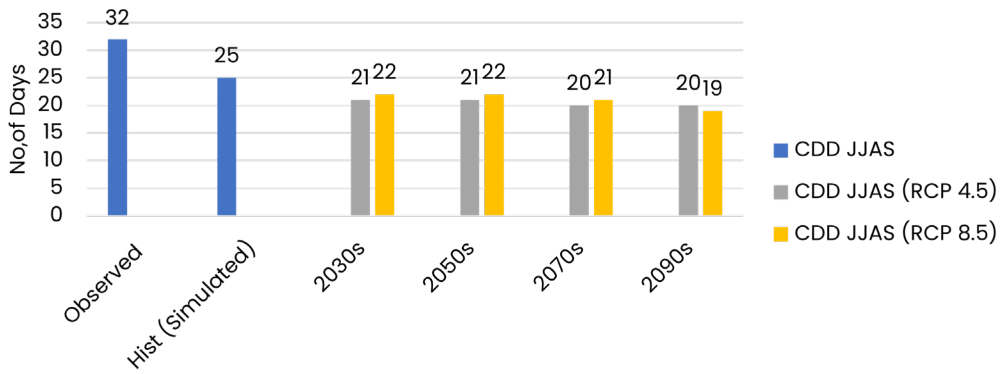


Figure 3.15: Simulated and projected seasonal (JJAS) precipitation extremes, (CDD), Ramanathapuram

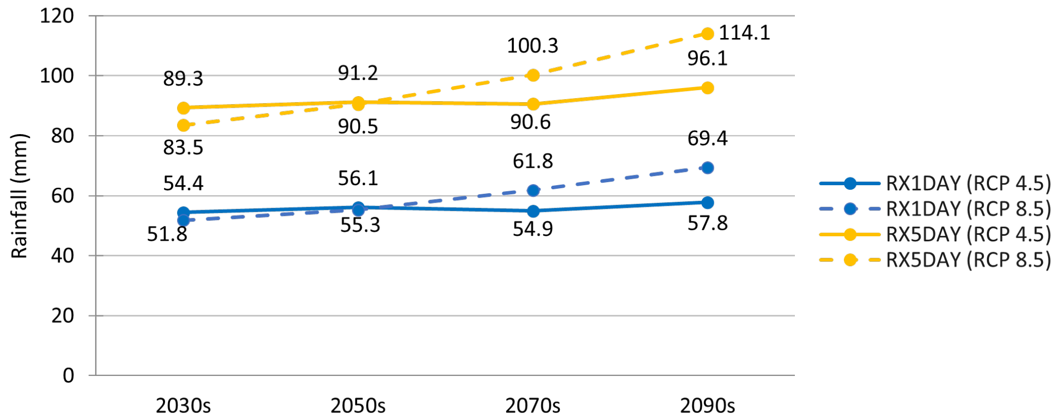


Figure 3.16: Simulated and projected seasonal (JJAS) precipitation extremes, (RX1 and RX5), Ramanathapuram

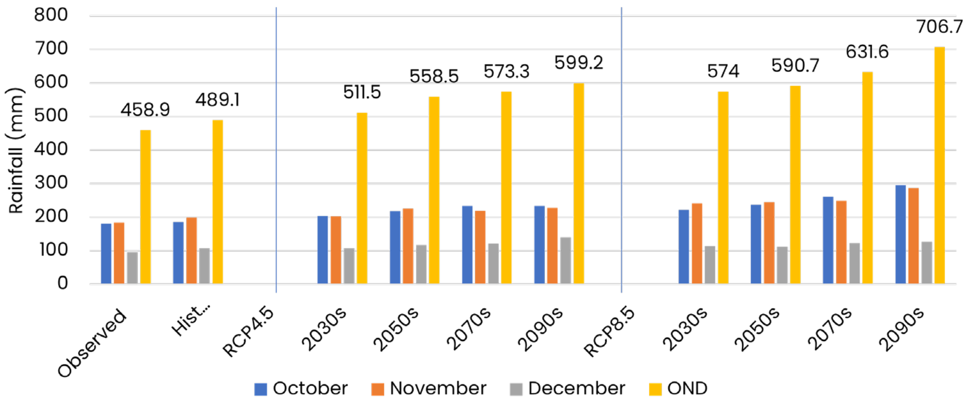


Figure 3.17: Observed (1986-2005), simulated (1986-2005) and projected mean monthly and northeast monsoon rainfall (mm) for Ramanathapuram

Table 3.2: Observed (1986-2005), simulated (1986-2005) and projected mean monthly and northeast rainy days (rainfall >2.5 mm) for Ramanathapuram district

Obs.	Hist. (Simulated)	RCP 4.5	2030s	2050s	2070s	2090s	RCP 8.5	2030s	2050s	2070s	2090s
27	32		35	37	37	39		35	36	37	39

- There is a slight decrease in the number of consecutive dry days during the northeast monsoon season during the historical period and in the future under RCP4.5 and RCP8.5 scenarios (Figure 3.18).
- The 1-day highest rainfall amount during the southwest monsoon season decreases from 60 mm to 55 mm under the RCP4.5 and increases from 165 mm to 176 mm under the RCP8.5 scenarios (Figure 3.19).

- The 5-day cumulative highest precipitation during the southwest monsoon is also projected to increase from 126 mm to 142 mm under the RCP4.5 and from 232 mm to 254 mm under the RCP8.5 scenarios (Figure 3.19).

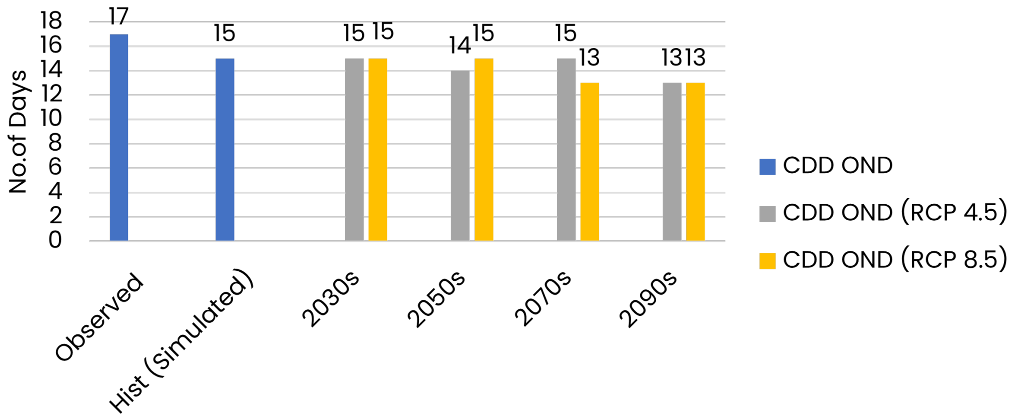


Figure 3.18: Simulated and projected seasonal (OND) precipitation extremes, (CDD), Ramanathapuram

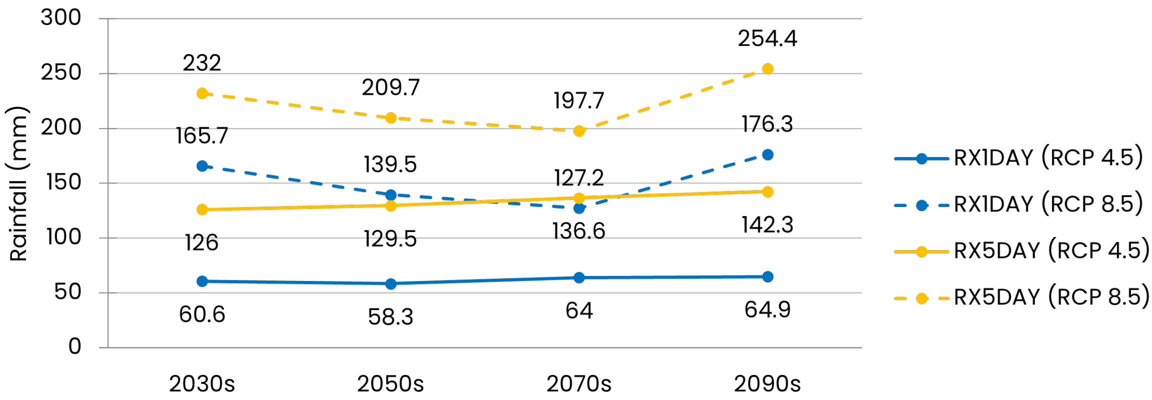


Figure 3.19: Simulated and projected seasonal (OND) precipitation extremes, (RX1 and RX5), Ramanathapuram

3.3 Vulnerabilities[24]

Flooding has historically been a major concern in the district, primarily due to heavy rainfall from the northeast monsoon and cyclonic events. Nearly 80 percent of the annual rainfall occurs between October and December, often leading to flooding in areas that previously remained unaffected. The Vaigai river, which carries heavy sediment load from its catchments, adds to the problem. Combined with the limited capacity of local rivers and drainage systems, this results in frequent flooding, drainage congestion, and riverbank erosion.

The villages most at risk of flooding include Muthalur, Sevur, Nagachi, Thurathiyendal, Kannirajpuram, Narippaiyur, Kuthiraimozhi, Mookkayur Periakulam, Mariyur, and Valinokam. While there has been no significant rainfall trend for either the northeast or southwest monsoon, the climate projections for the northeast monsoon are projected to increase in the range of 5 percent to 22 percent under RCP4.5 and 17 percent to 43 percent under RCP8.5 emission scenarios. Building flood resilience is of utmost priority for the district.

Rising temperatures and the increasing likelihood of heat waves are emerging concerns. Historical data indicate a significant upward trend in both maximum temperatures and the number of warm days. Climate projections suggest this pattern will continue. As a result, building heat resilience is becoming increasingly important for the district.

4. GHG Profile

Key Findings:

- Ramanathapuram's total GHG emissions rose from 1,044 $ktCO_2e$ in 2005 to 1,999 $ktCO_2e$ in 2022, with a CAGR of 3.9 percent, driven primarily by emissions in the energy and AFOLU sectors.
- Ramanathapuram district contributed 1 percent of Tamil Nadu's total emissions and per capita emissions of 1.40 tCO_2e in 2022.
- The emission intensity of the district in 2022 decreased by 66 percent compared to the baseline year of 2005.[25]
- The energy sector was the largest emitter at 1,247 $ktCO_2e$ (62 percent of total emissions), followed by Agriculture, Forestry and Other Land Use (AFOLU) at 674 $ktCO_2e$ (34%) and waste at 78 $ktCO_2e$ (4%). Industrial Processes and Product Use (IPPU) emissions were negligible at 0.03 $ktCO_2e$ (0.01%).
- Public electricity generation was the top contributor at 28 percent of total GHG emissions, followed by rice cultivation (12%), road transport (11%), captive power plants (10%), and livestock and agricultural soils (7% each) in 2022.
- Energy sector emissions increased from 538 $ktCO_2e$ in 2005 to 1,247 $ktCO_2e$ in 2022, with public electricity generation rising from 205 $ktCO_2e$ to 559 $ktCO_2e$, and notable growth in road transport (132 to 224 $ktCO_2e$) and fisheries (28 to 119 $ktCO_2e$).
- AFOLU emissions grew from 437 $ktCO_2e$ in 2005 to 674 $ktCO_2e$ in 2022, with rice cultivation (37%), agricultural soils (21%), and livestock (21%) as key contributors, while the land category was a net sink between 2005 to 2015, it became an emitter post 2016 due to reduction in the forest cover.
- Waste emissions increased from 68 $ktCO_2e$ in 2005 to 78 $ktCO_2e$ in 2022, with 77 percent from domestic wastewater category, 15 percent from solid waste disposal and 8 percent from industrial wastewater category.
- IPPU emissions, driven by lubricant use, declined from 96 tCO_2e in 2005 to 25 tCO_2e in 2022 due to shifts in vehicle fuel use.

The GHG emissions estimate of Ramanathapuram has been developed for the period of 2005 to 2022, accounting for carbon dioxide (CO_2), methane (CH4) and nitrous oxide (N2O). The emissions estimated are of Scope 1[26] and reported in terms of CO_2 equivalent as per the Second Assessment Reports[27] (AR2) of the Intergovernmental Panel on Climate Change (IPCC).

The inventory follows the broad guidelines provided by the IPCC, specifically the 2006 and 2019 guidelines to estimate the GHG emissions, read with the approach and methodology of GHG inventory development followed by the government of India in NATCOM[28] and BUR reports[29].

The data and information used for the development of the inventory are only from government sources, directly accessed from various line departments of the government of Tamil Nadu and from national organisations such as the Central Electricity Authority (CEA), the Petroleum Planning and Analysis Cell (PPAC), amongst others. The data source is as detailed in Annexure 2.

4.1 Summary of GHG Profile of Ramanathapuram

The emission of the greenhouse gases, namely CO_2, methane and nitrous oxide, in Ramanathapuram accounted for 1,999 ktCO_2e in 2022. The energy sector emitted 1,247 ktCO_2e, AFOLU sector contributed 674 ktCO_2e, and the waste sector contributed 78 ktCO_2e. Emissions from the IPPU sector were negligible. The category and gas-wise emissions and their percentage contribution are as detailed in Table 4.1.

Table 4.1: Sector-wise and gas-wise GHG emissions (2022)

Sector	GHG Sources and Sink Categories	CO_2 (kt)	CH_4 (t)	N_2O (t)	kt CO_2 eq	Contribution
ENERGY	Public Electricity Generation	558	10	1	559	28%
	Captive Power Plants	208	3	2	209	10.46%
	Industries	12	1	0.1	12	0.6%
	Road Transport	219	51	11	224	11.21%
	Commercial	15	2	0.1	15	0.75%
	Residential	97	8	0.2	97	4.85%
	Agriculture	12	2	0.1	12	0.6%
	Fisheries	117	7	6	119	5.95%
	Energy Total	**1238**	**84**	**20.5**	**1247**	**62 %**

Sector	GHG Sources and Sink Categories	CO_2 (kt)	CH_4 (t)	N_2O (t)	kt CO_2 eq	Contribution
AFOLU	**a. Aggregate Sources and Non-CO_2 Emission Sources on Land**	**-**	**11898**	**450**	**389**	**19.46%**
	Agriculture soil	-	-	447	138	7%
	Biomass burning in cropland	-	99	3	3	0.2%
	Rice cultivation	**-**	**11799**	**-**	**248**	**12%**
	b. Land	138	-	-	138	7%
	Agricultural land	0.150	-	-	0.150	0.01%
	Forest land	138	-	-	138	7%
	Other land	0.06	-	-	0.06	0.003%
	Settlements	-0.15	-	-	-0.15	
	c. Livestock	**-**	**6983**	**2**	**147**	**7.35%**
	Enteric fermentation	-	6563	-	138	6.9%
	Manure management	-	420	-	-0.15	0.5%
	AFOLU Total (a + b + c)	**138**	**138**	**452**	**674**	**34%**
IPPU	Non-Energy Products from Fuels and Solvent Use - Lubricant use	0.025	-	-	0.025	0.001%
	IPPU Total	**0.025**	**-**	**-**	**0.025**	**0.001%**
Waste	Solid waste disposal	-	555	-	12	0.58%
	Domestic wastewater	-	1983	60	60	3%
	Industrial wastewater	-	293	-	6	0.31%
	Waste Total	**-**	**2831**	**60**	**78**	**4%**
	Total Emissions	**1376**	**21796**	**532.5**	**1999**	

4.2 Economy-wide Emissions

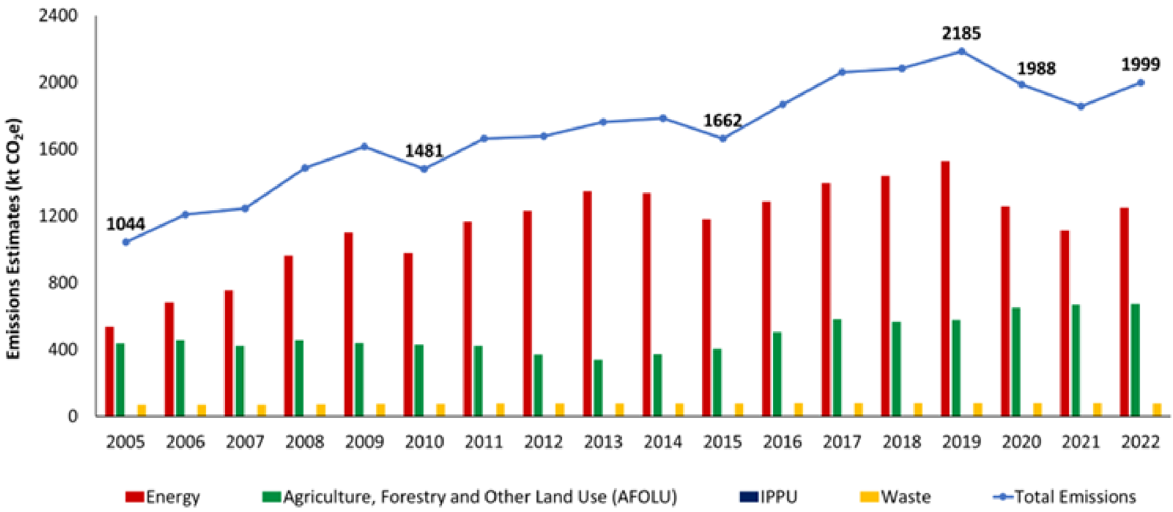


Figure 4.1: Economy-wide emissions of Ramanathapuram (2005 to 2022)

Note: IPPU emissions are not reflected in the graph due to their negligible quantity across the years

The total GHG emissions from Ramanathapuram increased from 1044 ktCO_2e in 2005 to 1999 ktCO_2e in 2022 at a CAGR of 3.9 percent. As illustrated in Figure 4.2.2, emissions from the energy sector increased from 538 ktCO_2e (~52%) in 2005 to 1247 ktCO_2e (~62%) in 2022, and it was the major contributor to the districts' total economy-wide emissions across the reference period. The AFOLU sector emitted 437 ktCO_2e, contributing to 42 percent of the total emissions in 2005 and 674 ktCO_2e in 2022, contributing to 34 percent of the total emissions. Emissions from the waste sector increased from 68 ktCO_2e in 2005 to 78 ktCO_2e in 2022, while the emissions from the IPPU sector remained negligible throughout the reference period due to the absence of significant industrial operations.

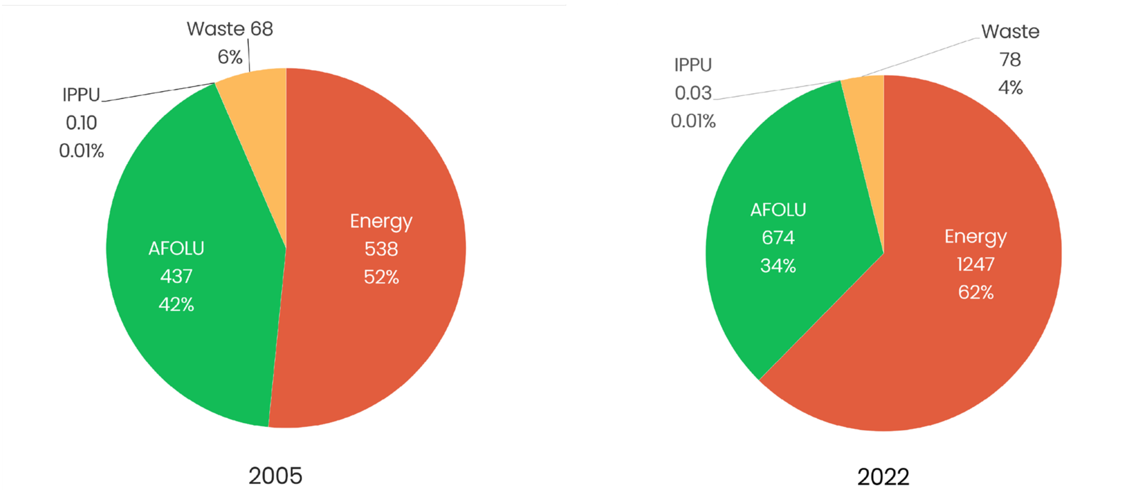


Figure 4.2: Sector-wise contribution (kt CO_2e) and percentage share in economy-wide GHG emissions of Ramanathapuram

4.3 Key Category Analysis

Figure 4.3 shows the top categories contributing to GHG emissions in Ramanathapuram in 2022. Emissions from public electricity generation were the major GHG contributor (~28%), followed by rice cultivation (~12%), road transport (~11%), captive power plants (~10%), livestock and agriculture soils (~7%).

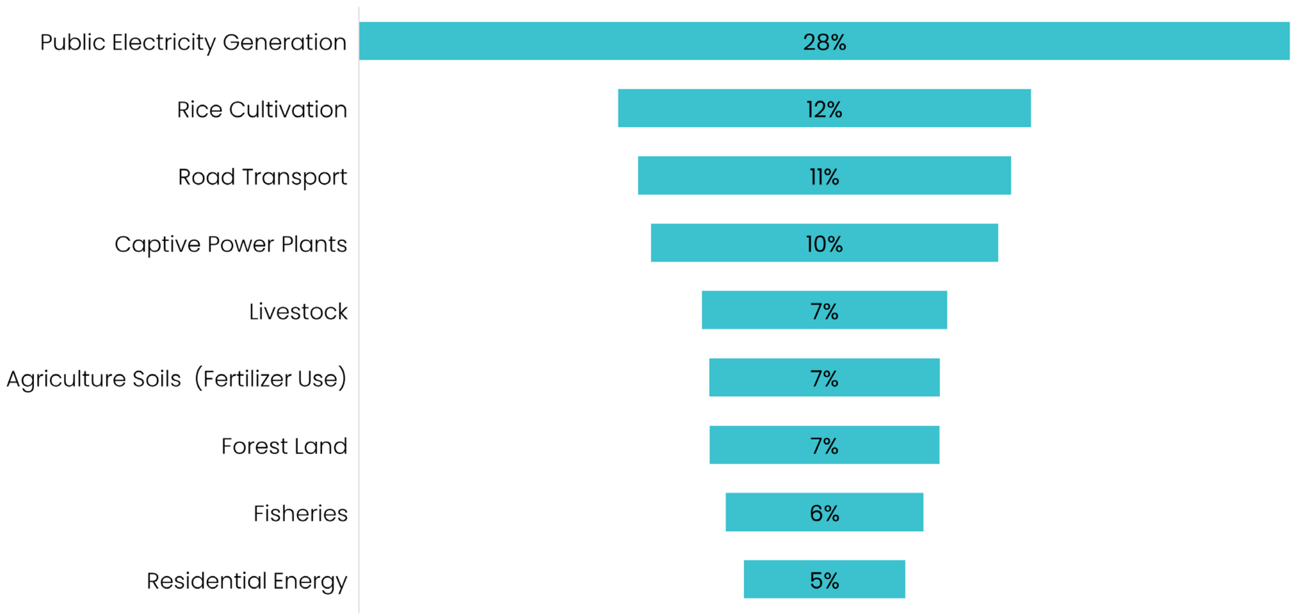


Figure 4.3: Key category analysis of Ramanathapuram (2022)

4.4 Sector-wise Emission Trends

4.4.1 Energy Sector

The energy sector emissions comprise of emissions from fuel combustion, including public electricity generation, captive power plants, road transport, industries, commercial, residential, agriculture, and fisheries categories, contributing 1,238 kilotonnes (kt) CO_2, 0.084 kt of CH_4 and of 0.02 kt of N_2O, amounting to 1,247 ktCO_2e in 2022 (Figure 4.4.1).

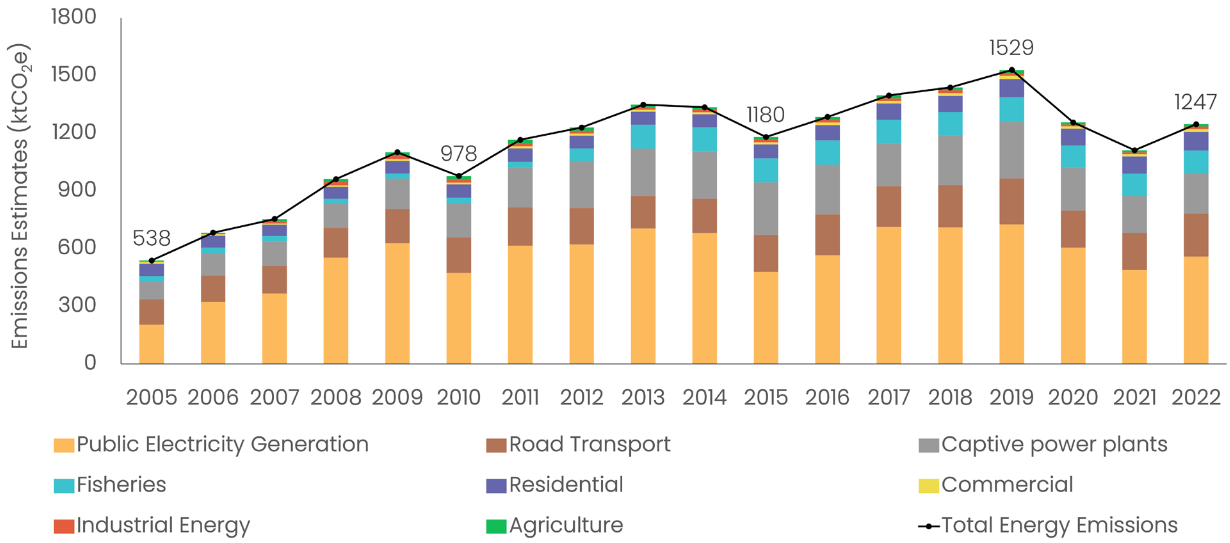


Figure 4.4.1: GHG emissions of Energy sector in Ramanathapuram (2005-2022)

Public electricity generation was the major contributor (~45%) and its emissions increased from ~205 kt CO_2e in 2005 to ~559 kt CO_2e in 2022. Road transport with a share of ~18% and captive power plants with a share of ~17% of emissions in 2022 were other key contributors. Emissions from road transport and captive power plants increased from ~132 and ~92 kt CO_2e in 2005 to 224 and 209 kt CO_2e in 2022, respectively, while the emissions from fisheries increased from ~28 kt CO_2e to ~119 kt CO_2e.

Box Item 1

Valuthur Gas Turbine Power Station is the Prime Contributor to Emissions from Public Electricity Generation in Ramanathapuram

In Ramanathapuram, two significant gas-based power plants, the Valuthur Gas Turbine Power Station (Units 1, 2, 3, and 4) with an installed capacity of 186.2 MW and the Valantharavai Gas Turbine Power Station (Units 1 and 2) with a capacity of 52.8 MW, were major contributors to the district's GHG emissions.

During the COVID-19 pandemic years of 2020-21 and 2021-22, the demand for electricity in the commercial and industrial sectors significantly decreased. Consequently, these power plants operated at lower Plant Load Factors (PLF), leading to a noticeable drop in GHG emissions.

In 2022, the Valuthur Gas Turbine Power Station recorded a PLF of 57.8 percent, generating 942.78 GWh of electricity. The Valantharavai Gas Turbine Power Station operated at a PLF of 15.6 percent, producing 72.17 GWh. However, in the subsequent financial year 2022-23, Valantharavai Gas Turbine Power Station did not generate a single quantum of electricity and became non-operational. Therefore, the Valuthur Gas Turbine Power Station is now the sole operational unit in the district contributing to GHG emissions.

Unit-wise Electricity Generation (GWh) and plant Load Factor (PLF) of gas-based PEG, in Ramanathapuram (Source: National Power Portal and ICED)

Plants Details		2018-19	2019-20	2020-21	2021-22	2022-23
Valuthur Power Station (186.2 MW)	Electricity Generation (GWh)	1178.03	1299.84	1018.19	942.92	1056.1
	PLF (%)	72.22	79.69	62.42	57.81	64.75
Valantharavai Power Station (52.8 MW)	Electricity Generation (GWh)	352.86	307.13	212.87	72.17	0
	PLF (%)	76.29	66.4	46.02	15.6	0

4.4.2 Industrial Processes and Product Use (IPPU) Sector

Since production industries in Ramanathapuram are still developing, emissions from the Industrial Processes and Product Use (IPPU) sector were negligible, and solely driven by lubricant use. Between 2005 and 2022, non-combustion emissions from the lubricant use reduced from ~96 tCO_2e to ~25 tCO_2e. (see Figure 4.4.2) This was driven by the wide usage of 4-stroke scooters and LPG/CNG powered rickshaws and the subsequent decline of 2-stroke scooters and diesel-fueled rickshaws.

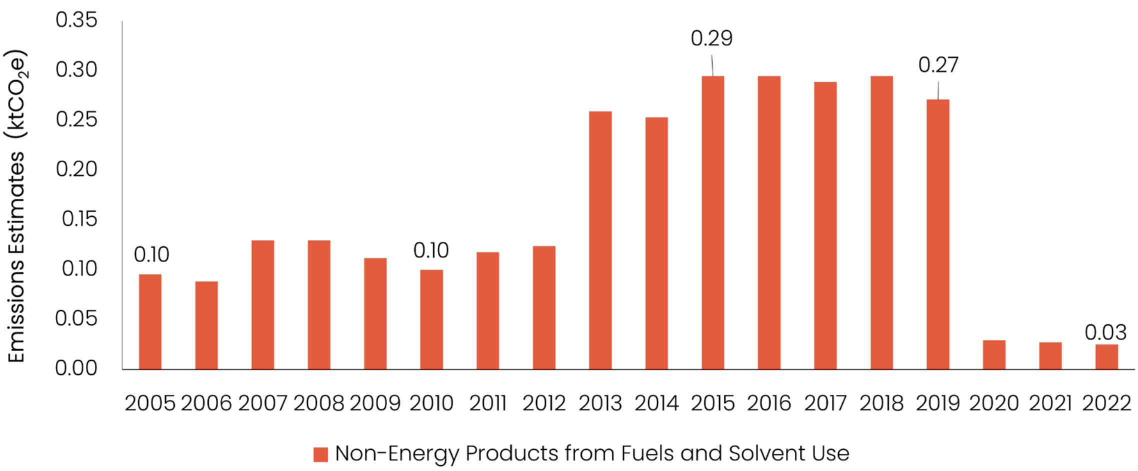


Figure 4.4.2: GHG emissions of IPPU sector in Ramanathapuram (2005-2022)

4.4.3 Agriculture, Forestry and Other Land Use (AFOLU) Sector

Emissions from the AFOLU sector arise from livestock (enteric fermentation and manure management), land, and the aggregate sources and non-CO_2 emissions sources on land. The sub-sector, aggregate sources and non-CO_2 emission sources on land includes emissions from rice cultivation, agriculture soils and biomass burning in cropland.

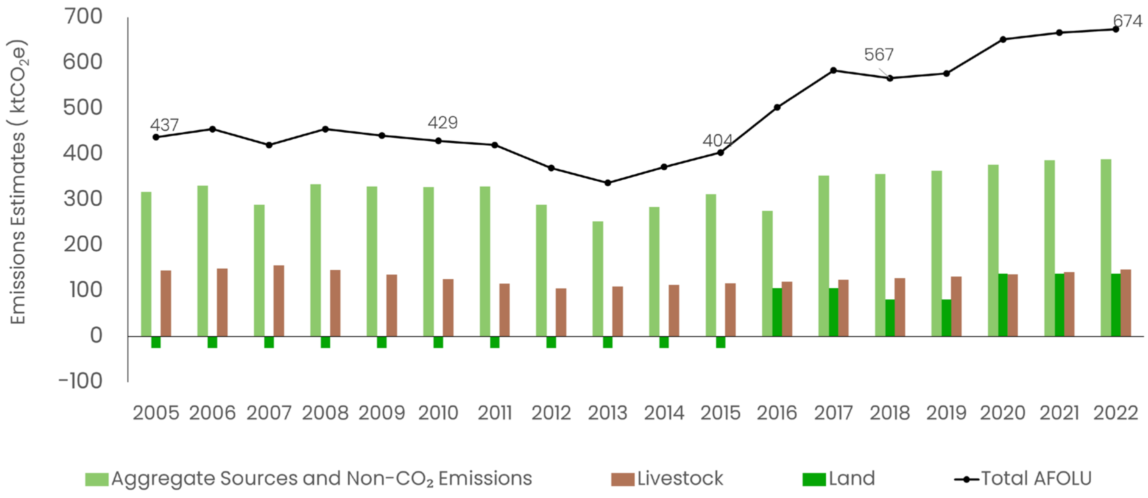


Figure 4.4.3 (a): GHG emissions of AFOLU sector in Ramanathapuram (2005-2022)

The AFOLU sector represented ~34 percent of the total economy-wide emissions of Ramanathapuram in 2022 and has increased by 1.5 times from 437 ktCO_2e in 2005 to 674 ktCO_2e in 2022. The land sub-sector contributed to an annual average carbon removal of around 25 ktCO_2e between 2005 to 2015 and became an emitter thereafter, emitting an average of 113 ktCO_2e, leading to a steep increase in the total AFOLU emissions (Figure 4.4.3 (a)). This can be attributed to the reduction in the forest cover and the carbon density, post-2015. Emissions from aggregate sources and non-CO_2, and livestock categories remained relatively constant throughout the reference period and contributed ~58% and ~22%, respectively to the total AFOLU emissions in 2022.

In the total AFOLU emissions, rice cultivation accounted for ~37% while enteric fermentation accounted for ~20% and agricultural soils contributed ~21% respectively in 2022.

In the aggregate sources and non-CO_2 category, rice cultivation was the major contributor, with its emission increasing from 233 ktCO_2e in 2005 to 248 ktCO_2e in 2022. The emissions from agricultural soils increased from 82 ktCO_2e in 2005 to 138 ktCO_2e in 2022 while the emissions from biomass burning in cropland was negligible throughout the reference period, accounting for around 2 ktCO_2e (see figure 4.4.3 (b)).

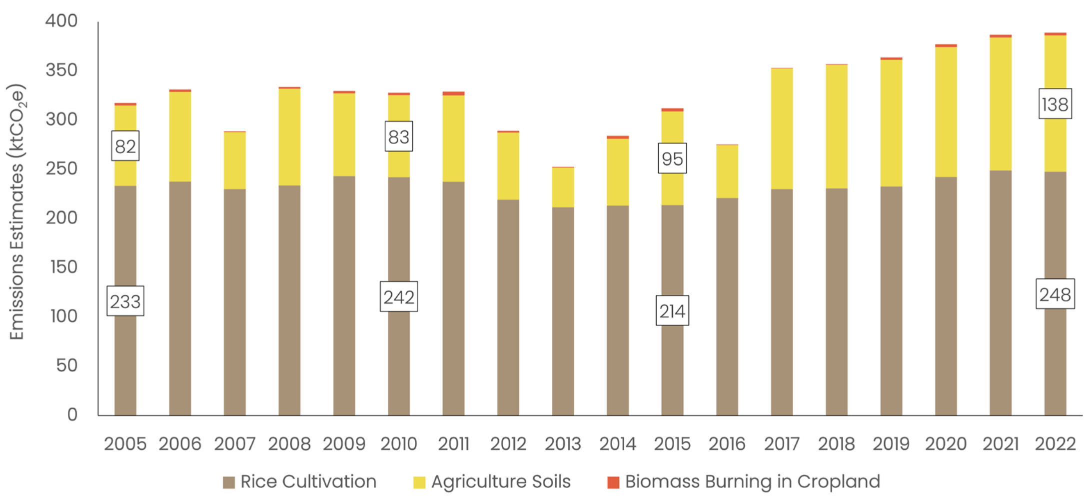


Figure 4.4.3 (b): Emissions from Aggregate sources and Non-CO_2 category in Ramanathapuram (2005 - 2022)

4.4.4 Waste Sector

In Ramanathapuram, the waste sector contributed ~2831 tonnes of CH4 and 60 tonnes of N2O, accounting to ~78 $ktCO_2e$ in 2022, compared to 68 $ktCO_2e$ in 2005. Domestic wastewater, solid waste disposal and industrial wastewater categories respectively contributed ~77%, ~15% and ~8% of sectoral emissions in 2022 (Figure 4.4.4 (a)).

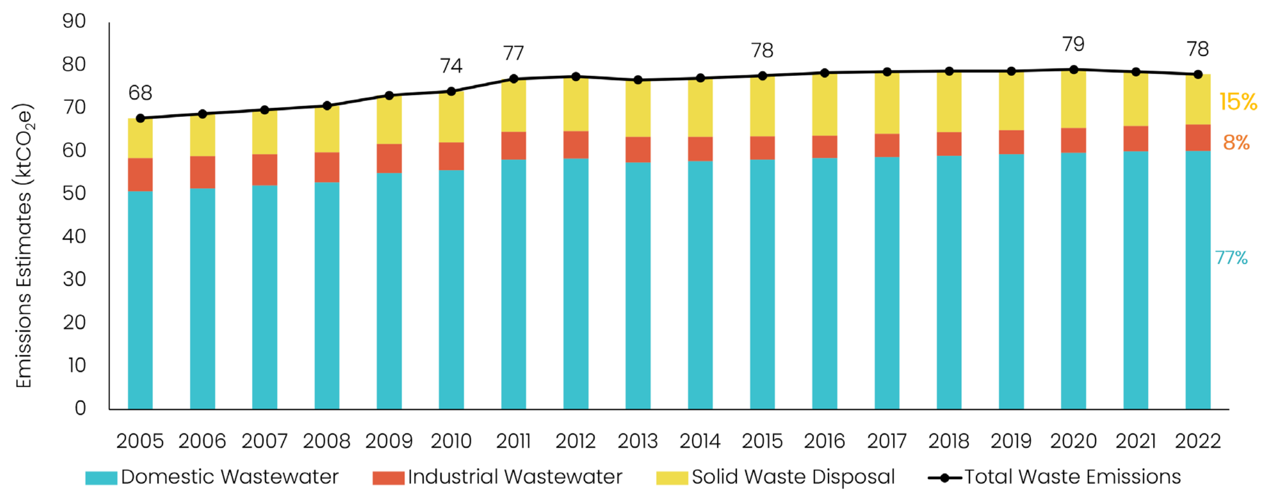


Figure 4.4.4 (a): GHG emissions of Waste sector in Ramanathapuram (2005 to 2022)

In 2022, about 25 $ktCO_2e$ out of 60 $ktCO_2e$, total GHG emissions from the domestic wastewater category, were emitted from urban domestic wastewater (42%) and 35 $ktCO_2e$ from rural domestic waste water (58%) (Figure 4.4.4 (b)).

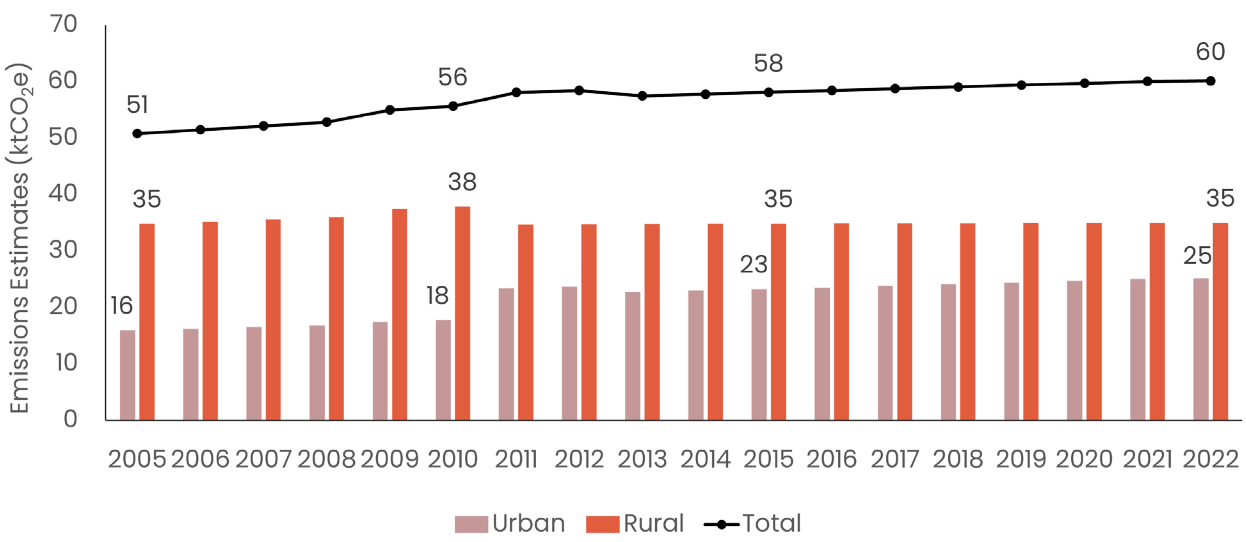


Figure 4.4.4 (b): Area-wise GHG emissions estimates of domestic wastewater (2005 to 2022)

Emissions from industrial wastewater largely accrued to cleaning and other water use in fish processing (~84%), backed by the district's fishing sector followed by emissions from meat processing (~16%) as illustrated in Figure 4.4.4 (c).

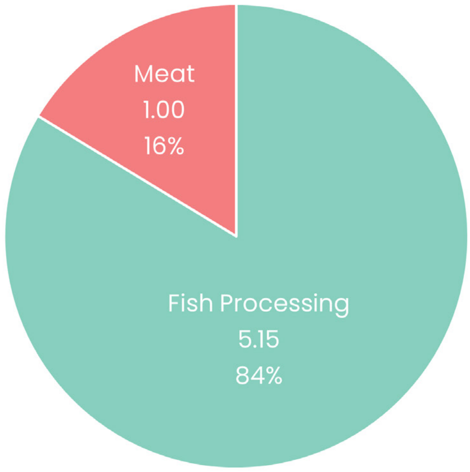


Figure 4.4.4 (c): Category-wise emissions (kt CO_2e) and percentage share in total industrial wastewater emissions (2022)

5. Deep Dive into District's Energy and Other Sectors (AFOLU & Waste) and Projections to 2050

Key Findings:

Emissions in Ramanathapuram are dominated by energy use (62%), followed by AFOLU (34%) and waste (4%).

- Energy emissions in Ramanathapuram, which were 1247 $ktCO_2e$ in 2022, are estimated to reduce to 664 $ktCO_2e$ by 2050 due to the timely retirement of public electricity generation units (gas-based power plants) and adoption of electric vehicles, in the business-as-usual scenario With decarbonisation across sectors, the energy related emissions would further reduce to 117 $ktCO_2e$ in AES scenario.
- Public Electricity Generation (PEG) units are the highest emitters in Ramanathapuram at 559 $ktCO_2e$ (45%). Given the economic lifetime of 25 years and high variable costs, these gas-based power plants are expected to retire by 2033, fully abating related emissions.
- The transport sector, the second highest emitting sector at 18 percent of energy emissions, is dominated by 2-wheelers (85%), with every 1 in 400 2W being electric in nature. The current policy landscape and evolving market dynamics will push EVs' penetration to nearly 100 percent of new sales in the 2W category by 2040.
- Similarly, across vehicle segments, the share of EV in total vehicle stock, which currently averages at 0.25 percent is predicted to reach ~65% by 2050 – reducing the gross GHG emissions in the transport sector by 53 percent from 1247 $ktCO_2e$ in 2022 to 664 $ktCO_2e$ in 2050. These emissions can be further reduced through full penetration of EVs in 2W, 3W, 4W and buses and partial penetration of EVs in HGVs (trucks, trolleys) in the same year.
- Captive power plants in Ramanathapuram rely on coal and gas, emitting 209 $ktCO_2e$ of GHG emissions, and are further predicted to surpass transport in becoming the second largest emitter in the energy sector by 2050. Electrification of the industrial sector, with RE integration for captive needs, can fully abate sectoral emissions.
- Fishing is an important sector in Ramanathapuram, and drives 40 percent of the total diesel consumption in the district. Due to continued reliance, emissions from diesel-run fishing boats

are projected to increase from 119 ktCO_2e in 2022 to 125 ktCO_2e in 2050. Through the electrification of fishing boats, the fishing industry in Ramanathapuram can be fully decarbonised by 2050 – requiring an additional 463 GWh of electricity.

- Higher space cooling requirements, along with electrification measures across sectors, are expected to triple the electricity demand from 613 GWh in 2022 to 2,938 GWh by 2050. Renewable energy integration of 1 GW in addition to the existing 1.05 GW RE capacity will be required to meet this need. PEG units are expected to retire by 2033 following their economic life cycle, abating 559 ktCO_2e directly.
- Livestock and aggregate sources (agriculture soils and rice cultivation) are projected to be significant contributors to GHG emissions, with estimated emissions rising from 147 ktCO_2e and 386 ktCO_2e in 2022 to approximately 257 ktCO_2e and 607 ktCO_2e respectively by 2050.
- Emissions from solid waste are projected to decline from 11.65 ktCO_2e in 2022 to approximately 8.68 ktCO_2e by 2050. Emissions from domestic wastewater and industrial wastewater are expected to remain largely unchanged by 2050, staying close to their 2022 levels of 61 ktCO_2e and 6 ktCO_2e, respectively.
- Carbon sequestration through social and agroforestry, mangrove restoration and other activities is a key for curtailing all of these emissions and yielding net negative carbon emissions by 2050. Promoting social and agroforestry in 98,722 ha of land - classified as barren, fallow, cultivable waste or land put to non-agricultural use - has the potential to sequester approximately 861 ktCO_2e by 2050.
- Enhancing carbon stock density by 5.5 percent from 2021 levels could enable the sequestration of approximately 13 ktCO_2e by 2050. Maintaining the existing mangrove cover and restoring an additional 304 hectares by 2050 would contribute a further 14 ktCO_2e in carbon sequestration. Likewise, expanding the seagrass area by 20 sq. km could potentially sequester around 12 ktCO_2e by 2050.

This chapter examines the GHG emitting sectors under two broad categories: energy and non-energy sectors. It further delves into various sub-sectors within the energy category—such as residential, transport, industry, agriculture, and services. Similarly, in the non-energy category, the chapter discusses the waste, AFOLU and IPPU sectors in detail.

It also outlines the methodology used to project future demands and emissions for all the sectors and sub-sectors.

The sectoral emission projections in this chapter form the basis for the three scenarios, one reference business as usual (BAU) scenario and two decarbonisation scenarios - Moderate Effort Scenario (MES) and Aggressive Effort Scenario (AES) as discussed in detail in Chapter

Limitations to the Study

1. While the demand projections are based on robust, sector-specific methodologies, certain sectors lack sufficient end-use activity and consumption data. In such cases, projections are made using estimated growth rates derived from the most reliable available data.
2. In addition to primary data collected from district offices in Ramanathapuram, the analysis relies on secondary data sources at national and international levels, particularly where necessary data is unavailable or not maintained in the required format. The energy and sectoral projections are guided by well-founded assumptions to ensure consistency despite data constraints.

However, the following data limitations were identified:

- Agriculture: The available data on crop production, irrigation requirements, groundwater usage, and water storage infrastructure for the past 10 to 15 years in the district are currently insufficient.
- Transport: There is no available data on railway as a means of transport; therefore, it is excluded from the transport sector in the projections.

- Industrial Production and Capacity: Data on the production and installed capacity of industries within the district is limited.
- Residential: There is no specific data on the number of electric appliances used by residential end-user customers.

5.1 Energy Sector

Demand forecasting at a sub-sectoral level, concentrating on specific end-use applications, is essential for gaining insights into future growth areas such as appliance penetration, industrial production, vehicle ownership, etc. For electricity distribution companies, such forecasting exercises support medium to long-term planning for power procurement. This section describes the methodology and metrics employed to estimate sectoral energy demand by 2050.

5.1.1 Public Electricity Generation

Public Electricity Generation is a major emitter in Ramanathapuram, accounting for 45 percent of total energy emissions in 2022. This makes tackling emissions from public electricity generation a priority within the decarbonisation action plan of the district.

The total installed power capacity in Ramanathapuram stands at 1,304.27 megawatts (MW) as of 2023-24. The Valantharavai Combined Cycle Gas Power Plant and the Valuthur Gas Turbine Power Station in the district hold a combined capacity of 239 MW to meet its electricity requirement. In addition to these gas power plants, the district has a significant solar power capacity of 1,049.3 MW and a wind power installed capacity of 5.60 MW.[30] The Valuthur Gas Turbine Power Station (Units 1, 2, 3, and 4) and the Valantharavai Gas Turbine Power Station (Units 1 and 2) in Ramanathapuram contribute the most to the district's greenhouse gas (GHG) emissions.

Table 5.1: Details of gas power plants in Ramanathapuram district (source: ICED)

Valantharavai Power Station.		
Installed capacity (MW)		Commissioning date
Unit 1	38	Oct 2005
Unit 2	14.8	May 2006
Valuthur Power Station		
Unit 1	60	Dec 2002
Unit 2	34	March 2003
Unit 3	59.8	May 2008
Unit 4	32.4	August 2008

The decarbonisation strategy for public electricity generation focuses on reducing emissions from the gas-based power plants, with its plant load factor (PLF) of 66 percent.

In 2022, the GHG emissions from public electricity generation were 559 ktCO_2e, accounting for 29 percent of the district's total GHG emissions. All units of these plants were installed between 2002 and 2008. Given the economic lifetime of 25 years and high variable cost, these gas-based power plants are expected to retire by 2033. This is projected to directly abate emissions from PEG, which will be nil by 2050, even in BAU scenario. (Figure 5.1.1)

In line with the growing population and increased electricity needs, particularly for heating and cooling, the district may have to resort to importing electricity due to the retirement of these gas-based public electricity generation units. However, with the integration of an additional RE capacity of 1GW, the district can fill the lacunae in electricity supply created by the phased-out gas plants.

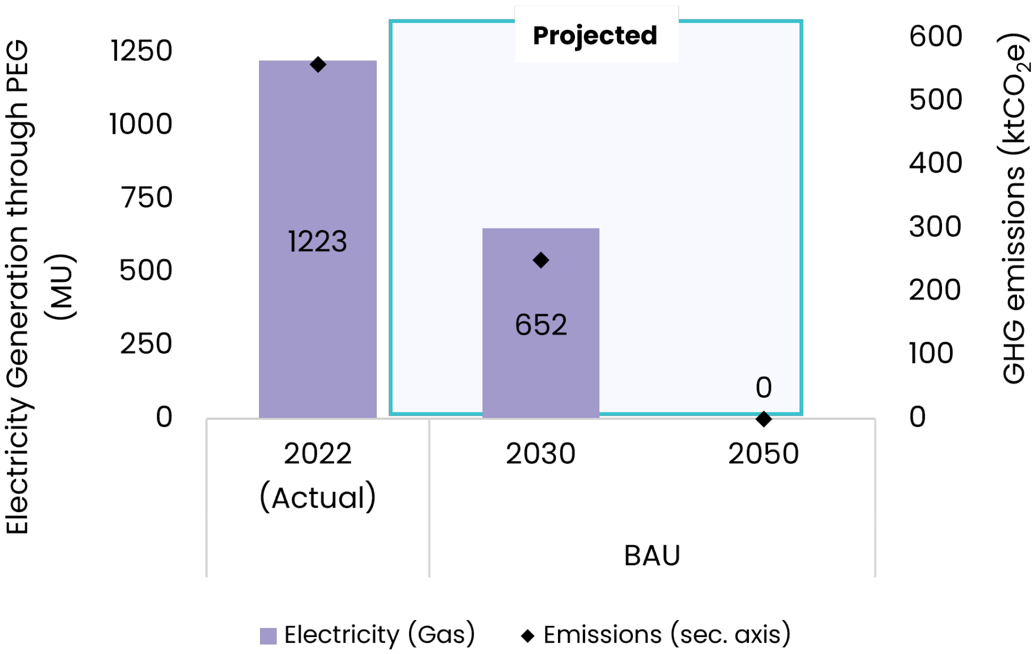


Figure 5.1: Electricity generation and respective emissions of public electricity generation units, in Ramanathapuram by 2050, in MU and ktco$_2$e respectively.

5.1.2 Buildings

Buildings in Ramanathapuram consume 32 percent of the total primary energy supply, particularly for cooling, heating, cooking, and appliance purposes. While cooking is largely driven by LPG and fuelwood, the others rely mainly on electricity.

Residential Buildings

In 2022, residential electricity demand in Ramanathapuram district was 447 GWh, accounting for ~45 percent of the district's electricity consumption. This demand is primarily driven by space cooling, appliances, and lighting. Overall, the district's residential electricity demand has increased with an average annual growth rate of 7.1 percent from 2012-13 to 2021-22.[31]

Methodology for Projection:

Demand for electricity across various appliances in residential buildings in Ramanathapuram is projected based on the data on penetration of household appliances from the National Family Health Survey (NFHS) Tamil Nadu reports for 2005-06, 2015-16, and 2019-21. Table 5.2 presents the appliance penetration rates for key appliances such as electric fans, refrigerators, air conditioners/coolers, and washing machines.

The annual growth rate of these appliances between 2005, 2016, and 2021 are analysed to project household appliance penetration up to 2050. For lighting devices, including incandescent bulbs, CFLs, CFL tubes, LEDs, and LED tubes, household penetration data is obtained from the 2020 India Residential Energy Survey (IRES).[32] Information on annual hours of usage and wattage for different appliances is retrieved from secondary literature.

Table 5.2: Residential appliance penetration per household in Ramanathapuram

Category	Appliance Penetration (number per household)			
	2020	2030	2040	2050
Lighting	4.89	4.88	4.88	4.88
Electric fan	1.92	1.92	1.92	1.92
Refrigerator	0.52	0.72	1	1
Air conditioner/cooler	0.04	0.51	0.81	1.01

The role of energy efficiency in evaluating residential electricity consumption is also assessed. In the BAU, energy efficiency mandates are assumed to retain current efficiency levels. Annual energy savings for appliances such as fans, refrigerators, air conditioners, and washing machines are computed based on energy efficiency indicators (star labels) of these appliances. Decarbonisation scenarios, MES and AES, assume higher efficiency levels, with adoption of energy-efficient applications such as BLDC fans, LED lights, ACs and fridge rated 3-stars and above.

Cooking

The cooking sector represents a significant share of residential energy use. Projections for cooking energy demand in the residential sector were based on district-specific per capita cooking fuel consumption data. In 2021-22, LPG consumption in the district amounted to 30.3 kilotonnes (kt) in the residential sector and 3 kt in the commercial sector. Since 2004-05, LPG consumption grew annually at 9.4 percent till 2022. Historically, residential LPG use has accounted for ~90-95 percent of the district's LPG consumption, while commercial LPG use made up the rest. These proportions were assumed to continue and the growth in per capita cooking fuel consumption was projected to estimate future cooking fuel demand. With the decline in kerosene usage in cooking from 2005 to 2022, the future projections exclude kerosene and fuelwood.

In the BAU scenario, 94 percent of cooking energy demand is met by LPG and 6 percent by electricity. Owing to population growth, GHG emissions from the LPG use in buildings are estimated to increase from 97 ktCO_2e in 2022 to 116 ktCO_2e by 2050.

In the MES and AES scenario, higher penetration of Piped Natural Gas (PNG) by 2030 is anticipated, driven by new CGD gas pipelines connecting the district, which is expected to represent a portion of cooking energy consumption and gradually replace LPG.[33] In the MES scenario, GHG emissions can be reduced by ~25% to 88 ktCO_2e in 2050. In the AES scenario, GHG emissions are expected to reduce to 70 ktCO_2e by the same year, achieving a 40 percent reduction compared to the BAU projection for 2050.

Box Item 2

Clean cooking using electric cookstoves and PNG fuel over LPG will increase handling efficiency in cooking

Electric cookstoves, including induction and infrared models, offer a clean, efficient, and safe alternative to traditional biomass and even LPG. They eliminate indoor air pollution, offer precise thermal control, and reduce fire hazards.

In 2021, adoption of electric cookstoves in the district was 6% as per IRES data, whereas in Tamil Nadu, as of 2021, about 17 percent of households had adopted some form of electric cooking, a rate matched only by Delhi among Indian states.[34] This adoption is driven by government campaigns like "Go Electric," which promote the benefits of electricity-based cooking, and is supported by relatively high urbanisation and awareness in the state. With Ramanathapuram's growing access to electricity and consumer awareness, it is assumed that electric cookstove adoption in Ramanathapuram is likely to reach 50 percent in limited cooking applications in AES.

In Ramanathapuram, PNG connections are being rolled out as part of the city gas distribution (CGD) network by authorised entities under the Petroleum and Natural Gas Regulatory Board (PNGRB). The main authorised entities for Ramanathapuram and nearby areas include AG&P Pratham and potentially others like THINK Gas, depending on specific localities and ongoing projects. Currently, AG&P Pratham is laying steel pipelines in Ramanathapuram and Keelakarai, with plans to provide PNG to 41,311 households over the next eight years, along with setting up 11 CNG stations[35].

Piped natural gas (PNG) offers uninterrupted supply through pipelines, eliminating the need for LPG cylinder storage and refills. Thus, PNG has fewer handling losses compared to LPG, and is often more economical with metered billing.

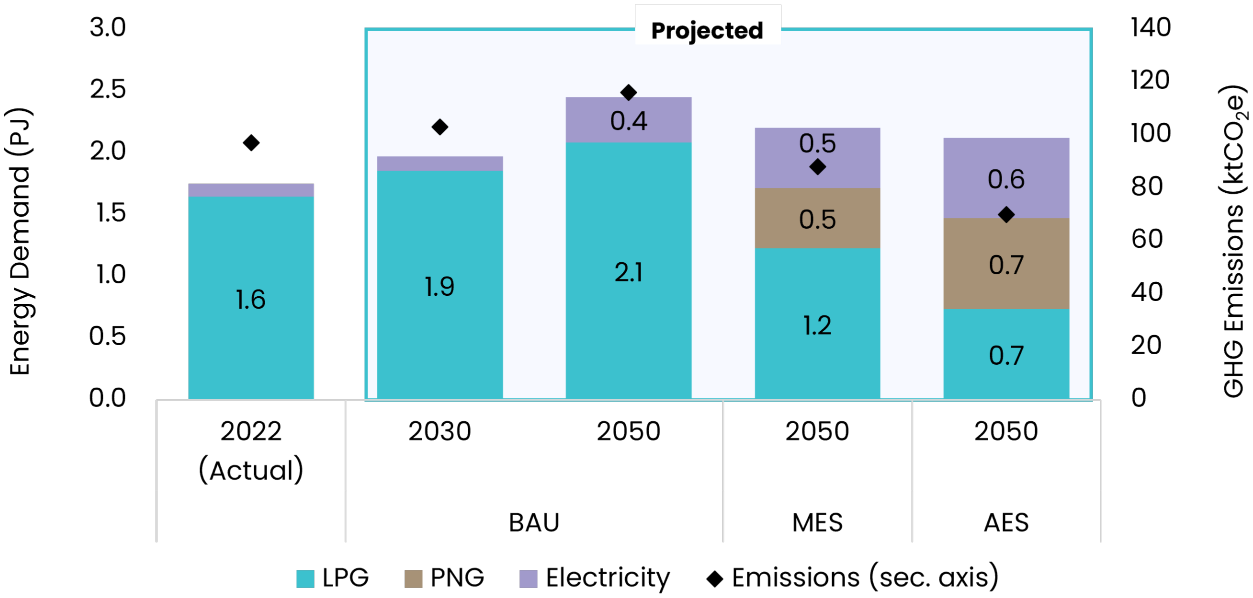


Figure 5.2: Fuel-wise energy demand and respective emissions in cooking, across scenarios, in PJ and $ktCO_2e$

Higher adoption of electric cook stoves, complemented with LPG to PNG shift, will abate 40 percent of GHG emissions in cooking

Results:

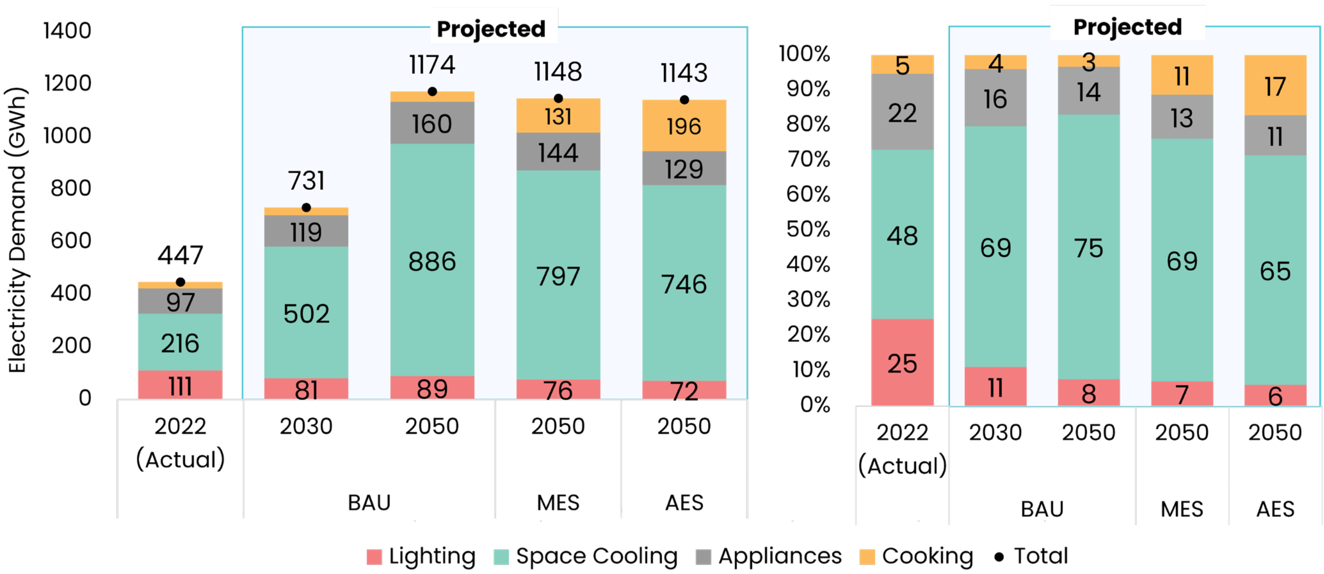


Figure 5.3: Sector-wise electricity demand in residential buildings, 2050, in GWh

Space cooling demand will drive the majority of the domestic electricity demand

By 2050, space cooling—which includes the use of ceiling fans and air conditioners—is projected to account for 75 percent of the total residential electricity consumption in Ramanathapuram in the business-as-usual scenario. This significant share is attributed to the energy-intensive nature of cooling appliances. In comparison, appliances such as refrigerators, washing machines, and motors are expected to consume 14 percent of the residential electricity. Cooking-related electricity usage is anticipated to constitute 3.4 percent of the residential sector's total, while lighting is projected to contribute 7.6 percent to overall residential electricity consumption in 2050.

In MES, electricity savings of 26 GWh could be achieved in the residential sector by 2050 due to energy efficiency measures such as the adoption of star-rated air conditioners, refrigerators and appliances. In AES, electricity savings of 84 GWh could be achieved in the residential sector by 2050 through energy efficiency measures.

Commercial Buildings and Public Services

The commercial and service sector in Ramanathapuram comprises finance, retail, education, healthcare, hospitality (hotels and restaurants), and religious activities. Energy consumption in this sector primarily relies on electricity. In 2022, commercial buildings in the district consumed 100.5 GWh of electricity, while public services and other miscellaneous activities accounted for 35.22 GWh. This electricity consumption is expected to rise alongside ongoing commercial development in the district.

Under the BAU scenario, the total electricity consumption from commercial buildings, public lighting, and miscellaneous categories in Ramanathapuram is projected to reach 371 GWh by 2050. In the MES, a moderate energy savings has been accounted for due to the adoption of energy-efficient systems (HVAC, efficient lighting, energy-efficient building envelope), while in the AES, an aggressive energy savings has been factored in with additional effort in energy efficiency measures. This is expected to result in electricity savings of 37 GWh in the MES and 56 GWh in the AES by 2050. Figure 5.3 shows the electricity requirements in different scenarios.

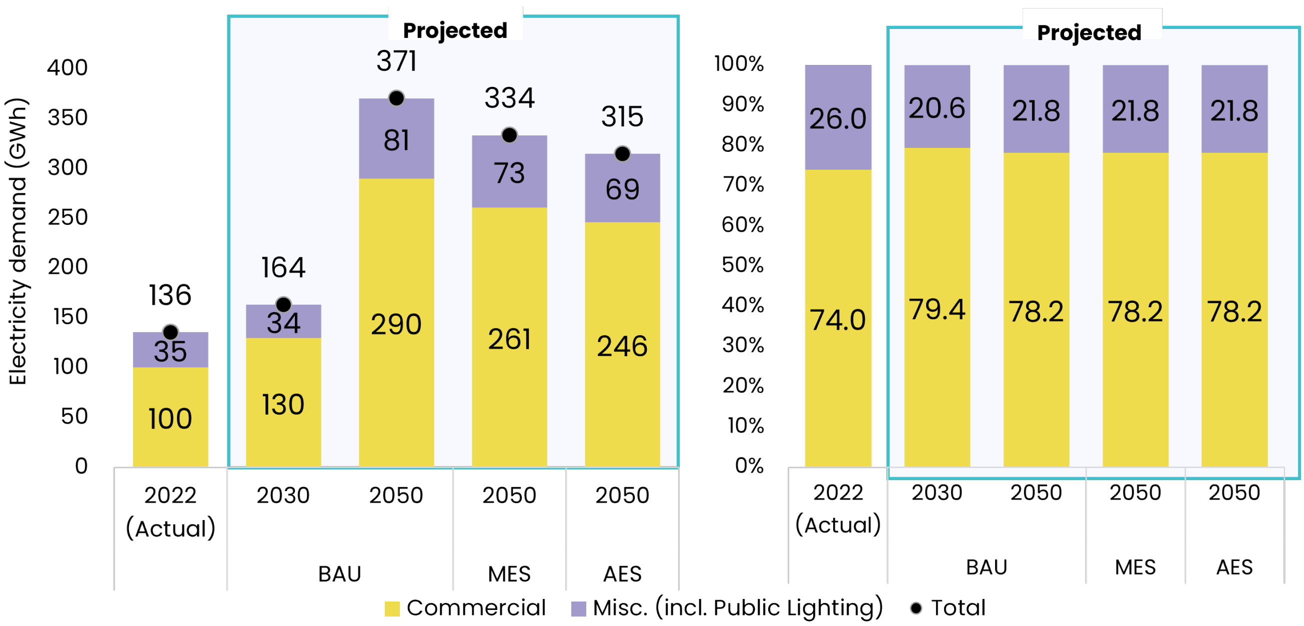


Figure 5.4: Sector-wise electricity demand in commercial buildings and public services, 2050, in GWh

Commercial activities will continue to dominate sub-sectoral electricity demand

Aggregate Results of Building Sector

Figures 5.5 show the total energy demand of the building sector by segment (residential, commercial, cooking) and its associated GHG emissions. Electricity consumption from buildings (residential, commercial, and other services) constitutes approximately 34 percent of the total electricity supplied in the district. The aggregate electricity consumption in buildings is projected to increase threefold, rising from 572 GWh in 2022 to 1,545 GWh by 2050 under the BAU scenario. The significant share of this increase is accounted for by the HVAC systems for space cooling. Notably, electricity consumption in the cooking sector is expected to rise due to substitution of LPG with electricity. In the BAU, the total energy demand in the building sector is expected to increase from 3.8 PJ in 2022 to 8.3 PJ by 2050. Under AES, energy efficiency measures will partially counterbalance the increase in energy demand. The total energy demand is accordingly expected to reach 6.2 PJ.

In BAU, building-related GHG emissions are projected to increase from 112 ktCO_2e in 2022 to 137 ktCO_2e by 2050. However, through the implementation of decarbonisation-related interventions, these could be reduced to 80 ktCO_2e by 2050, comprising 70 ktCO_2e from residential cooking and 10 ktCO2e from commercial cooking. This substantial reduction can be achieved through fuel mix transformation and energy efficiency improvements. The fuel mix transformation includes transitioning to an electricity-dominated system and switching from LPG to cleaner PNG. Energy efficiency improvements focus on adopting energy-efficient appliances, implementing building management systems, and enhancing operational practices. These strategic interventions demonstrate the potential to reduce GHG emissions by up to 42 percent compared to the BAU scenario.

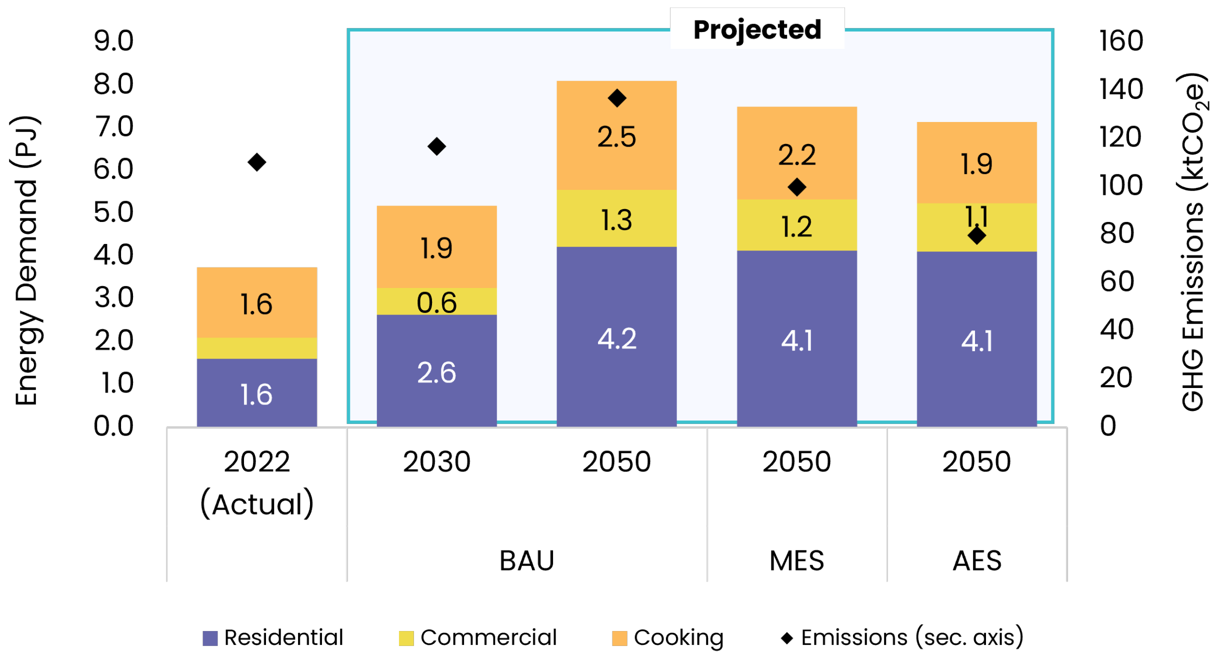


Figure 5.5: Aggregate energy demand and respective emissions in the building sector, across scenarios, in PJ and ktCO_2e

Energy efficiency and fuel switching measures can reduce building emissions by nearly half.

Key Interventions to Decarbonise the Building Sector

1. **Promoting Cleaner Fuels for Cooking in Residential and Commercial Buildings**:

   a. **Accelerate PNG Infrastructure Development-** Increase PNG share to 40-50 percent in residential cooking by 2050 by including credit-linked instalment mechanisms to boost new initial connection charges.

   b. **Promote High-Efficiency Electric Cooking Appliances:** Subsidise induction and electric cookstoves for approximately 72,000 units by 2050, including ~37,000 units by 2030 with support from the National Energy Cooking Programme (NECP).

   c. A biogas plant of approx 15000 m3/day capacity could supplement this transition in the distri

~57 ktCO$_2$e
(Scope 1)
of Decarbonisation Potential by 2050

Stakeholders:

Individual users, public/private developers, PNGRB, EESL

Additionally, Scope 2 emissions can be abated through the following interventions,

2. **Promote High-Efficiency Appliances and Cooling Solutions:** Encourage adoption of 3-5-star rated cooling appliances, approximately 6.4 lakh BLDC fans and 4.1 lakh air conditioners, gradually through incentives coupled with awareness campaigns to drive their market demand. Adopting high-efficiency appliances can save up to 84 GWh of electricity or 9 percent of the residential consumption by 2050.

110 ktCO$_2$e
(Scope 2)
of Decarbonisation Potential by 2050

Stakeholders:

Individual users, Bureau of Energy Efficiency (Central - for enforcement), Tamil Nadu Energy Development Agency and TANGEDCO (state policies and subsidies)

3. **Encourage Renewable Energy Integration**
    a. Solar Rooftop: Mandate or incentivise solar PV installations in residential and commercial buildings, aiming to cover at least 30 percent of electricity demand from on-site renewables by 2030. In existing and new commercial buildings, this could be aligned with ECBC/GRIHA standards compliance. Assessment of rooftop potential, door-to-door awareness campaigns, and access to low-cost financing can accelerate adoption. In addition to reducing grid dependence, rooftop solar panels offer the co-benefit of lowering indoor temperatures by providing shade, thereby enhancing thermal comfort and resilience during heat waves.
    b. Battery Storage: Encourage replacement of diesel generators by deploying battery storage systems to manage supply interruptions, power backup and enhance grid reliability.

Potential of RE Integration (solar rooftop, and building integrated photovoltaic) in further abating building emissions needs to be assessed.

Stakeholders: Individual users and commercial entities (for adoption), state energy department/Tamil Nadu Energy Development Agency (potential assessment and subsidies), private project developers and financiers

4. **Public Lighting and Infrastructure Upgrades to Smart LED Lighting:** Fast-tracking the replacement of existing ~7.3 lakh incandescent and CFL lights with LED-based lights at the household level, and converting ~0.56 lakh streetlights to smart LED systems by 2030, which could result in a 30-40% percent reduction in energy consumption. Explore adaptive lighting solutions that adjust based on usage patterns and time of day to enhance energy savings.

26 $ktCO_2e$
(Scope 2)
of Decarbonisation
Potential by 2050

Stakeholders:

Individual users (for adoption) and Urban Local Bodies (implementation

5.1.3 Transport

Similar to the trends observed across Tamil Nadu, road transport is a major contributor to transport-related GHG emissions in the district. Transport in Ramanathapuram also includes ferry services, but due to a lack of sufficient data and related information on ferries, this analysis primarily focuses on road transport in the district.

As of August 2024, the vehicle composition in Ramanathapuram includes a predominance of two-wheelers and a significant presence of diesel-powered vehicles, particularly in the heavy-duty segment. According to the Tamil Nadu Statistical Handbook (2022), Ramanathapuram accounts for 1 percent of the state's two-wheelers, three-wheelers, buses, and Heavy-Goods Vehicles (HGVs) like buses and trucks. Further, electric vehicles (EVs) currently represent a minimal share of the overall vehicle stock, indicating a significant reliance on fossil fuels.

To assess the decarbonisation potential of the transport sector in Ramanathpuram, a vehicle stock model was developed using historical vehicle ownership data from the Tamil Nadu Statistical Handbook, Ministry of Road Transport and Highways (MORTH) yearbook and the VAHAN dashboard. The model projects vehicle ownership from 2022 to 2050 across various segments, including two-wheelers (2W), three-wheelers (3W), cars(4W), buses, trucks (HGV), and others. Total vehicle stock for 2022 base year is calculated based on cumulative 2018 vehicle stock data from Transport Department Statistical Handbook 2017-18, with yearly additions based on new registrations in Ramanathapuram as per VAHAN Dashboard. (Table 5.3)

Table 5.3: Stock of all vehicles by category, Ramanathapuram, 2022 (in Numbers)

Year	2W	3W	4W	BUS	HGV	Others
2018	2,47,619	7671	21,395	900	3,955	8,764
2022	2,74,475	8,603	24,035	962	4,018	10,270

To explore pathways for reducing transport emissions, three scenarios were developed, reflecting varying levels of EV adoption and their impact on energy consumption and emissions from 2022 to 2050. (Table 5.4) The vehicle saturation level for 2050 is also incorporated, reflecting economic growth and increased vehicle ownership. Total electric vehicle stock accordingly, actual for 2022 and projected across scenarios until 2050, is given in Table 5.5.

Table 5.4: Projected Electric Vehicle Share in New Sales by Vehicle Type, across scenarios in Ramanathapuram

Vehicle type/Years		2W	3W	4W	BUS	HGV	Others
BAU	2022	0.30%	0.60%	0.30%	0%	0%	0%
	2030	30%	30%	30%	30%	7%	10%
	2050	100%	100%	70%	65%	20%	40%
MES	2050	100%	100%	100%	100%	50%	85%
AES	2050	100%	100%	100%	100%	80%	95%

Table 5.5: Projected Electric Vehicle Stock by Vehicle Type, across scenarios in Ramanathapuram

Scenario	Year	2W	3W	4W	BUS	HGV	Others
BAU	2022	721	56	75	1	1	1
	2030	3353	393	589	100	20	340
	2050	1,80,652	6,496	35,126	600	125	3,819
MES	2050	1,80,652	6,496	48,586	690	250	8,134
AES	2050	1,80,652	6,496	48,586	690	500	10,665

Source: Government of Tamil Nadu, Statistical Handbook 2017-18 & VAHAN Dashboard

The model incorporates several operational assumptions, including the annual kilometres driven across all vehicle segments, fuel efficiency, the average retirement age of vehicles,[36] and vehicle saturation per 1,000 people. These variables serve as inputs for the Gompertz growth model,[37] which is used to forecast the number of vehicles. This forecast is then utilised to calculate year-on-year fuel consumption and, ultimately, to estimate GHG emissions.

Key Insights:

The BAU scenario projections take into account the momentum built through policy shifts and fiscal incentives under Faster Adoption and Manufacturing of Hybrid and Electric Vehicles (FAME) Phase-I Scheme (2015), FAME-II (2019) and the Electric Vehicle Policy of Tamil Nadu (2019; 2023). These incentives resulted in an 8-fold increase in the new registrations of electric vehicles in India, and a 20-fold increase in Tamil Nadu between 2019-20 and 2023-24, which was led predominantly by two-wheelers (2W) and three-wheelers (3W).

Box Item 3

Historical increase in EV share in new registration is expected to continue throughout 2050

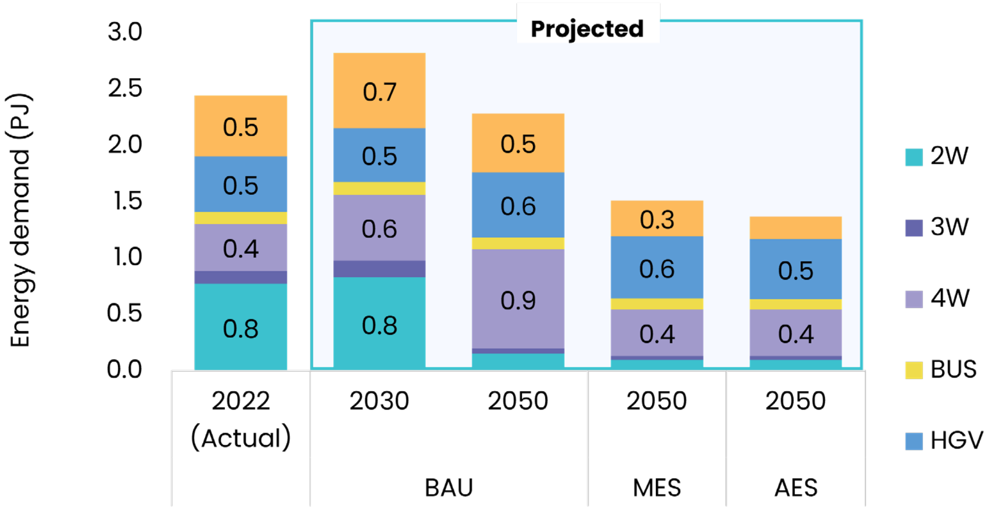
The table below presents the vehicle category-wise EV share as a percentage of total vehicle registrations in each category for the year 2023-24. Kerala, Karnataka, and Maharashtra exhibit strong EV penetration in the 2-wheeler segment. Similarly, the 3-wheeler segment is dominated by Uttar Pradesh, where a remarkable 82.4 percent of new registrations are electric. Meanwhile, Kerala, Maharashtra, and Tamil Nadu maintain a balanced EV share in this segment. In the Light Motor Vehicle category (LMV), mostly the 4-wheelers, states like Kerala, Maharashtra, Karnataka, and Tamil Nadu are experiencing an increasing growth in EVs registration. In Maharashtra, 28 percent of the new registration in HPV category were electric.

Vehicle category wise share of EVs in new registration in Indian states, (values in %), year 2023-24

Vehicle Category	Karnataka	Kerala	Maharashtra	Tamil Nadu	Uttar Pradesh
2-Wheeler	11.6	13.5	10.1	6.0	2.1
3-Wheeler	9.0	15.6	15.2	12.3	82.4
HPV (Buses)	22.6	12.3	28.0	5.6	0.0
LMV (Cars)	3.1	5.4	2.4	2.3	1.1

Following the trends in EV adoption, by 2030, the penetration of electric two-wheeler (2W), three-wheeler (3W), four-wheeler (4W) and e-buses in new sales is projected to increase to 30 percent. By 2050, it is expected to further increase to 100 percent for 2W and 3W, 70 percent for 4W and 65 percent for e-buses. Through full and effective implementation of the existing schemes, development and maturity of allied infrastructure for electric mobility, MES anticipates 100 percent electrification of buses and 50 percent electrification of HGVs, while the AES projects even greater progress, with almost all buses and other segments electrified.

Figure 5.6 highlights the total projected energy demand in the vehicle segment decreasing from 2.45 PJ to 2.29 PJ in 2050 in BAU. Energy requirements decrease in alternative scenarios due to the penetration of efficient EVs, which replace high-energy-intensive internal combustion vehicles. Thus, energy demand would further reduce from 2.29 to 1.37 PJ by 2050. Electrification of the road transport fleet is projected to increase electricity demand to 424 GWh in the BAU scenario by 2050, with the majority of this consumption attributed to 4-wheelers and heavy-duty goods vehicles.



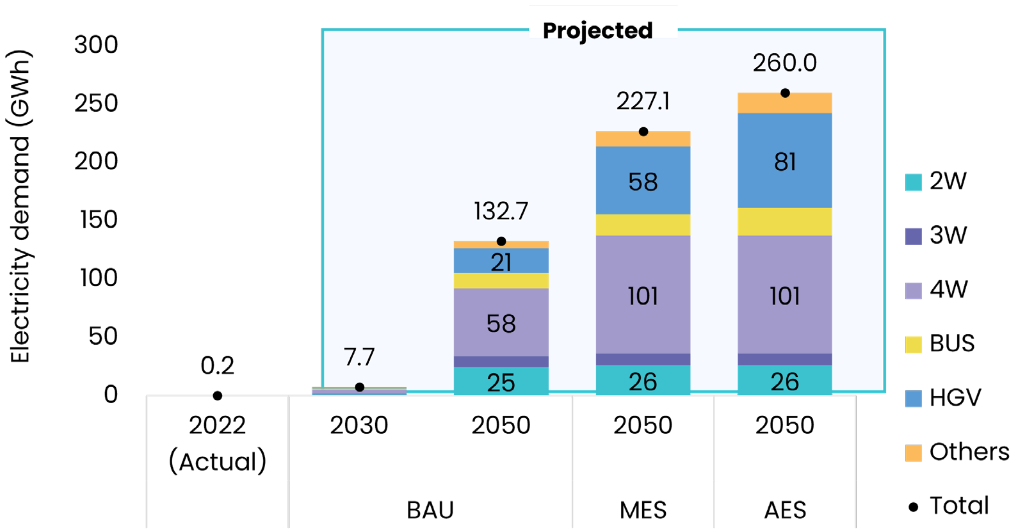


Figure 5.6: Energy and electricity demand by vehicle type, across scenarios, in PJ and GWh

Electrification of two-wheelers is the lowest-hanging fruit for decarbonising road transport.

The projected GHG emissions under the BAU scenario are estimated to decrease from 224 ktCO2e in 2022 to 155 ktCO2e by 2050 as a result of higher EV adoption incentivised under current policies. Under the MES, emissions are expected to decrease to 59 ktCO_2e, reflecting a significant reduction driven by increased adoption of electric vehicles. In the AES, emissions are further reduced to 37 ktCO2e, representing the most substantial decline due to more aggressive electrification strategies and improved fuel efficiency across vehicle segments. The residual emissions are due to diesel-based HGVs.

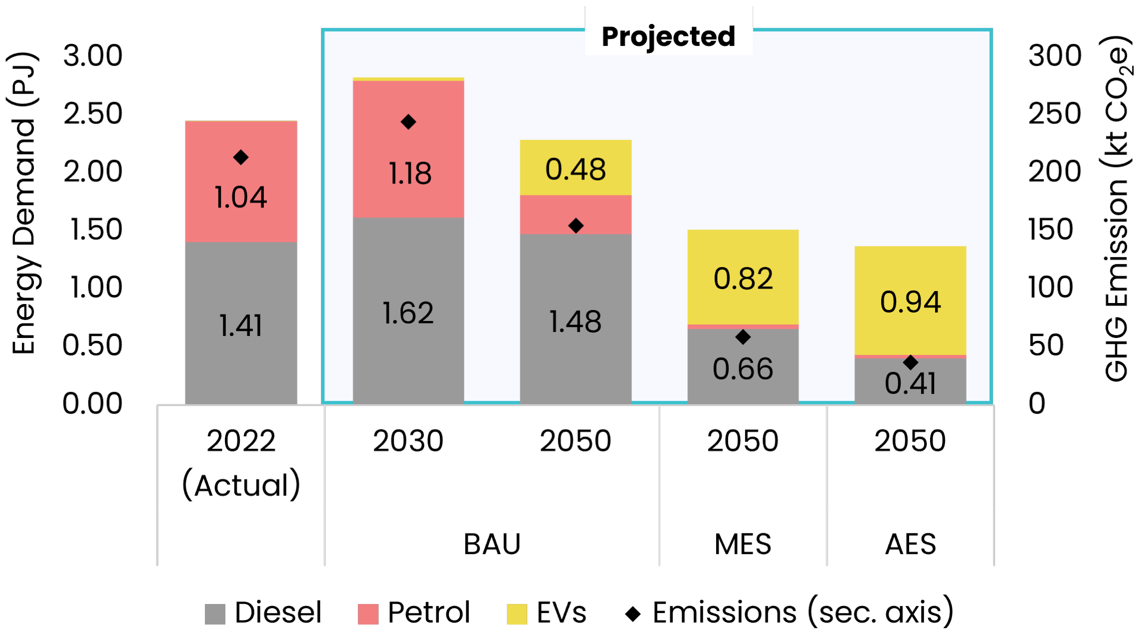


Figure 5.7: Energy and GHG emissions in transport sector by fuel type, across scenarios, in PJ and ktCO2e

Key Interventions to Decarbonise the Road Transport:

- **Prioritise Two-Wheeler and Three-Wheeler Electrification:** With 2,74,475 two-wheelers and 8,603 three-wheelers dominating the current fleet, out of which only 0.26 percent and 0.65 percent respectively are electric, electrification efforts in this segment can be expedited in alignment with the state EV policy. The district should target 100 percent electrification of 2W and 3W, to the total stock of ~1.8 lakh electric 2W and ~6000 electric 3W by 2050.
- **Scale Charging Infrastructure:** The analysis projects electricity demand reaching 132 GWh by 2050 under BAU scenario. Augment the electricity distribution infrastructure, focusing first on urban areas where 2W/3W adoption will be highest. Increase capital investment in public charging points at bus bays, fuel stations, parking lots, and malls. At least ~30 new charging stations should be targeted by 2030.
- **Accelerate Bus Fleet Transition:** Electrification of intra-city public and private buses needs to be prioritised. Given the potential for electrification of public buses and the high upfront costs involved, it is crucial to adopt innovative financing mechanisms, such as the OPEX (operational expenditure) model.

118 ktCO_2e
of Decarbonisation Potential by 2050

Stakeholders:

Individual users, State Transport department (policies/subsidies), RTO (monitoring and progress), Local Businesses (repair and allied services), Industry (tech availability and infrastructure).

Box Item 4

Driving change: EV surge and special NMT corridors for pilgrimage hubs

Ramanathapuram can benefit from Tamil Nadu's initiatives to push electricity mobility. Under the TN Electric Vehicle Policy 2023,

- The State Government has announced incentives up to Rs. 5000 for procurement of e-cycles, Rs.30,000 for e-2W, Rs. 40,000 for e-3W, Rs. 1,50,000 for e-4W and Rs. 10,00,000 for e-buses. In addition, a 100 percent road tax has been exempted, and registration charges and permit fees waived for electric vehicles in the state till 31.12.2025.
- Furthermore, to promote EV supply, the electricity tax on EV manufacturing has been exempted for the period of five years, and a 100% reimbursement of SGST is being offered on a minimum investment of Rs. 50 crores and the generation of at least 50 jobs.
- Further extension of the timeline under the EV policy could be explored.

Further, the scope for non-motorised transport (NMT), especially in Ramanathapuram district, is shaped by its urban structure and tourism profile. Rameswaram, a major pilgrimage and tourist destination attracting nearly 1.76 crore visitors annually. Rameswaram's flat terrain, high passenger footfall, and concentrated activity zones make it particularly well-suited for walking, cycling, and e-cart-based mobility. With only 10 percent of tourist and local trips shifting to NMT, ~5 ktCO2e of GHG emissions can be abated annually. This could furthermore remove nearly 2800 motor vehicles from the roads each day, significantly easing congestion around temples and town centres. NMT infrastructure—such as shaded walkways, dedicated cycle lanes, public bike-sharing systems, and integration with electric first- and last-mile services—would not only enhance the visitor experience but also stimulate the local economy.

5.1.4 Fisheries

Ramanathapuram district has a significant coastline compared to other coastal districts in Tamil Nadu. There are about 179 fishing villages located along this coastline. Table 5.6 provides the key statistics. Fishing operations are primarily conducted using mechanised boats, motorised boats, non-mechanised boats, and shore seines; however, the use of shore seines has declined in recent years due to their high operating costs. Among the three types of fisheries—marine, inland, and brackish water—marine fishing is the most dominant in this district. Ramanathapuram benefits from its natural fishing grounds in Palk Bay and the Gulf of Mannar.[38]

The fishing industry is a vital source of livelihood for many residents, contributing also to foreign exchange earnings through the export of high-quality sea fish. In the district, there are seven fish processing factories located in Tondi and Mandapam. These facilities process various seafood, including prawns, squids, cuttlefish, crabs, and fish, which are then exported to international markets. Additionally, many small entrepreneurs engage in fish drying, producing dried fish that is used in poultry and cattle feed manufacturing.

Table 5.6: Key statistics of the fisheries sector in Ramanathapuram

Total Coastal Line of the District		274 Kms.
Marine Fishing Village		179
No. of Coastal Centres		75
Fish Production	Marine	78810.1 tonnes
	Inland	4794.707 tonnes
Ice Plants		28
Fishing Vessels	Mechanised Fishing Boat	1432
	Motorised, non-mechanical	2012
	Deep Sea Fishing Vessels	37
Active Marine Fisherman		50,450

Most fishing activities in the district rely on diesel fuel; thus, the diesel consumption in the fisheries is high in the district. The fisheries sector accounts for the highest diesel consumption after the transport sector, comprising approximately 40 percent of the total diesel consumption in the district in 2022. The fisheries sector has consumed around 36 kt of diesel in 2022, and more or less it remains at the same level since 2013.

In the BAU scenario, it is anticipated that diesel consumption will continue to follow the trends of the past decade, growing at a similar rate. In the MES and AES scenarios, a transition from diesel-based fishing boats to electric boats is expected. In the MES scenario, a moderate shift of 50% of the total fishing fleet to electric boats, either by retrofitting the existing fleet or new replacement by 2050 is projected, while in the AES scenario, a complete transition to 100% electrification by 2050 is foreseen.[39]

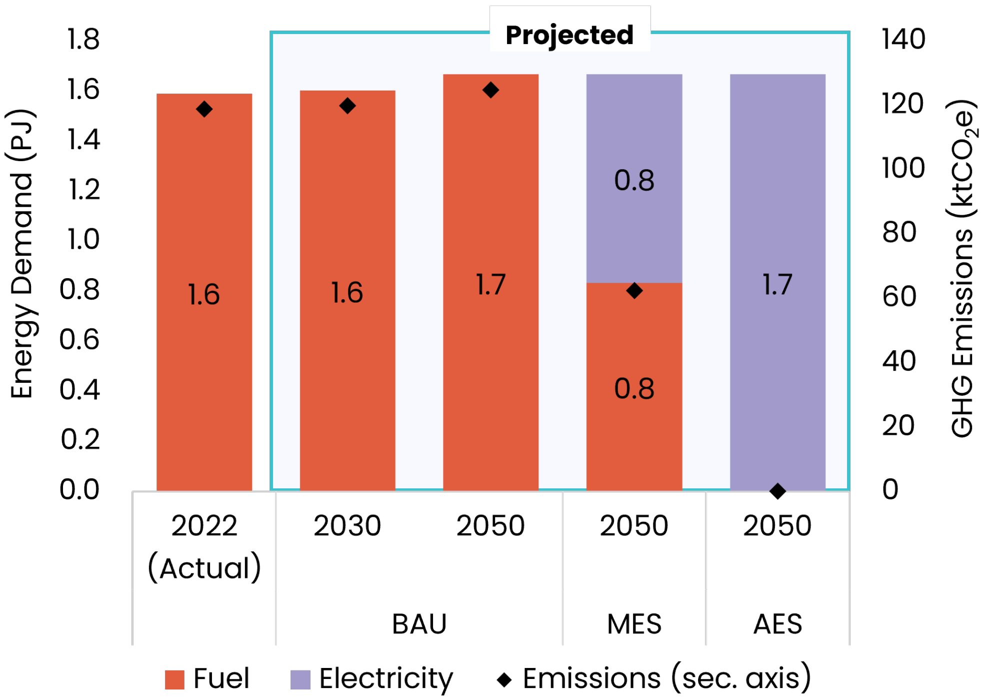


Figure 5.8: Energy demand and respective emissions in fisheries in Ramanathapuram, across scenarios, in PJ and $ktCO_2e$

Electrification of fishing boats will completely abate sectoral emissions by 2050

Key Intervention to Decarbonise Fishing Industry in Ramanathapuram

- To decarbonise the fishing sector in Ramanathapuram, a structured transition to electric fishing vessels by electrifying 1432 mechanised and 2390 country craft fishing boats and motorised fishing vessels by 2050 is proposed. This intervention will eliminate ~38 kt of diesel consumption and reduce ~125 $ktCO_2e$ emissions annually.

125 $ktCO_2e$
of Decarbonisation Potential by 2050

Stakeholders:

Fishing community, Ramanathapuram District Fishermen Sangam Federation, Ramnad Fish workers Trade Union (for adoption and usage), Ministry of Fisheries (Central) and State Fisheries Department (policies, subsidies and capacity building)

Box Item 5

Energy efficient building solutions, electrification of transport and cooking could promote sustainable tourism, especially in Rameswaram

Ramanathapuram is a famous pilgrim destination in South India, with Ramanathaswamy Temple in Rameshwaram, Dhanushkodi, Devipattinam (Nava Bashanam), Pamban Bridge and Thiru Uthirakosamangai acting as key tourist attractions. Within these, Ramanathaswamy Temple and other temples in Rameswaram alone account for 90% of all tourist visits to the district. With the announcement of a new airport in Rameswaram (TN State Budget 2025-26), this is expected to grow multifold over the next few years. While the district grows economically, emissions from this growth can be curbed by adopting a mix of energy efficiency and clean energy solutions across sectors. In Rameswaram especially, emissions from the building and transport sector – the majority of which are led by tourism – could be cut by 93% from 67.2 $ktCO_2e$ to 4.2 $ktCO_2e$.

- Building Emissions (Scope 1) in Rameswaram were estimated to be 9.4 $ktCO_2e$ in 2022, driven by use of LPG and PNG in residential and commercial cooking. By promoting adoption of electric cookstoves, and installing bio-methanation plants in 50% buildings - generating 3,000 m^3 biogas per day - as much as 5.7 $ktCO_2e$ can be abated.
- In addition, 57 $ktCO_2e$ of Scope 2 emissions can be curtailed through installation of a solar rooftop of 10-25 kW capacity while prioritising adoption in public and commercial buildings.
- Transport emissions in Rameswaram were estimated to be 32.1 $ktCO_2e$, about 82% of which were from vehicle trips by tourists. By electrifying ~15000 2-wheelers, 4000 3-wheelers, 3000 4-wheelers and 85 public buses, 96% of these emissions can be abated.

5.1.5 Industry

Ramanathapuram district's industrial sector is primarily characterised by 12000 micro, small, and medium enterprises (MSMEs),[40] with a limited presence of large-scale industries. The region's main industrial activities include agro-based industries such as modern rice mills and coconut-based processing units, seafood processing, fish net and fish meal oil manufacturing, and oleoresin spices production. Ramanathapuram is heavily dependent on agriculture and fisheries. While there are some clusters—notably the engineering cluster in Paramakudi, which manufactures metal products for utilities like the Tamil Nadu Electricity Board—the overall industrial landscape remains underdeveloped compared to other districts in Tamil Nadu.

Key challenges hindering industrial growth include a lack of mineral resources, scarcity of skilled labour, limited marketing facilities, water scarcity, and poor connectivity to ports and railway networks.[41] However, recent initiatives such as the establishment of the Manakudi SIPCOT Industrial Park aim to boost industrial infrastructure and attract new investments in the region.

Currently, the district hosts six large and medium-scale industries, including two spinning mills and two cotton mills, among others, located in Kamuthakudi, Kamuthi, Tiruvadanai, Abiramam, and Ramanathapuram (Table 5.7).

Table 5.7: Details of large and medium-scale industries in Ramanathapuram[42]

S. No.	Name and address of the industry	Address
1	Pioneer Spinnings, National Textile Corporation	Kamuthakudi
2	Co-operative Spinning Mills	Achankulam, Kamuthi
3	Sri Nithiyakalyani Textiles	Tiruvadanai
4	Mannan Cotton Mills	Veerasozhan Road, Abiramam
5	Ayisha Cotton Mills	Abiramam
6	Tvl. Srinithi Industries Limited	Achunthanvayal, Ramanathapuram

According to Udyam Registrations under MSME DI, as of June 2021, there are 2,816 MSME registered in Ramanathapuram district, of which 768 units are manufacturing based.[43] The predominant industries within the district include textiles, handloom and spinning, salt and chemical industries, cement, and the production of matches, fireworks, and printing-related activities.

In Ramanathapuram, the majority of industries are electrified. This has significantly increased electricity consumption in the sector from 18.6 GWh in 2012 to 38 GWh in 2022. This growth reflects a rising reliance on electric processes for manufacturing. In terms of fuel usage, the primary fuels used in the industrial sector are HSD and bitumen. In 2022, the district recorded a consumption of 3.88 kt of HSD and 0.39 kt of bitumen. This indicates the ongoing transition toward electrification and highlights the need for further electrification in the sector.

In the BAU scenario, it is assumed that current trends and growth rates will continue. In contrast, the MES and the AES involve a shift from fuel usage to electrification in industries. In the MES, a 50 percent replacement of fuel with electricity is projected by 2050, while the AES anticipates a complete transition to 100% electricity usage by 2050. The graph below illustrates the results of these scenarios.

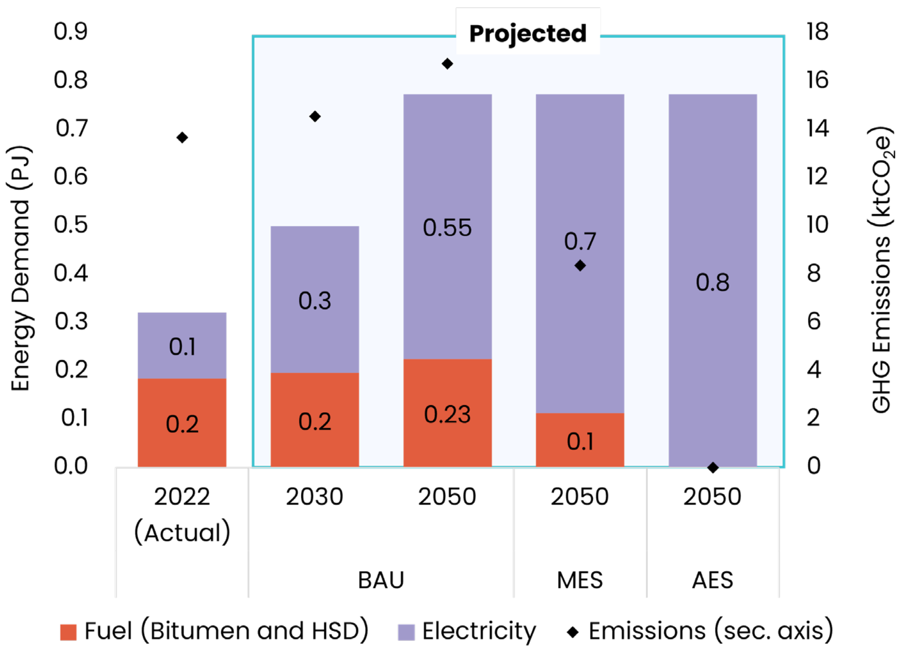


Figure 5.9 (a): Fuel-based energy demand and respective emissions in the industrial sector (excluding captive power), across scenarios, in PJ and ktCO$_2$e

Electrification can abate 100 percent of emissions from heating and other industrial processes

Overall fuel consumption in the industrial sector is projected to increase by ~2.5 times by 2050 in the BAU scenario, leading to a corresponding rise in emissions from 12 ktCO$_2$e in 2022 to 17 ktCO$_2$e in 2050. However, in the MES and AES, due to electrification of various processes, the reduction in fuel consumption is expected to result in a decrease in emissions, ultimately reaching zero in the AES.

Captive Power Plant in Ramanathapuram

Captive Power Plants (CPPs) play a significant role in GHG emissions in the Ramanathapuram district, contributing approximately 11 percent of the district's total GHG emissions in 2022. These plants serve industries across sectors such as textiles, plastics, chemicals, and electrical engineering to meet their electricity requirements. The primary fuels used in these CPPs are coal, natural gas, and high-speed diesel (HSD).

According to the Central Electricity Authority (CEA), as of 2018–19, the total installed capacity of captive power plants (CPPs) in Ramanathapuram was 86.11 MW, comprising 38.75 MW of steam-based, 39.2 MW of gas-based, and 8.16 MW of diesel-based systems.

Due to the unavailability of an active number of captive power plants in the district from 2018-19, the plant capacity (MW), electricity generation (GWh) and GHG emissions (ktCO$_2$e) are assumed to remain unchanged in the future.

Table 5.8: List of captive power plants in Ramanathapuram for the year 2018-19,

Source: CEA

Name of Industry with Address	Fuel Used	Type of Industry	Installed Capacity (MW)	Gross Electricity Generation (GWh)
Raghu Rama Renewable Energy Ltd.	Coal	Elect. Engg.	18.0	0
Sai Regency Power, Corporation Ltd.	Coal	Elect. Engg.	18.8	122.61
EID Parry Ltd Distillery Unit	Coal	Chemical	2.0	8.06
Livia Polymer Bottles Pvt. Limited,	HSD	Plastic	6.3	0.26983
Pioneer Spinners	HSD	Textile	0.8	0.003
Premier TEx Products (P) Ltd.	HSD	Textile	1.1	0.00936
Sai Regency Power Corporation Ltd.	Natural Gas	Elect. Engg.	39.2	256.33
Total CPP capacity	-	-	**86.1**	**387**

The average plant load factor (PLF) for gas-based CPPs is 74.6 percent, while for coal-based CPPs, it is 40.2 percent. HSD-based CPPs, however, have a PLF of only 0.2 percent. Under the BAU scenario, CPP-related annual GHG emissions have been considered constant from 209 ktCO_2e in 2022 to 2050. In AES, replacing all diesel, gas and coal-based CPPs with renewable energy sources, such as solar, wind and green hydrogen by 2050 would reduce CPP-related emissions to zero. (Figure 5.9 b. and c.)

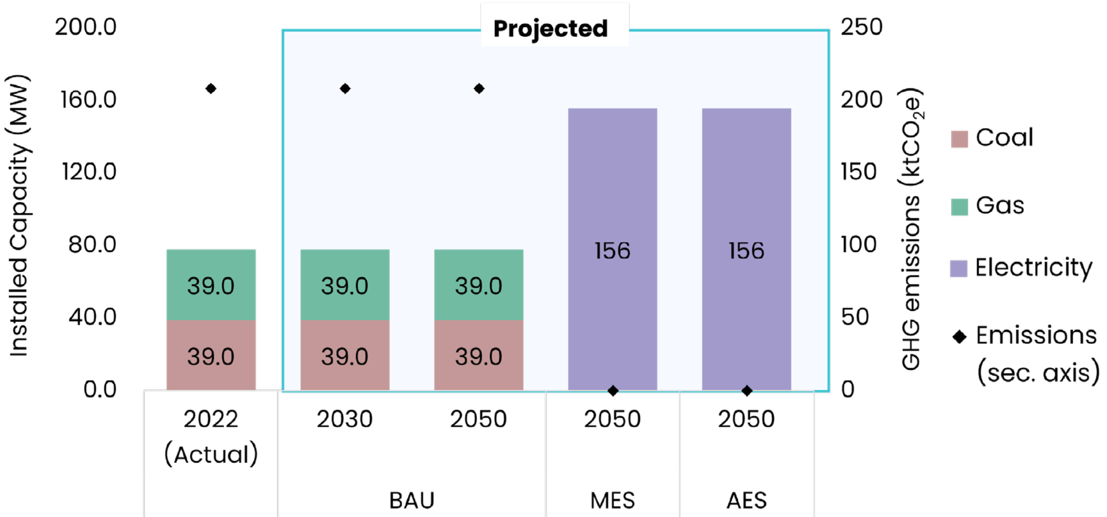


Figure 5.9 (b): Fuel-based captive power emissions, across scenarios, in PJ and ktCO_2e

RE-based captive power generation can fully abate CPP related emissions, even when electricity demand for captive power generation remains unchanged till 2050.

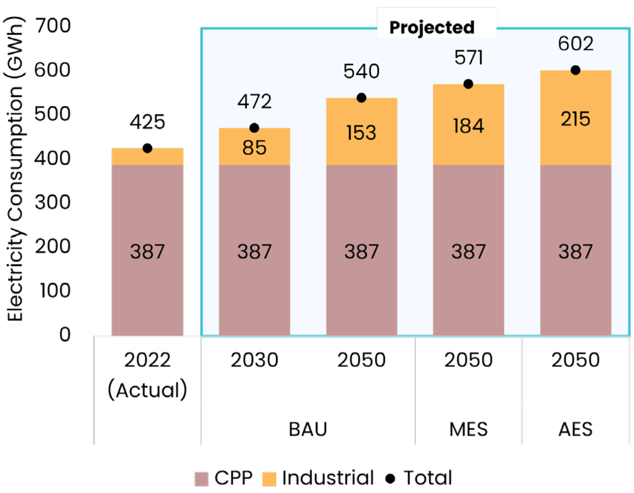


Figure 5.9 (c): Source wise electricity demand across scenarios, in GWh

Any increase in electricity demand in industries by 2050 will be due to electrification of industrial processes, particularly heating

Key Interventions to Decarbonise the Industrial Sector:

- Replace 100 percent of gas, diesel and coal based captive power plants with renewable energy (solar, wind) by 2050. This could either be done through integration of renewable energy for captive power or market-based power procurement (open access or power exchange route).

209 ktCO_2e
of Decarbonisation Potential by 2050

Stakeholders:

Primarily Industries with support/incentives from TEDA/TANGEDCO, DICs

- Explore electrification of heating processes in industries. Conduct an assessment on the potential of rooftop solar in industries and undertake installation.

17 ktCO_2e
of Decarbonisation Potential by 2050
**from electrification*

Stakeholders:

Primarily industries, State Industries department, District Industries Centre

- Energy audits and other energy efficiency measures in industries can result in electricity savings of 7–11 percent. It is also essential to implement the recommendations provided in energy audit reports to achieve the potential energy savings.

Stakeholders:

Primarily industries, State Industries department, District Industries Centre

5.1.6 Agriculture

The agricultural landscape of Ramanathapuram district comprises a variety of crops, including paddy, cotton, groundnuts, sugarcane, and coconut, which account for approximately 90.93 percent of the gross sown area. In 2021-22, agricultural electricity consumption in the district was recorded at 2.76 GWh .

The estimation of electricity consumption was based on the water pumping requirements for each cropping season, which served as a key metric. Due to limited historical crop production data specific to Ramanathapuram, the analysis utilised 10-year crop production patterns from Tamil Nadu. Projections for agricultural production up to 2050 were developed using these patterns, along with past crop yield data.

Currently, 36 percent of the total sown area is irrigated, with 77 percent of this irrigation supported by tanks. and 23 percent by wells.[44] The average depth of water in Ramanathapuram is 7.22 meters below ground level.[45] Electricity requirements for irrigation were projected using water needs per hectare for major crops and the number of electrified pumpsets, which rose from 8,348 in 2010-11[46] to 9,621 in 2021-22.[47] Under the BAU scenario, 90.3 percent of irrigation pumps operate on grid electricity, 9 percent on diesel, and the rest are solar-powered. Diesel-based operations result in

GHG emissions of 12.3 $ktCO_2e$, which are expected to reach 21.3 $ktCO_2e$ by 2050.

The PM-KUSUM scheme aims to reduce diesel usage by promoting solar pumps. In the MES, converting 50% of diesel pumps to solar and electrifying 50 percent of agro-machinery can lower GHG emissions to 11 $ktCO_2e$ by 2050, with electricity consumption of 35 GWh. In the AES, conversion of 100 percent or ~5800 diesel pumps to solar and electrifying all of ~1400 tractors and tillers could fully abate the concerned GHG emissions, requiring an additional 56 GWh of electricity by 2050.

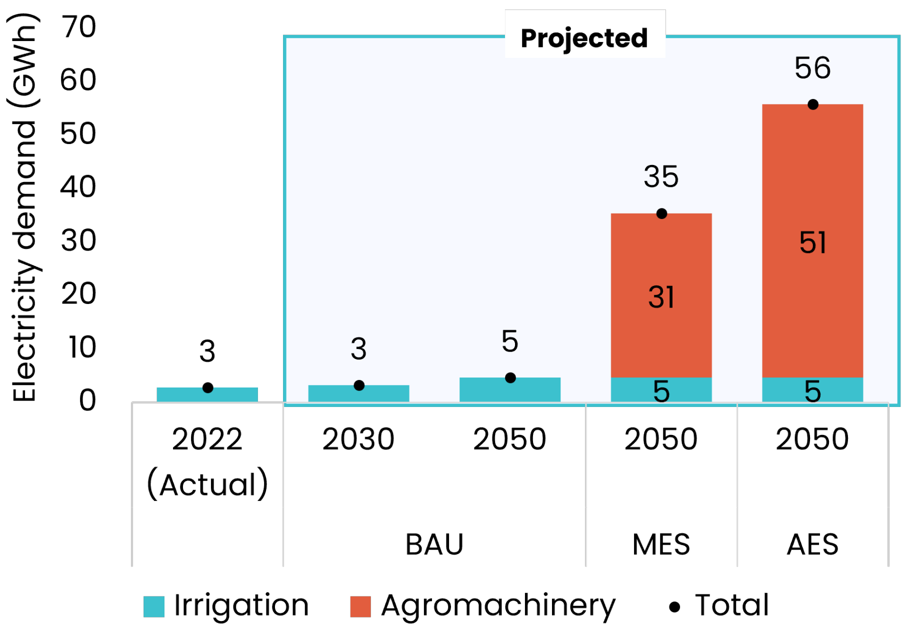


Figure 5.10 a.): Electricity consumption in agriculture sector by source, across scenarios, in GWh

Shift from diesel-run tractors and tillers to electric counterparts will substantially increase electricity demand under the decarbonisation scenarios

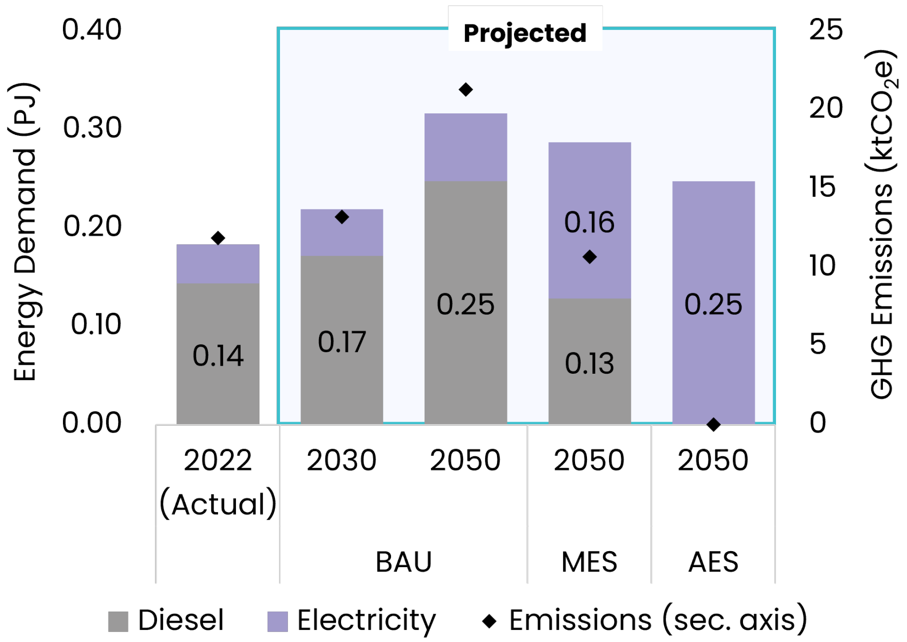


Figure 5.10 b.): Energy demand and respective emissions in agriculture sector by source, across scenarios, in PJ and $ktCO_2e$

Emissions from the agricultural sector (energy) could be fully abated due to this shift

Key Interventions to Decarbonise Energy in Agriculture:

- **Promotion of Renewable Energy Solutions:**
  - *Solar-Powered Irrigation Systems:* Replace ~5837 existing diesel pump sets with solar pumps by 2050, in convergence with the PM-KUSUM scheme.
  - *Agrivoltaics:*[48] Explore potentials for implementing agrivoltaic systems that allow for the dual use of land for both agriculture and solar energy production. This can be done through detailed assessment of crop diversity in the district and viability assessment.[49]
- **Transitioning from diesel agro machineries to electric agro machineries:** Promote electric tractors by targeting at least 30 percent of new tractor sales to be electric by 2035, supported by tailored financing solutions from agricultural banks and financial institutions. Additionally, transition all 1400 projected diesel-based tractors and tillers to electric by 2050.

21 $ktCO_2e$
of Decarbonisation Potential by 2050

Stakeholders:

Individual Farmers / Farmer Producer Organisation (FPO) / Water User Associations, State Agriculture and Energy Department, TANGEDCO

Aggregate Results of the Energy Sector

1. Electricity:

Electricity consumption in Ramanathapuram in 2022, which stood at 1000 GWh in 2022, is estimated to increase ~2.5x to 2224 GWh in 2050 due to continued growth in industrial, residential and commercial sectors, and higher adoption of electric vehicles in transport. Further, a full and effective implementation of decarbonisation strategies across sectors could triple the district's electricity demand, from its current level to 2893 GWh under AES 2050 – accounting for both demand reduction due to energy efficient equipments in residential and commercial sector, and demand increase due to electrification in industries, transport, cooking, and agriculture.

In 2022, the residential sector was the largest consumer of electricity, accounting for nearly 45 percent of the total consumption, equivalent to 447 GWh. Over the coming decades, a shift in sectoral shares of electricity consumption is anticipated. By 2050, the residential sector's share is projected to increase to 53 percent, with an overall increase in absolute electricity demand to 1,174 GWh.

The second-largest electricity-consuming sector in the district is the industrial sector including captive power plants, which held a 43 percent share in 2022, corresponding to 425 GWh. where the majority of electricity is generated by captive power plants i.e. 387 GWh and the rest 38 GWh was taken from the grid. By 2050, its share is expected to decrease, with the absolute value of electricity consumption increasing to 540 GWh.

The transport sector's electricity consumption is forecasted to rise significantly due to the rapid adoption of electric vehicles (EVs) and the early retirement of conventional vehicles (within 15 years). In 2022, the electricity demand for this sector was 0.35 GWh, which is expected to grow to 133 GWh by 2050, increasing its share from 0.06 percent to approximately 7 percent.

The agriculture sector is projected to contribute 0.24 percent of the total electricity demand by 2050, while the industrial sector will account for nearly 8 percent. Currently, the fisheries and captive power plant (CPP) sectors rely on fossil fuels. In alternative scenarios, the electrification of these sectors is assumed, which will significantly increase electricity demand.

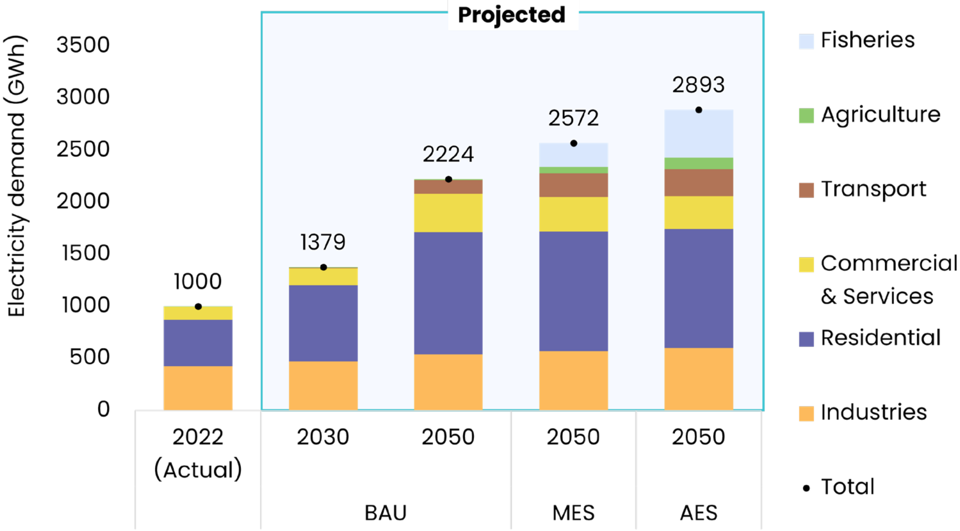


Figure 5.11: Projected Sector-wise electricity demand, across scenarios, in GWh

Deep electrification of fisheries and agriculture sectors will drive an increase in electricity demand in the decarbonisation scenario.

2. Total Energy Consumption:

Under the BAU scenario, total energy use is projected to grow from 11 PJ in 2022 to 17 PJ by 2050, refer figure 5.12. In 2022, the residential sector was the largest energy consumer, accounting for 30 percent of total energy use. This sector is expected to remain the largest by 2050, with its share increasing to 38 percent.

The industrial sector, the second-largest consumer in 2022 with a 28 percent share, is projected to see its share constant by 2050. The transport sector, which held a 22 percent share in 2022, is projected to decrease to 14 percent by 2050 due to the increasing penetration of energy-efficient electric vehicles (EVs).

Fisheries also represent a significant energy-consuming sector, accounting for 14 percent of total energy use in 2022.

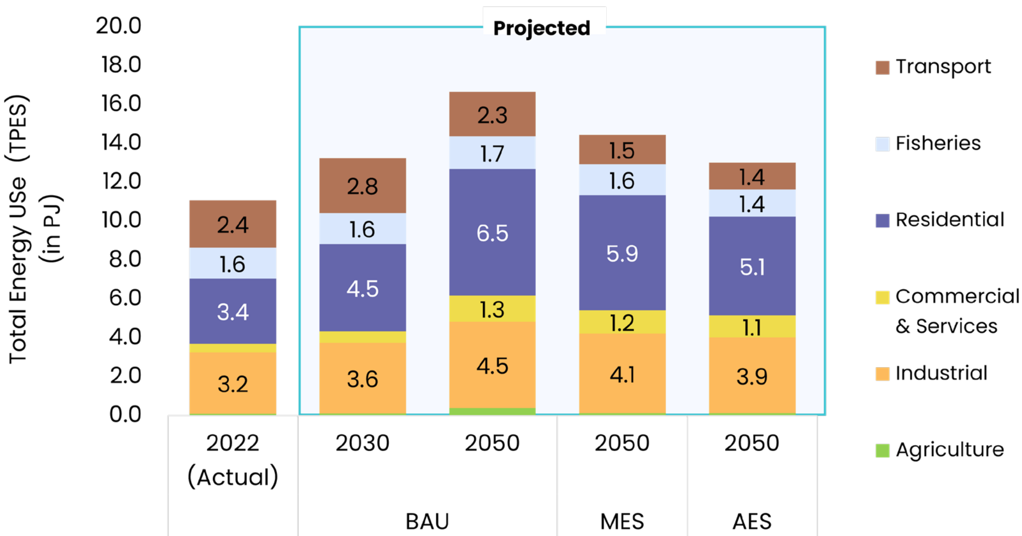


Figure 5.12: Projected Sector wise TPES, across scenarios, in PJ

Energy efficiency vehicles and equipment across sectors are projected to reduce TPES even as electrification drives electricity demand

3. Emissions from the Energy Sector:

Figure 5.13 illustrates the projected total GHG emissions from the energy sector up to 2050. GHG emissions from this sector are expected to decrease significantly, from 1,247 ktCO_2e in 2022 to 726 ktCO_2e by 2050, marking a 42 percent reduction. The primary drivers of this reduction are the timely retirement of all gas-based public electricity generation plants and the accelerated adoption of electric vehicles (EVs).

In 2022, the Public Electricity Generation (PEG) sector accounted for approximately 45% of energy-related emissions. By 2050, its emissions are projected to drop to nearly zero, reflecting the complete phase-out of fossil fuel-based generation. The transport sector, which was the second-largest emitter in 2022 with a share of 18 percent, will see its share of emissions rise to 22 percent by 2050. However, in absolute terms, emissions from the transport sector are expected to decline from 225 ktCO_2e to 155 ktCO_2e.

The industrial sector including the Captive Power Plant (CPP) contributed 18 percent of energy-related emissions in 2022. Under the BAU scenario, its share is projected to increase to 40 percent by 2050, with absolute emissions rising from 209 ktCO_2e in 2022 to 271 ktCO_2e by 2050 due to increasing fossil fuel consumption.

The building sector's emissions, driven mainly by the use of LPG and PNG, are projected to grow from 9 percent to 17 percent of total energy-related emissions by 2050. In absolute terms, emissions will increase from 110 ktCO_2e in 2022 to 132 ktCO_2e by 2050.

Under alternate scenarios, the industrial, agricultural, fisheries, and CPP sectors are projected to achieve full decarbonisation by 2050, facilitated by a deep decarbonisation approach

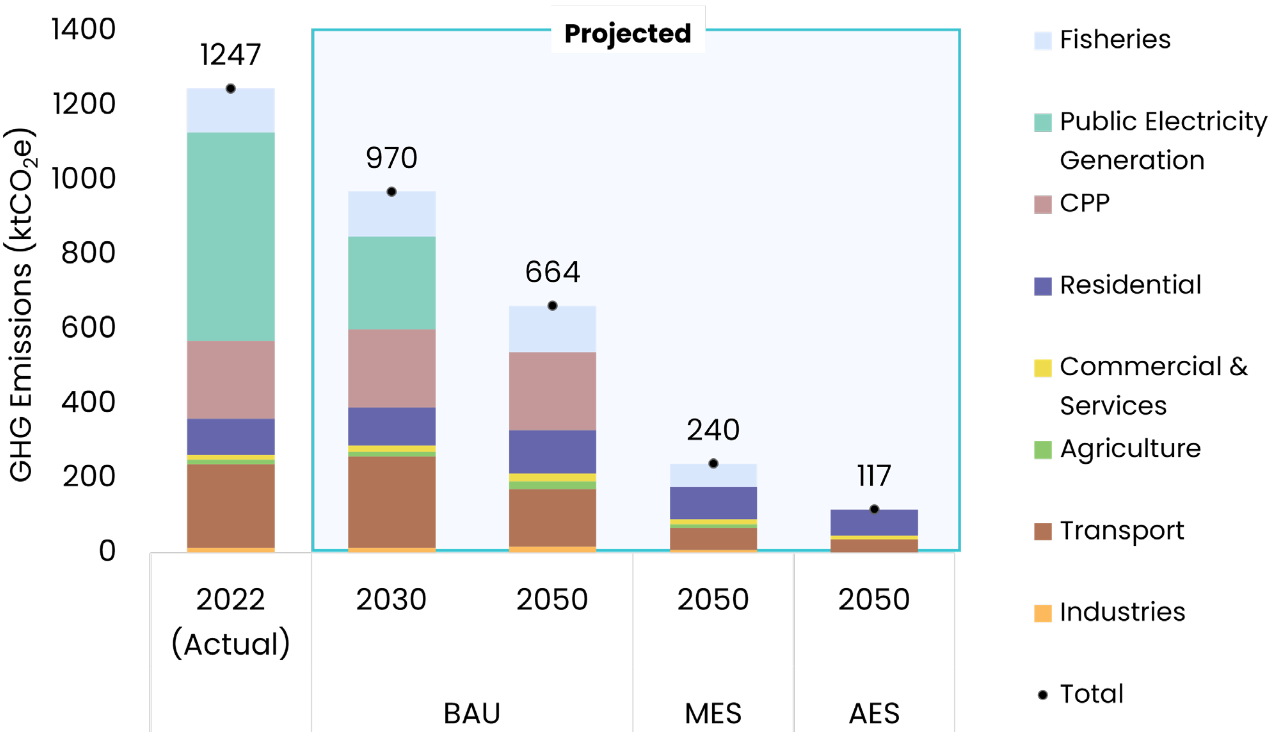


Figure 5.13: Projected sector wise emissions, across scenarios, in ktCO_2e

Energy emissions could be reduced by 90 percent with effective decarbonisation strategies across sectors

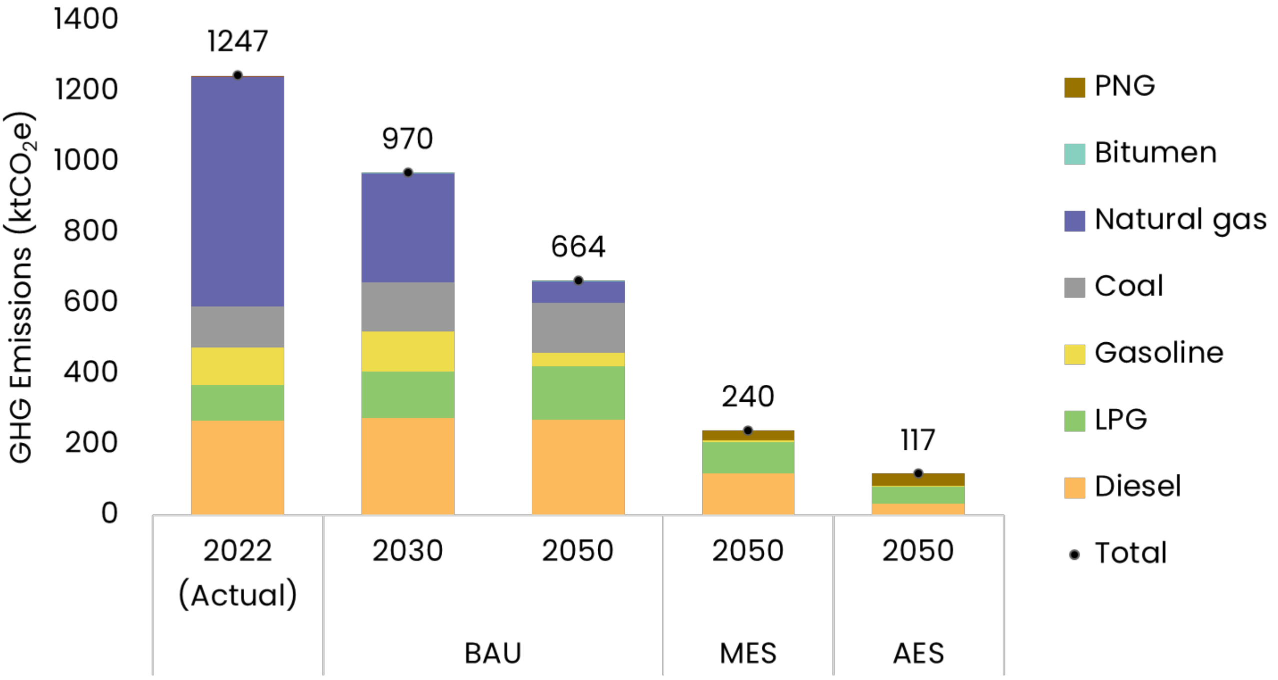


Figure 5.14: Projected fuel wise emissions, across scenarios, in $ktCO_2e$

As a result of decarbonisation efforts, emissions from diesel, natural gas and coal – accounting for 84 percent of the total emissions in 2022 – can be completely abated by 2050

5.2 Projection of Emissions from Non-energy Sectors

5.2.1 Livestock

The GHG emissions from livestock management contributed 22 percent of the AFOLU emissions. Enteric fermentation and manure management respectively accounted for 94 percent and 6 percent of these livestock emissions. Under BAU, the GHG emissions are projected to increase from 147 $ktCO_2e$ in 2022 to 257 $ktCO_2e$ in 2050 due to the projected increase in the livestock count. (Figure 5.15)

The emissions from the livestock could be significantly reduced through the implementation of balanced rationing[50] and feed additives[51] to control methanogens[52] and through manure management. By 2050, in MES, emissions are expected to decrease from 257 kt CO_2e under BAU to 212 kt CO_2e and further to 186 kt CO_2e in AES. The decadal implementation is as detailed in Annexure 4.

Other Interventions that could further abate livestock emissions are

a. Use of improved feed supplements for suppressing methanogens.

b. Promotion of better/efficient manure management practices, like biogas production from cattle manure by endorsing Gobar-Dhan scheme.[53]

c. Promotion of non-cattle (sheep, goat, donkey) dairy products.

d. Encouraging and subsidising large-scale cattle farming with advanced feed and manure management.

e. Training and promotion of balanced rationing, such as Ration Balancing Programme (RBP)-initiative of National Dairy Development Board.

f. Promotion of aerobic management of cattle manure such as composting or direct application to the soil.

71 $ktCO_2e$
of Decarbonisation Potential by 2050

Stakeholders:

Animal Husbandry and Dairy Development Department

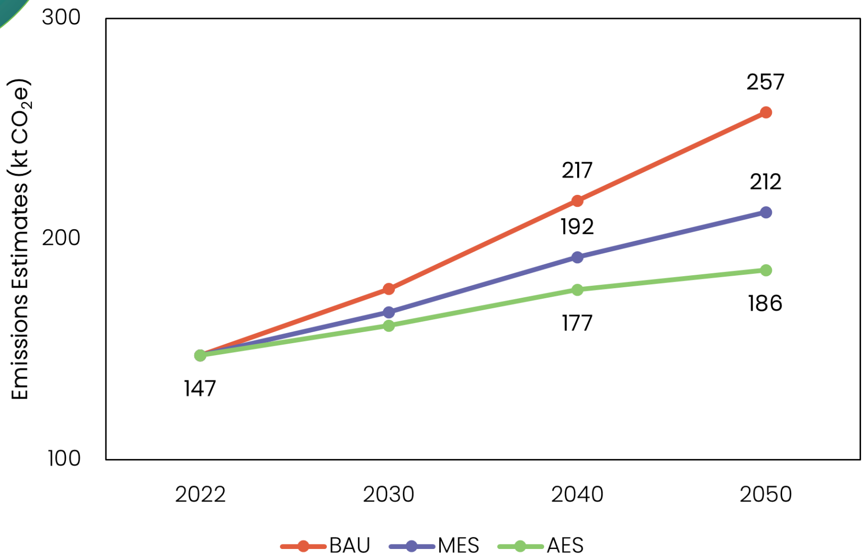


Figure 5.15 : Projected emissions from Livestock under various scenarios

Box Item 6

Climate resilient livestock management

Climate resilience of livestock management involves adopting strategies and practices that help livestock and farming systems withstand, adapt to, and recover from the impacts of climate change. Extreme heat and increasing atmospheric CO_2 levels affect livestock by impacting their feed, water availability, growth and reproduction, apart from increasing the susceptibility to vector-borne diseases.

Interventions:

- Select or develop livestock breeds that are naturally more resilient to extreme weather conditions, such as heat-tolerant or drought-resistant breeds. Indigenous breeds often have traits that make them more adapted to local climates.
- Provide shade, ventilation, and cooling systems (such as fans or sprinklers) in animal housing to reduce heat stress. Properly designed shelters can significantly lower the risk of heat-related illnesses and improve animal welfare.
- Implement water conservation practices and efficient water use strategies, such as rainwater harvesting, to ensure a reliable water supply for livestock during droughts.
- Integrate trees into grazing areas (silvopasture) to provide shade, reduce heat stress, and improve forage availability. Trees also contribute to soil and water conservation.
- Enhance disease surveillance and monitoring to detect and respond to emerging health threats, which may become more prevalent due to changing climates, such as vector-borne diseases.
- Adopt better grazing practices in pastures and hygienic environments
- Ensure complete nutrition requirement is met through the feed by implementing balanced rationing related schemes.
- Periodic veterinary camps to prevent spread of diseases
- Consider livestock insurance to mitigate financial losses due to climate-related events such as drought, floods, or disease outbreaks.
- Provide support for alternative livelihoods, such as algae culture, fish farming, etc., in case livestock farming becomes unsustainable due to severe climate impacts.

5.2.2 Agriculture Soils

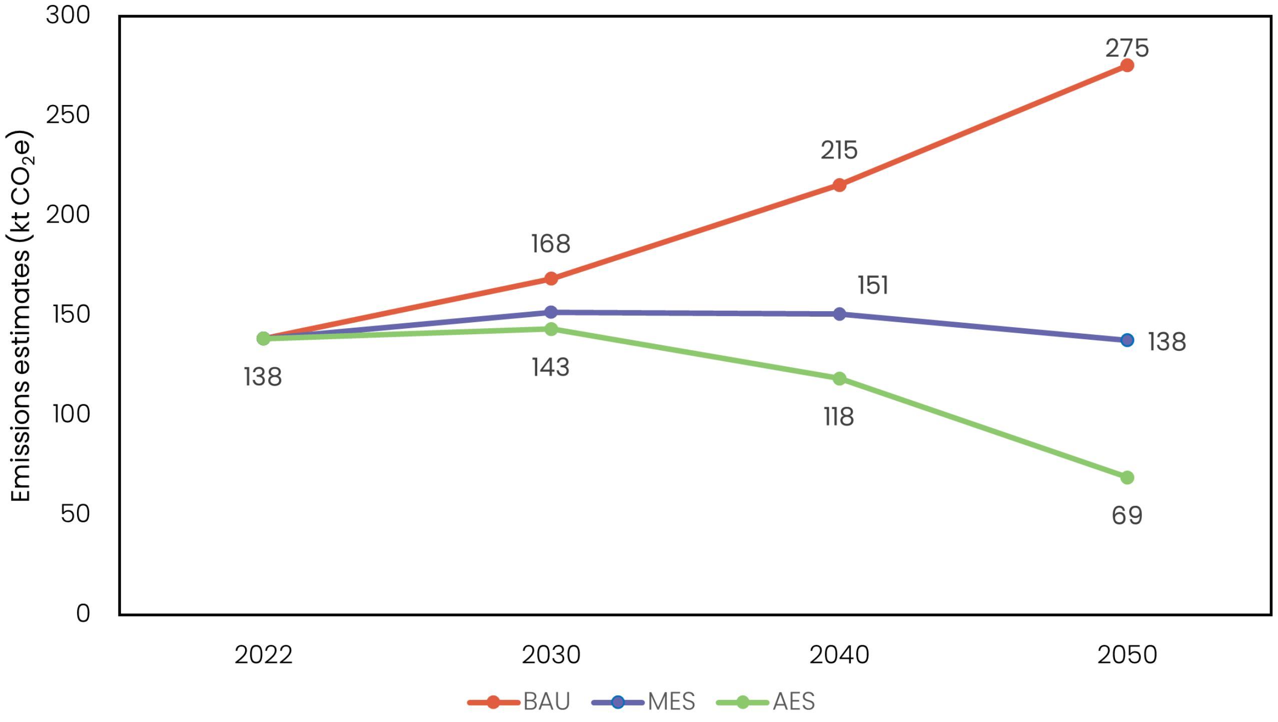


Figure 5.16 : Projected emissions from Agriculture Soils under various scenarios

Emissions from the agriculture soil mainly arise due to the use of synthetic nitrogen fertilisers and urea, and are projected to increase two times from 138 ktCO_2e in 2022 to 275 ktCO_2e in 2050. Nitrogen fertiliser consumption is projected[54] to increase from 46 kt in 2022 to 91 kt in 2050, while Urea consumption is projected[55] to increase from 19 kt in 2022 to 57 kt in 2050.

Substitution with organic fertilisers and nano urea can potentially reduce the GHG emissions arising from the use of synthetic fertilisers. Nano fertiliser[56] has the potential to regulate the release of nitrogen (N) for an extended period (20 days) in comparison to the conventional urea fertiliser (9 days). The slow and steady release of nitrogen assists in the reduction of nitrous oxide emissions by 50 percent in nano-fertiliser fertilised soils.[57]

Adoption of organic farming practices can not only decrease GHG emissions but can increase yield over the long-term. Shift to organic farming can contribute significantly towards the improvement of soil health by increasing soil nutrient mineralisation, microorganism abundance, diversity as well as soil physical properties. Farmer support including strengthened extension services with easy access to inputs, together with the development of robust markets for organic produce, certification and branding is recommended, to incentivize farmers to take up organic farming.[58]

In MES, an emission reduction of 50 percent from 275 kt CO_2e in BAU to 138 kt CO_2e by 2050 is estimated by replacing 50 percent of total nitrogen and urea by organic fertiliser and nano urea to meet the remaining urea requirement.

In AES, an emission reduction of 75 percent from 275 kt CO_2e in BAU to 69 kt CO_2e by 2050 is estimated by replacing 75 percent of total nitrogen fertiliser and urea by organic fertiliser and nano urea to meet the remaining urea requirement. See Annexure 4 for the details on organic fertiliser and nano urea substitution.

In addition, it is also recommended to:

- Promote and encourage use of bio-pesticides and 'zero budget natural farming' practices.
- Encourage use of decision support tools for effective input/nutrient management.

206 $ktCO_2e$
of Decarbonisation Potential by 2050

Stakeholders:

Individual Farmers / Farmer Producer Organisation (FPO), Agriculture department, Horticulture department

5.2.3 Rice Cultivation

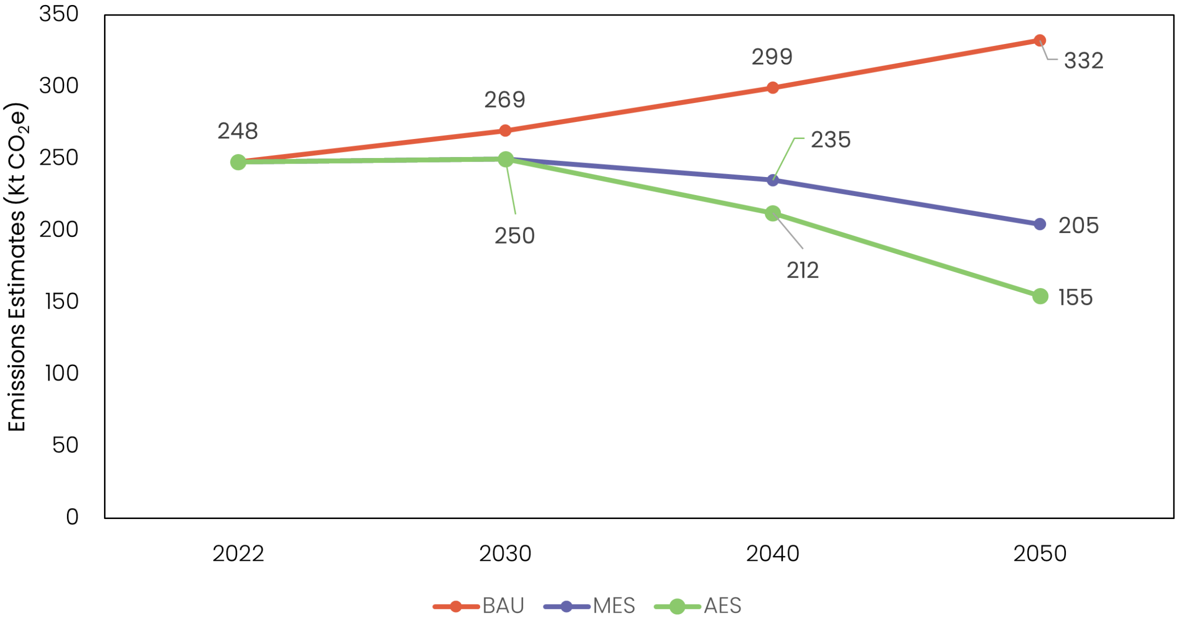


Figure 5.17 : Projected emissions from Rice Cultivation under various scenarios

Paddy cultivation is one of the significant sources of methane emissions in the agriculture sector. Methane emissions arise due to anaerobic decomposition of organic materials in flooded paddy fields. The rice cultivation water regimes followed in Ramanathapuram district is assumed to be the same as that for Tamil Nadu which is continuous flooding (30%), single aeration (43%), multiple aeration (20%), upland (1%), rainfed drought prone (3%), rainfed flood prone (1%) and deep water (1%).[59]

Emissions from rice cultivation are projected[60] to increase 1.3 times from 248 $ktCO_2e$ in 2022 to 332 $ktCO_2e$ in 2050 in the BAU scenario. These could be reduced by promoting multiple aeration water regimes over the more prevalent single aeration and continuous flooding. The methane emission factor for multiple aeration (18 kg CH4/ha) is nine times lower than that of continuous flooding (162 kg CH4/ha) and four times lower than single aeration (66 kg CH4/ha). Aeration results in reduced methane emissions by (i) reducing the activity of the methane-emitting microorganisms in the top soil as well (ii) promoting the growth of methane metabolising microorganisms. The details of the water regime recommended under MES and AES are as described in Annexure 4.

In MES, where multiple aeration is recommended in 60% of the cultivated area by 2050, emissions are projected to decrease from 332 $ktCO_2e$ to 205 $ktCO_2e$. In AES, with 77 percent of the rice cultivation following a multiple aeration water regime, by 2050, emissions are projected to decrease from 332 $ktCO_2e$ to 155 $ktCO_2e$ (see Figure 5.17).

In addition, it is also recommended to:

- Practice System of Rice Intensification (SRI), which presents an efficient approach to address methane emissions through a nature-centric method. It promotes aerobic soil conditions by employing Alternate Wetting and Drying (AWD). This technique permits the soil to come into contact with oxygen, effectively neutralising methanogens. Additionally, SRI has demonstrated the ability to increase aerobic bacteria, specifically methanotrophs, which actively consume methane. Moreover, the technique has the potential to enhance rice yield by 36-49 percent with about 22-35 percent less water than conventional transplanted rice.[61]

- Direct Seeded Rice serves as an effective strategy for mitigating methane emissions in rice cultivation. This method minimises methane release by eliminating the need for raising nurseries, puddling, and transplanting. In contrast to traditional transplanted paddy cultivation, the system doesn't maintain standing water.[62]

177 $ktCO_2e$
of Decarbonisation Potential by 2050

Stakeholders:

Individual Farmers / Farmer Producer Organisation (FPO) , Agriculture department, Environment and Climate Change department

5.2.4 Waste Sector

The Waste sector contributed 4 percent to the economy-wide emissions of the Ramanathapuram district in 2022. Within the waste sector, the largest contributor was the domestic wastewater category (~77%), followed by Solid Waste Disposal (~15%) and Industrial Wastewater (~8%). Under BAU, the emissions from the waste sector are projected to decline from 78 $ktCO_2e$ in 2022 to 76 $ktCO_2e$ in 2050.

Domestic Wastewater

The characteristics of domestic wastewater and the associated GHG emissions vary depending on factors such as economic status, community food intake, water supply status, treatment systems and climatic conditions of the area. The GHG emissions from the wastewater management are estimated to increase from 60 $ktCO_2e$ in 2022 to 61 $ktCO_2e$ in 2050 under BAU, resulting from ~169 million liters per day (MLD) of wastewater generated (at a BOD of 350 mg/L[63]) based on the projected population. As of 2025 , the centralised treatment capacity stands at 11.08 MLD[64], with a utilisation of 6.9 MLD ,12.5 MLD of STP is proposed in Parmakudi and 1 MLD is under construction in Mudukalathur. Additionally, 0.075 MLD FSTPs are also present in Ramanathapuram. Therefore, a treatment capacity of ~72 MLD (~20% excess) is recommended for urban and 101 MLD for rural areas for effective management and recycling. For urban areas, centralised sewage treatment[65] such as the activated sludge process[66] is suggested, while onsite treatment[67] such as septic tanks along with FSTPs[68] at Gram Panchayat cluster level is recommended for rural areas in Ramanathapuram. Additionally, advanced decentralized wastewater treatment (DEWAT) is recommended for spaces >2500 m2 and other isolated facilities such as resorts, restaurants, etc.

MES aims at treating 100 percent of wastewater by 2050, thereby reducing the projected GHG emissions from 61 kt CO_2e under BAU to 13 kt CO_2e and an ambitious target of 100 percent treatment by 2040 is set for AES, where in the BAU projected emissions would reduce to 13 kt CO_2e by 2040 (see Figure 5.18 (a)). The decadal plan is as detailed in the Annexure 4.

The recommended wastewater treatment plan contributes to several state and national programs towards improving public health and especially to the targets set by honorable NGT in OA-673.[69] Currently, a Memorandum of Understanding (MoU) has been established between the ULBs and the

48 $ktCO_2e$
of Decarbonisation Potential by 2050

Stakeholders:

Municipal Administration and Water Supply department, Tamil Nadu Water Supply and Drainage Board, Tamil Nadu Pollution Control Board, Rural Development and Panchayat Raj department

Municipal Administration and Water Supply department, Tamil Nadu Water Supply and Drainage Board, Tamil Nadu Pollution Control Board, Rural Development and Panchayat Raj department

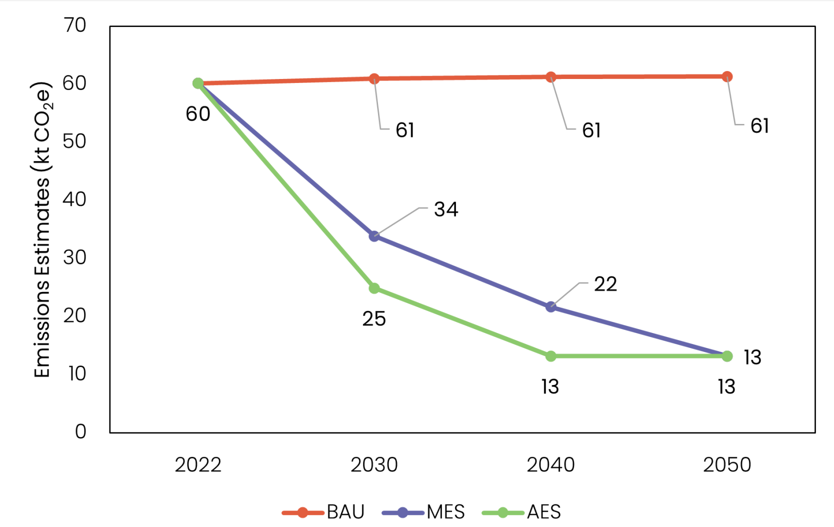


Figure 5.18: Projected emissions from Domestic Wastewater under various scenarios

Box Item 7

Domestic Wastewater Management

In Ramanathapuram, the growing urban settlements and tourism infrastructure to cater the increasing year-round tourist footfall, along with heavy seasonal influx, highlight the need to strengthen the domestic wastewater management systems. Avoiding untreated wastewater discharge is critical to safeguard the sensitive ecosystems in the region, including Ramsar designated wetlands and the rich biodiversity habitats along the Gulf of Mannar coast.

KInterventions

- Set up adequate decentralised wastewater treatment facilities (DEWAT) at remote housing entities (resorts/camping grounds/homestays).
- Increase household connections to underground drainage (UGD) in urban areas and promote septic tank-based wastewater treatment for remote houses.
- Ensure FSTP facility at the GP cluster level.
- Ensure that untreated wastewater is not discharged into rivers/lakes and other water bodies.
- Periodic scouting of the water body periphery to check the discharge of untreated wastewater and penalising the violators.
- Ensure Underground Drainage (UGD) connection within the township to the respective STP to avoid ground and surface water body contamination.
- Zero discharge policy[70] for commercial and residential entities within the township boundary.
- Promote non-potable usage of treated wastewater (gardening, parks, golf courses, car wash).
- Regular water quality testing and monitoring to ensure the treatment standards
- Regulations for the use of treated water discharged from the STPs.

Solid Waste

The GHG emissions from solid waste are projected to decrease from ~11.65 kt CO_2e to ~8.68kt CO_2e between 2022 and 2050 in the BAU scenario (see Figure 5.19 (b)). By 2030 in MES, with Ramanathapuram district, segregating and managing 100 percent of the municipal solid waste and sending 0% to landfills/dumpsites, GHG emissions from solid waste could further be reduced by 98 percent, dropping from 8.68 kt CO_2e to just 0.21 kt CO_2e by 2050.

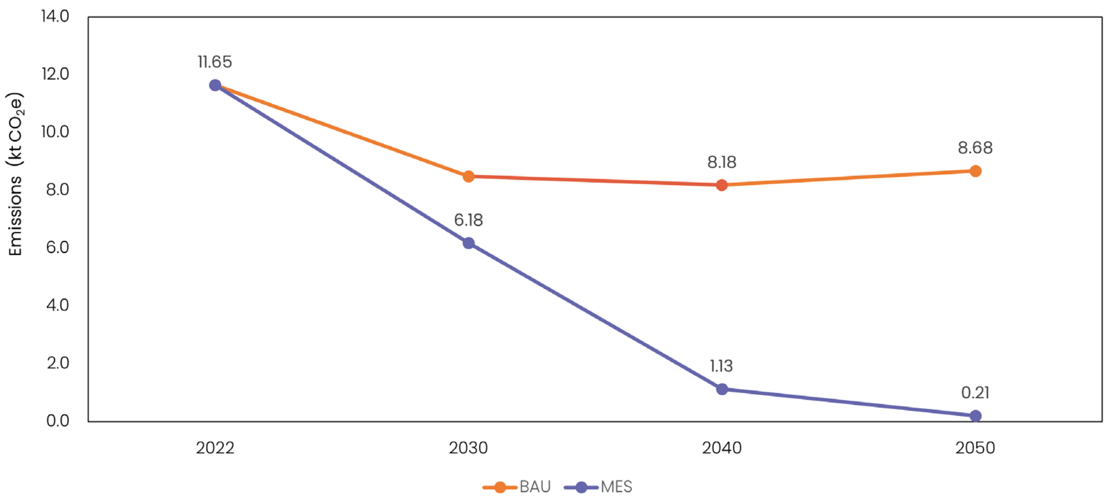


Figure 5.19: Projected emissions from Solid Waste under various scenarios

8.48 ktCO$_2$e
of Decarbonisation Potential by 2050

Stakeholders:

Municipal Administration and Water Supply department, , Tamil Nadu Pollution Control Board, Rural Development and Panchayat Raj department

Box Item 8

Solid waste management

Ramanathapuram district is a global tourist attraction with renowned places like Rameswaram temple, Pamban Bridge, Dhanushkodi and Dr APJ Abdul Kalam's memorial, handling a floating tourist population of approximately 20,000 per day which might peak to more than 50,000 during holidays or festivals. The tourism sector creates an imposing challenge for waste management in the district, adding to the existing industries and domestic population. Some key issues and interventions pertaining to tourism and local waste management are as follows,

Interventions for Solid Waste Management:

- Encourage 100% segregation and collection of waste at source at both rural and urban areas.
- Ensure adequate placement and management of waste collection bins, segregation centres.
- Install community waste bins with sensors to monitor volume and optimize routes of waste collection vehicles.
- Encourage and promote decentralised, community-based composting, vermi-composting and biogas plants at residential and commercial entities (hotels / resorts / homestays).
- Set up and incentivise dry waste collecting centres at village/panchayat level.

- Incentivise the informal sector and build public-private partnerships for segregation, collection and disposal of waste.
- Develop waste management knowledge banks, theme centres, and audio/visual promotions.
- Promote resource utilisation and entrepreneurship focusing on waste reuse, recycle and recovery.
- Facilitate and conduct behaviour change communications workshops on appropriate disposal of solid waste
- Facilitate infrastructure creation for waste to energy plants.
- Promote Biomining[71] of legacy waste at the administrative level.
- Facilitate cleaning of dumpsites and encourage development of eco parks.
- Promote zero waste,[72] zero carbon footprint[73] , organic thematic centres (restaurants / home stays).

Tourism industry:

- Ensure proper waste management at tourist hotspots through appropriate sign boards, surveillance and penalty to avoid littering and throwing of waste.
- Facilitate dry and wet waste bin placement, collection and management of waste in strategic tourist locations.
- Ensure timely and regular collection of waste to avoid overflow and assign staff specifically for waste management, ensuring efficient collection and transportation.
- Encourage the use of reusable items like cloth bags, leaf bowls, etc. and discourage single-use plastics.
- Declare no plastic, zero litter zones, etc.
- Limit the use of non-biodegradable materials in religious offerings (eg. packaging).
- Promote eco-tourism and the concept of "Responsible Tourism[74] "
- Facilitate and conduct "Sustainable Consumption" awareness campaigns
- Engage local volunteers or community groups to monitor and guide proper waste disposal.
- Regularly audit the waste management system to identify areas for improvement.
- Develop a sophisticated Sewage network with suitable capacity STPs at designated locations in and around the Agnitheertham beach location to avoid sewage flow into the sea.
- Promote Deposit Refund System[75] for managing plastic waste in the temples, beaches, bird sanctuaries and tourist spots in and around Gulf of Mannar Biosphere Reserve areas.

Special events (fares, celebrations):

- Develop a special waste management plan for large religious festivals or events that attract massive crowds.
- Set up additional waste disposal and management facilities during peak times.
- Explore waste management outsourcing through Public Private Partnership (PPP) mode.
- Ensure strict regulation, surveillance and penalty for violators.
- Set up onsite composting units for biodegradable waste like flowers, leaves, and food waste. Install biogas plants to convert organic waste into energy.
- Ensure a waste management plan before event permission sanction.

Box Item 9

Harnessing Ramanathapuram's waste-to-energy potential can save 135 GWh of electricity demand, abating 108 ktCO_2e GHG emissions by 2050

Ramanathapuram district, with its large livestock population, holds significant potential for biogas production, capable of generating an estimated 15,000 m³/day of biogas (from a potential of 30,000 m³/day at 50% efficiency). This can contribute to clean energy, including compressed biogas (CBG), and mitigate 28 ktCO_2e of greenhouse gas emissions annually. As an agricultural area, the district also produces substantial crop residues (an estimated 3,68,668 tonnes per year) from crops like paddy, cotton, groundnuts, sugarcane, and coconut. These residues can be converted into electricity through biomass power plants, with the potential to generate 36–52 MW of electricity, yielding 90–130 GWh of energy per year and offsetting 68–97 ktCO_2e of greenhouse gas emissions. Furthermore, Ramanathapuram's municipal waste offers another avenue for power generation; in 2022, the district processed about 30 tons of biodegradable waste daily, which could power a 1 MW plant, generating roughly 4 GWh of energy annually and reducing emissions by approximately 5 ktCO_2e. Collectively, the utilisation of these waste streams presents a robust pathway for Ramanathapuram to enhance clean energy generation, improve waste management, and significantly reduce its carbon footprint.

Industrial Wastewater Treatment

In 2022, industrial wastewater emissions from meat processing and fish processing in Ramanathapuram district accounted for 6 ktCO_2e. The MES scenario targets a 60 percent wastewater treatment rate by 2050, which will reduce GHG emissions from 6 ktCO_2e to 2 ktCO_2e. The AES scenario aims for an 80 percent treatment rate by 2050, further lowering emissions to 1 ktCO_2e. Based on the production data, meat and fish processing produced 1.13 and 2.9 MLD of wastewater, respectively in 2022.

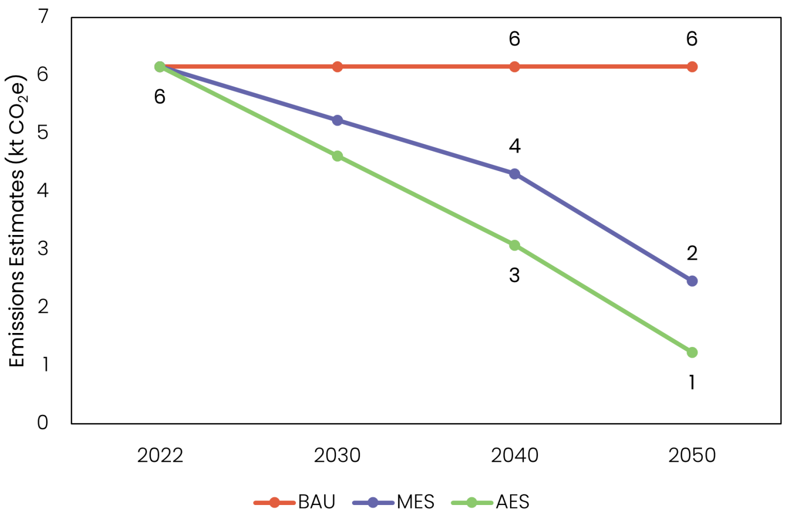


Figure 5.20: Projected emissions from Industrial Wastewater under various scenarios

5 ktCO_2e
of Decarbonisation Potential by 2050

Stakeholders:

Environment and Climate Change department, Tamil Nadu Pollution Control Board, Individual Industries

The emissions from industrial wastewater could be further reduced by the following interventions.

Box Item 10

Industrial Wastewater Management

Ramanathapuram is an industrially underdeveloped district, but still has around 700 MSMEs involved in the manufacturing sector. Charcoal production and seafood processing are predominant in the district apart from a few chemical and leather industries. The chief water polluting industries in the district are meat and fish processing industries. Mining activities in the district include gravel, rough stone, along with oil and natural gas. The key issues from these industrial and mining activities in the district are the air, water, soil, and noise pollution induced by them. The discharge of effluents and waste from the processing units directly into the sea and other water bodies is a threat. Some of the key interventions for industrial wastewater management in the district are as follows,

- Adopt Zero Liquid Discharge process by the industries.
- Increase the Effluent Treatment Plants with higher capacities, and also sludge waste treatment[76]
- Encouraging the installation of Online Continuous Emission/Effluent Monitoring System (OCEMS) in the industries

Meat Processing Industry:

- Setup adequate common effluent treatment plants (CETPs) in areas with a high number of small meat processing industries.
- Mandating pre-treatment of wastewater from meat/poultry processing plants prior to the discharge to CETPs
- Sludge management and disposal
- Installation of monitoring/instrumentation mechanisms to ensure the reduction of BOD, COD, Total Suspended Solids (TSS) and Fats, Oils and Grease (FOG) to permissible levels before sewer discharge

Seafood Processing Industry:

- Prohibit discharge of effluents into sea
- Physical screening to remove suspended solids
- Recovery of materials with industrial significance and byproducts from wastewater
- Reusing the recovered materials in other industries such as agrochemical and pharmaceutical industries.
- RE powering the storage systems for processed seafoods

Other best practices for Industries and Mining:

- Proper segregation and disposal of waste and solid leather scraps from Municipal Solid Waste.
- Alternate raw materials/Sustainably sourced wooden raw material- (wood and hazardous chemicals) that have lesser emission potential for leather (chemical) industries
- Greener captive energy consumption by the industries.
- Develop green belt and plantation in undisturbed areas of the mines.
- Plant rows of native trees as acoustic barriers around mines, roads and other noise generating centres.
- Adopt and maintain air silencers of suitable type which can modulate the noise of the machinery's engine to reduce the noise pollution arising from mining.

5.2.5 Enhancing Carbon Sequestration Potential in Ramanathapuram

The total GHG emissions of Ramanathapuram were 1,999 ktCO_2e in 2022, while the sector of 'Land Use, Land Use Change and Forestry' (LULUCF) removed a negligible amount of 153 tCO_2e . For effective decarbonisation of the district, along with the measures to reduce the GHG emissions, efforts to enhance carbon sequestration are very pertinent.

If the existing forest cover of 242.34 square kilometers and the current carbon stock density of 82.25t/ha are preserved without any deforestation, forest fires, or land degradation, the GHG emissions are projected at 138 ktCO_2e by the year 2050 under a BAU scenario. This projection assumes that no significant changes occur in land use practices or forest management.

To offset the GHG emissions of the district, strategies for enhancing land-based sequestration and blue carbon sequestrations are suggested.

Land based carbon sequestration: Ramanathapuram has a forest cover of 6.12 percent (significantly lower than Tamil Nadu's average forest cover of 20.31 percent) and the area under the forest cover has decreased from 303 sq.km in 2010 to 242.34 sq. km in 2021. Further, the carbon stock density of Ramanathapuram forests (i.e Tamil Nadu's carbon stock density) has decreased from 87.26 tonnes/hectare in 2015 to 82.25 tonnes/hectare in 2021[77]. In addition to this, 2,19,383 ha of land in Ramanathapuram is barren or fallow or cultivable waste land or land put to non-agricultural uses accounting to 53.65 percent of the total geographical area. Ramanathapuram is the only district in the state to have 5 bird sanctuaries and 5 Ramsar sites.

Blue carbon capture: Blue carbon refers to the carbon captured and stored in coastal and marine ecosystems such as mangroves, seagrasses, and salt marshes. Along with hosting a wide range of biodiversity, these ecosystems play a crucial role in sequestering carbon dioxide from the atmosphere and storing it in biomass and sediments. Recent studies estimate carbon storage in the top 1 meter of soil to be approximately 1,030 megagrams of CO_2e per hectare (Mg CO_2e/ha) for estuarine mangroves and 920 Mg CO_2e/ha for tidal marshes/wetlands. There are 13 mangrove blocks spread across an area of 607 hectares, in Ramanathapuram. The current status of mangroves in Ramanathapuram presents a crucial opportunity for blue carbon capture through wetland and mangrove restoration.[78] Tourism, shrimp farming, changes in land use pattern, rising sea level, pollution from agricultural runoff and industrial waste are few major threats for mangrove forests in Ramanathapuram. Therefore, protecting and restoring mangroves through sustainable management practices, conservation initiatives and policies are essential for the ecosystem.

Interventions for enhancing sequestration potential of land and blue carbon:

The carbon sequestration of Ramanathapuram (153 tCO_2e) could be enhanced to 603 ktCO_2e/year and 944 ktCO_2e/year under MES and AES through following interventions that focus on land and blue sequestration:

1. **Promoting social and agroforestry in land classified as barren or fallow, land put to non-agricultural uses and cultivable waste land**

A total of 2,19,383 hectares of land is either barren, fallow, cultivable waste, or used for non-agricultural purposes, making up 54 percent of the total geographical area. These land areas are well-suited for agroforestry practices [79]. To implement these agroforestry practices and increase carbon sequestration, two scenarios are suggested in phases across 2030, 2040, and 2050.

MES considers conversion of 25 percent to 35 percent of the total fallow land area (2,19,383 hectares), with a dedicated area of approximately 64431 hectares into social and agroforestry and is projected to sequester approximately 567 ktCO_2e by the year 2050.

AES, on the other hand, expands this vision by considering 40% to 50% of the same total fallow land area, with a dedicated area of 99597 hectares and is anticipated to achieve a carbon sequestration potential of around 876 ktCO_2e within the same time frame.

Box Item 11

Social Forestry

Social forestry in fallow and waste lands is a community-centred approach to managing forests that integrates social, economic, and environmental objectives. Active participation of local communities in the planning, implementation, and management of forest resources is essential. Along with the social benefits such as food security, community empowerment, cultural preservation, health and nutrition benefits, social forestry could effectively contribute towards enhancing biodiversity, soil health, microclimate regulation, carbon sequestration, water conservation, pollution reduction and improve the mental health of the citizens.

- Encourage community/farm/village forests.
- Involve local communities in decision-making processes related to forest management, ensuring that their needs and knowledge are respected and utilised.
- Involve schools and academic institutions, especially children and young adults.
- Training and support to effectively manage forest resources and engage in sustainable practices.
- Analyse soil type, fertility and water availability and choose appropriate species.
- Promote tree diversity and opt for trees that offer multiple benefits, such as timber, fruit, fodder, or nitrogen fixation.
- Increasing tree cover outside the forest area. In addition to agroforestry, measures such as planting avenue trees and implementing social forestry in upcoming towns, municipalities can increase the carbon uptake along with shade, oxygen and pollutant absorption benefits.

2. Enhancing Carbon Stock Density

- In 2021, the carbon stock density of the Ramanathapuram forest was measured at 82.25 tons per hectare (t/ha), compared to 87.26 t/ha in 2015. To reach carbon stock densities near the 2015 level by 2050, two scenarios have been proposed: MES aims for a 3 percent increase from 82.25 t/ha to 84.76 t/ha, while AES targets a 5.5 percent increase from 82.25 t/ha to 86.76 t/ha. Achieving these targets could potentially sequester 9 ktCO_2e in MES and 13 ktCO_2e in AES.

Box Item 12

Safeguarding Forest Ecosystem for Climate Resilience and Carbon Sequestration in Ramanathapuram

- Reforestation and Afforestation: Planting trees in deforested or degraded forest patches by selecting native species adapted to the local climate and ecosystem, controlling invasive species and ensuring regular maintenance and monitoring.
- Improved Forest Management: Implementing sustainable forest management practices such as minimising forest degradation through selective logging, protecting old-growth forests, and promoting natural regeneration; preventing forest degradation activities such as illegal logging and forest fires, promoting sustainable collection of forest produce.
- Monitor and remove encroachment of forest land.
- Use of satellite imagery and other modern technology to identify encroachment, illegal construction and plantation health, threat from invasive tree species etc.
- Mark and place appropriate boundaries for the forest lands.
- Install strategic check-points.
- Promote social and agroforestry.
- Promote and sponsor awareness, plantation and logging activities in the forest areas that are more susceptible to waste littering and dumping.

Additionally, forest fire management should be carried out through:

- Strategic controlled burning, where patches of the grassland are burnt at regular intervals in high forest fire susceptible zones to avoid spreading of fire across a big area, would reduce the burn extent.
- Install strategic watch stations to monitor wildfires.
- Formalise protocol for fire control and ensure immediate access to fire extinguishing equipment.
- Establish a protocol for the use of helicopters for dousing bigger fires across forests and sholas.
- Ground mapping and integration of remote sensing technology to identify fire-prone areas in the forest.

3. Restoration of Mangroves, Wetland, Seagrass and Seaweed

- The current mangrove stretch of Ramanathapuram is 607 ha [80]. Assuming a 25 percent and 50 percent increase in mangrove coverage by, an additional 152 and 304 hectares in MES and AES respectively, along with proper maintenance, the carbon sequestration potential from mangrove restoration in Ramanathapuram is projected to reach 14 ktCO_2e in MES and 28 ktCO_2e in AES by 2050.
- Seagrass meadows are vital marine ecosystems known for their ability to sequester carbon by capturing carbon dioxide from the atmosphere and store it in their roots and sediments. Remarkably, one square kilometre of seagrass has the potential to sequester 0.44 gigagram of carbon annually.Seaweeds are marine algae, ranging from small, delicate forms to large, complex organisms like kelp are also essential part of marine ecosystems, providing habitat, food, and oxygen to a variety of marine life. A single hectare of seaweed has the capacity to sequester 1.4 tonnes of CO_2 annually. Thus, if a 10 and 20 square kilometer area of seagrass and seaweed is expanded together under MES and AES with a 75 percent survival rate , it could potentially sequester 13.2 ktCO_2e and 26.3 ktCO_2e respectively by 2050.

Fig. 5.21 Carbon Sequestration potential in Ramanathapuram under various scenarios

944 ktCO_2e
of Decarbonisation
Potential by 2050

Stakeholders:

Environment and Climate Change department, Forest department, Municipal Administration and Water Supply department, Fisheries department

Box Item 1 3

Marine ecosystem management

Ramanathapuram district has the highest wetland cover in the state of 73,808 hectares, which is 18.05 percent of its district geographical area. The Gulf of Mannar region, which lies across the coast of Ramanathapuram district, is endowed with three distinct coastal ecosystems, namely seagrass bed, coral reefs and mangroves. It is one of the richest marine biodiverse regions globally, being a home to 4223 species of flora and fauna. Some of the key strategies for wetland restoration and protecting the biodiversity in the Gulf of Mannar region are listed below.

Strategies to Restore Mangroves and Wetland Include:

- Hydrological Restoration: Restoring natural water flow patterns by removing or modifying dams, dikes, or levees, wherever possible. Reconnecting mangroves and wetlands to their historical water sources, such as rivers, streams, or groundwater, can help recreate natural hydrological cycles to facilitate nutrient uptake, resulting in natural restoration.
- Pollution Prevention: Preventing the inflow of raw sewage to the natural mangrove forests and adapting integrated approaches wherein mangroves and wetlands are used as tertiary treatment options after the sewage has undergone primary and secondary treatment in STPs and meets the treated water standards.
- Vegetation Management: Selecting appropriate native tree/plant species that are adapted to local conditions helps stabilise soil, filter pollutants, and provide habitat for wildlife. Regular monitoring of hydrology, vegetation, wildlife, and water quality helps assess the success of restoration efforts and identify any necessary adjustments.
- Soil Restoration: Dredging to remove mixed waste (especially non-degradable and toxic) and application of soil amendments such as organic matter, compost, or mulch can help improve soil structure, fertility, and moisture retention.
- Controlling Invasive Species: Mechanical removal, herbicide application, or biological control to manage invasive species that otherwise outcompete native plants and disrupt ecosystem processes.
- Restoring Wildlife Habitat: Creating diverse habitat structures such as ponds, shallow water areas, and marshes to attract a variety of wildlife species. Further, providing nesting sites, food sources, and shelter enhances the ecological value of restored mangrove and wetland habitats.
- Monitoring and Adaptive Management: Regular monitoring of restored habitats for assessing the effectiveness and undertaking adaptive management strategies to ensure long-term success.
- Community Engagement and Education: Involving local communities, stakeholders, and volunteers in restoration projects to raise awareness and foster a sense of stewardship.
- Educational programmes, workshops, and volunteer opportunities to engage people in restoration efforts are beneficial.
- Collaborative Research, Policy and Regulation: Implementing and enforcing policies and regulations that protect mangroves and wetlands from further degradation and promote restoration is crucial. Collaborations between government agencies, non-profit organisations, and landowners to develop and implement mangrove and wetland conservation plans will ensure the long-term sustainability of restored wetlands.
- Carbon Pricing: Monetising the carbon captured through restored mangroves and wetlands by quantifying the emission reduction or removal equivalent and pricing the captured carbon. Carbon credits through projects or activities that result in emission reductions or removals beyond what would have occurred in a business-as-usual scenario are crucial.

Interventions for Coral Reefs:

- Prohibit and monitor the usage of bottom trawling nets, fish traps and beach seine nets
- Put a check on the coral mining activity

- Explore alternate materials for the lime and ornamental industries that look out for corals as raw materials
- Prevent destructive fishing practices like dynamite and cyanide fishing
- Take preventive measures to address coral disease
- Ensure 'Marine Elite Force' has equipments to safeguard the marine biodiversity

Box Item 14

Carbon Sequestration from Seagrass

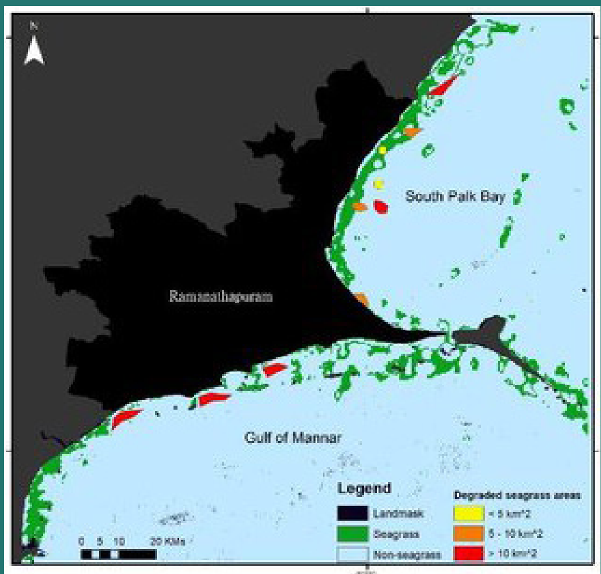
Seagrasses are underwater flowering plants that form dense meadows on the seafloor. Seagrass ecosystems are recognised globally for their ability to sequester carbon, nurture fish communities and support marine **Mammals such as sea cows or dugongs.**

Carbon Sequestration: Seagrass meadows play a role in mitigating climate change by absorbing carbon dioxide from the atmosphere and storing it in underwater sediments. Seagrass hold a potential of sequestering up to 1.61 kilo tonnes CO_2eq Km-2 year-1 at a planting density of 10,000 units Km-2 under the condition that calcification rates do not exceed net primary production and burial[81].

Seagrass distribution in the Tamil Nadu coast, seagrass is distributed along the Palk Bay (330 Km-2) to the north and the Gulf of Mannar (69.11 Km-2) to the south of Rameshwaraz[82], majority of which is along the coast of Ramanathapuram district.

Other Importance of Seagrass Ecosystems

- Biodiversity: Seagrass meadows support a diverse range of marine life by providing critical nursery grounds, including several commercially important fish species.
- Habitat: They offer shelter and food for marine organisms, enhancing biodiversity in coastal waters.
- Water Quality: Seagrasses help in stabilising sediments and improving water quality by trapping particles and reducing turbidity.
- Coastal Protection: They help in reducing coastal erosion by stabilising the sea floor and dissipating wave energy.
- Local Livelihoods: The health of seagrass meadows directly impacts the livelihoods of communities dependent on marine resources, including seagrass.



Threats: Habitat loss and degradation due to urbanisation and infrastructure development, untreated wastewater runoff containing sediments, nutrients, and chemicals and physical damage due to certain fishing practices.

Restoration: Several demonstrations of seagrass restorations and cultivation have been successful[83]. The Gulf of Mannar Marine Biosphere Reserve, running down south from Rameswaram to Kanyakumari, spanning across a total area of 10,500 Km2, protects seagrass ecosystems. Several NGO and academic collaborations actively work on seagrass/seaweed cultivation as an alternative income source. Further, a multi-purpose seaweed park, spanning across Ramanathapuram, Thoothukudi and other coastal districts is proposed for scientific cultivation and processing[84]. This initiative aims to enhance coastal livelihoods, promote blue economy opportunities, contribute to carbon sequestration, and support climate-resilient marine resource management.

6. Scenario Results and Insights

This chapter highlights key insights from the GHG emission projections from 2022 to 2050 under BAU and abatement potential through proposed decarbonisation strategies under MES and AES. The energy sector emerges as the primary contributor to emission growth, with the public electricity generation sector accounting for ~45 percent of emissions, followed by the transport sector at around 18 percent. The AFOLU (Agriculture, Forestry, and Other Land Use) sector plays a crucial role in offsetting emissions, with sequestration improving significantly in both the MES and AES scenarios.

GHG Emissions

Table 6.1: Sector-wise GHG emissions in BAU 2022 and estimates in BAU 2050, MES 2050 and AES 2050 for Ramanathapuram, in ktCO$_2$e

Sectors	GHG Emissions (KtCO$_2$e) in year 2022	GHG Emissions (KtCO$_2$e) in year 2050		
		BAU	MES	AES
Energy	**1247**	**664**	**240**	**117**
Agriculture	12	21	11	0
Industry	12	17	8	0
Commercial	15	21	12	10
Residential	97	116	88	70
Captive Power Plant	209	209	0	0
Public Electricity Generation	559	0	0	0
Fisheries	119	125	62	0
Transport	224	155	59	37
IPPU	**0.03**	**0.03**	**0.03**	**0.03**
AFOLU	**674.40**	**1006**	**92**	**-394**

Agggregate Sources and Non-CO_2 Emission Sources on Land	389.09	611	345	226
Arricuiture Soil	138.44	275	138	69
Biomass burning in Cropland	2.87	3	3	3
Rice Cultivation	247.78	332	205	155
Livestock	**147.27**	**257**	**212**	**186**
Net Land Emissons / Removals	**138.03**	**138**	**-465**	**-806**
Land Emissions	138.19	138	138	138
Removals	-0.15	-0.15	-603.20	-944.26
Waste	**77.96**	**76**	**16**	**15**
Domestic Wastewater	60.15	61	13	13
Industrial Wastewater	6.15	615	2.46	1.23
Solid Waste Disposal	11.65	8.68	0.21	0.21
Gross Emissions	**1999**	**1746**	**951**	**682**
Net Emissions	**1999**	**1746**	**348**	**-262**

Figure 6.1 illustrates GHG emissions trajectories under a BAU scenario and the impact of various mitigation measures, emphasising the potential to achieve sectoral decarbonisation, which would be the first step towards a carbon-negative future.

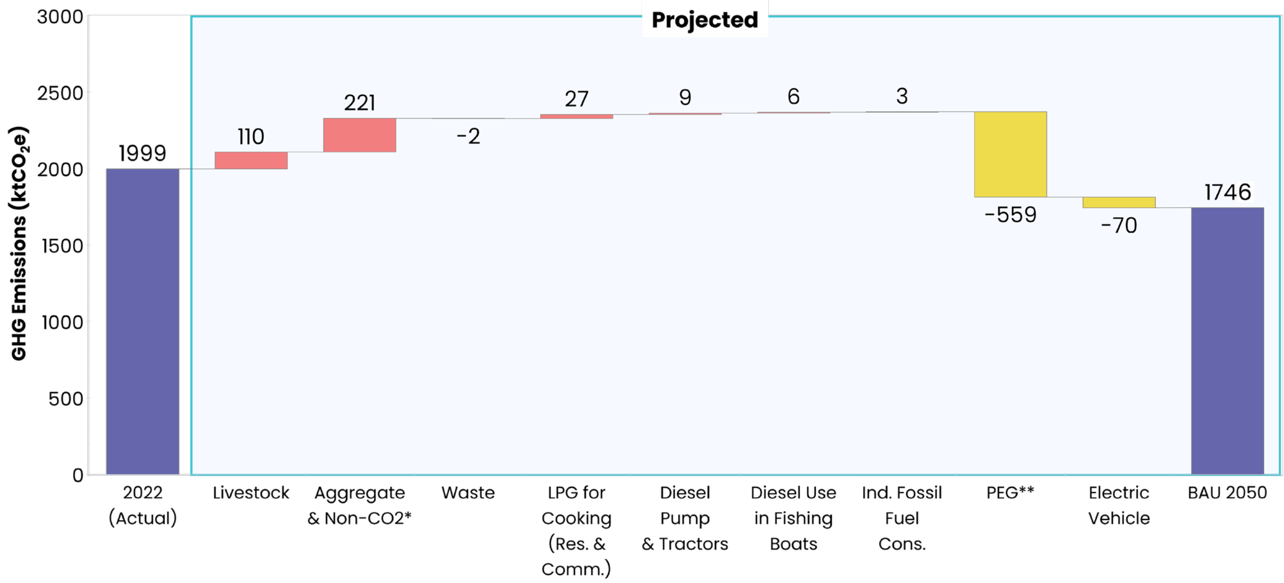


Figure 6.1: Projected GHG emissions under BAU scenario, by 2050, in ktCO$_2$e

Emissions are expected to decline by 2050 due to the retirement of aging public power plants and increased electric vehicle adoption.

* Aggregate and non-CO_2 represents aggregate sources and non-CO_2 emission sources on land consisting of rice cultivation, agriculture soil and biomass burning in cropland.

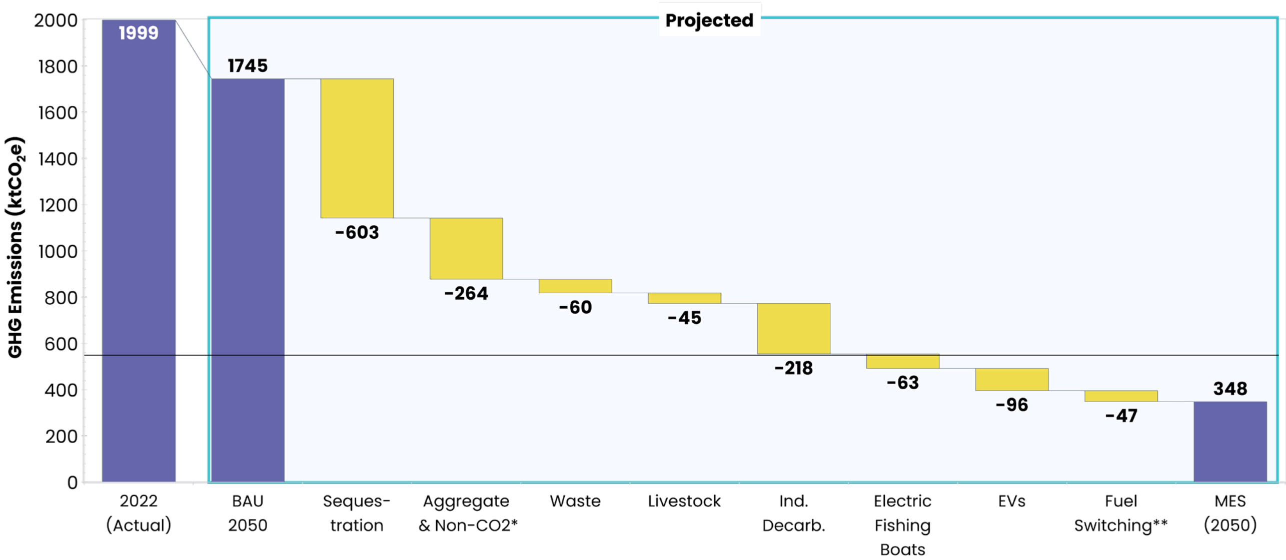
** PEG refers to the Public Electricity Generation Units, which are expected to retire as per their economic lifetime, by 2032.

In the BAU scenario, total net GHG emissions are projected to decline by 13 percent from 1999 ktCO$_2$e in 2022 to 1746 ktCO$_2$e by 2050, primarily due to the phase out of gas-based public electricity generators and the growing adoption of electric vehicles (EVs). Increase in GHG emissions is driven by the AFOLU sector, with significant contributions from rice cultivation and livestock. By 2050, the AFOLU sector is expected to account for 58 percent of total emissions, followed by the energy sector at 38 percent, while the waste sector would contribute only 4 percent. Emissions from the IPPU sector remain negligible across all scenarios. In the AFOLU sector, the aggregate sources and non-CO_2 emission sources on land comprising rice cultivation, agriculture soil and biomass burning in cropland, accounts for 61 percent of the emissions, followed by livestock at 26 percent and the rest 13 percent of emissions from land.Emissions are expected to decline by 2050 due to the retirement of aging public power plants and increased electric vehicle adoption.

These emissions could be significantly abated by 2050, under the moderate and aggressive effort scenarios as detailed below.

Emission Reduction Potential under Moderate Effort Scenario (MES)

In MES, significant reductions are observed, with emissions from the energy sector decreasing to 240 ktCO_2e due to partial electrification of irrigation pumps, tractors and tillers in agriculture, gradual fuel switching from LPG to PNG and electricity. The emissions from the waste sector, aggregate and non-CO_2 sources, and livestock are expected to reduce to 16 ktCO_2e, 345 ktCO_2e and 212 ktCO_2e respectivelyThrough agroforestry and social forestry, as well as restoration of mangroves, seagrass and seaweeds, and enhancement of carbon stock density, the land category could potentially sequester an additional 603 ktCO_2e. Overall, these measures result in total net emissions of 348 ktCO_2e under the MES. (Figure 6.2)



Mitigation Potential (%)* *against BAU 2050 emissions	~35%	15%	~4%	~3%	13%	4%	~6%	~3%

Figure 6.2: Projected GHG emissions in BAU, and category wise decarbonisation potential under moderate effort scenario (MES), by 2050, in ktCO_2e

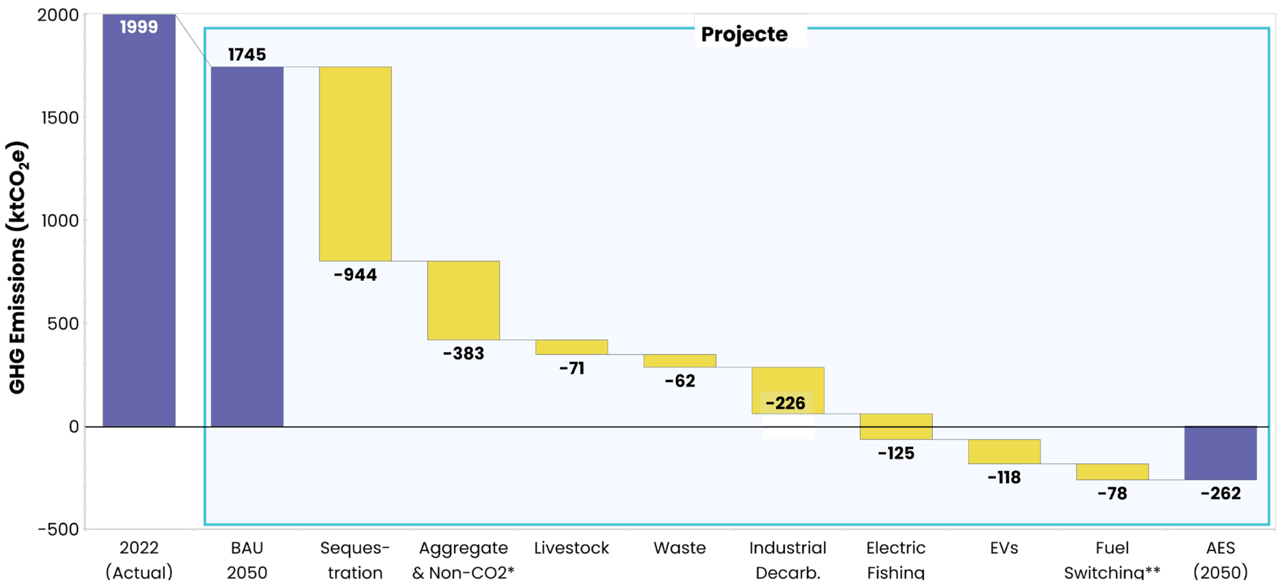
Industrial decarbonisation in the energy sector, livestock and soil management and sequestration in the non-energy sector could drive emission reductions in moderate scenarios.

** Aggregate and non-CO_2 represents aggregate sources and non-CO_2 emission sources on land consisting of rice cultivation, agriculture soil and biomass burning in cropland.*

***Fuel switching consists of partial electrification of tractors and tillers in agriculture and shift from LPG to PNG and electric cookstoves in the residential and commercial sector.*

Emission Reduction Potential under Aggressive Effort Scenario (AES)

In contrast, an aggressive approach can result in a net negative emissions of 262 ktCO_2e by 2050. The most significant contributions come from carbon sequestration (944 ktCO_2e), underscoring its critical role in emission reduction strategies. Additional measures such as methanogen inhibiting feed additives and balanced rationing for livestock, substituting synthetic nitrogen fertiliser and urea with organic fertiliser and nano urea, increasing multiple aeration water regime for rice cultivation contribute to a cumulative reduction of 456 ktCO_2e. Clean technologies in industry including captive power (226 ktCO_2e), using electricity to run fishing boats (125 ktCO_2e), road transport electrification (118 ktCO_2e), fuel switching in residential and commercial sector (78 ktCO_2e), together could potentially reduce energy sector emissions by 547 ktCO_2e, and improved waste management can further abate 61 ktCO_2e. This integrated approach demonstrates the effectiveness of combining land sequestration, renewable energy deployment, electrification, and sustainable practices across sectors to offset emissions, aligning with ambitious climate targets (Figure 6.3).



Mitigation Potential (%)* *against BAU 2050 emissions	54%	22%	4%	~4%	13%	7%	~7%	~5%

Figure 6.3: Projected GHG emissions in BAU, and category wise decarbonisation potential under aggressive effort scenario (AES), by 2050, in ktCO_2e

Emissions can be fully abated and a net negative achieved by 2050 through aggressive pursuit of decarbonisation strategies and enhancing sequestration

* Aggregate and non-CO_2 represents aggregate sources and non-CO_2 emission sources on land consisting of rice cultivation, agriculture soil and biomass burning in cropland.

**Fuel switching consists of partial electrification of tractors and tillers in agriculture and shift from LPG to PNG and electric cookstoves in the residential and commercial sectors.

Leveraging Non-CO_2 Mitigation for Deep Decarbonisation

Addressing Non-CO_2 emissions is increasingly recognized as a critical component of comprehensive climate mitigation strategies, especially for achieving near to medium-term climate goals. Non-CO_2 climate pollutants—including methane (CH4), nitrous oxide (N_2O), black carbon, and hydrofluorocarbons (HFCs)—exhibit significantly higher global warming potential (GWP) per unit mass than CO_2 and exert strong short-term radiative forcing. For instance, methane has a GWP of nearly 56 times that of CO_2 over a 20 year horizon and about 21 times over a 100 year horizon [85], making their mitigation essential for near-term climate stabilization.

In Ramanathapuram, under the Business-as-Usual (BAU) scenario, emissions are projected to decline marginally from 2143 ktCO_2e in 2022 to 1935 ktCO_2e by 2050 due to underlying structural trends. Under the AES pathway, targeted mitigation of CO_2 alone could reduce emissions by 28%, resulting in emissions of 1388 ktCO_2e by 2050, while exclusive action on Non-CO_2 pollutants could reduce emissions by 27.5%, with residual emissions at 1396 ktCO_2e. This indicates that Non-CO_2 mitigation delivers climate benefits nearly on par with CO_2-focused strategies. It underscores the strategic importance of Non-CO_2 interventions, particularly in sectors such as agriculture, waste, and transport, where such pollutants dominate.

Inclusion of black carbon—traditionally excluded from GHG inventories—could further elevate the estimated mitigation potential, particularly in districts like Ramanathapuram where biomass use and transport-related, particularly tourism, emissions are significant.

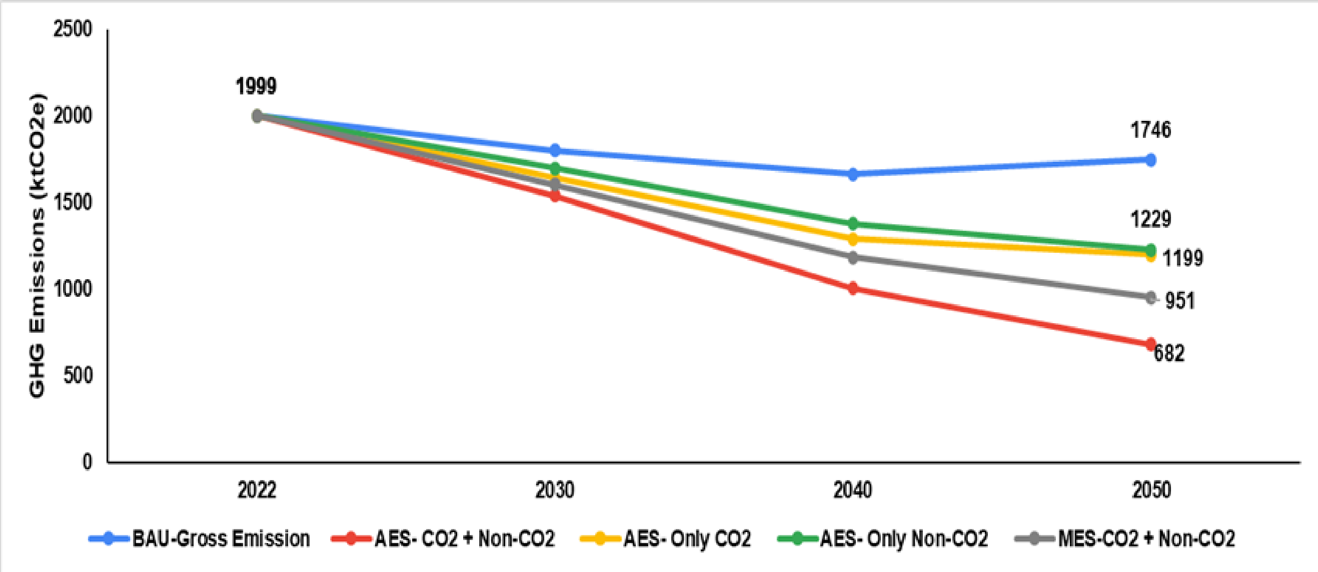


Figure 6.4: Projected GHG emissions highlighting the mitigation potential of only non-CO2 action

Furthermore, Non-CO_2 action provides substantial co-benefits, including:

- Improved air quality: Reductions in black carbon and methane lead to lower levels of particulate matter and ground-level ozone, improving ambient air quality.
- Reduced premature mortality and morbidity: Improved air quality directly reduces the incidence of respiratory and cardiovascular diseases, thereby lowering health burdens and preventing premature deaths.
- Enhanced crop yields: Lower concentrations of ground-level ozone and improved climatic conditions support healthier plant growth and improved agricultural productivity.
- Economic savings: Health and agricultural co-benefits translate into reduced healthcare costs and increased economic resilience, particularly in vulnerable communities.
- Alignment with development goals: Non-CO_2 mitigation supports multiple Sustainable Development Goals (SDGs), including those related to health (SDG 3), food security (SDG 2), and climate action (SDG 13).

Key Insights

Decarbonisation of the industries, particularly captive power plants, is essential for Ramanathapuram to achieve net zero

The industrial sector's contribution to the GHG emissions in Ramanathapuram is marginal at 12 ktCO_2e in 2022, expected to rise to 17 ktCO_2e by 2050 due to the underdeveloped nature of the sector. However, emissions from captive power plants are high at 209 ktCO_2e in 2022 and 2050. By replacing 100 percent of gas, diesel and coal based CPPs with renewable energy and adopting other decarbonisation strategies for industrial emissions, a total of 266 ktCO_2e can be abated in 2050 – 41 percent of the total possible abatement under AES.

Full electrification of fishing boats and vessels will enable Ramanathapuram decarbonise its fishing sector

Fishing is a major economic activity in the district. Fishing operations are primarily conducted using mechanised boats, motorised boats, non-mechanised boats, etc. Marine fishing is the most dominant in this district and requires HSD as a fuel for these operations. Full electrification of mechanised fishing boats and vessels could abate 125 $ktCO_2e$ by 2050 – 23 percent of the total possible abatement under AES.

Replacement of ICE vehicles with electric counterparts will have a significant impact on emission abatement in the sector

Full electrification of 2W, 3W, 4W and buses and partial electrification of Heavy Goods Vehicles (trucks, trolleys) could save the district 76 percent of sectoral emissions, from 155 $ktCO_2e$ to 37 $ktCO_2e$ by 2050, which is 22 percent of total possible abatement under AES. To achieve this, the district will have to invest in development of allied infrastructure for electric mobility, including installation of charging stations.

Clean cooking practices could reduce GHG emissions significantly in residential and commercial sector

Adopting ~0.72 lakh electric cookstoves to reduce LPG consumption in cooking and using cleaner alternatives like solar energy and biofuels for power backup in buildings can lower buildings carbon footprint by 42 percent from 137 $ktCO_2e$ to 80 $ktCO_2e$ by 2050.

The agriculture sector could further save 80 $ktCO_2e$ of emissions by 2050, through prioritising solarisation of existing ~5837 diesel pumps and electrification of ~1400 tractors and tillers.

Decarbonising electricity sector and energy efficiency measures in buildings will abate Scope 2 GHG emissions

Electrification of the road transport fleet, fishing boats and vessels, and increased demand for space cooling are expected to increase electricity consumption in the district. Electricity consumption is projected to rise three folds, from 1,000 GWh in 2022 to 2,893 GWh by 2050. Out of this, 886 GWh will be required for space cooling needs alone, driven by higher temperature as per RCP 8.5 scenario. Moreover, the existing gas based public electricity generating units are expected to phase out by 2033 because of economic lifetime (25 years) and high variable cost, abating 559 $ktCO_2e$ GHG emissions even in the BAU scenario.

To meet this demand through renewable energy, an additional equivalent capacity of 0.7 GW will be required. Therefore, a comprehensive assessment of the resource potential across various renewable energy sources such as solar rooftops, utility-scale solar, wind energy, agro-photovoltaics, and others are essential. Adopting energy-efficient appliances, insulation, rooftop solar, and smart technologies will curb emissions, ease grid pressure, and support decarbonisation efforts.

In the 'Solar PV Potential of India: Ground Mounted' assessment report published in September 2025, the National Institute of Solar Energy (NISE) has estimated a potential of ground-mounted solar capacity of 9.7 GW in the Ramanathapuram district. This potential assessment is based on a dynamic land use modeling that identify 10% of total wasteland with high irradiance and adequate grid access as feasible site for deployment of ground mounted solar in the State. Realising this potential in medium to long term will make the district carbon neutral from electricity standpoint, and support the state's vision of achieving net zero by 2070.

Improving waste management and converting waste to energy can mitigate 61 $ktCO_2e$ by 2050:

Waste sector emissions projected at 76 $ktCO_2e$ by 2050 could be reduced to 15 $ktCO_2e$ by implementing measures such as 100 percent source segregation and processing of municipal solid waste with zero landfilling, comprehensive domestic wastewater management through 100 percent UGD connections, centralised STPs in urban areas, septic tanks with FSTPs in rural areas, and improved industrial wastewater management.

About 30 TPD of **municipal waste** could further generate ~4 GWh annually, mitigating 5 $ktCO_2e$

emissions through municipal solid waste and refuse derived fuel (RDF) based projects. Similarly, 3,68,668 tonnes of **annual crop residues** could generate 36–52 MW of power, producing 97–138 GWh and reducing 68–97 $ktCO_2e$ emissions. **Livestock waste** could also produce 15,000 m^3/day of biogas, enabling compressed biogas (CBG) production and mitigating 28 $ktCO_2e$ annually.

Additionally

- Ramanathapuram's carbon sequestration could be enhanced from 0.15 $ktCO_2e$ to 944 $ktCO_2e$ by 2050 through enhanced carbon sequestration efforts such as agroforestry, social forestry, restoration of mangroves, seagrass and seaweed, and the enhancement of carbon stock density.
- **Sustainable Agriculture Practices:** Rice cultivation emissions, projected to rise from 248 $ktCO_2e$ in 2022 to 332 $ktCO_2e$ by 2050, could potentially be reduced to 155 $ktCO_2e$ by expanding multiple aeration water regimes from 20 percent to 77 percent. Livestock emissions, expected to grow from 147 $ktCO_2e$ in 2022 to 257 $ktCO_2e$ by 2050, can be reduced to 186 $ktCO_2e$ through balanced rationing, adoption of methanogen-inhibiting feed additives, and improved manure management practices. Emissions from agricultural soils, projected to increase from 138 $ktCO_2e$ to 275 $ktCO_2e$ by 2050, could be reduced to 69 $ktCO_2e$ by replacing synthetic nitrogen fertilisers and urea with organic fertilisers and nano-urea.

Box Item 15

Behavioural shifts will drive deeper emission abatements over and above key interventions in Ramanathapuram

By nudging behavioural shifts and promoting mindful decision-making regarding choice of fuel, materials and use of appliances, electricity demand can be avoided, and wherever unavoidable, electricity consumption can be made efficient. In the building and transport sector, this can take the following forms:

In the building sector

- Temperature control, i.e., setting the AC to 24–26°C, can supplement sectoral abatement. A conservative increase in the temperature setting by 2 from 24°C to 26°C could reduce electricity demand by approximately 57 GWh, saving ~40 $ktCO_2e$ (Scope 2) emissions.
- Smart lighting solutions using motion/occupancy sensors and daylight integrators can prevent idle running of utilities and save the district 40 percent electricity in lighting or ~68 GWh out of ~171 GWh of projected electricity consumption in lighting in residential and commercial buildings by 2050.

In the transport sector

- A shift in transportation mode from 4W cars to public buses by one-tenth of commuters in Ramanathapuram can lead to an additional abatement of ~13.2 $ktCO_2e$ of GHG emissions by 2050. This would also avoid the need for ~6100 four-wheelers on the road, replacing it with an addition of ~280 buses.
- Smart traffic systems that optimise signal timings based on real-time traffic data, reduce idle time at intersections and minimise stop-and-go traffic can save up to 25 percent of emissions at traffic lights and intersections. (ITF-OECD)
- Non-motorised transport (bicycle, cycle rickshaw, push scooters, etc.) for shorter distances (3.5-4 km), supported with the development of sidewalks, pedestrian zones, and safe crosswalks for walkers and cyclists, can further avoid unnecessary emissions.

Box Item 16

A multi-stakeholder approach can enable clean energy and cooling solutions reach households, especially in rural areas

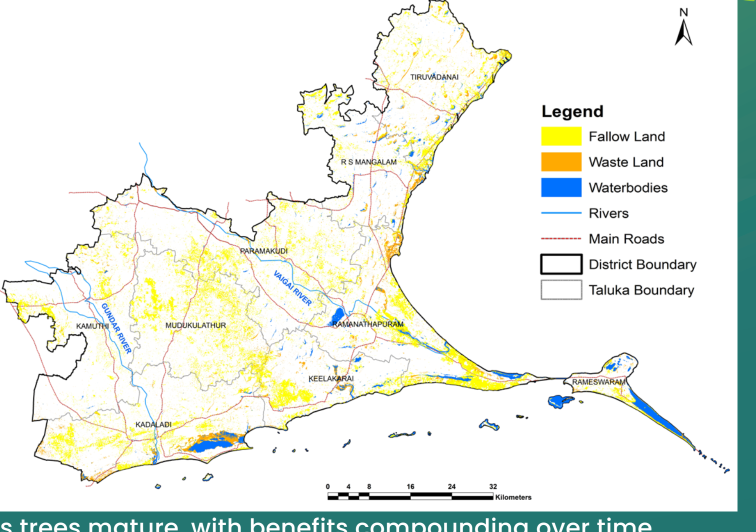
Effective deployment of clean energy solutions could struggle with issues of affordability and accessibility. In Ramanathapuram, 70 percent of the population is rural in nature, this could pose a challenge in enabling that the district's decarbonisation leaves no one behind. Furthermore, some solutions may require community ownership for them to become sustainable, or proof of concept may need to be established through piloting. A multi-stakeholder approach, with the government and think tanks leading from the front with support from civil society actors and the private sector, could be a solution.

In Gujarat and Rajasthan, for instance, the Natural Resources Defense Council (NRDC), the Self-Employed Women's Association (SEWA) and the Association of Renewable Energy Agencies of State under the Ministry of New and Renewable Energy (AREAS-MNRE) joined hands to implement Hariyali Green Villages (2019) – an initiative aimed at enhancing accessibility and affordability of clean energy technologies while improving livelihood opportunities at household level in rural areas.[86] Each village (or Hariyali Gram) was provided with a suite of clean energy solutions, consisting of LED bulbs and energy-efficient fans for thermal comfort, biogas plants for clean cooking, solar-powered water pumps for irrigation and cool roofs for reducing heat stress. Cost of these solutions were partially borne by SEWA, partially covered by schemes such as PM KUSUM and partially funded through contributions from the community. Other financing mechanisms were also operationalised. The entire model relies on local employment and community support. SEWA-supported Self-Help Groups in Gujarat and Rajasthan were mobilised, trained and employed wherever necessary during the intervention. With its roots in the communities, the Hariyali Green Village programme had benefited more than 300 families by 2021-22.

Box item 17:

Initiation of Agro/social forestry in fallow and waste land

For developing the agro/social forestry in 2026 activities focusing on laying the groundwork — identifying suitable native species, preparing nurseries, stakeholder coordination, approvals and securing planting sites — are proposed. From 2027, plantations could be rolled out progressively across the district, integrating fallow and under-utilised land, with institutional mechanisms, irrigation facilities and building capacity. The programme could include protective measures such as fencing, maintenance systems, survival monitoring along with value chain development and impact assessment. Carbon sequestration is expected to gradually increase from 2028 as trees mature, with benefits compounding over time.



Categories of land under non-agriculture uses, barren and uncultivable land, fallow lands other than current fallow and current fallow that are suitable for agro/social forestry and horticulture interventions have been identified based on expert inputs, historic trend and literature review. In addition to this, the possible site for plantations, reforestation, and enhancing green cover have also been mapped through spatial analysis and is as represented in the map below. These areas represent high potential for enhancing carbon sequestration, restoring ecological function, and supporting sustainable land use practices.

However, it is important to note that these mapped areas are indicative in nature and serve as a preliminary planning tool. Prior to implementation, detailed on-ground verification and ecological assessments are essential to validate site suitability. Such field surveys should evaluate soil characteristics, existing vegetation, slope stability, land tenure, and proximity to water sources, among other factors, thereby ensuring that plantation activities are context-sensitive, ecologically appropriate, and aligned with long-term sustainability goals.

7. Implementation Plan for Decarbonising Ramanathapuram

Short-term, medium-term and long-term strategies for decarbonising Ramanthapuram are proposed along with their emission abatement potential in Table 7.1. Through full and effective implementation of these strategies, the district could achieve carbon neutrality well before 2050, going so far as achieving a net negative carbon stock of 262 ktCO_2e due to sequestration through mangrove plantation, seagrass/weeds and other measures.

Convergence with the government schemes and policies, along with private investments, can support this implementation. A list of conducive schemes is provided in Annexure

Table 7.1: Key short, medium and long-term sectoral interventions to decarbonise Ramanathapuram

	Key Intervention	Activity/Target	Short Term (till 2030)		Medium Term (2030-40)		Long Term (2040-50)		Incentive under Central/ State Schemes and Policies
			Target	AMP in 2030 ($ktCO_2e$/ yr)*	Target	Cumulative AMP in 2040 ($ktCO_2e$/ yr)	Target	Cumulative AMP in 2050 ($ktCO_2e$/ yr)	
	Interventions to Mitigate Scope 1 Emissions								
A.	**Decarbonising the Energy Sector**								
A.1	Shift from Fossil-Fuel to RE based Captive Power Generation	Replacing/tying up PPAs from existing ~87 MW fossil-fuel based Captive Power Plants (CPPs) to equivalent renewable energy capacity of ~156 MW (solar, wind and GH2) by 2050.	~40% of the existing tied up capacity (equivalent RE capacity 65 MW)	87 (4.84%)	30% additional capacity (equivalent RE capacity ~50 MW)	154 (9.26%)	30% of the balance (equivalent RE capacity 50 MW)	209 (11.97%)	- 100% electricity tax exemption for 5 years on power generated and consumed from captive sources - Concessions on land purchase or lease through reduced stamp duty available under Tamil Nadu Industrial Policy 2021
A.2	Use of Electric Cookstove in Cooking	Adoption of ~0.72 lakh electric cookstoves in residential cooking by 2050	0.37 lakh	14 (0.78%)	0.3 lakh additional	25 (1.5%)	0.04 lakh additional	29 (1.66%)	Potential of covering 0.9 lakh electric cookstoves under National Efficient Cooking Program (NECP) which provides cookstoves at a low cost (35% concession)
A.3	Use of Biogas using Waste (Agrowaste, Cow Dung, Food Scaps etc)	Installing a biogas plant of approx 15000 m3/day capacity, considering 50% realisation of total potential of 30000 m3/day of the district	20% of the total capacity	6 (0.33%)	50% of the remaining	20 (1.2%)	30% of the remaining	28 (1.6%)	Potential of coverage of 12 small biogas plants of 25 m3/ day capacity (worth Rs. 0.08 crores) by March 2026 under National Biogas Programme. Higher coverage subject to scheme extension.

	Key Intervention	Activity/Target	Short Term (till 2030)		Medium Term (2030-40)		Long Term (2040-50)		Incentive under Central/ State Schemes and Policies
			Target	AMP in 2030 ($ktCO_2e$/ yr)*	Target	Cumulative AMP in 2040 ($ktCO_2e$/ yr)	Target	Cumulative AMP in 2050 ($ktCO_2e$/ yr)	
A.4	Replacement of diesel pumps with solar pumps for irrigation	Conversion of 5837 diesel pumpsets to off-grid solar pumps by 2050	20% of the target	3 (0.17%)	40% additional	10 (0.6%)	40% remaining target	16 (0.92%)	Potential of covering 100 off-grid solar pumps of approx. Rs. 31.4 Crore under PM KUSUM (Component B) by December 2026. Higher coverage subject to scheme extension.
A.5	Use of EV tractor and tillers for agriculture land preparation	Electrifying ~1400 tractors and tillers with EV by 2050	NA	0	600	2 (0.12%)	800	5 (0.29%)	
A.6	Replacement of HSD by Biodiesel in Diesel Generator for Backup Supply / Renewable based Backup Supply Support	"Replacement of HSD by Biodiesel in Diesel Generator for Backup Supply / Renewable based Backup Supply Support • Exploring biodiesel availability production in the district (assessment) • Pilot implementation of biodiesel use in commercial DG sets / RE based backup supply support • Using biodiesels in all the DG sets in the districts"	To be assessed						

	Key Intervention	Activity/Target	Short Term (till 2030)		Medium Term (2030-40)		Long Term (2040-50)		Incentive under Central/ State Schemes and Policies
			Target	AMP in 2030 ($ktCO_2e$/ yr)*	Target	Cumulative AMP in 2040 ($ktCO_2e$/ yr)	Target	Cumulative AMP in 2050 ($ktCO_2e$/ yr)	
B.	**Shift to Electric Mobility*** *The target suggested in below mentioned interventions are over and above the stock in BAU scenario.								
B.1	Shift to EV 2 Wheeler	Increasing the share of EV in 2W sales to achieve 100% penetration (upto ~1.8 lakhs EV 2W) by 2050	0.03 lakh	1.42 (0.08%)	0.28 lakh additional	13 (0.78%)	1.49 lakh	22 (1.26%)	The current market price of EV 2W are comparable with the ICE counterparts, hence market dynamics will decide the pace of 2W EV sales. However, a sum of Rs. 1.8 crore (Rs. 1.5 crore + Rs. 0.3 crore) is available under current center and state policies (PM E-DRIVE Scheme 2024 and TN zEV Policy 2023) for 3000 2W EVs. Higher coverage possible subject to scheme extension.
B.2	Shift to EV 3 Wheeler	Increasing the share of EV in 3W sales to achieve 100% penetration (upto ~6000 EV 3W) by 2050	~300	0.415 (0.02%)	1500 additional	2.30 (0.14%)	4200 additional	4 (0.23%)	The current market price of EV 3W are comparable with the ICE counterparts, hence market dynamics will decide the pace of 3W EV sales. However, a sum of Rs. 1.13 crore (Rs. 0.23 crore + Rs. 0.9 crore) is available under current center and state policies (PM E-DRIVE Scheme 2024 and TN EV Policy 2023) for 300 3W EVs. Higher coverage possible subject to scheme extension.

	Key Intervention	Activity/Target	Short Term (till 2030)		Medium Term (2030-40)		Long Term (2040-50)		Incentive under Central/ State Schemes and Policies
			Target	AMP in 2030 ($ktCO_2e$/yr)*	Target	Cumulative AMP in 2040 ($ktCO_2e$/yr)	Target	Cumulative AMP in 2050 ($ktCO_2e$/yr)	
B.3	Shift to EV 4 Wheeler	Increasing the share of EV in 4W sales to achieve 100% penetration (upto ~0.48 lakhs EV 4W) by 2050	~500	1.17 (0.07%)	5000 additional	10 (0.6%)	43000 additional	23 (1.32%)	Maximum incentive of up to Rs. 1.5 lakh for 4W commercial vehicle is available under TN EV Policy 2023 for a maximum of 3000 vehicles per year.
B.4	Shift to EV Buses	Increasing the share of EV buses in sales to achieve 100% penetration (upto ~600 EV buses) by 2050	100	6 (0.33%)	400 additional	27 (1.62%)	100 additional	31 (1.78%)	The current market price of electric buses are comparable with the ICE counterparts, hence market dynamics will decide the pace of EV buses' sales. However, a sum of Rs. 21.4 crore (Rs. 20.6 crore + Rs. 0.8 crore) is available under current center and state policies (PM E-DRIVE Scheme 2024 and TN EV Policy 2023) for 75 EV buses. Higher coverage possible subject to scheme extension.
B.5	Shift to Electric based Heavy Goods Vehicles (HGVs)	Increasing the share of electric Heavy Goods Vehicles (trucks, trolleys) in sales to achieve 80% penetration (upto ~500 EV HGVs) by 2050	20	1.46 (0.08%)	250 additional	20 (1.2%)	200 additional	38 (2.18%)	
B.6	Creation of EV Charging Infrastructure	Installation of ~400 charging stations in total by 2050	33	NA	140	NA	227	NA	Incentives worth Rs. 1 lakh for slow charging and Rs. 10 lakh for fast charging stations are available under TN EV Policy 2023 and further coverage under PM E-DRIVE subject to scheme extension.

	Key Intervention	Activity/Target	Short Term (till 2030)		Medium Term (2030-40)		Long Term (2040-50)		Incentive under Central/ State Schemes and Policies
			Target	AMP in 2030 ($ktCO_2e$/ yr)*	Target	Cumulative AMP in 2040 ($ktCO_2e$/ yr)	Target	Cumulative AMP in 2050 ($ktCO_2e$/ yr)	
B.7	Electrification of Mechanised and Motorised Fishing Vessels	Electrifying ~3300 mechanised and motorised fishing vessels by 2050	900	35 (1.95%)	1171	80 (4.81%)	1158	125 (7.61%)	
C.	**Decarbonising the Industry Sector**								
C.1	Exploring Electrification of Heating Processes in Industries to Reduce Fossil Fuel Consumption (Furnace Oil, HSD etc)	Identification of heating processes for electrification by 2050.	25% of the target	4 (0.22%)	20% additional	10 (0.6%)	55% of the remaining target	17 (0.97%)	
	Total Scope 1 Mitigation Potential (ktCO2e)		**159.0** (8.86%)		**373.2** (22.46%)		**548** (31.33%)		
	Interventions to Mitigate Scope 2 Emissions (Electricity Sector)								
a	Additional RE capacity integration of 0.7 GW (in addition to existing RE capacity of 1.05GW)"	Electrifying ~3300 mechanised and motorised fishing vessels by 2050 • Potential Assessment for various RE sources including rooftop solar, utility scale, wind, floating solar, agro PV and others) • Installation as per assessment	NA	0.00	0.25 GW of the additional RE capacity integration target	276	0.5 GW of the remaining RE capacity integration target	816	- Subsidy maximum up to Rs. 78,000 for rooftop system under PM Surya Ghar Muft Bijli Yojana

	Key Intervention	Activity/Target	Short Term (till 2030)		Medium Term (2030-40)		Long Term (2040-50)		Incentive under Central/ State Schemes and Policies
			Target	AMP in 2030 ($ktCO_2e$/ yr)*	Target	Cumulative AMP in 2040 ($ktCO_2e$/ yr)	Target	Cumulative AMP in 2050 ($ktCO_2e$/ yr)	
b	Energy Efficiency (EE) improvements*	Installation of ~4 lakh 3/5 star EE ACs in residential spaces to replace old/ inefficient ACs	1.9 lakh	48	1.2 lakh	74	0.9 lakh	96	
		Installation of 3/5 star EE refrigeration units up to a total of 4.2 lakh by 2050	2.74 lakh	4	1.24 lakh	10	0.22 lakh	10	
		Replacing existing ~7.3 lakh incandescent/CFL bulbs and tubelights with LED in residential space by 2030	100%	2	NA	3	NA	5	
		Replacing ~0.5 lakh street lights with LED lights by 2030	100%	21	NA	21	NA	21	
		Adoption of ~5.76 lakh BLDC fan by 2030, to a total of ~6 lakh by 2050.	5.76 lakh	2	0.15 lakh	4	0.09 lakh	4	
c	Utilizing biodegradable waste to generate electricity	Installation of waste to energy plant of 1 MW (the plant will require ~30 tons waste per day) by 2030	100%	5	NA	5	NA	5	Potential for covering 1MW project worth INR. 2 crore under National Mission for Waste to Wealth (Policy for Promotion of City Composting)
	Total Scope 2 Mitigation Potential ($ktCO_2e$)		**77.0**		**387.3**		**952**		

Non Energy Interventions

	Key Intervention	Activity/ Target	Description of Financing the Activity (to be read with color codes)	Short Term (till 2030)		Medium Term (2030-40)		Long Term (2040-50)		Policies/Fiscal Measures by State and Central Govt.
				Target	Approximate AMP in 2030 ($ktCO_2e$/yr)* (Percentage to BAU gross emissions)	Target	Approximate AMP in 2040 ($ktCO_2e$/yr)* (Percentage to BAU gross emissions)	Target	Approximate AMP in 2050 ($ktCO_2e$/yr)* (Percentage to BAU gross emissions)	
A.	**Waste Management**									
A.1	Domestic Wastewater Management	Set up adequate centralised wastewater treatment plants for urban	Government initiated with possibilities for gap funding through private, CSR	Facility to treat 56 MLD of wastewater	36 (2.00%)	Facility to treat additional 15 MLD wastewater	48 (2.89%)	Additional maintenance	48 (2.76%)	Swachh Bharat Mission, AMRUT 2.0, Kalaignarin Nagarpura Mempattu Thittam (KNMT), Tamil Nadu Urban Development Project (TNUDP) III, Namakku Namae Thittam
A.2		Enhancing decentralised treatment	Market/ household driven with possibilities of government subsidies	Retrofitting unsanitary septic tanks and unlined hole in the ground with leach pit or twin-pit septic tanks at household level for 119493 households		Retrofitting unsanitary septic tanks and unlined hole in the ground with leach pit or twin-pit septic tanks at household level for 51211 households		Additional maintenance		
A.3		Setting up Fecal Sludge treatment plant (FSTP) at firka level	Government or private initiative	27 FSTP for 27 firkas		11 FSTP for remaining 11 firkas		Additional maintenance		

	Key Intervention	Activity/ Target	Description of Financing the Activity (to be read with color codes)	Short Term (till 2030)		Medium Term (2030-40)		Long Term (2040-50)		Policies/Fiscal Measures by State and Central Govt.
				Target	Approximate AMP in 2030 ($ktCO_2e$/ yr)* (Percentage to BAU gross emissions)	Target	Approximate AMP in 2040 ($ktCO_2e$/ yr)* (Percentage to BAU gross emissions)	Target	Approximate AMP in 2050 ($ktCO_2e$/ yr)* (Percentage to BAU gross emissions)	
A.4		Increase household connections to underground drainage	Government initiated and funded	70 % Households to be connected with UGD		100 % Households to be connected with UGD		Additional maintenance		
A.5	Industrial Wastewater Management	Setting up of ETPs and continous treated effluent monitoring system	Market/industry driven with possibilities of Government funds for industrial areas developed by the Government	Facility to treat 4 MLD	2 (0.09%)	Maintenance and additional capacity if required	3 (0.18%)	Maintenance and additional capacity if required	5 (0.28%)	Tamil Nadu Industrial Policy 2021

	Key Intervention	Activity/ Target	Description of Financing the Activity (to be read with color codes)	Short Term (till 2030)		Medium Term (2030-40)		Long Term (2040-50)		Policies/Fiscal Measures by State and Central Govt.
				Target	Approximate AMP in 2030 ($ktCO_2e$/ yr)* (Percentage to BAU gross emissions)	Target	Approximate AMP in 2040 ($ktCO_2e$/ yr)* (Percentage to BAU gross emissions)	Target	Approximate AMP in 2050 ($ktCO_2e$/ yr)* (Percentage to BAU gross emissions)	
A.6	Solid Waste Management	Dry waste recycling centre	Government or private initiative	1. 27 recycling centres for 27 firkas at village level 2. 1 recycling centre per 1 lakh population (total 6 recycling centres)	2 (0.13%)	1. 11 recycling centres for remaining 11 firkas at village level 2. 2 additional recycling centre (total 8 recycling centres)	7 (0.42%)		8 (0.49%)	Swachh Bharat Mission, Solid Waste Management Rules 2016
A.7		Composting Centres	Government or private initiative	6 composting centre (1 per 1 lakh population)		2 additional composting centre (total 8)				
A.8		Stakeholder capacity building and awareness generation	Government initiated with possibilities for gap funding through private, CSR	Ongoing initiative		Ongoing initiative		Ongoing initiative		
	Total Mitigation Potential of Waste Management				**40 (2.22%)**		**58 (3.49%)**		**61 (3.53%)**	
B.	**Sustainable Agriculture Practices**									

	Key Intervention	Activity/ Target	Description of Financing the Activity (to be read with color codes)	Short Term (till 2030)		Medium Term (2030-40)		Long Term (2040-50)		Policies/Fiscal Measures by State and Central Govt.
				Target	Approximate AMP in 2030 ($ktCO_2e$/yr)* (Percentage to BAU gross emissions)	Target	Approximate AMP in 2040 ($ktCO_2e$/yr)* (Percentage to BAU gross emissions)	Target	Approximate AMP in 2050 ($ktCO_2e$/yr)* (Percentage to BAU gross emissions)	
B.1	Modern Cultivation Techniques	Use of organic fertiliser and compost in place of urea in agricultural production	Farmer driven with possibilities of Government funds as subsidies under various listed schemes	15% agriculture area transitioned to organic fertiliser	25 (1.40%)	45% agriculture area transitioned to organic fertiliser	97 (5.83%)	75% agriculture area transitioned to organic fertiliser	207 (11.83%)	National Mission for Sustainable Agriculture, Chief Minister's Manniyur Kaathu Mannuyir Kappom Scheme (CM MK MKS), National Mission on Natural farming
B.2		Use of nano urea in place of urea in agricultural production	Farmer driven with possibilities of Government funds as subsidies under various kisted schemes	30% of urea requiremnt met through nano urea		55% of urea requiremnt met through nano urea		25% of urea requiremnt met through nano urea		
B.3		Capacity building programmes can be conducted through Krishi Vigyan Kendra for creating awareness on climate resilient practices	Government initiated with possibilities for gap funding through private, CSR	Can be an ongoing initiative	NA	Can be an ongoing initiative	NA	Can be an ongoing initiative	NA	National Innovations in Climate Resilient Agriculture (NICRA), Paramparik Krishi Vikas Yojana

	Key Intervention	Activity/ Target	Description of Financing the Activity (to be read with color codes)	Short Term (till 2030)		Medium Term (2030-40)		Long Term (2040-50)		Policies/Fiscal Measures by State and Central Govt.
				Target	Approximate AMP in 2030 ($ktCO_2e$/ yr)* (Percentage to BAU gross emissions)	Target	Approximate AMP in 2040 ($ktCO_2e$/ yr)* (Percentage to BAU gross emissions)	Target	Approximate AMP in 2050 ($ktCO_2e$/ yr)* (Percentage to BAU gross emissions)	
B.4		Establish local network of mini weather monitoring stations to monitor rainfall and temperature as well as to be able to forecast extreme weather conditions - this can help inform farmers of appropriate sowing, harvesting and irrigation timings	Government or private initiative	27 mini weather monitoring stations	NA	11 mini weather monitoring stations	NA	Additional maintenance	NA	Krishi Decision Support System, Agricultural Infrastructure Fund (AIF)
B.5	Emission Reduction from Rice Cultivation	Increase the percentage of multiple aeration in the rice cultivated area	Farmer driven with possibilities of Government funds as subsidies under various schemes as listed	Increase in multiple aeration from 20% to 27%	20 (1.09%)	Increase in multiple aeration from 20% to 51%	87 (5.24%)	Increase in multiple aeration from 20% to 77%	178 (10.19%)	Chief Minister's Manniyur Kaathu Mannuyir Kappom Scheme (CM MK MKS)

	Key Intervention	Activity/ Target	Description of Financing the Activity (to be read with color codes)	Short Term (till 2030)		Medium Term (2030-40)		Long Term (2040-50)		Policies/Fiscal Measures by State and Central Govt.
				Target	Approximate AMP in 2030 ($ktCO_2e$/ yr)* (Percentage to BAU gross emissions)	Target	Approximate AMP in 2040 ($ktCO_2e$/ yr)* (Percentage to BAU gross emissions)	Target	Approximate AMP in 2050 ($ktCO_2e$/ yr)* (Percentage to BAU gross emissions)	
B.6	Livestock Management	feed inputs for livestock - Tamarin plus and Harit Dhara and balanced rationing to reduce methane emissions from enteric fermentation. Implemetation of GOBARdhan scheme for manure maangement	Farmer driven with possibilities of Government funds as subsidies under various schemes as listed	Balanced rationing introduced in 30% and improved feed supplemts like Harit Dhara and Tamrin plus in 25% of livestock . 90% reduction in manure managemnt emisison through GOBAR dhan scheme	17 (0.92%)	Balanced rationing introduced in 60% and improved feed supplemts like Harit Dhara and Tamrin plus in 50% of livestock . 90% reduction in manure managemnt emisison through GOBAR dhan scheme	40 (2.43%)	Balanced rationing introduced in 90% and improved feed supplemts like Harit Dhara and Tamrin plus in 75% of livestock . 90% reduction in manure managemnt emisison through GOBAR dhan scheme	71 (4.09%)	Balanced Ration Programme (BRP) GOBAR dhan scheme
	Total Mitigation Potential of Sustainable Agriculture Practices				**62 (3.41%)**		**224 (13.5%)**		**456 (26.11%)**	
C.	**Green Spaces and Carbon Sequestration**									

	Key Intervention	Activity/ Target	Description of Financing the Activity (to be read with color codes)	Short Term (till 2030)		Medium Term (2030-40)		Long Term (2040-50)		Policies/Fiscal Measures by State and Central Govt.
				Target	Approximate AMP in 2030 ($ktCO_2e$/ yr)* (Percentage to BAU gross emissions)	Target	Approximate AMP in 2040 ($ktCO_2e$/ yr)* (Percentage to BAU gross emissions)	Target	Approximate AMP in 2050 ($ktCO_2e$/ yr)* (Percentage to BAU gross emissions)	
C.1	Restoration and Conservation of Existing Forest Area and Tree Cover	Maintaining the current carbon stock densities to ensure the carbon sequesteration of -153 t CO_2e per year	Government initiated with possibilities for gap funding through private, CSR	Strengthening protection around existing reserved forest areas with additional measures of protection like: strengthening the fencing; eliminating encroachment; levying penalty on defaulters; etc.	0.15 (0.01%)	Strengthening protection around existing reserved forest areas with additional measures of protection like: strengthening the fencing; eliminating encroachment; levying penalty on defaulters; etc.	0.15 (0.01%)	Strengthening protection around existing reserved forest areas with additional measures of protection like: strengthening the fencing; eliminating encroachment; levying penalty on defaulters; etc.	0.15 (0.01%)	Compensatory Afforestation Fund Management and Planning Authority Fund (CAMPA), Nagar Van Yojana, Rashtriya krishi Vikas Yojana (RKVY), National Afforestation Programme, Sub-mission on Agroforestry (SMAF) - Har Medh Par Ped Scheme; Kalaignarin All Village Integrated Agriculture Development Programme (KAVIADP);

	Key Intervention	Activity/ Target	Description of Financing the Activity (to be read with color codes)	Short Term (till 2030)		Medium Term (2030-40)		Long Term (2040-50)		Policies/Fiscal Measures by State and Central Govt.
				Target	Approximate AMP in 2030 ($ktCO_2e$/ yr)* (Percentage to BAU gross emissions)	Target	Approximate AMP in 2040 ($ktCO_2e$/ yr)* (Percentage to BAU gross emissions)	Target	Approximate AMP in 2050 ($ktCO_2e$/ yr)* (Percentage to BAU gross emissions)	
C.2		Promoting social and agroforestry in land classified as barren or fallow, land put to non-agricultural uses of cultivable waste land	Private driven for private lands and Goverent initiated for Government lands with possibilities for gap funding through private, CSR	Social and agroforestry in 24899 ha In the subsequent years, continuous monitoring and maintenance of the plantations need to be undertaken	137 (7.61%)	Social and agroforestry in additional 34859 ha In the subsequent years, continuous monitoring and maintenance of the plantations need to be undertaken	466 (28.01%)	Social and agroforestry in additional 39839 ha In the subsequent years, continuous monitoring and maintenance of the plantations need to be undertaken	876 (50.20%)	National Agriculture Development Programme (NADP); CCUS Policy; Tamil Nadu Climate Change Mission; Green India Mission; Green Tamil Nadu Mission; Trees Outside Forests in India' initiative by MoEFCC and Governemnt of Tamil Nadu;
C.3		Enhancing carbon stock density	Government initiated with possibilities for gap funding through private, CSR	Enhancement of carbon stock density by 2% increase from 82.25 t/ha to 83.75 t/ha	33 (1.86%)	Enhancement of carbon stock density by 4% increase from 82.25 t/ha to 85.26 t/ha	13.36 (0.80%)	Enhancement of carbon stock density by 5.5% increase from 82.25 t/ha to 86.76 t/ha	13.36 (0.76%)	

	Key Intervention	Activity/ Target	Description of Financing the Activity (to be read with color codes)	Short Term (till 2030)		Medium Term (2030-40)		Long Term (2040-50)		Policies/Fiscal Measures by State and Central Govt.
				Target	Approximate AMP in 2030 ($ktCO_2e$/ yr)* (Percentage to BAU gross emissions)	Target	Approximate AMP in 2040 ($ktCO_2e$/ yr)* (Percentage to BAU gross emissions)	Target	Approximate AMP in 2050 ($ktCO_2e$/ yr)* (Percentage to BAU gross emissions)	
C.4		Restoration of mangroves	Government initiated with possibilities for gap funding through private, CSR	Restoring 61 Ha of mangrove forests	5.6 (0.31%)	Restoring additional 91 Ha of mangrove forests	14 (0.84%)	Restoring additional 152 Ha of mangrove forests	28 (1.60%)	
C.5		Enhancing seagrass and sea weed stretch	Government initiated with possibilities for gap funding through private, CSR	Enhancement of seagrass and seaweed both by 4 sq km	5.3 (0.29%)	Enhancement of seagrass and seaweed both by additional 6 sq.km	13.2 (0.79%)	Enhancement of seagrass and seaweed both by additional 10 sq.km	26.3 (1.51%)	
	Total Mitigation Potential of Green Spaces and Carbon Sequestration				**181 (10.08%)**		**506 (30.46%)**		**944 (54.08%)**	

* AMP = Annual Mitigation Potential
Note: Percentages denote AMP as a share of respective BAU emissions.

Purely Government Backed / Investment

Partially backed by Government

Market Driven

8. Priority Actions to Foster Climate Resilience

8.1 Addressing Coastal Climate Risks in Ramanathapuram

Ramanathapuram's district's 276-kilometre-long coastline, bound by the Bay of Bengal and the Gulf of Mannar, hosts ecologically rich coastal ecosystems including sandy beaches, coral reefs, mangroves, seaweed beds, and seagrass meadows. These ecosystems sustain productive fisheries and coastal livelihoods but are increasingly at risk from sea-level rise, cyclonic storms, saline intrusion, coastal erosion, and pollution. Vulnerability is particularly acute in island towns like Rameswaram and low-lying blocks such as Mandapam and Thiruppullani, where ecological sensitivity is compounded by intense tourism and pilgrimage activity. Declining fish stocks, groundwater salinity, and habitat loss are eroding the resilience of coastal communities. Building long-term resilience calls for a climate-responsive strategy that integrates ecosystem restoration, traditional knowledge, decentralised risk governance, and sustainable livelihood approaches.

Key Recommendations and Priority Interventions

Ecosystem Restoration

- Restore degraded mangrove patches in Mandapam, Thiruppullani, and estuarine zones of the Vaigai River using native species like Avicennia marina and Rhizophora mucronata, under the Tamil Nadu Forest Department's Joint Mangrove Management programme.
- Engage Eco-Development Committees (EDCs) and local communities in Devipattinam and Maraikkayar Pattinam for mangrove nursery management, seedling transplantation, and monitoring, with support from the Gulf of Mannar Biosphere Reserve Trust (GoMBRT).
- Promote bio-shields and dune restoration using Casuarina equisetifolia, Calophyllum inophyllum, and Leucas aspera, integrating with the Climate Resilient Village initiative and the Tamil Nadu Coastal Restoration Mission (TN-SHORE).
- Expand artificial coral reefs off the Rameswaram coast, building on the 2024 installation of 300 units to reduce erosion, enhance biodiversity, and sustain fisheries.

Cyclone Preparedness

- Construct multi-purpose cyclone shelters in Ariyankundu, Kunthukal, and Maraikkayar Pattinam under the National Cyclone Risk Mitigation Project (NCRMP).
- Upgrade the District Disaster Management Plan (DDMP) to include village-level contingency plans, evacuation routes, and cyclone drills with support from the District Disaster Management Authority (DDMA).
- Install early warning systems and community radios in vulnerable fishing hamlets like Olaikuda and Pudukudi.

Institutional Coordination and Community Organisation

- Form Village Climate Resilience Committees (VCRCs) in coastal panchayats to coordinate early warning, disaster planning, and coastal zoning.
- Integrate Coastal Regulation Zone (CRZ) guidelines into Gram Panchayat Development Plans (GPDPs) to regulate construction in high-risk zones.
- Mobilise women's SHGs and youth-led collectives for mangrove restoration and early warning outreach.

8.2 Sustainable and Climate Resilient Fisheries in Ramanathapuram

Ramanathapuram district, located along Tamil Nadu's southeastern coast, has the longest coastline of about 276 kms, accounting for nearly a quarter of Tamil Nadu's coastline. It is home to five Ramsar sites spanning over 53,289 ha, including the Gulf of Mannar Biosphere Reserve (52,672 ha), a globally significant marine ecosystem rich in coral reefs, seagrass meadows, mangroves, and marine biodiversity. Fishing is the primary livelihood for thousands of coastal families, with the district contributing 13.94 percent of the state's marine fish production (2021–22).

However, the marine ecosystem and the livelihoods it sustains are increasingly at risk from habitat degradation, overfishing, mechanised trawling, non-selective fishing gear, and climate-induced changes such as sea temperature rise and erratic monsoons. Disruptions in fish migratory routes, reproductive cycles, and traditional fishing seasons are already being reported.

Key Recommendations and Priority Interventions

1. **Conservation of the Blue Carbon Ecosystem**

- Develop a Blue Carbon Ecosystem Inventory, mapping coral reefs, seagrass beds, and mangrove cover across the Gulf of Mannar and Palk Bay, using satellite imagery and ecological assessments. Identify and notify community-managed conservation areas in biodiversity hotspots through participatory processes. This will help in prioritising areas for conservation.
- Establish Marine Protected Areas (MPAs) with zonation of sensitive habitats (spawning grounds, reef patches), and form Blue Carbon Monitoring Units comprising local fishers and scientists for continuous ecological assessment.
- Restore degraded coral reefs, mangroves (e.g., Avicennia marina, Rhizophora mucronata), and seagrass meadows through community-led actions and clearly defined conservation targets. Launching a Blue Carbon Mission under the District Climate Change Mission could be considered.

2. **Sustainable Fishing Practices**

   Enforce seasonal fishing bans during breeding periods, backed by compensation schemes for fisher families to avoid livelihood loss. Enforce no-fishing zones around coral reefs in the Gulf of Mannar Marine National Park (GoMMNP) with support from the Suganthi Devadason Marine Research Institute (SDMRI).

- Prohibit bottom trawling, pair trawling, and push nets in the Gulf of Mannar Biosphere Reserve; enforce use of selective fishing gear like square mesh cod ends to protect juvenile fish stocks.
- Promote traditional low-impact practices such as Kattumaram (catamaran) sailing, hook-and-

line fishing, and reviving indigenous marine closure periods.

- Strengthen Fishery Management Committees at the village level for gear regulation, conflict resolution, and co-management of marine resources.

3. **Livelihood Diversification**

- Conduct large scale training programmes for fishers and Self-Help Groups (SHGs) on sustainable fishing, post-harvest handling, and value-added product development.

Promote alternative and climate resilient livelihoods such as:

- Seaweed farming (e.g., Gracilaria, Kappaphycus)
- Pearl and cage aquaculture
- Eco-tourism and marine biodiversity trails around Dhanushkodi, Pamban, and Rameswaram
- Ornamental fish trade and fish-based nutraceuticals

4. **End-to-End Technical and Infrastructure Support**

- Develop Integrated Fisheries Service Centres in all four marine zones of the district to provide end-to-end support: scheme access, cold chains, ice plants, financial services, technical advice, and market linkages, all under one roof.
- Upgrade fish landing centres in Pamban, Mandapam, and Rameswaram with solar-powered cold storage, hygienic auction halls, stormwater drainage, and shade.
- Complete registration and digitisation of all fishing vessels, including country boats and small mechanised crafts, with real-time monitoring using GPS and digital logbooks. Digitisation supports sustainable and climate resilient fisheries by enabling real-time monitoring, efficient resource management, and early warning access, helping fishers adapt to changing ocean conditions. It also enhances traceability, market access, and disaster response, strengthening both ecological sustainability and the economic resilience of fishing communities.

8.3 Sustainable Agriculture

Ramanathapuram district, located in Tamil Nadu's dry southern agro-climatic zone, is predominantly rainfed and known for cultivating crops such as black gram, green gram, cotton, millets (particularly pearl millet and finger millet), groundnut, and paddy in irrigated pockets like Paramakudi, R.S. Mangalam, and Thiruvadanai. With saline soils in the coastal belts and increasing climate variability, the promotion of sustainable agriculture practices is critical for food security, enhancing livelihoods and reducing greenhouse gas emissions, especially methane from rice cultivation and nitrous oxide from extensive use of synthetic fertilisers.

Key Recommendations and Priority Interventions

Water Efficient Practices

- Promote drip and sprinkler irrigation systems especially for groundnut and cotton in dryland blocks like Mudukulathur and Kamuthi. Leveraging support through Pradhan Mantri Krishi Sinchayee Yojana may be considered.
- Construct farm ponds, percolation tanks, and implement field bunding under Mahatma Gandhi National Rural Employment Guarantee Act for moisture conservation in areas like Nainarkoil and Kadaladi.
- Encourage mulching and cover cropping to reduce evapotranspiration and improve soil organic matter.
- Introduce Alternate Wetting and Drying (AWD) techniques in rice fields to reduce methane generation and water use.
- Promote System of Rice Intensification (SRI) practices across blocks with canal irrigation.

- Encourage Direct-Seeded Rice (DSR) where feasible to bypass water-intensive nursery raising and transplanting stages.
- Promote conjunctive use of surface and groundwater, and alternate cropping in upstream tank command areas to balance irrigation demand.

Crop Diversification

- Support transition from water-intensive paddy to drought-resilient crops like black gram, cowpea, foxtail millet, and sorghum in moderately irrigated and rainfed blocks.
- Promote climate-resilient and short-duration crop varieties developed by Tamil Nadu Agricultural University (TNAU) and adapted to saline and arid conditions.
- Encourage horticulture diversification with brinjal, drumstick, and chillies in blocks like Bogalur and Thiruppullani.
- Encourage cultivation of salt-tolerant crops like finger millet, foxtail millet, and Sesbania in brackish zones to reduce irrigation dependency.

Organic farming

- Implement the Soil Health Card Scheme to tailor fertiliser and micronutrient application based on soil testing.
- Promote bio-fertilisers, green manures, and farmyard manure (FYM) to build carbon-rich soils.
- Engage with the Tamil Nadu Organic Certification Department (TNOCD) to certify organic produce and enhance market value.

Agroforestry and Trees Outside Forests (TOF)

- Integrate native, drought-tolerant tree species such as Pongamia pinnata (Pungan), Azadirachta indica (Neem), and Tamarindus indica along farm boundaries and field bunds.
- Promote silvopastoral systems in coastal and dry inland regions to combine tree planting with livestock fodder needs.

Farmer Institutions and Market Linkages

- Enable farmers to access Electronic National Agricultural Market (e-NAM) and organic produce certification to improve income.
- Support rural haats and collection centres for processing and marketing low-carbon crops like millets and pulses.

Climate Risk Management and Insurance

- Expand coverage of Pradhan Mantri Fasal Bima Yojana (PMFBY) for drought and cyclone prone farmers.
- Collaborate with India Meteorological Department (IMD) and KVK Ramanathapuram to disseminate agro-weather advisories tailored to local cropping systems.

Women and Youth in Resilient Farming

- Engage Self-Help Groups (SHGs) in producing and distributing organic inputs, maintaining community seed banks, and nursery raising.
- Provide training and microenterprise support to rural youth under National Rural Livelihoods Mission (NRLM) for climate-smart agribusiness, input supply chains, and produce processing.

Energy Acess and Resilence to Shocks

- Promote adoption of solar pumps, particularly in the remote or poorly served areas where fuel transport is erratic or power outages frequent. This will also save farmers from the supply chain and price volatilities commonly associated with diesel pumps.

8.4 Strengthening Water Security in Ramanathapuram

Ramanathapuram faces acute water stress due to its semi-arid climate, over-extraction of groundwater, and saline intrusion in coastal aquifers. While rural blocks like Bogalur and Mudukulathur rely heavily on rainfed tanks and borewells, urban centres like Ramanathapuram town and Rameswaram face rising water demand, aged infrastructure, and poor recharge. Climate change has exacerbated seasonal water scarcity, making integrated water resource management essential to enhance resilience, ensure drinking water security, and support agriculture and livelihoods. Additionally, some of the villages on the banks of the Vaigai river experience flooding during the North East monsoon.

Key Recommendations and Priority Interventions

Rainwater Harvesting and Groundwater Recharge

- Mandate rooftop rainwater harvesting (RWH) in all new buildings in Ramanathapuram Municipality and Rameswaram Municipality under the Tamil Nadu Combined Development and Building Rules (TNCDBR), 2019.
- Rejuvenate urban recharge structures like open wells, percolation pits, and temple tanks in urban wards of Paramakudi and Mandapam. Leveraging support from Atal Mission for Rejuvenation and Urban Transformation (AMRUT) 2.0 may be explored.
- Construct check dams, subsurface dykes, and percolation ponds in dry blocks such as Mudukulathur and Nainarkoil to improve recharge and reduce salinity.

Revival of Traditional Water Systems

- Restore eris (traditional tanks) such as Kanmoi in Kamudhi and Bogalur blocks under Tamil Nadu's Kudimaramathu scheme through community-led desilting and bund strengthening.
- Map and revive cascading tank systems (tank-to-tank linkages) that historically connected villages across Kamuthi, Paramakudi, and Tiruvadanai blocks.
- Integrate traditional water managers like Neerkattis and Nattamai institutions into local water governance for equitable distribution and conflict resolution.

Urban Water Efficiency and Greywater Management

- Reduce Non-Revenue Water (NRW) in Ramanathapuram Municipality by fixing pipeline leaks, upgrading metering, and enforcing illegal connection audits.
- Explore dual plumbing systems and greywater reuse for toilet flushing and landscaping in institutions and gated layouts in Rameswaram and Paramakudi towns.
- Establish Decentralised Wastewater Treatment Systems (DEWATS) with treated greywater reuse in government schools, hospitals, and public toilets. Leveraging the Swachh Bharat Mission – Urban (SBM-U) may support implementation.

Drinking Water Access and Safe Storage

- Ensure piped water supply to 100 percent households in remote and Scheduled Tribe habitations such as in Sayalkudi and Sikkal blocks under Jal Jeevan Mission (JJM)-Gramin.
- Promote overhead tanks with chlorine dosing units and solar pumps in water-stressed panchayats through convergence with Pradhan Mantri Kisan Urja Suraksha evam Utthaan Mahabhiyan (PM-KUSUM).

Community Governance and Capacity Building

- Train local youth and women's Self-Help Groups (SHGs) as Jal Doots for water budgeting, borewell monitoring, and awareness campaigns.
- Launch school-based water literacy campaigns and promote 'Catch the Rain' drives during monsoon seasons in collaboration with the District Education Office.

Water Salinity Management

- Construct recharge shafts, check dams, and sub-surface barriers in coastal aquifers of Thiruppullani and Mandapam to prevent seawater ingress.
- Install piezometers and automated salinity sensors in Mandapam and Thiruppullani to monitor saline ingress into freshwater lenses.
- Install solar desalination units in water-stressed habitations like Thangachimadam and Periyapattinam for decentralised drinking water access.

8.5 Strengthening Heat Resilience in Ramanathapuram

Ramanathapuram district is increasingly vulnerable to rising temperatures and extreme heat events due to its arid climate, low vegetation cover, and expansive coastal exposure. Climate projections suggest a rise in maximum temperatures by approximately 0.9°C by 2030 and up to 2.4°C by 2090 under the Representative Concentration Pathway (RCP) 8.5 scenario, potentially exacerbating heat stress across urban and rural populations. This is especially critical in urban centres like Ramanathapuram town, Paramakudi, and coastal settlements like Rameswaram and Mandapam, which are densely populated and lack adequate thermal comfort infrastructure. Strengthening district-wide heat resilience will require an integrated approach combining climate-smart space cooling, public health preparedness, and community engagement.

Built Environment and Sustainable Cooling

- Enforce Energy Conservation Building Code (ECBC) and Eco Niwas Samhita (ENS) norms in new government, residential, and institutional constructions in Ramanathapuram, Paramakudi, and Rameswaram.
- Retrofit existing public buildings such as the Ramanathapuram District Collectorate, government hospitals, schools, and Primary Health Centres (PHCs) with passive cooling solutions—shaded verandahs, cross ventilation, cool roofing, and tree-lined courtyards.
- Promote cool roof technology (lime or white reflective coatings) in low-income settlements of Sayalkudi, Kamuthi, and Kadaladi.
- Develop urban forests and green corridors in Mandapam, Rameswaram, and Paramakudi, using native species such as Casuarina equisetifolia, Pongamia pinnata, and Thespesia populnea for shade and cooling.
- Create blue-green infrastructure around tanks like Ariyakulam and Uchipuli Periyakulam by integrating bio-parks, shaded walking paths, rain gardens, and water retention areas.
- Encourage rooftop gardens and Agro-Photovoltaic (Agro-PV) systems on buildings and fishery cooperatives in coastal villages to combine food, energy, and shade.

Public Health Preparedness

- Develop a district-wide Heat Action Plan (HAP) led by the District Health Officer and coordinated by the District Disaster Management Authority (DDMA), including heatwave alerts, early warning dissemination via SMS, radio, and community networks.
- Set up cooling shelters in community halls, libraries, and anganwadis in Ramanathapuram, Paramakudi, and coastal blocks like Rameswaram and Mandapam, equipped with fans, shaded seating, and water stations.
- Train health personnel in Primary Healthcare Centres across remote locations like Thondi, Bogalur, and Mudukulathur to diagnose and treat heat-related illnesses such as dehydration, sunstroke, and acute respiratory distress.
- Install public hydration stations at bus stands, markets, and fishing harbours in Ramanathapuram town and Rameswaram.
- Conduct Information, Education and Communication (IEC) campaigns on recognising heat stress symptoms, drinking water intake, and clothing choices—disseminated through FM radio, schools, local youth groups, and Gram Panchayats.

- Deploy mobile medical units and electric ambulances through the Promotion of Electric Vehicles for Medical Emergency Transport under PM-E-DRIVE (Prime Minister's Electric Vehicle Deployment for Rapid Intervention in Vulnerable Emergencies) scheme in hard-to-reach villages.

Institutional Strengthening and Community Engagement

- Establish Local Body-Level Health and Climate Cells to implement HAPs, provide heat alerts, and coordinate emergency responses during extreme events.
- Encourage workplace heat safety protocols in fish markets, salt pans, and daily-wage labour settings, ensuring shaded rest areas, hydration breaks, and first-aid availability.
- Engage women's self-help groups (SHGs), Village Health Sanitation and Nutrition Committees (VHSNCs), and School Eco-clubs in campaigns for sustainable cooling, water conservation, and mosquito control.
- Include frontline workers such as ASHAs (Accredited Social Health Activists), Anganwadi workers, and Panchayat-level volunteers in awareness generation, heat illness surveillance, and household-level behavioural change communication.

8.6 Fostering Green Entrepreneurship for Livelihood Enhancement in Ramanathapuram

Ramanathapuram district, with its expansive coastal ecosystems, semi-arid inland zones, and strong traditional knowledge base, presents unique opportunities to promote green entrepreneurship. With rising climate stress, livelihood diversification through sustainable, nature-based, and low-carbon enterprises is essential to reduce vulnerability, especially among youth, women, and coastal communities. Green entrepreneurship can enhance income, protect ecosystems, and build a climate-resilient rural economy.

Priority Areas and Interventions

Seaweed Farming and Coastal Bio-Enterprises

- Scale up community-based seaweed cultivation (e.g., Kappaphycus alvarezii, Gracilaria edulis) in intertidal zones of Thangachimadam, Vedalai, and Mandapam.
- Provide technical and financial support through National Fisheries Development Board (NFDB) and Department of Fisheries, with training from SDMRI and CMFRI.
- Promote seaweed-based value-added products (fertilisers, cosmetics, nutraceuticals) via SHG-led microenterprises.

Ecotourism

- Develop eco-tourism circuits in Rameswaram, Dhanushkodi, and Gulf of Mannar Biosphere Reserve, offering coral reef walks, mangrove kayaking, biodiversity trails, and homestays.
- Support zero-waste, plastic-free tourism initiatives under Tamil Nadu Green Temple Initiative and Blue Flag Beach certification.

Access to Finance and Capacity Building

- Facilitate access to green microfinance, MUDRA loans, and venture capital for social enterprises via tie-ups with NABARD, TNSRLM, and Start-up India. Establish linkages with the District and State Level Bankers' Committees for priority lending to women-led green enterprises.
- Conduct entrepreneurship development programs through Rural Self Employment Training Institutes (RSETIs) and District Skill Training Centres, with a focus on climate-smart business models.
- Create a district-level Green Livelihood Incubation Cell under the District Climate Change Mission, linking entrepreneurs with technical institutions, government schemes, and markets.

8.7 Low Carbon Eco-Spiritual Corridor in Rameswaram

Rameswaram holds a unique position as both a sacred pilgrimage destination and an ecologically sensitive coastal zone in the Ramanathapuram district. While it is revered as part of the country's principal sacred pilgrimage circuit and home to the Ramanathaswamy Temple, it also lies within the Gulf of Mannar Biosphere Reserve, known for its coral reefs, seagrass beds, mangroves, and marine biodiversity.

This dual identity demands a balanced tourism model—one that preserves spiritual sanctity, ensures environmental stewardship, and enhances community livelihoods. The legacy of Dr. A.P.J. Abdul Kalam, a native of Rameswaram, reinforces this vision with his emphasis on sustainability, scientific thinking, and ethical citizenship. Key strategies outlined for this tourism model include:

Sacred Ecology and Spatial Zoning

- Identify and protect ecologically sensitive zones (e.g., coral reefs, theerthams, sand dunes) through zoning regulations.
- Map and connect sacred, ecological, and heritage landmarks into a unified spatial plan.

Sustainable Infrastructure and Green Mobility

- Develop green mobility corridors with pedestrian paths, and cycling lanes to promote Non-Motorised Transport (NMT) alongside battery-operated shuttles – linking the temple, Dhanushkodi, and Kalam Memorial.
- Promote solar installations in public buildings, temples, and key civic spaces; implement zero-waste precincts and bio-toilets near high-traffic zones.

Eco-Cultural-Spiritual Circuits and Digital Interpretation

- Curate integrated visitor experiences linking temples, marine ecology centres, legacy sites, and local folklore.
- Deploy storytelling kiosks, mobile apps, and interpretive signage to highlight mythology, biodiversity, and civic values.

Community-Based Tourism and Capacity Building

- Train youth, women, temple staff, and drivers as eco-cultural guides, focusing on marine conservation, temple traditions and heritage values.
- Support homestays, local food stalls, mythology and Kalam-themed souvenir cooperatives near tourism nodes.

Pilgrimage Management and Coastal Clean-Up

- Introduce zoned pilgrimage pathways and crowd flow mechanisms, especially during peak seasons.
- Conduct regular clean-up and water quality monitoring at theerthams; launch campaigns to promote eco-friendly religious offerings.

Monitoring, Governance, and Public Engagement

- Establish a Rameswaram Sustainable Tourism Council with representation from local authorities, temple boards, community leaders, and conservation experts.
- Launch citizen, science and school-based initiatives to monitor marine litter and biodiversity.
- Publish an annual "Spirit of Rameswaram" Sustainability Report to highlight transparent governance through environmental performance and community benefits, fostering trust and participation.

9. Monitoring and Evaluation

Monitoring and Evaluation (M&E) is essential to effectively implement, track progress and assess impacts of the decarbonisation plan for any district. This section proposes some measurable indicators to monitor outcomes, optimise resources, and align actions with Ramanathapuram's decarbonisation agenda while supporting continuous, community-focused adaptation. It also identifies key stakeholders and institutions that could be engaged in the monitoring and evaluation process to optimise processes and foster ownership.

Suggested Indicators

The following table provides indicators across key themes of the decarbonisation plan. The indicators provided as part of this plan are not exhaustive, and should be updated periodically to better reflect the outcomes achieved through the implementation of the suggested interventions.

Indicators can be against an established baseline (year when the implementation starts), and then progress of the implementation can be measured annually or bi-annually as per decision of the Monitoring Committee.

Table 9.1: Probable list of indicators for monitoring and evaluation of Ramanathapuram decarbonisation plan

Category	Proposed Interventions	Broad Suggested Indicators	Broad Anticipated Outcomes
Electricity	Transition to 100% renewable energy in the district through potential assessment and installation of rooftop solar, agro photovoltaic, captive RE etc.	Annual addition to new RE capacity	0.7 GW of new and additional renewable energy capacity built by 2050
Transport	Achieve full electrification of 2W, 3W, 4W, and buses, and partial electrification of HGVs 2050 • Promote electric vehicle (EV) adoption and set up EV charging stations • Electrify public transportation (buses, 3W, 4W passenger vehicles)	Number of EV registered per vehicle category OR % penetration of EV in the new sales	• 100% penetration of electric vehicles in new sales of 2W, 3W, 4W, and bus by 2050. • 80% penetration of electric vehicles in new sales of HGVs (trucks, trolleys) by 2050.
Agriculture	Transition to Solar pumps: Replace 100% of diesel pumps with decentralised solar pumps under PM KUSUM scheme Electrification of agro-machinery (tractors and tillers)	• Percentage of Electric Tractors in New Sales • Number of farmers benefiting from solar pumps installation by total/new number of off-grid solar pumps installed	• 100% conversion of existing 5837 diesel pumpsets to off grid solar by 2030 • Electrification of 1400 tractors and tillers by 2050
Industry	Electrify commercial heating systems in sectors Promote shift from fossil fuel to RE based captive power generation	Renewable energy capacity addition Annual emissions saved	Transition to 100% electrified heating systems by 2050 ~87 MW of renewable energy capacity to run captive power plants in industries
Buildings	Shift to energy efficient residential appliances Adoption of LED based lighting Replacement of Diesel generators with clean source of electricity backup Mandate energy efficiency retrofits in commercial buildings	Number of five-star rated appliance sales in new appliance sales • % penetration of 3-5 star ACs, fans and bulbs in new sales in the district • % of electric cookstoves in the total stock in the district Number of DG sets replaced with electricity-based alternatives Number of residential/ commercial buildings installing rooftop solar. Number of households purchasing electric or induction cooking	Long term: 100% adoption of super-efficient appliances in households. More than 40-50% adopt electric cooking. 100% commercial buildings adopt building retrofits

Category	Proposed Interventions	Broad Suggested Indicators	Broad Anticipated Outcomes
Solid Waste Management	Ensure 100% segregation and collection of waste at source	Percentage of households (urban+rural) from where segregated waste is collected	Efficient waste collection and processing, increased recycling, and enhanced sanitation services contribute to cleaner and healthier communities, and reduce emissions by preventing waste to reach landfills
		Percentage of commercial and institutional/ administrative establishments from where segregated waste is collected	
		Number of EVs in use for waste collection	
		Percentage of collected dry waste recycled/processed (urban+rural)	
		Percentage of collected wet waste processed (urban+rural)	
		Number of waste collection bins installed at strategic locations	
		Number of operational e-waste collection points established	
		Percentage of localities covered under monthly collection of e-waste	
Solid Waste Management	Management of Organic Waste 1. Setting up of waste management facilities 2. Encourage and promote composting, vermi-composting and biogas plants at residential and commercial entities (hotels/resorts/homestays) 3. Facilitate and conduct Behaviour Change Communications workshops on proper disposal of solid waste.	Number and installed capacity of composting centres established	Efficient waste collection and processing, increased recycling, and enhanced sanitation services contribute to cleaner and healthier communities, and reduce emissions by preventing waste to reach landfills
		Compost sold	
		Number and installed capacity of vermicomposting plants	
		Capacity of waste management plants (TPD)	
		Number and installed capacity of biogas plants	
		Number of waste collection bins installed at strategic locations	
		Number of operational e-waste collection points established	

Category	Proposed Interventions	Broad Suggested Indicators	Broad Anticipated Outcomes
	Management of C&D Waste	Number of C&D collection and transfer stations	
		Total installed capacity of C&D waste management plants (TPD)	
		Amount of recycled material sold/reused (concrete, ceramics, iron, wood, etc)	
	Management of Legacy Waste	Quantity of legacy waste in all the identified dumpsite underwent remediation	
		Number of eco parks	
	Waste Management through Circular Economy	Dry waste being processed out of total dry waste collected	
		Total dry waste collected and capacity of dry waste processing facility	
		Number of waste management based entrepreneurship supported	
	Management of water bodies • Marking and bund construction around the boundaries of the water bodies. • Restoration of wetlands • Restoration and soft scaping of lakes	Wastewater nalahas emptying into water bodies and Interception and Diversion (I&D) works undertaken	Improved water access, groundwater conservation, and rejuvenated water bodies support sustainable water management and resilience Reduced GHG emissions from wastewater, and enhanced sanitation services contribute to cleaner and healthier communities
		Water quality assessment test for the lakes	
		Amount spent on lake restoration/dredging	
		Number of employment generated for lake restoration/ dredging	
		Number of wetlands rejuvenated/restored	
		Number of lakes restored, dredged and soft scaping carried out	

Category	Proposed Interventions	Broad Suggested Indicators	Broad Anticipated Outcomes
	Groundwater Management v 1. Construction of rainwater harvesting structures (RwH) across • commercial and residential buildings • Construction of RwH in PRI buildings • RwH in all suitable tourist accommodations	Number of public buildings (Government offices, government schools, institutes, etc.) having functional rainwater harvesting mechanism	
		Total dry waste collected and capacity of dry waste processing facility	
		Number of waste management based entrepreneurship supported	
Tourism	Incorporate sustainable waste management awareness with tourism activities	Number of capacity building workshops organised for hospitality professionals (waste, management)	Increased sustainability practices in hospitality, including water management, waste management and energy efficiency, enhance eco-friendly tourism experiences.
		Number of 'Swacchta Saarthis' deployed at key locations	
		Number of hotels/ lodges/rest houses with IEC material on waste segregation and disposal displayed	
		Number of solar water kiosks installed and operational at public places	
		Percentage of hotels/ lodges/guest houses with sustainable infrastructure (ECBC compliant, etc.)	
Sustainable Agriculture	Increased use of organic fertilisers, promoting balanced rationing for livestock and alternate wetting and drying of paddy fields	Quantity of nano urea and organic fertilisers used annually (in tonnes)	Quantity of nano urea and organic fertilisers used annually (in tonnes) Reduced GHG emissions from synthetic fertiliser use and livestock, improved soil quality, increased productivity of crops, increased climate resilient crops Quantity of improved feed supplements incorporated in the livestock diet (in tonnes) Annual productivity of crops
		Quantity of improved feed supplements incorporated in the livestock diet (in tonnes)	
		Annual productivity of crops	
		Agriculture area affected by extreme weather events (Hectare) and change in production of crops (tonnes)	
		Area of cultivated rice under multiple aeration and system of rice intensification	

Category	Proposed Interventions	Broad Suggested Indicators	Broad Anticipated Outcomes
Enhancing Carbon Sequestration	1. Promoting social and agroforestry 2. Enhancing carbon stock density through reforestation and afforestation 3. Enhancing the mangrove stretch 4. Enhancing seagrass and seaweed stretch	Percentage increase in tree cover in the planning area since baseline year	Expanded green cover, enhanced carbon sequestration leading to reduced GHG emissions, improved biodiversity conservation, and increased urban green spaces for environmental and social benefits
		Number of trees planted/plantation activities carried out	
		Number of plants survived	
		Percentage increase in mangrove, seagrass and seaweed stretch	Enhanced blue carbon sequestration potential, improved biodiversity in Gulf of Mannar Biosphere reserve region

10. Conclusion and Way Forward

Ramanathapuram is uniquely placed to align its industry, transport and other sectors towards achieving carbon neutrality well before 2050. Through the right set of decarbonisation and sequestration measures, it can become one of the first districts in Tamil Nadu to become carbon negative, thereby setting an example for the other districts to follow and make a significant contribution to the state's net zero target.

Tourism and transport are two of the key sectors focused on decarbonisation. As a popular heritage destination with further plans of developing an airport in Rameswaram, the tourist influx is only predicted to grow in the district. While this will be economically beneficial, it is important to decouple this growth from emissions and keep GHG emissions in check. Electrification of 2W, 3W, 4W, buses and HGVs can nearly eliminate predicted emissions from road transport. The use of electric cookstoves in residential and commercial areas and management of domestic wastewater and solid waste through treatment, underground drainage, waste to energy and other interventions will also abate sectoral emissions.

The public electricity generation units are one of the major emitters in the district, and their expected retirement by 2033 will offer Ramanathapuram a transformative opportunity to fuel its whole economy through installation of new and additional renewable energy capacity. By ensuring early investments – monetary and non-monetary – in the potential assessments of such installation, Ramanathapuram can prepare itself for this opportunity as it arises (Scope 2 emissions). This is in addition to the abatements realised through fuel switching and other measures across industry, fishing, transport, agriculture and waste sectors.

The success of this plan relies on **sustained collaboration between the government agencies, industries and local communities.** A dedicated **project management unit (PMU)** could be formed to operationalise the plan including monitoring the progress and evaluating the impacts of such decarbonisation measures.

Furthermore, the decarbonisation plan should be **reviewed and updated periodically** to incorporate the latest technological advancements, changes in policy frameworks, and evolving socio-economic conditions. This will ensure that the strategies remain relevant and aligned with the district's long-term vision.

A central repository of energy, emissions, and progress-related data should be established to enable transparent monitoring and tracking. The availability of real-time, granular data will facilitate informed decision-making and course corrections where necessary. This will also enhance accountability among stakeholders.

By implementing measures/interventions in the decarbonisation plan, Ramanathapuram can establish itself as a model for district-level decarbonisation in India. The plan's **holistic approach, combined with adaptive strategies and collaborative efforts,** will enable the district to balance economic growth with environmental sustainability, ensuring a thriving and resilient future for its residents.

11. Annexures

Annexure 1

Methodology of Climate Variability

Climate variability refers to variations in the mean state of the climate parameters (temperature, rainfall, etc.) and other statistics (such as standard deviations, statistics of extremes, etc.) on temporal and spatial scales beyond that of individual weather events. Variability may be due to natural internal processes within the climate system (internal variability), or due to variations in natural (e.g. solar and volcanic) external forcing (external variability).

Rainfall variability has been analysed for the Southwest monsoon (June to September) and Northeast monsoon (October to December) seasons. Additionally, the precipitation extremes, such as the number of rainy days, Consecutive Dry Days (CDD), and heavy rainfall amounts (RX1DAY, RX5DAY), have been analysed.

Temperature has been analysed for the summer season (March to May) and the winter season (December to February). The temperature extremes such as Warm days (%), Cold days (%), Heat wave duration and Frequency have been analysed.

To assess future climate projections for Ramanathapuram, the analysis uses the NEX-GDDP (0.25 x 0.25) bias-corrected, high-resolution, statistically downscaled dataset derived from 20 Global Climate Models (GCMs) under the CMIP5 framework. Projections are made across two greenhouse gas emission scenarios: RCP4.5 (medium emission) and RCP8.5 (high emission), covering the time periods 2021-2040, 2041-2060, 2061-2080, and 2081-2100

Rainy day: A rainy day, according to the India Meteorological Department, is defined as any day receiving >2.5 mm rainfall.

Consecutive Dry Days (CDD): Maximum number of consecutive dry days per time period with daily precipitation amount of less than 1 mm.

RX1DAY: Highest 1-day precipitation amount.

RX5DAY: Highest consecutive 5-day precipitation amount.

Warm days: Percentage of days when maximum temperature greater than the 90th percentile

Cold days: Percentage of days when maximum temperature is less than the 10th percentile

Annexure 2

Methodology- GHG Emission Profile- Ramanathapuram

The GHG inventory has been developed for the period 2005 to 2022, accounting for carbon-dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) emissions. The inventory covers the four emission sectors, namely, Energy, Industrial Processes and Product Use (IPPU), Agriculture, Forestry & Other Land Use (AFOLU) & Waste, and relevant sub-sectors, as per the IPCC methodology and guidelines. Since Ramanathapuram district does not have sizable industrial and processing units, the emission from the IPPU sector is nil and does not reflect in this inventory.

The GHG inventory follows a robust approach based on information received from relevant line departments of the Government of Tamil Nadu, and reports published at national and state level, as detailed in Table A.2. The emission factors are extracted from Government of India's inventory submissions.

The GHG estimation is based on IPCC Tier 1 (T1) and Tier 2 (T2) approaches. The best effort was made to source activity data and emission factors at the state-level. Although the T2 approach was prioritised, T1 has been followed in the absence of country-specific emission factors. The sector-wise approach is as detailed in Table A.2

The inventory also estimates the Global Warming Potentials (GWP) for CH_4 and N_2O based on the GWP of greenhouse gasses for a 100-year timeframe, as per IPCC AR2 (IPCC, 1995).

Table A.2: Sector-wise Data source, Tiers and Assumption Used for Emission Estimations

Table A.2: Sector-wise Data source, Tiers and Assumption Used for Emission Estimations

IPCC ID	Category	Data Source	Approach	Assumptions
ENERGY				
1A1 ai	Public Electricity Generation	Valuthur Gas Turbine power station (Unit 1, 2, 3, 4)- 2007-08 to 2023-24 - ICED Valantharavai Gas Turbine power station (Unit 1 and 2 - 2007-08 to 2021-22-ICED	T2	**Valantharavai Gas Turbine power station** - 2022-23 data was the average of 2018-19 to 2021-22 - 2005 data was taken as zero since no unit was commissioned - 2006 data was derived by applying the % of installed capacity of unit 1 in 2007 generation data from ICED. - 2007 data was derived by taking average of 2008 to 2011 data from ICED **Valuthur Gas Turbine power station** - 2005, 2006 and 2007 data was derived by applying the % of installed capacity of unit 1 and 2 in average of 2008-2011 generation data from ICED
1A1 aii	Captive Power Plant	a. Electricity generation data based on fuel-type (Coal, Diesel and Gas) of district for the year 2018-19 obtained from CEA b. Electricity generation data based on fuel-type (Gas and Coal) for Tamil Nadu for the years 2004-05 to 2022-23 obtained from CEA General Review Report c. Specific coal consumption	T2	The activity data for the Gas, Coal and Diesel were estimated using the following assumption: • **Gas consumption:** a. The gas consumption by Captive power plants of Tamil Nadu were estimated between 2005 and 2022 using the electricity generation data and specific gas consumption. For 2023, the activity data was estimated using the CAGR. b. For Ramanathapuram district, 2018's gas consumption by captive power plants was estimated using the electricity generation data and specific gas consumption. c. The percentage share of gas consumption in 2018 was calculated for Ramanthapuram, which was then applied on year-on-year (2005 to 2023) estimated gas consumption to data of Tamil Nadu by captive power plant to estimate the district's gas consumption by captive power plant.

IPCC ID	Category	Data Source	Approach	Assumptions
		data for the years 2005 to 2022 was obtained from CEA General Review Report		• **Coal Consumption:** a. The coal consumption by captive power plants of Tamil Nadu were estimated between 2005 and 2022 using the electricity generation data and specific gas consumption. For 2023, the activity data was estimated using the CAGR. b. For Ramanathapuram, 2018's coal consumption by captive power plants was estimated using the electricity generation data and specific coal consumption. c. The percentage share of coal consumption in 2018 was calculated for Ramanthapuram, which was then applied on year-on-year (2005 to 2023) estimated gas consumption to data of Tamil Nadu by captive power plant to estimate the district's gas consumption by captive power plant. • **Diesel Consumption:** a. For Ramanathapuram, 2018's diesel consumption by captive power plants was estimated using the electricity generation data and specific diesel consumption. b. The percentage share of diesel consumption in 2018 was calculated for Ramanthapuram, which was then applied year-on-year (2005 to 2022) to the total diesel consumption of Ramanathapuram (PPAC data) to estimate the diesel consumption by captive power plants.
1A2	Industrial Energy	Fuel consumption data of FO/LSHS, LDO, HSD and Bitumen was obtained from the Petroleum Planning and Analysis Cell (2006 to	T2	• The emissions from overall Industrial energy were estimated due to unavailability of industry-wise fuel consumption data. • The district level FO/LSHS and LDO data from the PPAC was considered solely for the industries category. • The HSD consumption for the industries category was estimated by applying the National-level percentage share of HSD

IPCC ID	Category	Data Source	Approach	Assumptions
		2022)		consumption in retail and the Tamil Nadu state-level percentage share of diesel consumption for industrial purposes (obtained from PPAC report 2013[1] and 2021[2]) on the overall district's HSD consumption. • Bitumen consumption in industries was estimated by allocating 5% of total bitumen consumption in Ramanathapuram.
1A3b	Road Transport	Fuel consumption data of Motor Spirit and HSD was obtained from the Petroleum Planning and Analysis Cell (2006 to 2022)	T1, T2	The fuel consumption data of Motor Spirit and HSD data was estimated using the below assumptions, since data was unavailable. a. **Motor Spirit:** The year-on-year national level retail motor spirit percentage share (obtained from Indian Petroleum and Natural Gas Statistics) and the percentage share of petrol-retail consumption in road transport for Tamil Nadu (obtained from PPAC report 2013) was applied to the district's overall motor spirit consumption to estimate the Ramanathapuram district's motor spirit consumption in road transport. **b. HSD:** The year-on-year national level road transport private sales and retail HSD percentage share (obtained from Indian Petroleum and Natural Gas Statistics) and the percentage share of diesel-retail consumption in road transport for Tamil Nadu (obtained from PPAC report 2013 and 2021) was applied to the district's overall HSD consumption to estimate the Ramanathapuram district's HSD consumption in road transport. • For the year 2005, the overall district's

1 All India Study on Sectoral Demand on Diesel and Petrol , Petroleum Planning and Analysis Cell (2013)
https://ppac.gov.in/uploads/rep_studies/1674814577_20141111032945006974OAllIndiaStudyonSectoralDemandofDiesel%20%282%29.pdf

2 All India Study on Sectoral Demand on Diesel and Petrol , Petroleum Planning and Analysis Cell (2021) accessed from the hard copy.

IPCC ID	Category	Data Source	Approach	Assumptions
				motor spirit and HSD fuel consumption data was estimated using the CAGR method.
1A4	**Other Sectors**			
1A4a	Commercial	Fuel consumption data of LPG HSD and Kerosene was obtained from the Petroleum Planning and Analysis Cell (2006 to 2022)		The fuel consumption data of LPG, HSD and Kerosene data was estimated using the below assumptions, since data was unavailable. **a. LPG consumption:** District-level commercial LPG fuel consumption data was estimated by applying the National-level percentage share of LPG consumption at commercial level on the overall district-level fuel consumption data. **b. HSD consumption:** District-level commercial HSD consumption data was estimated by applying the National-level retail and private sales percentage share and state-level percentage share diesel consumed for the other sector (obtained from PPAC report 2013 and 2021) along with the percentage share of diesel consumed in the commercial sector on the overall district-level fuel consumption data. **c. Kerosene consumption:** District- level commercial kerosene fuel consumption data was estimated by applying the National-level percentage share of kerosene consumption at commercial level on the overall district-level fuel consumption data. - For the year 2005, the overall district's motor spirit and HSD fuel consumption data was estimated using the CAGR

IPCC ID	Category	Data Source	Approach	Assumptions
				method.

IPCC ID	Category	Data Source	Approach	Assumptions
1A4b	Residential	Fuel consumption data of Kerosene, LPG HSD was obtained from the Petroleum Planning and Analysis Cell (2006 to 2022)		- The fuel consumption data of Kerosene, LPG and HSD data was estimated using the below assumptions, since data was unavailable. **d. Kerosene consumption:** District- level residential Kerosene fuel consumption data was estimated by applying the national-level percentage share of domestic kerosene consumption and national-level percentage share of private sales of kerosene on the overall district-level fuel consumption data. **e. LPG consumption:** District-level residential LPG fuel consumption data was estimated by applying the national-level percentage share of domestic LPG consumption and national-level percentage share of private sales of LPG on the overall district-level fuel consumption data. **f. HSD consumption:** District-level residential HSD consumption data was estimated by applying the national-level retail and private sales percentage share and state-level percentage share diesel consumed for the other sector (obtained from PPAC report 2013 and 2021) along with the percentage share of diesel consumed in the residential sector on the overall district-level fuel consumption data. - For the year 2005, the overall district's motor spirit and HSD fuel consumption data was estimated using the CAGR method.

IPCC ID	Category	Data Source	Approach	Assumptions
1A4c	Agriculture	Fuel consumption data HSD was obtained from the Petroleum Planning and Analysis Cell (2006 to 2022)		• District-level residential HSD consumption data was estimated by applying the national-level retail and agriculture consumption percentage share and state-level percentage share diesel consumed in the agriculture sector (obtained from PPAC report 2013 and 2021) on the overall district-level fuel consumption data. • The Ramanathapuram district overall HSD fuel consumption for the year 2020 to 2022 was estimated, since the 2020 consumption data was miniscule while, 2021 to 2022 data was not available. The following steps were used to estimate the district's overall HSD fuel consumption: a. The percentage share of districts overall HSD consumption was calculated for the years 2014 to 2019, using the districts overall HSD consumption and Tamil Nadu's overall fuel consumption (obtained from Indian Petroleum and Natural Gas Statistics). b. Then average of percentage share was calculated and then applied on the Tamil Nadu's overall HSD consumption data from 2020 to 2022 to estimate the Ramanathapuram districts overall HSD consumption data. - For the year 2005, the overall district's motor spirit and HSD fuel consumption data was estimated using the CAGR method.
1A4c	Fisheries	Fuel consumption data of motor spirit, kerosene and diesel		

IPCC ID	Category	Data Source	Approach	Assumptions
		obtained from the Petroleum Planning and Analysis Cell (2006 to 2022)		
IPPU				
2D1	Lubricant Use (Non energy products from fuels and solvent use)	Lubricant consumption data received from the Petroleum Planning and Analysis Cell (2006 to 2020)	T1	• Wherever direct data was not available, suitable statistical methods were applied for estimation like CAGR • Due to lack of segregated data, lubricants' consumption by 2-stroke engines have also been accounted for within the IPPU sector. Due to this, the emissions from this category were calculated using a Tier-1 approach.
AFOLU				
3A	Livestock	Livestock data of cattle, buffaloes, sheep, goats, pigs, horses & ponies, donkeys and poultry: **a**.2004 and 2017 district-level livestock population data obtained from Tamil Statistical Handbook 2018 and 2022 **b**.2019 district-level population data obtained from Open Government Data (OGD) Platform India	T1, T2	- District-level cattle and buffaloes data for years 2004, 2007 and 2019 were estimated by applying the percentage share of age-wise cattle and buffaloes population data of 2012. - For years between 2004 and 2007; 2007 and 2012, and 2012 and 2019, livestock population data were estimated using the interpolation method. While for the years 2020 to 2022, livestock population data were estimated using the CAGR method.

IPCC ID	Category	Data Source	Approach	Assumptions
		c. 2012 district-level livestock population data of cattle and buffaloes (age-wise) and other livestock population data was obtained from Department of Animal Husbandry and Dairying - Govt of India		
	Biomass Burning in Forestland	Not estimated		
3C1b	Biomass Burning in Cropland	The crop production data at district-level was obtained from Directorate of Economics and Statistics, Department of Agriculture and Farmers Welfare, GoI **a**. Rice, Cotton, Sugarcane Groundnut and Ragi: 2004-05 to 2019-20. **b.** Maize: 2004-05, 2006-07 to 2019-20 **c.** Small millets: 2004-05 to 2009-10;2011-12 and 2013-14 and	T1	Wherever direct data was not available, suitable statistical methods were applied for estimation like the CAGR and interpolation method

IPCC ID	Category	Data Source	Approach	Assumptions
		2018-19 **d.** Jowar: 2004-05 to 2009-10;2011-12 and 2013-14 and 2019-20 **e.** Bajra: 2004-05 to 2009-10; 2011-12; 2013-14 to 2015-16, and 2017-18 to 2019-20		
3C7	Rice Cultivation	2004-05 to 2019-20 Directorate of Economics and Statistics, Department of Agriculture and Farmers Welfare, GoI	T2	- The percentage of rice cultivated area under different water management regimes of Tamil Nadu is assumed to be the same for Ramanathapuram district - Wherever direct data was not available, suitable statistical methods were applied for estimation like CAGR
3C4 & 3C5	Agriculture Soils	**Urea and Nitrogen Consumption Data** Nitrogen consumption data 2005-2017 International Crops Research Institute for the Semi-Arid Tropics Urea consumption data	T1 and T2	Wherever direct data was not available, suitable statistical methods were applied for estimation like the CAGR and interpolation method.

IPCC ID	Category	Data Source	Approach	Assumptions
		2011-12- 2020-21- Tamil Nadu Dashboard		
3B2,3B3, 3B5 & 3B6	Land Use (except Forest land)	2005-06, 2011-12 and 2015-16 of LULC from BHUVAN		In the absence of the Land use Land Cover Change (LULC) matrix, the emissions from LULC was estimated by taking the difference between 2005-06 and 2011-12, and 2011-12 and 2015-16 for the categories of Agricultural Land, Other Land and Settlements.
3B1	Forest Land	**a**. District-level Forest cover data for years 2004, 2006, 2008, 2010, 2013, 2015,2017 2019 and 2021 obtained from India State Forest Reports (ISFR) reports **b**. Carbon stock density data of Tamil Nadu was obtained for years 2015, 2017, 2019 and 2021 from ISFR reports	T2	a. **Forest Cover**: For the years between 2004 and 2021 was estimated using the interpolation method b. **Carbon stock Density:** 2015 CSD was applied between 2005 and 2015, 2017 CSD was applied for 201 and 2017, 2019 CSD was applied for the years between 2018 and 2019; and 2021 CSD was applied for the years 2020 and 2021 c. Since, the forest cover data for the year 2022 was not available, hence the emissions were kept the same as of 2021
Waste				
4A	Solid Waste Disposal	**Population data:** census 1951, 1961, 1971, 1981, 1991, 2001, 2011 **Per capita generation:** Waste	T1, T2	• Population in between census years were calculated applying decadal population growth percentage • The proportion of solid waste going to the dumpsite for years between 1951 and 2015 was taken as 70% (National Average) as per NATCOM 2 (MoEFCC,2012) • Estimates are based on state level values

IPCC ID	Category	Data Source	Approach	Assumptions
		generation and composition for 2004-05, Central Pollution Control Board (CPCB), per capita waste generation data for year 2022 from Tamil Nadu State Pollution Control Board **Proportion going to landfill:** CPCB annual reports for 2016-2022 1951 to 2015 from NATCOM 2 **DOC:** Integrated Modeling of Solid Waste in India (March, 1999) CREED Working Paper Series no 26 and CPCB, 1999 2005 CPCB and NEERI study in 59 cities The Central Public Health and Environmental Engineering Organisation (CPHEEO), Ministry of Urban Development,		of per capita waste generation • State-level DOC proportions were used to estimate GHG emissions due to lack of data at the district level

IPCC ID	Category	Data Source	Approach	Assumptions
		GoI (2015): Manual on Municipal Solid Waste Management-2016, Table 1.6		
4D1	Domestic Wastewater Treatment and Discharge	**Population data:** Census 2001, 2011 **Protein intake:** MOSPI **BOD:** National Environmental Engineering Research Institute (NEERI), 2010: Inventorisation of Methane Emissions from Domestic & Key Industries Wastewater – Indian Network for Climate Change Assessment **STP:** NGT monthly progress report 2020 to 2024 STP commissioning date was obtained from National Inventory of Sewage Treatment	T1	• Population in between census years were calculated applying decadal population growth percentage • Year-wise values of BOD generated per person are not available, hence an average national value for BOD of 40.5 gm/person/day is used across the reporting period. While converting BOD values from daily basis to an annual basis, 365 days have been assumed across all years, including for leap years. • Since the installed and actual utilisation data for STPs from 2014 is unavailable, the 2020 data was used to estimate the 2014 capacity, assuming no significant changes in the system during this period • Based on the NATCOM 2 and the 2006 IPCC Guidelines, the default values of Correction Factor are 1.25 for 'I' for collected wastewater and 1 for uncollected wastewater respectively are used in this assessment • 2011 census data is used to find the degree of utilisation of septic tank, sand public latrine of the year 2001. Corresponding proportions of these systems which are available in the Census 2011 data have been used to estimate the percentage distribution of these systems in year 2001

IPCC ID	Category	Data Source	Approach	Assumptions
		Plants 2021 **Urban degree of utilisation:** Availability and Type of Latrine facility is sourced from Census report 2011 and 2001 (Census of India, Ministry of Home Affairs, Government of India)		
4D2	Industrial Wastewater	**Meat**- Production data from 2009-10 to 2018-19 from tn.data.gov **Fish processing** data 2010-11, 2016-17, 2020-21 data from statistical handbook		Wherever direct data was not available, suitable statistical methods were applied for estimation like the CAGR and interpolation method

Annexure 3

Sector-wise BAU and CN50 Emissions/Removals

Sector	GHG Sources and Sink Categories	2050		
		BAU kt CO_2e	**MES kt CO_2e**	**AES kt CO_2e**
Energy	Public Electricity Generation	0	0	0
	Captive Power Plants	209	0	0
	Industries	17	8	0
	Road Transport	155	59	37
	Other Sectors	**283**	**173**	**80**
	Commercial	21	12	10
	Residential	116	88	70
	Agriculture	21	11	0
	Fisheries	125	62	0
	Energy Total	**664**	**240**	**117**
AFOLU	**Aggregate Sources and Non-CO_2 Emissions Sources on Land**	**610**	**346**	**227**
	Agriculture Soil	275	138	69
	Biomass Burning in Cropland	2.87	2.87	2.87
	Rice Cultivation	332	205	155
	Net Land Emissions/Removals	**138.03**	**-465**	**-806**
	Land Emissions	138.19[3]	138.19	138.19
	Land Removals	-0.15	-603 [4]	-944
	Livestock	**257[5]**	**212**	**186**

[3] Land sub-sector includes emissions from categories namely, Agriculture Land (0.15 kt CO_2e), Other Land (0.06 kt CO_2e) and Forest Land (137.97 kt CO2e) and removal from Settlements (-0.15 ktCO2e) in 2022. Since no change in land use pattern is foreseen, the emissions and removal up to 2050 from the land category is assumed to be the same as that of 2022.

[4] Under the MES and AES scenario, the enhanced sequestration is achieved through: (a) adapting agro/social forestry in land classified as cultivate waste land (MES=50%, AES=75%), other fallows (MES=50%, AES=75%), current fallows (MES=10%, AES=20%), barren and uncultivable waste land (MES=10%, AES=25%), land put to non-agriculture uses (MES=5%, AES=10%), (b) restoring the carbon stock density recorded in 2021 (82.25 t/ha) to that recorded in 2015 (87.26 t/ha), and (c) restoration of Mangroves (MES=25%,AES= 50%) and seaweeds (MES=10 sq km and AES=20 sq km)

[5] Livestock sub-sector emissions projected in 2050 is 257 ktCO_2e consisting of emissions from Enteric Fermentation (243 ktCO_2e) and Manure Management (15 ktCO_2e).

Sector	GHG Sources and Sink Categories	2050		
		BAU **kt CO_2e**	**MES** **kt CO_2e**	**AES** **kt CO_2e**
	AFOLU Total	**1006**	**92**	**394**
Waste	Solid Waste Disposal	8.68	0.21	0.21
	Domestic Wastewater	61	13	13
	Industrial Wastewater	6.15	2.46	1.23
	Waste Total	**76**	**16**	**-14**
Gross Emissions		**1746**	**951**	**682**
Net Emissions		**1746**	**348**	**-262**

Annexure 4: Scenarios

1. Livestock

Year	MES		
	Enteric Fermentation		Manure Management (GOBAR-Dhan Scheme)
	Balanced Rationing	Feed Supplements	
2030	20%	15%	20%
2040	40%	30%	40%
2050	60%	45%	60%

Year	AES		
	Enteric Fermentation		Manure Management (GOBAR-Dhan Scheme)
	Balanced Rationing	Feed Supplements	
2030	30%	25%	30%
2040	60%	50%	60%
2050	90%	75%	90%

2. Agriculture Soils

Year	Organic Fertiliser Substituted for Total Nitrogen and Urea		Nano Urea Substituted for Urea	
	MES	AES	MES	AES
2030	10%	15%	25%	35%
2035	20%	30%	50%	70%
2040	30%	45%	75%	100%
2045	40%	60%	100%	100%
2050	50%	75%	100%	100%

3. Rice Cultivation

MES							
Year	MA	SA	CF	Upland	Rainfed Flood Prone	Rainfed Drought Prone	Deep Water
2022	20%	43%	30%	1%	1%	3%	1%
2030	27%	39%	27%	1%	1%	3%	1%
2040	42%	29%	21%	1%	1%	3%	1%
2050	60%	18%	15%	1%	1%	3%	1%

AES							
Year	MA	SA	CF	Upland	Rainfed Flood Prone	Rainfed Drought Prone	Deep Water
2022	20%	43%	30%	1%	1%	3%	1%
2030	27%	39%	27%	1%	1%	3%	1%
2040	51%	23%	19%	1%	1%	3%	1%
2050	77%	7%	9%	1%	1%	3%	1%

4. Domestic Wastewater

Year	Percentage share of Treatment	
	MES	AES
2030	50%	70%
2040	80%	100%
2050	100%	100%

5. Enhancing Carbon Sequestration potential

i. Shifting 100 percent of the 64431.27 ha and 9956.6 ha of land under MES and AES respectively of fallow land to social forestry by 2050

Table 5.1: Category-wise land suggested for Agro/Social forestry

Land Classification	Area (in ha)	MES	AES
Barren and Uncultivable Uses	4342.34	10%	20%
Land put to Non-agricultural uses	86649.29	5%	10%
Cultivable Waste	29424.215	50%	75%
Current Fallows	11328.075	10%	20%
Other Fallows Land	87639.305	50%	75%

Table 5.2: Agro/Social Forestry in Follow land under MES and AES scenarios

Year	% of Fallow Land Shifting to Social Forestry	Trees Planted Per Hectare	Carbon Stored Per Tree Per Year (kg)	Carbon Sequestration Potential with 50 % Survival Rate (tCO_2/yr)	
				MES	AES
2030	25%	200	30	-89	-137
2040	60%			-301	-466
2050	100%			-567	-876

ii. Increasing the Carbon Stock Density from 82.25 tons per hectare (as recorded in 2021) to 87.26 tons per hectare (recorded in 2005), while maintaining the forest cover at its 2021 extent of 24,234 hectares under

a. MES

Year	Carbon Stock Density	Carbon Sequestration Potential ($ktCO_2/yr$)
2030	82.75	-11
2040	83.75	-9
2050	84.76	-9

b. AES

Year	Carbon Stock Density	Carbon Sequestration Potential ($ktCO_2/yr$)
2030	83.75	-33
2040	85.26	-13
2050	86.76	-13

iii. Mangroves

a. MES

Year	% of Mangrove Restored	Trees Planted Per Hectare	CO_2 Sequestered Per Tree Per Year (kg)	Carbon Sequestration Potential with 75 % Survival Rate (tCO_2/yr)
2030	20%	10,000	12.3	-2.80
2040	30%			-7
2050	50% + maintained			-14

b. AES

Year	% of Mangrove Restored	Trees Planted Per Hectare	CO_2 Sequestered Per Tree Per Year (kg)	Carbon Sequestration Potential with 50% Survival Rate ($ktCO_2/yr$)
2030	20%	10,000	12.3	-5.60
2040	30 %			-14
2050	50%			-28

iv. Seagrass

Increase seagrass stretch by 1000 hectares and 2000 hectares in MES and AES by 2050 with 75 percent survival rate

a. MES

Year	Area of Seagrass Restored (hectares)	% of Seagrass Restored	Carbon Sequestered Per Square Kilometre Per Year (GgC/yr)	Carbon Sequestration Potential with 75% Survival Rate ($kktCO_2/yr$)
2030	1000	20%	0.44	-0.81
2040		30%		-6.05
2050		50 %		-12.1

b. AES

Year	Area of Seagrass Restored (hectares)	% of Seagrass Restored	Carbon Sequestered Per Square Kilometre Per Year (GgC/yr)	Carbon Sequestration Potential with 50% Survival Rate ($ktCO_2/yr$)
2030	2000	10%	0.44	-4.8
2040		50%		-12.1
2050		100%		-24.2

v. Seaweed

Increase seaweed stretch by 1000 hectares and 2000 hectares in MES and AES MES and AES by 2050 with 75 percent survival rate

a. MES

Year	Area of Seaweed Restored (hectares)	% of Seaweed Restored	CO_2 Sequestered Per Hectare Per Year (t CO_2/ha/yr)	Carbon Sequestration Potential with 50% Survival Rate (tCO_2/yr)
2030	1000	20%	1.4	-0.21
2040		30%		-0.53
2050		50 %		-1.05

b. AES

Year	Area of Seaweed Restored (hectares)	% of Seaweed Restored	CO_2 Sequestered Per Hectare Per Year (t CO_2/ha/yr)	Carbon Sequestration Potential with 50% Survival Rate (tCO_2/yr)
2030	2000	10%	1.4 0.44	210
2040		50%		840
2050		100%		1050

Annexure 5

List of Schemes and Policies for Convergence with Ramanathapuram's Decarbonisation Plan

S.No	Scheme	Key Highlights	Applicability to Sectors					
Central & State Policies/Schemes			**Agri.**	**Buil.**	**Trans.**	**Ind.**	**Waste**	**AFOLU**
A.	**Promoting Shift to Renewable Energy**							
A.1	Development of Solar/Green Cities Programme	• Up to Rs. 50 lakh per city/town is provided for preparation and implementation of master plans with a goal of minimum 10% reduction in projected total demand of conventional energy at the end of 5 years. This is to be achieved through EE and RE installation measures. ***Who applies for it?*** State governments nominate cities.		YES			YES	
A.2	Pradhan Mantri Kisan Urja Suraksha evam Utthan Mahabhiyan (PM-KUSUM)	• Focuses at de-dieselisation of the farm sector and enhancing income of farmers. • Subsidy up to 30-50% of the total cost for installation of standalone solar pumps and solarisation of existing grid-connected agricultural pumps. • Farmers can install grid-connected power plants up to 2 MW on their barren/fallow land and sell electricity to local DISCOM at a tariff determined by state regulators. ***Who can apply?*** Individual Farmers, FPOs and Cooperatives	YES					
A.3	PM Surya Ghar Muft Bijli Yojana	Under the scheme, households will be provided with a subsidy to install solar panels on their roofs. The subsidy will cover up to 40% of the cost of the solar panels. The		YES				

		scheme is expected to benefit 1 crore households across India. It is estimated that the scheme will save the government Rs. 75,000 crore per year in electricity costs. ***Who can apply?*** Individual Households						
A.4	Pradhan Mantri Ujjwala Yojana	Aims at making clean cooking fuel available to rural and deprived households. LPG connections are now being released under an additional 75 lakh connections target.[6] ***Who can apply?*** Adult women belonging to SC/ST/OBC households, those enrolled in Pradhan Mantri Awas Yojana (Gramin), Anatyodaya Anna Yojana (AAY), tea and ex-tea garden tribes, forest dwellers, SECC households (AHL TIN) and poor households as per 14-point declaration.		YES				
A.5	Development of Green Hydrogen Hubs under National Green Hydrogen Mission	The Mission provides infrastructure support and policy incentives for private investments in Green Hydrogen Parks in areas close to renewable energy sources, industrial clusters with high hydrogen demand, access to water etc. V.O Chidambaranar Port in TN has already been selected as one of the first Green Hydrogen Parks. ***Who can apply?*** Central and State Public Sector Undertakings, Private Sector Companies, State Corporations and Consortiums through the Scheme Implementing Agency (SIA)	YES		YES	YES		
A.6	Incentives for setting up of biogas unit of size up to 25 M3 under National	Central Financial Assistance up to Rs. 70,400 per plant depending upon the State and size of the biogas plant. Additional Incentives, • An additional subsidy of Rs.1600 if the biogas plant is linked with a sanitary toilet or MNRE approved Biogas slurry filter unit.	YES			YES		

[6] The original target under the scheme was to release 8 crore LPG connections to deprived households by March 2020. Under Ujjwala 2.0, an additional allocation of 1.6 Crore LPG connections with special facilities to migrant households is provided. This target was achieved during December 2022.

	Biogas Programme	• Rs. 3,000 per biogas plant for size ranging from 1 M3 to 10 M3 and Rs. 5,000 for size ranging from 15 M3 to 25 M3 as turnkey job fee for biogas plants involving onsite construction such as fixed dome design Deenbandhu Model, floating gas holder KVIC model etc. • Rs. 10,000 per 100% biogas-based generator set/biogas engine water Pumping System (BPS) for meeting small farm needs and water pumping from the biogas plant of 10 to 25 M3. ***Who can apply?*** Individuals will own land/space about 50 sq meter area for installation of small biogas plants.						
A.7	Incentives for setting up of biogas unit of size above 25 M3 under National Biogas Programme	Central Financial Assistance up to Rs. 45,000 per kW for power generation and Rs. 22,500 per kWeq thermal/cooling for thermal application is provided. Administrative charges up to 10% of the CFA or Rs. 250,000 for power generation and 5% of the CFA or Rs. 100,000 for thermal application will be provided for technical supervision, submission of project completion and commissioning reports, and monitoring of projects. ***Who can apply?*** Individuals will own land/space.	YES			YES		
B.	**Incentivising Energy Efficiency in Buildings**							
B.1	Market Transformation for Energy Efficiency (MTEE)	Aims to make energy-efficient appliances more affordable in specific sectors. It comprises of two programs - • Bachat Lamp Yojana (BLY)[7] provides CFLs at the same price as in-candescent bulbs. The cost difference is adjusted by the project implementer through carbon credits earned.		YES		YES		

[7] Promoted energy efficient lighting in the country.

		Who can apply? Residential Consumers ● Super-Efficient Equipment Programme (SEEP) provides financial stimulus to manufacturers to produce and sell super-efficient appliances. Ceiling fans were the first appliance to come under SEEP with a target of making them 50% more efficient than market average ***Who can apply?*** Manufacturers/Industries						
B.2	Unnat Jyoti by Affordable LEDs for All (UJALA)	Aims to make LED Lighting more affordable for all. It promotes replacement of incandescent lamps with LED (Light-Emitting Diode) bulbs by providing LED bulbs to domestic consumers at a low cost. ***Who can apply?*** Domestic Households with a Metered Connection[8]		YES				
C.	Decarbonising Industrial Sector							
C.1	Perform, Achieve and Trade (PAT)[9]	Focused at reducing specific energy consumption in energy-intensive industries, improving their energy efficiency and enhancing cost effectiveness through certification of excess energy saved which can then be traded. ***Who can apply?*** Designated consumers (DCs) (industrial units notified by central government to participate in PAT)				YES		
C.2	**MSME Sustainable (ZED)**	Envisions promotion of Zero Defect Zero Effect (ZED) practices among MSMEs to improve their productivity, reduce waste				YES		

[8] National Ujala Dashboard. Accessed at http://ujala.gov.in/

[9] Currently, PAT Cycle VII is in progress for the FY 2022-23 to the FY 2024-25, covering 707 designated companies with an overall energy saving target of around 8.5 million tonnes of oil equivalent (MTOE) in 9 major energy intensive sectors. Also, with the introduction of the Carbon Credit Trading Scheme (CCTS) in June 2023, industries including aluminum, cement, fertilizers, petrochemicals, petroleum refining, pulp and paper have moved from PAT to CCTS. Refineries, iron and steel plants and textile industries will transition out of PAT into CCTS by 2026-27. PAT will only cover thermal power plants.

	Certification	and enhance their environmental consciousness. ● Subsidy up to 80% for micro, 60% for small and 80% for medium enterprises on cost of ZED certification ● Additional subsidy of 10% for women/SC/ST owned MSMEs or those in NER/Himalayan/LWE/island territories/aspirational districts, as well as another 5% for MSMEs which are also a part of the SFURTI or Micro and Small Enterprises - Cluster Development Programme (MSE-CDP) ● Up to 75% of the total cost of testing, maximum of ₹50,000 in financial assistance for testing/quality/product certification ● Up to ₹2,00,000 for consultancy for all ZED certified MSMEs ● Up to ₹3,00,000 in support for technology upgradation to Zero Effect solutions for all ZED certified MSMEs. ***Who can apply?*** Micro, Small and Medium Enterprises						
C.3	**Tamil Nadu MSME Capital Subsidy[10]**	● Capital subsidy up to 25% or maximum of ₹1,50,00,000 on the value of eligible plant and machinery ● Additional subsidy up to 5% of the plant/machinery value or a maximum of ₹5,00,000 for enterprises set up by women/SC/ST/PwD/Transgender entrepreneurs ● Additional capital subsidy at 25% of the plant and machinery value or maximum of ₹10,00,000 to promote cleaner and environmentally friendly technologies. ***Who can apply?*** All new Micro, Small and Medium Enterprises (including those engaged in solar energy equipments and		YES	YES	YES		

[10] Department of MSME, Government of Tamil Nadu. Guidelines for Availing Capital Subsidy. Accessed at https://www.msmeonline.tn.gov.in/incentives/html_cye_CS.php

		electric vehicle components, clean building materials, charging infrastructure, pollution control equipments, bio technology etc.)						
C.4	**Tamil Nadu MSME Energy Audit Subsidy (PEACE) Scheme[11]**	PEACE Scheme aims to promote energy efficiency in MSME units so as to enable them to reduce costs and improve competitiveness. Under this scheme, • The Government will reimburse 75% of the cost of conducting an energy audit subject to a ceiling of ₹100,000 per energy audit per unit • 50% of the cost of machinery and equipment replaced, retrofitted and technology acquired for implementing the recommendations of the audit will be subject to reimbursement to a maximum of ₹10,00,000. ***Who can apply?*** All existing Micro, Small and Medium Enterprises				YES		
C.5	**Tamil Nadu Quality Certification (Q-cert) Scheme**	This scheme aims to encourage MSMEs to acquire quality standards and certifications for processes and products including ZED rating. The government reimburses payments made to certification and/or consultancy agencies up to ₹2,00,000 for national level quality certification and ₹10,00,000 for international level quality certification. ***Who can apply?*** All existing Micro, Small and Medium Enterprises				YES		
C.6	**Green Industry Incentive under the Tamil Nadu Industrial**	Industrial projects undertaking initiatives in safety and energy efficiency, water conservation and greening (including green buildings) and pollution control solutions are provided a 25% subsidy on the cost of setting up of environmental protection infrastructure to a maximum of ₹1 Crore.		YES	YES	YES	YES	

[11] Department of MSME, Government of Tamil Nadu. Guidelines for Availing Energy Audit Subsidy. Accessed at https://msmeonline.tn.gov.in/incentives/html_cye_peace1.php

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<tr><td></td><td>Policy 2021[12]</td><td>Who can apply? Industries, including MSMEs</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>C.7.</td><td>TANSEED 3.0 Grant Programme by Tamil Nadu StartUp and Innovation Mission (TANSIM)[13]</td><td>Grant funding up to ₹1,00,00,000 and an AWS promotion credit up to US$ 100,000 is provided to grant winners in agriculture, climate action and livelihood space. Key focus is on feeds, fodder, animal nutrition and waste to value/circular economy initiatives.</td><td>YES</td><td></td><td></td><td>YES</td><td></td><td></td></tr>
<tr><td>D.</td><td colspan="8">Decarbonising the Transport Sector</td></tr>
<tr><td>D.1</td><td>PM Electric Drive Revolution in Innovative Vehicle Enhancement (PM E-DRIVE) Scheme 2024[14]</td><td>Promotes faster adoption of electric vehicles (EVs), setting up of charging infrastructure and development of EV manufacturing ecosystem.
● Demand incentives at ₹5,000 per kWh for e-2W and e-3W registered in FY 24-25 and for FY 25-26 as under,
<table>
<tr><td>Category</td><td>Incentive</td><td>Total Number of Vehicles to be supported</td></tr>
<tr><td>EV 2W</td><td>₹2,500 per kWh</td><td>24,79,120</td></tr>
<tr><td>EV 3W L5</td><td>₹2,500 per kWh</td><td>2,05,392</td></tr>
<tr><td>EV Buses</td><td>₹20 lakh to ₹30 lakh depending upon the size</td><td>14,028</td></tr>
<tr><td>e-Ambulances</td><td colspan="2">To be notified separately</td></tr>
</table></td><td></td><td></td><td>YES</td><td></td><td></td><td></td></tr>
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[12] Government of Tamil Nadu. Tamil Nadu Industrial Policy 2021. Accessed at https://tidco.com/wp-content/uploads/2021/08/Industrial%20Policy%202021.pdf
[13] StartUp Tamil Nadu. TANSEED 3.0. Accessed at https://villgro.startuptn.in/
[14] The Electric Mobility Promotion Scheme 2024, implemented for the period from 1st April 2024 to 30th September 2024 is subsumed under PM E-Drive. Another scheme, Faster Adoption and Manufacturing of Electric Vehicle (FAME) had supported development of EV infrastructure. Phase II of this scheme concluded in March 2024. The suggestions received on scope of improvements in FAME under Phase I and II have been incorporated in the PM E-DRIVE. Source: Ministry of Heavy Industries, Government of India. Lok Sabha, Unstarred Question No. 2448. Phase-III of FAME Scheme. Accessed here. https://sansad.in/getFile/loksabhaquestions/annex/183/AU2448_7DstiP.pdf?source=pqals

		e-Trucks | **Other incentives include,** ● Grants for creation of capital assets (charging stations, testing agencies and others) ● Support for IEC activities ***Who can apply?*** EV Buyers (claim for subsidy), Original Equipment Manufacturers (claim for reimbursement of subsidy)						
D.2	**Tamil Nadu Electric Vehicle Policy 2023**[15]	The policy provides special demand and supply sided incentives for promotion of electric vehicles and allied infrastructure in the State. Under the policy, the State targets increasing the share of electric buses to 30% of the fleet by 2030. Supply-Sided Incentives: ● Investment Promotion Subsidy in the form of 100% reimbursement of SGST upon achieving a minimum eligible investment threshold of ₹50 Crore and minimum employment threshold of 50 jobs, whichever is lesser. (OR) ● Turnover based Subsidy up to 2% of the project's annual turnover subject to a cap of 4% of the cumulative investment in eligible fixed assets for a period of 10 years from the date of commercial production. (OR) ● Capital Subsidy of 15% of investment in eligible fixed assets. (OR) ● Special ACC Capital Subsidy of 20% of investment in eligible fixed assets ● Electricity tax exemption (100%) for a period of 5 years ● 100% exemption on stamp duty for purchase/lease of land from government			YES	YES		

[15] Government of Tamil Nadu. Tamil Nadu Electric Vehicle Policy 2023. Accessed at https://investingintamilnadu.com/DIGIGOV/StaticAttachment?AttachmentFileName=/pdf/poli_noti/TN_Electric_Vehicles_Policy_2023.pdf

		agencies or in case of private land, as a backup subsidy for up to 50 acres • Other interest subvention, transition and special incentives for MSMEs. ***Who can apply?*** Micro, Small and Medium Enterprises Demand Sided Incentives							

Type	Category	Incentive Based on Better Capacity (Rs/kWh)	Maximum Incentive (Rs.)	Number of Vehicles to Support Per Year
Private	e-Cycles	-	20% of cost up to Rs. 5000	6,000
Commercial	e-2Wheelers	10,000/kWh	30,000	6,000
Commercial	e-3Wheelers (autos/ light goods carriers)	10,000/kWh	40,000	15,000
Commercial	e-4Wheelers (cabs/good vehicles)	10,000/kWh	1,50,000	3,000
Commercial	e-Buses	20,000/kWh	10,00,000	300

		Other demand sided incentives include, • Subsidy for using EVs for transportation of goods and services by industrial units • 100% road tax exemption to EVs, waiver on registration charges and permit fees till 31.12.2025 • Incentives ranging from ₹5,000 to ₹10,00,000 for procurement of electric vehicles by categories. ***Who can apply?*** Individuals The policy also provides for incentives to build charging infrastructure including public charging stations, battery swapping stations, as well as for capacity building and skilling.						

SI No	Schemes /Policies	Key Highlights	Applicability to Sectors					
			Agri	**Build**	**Trans**	**Ind**	**Waste**	**Water & Carbon Seq**
1.	Prime Minister - Rashtriya Krishi Vikas Yojana (PM-RKVY)[16]	The PM-RKVY scheme aims to provide flexibility and autonomy for states to implement projects as per local farmers' needs and priorities thus making farming as a remunerative economic activity To support and scale up the startups under innovation and entrepreneurship in various fields of agriculture and allied sectors to enhance income of farmers and to create employment opportunities for youth	YES					

[16] https://agriwelfare.gov.in/Documents/Guidelines/PM_RKVY_Guidelines_14112024.pdf

		Few major components under PM-RKVY include Per Drop More Crop (PDMC), Sub-Mission on Agriculture Mechanization (SMAM), Soil Health and Fertility (SH&F), Paramparagat Krishi Vikas Yojana (PKVY) etc.						
2.	Paramparagat Krishi Vikas Yojana (PKVY)[17]	PKVY aims at supporting and promoting organic farming by providing end-to-end support from production to processing certification and marketing by a cluster approach. Under PKVY, states are provided overall financial assistance of ₹31,500/ha covering on-farm and off-farm organic inputs (for this ₹15,000/ha is provided directly to farmers through DBT), marketing, packaging, branding, value addition, certification and residual analysis	YES					
3.	Bharatiya Prakriti Krishi Paddhati (BPKP)[18]	BPKP aims at promoting on-farm biomass recycling, use of cow dung-urine formulations and plant-based preparations in exclusion of synthetic chemical inputs. Financial assistance of ₹12,200/ha for 3 years is provided for cluster formation, capacity building and continuous hand holding by trained personnel, certification and residue analysis Under this scheme dry lands, rainfed areas and tribal areas are to be given	YES					

[17] https://pib.gov.in/PressReleasePage.aspx?PRID=2099756#:~:text=Under%20PKVY%2C%20States%2FUTs%20are,and%20off%2Dfarm%20organic%20inputs.

[18] https://naturalfarming.dac.gov.in/Initiative/BPKP

		preference, where small and marginal farm holders, including tenant farmers being the preferred target group.							
4.	National Mission on Natural farming [19]	This mission aims at implementing self-sustainable and self-generating natural farming systems to enhance income, ensure resource conservation and soil health. Centrally sponsored scheme with an overall outlay of ₹2,481 crore targeting to initiate 1 crore farmers to natural farming spreading over 7.5 Lakh ha land.	YES						
5.	National Mission for Sustainable Agriculture (NMSA)[20]	NMSA also aims to make agriculture more productive, sustainable, remunerative and climate resilient by promoting location specific Integrated / Composite farming systems. Components under NMSA include Rainfed Area Development (RAD), Sub-Mission on Agroforestry (SMAF), National Bamboo Mission (NBM), Soil Health Management (SHM) and Climate Change and Sustainable Agriculture: Monitoring, Modelling and Networking (CCSAMMN).	YES						
6.	Soil Health Card (SHC) Scheme[21]	In the form of a soil card, farmers will get a report containing all the details about the soil of their particular farm once in every 3 years.	YES						

[19] https://www.agriwelfare.gov.in/Documents/HomeWhatsNew/GuidelineofNMNF_FinalApproved_27122024.pdf
[20] https://nmsa.dac.gov.in/Default.aspx

[21] https://www.soilhealth.dac.gov.in/home

		SHC displays soil health indicators that can be assessed without the requirement of a laboratory or technical equipment, and are based on farmers' practical experience and knowledge of local natural resources.						
7.	Chief Minister's Manniyur Kaathu Mannuyir Kappom Scheme (CM MK MKS)[22]	CM MK MKS aims to achieve sustainable and chemical free agricultural practices through distribution of Green Manure seeds and vermicompost pits and beds for farmers. For the FY 2024-25 the scheme has an outlay of ₹206 crores covering 22 components to maintain soil health for supply of healthy food to society.	YES				YES	
8.	Kalaignarin All Village Integrated Agriculture Development Programme (KAVIADP)[23]	KAVIADP strives to increase the economic status of farmers by bringing fallow lands under cultivation and increase the cultivable area by creation of new water sources thereby to increase agricultural production and productivity. 100% funding for community water source creation (State Plan Scheme) For Union Government shared schemes like PM-KUSUM, PMKSY etc. based on respective guidelines and funding pattern.	YES					

[22] http://tnenvis.nic.in/Database/TN-ENVIS_792.aspx
[23] https://aed.tn.gov.in/en/schemes/special-schemes/kagovvt/

9.	Kalaignarin Nagarpura Mempattu Thittam (KNMT)[24]	KNMT aims to fulfil infrastructural gaps in municipalities and town panchayats until Urban Local Bodies (ULB) level. This scheme covers funding for rejuvenation of water bodies, Solid Waste Management (SWM) infrastructure development including greening the vehicle fleet, construction of public toilets and parks etc.					YES	
10.	Namakku Naamae Thittam (Urban)[25]	This scheme improves the self-support mechanism of public participation in creating and maintaining community infrastructure. Renovation of water bodies, storm water drain, Upgradation of earthen /gravel/WBM roads/streets to all-weather roads, Community toilets/Public toilets, shops, Markets etc. can be taken under this scheme. Minimum public contribution for any identified work (except renovation of water bodies) should be one third of the estimated value and for the renovation of water bodies the contribution should be 50%. There is no upper limit for public contribution.					YES	YES

[24] https://cms.tn.gov.in/cms_migrated/document/GO/maws_e_70_2021.pdf

[25] https://www.tnurbantree.tn.gov.in/namakku-naame-thittam/

11.	Atal Mission for Rejuvenation and Urban Transformation Scheme (AMRUT 2.0)[26]	AMRUT 2.0 aims to provide universal coverage of sewerage and septage management in 500 AMRUT cities while also enabling them to become self-reliant and water secure. Total indicative outlay is ₹2,99,000 crore with central share of ₹76,760 crore for a period of 5 years from 2021-2026.					YES	
13.	Swachh Bharat Mission-Gramin (SBM-G) - Phase II[27]	SBM-G Phase II aims to sustain the Open Defecation Free (ODF) status while also promoting sustainable solid and liquid waste management. The total outlay of SBM(G) Phase II is 1.40 lakh crore with key focus on areas like 100% scientific processing of Municipal Solid Waste, remediation of all legacy waste dumpsites and ensuring ODF status with no untreated faecal sludge or used water is discharged into environment					YES	
14.	Galvanising Organic Bio-Agro Resources Dhan (GOBARdhan)[28]	GOBARdhan scheme aims to convert waste to wealth towards promoting a circular economy by building a robust ecosystem for setting up Biogas/Compressed Biogas (CBG) and Bio-Compressed Natural Gas (CNG) plants. 1. Any government/ private entity operating or intending to set up a	YES				YES	

[26] https://pib.gov.in/PressReleaseIframePage.aspx?PRID=2078409
[27] https://swachhbharatmission.ddws.gov.in/about_sbm

[28] https://www.india.gov.in/spotlight/gobardhan-galvanizing-organic-bio-agro-resources-dhan

		Biogas/ CBG/ Bio CNG plant can apply 2. Supporting villages to efficiently manage their agricultural and cattle waste thereby keeping the surroundings clean 3. Eligible entities are classified into Individual household model, Cluster model, Commercial model and Community model.						
15.	Waste to Wealth Mission[29]	This mission aims at strengthening the waste management system in India by identifying and validating innovative technology solutions and models to achieve a zero-landfill and zero-waste nation. The mission aims to achieve this through effective management of solid waste and development of robust waste-to-energy and composting facilities.					YES	
16.	Tamil Nadu Industrial Policy 2021[30]	Industrial projects undertaking green initiatives for recycling waste and water for industrial use and for sustainable energy usage, coupled with online monitoring. Wherever applicable shall be eligible for a 25% subsidy on the cost of setting up such environmental protection infrastructure subject to a limit of ₹1 crore.				YES	YES	

[29] https://www.psa.gov.in/waste-to-wealth
[30] https://spc.tn.gov.in/policy/tamil-nadu-industrial-policy-2021/

17.	Jal Jeevan Mission (JJM)[31]	JJM envisions to provide safe and adequate drinking water through individual household tap connections. Aims at providing Functional Household Tap Connections (FHTC) with 55 LPCD capacity and ensure long term sustainability with potable water The program also aims to implement source sustainability measures such as recharge and reuse through grey water management, water conservation and rainwater harvesting.							YES
18.	Pradhan Mantri Krishi Sinchayee Yojana (PMKSY)[32]	PMKSY focusses on sustainable water conservation practices exploring the feasibility of reusing treated municipal wastewater to the extent possible. This scheme has been conceived amalgamating various ongoing schemes and will be jointly implemented by agriculture, water resources and rural development departments. Creation of new water resources through minor irrigation along with repair, restoration and renovation of water bodies (Har khet ko pani scheme). Water harvesting structures like check dams, nala bund, farm ponds, tanks etc. (PMKSY-Watershed) and various components under PMKSY-PDMC scheme.							YES

[31] https://jaljeevanmission.gov.in/
[32] https://pmksy.gov.in/AboutPMKSY.aspx

19.	Amrit Dharohar Scheme[33]	This scheme promotes unique conservation values of Ramsar sites. These sites have multidimensional roles to play including enhancement of carbon sinks, buffer landscape from extreme events and provide water and food security. Encourage optimal use of wetlands, and enhance biodiversity, carbon stock, eco-tourism opportunities and income generation for local communities Key activities and components of the scheme include Species and Habitat conservation, Nature tourism, Wetlands livelihood, Wetlands carbon. Ramanathapuram district is home to five Ramsar sites[34] spanning over 53,289 ha, including the Gulf of Mannar Biosphere Reserve (52,672 ha), a globally significant marine ecosystem rich in coral reefs, seagrass meadows, mangroves, and marine biodiversity.						YES
20.	National Afforestation Program (NAP)[35]	NAP is a centrally sponsored scheme aiming to restore degraded forests and develop forest resources by supporting large-scale reforestation and afforestation projects.						YES

[33] https://indianwetlands.in/wp-content/uploads/library/1686133937.pdf
[34] https://tnswa.tn.gov.in/dashboard-ramsar-site-information.php
[35] https://pib.gov.in/PressReleaseIframePage.aspx?PRID=1795073

21.	Green India Mission (GIM)[36]	GIM aims to protect, restore and enhance India's forest cover, improve ecosystem services and enhance carbon sinks thereby responding to climate change. Key activities include enhancing tree cover in urban and peri-urban areas, eco-restoring open forests and grasslands, restoring mangroves and abandoned mining areas etc.						YES
22.	Agroforestry Policy[37]	This policy promotes integrating trees into agricultural landscapes to sequester carbon and boost farmer income. It also involves promoting climate resilient cropping and farming systems thus conserving environment and biological diversity. The Agroforestry component under RKVY provides up to ₹50 lakh for establishing nurseries to produce Quality Planting Materials, with 100% assistance for government agencies and 50% for private agencies	YES					YES
23.	Compensatory Afforestation Fund Management and Planning Authority (CAMPA)[38]	State CAMPA to submit the Annual Plan of Operations (APO) to get funds and engage the local communities in afforestation, soil water conservation and forest protection activities.						YES

[36] https://www.indiascienceandtechnology.gov.in/st-visions/national-mission/national-mission-green-india-gim
[37] https://agriwelfare.gov.in/Documents/Operational%20Guidelines%20of%20AGROFOREST%20Y%20under%20RKVY.pdf
[38] https://pib.gov.in/PressReleasePage.aspx?PRID=1906384

24.	Nagar Van Yojana[39]	Promotes urban forestry by creating urban forests/parks. Grants limited to 50 ha, with funding up to ₹4 lakhs per hectare. At least two-thirds of the area must be under tree cover and may include biodiversity parks, butterfly conservatories, smriti vans, herbal gardens, and waterbodies.						YES
25	National Fisheries Policy 2020[40]	NFP intends sustainable development of resources and associated habitats, protecting the rights of fishing and farming communities, making Indian fish products globally competitive and supporting India's commitment to sustainable usage of fisheries resources. Key components under environment & climate change include ensuring ecosystem health and integrity, protecting keystone species and iconic ecosystems, regulating fish meal production and wild collection of juveniles, blue economy and marine spatial planning.						YES
26	Pradhan Mantri Matsya Sampada Yojana (PMMSY)[41]	PMMSY aims to bring about the Blue Revolution through sustainable and responsible development of the fisheries sector with a total investment of ₹20,050 crore over a period of 5 years from FY 2020-21 to 2024-25. PMMSY aims to modernise and strengthen the value chain, enhance traceability and establish a robust fisheries management framework						YES

[39] https://nams.nic.in/nagarvan.php
[40] https://dof.gov.in/sites/default/files/2020-12/Policy_0.pdf
[41] https://pmmsy.dof.gov.in/new-download

		ensuring socio-economic welfare of fishers and fish farmers. Funding pattern: Centre share ₹1,500 + State share ₹1,500 + Beneficiary share ₹1,500 = ₹4,500 Under PMMSY around 6/7 villages from the district have been selected for development as Climate Resilient Coastal Fishermen Villages (CRCFV)						
27	Fisheries and Aquaculture Infrastructure Development Fund (FIDF)[42]	FIDF envisages development of fisheries infrastructure facilities in both marine and inland thus achieving sustainable growth in fish production. GoI provides interest subvention up to 3% per annum for the repayment period of 12 years inclusive of moratorium of 2 years for providing the concessional finance by the Nodal Loaning Entities (NLEs) at the interest rate not lower than 5% per annum.						YES

[42] https://pmmkssy.dof.gov.in/pmmkssy/#/guidelines

Endnotes

1 Chennai recently deployed 120 electric buses under the MTC fleet with a total investment of Rs. 207.9 Crore. Since the cost of electric buses could vary by seating capacity and features, this investment is taken as a comparable figure for Ramanathapuram too. An average of Rs. 1.8 Crore is assumed per electric bus.

2 Estimated for all 64 buses. The scheme is valid till March 2026, unless extended.

3 Only 300 buses can be supported under TN EV Policy per year, giving an average of 8 EV buses per district. Estimates are generated accordingly. The scheme is valid till December 2025, unless extended.

4 https://tnpcb.gov.in/PDF/About_Us/Announcementgos/GONo116_16625.pdf

5 Tamil Nadu State Budget 2024-25, Speech. https://financedept.tn.gov.in/en/my-documents/2020/07/BS_2025-26_English_A4_Final.pdf

6 Ramanathapuram District Statistical Handbook 2022-23

7 https://cgwb.gov.in/sites/default/files/2022-10/ramanathapuram.pdf

8 India Climate and Energy Dashboard

9 It is to be noted that while there is only ~1% of area classified as forest in the district, other land use categories cover forestry in some form or another, such as in case of social forests under other fallow land.

10 LISS III and IV Satellite Imageries for 2013 and 2023, Author's Analysis

11 https://www.tnswa.org/wetlands-of-tamil-nadu

12 District Diagnostic Report

13 MSME Dashboard. Accessed at https://dashboard.msme.gov.in/uam_dist_wise.aspx?stid=33

14 https://msmedi-chennai.gov.in/GARMS_Admin/basictools/images/DIPSReport/Ramanathapuram.pdf

15 District Statistical Handbook 2023-24

16 District Statistical Handbook Ramanathapuram District 2023-24

17 Source: District Handbook 2023-24, Tamil Nadu Generation and Distribution Corporation (TANGEDCO)

18 Swachh Survekshan 2022 https://ss2022.sbmurban.org/#/dashboard

19 National inventory of Sewage Treatment Plants, March 2021 https://cpcb.nic.in/openpdffile.php?id=UmVwb3J0RmlsZXMvMTIyOF8xNjE1MTk2MzIyX21lZGlhcGhvdG85NTY0LnBkZg==

20 October and November are the principal rainy months; November is the wettest month (mean rainfall of 182 mm), whereas the mean rainfall in October is about 177 mm.

21 Representative Concentration Pathways (RCPs) are concentration pathways used by the IPCC. They are prescribed pathways for greenhouse gas and aerosol concentrations, together with land use change, that are consistent with a set of broad climate outcomes used for climate modelling. The pathways are characterised by the radiative forcing produced by the end of the 21st century. Radiative forcing is the extra heat the lower atmosphere will retain as a result of additional greenhouse gases, measured in Watts per square metre (W/m^2). There are four RCPs, RCP2.5 (low pathway where radiative forcing peaks at approximately 3 W m-2 before 2100), RCP4.5 and RCP6.0 (two intermediate stabilisation pathways in which radiative forcing is stabilised at approximately 4.5 W m-2 and 6.0 W m-2 after 2100) and RCP8.5 (high pathway for which radiative forcing reaches greater than 8.5 W m-2 by 2100).

22 The number of heat wave periods not less than 5 days

23 Maximum number of consecutive days per year when the daily maximum temperature is above the 90th percentile

24 Ramanathapuram District Disaster Management Plan,2024 https://tnsdma.tn.gov.in/img/document/DDMPPDF/Ramanathapuram%20-%20DDMP.pdf

25 Under the updated NDC submitted in 2022, India has committed to reduce the emission intensity of its GDP by 45 percent, by 2030, from the 2005 levels.

26 Scope 1 indicates direct greenhouse gas emissions that are from sources owned or controlled by the reporting entity.

27 CO2e are also calculated in terms of Global Warming Potential (GWPs) as reported in the Sixth Assessment Report (AR6) of the IPCC.

28 The National Communications (NATCOM) provides information on GHG inventories, measures to mitigate and to facilitate adequate adaptation to climate change, and any other information that the Party considers relevant to the achievement of the objective of the Convention. They are submitted every four years.

29 Biennial Update Report (BUR) provides an update of the information presented in NCs, in particular on national GHG inventories, mitigation actions, constraints and gaps, including support needed and received.

30 District Statistical Handbook Ramanathapuram District 2022-23

31 District Statistical Handbook 2022-23. Accessed at https://cdn.s3waas.gov.in/s3c86a7ee3d8ef0b551ed58e354a836f2b/uploads/2023/12/2023120538.pdf

32 India Residential Energy Survey (IRES) 2020. Accessed https://dataverse.harvard.edu/dataset.xhtml?persistentId=-

doi:10.7910/DVN/U8NYUP

33 https://www.newindianexpress.com/states/tamil-nadu/2024/Jan/03/pm-lays-foundation-stone-for-rs-829-crore-oil-pipelines-in-chennais-vallur-2647343.html#:~:text=This%20pipeline%20section%20traverses%20through,from%20ensuring%20environmental%20well%2Dbeing

34 https://www.ceew.in/press-releases/delhi-and-tamil-nadu-lead-indias-switch-electric-cooking-percent-adoption-ceew

35 https://agpglobal.com/wp-content/uploads/2022/01/agp-pratham-opens-tamil-nadus-first-natural-gas-mother-station.pdf

36 https://cea.nic.in/wp-content/uploads/ps___lf/2023/07/Guidelines_for_Medium_and_Long_Term_Demand_Forecast-1.pdf

37 Gompertz Growth model is a function that describes growth as being slow at the start and the end of a given period of time. Originally used in biology, it is being increasingly applied for economic and non-economic predictions, including that of vehicle ownership growth. Read Torok, Adam. “Prediction of Vehicle Ownership Growth using Gompertz Model, Case Study of Hungary.” CzOTO 2022, Volume 4, Issue 1, PP. 164-169.

38 https://tamil.vkp-tnrtp.org/wp-content/uploads/2023/06/RAMNAD.pdf

39 National Fisheries Development Board. “Utilising Solar Wind Energy in the Fisheries Sector.” Accessed at https://nfdb.gov.in/PDF/Utilising%20Solar%20Wind%20Energy%20in%20Fisheries%20Sector.pdf

40 https://www.newindianexpress.com/states/tamil-nadu/2024/Jan/29/ramnad-requires-govt-attention-to-propel-industrial-growth-experts?utm_source=chatgpt.com

41 https://msmedi-chennai.gov.in/GARMS_Admin/basictools/images/DIPSReport/Ramanathapuram.pdf

42 https://agritech.tnau.ac.in/govt_schemes_services/pdf/NADP/17.%20Ramanathapuram%20DAP%20Final%20Report%20 2017-18.pdf

43 https://msmedi-chennai.gov.in/GARMS_Admin/basictools/images/DIPSReport/Ramanathapuram.pdf

44 https://mowr.nic.in/core/WebsiteUpload/2023/MI6.pdf

45 https://www.cgwb.gov.in/cgwbpnm/public/uploads/documents/17135107192062732741file.pdf

46 https://cdn.s3waas.gov.in/s3c86a7ee3d8ef0b551ed58e354a836f2b/uploads/2022/06/2022060866.pdf

47 https://environment.tn.gov.in/assets/report/Database%20on%20Energy%20Resources%20in%20Tamil%20Nadu.pdf

48 GIZ. “Agrivoltaics in India.” January 2024. Accessed at https://beta.cstep.in/staaidev/assets/manual/APV.pdf

49 NREL, Energy Analysis. Agricultural decarbonisation. Accessed at https://www.nrel.gov/analysis/agricultural-decarbonisation.html

50 Balanced rationing: process to balance the level of various nutrients of an animal, from the available feed resources, to meet its nutrient requirements for maintenance and production. https://www.nddb.coop/services/animalnutrition/programmes/ration-balancing-programme

51 Improved Feed Supplements: Use of improved feed supplements have been shown to decrease methane emissions from livestock. ICAR-National Institute of Animal Nutrition and Physiology developed a feed supplement - Harit Dhara and Tamarin Plus, for cattle, are effective in cutting down enteric methane emissions by 20% http://nianp.res.in/harit-dhara-tamarin-plus.

52 Feed additives like neem cake, seaweed, tannins, essential oils and enzyme supplements.

53 Galvanizing Organic Bio-Agro Resources Dhan (GOBAR-Dhan) Scheme launched in April 2018 by the Ministry of Drinking Water & Sanitation focuses to generate energy and organic manure from cattle waste, promote circular economy, reduce GHG emissions, create rural employment opportunities etc. https://gobardhan.co.in/about-us

54 Projected based on CAGR between 2008 and 2017 data.

55 Projected based on the CAGR between 2012 and 2022 data

56 Nano ss are nutrients that are encapsulated or coated within nano material in order to enable controlled release and its subsequent slow diffusion into the soil.

57 Jagatheesan, Mohanraj & Subramanian, K. & Lakshmanan, A. (2019). Role of Nano-Fertilizer on GHG Emission in Rice Soil Ecosystem. Madras Agricultural Journal. 106. 10.29321/MAJ.2019.000327.

58 United Nations Environment Programme (2024). Promoting a Sustainable Agriculture and Food Sector in India. Nairobi

59 In the absence of district-level data on paddy cultivation water regimes, state-level averages for Tamil Nadu have been used. However, these figures may be skewed by high water availability districts such as Thanjavur, Thiruvarur, and Nagapattinam, which traditionally follow water-intensive practices.

60 Projected based on the CAGR adjusted area under rice cultivation between 2020 and 2022

61 Measures to reduce methane emissions, Ministry of Environment, Forest and Climate Change https://pib.gov.in/PressReleaseIframePage.aspx?PRID=1942106

62 Ibid.

63 https://kspcb.kerala.gov.in/assets/uploads/widget/wm_files/guidelines_swm.pdf

64 https://nmcg.nic.in/writereaddata/fileupload/ngtmpr/14_Tamil%20Nadu%20-%20MPR%20May%202025.pdf

65 Centralised wastewater treatment involves three stages: primary, secondary, and tertiary. In primary treatment, larger solids are removed through physical processes. Secondary treatment uses microorganisms to biodegrade remaining particulates. Tertiary treatment further purifies the water using advanced filtration, disinfection, and other methods to remove pathogens and nutrients, achieving 50-90 percent BOD removal efficiency

66 Activated sludge process- In the activated sludge process, wastewater is mixed with treated sludge in an aeration tank, where microorganisms break down organic pollutants into carbon dioxide, water, and biomass.

67 An on-site sewage system with multiple compartments allows sedimentation and sludge digestion. Solids settle as sludge, and scum is retained. Sludge undergoes anaerobic digestion, achieving 20-40% BOD removal efficiency.

68 An independent facility treats faecal sludge and septage for safe disposal and reuse using four modules: Sludge Drying Beds, Anaerobic Baffled Reactor, Planted Gravel Filter, and a Disinfection unit, achieving over 80 percent BOD removal efficiency

69 https://www.dpcc.delhigovt.nic.in//uploads/pdf/NGT-Order-OA-673-of-2018-22-02-2021pdf-d2c576ccba58ab-628083796149355cad.pdf

70 Zero liquid discharge (ZLD) is a strategic wastewater management system that ensures that there will be no discharge of industrial wastewater into the environment. It is achieved by treating wastewater through recycling and then recovery and reuse for industrial purposes.

71 Biomining is a process that uses living organisms, such as microorganisms, to extract metals from ores, minerals, and other solid materials.

72 Zero waste is the principle of minimizing waste production as much as possible, then composting, reusing, or recycling any other waste generated.

73 A zero-carbon footprint, also known as carbon neutrality or net zero, means that an individual, organization, or entity balances the amount of greenhouse gas emissions it produces with an equivalent amount removed from the atmosphere

74 Responsible tourism is a collaborative approach to tourism that aims to reduce the negative impacts of tourism on local communities while maximizing its positive benefits. It involves addressing issues such as climate change, over-tourism, and biodiversity loss, while also supporting the local economy and cultural heritage

75 A deposit-refund system combines a tax on product consumption with a rebate when the product or its packaging is returned for recycling. https://www.rff.org/publications/working-papers/deposit-refund-systems-in-practice-and-theory/

76 https://msmedi-chennai.gov.in/GARMS_Admin/basictools/images/DIPSReport/Ramanathapuram.pdf

77 Forest Survey of India Annual Reports

78 https://ramanathapuram.nic.in/departments/forest-environment-climate-change/

79 Agroforestry involves integrating trees with agriculture through practices like planting trees along farm boundaries, alternating tree strips with crops, growing crops under a tree canopy, creating riparian buffers to prevent runoff, and using silvopasture where trees provide shade for grazing livestock.

80 https://www.newindianexpress.com/states/tamil-nadu/2023/May/13/concerted-efforts-under-way-to-reverse-mangrove-forest-depletion-in-ramnad-2574879.html

81 Krishnamurthy, R. R., Jonathan, M. P., Srinivasalu, S., & Glaeser, B. (Eds.). (2018). Coastal Management: Global Challenges and Innovations. Academic Press.

82 Bryce R. Van Dam et al.,Calcification-driven CO2 emissions exceed “Blue Carbon” sequestration in a carbonate seagrass meadow.Sci. Adv.7,eabj1372 (2021).

83 Edward, J. P., Raj, K. D., Mathews, G., Kumar, P. D., Arasamuthu, A., D’Souza, N., & Bilgi, D. S. (2019). Seagrass restoration in Gulf of Mannar, Tamil Nadu, Southeast India: a viable management tool. Environmental monitoring and assessment, 191, 1-14.

84 https://www.pib.gov.in/PressReleasePage.aspx?PRID=1954383&utm

85 https://unfccc.int/process/transparency-and-reporting/greenhouse-gas-data/greenhouse-gas-data-unfccc/global-warming-potentials

86 Hariyali Green Villages: Women-led Climate and Clean Energy Solutions for Prosperity in Rural India. Accessed at https://www.nrdc.org/sites/default/files/hariyali-green-villages-climate-clean-energy-solutions-rural-india-report.pdf

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