BASELINE STUDY FOR WASTE TO ENERGY A PATHWAY TO CLEAN POWER GENERATION

REPORT

Submitted to

TAMIL NADU POLLUTION CONTROL BOARD,

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LIST OF ABBREVIATION

MSW	-	Municipal Solid Waste
GHG	-	Green House Gas
TNPCB	-	Tamil Nadu Pollution Control Board
RDF	-	Refuse-Derived Fuels
WTE	-	Waste to Energy
ULBs	-	Urban Local Bodies
GCC	-	Greater Chennai Corporation
CMA	-	Commissionerate of Municipal Administration
MCC	-	Micro Composting Centre
OCC	-	Onsite Composting Centre
CNG	-	Compressed Natural Gas
FOD	-	First Order Decay
DOC	-	Degradable Organic Carbon
MCF	-	Methane Correction Factor
KDG	-	Kodungaiyur Disposal Ground
PDG	-	Perungudi Disposal Ground
BoV	-	Battery Operated Vehicles
MW	-	Mega Watt
LDV	-	Light-Duty Vehicle
HDV	-	Heavy-Duty Vehicle
MDV	-	Medium-Duty Vehicle

EXECUTIVE SUMMARY

As part of the several initiatives under the Tamil Nadu Climate Change Mission, the Tamil NaduPollution Control Board (TNPCB) has entrusted an assignment titled "**Baseline Study for Waste to Energy - A Pathway to Clean Power Generation"** to the Centre for Climate Changeand Disaster Management (CCCDM), Anna University. The study focus was on the potential to use Municipal Solid Wastes (MSW) in Tamilnadu for Waste to Energy in line with the requirements of SWM Rules (2016). The Scope of the work included assessment of the quantity and characteristics of MSW generated in urban local bodies (ULBs0 of Tamilnadu, report on the current SWM practices in ULBs of Tamilnadu, estimate the Green House Gas (GHG) emissions from SWM Practices and to develop the plan for Waste to Energy Projects to utilise the Municipal solid wastes in the ULBs taking into account the best practices.

Based on the data from the Commissionerate of Municipal Administration and Directorate of Town Panchayaths, Tamil Nadu generates about 17000 Tons/Day of municipal solid waste, of which about 45 % (7600 TPD) is from the Greater Chennai Corporation (GCC) and about 5200 TPD is from the other 20 Municipal Corporations. About 5300 TPD of waste from GCC is currently disposed at Kodungaiyur and Perugudi. Biodegradable waste disposed at the GCC disposal facility has potential to emit 28870 Tons CH_4 / year. Methane emissions from the other ULBs in different regions range from 600 to 3779 Tons CH_4/ year. Methane emission from the dumpsites can be avoided by enhancing source segregation and increasing biodegradable waste processing through composting and biomethanation. Highly biodegradable food wastes from bulk generators has the potential to be diverted to biomethanation/bio-CNG Plants. Accordingly, GCC has the potential to setup Bio CNG plants of 600 TPD capacity in addition to the one CNG Plant of 100 TPD Capacity already in operation.

Waste characteristics from the ULBs also indicate that about 30% of the waste disposed is non- recyclable combustibles such as contaminated plastics, paper, textile, etc. Accordingly, it is recommended to setup Regional Waste to Energy Plants in Chennai (2300 TPD), Kancheepuram (850 TPD from Chegelpet and Vellore region), Coimbatore (900 TPD from Tirupur region), Salem (700 TPD from salem region) and Madurai (1200 TPD from Madurai and Tirunelveli region) . It is also recommended to implement appropriate carbon capturing technology as part of the regional waste to energy plant to avoid carbon emissions. The bottom ash from the facility may be utilised to make pavement blocks so as to have zero residue for disposal.

BASELINE STUDY FOR WASTE TO ENERGY - A PATHWAY TO CLEANPOWER GENERATION

1.0 PREAMBLE

Municipal solid waste (MSW) in the form of food wastes, garden wastes, paper, cardboard, plastics, textiles, leather, wood, glass, and other household/commercial items is generally considered as a renewable energy resource. From a sustainable development perspective, the focus is on the reduction of waste, followed by recycling, both of which are advantageous in terms of reducing greenhouse gas emissions. However, not all wastes are recyclable, and thus energy recovery methods that allows for the generation of energy in the form of electricity or heat from wastes, that would have otherwise been disposed of in landfills, is worth consideration.

Green House Gas (GHG) emissions can be reduced through waste recycling, controlled composting of organic waste and state-of-the-art incineration of non-recyclable combustible fractions. However, there are significant ambiguities regarding the waste sector's direct Green House Gas (GHG) emissions, indirect GHG emissions, and GHG mitigation potentials and generate co-benefits for public health, environmental protection, and sustainable development. In this context, as part of the several initiatives under the Tamil Nadu Climate Change Mission, the Tamil Nadu Pollution Control Board (TNPCB) has entrusted an assignment titled "**Baseline Study for Waste to Energy - A Pathway to Clean Power Generation"** to the Centre for Climate Change and Disaster Management (CCCDM), Anna University. The study focuses on municipal solid waste and its potential use for waste-to-energy.

The study focus on MSW and its potential use for waste-to-energy to assess the quantity of MSW with potential for energy recovery through thermochemical and biochemical routes in line with the requirements of Solid Waste Management rules 2016 and the principles of Circular Economy. Evaluating a large incinerator burning solid MSW, making biogas from organic fraction of MSW converting biogas to compressed biomethane fuel (Bio CNG) and Refuse-derived fuels (RDF) from combustible materials are all considered within the scope of study. Also the study will analyses the life cycle impact of waste management for significant components of MSW and emission reduction or fossil fuel offset, including MSW co-processing in the cement industry. The specific objectives included the following.

- To understand waste characteristics data on organic and non- biodegradable waste fractions for further processing like bio- methanation, co-processing of waste and composting effectiveness.
- To report on current practices and performance aspects of thermochemical and biochemical WTE in Tamilnadu.
- To undertake stakeholder consultation on WTE potential and challenges.
- To assess the sources and sinks of GHG emissions within the control of the waste processing facility operator as direct emissions per unit of output as a result of the WTE project intervention.
- To explore the potential of carbon capture and utilisation systems as part of WTE facilities. The study started in October 2022 and the findings during the study is presented in this Report.

2.0 MUNICIPAL SOLID WASTE MANAGEMENT IN TAMIL NADU

As per the Solid Waste Management Rules (2016), Urban Local Bodies (ULBs) are entrusted with the task of municipal solid waste management, which includes waste collection including street sweeping, transportation, processing and disposal. The waste management activities in Tamilnadu are carried out by the Greater Chennai Corporation (GCC) and other 20 Municipal Corporations, 138 Municipalities and 490 Town Panchayats. As per the data obtained from these ULBs, summarised in Table 1, about 17000 tonnes of solid waste are generated daily, of which about 6155 tonnes are processed through dry waste recycling, micro composting and biomethanation. About 10856 tonnes of municipal solid waste are disposed through open dumping. Authorisation has been granted by TNPCB for 224 ULBs.

The total generation of municipal solid waste from the other 20 Municipal Corporations is 5178 TPD. 138 Municipalities generate about 2340 TPD and the 490 Town Panchayats generate 1840 TPD. The District wise solid waste generation rates are summarised in Table 2 and the district wise variation in the daily waste generation is depicted in Figure 1. The per capita waste generation is expected to increase by about 1.3% per year, and with growth of urban population between 3 % to 3.5 % per annum, the overall quantity of solid waste generation may increase by about 5 % per year (CPHEEO, 2016).

Urban local bodies have door to door waste collection systems utilising collecting bins, tricycles, compactor bins, Lorries using dust bins, etc. All urban local government organisations have started composting the biodegradable waste and partially source-segregating the municipal solid waste generated within their jurisdictions. The Municipal Corporations have employed dumper trucks, tipper lorries, tipper tractors, trucks, etc. to transport rubbish, and in certain cases the vehicles are closed or pneumatic compactors are used in a small number of corporation locations. Similar to this, Municipalities and town panchayats make use of transportation tools such tractor trailers, tippers, dumper-placers, tricycles, and push carts.

Table 1 Municipal solid waste generation in Urban Local Bodies of Tamil Nadu

URBAN LOCAL BODIES - TAMIL NADU	NO S.	SOLID WASTE GENARATION (TPD)
Greater Chennai Corporation(GCC)	1	7663
Corporations	20	5178
Municipalities	138	2340
Town Panchayats	490	1840
TOTAL		**17021**

Source: GCC, CMA and Directorate of Town Panchayats

2.1 CHARACTERISTICS OF SOLID WASTES

Physical characterization of solid waste disposed at dumpsites was conducted in Greater Chennai Corporation (GCC) and Tirunelveli Municipal Corporation. Table 3 shows the summary of physical compositions of municipal solid waste in GCC and other districts in Tamilnadu.

It shows that about 50 - 55% of the wastes disposed at dumpsites are still biodegradable fraction, inspite of the efforts for source segregation and Door to door collection. There is a need to enhance awareness and promote source segregation and segregated collection so that the biodegradable wastes reaching the dumpsites can be avoided, which will help in reducing the GHG emissions due to open dumping of biodegradable wastes. All the urban local bodies have to pay immediate attention to this aspect.

Another important observation is that about 20% of the wastes reaching the dumpsites are combustible fractions such as plastics, paper, textiles, rubber, leather etc. that are non-recyclable but combustible materials which has the potential to be used as feed to Waste to Energy plants or Processing in cement plants. Considering about 10% leakage of biodegradable fractions and 20% non-recyclable combustible fractions, it is advisable to consider about 30% of the solid wastes currently dumped may be considered to estimate the capacity of Waste to Energy Facilities.

2.2 SOLID WASTE PROCESSING AND DISPOSAL SYSTEM

Different element of waste management practices in tamilnadu is depicted in fig.2. Predominantly, the biodegradable fraction of the solid waste is processed using facilities like Micro Compost Centres (MCC), Onsite Composting Centres (OCC), windrow composting and biomethanation. Composting method decompose the organic MSW by microorganisms under controlled aerobic conditions i.e. in the presence of air under humid and warm or in an anaerobic environment. The proper mixture of water, oxygen, carbon, and nitrogen, micro-organisms are allowed to break down organic matter to produce compost. There are many types of microorganisms found in active compost of which the most common are bacteria. Depending on the phase of composting, mesophilic or thermophilic bacteria may predominate.

The end product of composting is rich in excessive nutrients called humus or compost. This compost, the solid product is used to fertilize crops. In anaerobic method, mixture of carbon dioxide and methane called biogas, is used to produce heat and/or electric energy.

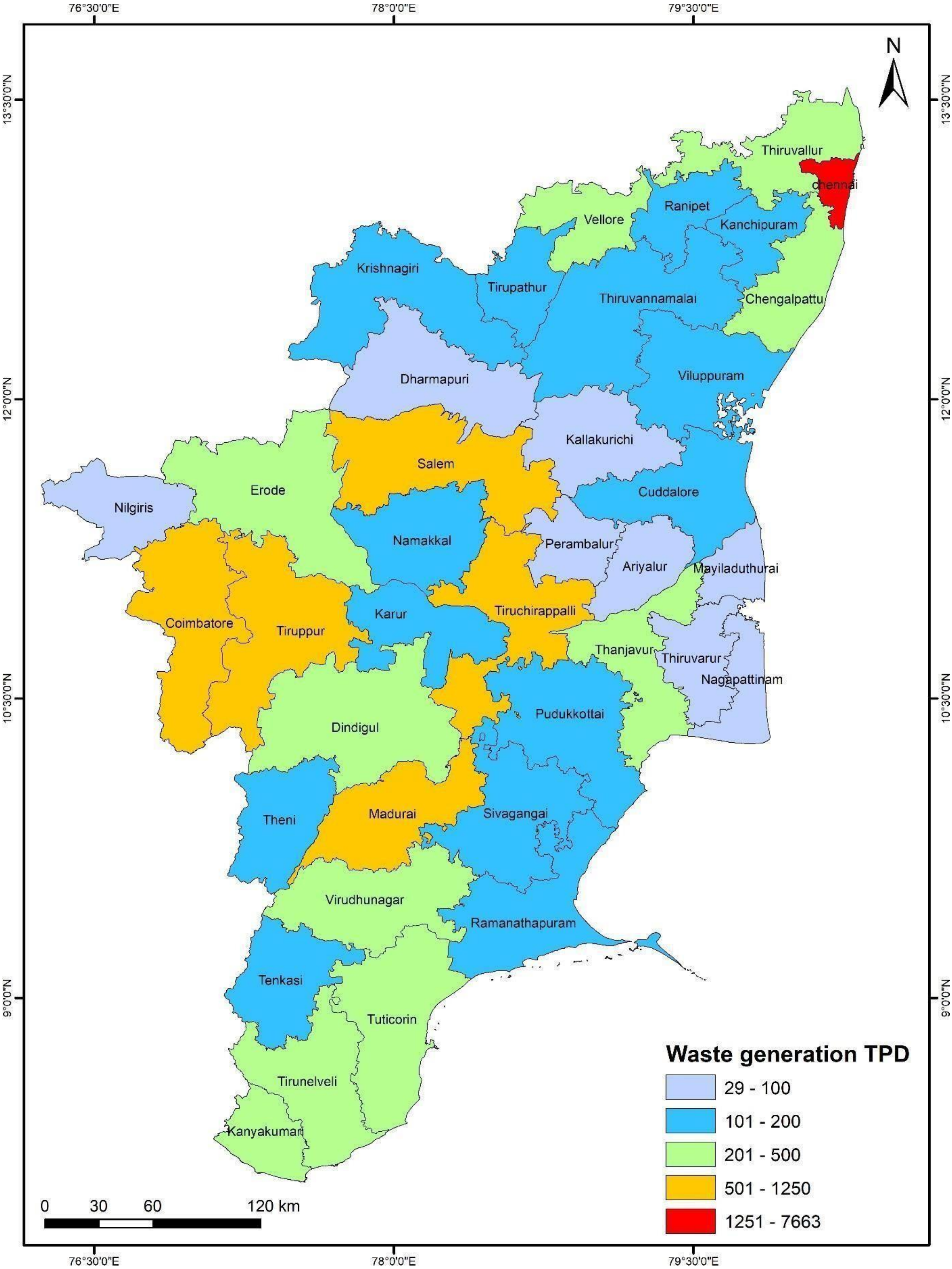

Figure 1 District wise Spatial variation of municipal waste generation inTamilnadu.

Table 2 District wise Municipal Solid Waste Generation in Tamil Nadu

S.no	District Name	Corporation (TPD)	Municipalities (TPD)	Town panchayat (TPD)	Total Waste Generation (TPD)	Waste processing (TPD)	Waste disposal facility (TPD)
1	Chennai	7663	NIL	NIL	7663	1963	5300
CHENGALPATTU REGION							
2	Chengalpattu	390	51	28	469	206	263
3	Kancheepuram	65	23	18	106	47	59
4	Cuddalore	33	78	65	176	73	104
5	Thiruvallur	118	87	50	255	164	91
VELLORE REGION							
6	Vellore	210	16	31	256	178	78
7	Ranipet	-	86	21	107	58	49

S.no	District Name	Corporation (TPD)	Municipalities (TPD)	Town panchayat (TPD)	Total Waste Generation (TPD)	Waste processing (TPD)	Waste disposal facility (TPD)
8	Tirupathur	-	101	8	109	92	17
9	Tiruvannamalai	-	107	38	145	93	52
10	Viluppuram	-	73	29	102	69	33
11	Kallakurichi	-	37	23	60	25	35
SALEM REGION							
12	Salem	550	62	106	718	216	502
13	Dharmapuri	-	22	36	58	17	41
14	Karur	74	24	25	123	68	55
15	Krishnagiri	72	17	26	115	74	41

S.no	District Name	Corporation (TPD)	Municipalities (TPD)	Town panchayat (TPD)	Total Waste Generation (TPD)	Waste processing (TPD)	Waste disposal facility (TPD)
16	Namakkal	-	107	69	176	63	113
TIRUPPUR REGION							
17	Coimbatore	1037	77	135	1249	282	967
18	Erode	196	45	156	397	152	245
19	Tiruppur	470	79	64	613	218	395
20	Nilgiris	-	59	40	99	39	60
MADURAI REGION							
21	Madurai	700	43	40	783	230	553
22	Dindigul	92	72	94	258	103	155

S.no	District Name	Corporation (TPD)	Municipalities (TPD)	Town panchayat (TPD)	Total Waste Generation (TPD)	Waste processing (TPD)	Waste disposal facility (TPD)
23	Theni	-	116	74	190	79	111
24	Sivagangai	-	80	37	117	45	72
25	Ramanathapuram	-	90	26	116	65	51
THANJAVUR REGION							
26	Thanjavur	177	77	69	323	121	202
27	Trichirappalli	470	57	50	577	253	324
28	Ariyalur	-	25	4	29	16	13
29	Mayiladuthurai	-	41	14	55	27	28
30	Nagapattinam	-	44	14	58	27	31

S.no	District Name	Corporation (TPD)	Municipalities (TPD)	Town panchayat (TPD)	Total Waste Generation (TPD)	Waste processing (TPD)	Waste disposal facility (TPD)
31	Pudukottai	-	84	20	104	48	56
32	Thiruvarur	-	59	22	81	38	43
33	Perambalur	-	18	11	29	11	18
TIRUNELVELI REGION							
34	Tenkasi	-	95	56	151	93	58
35	Tuticorin	180	51	50	281	136	145
36	Thirunelveli	183	33	61	277	128	149
37	Kanyakumari	115	38	219	372	88	284
38	Virudhunagar	46	128	39	213	150	63

Table 3 Characteristics of Municipal solid waste disposed in GCC and other ULBs

Physical Composition of samples		Chennai (2022)			Krishnagri (Yeshodha 2015)	Thiruvallur (J Sankar 2018)	Thanjavur (Sowmeyan 2015)	Kancheepuram (N. Mariappan 2018)	Salem (Sankar 2019)	SWM (CPHEEO ,2016)	Tirunelveli (ICLEI, 2023)	Average (%)
		Min	Max	Mean								
Biodegradable		43	68	56	50.09	50	45	55.8	71	47	75	56.2
Combustible (21.7%)	Plastic	5.3	20	12	6.29	3	5.7	11.2	12	9	8.3	8.4
	Paper	7.4	20.4	13	4.58	5	5.5	13	6	8.13	5.3	8.0
	Textile	1.8	9	6	3.77	0	0.06	0.9	0	4.2	1.6	2.0
	Wood	0	0.9	0.2	4.8	5	0.89	0	0	4.49	1.6	2.1
	Rubber & Leather	0	1.8	0.4	0.19	1	0.07	3.7	2	0.6	1	1.1
Non-Combustible	Metal	0	2.1	0.6	0.16	1	0.06	1	0	0.5	0	0.4
	Glass	0	2.8	0.6	0.57	4	0.01	1.3	0	1	0	1.0
Domestic Hazardous		1.6	6.8	3.6	0.46	1	0	0	0	0	4.5	1.2
Residuals		4	13.6	8	29.4	30	33	13	9	25	4	19

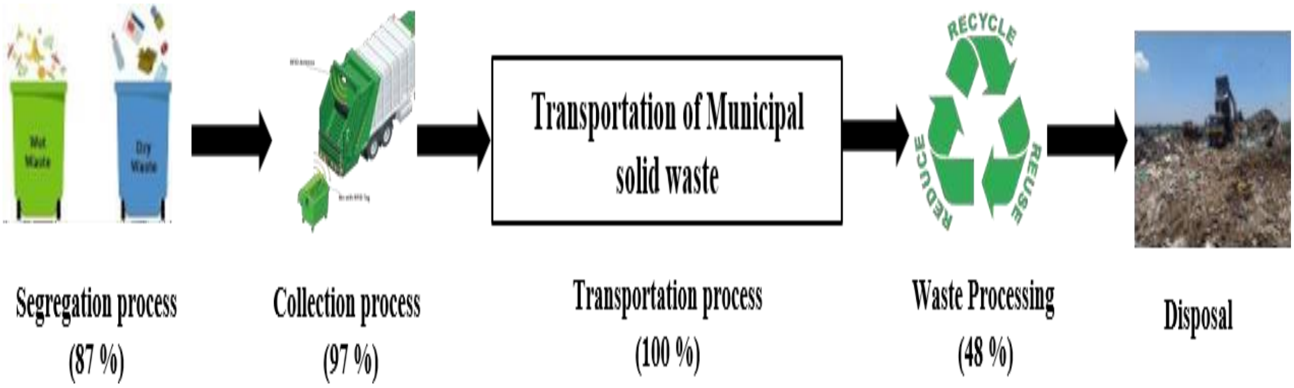

Figure 2 Overall Status of municipal Solid Waste Management in Tamilnadu

Solid waste management practices in Greater Chennai corporation (GCC) is summarized in Table 4. Out of the 7663 TPD of solid waste generated in GCC, 1148 TPD wet waste is processed through different decentralized processing facilities like Windrow Composting, Micro Composting and Biomethanation. About 5300 TPD of solid waste is disposed by open dumping at Perungudi and Kodungaiyur.

Tamilnadu has 807 MCC processing 3129 TPD of wet waste in 20 Corporations and 138 Municipalities and 490 Town panchayats. But only 750 MCCs are in full operation, processing 2880 TPD of wet waste. About 891 OCCs are established in Corporations and Municipalities, with a total operational capacity of 450 TPD.

In Tamilnadu, there are 27 vermi-compost plants in 25 municipalities, each operating in the range of 1-3 TPD, and a total operational capacity of 115 TPD. Vermi-compost is the process of composting using various worms to create a heterogeneous mixture of decomposing vegetable or food waste, bedding materials, and vermicast. The most common worms used in composting systems, red-worms (Eisenia foetida, Eisenia andrei, and Lumbricus rubellus). These castings have been shown to contain reduced levels of contaminants and a higher saturation of nutrients than organic materials. Having water-soluble nutrients, vermi-compost is an excellent, nutrient-rich organic fertilizer and soil conditioner. Bulk waste generators like high-rise building community, commercial building, and community halls compost the generated wet waste within their premises or transfer the waste to waste processing units.

Table 4 Waste Processing and Disposal Facility in Greater Chennai Corporation (GCC)

S.NO.	Greater Chennai Corporation (GCC)		Waste Generation (TPD)
1	Wet waste processing Facility	MCC	500
		Windrow Composting	100
		Biogas plant	28
		Green waste	320
		Bio-CNG plant	200
		TOTAL	1148
2	Dry waste processing	RRC	450
		Incinerator at manali	10
		Dry waste sent to dalmia cements from 4 baling centres	300
		Incinerator at kodungaiur	50
		Mobile Incinerator	5
		TOTAL	815
3	C & D Waste processing		400
4	Kodungaiur Disposal Facilities		2500
5	Perungudi Disposal Facilities		2800
6	Total		7663

Table 5 shows details of biomethanation plant in Tamilnadu. There are 27 biomethanation units in corporation and 20 in Municipalities with total processing capacity of 189 TPD. Organic waste material is decomposed by microorganisms in an anaerobic environment. In other words, Methanogenesis or biomethanation is the process of generating methane by microbes known as methanogens. These organisms produce methane during microbial metabolism, are identified only in the domain Archaea. These organisms decompose biomass, thus reduce the amount of waste and produce biogas (carbon dioxide and methane). Biogas is used to generate heat and electricity. About 50-100 kg of methane could be released for each tonne of waste disposed at disposal facility.

Table 5 Details of Biomethanation and Plants and Current Status

S.No	Name of ULB's	Biomethanation plant		
		No.	Capacity in MT	Status
	CHENGALPATTU REGION			
1	Poonamallee	1	5	Non-functional
2	Tiruthani	1	5	Non-functional
	VELLORE REGION			
3	Arcot	1	3	Functional
4	Thiruvannamalai	1	5	Non-functional
	MADURAI REGION			
5	Palani	1	5	Functional
6	Paramakudi	1	1	Non-functional
7	Rameswaram	1	1	Non-functional
	TIRUPPUR REGION			
8	Pollachi	1	5	Functional
9	Mettupalayam	1	3	Non-functional
10	Gobichettipalayam	1	3	Functional
11	Udhagamandalam	1	5	Functional
	THANJAVUR REGION			
12	Nagappattinam	1	5	Non-functional
13	Perambalur	1	3	Functional
	TIRUNELVELI REGION			
14	Kayalpattinam	1	5	Not Functioning

S.No	Name of ULB's	Biomethanation plant		
		No.	Capacity in MT	Status
15	Colachel	1	1	Not Functioning
16	Rajapalayam	1	5	Not Functioning
	SALEM REGION			
17	Mettur	1	5	Non-functional
18	Namakkal	1	5	Functional
19	Tiruchengode	1	5	Functional
20	Pallipalayam	1	5	Functional
	CORPORATIONS			
21	Coimbatore	4	6	Non-functional-3 & Functional-1
22	Madurai	1	4	Non-functional
23	Salem	2	8	Non-functional -1 No&Functional-1 No
24	Erode	2	11	Functional
25	Tirunelveli	2	7	Non-functional
26	Dindigul	2	7	Non-functional -1 No& Functional-1 No
27	Vellore	1	1	Non-functional
28	Thanjavur	2	7	Non-functional
29	Trichy	2	7	Functional
30	Tiruppur	2	12	Non-functional
31	Avadi	1	5	Non-functional
32	Hosur	1	10	Non-functional
33	Karur	1	5	Functional
34	Kumbakonam	1	5	Non-functional
35	Kancheepuram	1	5	Functional
36	Tambaram(Pallavapuram)	1	5	Non-functional
37	Nagercoil	1	5	Non-functional
	Total	47	189	

2.2.1 Dry Waste Processing

Recycling glass, plastic and metal is taking place through 438 Material Recovery Facilities/Resource recovery centres established in the ULBs. About 16,000 Tonnes of non-recyclable combustible waste are baled and sent to cement factories/power plants for fuel. Dry waste generated in the households is diverted to private dry waste processing units. Recycling saves space in landfills and reduces the amount of virgin materials that must be mined or manufactured to make new products and thus saving energy.

2.2.2 Waste Processing and Disposal facility in Chengalpattu Region

Details of Waste Processing facilities in the Chengalpattu Region is summarised in Table 6. About 1006 TPD solid waste generated in this region is processed in 207 Composting units and 5 Biomethanation plants. Thus the region process 48 % of waste generated. By dumping 532 TPD the region emits 1170 T/Year of methane. 5 TPD biomethanation plant are located in Tambaram, Chengallpattu district and Avadi Corporation. The biomethanation units in Poonamalle, and Tiruthani Municipality is non-functional.

2.2.3 Waste Processing and Disposal facility in Vellore Region

Details of Waste Processing facilities in the Vellore Region is summarised in Table 7. 780 TPD solid waste generated in this region is processed in 220 composting units and 2 biomethanation plants. The biomethanation facilities located in Vellore and Ranipet are non-functional. Thus, Vellore Region process 67% of wet waste generated and dump 260 TPD in the open dumpsite. Vellore emits 600 T/Year of methane.

2.2.4 Waste Processing and Disposal facility in Salem Region

Details of Waste Processing facilities in the Salem Region is summarised in Table 8. Total waste generated in the region is 1190 TPD whereas only 35 % of waste is diverted to 220 compost and biomethanation processing facilities. After processing 419 TPD, 771 TPD of waste is dumped, which emits 1704 T/Year of methane. The biomethanation units in Salem, Karur, Krishnagiri, and Namakkal of 13, 5, 10 and 15 TPD operational capacities are non-functional.

2.2.5 Waste Processing and Disposal facility in Tiruppur Region

Details of Waste Processing facilities in the Tiruppur Region is summarised in Table 9. 2358 TPD solid waste generated in this region is processed in 274 composting units and 12 biomethanation units. Tiruppur Region process 691 TPD of waste generated. After processing 29 % of waste, 1667 TPD of waste is dumped in open dumpsite generating 3779 T/Year of methane into atmosphere. The biomethanation units in Coimbatore, Erode, Tiruppur and Nilgiris of operational capacity 6, 14, 11 and5 TPD are non-functional.

2.2.6 Waste Processing and Disposal facility in Madurai Region

Details of Waste Processing facilities in the Madurai Region is summarised in Table 10. 1464 TPD solid waste generated in this region is processed in 285 composting units and 6 biomethanation units. Madurai Region process 522 TPD of wet waste. Remaining 64 % of waste in this region is dumped which produce 2135 T/Year of methane. The biomethanation units in Madurai, Dindigul and Ramanathapuram of operational capacity 4, 12 and 2 TPD are non-functional.

2.2.7 Waste Processing and Disposal facility in Thanjavur Region

Details of Waste Processing facilities in the Thanjavur Region is summarised in Table 11. 1256 TPD solid waste generated in this region is processed in 255 composting units and 8 biomethanation units. Thanjavur Region process 541 TPD of wet waste. 57 % of waste dumped in the open dumpsite generate 1620 T/Year of methane. Thanjavur, Thiruchirapalli, Nagapatinam and Perambalur of operational capacity 12, 7, 5 and 3 TPD are non-functional.

2.2.8 Waste Processing and Disposal facility in Tirunelveli Region

Details of Waste Processing facilities in the Tirunelveli Region is summarised in Table 12. 1294 TPD solid waste generated in this region is processed in 223 composting units and 5 biomethanation units. Tirunelveli Region processing was 595 TPD of wet waste. 54 % waste dumped in the dumpsite emits about 1149 T/Year of methane. The biomethanation units located in Tirunelveli, Thoothukudi, Virudhunagar and Kanyakumari of operational capacity 7, 5, 5 and 6 are non-functional.

Table 6 Waste Processing and Disposal facility in Chengalpet Region

District Name	Waste Generation TPD				MCC		OCC		Biomethanation Plant		Windrow Composting		Vermi Composting		Waste Processing TPD	Waste disposal facility TPD
	C	M	TP	T	No	Capacity TPD	No	Capacity TPD	No	Capacity TPD	No	Capacity TPD	No	Capacity TPD		
Chengalpattu	390	51	28	469	33	131	62	37	1	5	6	32	1	1	201	268
Cuddalore	33	78	65	176	12	51	31	14	-	-	1	1	1	1	73	104
Kancheepuram	65	23	18	106	4	20	25	12	1	5	2	5	2	5	47	59
Thiruvallur	118	87	50	255	36	128	48	19	1	5	1	1	1	1	154	101
Total	1006				85	330	166	82	3	15	10	39	5	8	475	532

C-Corporation, M-Municipalities and TP-Town Panchayats

Table 7 Waste Processing and Disposal facility in Vellore Region

District Name	Waste Generation TPD				MCC		OCC		Biomethanation Plant		Windrow Composting		Vermi Composting		Waste Processing TPD	Waste disposal facility TPD
	C	M	TP	T	No	Capacity TPD	No	Capacity TPD	No	Capacity TPD	No	Capacity TPD	No	Capacity TPD		
Kallakurichi	-	37	23	60	3	12	13	7	-	-	2	6	-	-	25	35
Vellore	209	16	31	256	54	175	21	2	1	1	-	-	-	-	177	79
Ranipet	-	86	21	107	13	43	26	9	1	3	-	-	1	3	58	49
Tirupathur	-	101	8	109	14	57	23	20	-	-	1	15	-	-	92	17
Tiruvannamalai	-	107	38	145	23	93	-	-	1	5	-	-	-	-	93	52
Viluppuram	-	73	29	102	13	61	12	6	-	-	1	2	-	-	69	33
Total	**780**				**120**	**441**	**95**	**44**	**3**	**9**	**4**	**23**	**1**	**3**	**520**	**260**

C-Corporation, M-Municipalities and TP-Town Panchayats

Table 8 Waste Processing and Disposal facility in Salem Region

District Name	Waste Generation TPD				MCC		OCC		Biomethanation plant		Windrow Composting		Vermi Composting		Waste Processing TPD	Waste disposal facility TPD
	C	M	TP	T	No	Capacity TPD	No	Capacity TPD	No	Capacity TPD	No	Capacity TPD	No	Capacity TPD		
Salem	550	62	106	718	44	188	28	8	3	13	2	6	1	2	207	511
Karur	74	24	25	123	13	48	3	0.3	1	5	8	18	8	10	68	55
Dharmapuri	-	22	36	58	5	17	3	0.3	-	-	-	-	-	-	17	41
Krishnagiri	72	17	26	115	15	59	17	5	1	10	-	-	-	-	64	51
Namakkal	-	107	69	176	14	47	13	2	3	15	-	-	-	-	63	113
Total	**1190**				91	359	64	15.6	8	24	10	24	9	12	**419**	**771**

C-Corporation, M-Municipalities and TP-Town Panchayats

Table 9 Waste Processing and Disposal facility in Tiruppur Region

District Name	Waste Generation TPD				MCC		OCC		Biomethanation Plant		Windrow Composting		Vermi Composting		Waste Processing TPD	Waste disposal facility TPD
	C	M	TP	T	No	Capacity TPD	No	Capacity TPD	No	Capacity TPD	No	Capacity TPD	No	Capacity TPD		
Coimbatore	1037	77	135	1249	42	156	49	20	2	6	4	11	2	81	282	967
Erode	196	45	156	397	31	110	36	17	3	14	2	10	-	-	152	245
Tiruppur	470	79	64	613	38	172	45	20	2	11	5	15	-	-	218	395
Nilgiris	-	59	40	99	8	24	4	2	1	5	8	8	-	-	39	60
Total	**2358**				119	462	134	59	12	44	19	44	2	81	**691**	**1667**

C-Corporation, M-Municipalities and TP-Town Panchayats

Table 10 Waste Processing and Disposal facility in Madurai Region

District Name	Waste Generation TPD				MCC		OCC		Biomethanation Plant		Windrow Composting		Vermi Composting		Waste Processing TPD	Waste disposal facility TPD
	C	M	TP	T	No	Capacity TPD	No	Capacity TPD	No	Capacity TPD	No	Capacity TPD	No	Capacity TPD		
Madurai	700	43	40	783	43	211	44	15	1	4	-	-	-	-	230	553
Dindigul	92	72	94	258	15	67	13	2	3	12	3	21	-	-	103	155
Theni	-	116	74	190	14	57	41	9	-	-	5	9	2	4	79	111
Sivagangai	-	80	37	117	11	37	52	5	-	-	1	3	-	-	45	72
Ramanathapuram	-	90	26	116	9	35	28	8	2	2	3	19	1	1	65	51
Total	**1464**				92	406	178	42	6	8.5	12	49	3	5	**522**	**942**

C-Corporation, M-Municipalities and TP-Town Panchayats

Table 11 Waste Processing and Disposal facility in Thanjavur Region

District Name	Waste Generation TPD				MCC		OCC		Biomethanation Plant		Windrow Composting		Vermi Composting		Waste Processing TPD	Waste disposal facility TPD
	C	M	TP	T	No	Capacity TPD	No	Capacity TPD	No	Capacity TPD	No	Capacity TPD	No	Capacity TPD		
Thanjavur	177	77	69	323	19	75	60	30	3	12	1	2	2	2	121	202
Trichirappalli	470	57	50	577	46	227	30	13	2	7	2	4	1	1	253	324
Mayiladuthurai	-	41	14	55	5	21	8	4	-	-	1	2	-	-	27	28
Nagapattinam	-	44	14	58	5	20	8	2	1	5	-	-	-	-	27	31
Ariyalur	-	25	4	29	4	13	5	3	-	-	-	-	-	-	16	13
Perambalur	-	18	11	29	2	6	3	2	1	3	-	-	-	-	11	18
Pudukottai	-	84	20	104	8	23	20	19	-	-	1	4	1	2	48	56
Thiruvarur	-	59	22	81	8	27	14	8	-	-	1	3	-	-	38	43
Total	**1256**				97	412	148	81	7	27	6	15	4	5	**541**	**715**

C-Corporation, M-Municipalities and TP-Town Panchayats

Table 12 Waste Processing and Disposal facility in Tirunelveli Region

District Name	Waste Generation TPD				MCC		OCC		Biomethanation Plant		Windrow Composting		Vermi Composting		Waste Processing TPD	Waste disposal facility TPD
	C	M	TP	T	No	Capacity TPD	No	Capacity TPD	No	Capacity TPD	No	Capacity TPD	No	Capacity TPD		
Tenkasi	-	95	56	151	21	64	16	24	-	-	2	2	3	3	93	58
Tirunelveli	183	33	61	277	54	112	5	6	2	7	1	2	1	1	128	149
Tuticorin	180	51	50	281	24	111	19	18	1	5	1	2	-	-	136	145
Virudhunagar	46	128	39	213	28	95	14	43	1	5	2	7	-	-	150	63
Kanyakumari	115	38	219	372	14	68	18	15	2	6	-	-	-	-	88	284
Total	**1294**				141	450	72	106	6	23	6	13	4	4	**595**	**699**

C-Corporation, M-Municipalities and TP-Town Panchayats

3.0 METHANE EMISSION FROM SOLID WASTE DISPOSAL FACILITY

Open dumpsites are the common form of waste disposal method in Tamil Nadu. These landfills generate greenhouse gases (GHGs) such as Methane (CH_4) which is 25 times more potent than CO_2 and a serious threat to global warming and climate change. CH_4 emissions from the dumpsites are calculated to evaluate the current emission of CH_4 and possibility of reducing CH_4 through capacity building. IPCC (2006) issued guidelines for calculating CH_4 from the solid waste disposal facility. There are two methods mentioned in the guidelines,the default method (Tier 1) and the First Order Decay (FOD) method (Tier 2). The default method is based on the assumption that all the potential CH_4 is released in the year of disposal,whereas the FOD calculate time-dependent emission based on degradation process. The GHG estimation is done by the default method (Tier 1). In this study, year 1990 was assumed as starting year for inventory preparation and IPCC 1996 methodology in conjunction with IPCC Good Practice Guidance, 1991 was followed to estimate $_{CH4}$ emission. The default method is based on the following equation,

CH4 emissions (T/yr) = [(MSWT • MSWF • L0) – R] • (1 – OX) eqn (1)

Where:

MSW_T = Total MSW generated (Ton /yr)

MSW_F = Fraction of MSW disposed at SWDS

L_0 (CH_4 generation potential) = [MCF • DOC • DOCF • F • 16 / 12 (Ton CH_4/Ton waste)]

MCF = CH_4 correction factor (fraction). MCF value of 0.4 is used in the study, considering Unmanaged shallow (<5 m waste) dumpsites, based on the IPCCC Guidelines presented in Table 13.

DOC = Degradable organic carbon [fraction (Gg C/Gg MSW)]

DOC = (0.4 • A) + (0.17 • B) + (0.15 • C) + (0.3 • D)

Where:

A = Fraction of MSW that is paper and textiles

B = Fraction of MSW that is garden waste, park waste or other non-food organic putrescibles

C = Fraction of MSW that is food waste

D = Fraction of MSW that is wood or straw

Fraction of degradable organic carbon dissimilated (DOC_F)

The IPCC Guidelines provide a default value of 0.77 for DOC_F. Based on a review of recent literature, it appears that this default value may be an overestimate. It should only be used if lignin C is excluded from the DOC value. For example, experimental values in the order of 0.5 - 0.6 (including lignin C) have been used in the Netherlands (Oonk and Boom, 1995) and demonstrated to give reliable estimates of landfill gas generated and recovered in the Netherlands. It is also good practice to use a value of 0.5-0.6 (including lignin C) as the default. National values for DOC_F or values from similar countries can be used for DOC_F, but they should be based on well documented research. DOC_F value of 0.5 is used in this study.

F = Fraction by volume of CH_4 in landfill gas

Landfill gas consists mainly of CH_4 and carbon dioxide (CO_2). The CH_4 fraction F is usually taken to be 0.5, but can vary between 0.4 and 0.6, depending on several factors including waste composition (e.g. carbohydrate and cellulose).

16 / 12 = Conversion from C to CH4

R = Recovered CH_4 (Gg/yr)

The default value for methane recovery is zero. This default should only be changed when references documenting the amount of methane recovery are available

OX = Oxidation factor (fraction)

The oxidation factor (OX) reflects the amount of CH_4 from SWDS that is oxidised in the soil or other material covering the waste. If the oxidation factor is zero, no oxidation takes place, and if OX is 1 then 100% of CH_4 is oxidised.

Overall, Chennai generates (MSW_T) 7663 TPD of MSW, where 69% of MSW ends up at two SWDS. These dumpsites are not managed and have depths less than 5 meters, where most of MSW decomposes aerobically. Thus Methane Correction Factor (MCF) under this condition is chosen as 0.4 (as per IPCC default values).

Table 13 Methane correction factor as per IPCC Guidelines (2016)

Type of Site	Methane Correction Factor (MCF) Default Values
Managed	1.0
Unmanaged – deep (>5 m waste)	0.8
Unmanaged – shallow (<5 m waste)	0.4
Uncategorised SWDS	0.6
Managed SWDS must have controlled placement of waste (i.e. waste directed to specific deposition areas, a degree of control of scavenging and a degree of control of fires) and will include some of the following: cover material, mechanical compacting or levelling of waste. b The default value of 0.6 for un-categorized SWDS may be inappropriate for developing countries with a high percentage of unmanaged shallow sites, as it will probably lead to overestimation of emissions. Therefore, inventory agencies in developing countries are encouraged to use 0.4 as their MCF, unless they have documented data that indicates managed landfill practices in their country.	

Also, it is assumed that about 50% of the organic carbon is ultimately degraded, and released from SWDS, where 50% of organic carbon does not degrade or degrade very slowly, deposited in SWDS. Out of all landfill gas emission, CH_4 and CO_2 is released predominantly. Since the SWDS is not managed appropriately, CH_4 recovery and oxidation factor is considered as 0.

To evaluate the waste composition in SWDS, 100 kg of MSW was taken and waste characterization study was carried out in Kodungaiyur and Perungudi Disposal Facility. The results from the findings were later converted for total MSW disposed (5300 TPD) in SWDS, and the massof fraction of paper (A), garden waste (B), food waste (C), and wood (D), in SWDS is calculated. Assuming that paper, garden waste, food, wood, and textiles contains 40%, 20%, 15%, and 43%, DOCs respectively, the total DOC was calculated by (0.4 • A) + (0.2 • B) + (0.15 • C) + (0.43 • D). Accordingly, the methane emission was calculated as summarised in Table 14 which indicate that Chennai generates about 28870 Ton of CH_4 /yr from the 3000 TPD of biodegradable wastes disposed in the two disposal facility.

Table 14 GHG emission from Disposal facility in Chennai

ULBs	Total generation MSW T	Fraction of MSW F	Lo							CH$_4$ Emission / yr.
			MCF	DOC				DOC$_F$	F	
				0.4*A	0.2*B	0.15*C	0.43*D			
GCC	7663	0.69	0.4	0.03	0.0005	0.08	0.003	0.5	0.5	28870

The segregated MSW from the households are collected and transferred to respective processing facilities. While other MSW are transported to landfills. Most of the corporations (Vellore, Kumbakonam, Hosur, Karur, Tiruchy, Tiruppr, Dindigul, Madurai, Sivakasi, Nagercoil, Tirunelveli, Thoothukudi) cover 80-95 % of the households through door-to-door collection. As a whole, Tamil Nadu generate 17021 TPD of MSW. After processing 6155 TPD of solid waste, the non-segregated waste of about 10856 TPD is transferred to open dumpsites. Based on the wet and dry waste composition in the dumpsite, methane emission from the dumpsites of Tamilnadu is calculated and shown in Table 15.

Of all other regions of Tamilnadu, GCC, a metropolitan city with an 8 million populations, generates and dumps an enormous amount of solid waste into open disposal facility of Kodungaiur and Perungudi, emitting 28870 Tons of methane every year. The methane emission from GCC disposal facilitys accounts for 52 % of methane emitted in Tamilnadu (as spatially mapped in Fig. 3). Methane emissions from other regions of Tamilnadu are recorded high in Tiruppur region (3779CH_4 Tons/yr), followed by Madurai (2135 CH_4 Tons/yr), Salem (1704 CH_4 Tons/yr), Thanjavur(1620 CH_4 Tons/yr), Tirunelveli (1584 CH_4 Tons/yr), Chengalpattu (1169 CH_4 Tons/yr), vellore(600 CH_4 Tons/yr).

Table 15 Methane Emission from disposal facility in Tamil Nadu

ULB	Total MSW generation (MSW_T)	Total MSW to processing facilities	Total MSW to disposal facility	MSW_F	CH_4 Tons/day	CH_4 Tons/yr
GCC	7663	2363	5300	0.69	79	28870
Chengalpattu Region	1006	490	516	0.51	3	1169
VelloreRegion	780	515	265	0.34	2	600
Salem Region	1190	438	752	0.63	5	1704
Tiruppur Region	2358	691	1667	0.71	10	3779
Madurai Region	1464	522	942	0.64	6	2135
Thanjavur Region	1256	541	715	0.57	4	1620
Tirunelveli Regions	1294	595	699	0.46	4	1584
Tamil Nadu	17021	6155	10856	0.64	151	55420

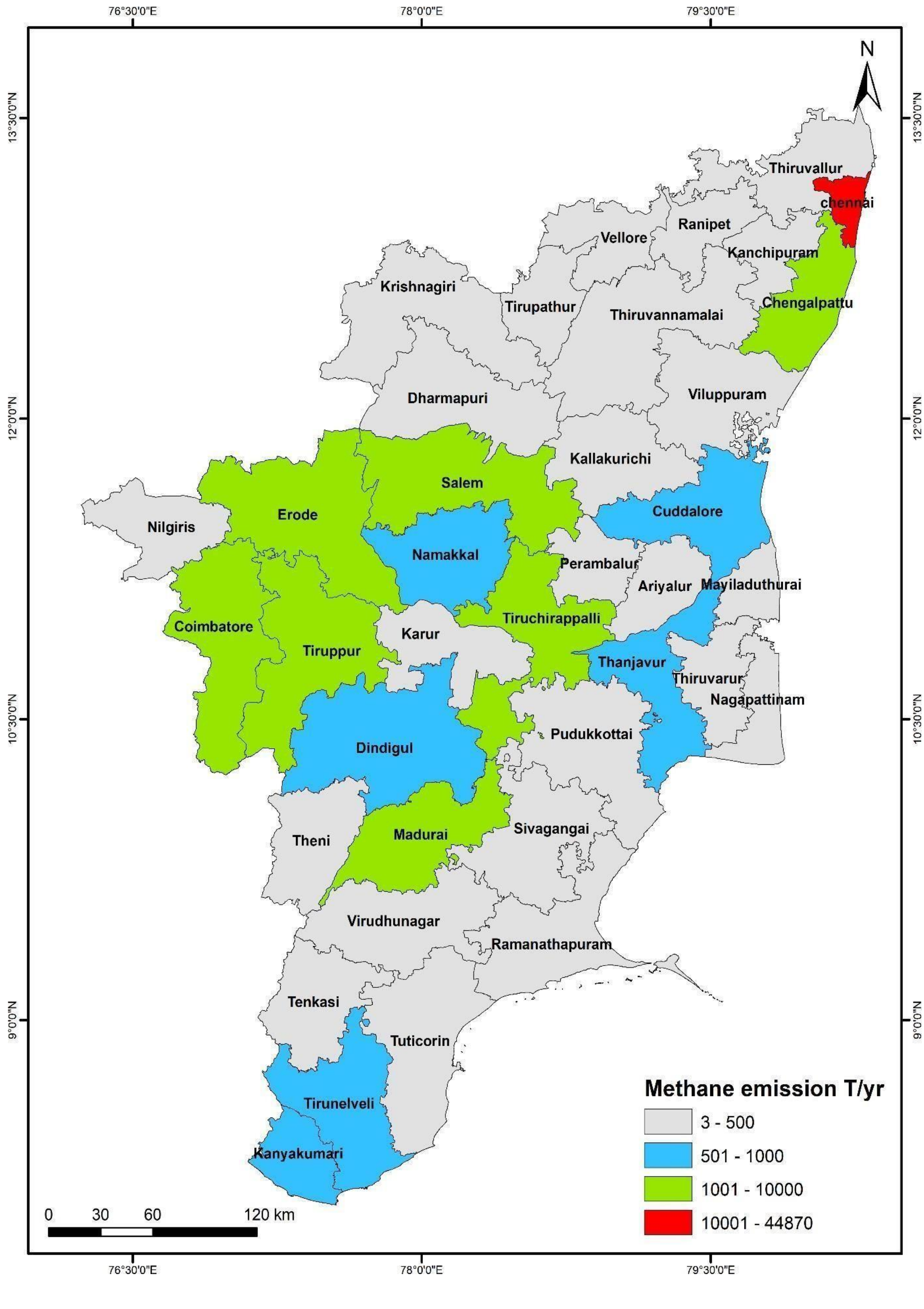

Figure 3 District wise methane emission from the Disposal facilities in Tamilnadu

3.1 PREVENTION OF DISPOSAL FACILITY METHANE EMISSION BY BIOMINING

Biomining is the process of reclamaining of dumpsites sites by Legacy Waste excavation, stabilisation and mechanical processing to separate the biodegraded fraction of the wastes as bioearth. The combustible fractions are recovered and disposed as RDF through cement plants and the inert fractions are disposed by landfilling in low lying areas. 5711624 m^3 of Legacy wastes have been bio mined from the disposal facility in 9 Municipal corporations as summarised in Table 16. 89 Municipalities have already processed 4672763 m^3 of Legacy wastes and 676169m^3 of Legacy wastes is Recommended to be processed in Phase II. About 362519 m^3 of Legacywastes is processed in 50 town panchayats. The details are presented in Annexure I.

Table 16 Details of Bio mining Activities in Municipal Corporations of Tamilnadu

S.NO.	NAME OF CORPORATION	QUANTITY OFWASTE PROCESSED BY BIO-MINING (m^3)
1	Greater Chennai Corporation - Perungudi (PDG)	3565887
2	Greater Chennai Corporation - Athipet	107811
3	Greater Chennai Corporation - Sathangadu	147029
4	Greater Chennai Corporation - Pallikarnai	56000
5	Dindigul	200000
6	Nagercoil	153000
7	Vellore	200000
8	Coimbatore	1051897
9	Thanjavur	230000
Total		5711624

4.0 CO_2 REDUCTION FROM PRIMARY COLLECTION VEHICLES AND EMISSION FROM TRANSPORT VEHICLE IN GREATER CHENNAI CORPORATION

4.1 CO_2 Reduction from Primary Vehicles Using BoV in GCC

GCC have 5289 battery operated vehicles used for the door - to - door collection inward wise average distance of BoV 5 km in the currently 2956 MT CO_2 /day reduced from BoV vehicles.

Total number of BOV = 5289

Average to and from Haul distance per trip =5 km

GHG (CO_2) emission = 0.0.3070 kg CO_2/km

Total CO_2 emission = 5289*5*0.3070

= 8118 kg CO_2 /day

= 8.1 T CO2/day

= 2956 MT of CO_2 /year

4.2 CO_2 Emission from Transport Vehicle -Greater Chennai Corporation

GHG (CO_2) emission from vehicles - 0.7375 kg CO_2/km used in this study India GHG program presented in Table 17.

Zone 1 CO_2 emission = 287 x 7.5 x 0.7375

=1587 kg CO_2 / Month

=1.587 T CO_2 / Month

=19.049 MT of CO_2/year

Freight Vehicles (India GHG Program)

Table 17 CO2 Emission from vehicles

S.No.	Category	kg CO2/km
1	LDV (< 3.5 T)	0.3070
2	MDV (<12 T)	0.5928
3	HDV (>12 T)	0.7375

The Greater Chennai Corporation is administered into waste from first eight zones (1-8) are transferred to KDG, whereas the waste from other seven zones (9-15) are transferred to PDG. By transferring the wastes to the disposal facility through LDV, MDV and HDV, the CO_2 emissions from thevehicles are calculated and summarized in Table 18.

Table 18 CO_2 emission from solid waste collection practices in Chennai

Zone	Haul distance km	Trips (Month)	CO_2 emission x 10^3 MT / year
Z1	7.5	287	19
Z2	9.6	11	0.9
Z3	5.6	352	17
Z4	3.7	3193	104
Z5	5.9	1795	93
Z6	6.2	1902	104
Z7	17.6	1290	200
Z8	12.3	2091	227
Z9	14	56	6
	16.2	2087	299
Z10	18.1	2223	356
Z11	20.2	819	146
Z12	10	596	52
Z13	7	1535	95
Z14	3	1447	38
Z15	9.8	820	71
Total			1834

4.3 POTENTIAL FOR WASTE TO ENERGY TECHNOLOGIES

There are several wastes to energy technologies available based on the type, quantity and characteristics of raw material, the required method of the energy, economic conditions, environmental standards and specific factors. The most commonly used waste to energy technologies are thermal, bio-chemical and chemical technologies. Incineration, pyrolysis, gasification and refused derived fuel (RDF) are included in thermal technologies of waste. In this process, numerous by-products are formed that can be referred to different energy generation and resource recovery techniques for treatment. Incineration, in which waste mass is reduced depending on the inert fraction in the wastes.

Incineration is suitable for high calorific value wastes. In MSW, the energy produced through incineration can be converted to electricity. The whole process is carried out in three phases i.e. incineration, energy recovery and control of air pollution. In the first phase (incineration process), waste is directly burned at 700-1000^{o}C in the combustion chamber by using flue gas and preheated air. Ultra-hot steam is produced after combustion of waste and this steam is used to create heat energy. Bottom ash primarily contains of silica, iron, calcium, aluminium, sodium and potassium. Heat and energy are recovered in second phase of incineration process.

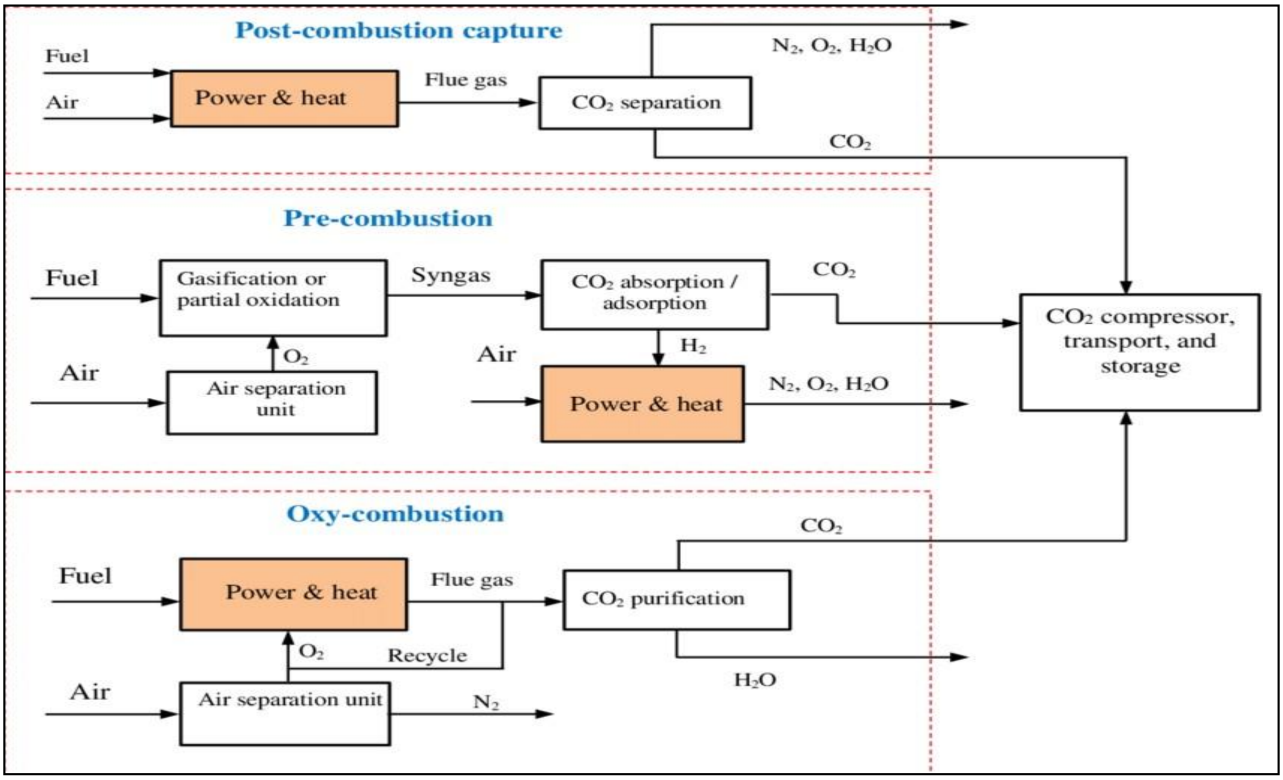

Fig 4. Carbon capture technologies

The biggest disadvantage of incineration process is the production of greenhouse gases. Thus, it is of prime concern to install emission control equipment to the incinerator, which is the third phase of incineration process. Incineration of mixed MSW is not feasible as it contains high organic composition, moisture content or inert content (range 30-60% each) and low calorific value (range 800-1100 kCal/kg).

Carbon capture is the process of removing carbon dioxide from an industrial process. There are three methods to capture carbon: post-combustion capture, pre-combustion and oxy–combustion (Fig. 4). Pre-combustion capture involves sequestering carbon before the combustion process. In post-combustion, as the name suggest, after the process of combustion, the exhaust fumes are re-routed through a gas separator which removes carbon dioxide from the other greenhouse gases. Oxy– combustion is popular but is only useful in a specific situation, where the fuel is oxygen-enriched steam instead air. During this combustion, predominantly, carbon dioxide and water vapour are produced. In the separator, the water vapour is cooled into a liquid, capturing the CO_2. Carbon capture provides a potential alternative for industries (Steel, Cement and power plant) actively removing emissions, and sequestering for utilization in other sectors.

Pyrolysis is the thermal waste method, uses heat at 300-800^{o}C to break down organic constituents in the anaerobic environment. It produces the syngas (methane, carbon dioxide, hydrocarbons, hydrogen and carbon mono-oxide), liquids and solids residues. The produced syngas can be utilized in different energy applications such as engines, boilers, turbines, heat pumps. Small temperature pyrolysis can also be used to generate a synthetic diesel fuel from plastic waste. Pyrolysis is successful only for specific type of highly segregated organic fractions such some clean plastics.

RDF is an alternating fuel which can be used in boilers in place of fossil fuels. A few RDF plants were setup in India. RDF pellets is frequently used for pulp, paper industry, wood industry waste and saw- mill industry.

4.4 CASE STUDY ON WASTE TO ENERGY PLANT – GUNTUR

The waste to energy plant of 1200 TPD capacity located on the outskirts of Guntur city (fig. 6) and generate 16 MW of power with waste collected from Guntur and Vijayawada Corporations and other 7 Municipalities is transported by the government to the Jindal Waste to Energy plant as summarized Table 19.

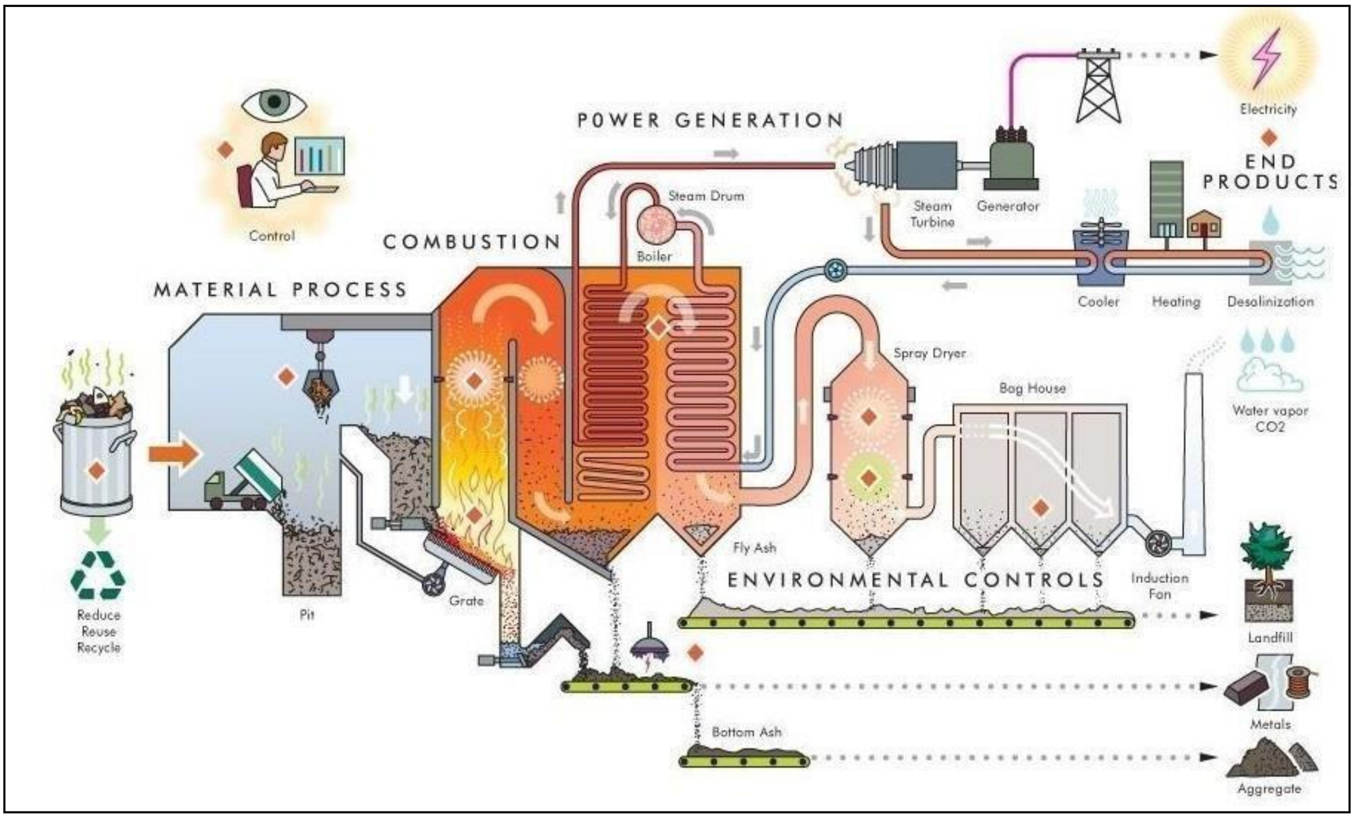

Fig. 5. A Schematic Diagram of Waste to Energy (WtE) Plant.

the typical waste-incineration facility (Fig. 5) includes the following operations:

- Waste storage and feed preparation.
- Combustion in a furnace, producing hot gases and a bottom ash residue for disposal.
- Gas temperature reduction, frequently involving heat recovery via steam generation.
- Treatment of the cooled gas to remove air pollutants, and disposal of residuals from this treatment process.
- Dispersion of the treated gas to the atmosphere through an induced-draft fan and stack.

Fig 6. Waste to Energy plant – Guntur

Table. 19 ULBs from where waste is processed at plant

S.No.	ULBs	Municipal Solid waste in TPD	Distance from Guntur (kms)
1	VIJAYAWADA	525	50
2	GUNTUR	320	15
3	TADEPALLE	30	44
4	MANGALAGIRI	52	37
5	TENALI	68	37
6	PONNUR	35	40
7	CHILAKALURIPETA	62	31
8	NARASROPETA	65	51
9	SATTENPALLI	45	37

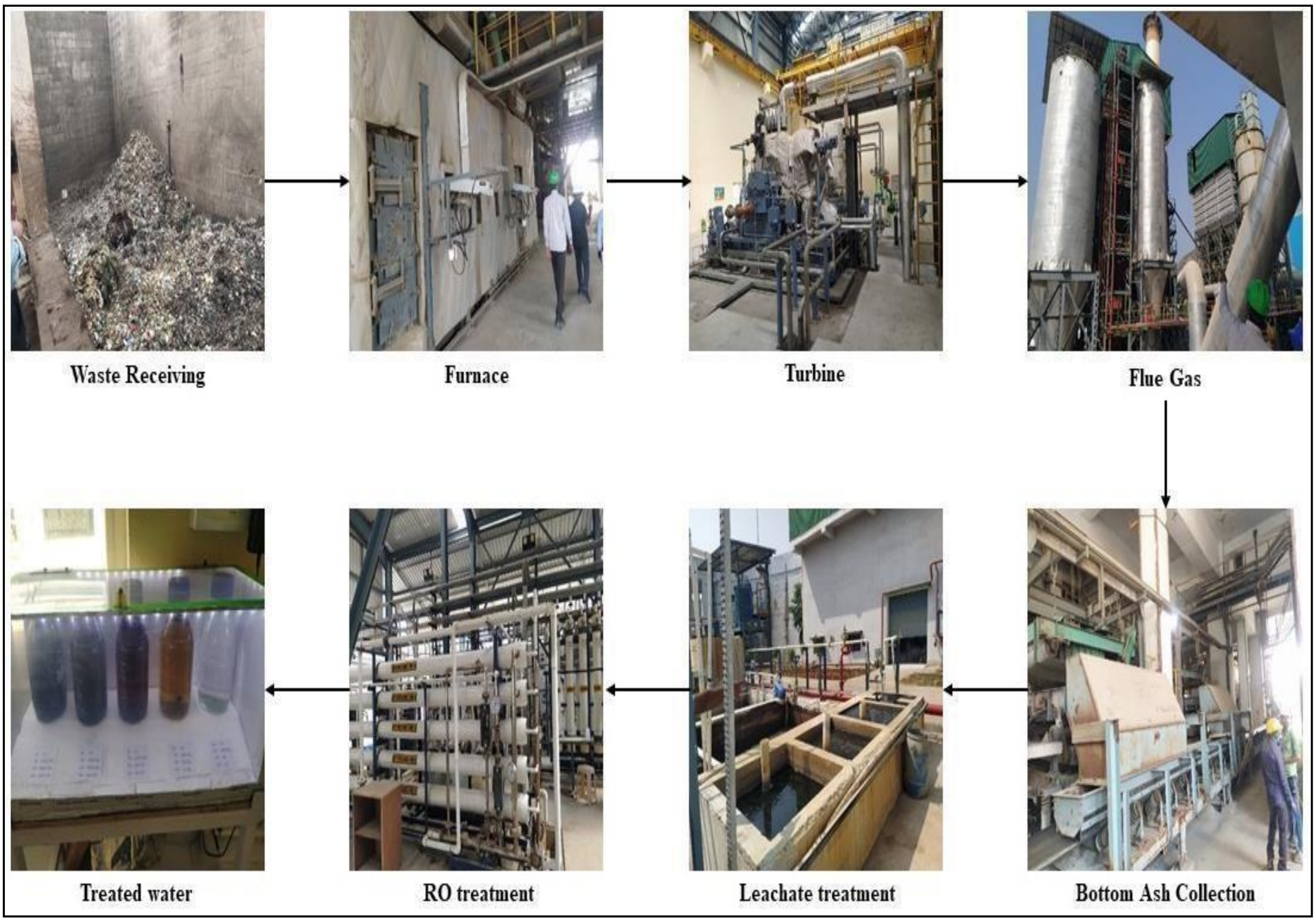

Fig 7. Process Flow diagram of Guntur Plant

The overall process carried out in Jindal urban waste management is shown in Fig. 7. Municipal solid waste (MSW) is delivered to the site in closed vehicles and stored in pits with capacity to store 40,000 T. Average Calorific value of the waste is 1500 to 2000 kCal/kg. A grap crane thoroughly mixes the waste in the pits and feed the two boilers at the rate of 4 tons per charge. The leachate from the pits is collected and treated. Waste from the feed hoppers is pushed onto the combustion bed by a ram feeder. A fully integrated control system ensures stable and efficient operation and optimizes the fire position on the combustion bed inside the boiler at temperature 800 to 950ºC. Once combustion is complete, the inert ash falls into the bottom ash extractor. The process follows Rankine Cycle and the energy released during combustion is used to produce superheated steam, which is expanded in a turbine generator to produce electricity 16MW. 2MW power is used for the plant operations and 14MW is exported to the power grid. The flue gas cleaning system and proper combustion ensure that the emission standards are achieved.

4.5 CASE STUDY ON INCINERATOR PROCESS AT KODUNGAIYUR

Fig. 8 Incinerator Plant at Kodungaiyur Disposal Ground

Fig. 8 depicts the incinerator located at Kodungaiyur disposal ground. GCC in joint partnership with MAK constructed the incinerator of 50 TPD in the premises of KDG. Solid waste reaching the KDG is segregated to wet waste and dry waste. Wet waste is processed in the MCC and converted into organic manure. Dry waste is processed in the incinerator to produce cement-like ash and granulated carbon. Dry waste is fed into the furnace with the help of conveyor. The furnacetemperature is maintained from 800 to 900ºC. The outlet of hot-air is fed back into the furnace for maintaining temperature within. Water is sprayed in the outlet pipe to clean up the flue gas, and toenhance absorption of acid components, ensuring the emission standards. The final outcome ash isprocessed further in making pavement blocks.

4.6 CASE STUDY ON BIO-CNG PLANT AT EGMORE:

Fig. 9 Overview of SWMS BIO-CNG plant

Srinivas Waste Management Services (SWMS), is a private Ltd, significantly contributing to the solid waste management in GCC. In focus to generate Compressed Natural Gas from waste, GCC has engaged with SWMS to construct a 100 TPD Bio CNG plant in Egmore, Chennai (as shown in Figure 9 & 10). The Bio-CNG unit produce about 3 metric tonnes biogas and 10 metric tonnes of bio manure every day. In comparison to regular biogas unit comprising 55-65 % methane and 35-45 % carbon dioxide, the bio-CNG at Egmore effectively produce 92-98 % methane and 2 %-3 % carbon dioxide. The unit receives bulk wet waste generators like hotels, restaurants, hospital-canteen, and community halls. Generally, the solid waste reaching the SWMS Bio-CNG unit is non-segregated. Thus the solid waste received is passed through the conveyor belt. The conservancy workers pick the dry waste leaving wet waste in the belt. The segregated wet waste is roughly shredded and transferred to another grinder for fine shredding. The shredded waste is send to mixing tank and passed to feeding tank. The waste from feeding tank is later fed to digester. Gas from the digester is stored in the storage balloon. The stored gas is compressed and filled in cascade cylinders (as shown in Figure 11). The successful deployment and functioning of any bio-CNG is based on the feedstock supply, feedstock storage, suitable site selection, product market, analyze competitors, and incentives.

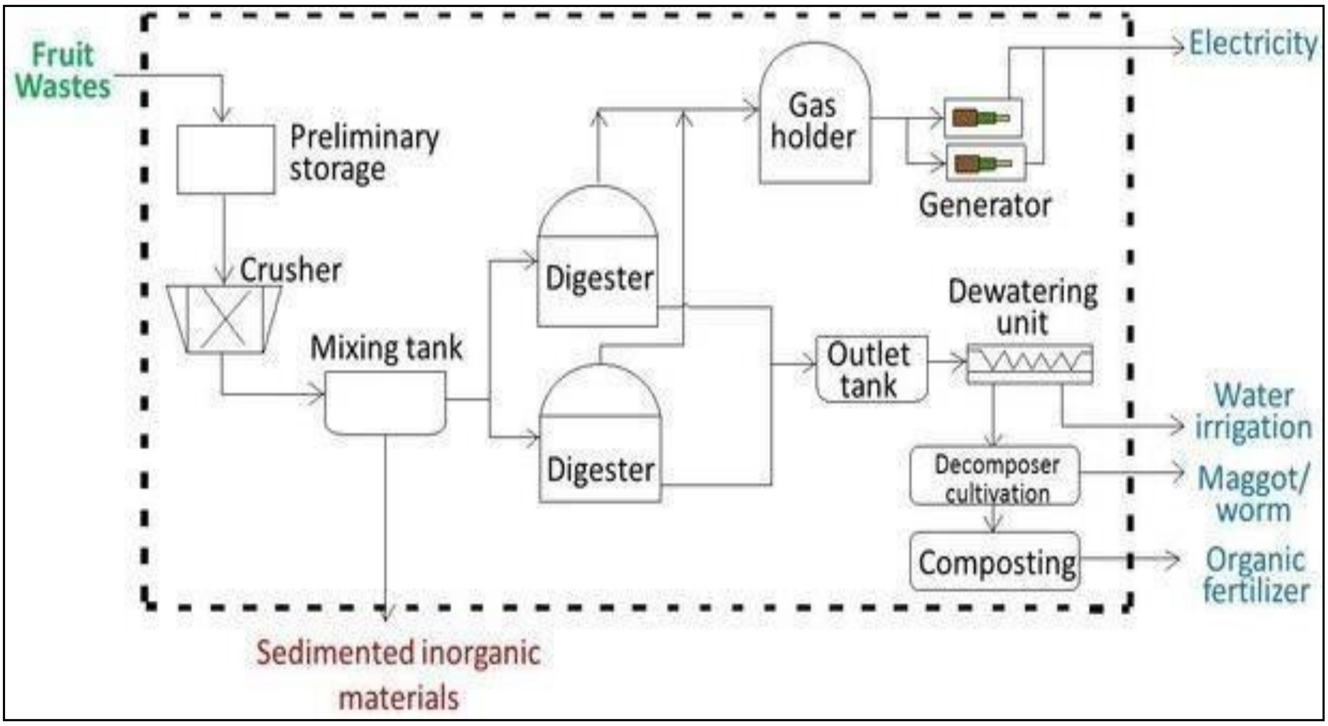

Fig 10. A Schematic Diagram of BIO-CNG Plant

Fig. 11 Overall process of Bio-CNG plant

Feedstock supply:

There are potentially four major waste on the target feedstock for CNG production: Waste from agriculture, animals, industry, and municipalities. The biomass that is easily accessible should be located within a 15-kilometer radius of the biogas plant. It is advisable to the fix at least 80 % of the feedstock supply using long-term agreements with either farmer-producer organizations or through contracts with secondary biomass suppliers. The quantity and quality of the supply responsibilities must be specified.

Feedstock storage:

An area of 4,000 square meters (m^2) is typically needed for a 50 cubic meter (m^3) Bio-CNG production facility to place digestion units, gas storage, purification compartments, and other machineries. If the plant is operate using agricultural feedstock, an extra 5,400 m^2 of area is thought to be needed for storage.

Site selection:

Road access to the plant is crucial to ensure consistent supply and outflow of biomass. If the plant is automated and requires 24x7 power, the possibility of availing an independent feeder line from a nearby power substation needs to be explored. Additionally, because it is impossible to avoid the plant's unpleasant odour and noise emissions, an appropriate neighborhood must be chosen in order to prevent future issues.

Product market:

The two major outputs of the Bio-CNG facility are compressed natural gas and organic fertilisers. The Bio-CNG facility was built within a 15-20 kilometer radius for marketing purposes. Digestate is a superior soil conditioner that can be enhanced with crop-specific nutrients to become a high-value organic fertiliser. which is the digestate, needs to be marketed and sold.

Analyze competitors:

The other Bio-CNG plant or a similar setup in the area that uses the same biomass feedstock as input must be kept at least 30 kilometers away, this will help save on the market conflict.

Incentives:

Some states provide financial incentives for the construction of bio-CNG facilities. Since these states have bioenergy regulations in place, obtaining regulatory approvals for the installation of bio-CNG plants is a simpler and quicker process.

5.0 SUMMARY AND CONCLUTION

As part of the several initiatives under the Tamil Nadu Climate Change Mission, the Tamil NaduPollution Control Board (TNPCB) has entrusted an assignment titled "**Baseline Study for Waste to Energy - A Pathway to Clean Power Generation"** to the Centre for Climate Change and Disaster Management (CCCDM), Anna University. The study focuses on municipal solid waste and its potential use for waste-to-energy.

Tamil Nadu generates about 17000 TPD of municipal solid waste, of which about 45 % (7600 TPD) is from the Greater Chennai Corporation (GCC). Average Solid Waste generation in the Municipal Corporations, Municipalities and Town Panchayats in Chengalpattu, Vellore, Salem, Tirupur, Madurai, Tanjavur and Tirunelveli Regions vary in the range between 500- 2500 TPD. About 2300 TPD of Solid waste generated in Chennai is diverted through Wet waste processing in MCCs, Biomethanation, garden waste processing, dry waste recovery and C&D waste processing. About 5300 TPD of wastes from GCC is currently dumped at the Kodungaiyur and Perungudi disposal facility. About 3800 TPD of wet wastes from the different regions is transported to decentralized processing units, and the remaining 5500 TPD is disposed in the open disposal facility. There are about 47 biomethanation units built across Tamilnadu, but only 14 units are operational and other 33 units are non-operational.

Biodegradable waste disposed at the GCC disposal facility has potential to emit 28870 Tons CH_4 / year. Methane emissions from the other ULBs in different regions range from 600 Tons CH4 / year in Vellore region 600 Tons CH_4/ year to 3779 Tons CH_4/ year in Tiruppur region. Methane emission from the disposal facility can be avoided by enhancing source segregation and increasing biodegradable waste processing by additional facilities for composting and biomethanation. CO_2 Emission from the vehicles used for transport of wastes to the disposal facility in Greater Chennai Corporation is 19 MT of CO_2/year. This can be substantially reduced by enhancing the decentralized processing of composting and thus reducing the need for transport to centralized processing.

Burning 1 kg of anthracite will produce about 3.3 kg of CO_2. Similarly, each tonne of MSW incinerated typically releases **0.7 tonnes** of CO_2 including both fossil CO_2 (e.g. from burning plastics) and biogenic CO_2 emissions (e.g. from burning wood, paper and food). Although biogenic CO_2 is directly released into the atmosphere making a significant contribution to climate change, only the CO_2 emissions from fossil sources will be considered for the purposes of a global analysis – an important loophole in GHG emissions accountability (UKWIN-2018). Recent advancements in carbon capture and Waste-to-energy technology abate the emission of CO_2. In Waste-to-energy, the emissions per unit of electricity are estimated to be in the range of **0.91 to 0.95 kg/kWh** for CO_2 generated from thermal power plants in India.

Waste characteristics from other ULBs also indicate that non- recyclable combustible, waste like plastic, paper, textile, wood, rubber and leather contribute 30% of the waste disposed at the dumpsite. Based on the spatial analysis of waste generation, it is recommended to setup Regional Waste to Energy Plant of at least 500 TPD in the Chennai, Kancheepuram, Coimbatore, Salem and Madurai region as summarized in Table 20 and represented in Figure 12. It is recommended to implement appropriate carbon capturing technology like chemical absorption method in a post-combustion capture process as partof the Regional waste to energy plant to avoid carbon emissions from the Waste to energy plant. Also, the bottom ash from the incineration plant must be utilsed to make pavement blocks so as tohave zero residue for disposal.

About 10% of the waste generated from the ULBs are highly biodegradable food wastes from bulk generators which has the potential to be diverted to biomethanation/ bio CNG Plants. Accordingly, GCC has the potential to setup Bio CNG plants of 600 TPD capacity in addition to the one CNG Plant of 100 TPD Capacity already in operation. Based on the spatial analysis of waste generation across Tamil Nadu, it is recommended to setup Regional Bio CNG Plant of at least 100 TPD in the Chennai, Kancheepuram, Coimbatore, Salem and Madurai region as summarized in Table 21 and represented in Figure 13.

Table 20 Waste to Energy Facilities (Incinerator) Recommendation for Tamil Nadu

S.No	ULB/Cluster	Location / Region	Recommended capacity (TPD) of Regional Incinerator[1]		Estimated power generation(MW) @ (1.5 MW/100 Ton Waste)[2]	
			2022	2030	2022	2030
1	Greater Chennai Corporation	Chennai (Kodungaiyur)	1600	2300	24	34
2	Chengalpattu and Vellore Regions	Kanchipuram	550	850	8	12
3	Salem Region	Salem	500	700	7	10
4	Tiruppur Region	Coimbatore	600	900	9	14
5	Madurai and Tirunelveli Regions	Madurai	800	1200	12	18

[1] As per CPHEEO, waste generation is estimated to increase by 5% per year.

[2] Based on power generation at MSW based WTE plant at Guntur.

Table 21 Waste to Energy Facilities (Bio-CNG) Recommendation for Tamil Nadu

S.No	ULB/Cluster	Location / Region	Regional Bio CNG Capacity (TPD) (2030)
1	Greater Chennai Corporation	Chennai (Kodungaiyur)	700
2	Chengalpattu and Vellore Regions	Kanchipuram	300
3	Salem Region	Salem	250
4	Tiruppur Region	Coimbatore	300
5	Madurai and Tirunelveli Regions	Madurai	500

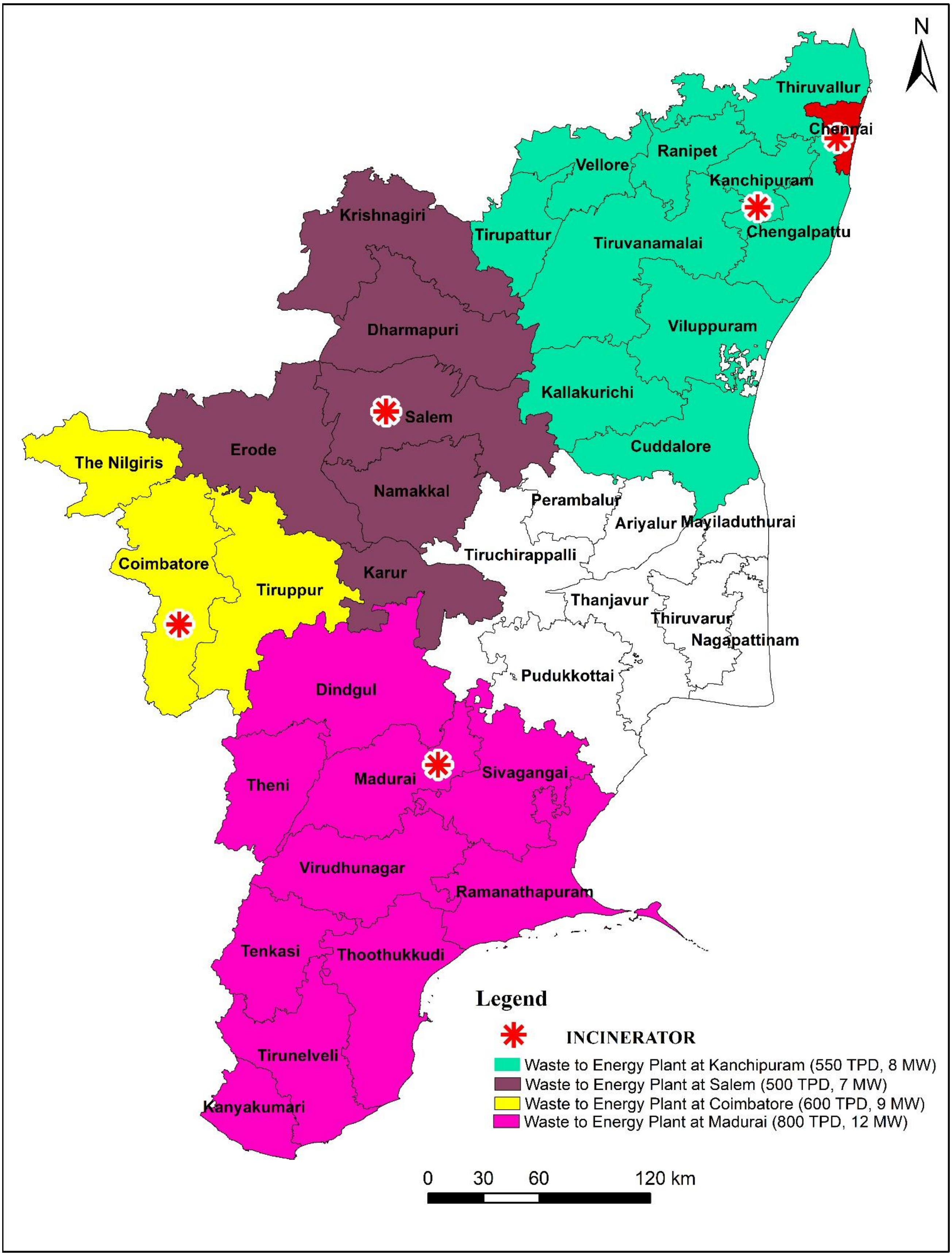

Fig. 12 Recommended Locations for Waste to Energy Facilities (Incinerator)

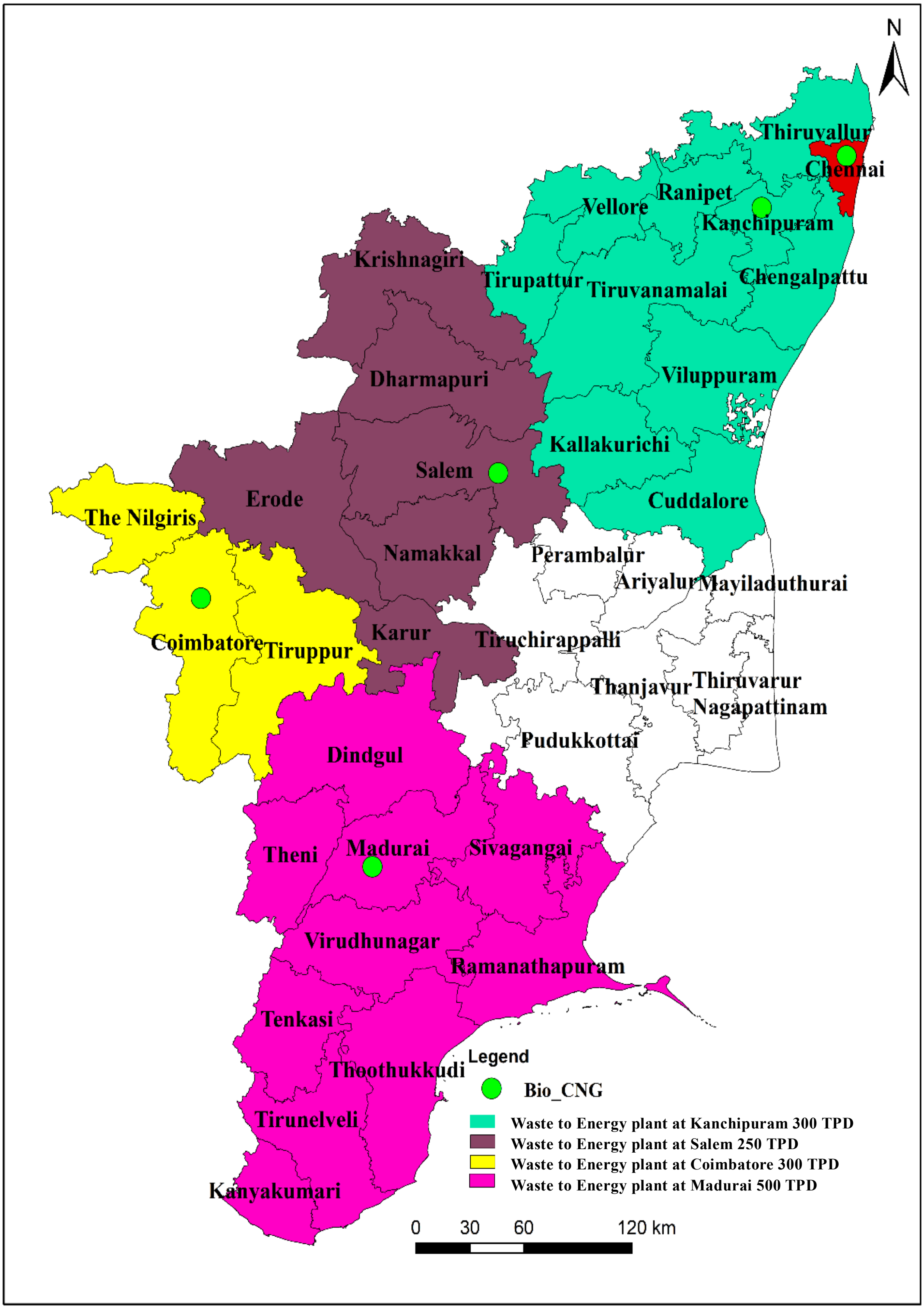

Fig. 13 Recommended Locations for Waste to Energy Facilities (Bio CNG)

Table 22 RECOMMENDED CLUSTER OF ULBs FOR REGIONAL WASTE TO ENERGY PLANT AT KANCHEEPURAM

ULB Cluster	Total waste (TPD) 2030	Distance from Kancheepuram (km)	Quantity of waste (TPD) (2030)
Vellore Corporation	**310**	**72**	**94**
Kancheepuram Corporation	**96**	**Nil**	**29**
Tambaram Corporation	**576**	**52**	**174**
Avadi Corporation	**174**	**67**	**52**
Cuddalore Corporation	**48**	**137**	**14**
Ambur	44	120	13
Arakkonam	41	32	12
Arcot	28	48	8
Gudiyatham	32	102	9
Ranipet	25	53	7
Thirupathur	44	157	13
Vaniyambadi	48	135	14
Walajapet	17	53	5
Jolarpet	11	185	3
Melvisharam	23	53	7
Pernambut	22	137	6
Thiruvannamalai	81	116	24
Arani	39	60	12
Thiruvathipuram	19	147	5
Vandavasi	17	38	5
Villupuram	62	115	18
Tindivanam	33	72	10
Kallakurichi	25	193	7
Sholingur	14	55	4
Kottakuppam	10	118	3
Tirukkoyilur	16	134	4

Table 22.....Continued

ULB Cluster	Total waste (TPD) 2030	Distance from Kancheepuram (km)	Quantity of waste (TPD) (2030)
Ulundurpettai	13	154	4
Chengalpattu	32	40	9
Madurantakam	10	54	3
Maraimalainagar	32	47	9
Tiruvallur	35	54	10
Poonamallee	31	68	9
Tiruthani	17	44	5
Tiruverkadu	32	75	9
Chidambaram	26	219	8
Nellikuppam	19	140	5
Panruti	25	133	7
Virudhachalam	35	174	10
Kundrathur	19	60	5
Mangadu	16	65	4
Ponneri	11	111	3
Thirunindravur	14	66	4
Tittakudi	8	195	2
Vadalur	11	155	3
Nandivaram - Guduvancheri	20	56	6
Town Panchayats	459	Nil	139
Total	**2740**		**830 (Round off to 850)**

*** Non-recyclable combustible fraction of waste shall only be disposed to the Regional waste to energy facility.**

*** 10 % of biodegradable fraction of waste generated shall only be disposed to the Regional waste to energy facility.**

Table 23 RECOMMENDED CLUSTER OF ULBs FOR REGIONAL WASTETO ENERGY PLANT AT SALEM

ULB Cluster	Total waste (TPD) 2030	Distance from Salem (km)	Quantity of waste (TPD) (2030)
Salem Corporation	**812**	**Nil**	**246**
Karur Corporation	**109**	**95**	**33**
Erode Corporation	**289**	**70**	**87**
Hosur Corporation	**106**	**163**	**32**
Attur	17	55	5
Mettur	22	51	6
Idappadi	20	44	6
Narasingapuram	10	52	3
Namakkal	51	56	15
Tiruchengode	44	47	13
Rasipuram	25	31	7
Komarapalayam	17	60	5
Pallipalayam	19	63	5
Dhamapuri	32	66	9
Krishnagiri	25	114	7
Kulithalai	10	103	3
Edaganasalai	7	20	2
Tharamangalam	13	22	4
Pallapatti	13	138	4
Pugalur	11	83	3
Gobichettipalayam	26	92	8
Sathyamangalam	14	120	4
Bhavani	14	67	4
Punjaipuliampatti	10	149	3
Town Panchayats	388	-	117
Erode (Town Panchayats)	229	-	69
Total	**2344**	**-**	**710 (Round off to 700)**

*** Non-recyclable combustible fraction of waste shall only be disposed to the Regional waste to energy facility.**

*** 10 % of biodegradable fraction of waste generated shall only be disposed to the Regional waste to energy facility**

Table 24 RECOMMENDED CLUSTER OF ULBs FOR REGIONAL WASTE TO ENERGY PLANT AT COIMBATORE

ULB Cluster	Total waste (TPD) 2030	Distance from Coimbatore (km)	Quantity of waste (TPD) (2030)
Coimbatore Corporation	**1532**	**Nil**	**464**
Tiruppur Corporation	**694**	**57**	**210**
Pollachi	41	43	12
Mettupalayam	29	36	8
Valparai	10	108	3
Udumalpet	28	72	8
Dharapuram	25	85	7
Kangeyam	16	72	4
Palladam	14	40	4
Vellakoil	17	90	5
Udhagamandalam	39	86	12
Coonoor	20	70	6
Gudalur	20	136	6
Nelliyalam	5	164	1
Karamadai	11	29	3
Karumathampatti	10	33	3
Madukkarai	10	13	3
Thirumuruganpoondi	14	55	4
Town Panchayats	295	Nil	89
Total	**2839**	**-**	**860 (Round off to 900)**

*** Non-recyclable combustible fraction of waste shall only be disposed to the Regional waste to energy facility.**

*** 10 % of biodegradable fraction of waste generated shall only be disposed to the Regional waste to energy facility.**

Table 25 RECOMMENDED CLUSTER OF ULBs FOR REGIONAL WASTE TOENERGY PLANT AT MADURAI

ULB Cluster	Total waste (TPD) 2030	Distance from Madurai (km)	Quantity of waste (TPD) (2030)
Madurai Corporation	**1034**	**Nil**	**313**
Dindigul Corporation	**135**	**64**	**41**
Sivakasi Corporation	**67**	**75**	**20**
Tirunelveli Corporation	**270**	**160**	**81**
Thoothkudi Corporation	**265**	**150**	**80**
Nagercoil Corporation	**169**	**240**	**51**
Tirumangalam	23	22	7
Melur	25	32	7
Usilampatti	14	40	4
Theni Allinagaram	48	77	14
Bodinayakanur	35	92	10
Chinnamanur	19	98	5
Cumbum	26	115	8
Gudalur	17	124	5
Periyakulam	23	80	7
Kodaikanal	23	116	7
Palani	60	121	18
Oddanchatram	22	91	6
Sivagangai	17	45	5
Karaikudi	70	86	21
Devakottai	20	97	6
Ramanathapuram	29	115	8
Paramakudi	51	77	15
Rameswaram	25	173	7
Keelakarai	26	129	8
Manamadurai	8	50	2
Tenkasi	25	160	7
Sankarankovil	26	140	8

Table 25.....Continued

ULB Cluster	**Total waste (TPD) 2030**	**Distance from Madurai (km)**	**Quantity of waste (TPD) (2030)**
Kadayanallur	38	140	11
Puliangudi	26	130	8
Sengottai	8	160	2
Ambasamudram	16	190	4
V.K.Puram	20	200	6
Kovilpatti	42	110	12
Kayalpattinam	20	180	6
Kuzhithurai	8	167	2
Colachel	11	260	3
P.Puram	10	240	3
Virudhunager	33	66	10
Rajapalayam	69	90	21
Srivilliputhur	35	78	10
Aruppukottai	36	60	11
Sattur	14	75	4
Kalakad	11	200	3
Surandai	13	168	4
Tiruchendur	11	180	3
Kollancode	25	284	7
Town Panchayats	1028	Nil	311
Total	**4078**	**-**	**1234 (Round off to 1200)**

*** Non-recyclable combustible fraction of waste shall only be disposed to the Regional waste to energy facility.**

*** 10 % of biodegradable fraction of waste generated shall only be disposed to the Regional waste to energy facility.**

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ANNEXURE I

DETAILS OF BIOMINING PROJECTS IN MUNICIPALITIES AND TOWNPANCHAYATS IN TAMILNADU

Table A1 Bio mining Activities in Municipalities of Tamilnadu

S.NO.	NAME OF MUNICIPALITY	QUANTITY OF WASTE PROCESSED BY BIO-MINING (m^3)
1	Ranipet	20,680
2	Tiruchengode	26,564
3	Tiruvallur	46,000
4	Karaikudi	1,12,000
5	Srivilliputhur	58,000
6	Palladam	3,900
7	Mettur	49,823
8	Arakkonam	54,000
9	Jolarpet	13,000
10	Perambalur	48,384
11	Tambaram	1,45,000
12	Dharmapuri	56,294
13	Pollachi	95,700
14	Gobichettipalayam	40,000
15	Pallipalayam	40,306
16	Udumalpet	33,700
17	Dharapuram	42,104
18	Kadayanallur	30,050
19	Periyakulam	57,835
20	Mathuranthagam	38,600
21	Cumbum	67,500
22	Gudalur	59,110
23	Vaniyambadi	32,050

S.NO.	NAME OF MUNICIPALITY	QUANTITY OF WASTE PROCESSED BY BIO-MINING (m^3)
24	Pammal	60,821
25	Sembakkam	38,026
26	Chidambaram	52,000
27	Poonamallee	25,500
28	Pallavaram	1,25,000
29	Anakaputhur	27,000
30	Idappadi	42,570
31	Karur	1,41,731
32	Kangeyam	22,018
33	Bhavani	33,566
34	Mettupalayam	32,454
35	Sathya mangalam	21,796
36	Vellakoil	8,752
37	Bodinayakanur	22,450
38	Kovilpatti	23,406
39	Keelakarai	9,350
40	Sankarankovil	63,000
41	Mayiladuthurai	32,500
42	Arani	16,650
43	Walajapet	20,000
44	Nagapattinam	23,213
45	Vickramasingapuram	25,000
46	Krishnagiri	61,577
47	Kulithalai	51,711
48	Virudhachalam	15522
49	Cuddalore	1,01,222
50	Avadi	64,174
51	Villupuram	53,000
52	Tirumangalam	26,400
53	Rasipuram	41,000

S.NO.	NAME OF MUNICIPALITY	QUANTITY OF WASTE PROCESSED BY BIO-MINING (m^3)
54	Vengadamangalam	1,40,829
55	Sivakasi	41,000
56	Kancheepuram	1,06,238
57	Maraimalai Nagar	33,200
58	Ambasamudram	20,500
59	Sattur	76,625
60	Tiruvarur	37,605
61	Hosur	1,28,196
62	Usilampatti	31,231
63	Thuraiyur	30,900
64	Sivagangai	34,000
65	Theni allinagaram	98,488
66	Rajapalayam	67,049
67	Chengalpattu	1,21,724
68	Attur	43,842
69	Kallakurichi	28,671
70	Tindivanam	45,085
71	Mannargudi	57,590
72	Tenkasi	27,956
73	Gudiyatham	1,11,720
74	Melur	41,800
75	Tirupattur	1,44,729
76	Ooty	1,34,000
77	Pattukottai	45,563
78	Palani	90,000
79	Aranthangi	45,105
80	Arcot	39,100
81	Ambur	1,14,720
82	Paramakudi	85,858
83	Thiruvannamalai	55,479

S.NO.	NAME OF MUNICIPALITY	QUANTITY OF WASTE PROCESSED BY BIO-MINING (m^3)
84	Pudukottai	60,000
85	Nellikuppam	11,450
86	Kuzhithurai	12,994
87	Thiruthangal	45,750
88	Sirkali	20288
89	Panruti	14426

Table A2 Bio mining Activites Recommended in Phase II in Municipalities

S.NO.	NAME OF MUNICIPALITY	QUANTITY OF WASTE PROCESSED BY BIO-MINING(m^3)
1	Namakal	102319
2	Manaparai	14571
3	Tenkasi (Boghanallur)	28449
4	Bodi - Siraikadu	36024
5	Chinnamannur	15762
6	Viruthunagar	19230
7	Ullundhurpettai	6400
8	Mangadu	7952
9	Vanthavasi	8238
10	Jayakondam	9278
11	Thramangalam	13840
12	Thirukovilur	14248
13	Thiruthuraipoondi	15201
14	Ariyalur	16055
15	Sholingur	17498
16	Senkottai	20015
17	Punjai Puliampatti	21824

18	Kayal Pattinam	22437
19	Ponneri	26432

S.NO.	NAME OF MUNICIPALITY	QUANTITY OF WASTE PROCESSED BY BIO-MINING (m^3)
20	Kovilpatti	27591
21	Puliyangudi	29197
22	Chithambaram	29791
23	Padhmanaathapuram	33846
24	Devakottai	34750
25	Aruppukottai	36493
26	Lalgudi	13495
27	Ranipet	18480
28	Kadayanallur	13796

Table A3 Bio mining Activites in Town Panchayat

S.NO.	NAME OF MUNICIPALITY	QUANTITY OF WASTE PROCESSED BIO-MINING (m^3)
1	Thirumazhisai	2265
2	Thenkarai	4750
3	Thirunindravur	6369
4	Tiruneermalai	13887
5	Meenjur	2300
6	Denkanikottai	14620
7	Chinnalapatti	6882
8	Kaveripattinam	16888
9	Naravarikuppam (Sothupakkam)	15883
10	Anthiyur	12975
11	Omalur	8089
12	Thammampatti	11700
13	Uthamapalayam	15163

S.NO.	NAME OF MUNICIPALITY	QUANTITY OF WASTE PROCESSED BIO-MINING (m^3)
14	Perundurai	20026
15	Paramathi Velur	15447
16	Avinasi	7583
17	Harur	11181
18	Pallapatti	27897
19	Musiri	11815
20	Manachanallur	15388
21	KC Palayam	16088
22	Vathalagundu	17271
23	Anaimalai	8993
24	Suleeswaranpatti	10883
25	Jalagandapuram	6935
26	Sulur	5300
27	Karamadai	6887
28	Kunnathur	8168
29	Annur	9357
30	Periyanaickenpalayam	11587
31	Madathukulam	7828
32	Lakkampatti	7925
33	Kanjikovil	5590
34	Ilayankudi	5534
35	Valappadi	6400
36	Muthukulathur	2641

Table A4 Bio mining Activites in Town Panchayat Phase II

S.NO.	NAME OF TOWN PANCHAYAT	QUANTITY OF WASTE PROCESSED BY BIO-MINING (m^3)
1	Aduthurai	3017
2	Andipatti	15337
3	Arani	4349
4	Ayyampettai	10540
5	B.Mallapuram	1991
6	Chinnasalem	4520
7	Chithode	5073
8	Kadathur	5050
9	Kattumannarkoil	4472
10	Kolathur	12013
11	Kottur	10398
12	Kurinjipadi	8298
13	Kutchanur	3028
14	Kuthalam	11853
15	Marandahalli	9740
16	Mecheri	9627
17	Melagaram	4221
18	Muthupettai	6471
19	Namagiripettai	9356
20	Natham	12401
21	Orathanadu	10000
22	Palacode	18135
23	Palani Chettipatti	17566
24	Pallipet	8430
25	Pennagaram	3622
26	Perungalathur & Madambakkam	32920

S.NO.	NAME OF TOWN PANCHAYAT	QUANTITY OF WASTE PROCESSED BY BIO-MINING (m^3)
27	Pillanallur	5291
28	Podhaturpet	9595
29	Puliyur	8716
30	Sarkarsamakulam	8365
31	Thirubhuvanam	2806
32	Thirukattuppalli	5332
33	Thiruppanandal	2138
34	Thirupporur	8022
35	Thisayanvillai	25557
36	Thiyagadurgam	4720
37	Tirukalukundram	14313
38	Uthangarai	10950
39	Uthukottai	5775
40	Vasudevanallur	5473
41	Vedasandur	13212
42	Velankanni	14520
43	Podathurpet	9595
44	Alangulam	16875
45	Kattupudhur	5589
46	Sholingar	17498
47	Thiruppuvanam	3764
48	Vennanthur	5876