

AI, GIG ECONOMY & SUSTAINABLE BUSINESS INNOVATION

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CONTENTS

S. No	Title	Page no.
1	GIG Economy: The Indian Way <i>a High Tide that Lifts All Boats</i> Dr. Parimala. G & Dr. Deepa. V	1
2	Redefining Humanity through Artificial Life: Ethics and Identity In <i>Frankenstein</i> and <i>Do Androids Dream Of Electric Sheep?</i> Mr. M. Vairamuthu	8
3	AI-Driven Financial Literacy Among Rural Entrepreneurs: Pathways, Challenges, And Sustainable Impact Mr. P. Arumugapandi	12
4	A Study on Sustainable Urban Waste Management through a Circular Economy Lens Sindhu Krishnan & Dr. S. Vennilaa Shree	23
5	Digital Transformation and Future Workforce Dr. P.V. Nandhini	32
6	Generative AI and the Future of Work and its Implications for Skills, Employment And Social Protection Dr. C. Keerthana	39
7	AI, GIG Economy and Sustainable Business Innovation: A Study among GIG Workers in Kanyakumari District Amsatha. K & Afrin. K	45
8	Digital Transformation and the Future of Work: Assessing Workforce Readiness, Digital Skills and Employability in Kanniyakumari District Dr. Regima. V & Dr. A. Franklin Ragila	51
9	AI and Business Innovation in the Gig Economy Dr. B. Indira Priyadharshini & Dr. T. Suriyaprabha	59
10	Digital Skills, Employability and Career Readiness Among Commerce Graduates: An Empirical Study in Kanniyakumari District Subhiksha SV & Dr. R. Vijimalar	66
11	AI Reshaping the Gig Economy: An Analysis of Technology Effects, Governance Responses and Future Paradigms M. Shanmugapriya & G. Sowbarani	74
12	Co-Evolving with Synthetic Intelligence: Redefining Human Agency, Skills Ecosystems, and Organizational Value in the Emerging Work Paradigm Ms. S. Rama Prabha & Dr. M. Chithirai Selvan	81

CIRCULAR ECONOMY APPROACHES FOR EFFECTIVE WASTE MANAGEMENT IN KUMBAKONAM, TAMIL NADU

A STUDY ON SUSTAINABLE URBAN WASTE MANAGEMENT THROUGH A CIRCULAR ECONOMY LENS

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Abstract

Waste management has become an important concern in growing towns such as Kumbakonam, where population growth, tourism and religious activities contribute to increasing waste generation. This study looks at how circular economy practices can be used to improve waste management in Kumbakonam, Tamil Nadu. It focuses on waste segregation, recycling, composting, biomethanation and the reuse of temple and other organic waste. The study also examines the scope for converting waste into useful products and income-generating activities. Based on the existing situation, it suggests a practical circular economy approach involving local communities, municipal authorities, temples and other stakeholders to promote cleaner surroundings, better resource use and sustainable development.

Keywords: *Circular Economy, Waste Management, Kumbakonam, Temple Waste, Recycling, Composting, Resource Recovery, Biomethanation, Waste-to-Wealth, Sustainable Development*

1. Introduction

The urbanization and changing consumption patterns have led to a significant rise in the volume of municipal solid waste (MSW) in Indian cities. The collection of MSW in India has increased from more than 170,000 metric tonnes per day (MTD) in a day (MOSPI, FY 2022) and the per capita generation of MSW has been estimated at 0.5 to 1 kg of MSW per day by the TNPCB (2021), with growth of MSW generation at 1.3% per year. The amount of MSW generated varies from 2.3 billion tonnes in 2023 to 3.8 billion tonnes by 2050 globally (UNEP, 2024). The 'take, make, use, dispose' linear approach to waste management has failed to meet the demands of these pressures. The Circular Economy (CE) has come to the fore as a paradigm shift on the path of resource efficiency, waste reduction and long material life cycles. The implementation of CE principles in urban waste management can bring benefits to less dependence on landfill, emission of greenhouse gases and generate green employment. The waste sector emissions in India have already increased by 226% from 1994 to 2020 (MoEFCC, 2024), emphasizing the need for a systemic change. Although initiatives like the Swachh Bharat Mission (SBM) and SDG commitments have been introduced at the national level, merely 17% of the households in India today practice complete waste segregation, and over 30,000 tonnes per day (TPD) of

MSW remains unprocessed, ending up in landfills (National Institute of Urban Environment (NITI Aayog) 2023, CPCB 2024). The municipal solid waste generation in Tamil Nadu is significant at 14,585 MT/day, of which about 5,400 MT/day is from Chennai (TNPCB, 2021). The historic town of Kumbakonam in Thanjavur district produces around 70 MTD of MSW. Being a pilgrimage centre, it caters to the needs of millions of tourists every year and the waste problem becomes greater during festivals like Mahamaham. This study aims to analyze the circular economy concept and its ability to shift the waste management system from a disposal-based approach to a resource-recovery based approach for the town of Kumbakonam.

2. Problem Statement and Context

The waste management system in Kumbakonam is handled by the Municipal Corporation that serves a population of more than 1.5 lakh people in 45 wards. Although there has been an effort to establish operational programs such as door-to-door collection, composting and biomethanation, the existing scheme basically focuses on collection and disposal rather than resource recovery. The 804 sanctioned Micro Composting Centres (MCCs) with a total capacity of 3,130 TPD are operational across Tamil Nadu with 691 MCCs operating at 2,649 TPD and a model Kumbakonam must replicate and scale locally (TNMA, 2023). One of the biggest problems is plastic waste. In Tamilnadu, the urban local bodies produce around 1178 tonnes of plastic waste daily with 96% of the waste being collected and segregated (TNPCB, 2020-21). India produces 4 – 9 million tonnes of plastic waste every year of which 13 – 60% is recycled through both formal and informal processes (CPCB/MoHUA, 2021). Temple tourism is one of the major drivers of single-use plastic usage in Kumbakonam, which is beyond the capacity of the existing waste management system. The informal sector is important but underutilized: India's 1.5 million waste pickers are crucial in the material recovery process, but remain unrecognised, unprotected and without formal social safety nets. They can be leveraged into formalized circular supply chains, both as a social equity and economic opportunity (FICCI, 2022).

3. Objectives of the Study

- To evaluate the present waste management system and waste profile of three different sectors in the town of Kumbakonam, namely Residential, Commercial and Temple.
- To assess the level of implementation of circular economy concepts in segregation, resource recovery and waste valorization processes.
- To uncover untapped composting, recycling, biomethanation, and waste-to-wealth entrepreneurship opportunities. To suggest a comprehensive and evidence based Circular economy policy for Kumbakonam and similar heritage towns.
- To craft specific policy recommendations to the municipality, religious institutions, civil society and the state government.

4. Statistical Overview: Waste Generation and Management

The following data tables provide a quantitative foundation for understanding the scale and urgency of circular economy adoption in Kumbakonam, Tamil Nadu, and India.

4.1 National and State-Level Waste Data

Indicator	Value / Data	Source
India MSW generation (FY 2022)	170,300 MT/day	MOSPI, 2024
Unprocessed MSW reaching landfills	30,000 MT/day (21%)	CPCB, 2024
Tamil Nadu MSW generation	14,585 MT/day	TNPCB, 2021
Indian household segregation compliance	17%	NITI Aayog, 2023
Organic fraction of India's MSW	~50%	MoHUA, 2022
India annual plastic waste generation	4–9 million tonnes	CPCB/MoHUA, 2021
Tamil Nadu daily plastic waste	1,178 tonnes/day	TNPCB, 2020–21
MSW sector emissions growth (1994–2020)	+226%	MoEFCC, 2024
Projected India MSW by 2050	435 million tonnes/year	Khan et al. / CEEW, 2024

4.2 Kumbakonam Municipal Solid Waste Profile

Indicator	Value / Data	Source
Daily MSW generation	~70 metric tonnes/day	Kumbakonam Municipality
Population served	~1.5 lakh (45 wards)	Census / KLMC
Estimated organic fraction	55–60%	Industry average, Tamil Nadu
Estimated plastic waste share	~6.92% of MSW	CPCB, 60-city study
Operational biomethanation units	1 (with expansion potential)	KLMC Reports
Micro Composting Centres (TN state)	691 operational / 804 sanctioned	TNMA, 2023
Legacy waste bioremediation (TN)	84.17 lakh cu.m (11 corps, 87 muni.)	TNMA / SBM
E-waste collection frequency	Once per month (TNPCB-authorized)	TNMA Guidelines

4.3 Circular Economy Opportunity: National Projections

Indicator	Value / Data	Source
India circular economy market value by 2050	USD 2 trillion	Min. Bhupender Yadav, 2025
Green jobs from circular economy by 2030	10–15 million jobs	FICCI 2022; Govt. India 2025
India recycling market projection by 2028	USD 20 billion	CRISIL, 2023
India waste management market (2023)	USD 22.17 billion	NextMSC Research

India waste management market by 2030	USD 54.20 billion (CAGR 12.5%)	NextMSC Research
Recycling vs. landfilling job creation ratio	Up to 10x more jobs	FICCI / Policy Circle
CE adoption potential GHG reduction	~44% emissions reduction by 2050	CEEW, 2025
Circular CE profit potential for India by 2050	INR 40 lakh crore (USD 624 bn)	CEEW, 2025

5. Circular Economy Strategies for Kumbakonam

5.1 Temple Waste Recycling and Resource Recovery

The temple ecology of Kumbakonam produces significant amounts of biodegradable floral, fruit and ritual wastes each day. In the country, the share of the organic fraction of MSW is around 50% of the total waste, on an average (MoHUA, 2022). The 50 TPD BioCNG plant produces approximately 2 tonnes of gas per day and 1,500 such plants across the country could produce 3,000 tonnes per day, resulting in a reduction of 44 million tonnes of CO₂ equivalent (CEEW, 2025) per year. Organic waste from the temple and market can play a meaningful role in the production of biogas, compost and income through SHG when applied locally.

- Use of floral waste in the production of incense sticks, natural dyes and handmade paper by SHG micro enterprises.
- Production of vermi compost using biodegradable feeds to be supplied to Cauvery delta farmers.
- Production of essential oil from jasmine, marigold and lotus flowers for the markets of commerce and aromatherapy.
- Utilization of coconut shell and husk for handicrafts, coir products and production of activated carbon.
- Women led SHG groups registered with the support and training of the municipalities and linkages with markets

5.2 Decentralized Composting and Organic Waste Management

Discussing decentralized composting and organic waste management. Talking about decentralised composting and organic waste management. The percentage of organic waste in Kumbakonam's MSW is 55-60%. The State of Tamil Nadu has already approved 804 Micro Composting Centres (MCCs) with 3130 tons per day (TPD) capacity in corporations and municipalities (TNMA, 2023). In the Kumbakonam area, this model, which can be implemented ward-wise, can cut secondary transportation cost and landfill loads drastically. The research study in Eluru MCorp showed that for 100% processing of wet waste in a municipal body, the value of the processed waste in the form of vermicompost is estimated at more than ₹0.89 crores per annum (2021, ResearchGate).

- Resident welfare associations' composting units at the ward level.
- Home composting through incentive programs with the provision of subsidies for bins and technical training.
- Establishment of institutional composter in temple campus, school, hotel and market complexes.

5.3 Plastic Waste Circularity and Recycling

India generates 26,000 tonnes of plastic waste daily (CSIRO, 2023) and only 9% of the globally produced plastic waste is formally recycled (OECD). Only 13-60% of plastics in India are estimated as being recycled formally (CPCB), while the rest are estimated to be in landfills or in the environment (79% worldwide) (Bansal et al., 2023). The establishment of strong infrastructure is essential in Kumbakonam for pilgrimage tourism as it increases plastic generation. The 230 registered plastic waste recycling units (TNPCB) in Tamil Nadu are a formal supply chain backbone for recovery.

Plastic collection and segregation centres dedicated to plastic with weighing facility. Inverse logistics systems for the recovery of tourist hot spots and the temple precincts. Association with the 230 registered plastic recycling units in Tamilnadu (TNPCB). Integration of recycled plastic in construction of roads and urban infrastructure.

- Sorting and cleansing facilities for materials.
- A buy-back program for citizens and vendors who want to return their clean plastics. Bio methanation and Renewable Energy

5.4 Biomethanation and Renewable Energy

The existing biomethanation plant of Kumbakonam can be expanded. On the national level, 11 projects are in operation using RDF-based and biomethanation technologies to recover energy from MSW in India (Vikram Reddy, 2014), and Tamil Nadu is the first state to have installed small-scale biogas plants which can produce electricity to light the streets (Deccan Herald, 2023). Using biogas generated from organic waste in Kumbakonam city is a promising option to decrease the energy bills and carbon footprint of the municipal corporation. Food waste collected in a systematic way from the hotels, restaurants, marriage halls and markets.

Other biomethanation plants in proximity to the high-density residential areas and municipal market. Integration of the organic waste from the temples in biogas and recycling of the slurry as bio-fertilizer. Use of produced biogas for street lighting and energy in the city hall.

5.5 Digital Technologies for Circular Waste Management

Smart city tools can have a direct impact on the results of the circular economy. The Tamil Nadu smart city study (Valai Ganesh et al., 2024) concluded that collection efficiencies of the sampled cities ranged from 80-100% which shows that technology should be complemented by enforcement and public engagement; segregation rate in the cities was below 50% to 100% in the sampled cities. In May 2024, the CPCB's mobile

application for illegal plastic waste reporting recorded a 19% redressal rate, suggesting the importance of robust digital monitoring systems. GPS waste vehicle tracking and route optimizing software. Citizen complaint app and mobile for waste segregation guidance.

Smart bins equipped with fill level sensors to ensure optimal collection times. Digital platforms for bringing together the sellers of recyclable material with registered buyers. Household segregation compliance monitoring using a QR code.

6. Proposed Circular Economy Framework for Kumbakonam

An integrated five-stage CE framework, anchored in the Reduce-Reuse-Recycle-Recover-Regenerate hierarchy, is proposed for Kumbakonam:

Stage	Key Actions and Targets
Stage 1 Waste Prevention & Reduction	Promote reusable bags, bottles, containers; ban single-use plastics at temple events; awareness campaigns on sustainable consumption; EPR enforcement on producers and importers targeting plastic waste reduction by 30% by 2028.
Stage 2 Source Segregation	Mandatory wet/dry/hazardous segregation across all 45 wards; color-coded bin distribution; ward monitors and grievance redress; positive incentive schemes targeting 60%+ household compliance within 3 years.
Stage 3 Resource Recovery	Ward-level MCCs for organic composting; biomethanation expansion for food and temple waste; formal recycling of plastics, paper, glass, metals; SHG-led upcycling of temple waste into artisan products.
Stage 4 Market Integration	Stable markets for compost, vermicompost, and recycled products; municipal green procurement policies; PPP arrangements with recycling firms under EPR mandates; start-up incubation for waste valorization enterprises.
Stage 5 Circular Governance	Public-private partnerships with performance contracts; ward-level circular economy committees; continuous monitoring against SDG 11/12/13 indicators; annual CE performance report by the Municipal Commissioner.

7. SWOT Analysis of Circular Economy Adoption

Strengths	Weaknesses
Door to door waste collection system, in all 45 wards, like for real. There are existing composting and biomethanation units already running, so things are not starting from zero. Also there is a strong temple based organic waste recovery potential, which people seem to understand pretty well. We have active SHG and community	Only about 17% of households actually follow full segregation (national average). There is also limited public awareness, and the enforcement capacity seems sort of thin. On top of that, the plastic recycling infrastructure is not really sufficient, plus there is heavy dependence on municipal funding. You can also see weak technical capacity in

organizations, working on and around this, kind of together. And honestly there is a cultural tradition of resourcefulness, plus local reuse , so the mindset helps. Right now 691 MCCs are operational across Tamil Nadu, and this can be treated as a state model to replicate elsewhere.	the local bodies, and generally the segregation rates under 50% show up as common in the Tamil Nadu smart cities.
Opportunities	Threats
<ul style="list-style-type: none"> India CE market projected at USD 2 trillion by 2050 15 million jobs from recycling & reuse by 2030 (FICCI) Growing organic manure demand in Cauvery delta Government funding via SBM, SDGs, Smart City Mission 230 plastic recycling units registered in Tamil Nadu (TNPCB) Sustainable pilgrimage tourism as a green economy driver 	<ul style="list-style-type: none"> MSW generation growing at 1.3% per year nationally 79% of plastics globally end up in landfills/environment MSW sector emissions up 226% between 1994-2020 Rising operational costs for urban local bodies Political resistance to land allocation for new facilities CPCB plastic redressal rate fell to 19% (May 2024)

8. Policy Recommendations

8.1 For Kumbakonam Municipal Corporation

For Kumbakonam Municipal Corporation Implement compulsory source segregation in all 45 wards with a goal of achieving 60% compliance by 2027 in line with SBM-U 2.0 requirements. Increase the number of ward level MCCs at high density areas and market areas first, based on the model of 691 operational MCCs in Tamilnadu. Collaborate with the plastic waste companies mandated by EPR and Tamil Nadu's 230 registered plastic recycling units to enhance plastic circularity. Implement GPS digital tracking of waste vehicles and a Household compliance dashboard using QR codes. Form a new Circular Economy Cell in the Municipal Engineering Department exclusively for the Circular Economy with a dedicated budget line and trained staff.

8.2 For Temples and Religious Institutions

To prepare guidelines for temple waste management in cooperation with HR&CE Department, which include segregation, composting and reduction of plastic waste. Engage with the SHG-led enterprises for the floral and ritual wastes valorisation with the aim to eliminate organic waste from major temples to landfill. Use biodegradable or reusable instead of single use plastic at festival activities.

8.3 For State Government

For State Government Introduce viability gap funding and green bonds for CE infrastructure in Tier-2 municipalities, with heritage or pilgrimage status. Formulation of Tamil Nadu Circular Economy Policy for MSW with quantified targets to the SDG 11, 12 and 13 timelines. Include CE indicators in the State Urban Performance Framework and annual reporting for the SBM.

9. Conclusion

The statistics are definitive: India's waste crisis is worsening with 170,000 MT/day of waste generated and 21% of this waste not processed, the waste generation is increasing by 226% since 1994 and the global MSW generation is expected to be 3.8 billion tonnes by 2050. The city of Kumbakonam with its low level of circular practices (~70 MT/day) is a microcosm of this national challenge and there is a transformative leadership opportunity. The circular economy is a clear economic and environmental opportunity for Kumbakonam – recycling and reuse in India could create 15 million jobs by 2030 and the recycling market could exceed USD 20 billion by 2028 (CRISIL, 2023). Emissions from the organic waste sector in India could be cut by 44 million tonnes of CO₂ equivalent (CEEW, 2025) if a CE transition is achieved for the sector. The benefits of even small-scale CE in Kumbakonam (compost income, biogas cost savings and SHG jobs) are substantial and attainable for the city, which has special waste streams from the temples, and an agricultural catchment area. Kumbakonam can shift from disposal-centric to resource-recovery-driven circular city with the integrated CE approach proposed in this study, which involves the five stages: source segregation, decentralized composting, biomethanation, plastic recycling and digital governance, and community participation. The transformation places it in a replicable context for heritage and pilgrimage locations in India, showing that cultural identity and environmental sustainability are not mutually exclusive, but are in fact great drivers of a just and circular urban future.

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