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A Sustainable Energy Option to the Expanding Chennai Metropolitan Area

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Abstract

India is experiencing rapid growth in inhabitants, economic reforms and industrial development, which lead to a significant upsurge in waste generation. Though burgeoning amount of waste generated is an index for India's socioeconomic development and economic prosperity, its management is an indispensable task to achieve defensible growth, was not given priority during the last decades. Moreover, the on-going solid waste management systems are found to be insignificant, impetuous, topsy-turvy, expensive, human-intensive, unsafe to human and environment. Furthermore, attempts on electricity generation from waste resulted in the closure of their operation owing to improper planning on the quantity of waste generated and its composition, inadequate public cooperation, lack of technical know-how and financial crisis. As India is to ensure passable energy provisions at an affordable cost to its citizens with environmental concern, after careful study and lessons learnt from the failures of the former waste to energy projects, this paper proposes a successful environmental friendly waste to energy project for the expanding Chennai metropolitan area, India.

Keywords: Electricity Generation, Municipal Solid Waste, Project Proposal, Waste-to-Energy

1. Renewable Energy Practices in India

India's cumulative Grid interactive Renewable Energy Capacity is 29.9 GW[6] of which 68.9% comes from wind, while solar PV contributed nearly 4.59%[2–4,9–13]. Figure 1 shows an achievement of 30178.62 MW of grid-connected renewable power as on 31st January 2014 and Figure 2 highlight an achievement of 960.77 MW_{eq} of off-grid captive power from renewables.

India ranks fifth in the global wind energy market, however the achievement on waste to energy technology is not quite promising though the Ministry is promoting setting up of Waste-to-Energy projects[2–4,9–13] with the objectives of

1. To promote setting up of projects for recovery of energy from wastes of renewable nature from Urban and Industrial sectors,
2. To create conducive conditions and environment with fiscal and financial regime to develop, demonstrate and disseminate utilization of wastes for recovery of energy, and
3. To develop and demonstrate new technologies on waste-to-energy through R and D projects and pilot plants. The promotional scheme is applicable to private and public sector entrepreneurs and organizations as well as Non-Governmental Organizations (NGOs) on the basis of Build, Own and Operate (BOO), Build, Own, Operate and Transfer (BOOT), Build, Operate and Transfer (BOT) and Build Operate Lease and Transfer (BOLT). It is being implemented through State Nodal Agencies, who forward the Project Reports, received from the promoters, to the Ministry along with their recommendations in respect of financial, managerial and technical capabilities of the promoters and on

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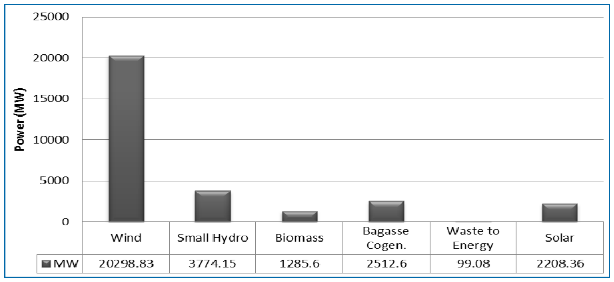

Figure 1. Grid-Interactive Power from Renewables as on 31.1.2014.

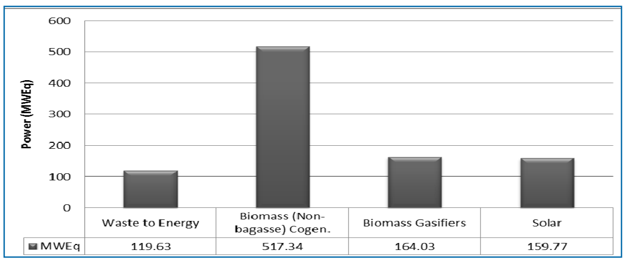

Figure 2. OFF-Grid/Captive Power from Renewables on 31.1.2014.

assured availability of waste materials on a long term basis (over 10 years) for operating the project successfully.

2. Barriers to Waste to Energy Technology

2.1 Government Support

The Indian Government has acknowledged waste to energy as a renewable technology and supports it through various subsidies and incentives. The Ministry of New and Renewable Energy (MNRE) is actively promoting all the technology options available for energy recovery from urban and industrial wastes[2–4,9–13]. MNRE is also promoting the research on waste to energy by providing financial support for R and D projects on cost sharing basis in accordance with the R and D Policy of the MNRE. In addition to that, MNRE also provides financial support for projects involving applied R and D and studies on resource assessment, technology up-gradation and performance evaluation. In spite of all the encouragements, the technology is not well-practiced[2–5,8,11–15].

2.2 Urbanization

Urbanization in India was mainly instigated after independence, due to adoption of a mixed system of economy of the country which gave rise to the development of the private sector. Urbanisation is taking place at a faster rate in India. Population residing in urban areas, according to the 1901 census, was 11.4% and this count increased to 28.53% according to the 2001 census, and crossing 30% as per 2011 census, standing at 31.16%[16–18]. For the first time in India's history, the nation will have five large states (Tamil Nadu, Gujarat, Maharashtra, Karnataka and Punjab) that will have more of their population living in cities than in villages in 2030[19]. The provision of infrastructural facilities required to support such large concentration of population is lagging far behind the pace of urbanization[19].

2.3 Waste Generation, Collection and Processing

Urban residents produce about twice as much waste as their rural counterparts[1,20].

1. As per Ministry of Urban Development[20–22], Government of India (Ministry of Environment and Forest 2013) that 100,000 MT of Municipal Solid Waste was generated daily in the country.
2. During the year 2004-05, Central Pollution Control Board (CPCB) through National Environmental Engineering Research Institute (NEERI), Nagpur conducted survey in 59 cities (35 Metro cities and 24 State Capitals) and estimated 39,031 Tons per day MSW generation in these 59 cities/towns[20–22].
3. The survey[20–22] reported that generation of 50,592 Tons of MSW per day in the year 2010-11 in the same 59 cities.
4. As per information received from State Pollution Control Boards/Pollution Control Committees[20–22], 127,486 TPD (Tons per day) municipal solid waste was generated in the Country during 2011-12, and
5. Out of the total MSW generated, only 89,334 TPD (70%) of MSW is collected and 15,881 TPD (12.45%) is processed or treated[20–22] as shown in Figure 3.

3. Chennai Metropolitan Area (CMA)

3.1 Location, Area and Population

The Chennai Metropolitan Area (CMA) comprises the Chennai Mega City (426 Sq. km area and 6.5 Million populations), 16 Municipalities, 20 Town

Panchayats and 214 Village Panchayats in 10 Panchayat Unions. The extent of CMA is 1189 Sq. km. There are about 15,000 industries and factories licensed in the Chennai city[20–22].

3.2 Electrical Energy Scenario

The Chennai Mega City's electrical energy requirement for the 11th (2010-11), 12th (2016-17) and 13th (2021-22) year plans[20–22] are given in Figure 4. The Peak Demand of City was 1290 MW during 1999-00 which rose to around 2206 MW by 2010-11 and is expected to grow at 7.11% and 6.28% during 12th and 13th plan respectively from the base year 2010-11 in spite of 5% actual growth from 1999-00 to 2010-11. The peak electric load will be 3370 MW and 4334 MW by the end of 12th (2016-17) and 13th (2021-22) plans respectively[20–22] as shown in Figure 5. The city will have to set aside 90 MW for the upcoming metro rail and other existing rail systems.

3.3 CMA's Share on State Grid

The total electrical energy requirement and the peak load demand met by the Tamil Nadu State and CMA during the year 2010-11 and the total energy requirement and the peak load demand projections for Tamil Nadu State as well as CMA for the years 2016-17 and 2021-22 are shown in Table 1. The Chennai City which has a population of only 8.8% of the Tamil Nadu State's population is in need of 18% of the State's total energy requirement and 16.2% share on the State's peak load demand[20–27].

The total energy requirement of the state for 2013-14 is pegged at 99,765 Million Units (MU), against the availability of 73,323 MU, a deficit of 26.5% i.e. 26,442 MU[28,29]. Against the all-India energy deficit of 70,232 MU, the southern regions accounts for 84%, with a shortage of 59,257 MU. Among energy deficit states, the biggest shortfall in absolute units of power will be in Tamil Nadu, which will have a shortfall of 26,442 MU or about one-third the net shortfall in the country as a whole.

4. Waste to Energy Proposal for Chennai

4.1 Solid Waste Generation

Chennai Corporation area is divided into zones and each zone is further sub-divided into about 15 Divisions. The

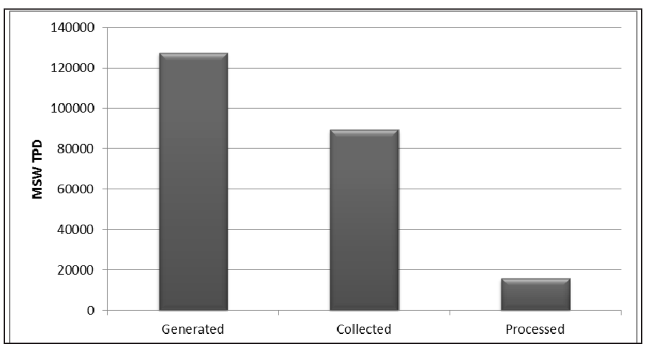

Figure 3. MSW Generation, Collection and Processing

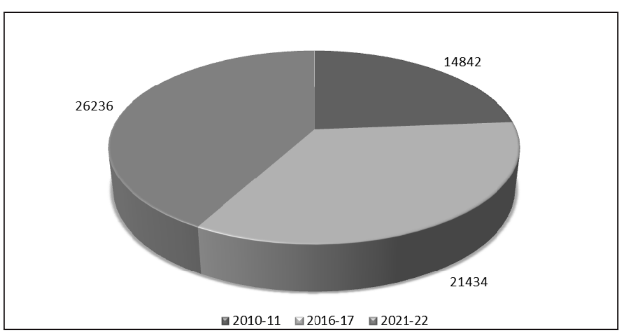

Figure 4. Electrical Energy Requirements in Million Units (MU)

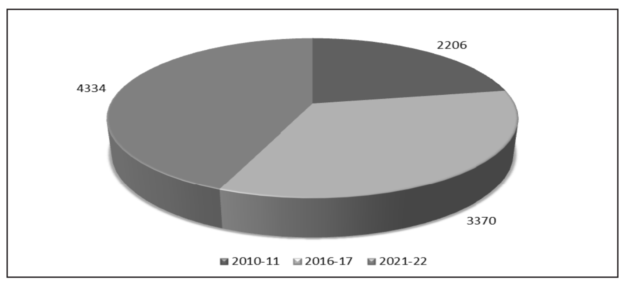

Figure 5. The Peak Demand in MW

Table 1. CMA's share on state energy and peak load requirements[21–23]

Category	Year 2010-11		Year 2016-17		Year 2021-22	
	Electrical Energy Require-ment (MU)	Peak Load Demand (MW)	Electrical Energy Require-ment (MU)	Peak Load Demand (MW)	Electrical Energy Require-ment (MU)	Peak Load Demand (MW)
Tamil Nadu State	80314	11728	119251	20816	171718	29975
CMA	14842	2206	21434	3370	26236	4334
CMA's share on State	18.5%	18.8%	18.0%	16.2%	15.2%	14.5%

Corporation of Chennai[27–30] is collecting an estimated quantity of 5200 Tons per Day of MSW which is presently disposed as open landfill at two sites viz. Kodungaiyur and Perungudi. Kodungaiyur located at northern part of City and Perungudi an adjoining village in the south. The extent of the Kodungaiyur landfill site is 182 hectares and the Perungudi land site is 142 hectares. About 45% of the total solid waste generated is disposed at Kodungaiyur site and the remaining at Perungudi site. Both sites are in use for more than 25 years and nearing their life expectancy; over loaded and cause serious health problems to nearby residents.

At present collection and transportation of waste is being out sourced in some zones (Zone-IX, Zone-X, Zone-XIII) and the corporation itself is carrying the activity in the remaining zones. The current solid waste management system in the Corporation needs to be improved and the management in the rest of CMA requires immediate attention since by the year 2026, about 6590 Tons of solid waste will be generated in the local body areas of CMA including Chennai City[36–41].

4.2 Physical Composition of Solid Waste

MSW in India mostly comprises of materials of three different types: organic, recyclable and inert. The solid wastes generated from different categories such as residential, commercial, halls, schools, institutions, and industrial are in the ratio of 68%, 16%, 14% and 2% respectively and the waste from hospitals and clinics are separately disposed by themselves[27–33]. The physical composition and chemical analysis of the solid waste generated in Chennai CMA are shown in Tables 2 and 3 respectively.

Table 2. MSW physical composition

Substance	Percentage
Food waste	8.00
Green waste	32.25
Timber (wood)	6.99
Consumable plastic	5.86
Industrial Plastic	1.18
Steel & Material	0.03
Rags & Textiles	3.14
Paper	6.45
Rubber & Leather	1.45
Inerts	34.65

4.3 Heating Value of Solid Waste

The quantity of MSW available after the removal of moisture, direct recoverables, non-combustibles, and inerts is estimated as 2460 Tons per day (from 5200 Tons per day). The heating value of MSW fuel per day is found to be 5435.20×10^6 kcal (22756.10×10^6 kJ) as shown in Table 4 and it works out to be 9.25 MJ/kg of MSW identified for waste to energy project. In terms of kWh, it is equivalent to 6.32×10^6 kWh. Considering 20% thermal efficiency, the estimated total power production is 144.31 MW. The useful 2460 Tons/day of MSW has a power generating capacity of 144.31 MW. According to the Corporation of Chennai[36–41], the heating value of the MSW generated is between 946 – 1032 kcal/kg and the present estimate indicates the value as 1045 kcal/kg of MSW generated in a day.

4.4 Identified Site

Alandur, Pallavaram and Tambaram, the three municipalities in the Chennai Metropolitan Development

Table 3. MSW chemical analysis

Substance	Percentage
Moisture Content	27.60
PH Value	7.68
Organic Content	39.06
Carbon content	21.53
Nitrogen Content	0.73
Phosphorous	0.63
Potassium	0.63

Table 4. MSW chemical analysis

Substance & % quantity	Fuel heating value/day
Food waste (8%), 1110 kcal/kg	218.45×10^6 kcal
Green waste (32.25%), 1556 kcal/kg	1234.45×10^6 kcal
Timber (wood) (6.99%), 4446 kcal/kg	764.51×10^6 kcal
Plastic (7.04%), 7780 kcal/kg	1347.37×10^6 kcal
Rags & Textiles (3.14%), 7500 kcal/kg	579.33×10^6 kcal
Paper (6.45%), 7200 kcal/kg	1142.42×10^6 kcal
Rubber & Leather (1.45%), 4168 kcal/kg	148.67×10^6 kcal
Total	5435.20×10^6 kcal

Area, each faced certain issues with regard to disposal of MSW. Pallavaram Municipality (the largest Urban Local Body, ULB) was designated[27–30,33–37] as the nodal ULB, and assigned the responsibility of preparing a master plan, including the technical and financial details of a facility for treatment and disposal. The three Urban Local Bodies acquired a 50-acre site at Venkatamangalam from the State Revenue Department for the purpose, situated within 10 km (approximately) of each ULB[33–37]. During April, 11 2013, a 3 MW per hour MSW to electricity project has been initiated and it is expected to complete by mid of 2014. Since the initiated project is of small capacity and capable of managing only 300 Tons per day whereas 2460 Tons per day are available for power generation; hence the remaining 2160 Tons of useful MSW need to be stored which results in similar storage problems as before. So it is judicious to go for a waste to energy project of handling higher MSW (than the planned one) in the same location with substantial land area.

4.5 Project Size and Technology

Hitachi Zosen Inova[45] is a leading global technology provider and contractor in the field of Energy from Waste facilities. It offers customized plant sections and turn-key plants, covering planning, design and engineering, construction and operation, as well as maintenance and overhaul of Energy from Waste plants. It has implemented Hitachi Zosen Inova's core technology in more than 190 Energy from Waste plants in Japan, China and other countries throughout East Asia.

While deciding the size of the project, the variation in daily MSW generated and collected and the climate of Chennai are considered. The variation in MSW generated is estimated to be 10 to 12% and the climate in Chennai varies from dry and hot weather to monsoon climate. The climate change results in great variations in moisture content of the MSW during the year which affects the heating value of MSW. It is estimated that only 900 to 1100 Tons/day of useful MSW would be available throughout the year in spite of the poor percentage of MSW collection and climate change for power generation. The financial viability and the technology of Hitachi Zosen Inova are found to be stable and proven. Hence a waste to energy project of handling 620 Tons per day of MSW with an electrical power generating capacity of 19.25 MW has been identified.

Technology	:	Hitachi Zosen Inova AG[38]
Annual capacity	:	226,300 Tons/annum (620 Tons per day)
Calorific value of MSW	:	7.0 MJ/kg – 12.5 MJ/kg
Thermal capacity	:	71.7 MW
Combustion system	:	Hitachi Zosen Inova grate, Air-cooled
Boiler	:	Four-pass boiler, horizontal Steam quantity – 87 Tons/h Steam pressure – 50 bar Steam temperature – 400°C
Energy recovery	:	Extraction-condensation turbine Electrical power output – 19.25 MW Expected generation – 146500MWh/annum Marketable energy – 124500 MWh/annum
Daily emission (max)	:	Dust (Particulates) – 10mg/m^3 Total Organic Carbon – 10mg/m^3 Hydrogen Chloride – 10mg/m^3 Carbon Monoxide – 50mg/m^3 Sulphur Dioxide – 50mg/m^3 Oxides of Nitrogen – 200mg/m^3

4.6 Economic Aspects

To illustrate the economic viability of the proposed 19.25 MW waste to energy project, its capital cost, expected annual electricity generation, operating and maintenance costs, annual profit, payback period and internal rate of return are compared with a same megawatt capacity wind farm project for the same equity/debt ratio. Same energy tariff (USD 0.09/kWh) has been considered for revenue calculations of both projects. While working out the annual revenue for the proposed MSW project, the income from by-product generation and sale of recyclables are not considered.

From the projections of Table 5, it is evident that the capital cost as well as the operation and maintenance costs of the MSW project is higher than the wind farm project of the same capacity by 1.2935 MUSD/MW, and 0.0647 MUSD/MW, respectively. However, the net operational profit per annum from the MSW project is found to be much greater than the wind farm project by 2.985 MUSD. Though the capital costs of the wind farm projects have

Table 5. Economic comparison

Description	MSW Project	Wind Power
Capital Investment (MUSD)	71.10	46.20
Annual O&M Cost (MUSD)	3.555	2.31
Annual Revenue (MUSD)	11.205	6.975
Annual Profit (MUSD)	7.650	4.665
Payback Period	9 years 3 months	9 years 9 months
IRR	10.75%	10.10%
Life-time	20 years	20 years

been slashed down during recent years, the net revenue from such projects is not very attractive due to their poor capacity factors in the areas nearer to Chennai. The payback period of the MSW project is approximately ten years, which is equally good as that of the wind farms in Chennai area. The payback period of the proposed MSW project will be more attractive if the revenues due to by-product generation of the MSW-fuelled power plant are considered while calculating the annual net profit. The estimated air emission rates per MWh energy produced by the proposed MSW project is found to be 1356 kg/MWh of carbon dioxide, 0.3629 kg/MWh of sulfur dioxide, and 2.4494 kg/MWh of nitrogen oxides.

5. Conclusions

Attempts on waste to energy projects resulted in the closure of their operation due to improper planning on the quantity of waste generated and its composition, inadequate public cooperation, lack of technical know-how and financial crisis. In this paper, the authors addressed a waste to energy project of 19.25 MW capacities suitable for the Chennai Metropolitan Area that is capable of handling 620 Tons of Municipal Solid Waste per day. While designing the project, utmost importance has been paid for analyzing the unsuccessful earlier attempts and the reasons for such failures. The proposed proposal tries to overcome all such issues and it presents a proven environmentally friendly technology with an adequate MW capacity that could accommodate the variations in the daily waste generation and its heat content. The economic viability is not as attractive as that of a coal-fired power plant but it is more environmentally friendly. It is comparable to a wind-power plant in non-windy areas such as Chennai in terms of cost of generation, pay-back period, etc. but the wind power-plants are more environmental friendlier than the MSW power plants and less capital intensive. Though the MSW power plants are capital intensive and pollute the atmosphere within the allowable limits, a feasible solution to the solid waste management problem and a source of energy are the greatest advantages of them.

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