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# Reduction of Greenhouse Gas Emissions by Clean Development Mechanism for Solid Waste Management in Nashik

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Abstract - **The Municipal solid waste in Nashik city has been observed to be increasing day by day due to heavy urbanization, industrialization, growth in population density and income. The growth of households, industries, commercial units such as hotels, theatres, restaurants, malls and other infrastructures are increasing at greater level; however Nashik Municipal Corporation (NMC) has joined hands with Mailhem Ikos Environment Pvt. Ltd (France-based)/ naming the facility in Nashik city as Nashik Waste Management (NWM) for collection ,segregation, processing, O&M of Nashik Waste Management. NMC has also made Partners with GIZ (German-based) recently and have installed a Biomethanation plant of 30 TPD especially for biodegradable waste from hotels, restaurants and other such units, but it is not under the scope of NWM. The solid waste collected in Nashik, its segregation at site and disposal of the same by Municipal Corporation is low and not adequate, but under Swachh Bharat Abhiyan (SBA, 2016), it is being implemented by Nashik Waste Management on fast-track basis. But from 1st April 2018, it has been mandatory for the citizen to segregate the waste at source. In the present study, the future population of Nashik city as well as the future waste generation has been forecasted (2019-2048) using CPHEEO guidelines, where it was observed, a significant increase in Municipal solid waste from (2019-2048) which will increase up to thrice as compared to the initial years. The forecasted waste generation were divided into three phases and the total landfill gas, methane, carbon dioxide in ($m^3$/year), (Mg/year) and (short tons/year) resp. using LandGEM V3.02 according to the availability of three landfills in the vicinity of NWM. Recommendations have also been provided in order to achieve Clean Development in the waste management facility.**

***Keywords — Clean Development Mechanism (CDM), Certified Emission Reduction (CER), Nashik Waste Management (NWM), Clean Air Act (CAA), Central Public Health and Environmental Engineering Organization(CPHEEO)***

## I. INTRODUCTION

The Clean Development Mechanism (CDM) is part of Kyoto protocol environmental agreement which was designed to stimulate sustainable development through people centered participatory developmental activity in order to reduce greenhouse gas (GHG) emissions. It is one of the Flexible Mechanisms defined in the Kyoto Protocol (IPCC, 2007) that provides for emissions reduction projects which generate Certified Emission Reduction units (CERs) which may be traded in emissions trading schemes. (IPCC 2007 B. Metz. Eds.)[1]. MSW generation are the significant contributors of GHG emissions (A.Kumar, M.P. Sharma., 2014)[2] . The purpose of this study is to estimate and analysis the future population of Nashik city as well as the emissions, so that remedial measures can be recommended under Clean Development Mechanism (CDM) to the solid waste management facility in Nashik city [also called Nashik Waste Management(NWM)] thus adopting measures for reducing the greenhouse gas emissions from Municipal Solid Waste in the facility thus providing confidence that the emission reductions are being achieved and are able to monitor the risks inherent to baseline and project emissions which plays a vital role in climate protection. There are 7987 CDM projects worldwide, among which 7801 projects have been registered by the CDM Executive Board, whereas the remaining 193 projects are still pending to be registered [3]. Around 50% projects are mainly from India & China. 2938 CDM projects have been registered by Indian CDM Executive Board in Delhi. Until Dec 2015, 1 billion metric tons of $CO_2e$ or (CERs) have been issued worldwide. There around 391 CDM projects related to MSW from which 114 projects are from India itself. Registering for CDM offers financial benefits as well as technology transfer and ultimately sustainable development.[4] Solid waste, including municipal waste and its management, is a major challenge for most cities and among the key contributors to climate change. GHG emissions can be reduced through recovery and recycling of resources from the MSW stream (King and Gutberlet,

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2013)[5]. Due to initiatives such as the Clean Development Mechanism (CDM), reducing GHG emissions for a for a developing country can offer an important route to attracting investment in a variety of qualifying project areas, including waste management (Barton JR, Issaias I, Stentiford EI , 2008)[6] especially in developing city like Nashik. CDM can play a major role in managing MSW by motivating municipalities to go in for energy recovery projects, as it will bring in carbon credits, which makes the projects financially more attractive (Unnikrishnan and Singh, 2010)[7].

## II. Need Of Research

The current level of generation of solid waste, population and their projected rate of annual increase pose a considerable environmental challenge which might be an indirect threat to Nashik. The heavy urbanization, industrialization and increasing population in Nashik, will generate solid waste in significant quantities in the near future along with increase in global warming which needs a way in order to control it or make ways to mitigate up to some extent. One way is to start reducing the Greenhouse gas emissions from the waste management facility itself. Due to improper segregation, proper organic matter is not available for degradation. The improvement of nearby local air quality of landfill sites should also be considered for the population living in the vicinity of waste management facility. To reduce the emission, practicing remedial alternatives like implementation of CDM can be adopted like collection of greenhouse gas emissions entering the environment which will act as clean technology as well as control over pollution, also produce power Identifying occupational and health related hazards and managing them. The increasing population, pollution and waste generation poses a great threat in the emissions of greenhouse gases. About 65-70% of the emissions are due to solid waste. As methane and carbon dioxide are main emissions from MSW, it can be utilized for power generation in order to reduce the cost of electricity to run the facility.

## III. Methodology

The study for this paper was done by visiting the waste management facility and studying the existing scenario of Nashik Waste Management facility. The Nashik Waste Management has 10 tons per day (TPD) biogas plant for biodegradable waste collected from hotel, restaurants, and for the leachate from landfill for its treatment from which methane is flared after treatment. Landfill, Biogas plant are the areas which mainly contribute to the greenhouse gas emissions in the waste management facility due to the biodegradable factors that contribute to such emissions. (i) Biogas emission measurement from the anaerobic digestor and comparing it with the theoretical daily based biogas emission. (ii) Landfill Gas measurement after closure and comparison with the theoretical emission estimated. Due to unforeseen circumstances and site conditions, the existing landfill was not able to be capped and closed, hence the comparative study will be difficult. Hence, emissions were forecasted using LandGEM V3.02. The population will be forecasted from 2018-2048 using combination of Incremental increase method and Geometric Mean Method and the forecasted waste using CPHEEO guidelines for Municipal Solid Waste which was observed to be around thrice as compared to the initial year. LandGEM is a single phase automated user interface tool for estimating total LFG, $CH_4$, $CO_2$, and non-methane organic compounds from MSW landfills using the total annual disposed wastes or that which will be disposed in the near future. However, it doesn't include the categorization of wastes. LandGEM V3.02 predicts the LFGs emissions based on a first order decay equation, which assumes that the $CH_4$ generation rate reaches its peak shortly after the initial waste is placed and decreases exponentially after that. The LandGEM model also assumes that the volume emission rate of $CO_2$ and $CH_4$ emissions are same or as specified as the user's-input, with trace amounts of non-methane organic compounds and other air pollutants. The following equation shows the first-order decay equation used to estimate $CH_4$ generation rate (Q, in $m^3$/year) (USEPA, 2005).

$$Q = \sum_{i=1}^{n} \sum_{j=0.1}^{1} kLo \frac{M}{10} \exp(-ktg)$$

Where, 'i' and 'j' denote time increment (in years), 'n' indicates the number of years of the landfill's operation, 'k' shows the first order CH4 generation rate (year$^{-1}$), '$L_0$' is $CH_4$ generation capacity ($m^3$/Mg), and 'M' is the mass of waste accepted in a year. The estimation of GHG emissions from a landfill requires significant input parameters such as landfill opening year, design capacity of landfill or landfill closure year, $CH_4$ generation rate, $CH_4$ generation potential and waste acceptance rates. For estimating the emission rates LandGEM uses either site-specific data or default parameters (Clean Air Act (CAA) defaults or Inventory defaults). While CAA uses $L_0$ of 170 $m^3$/Mg, and k of 0.05 $y^{-1}$, the default inventory uses $L_0$ of 100 $m^3$/Mg and k of 0.04 $y^{-1}$.[8]

## IV. Data Collection

It was proposed that the existing landfill will be closed and capped by the end of year 2017. But due to some unforeseen circumstances and site conditions, the landfill could not be capped and hence the emission estimation had to be done using LandGEM V3.02. Nashik city's population, waste collected i.e. from 2000- 2017 were provided by sources from NMC. Table IV.1 & Fig. IV.1 illustrates the waste collected from 2001-2017.

Table IV.1 1Waste Generation (2001-2018)

| Year | Incoming Garbage (M.Tons) |
|---|---|
| 2001-2002 | 46629 |
| 2002-2003 | 74435 |

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| | |
|---|---|
| 2003-2004 | 79096 |
| 2004-2005 | 75008 |
| 2005-2006 | 76517 |
| 2006-2007 | 88120 |
| 2007-2008 | 95362 |
| 2008-2009 | 98106.29 |
| 2009-2010 | 103654.47 |
| 2010-2011 | 116755 |
| 2011-2012 | 121256.942 |
| 2012-2013 | 123934.793 |
| 2013-2014 | 125813.632 |
| 2014-2015 | 136129.776 |
| 2015-2016 | 150041.26 |
| 2016-2017 | 168046.21 |
| **Total** | **1678905.373** |

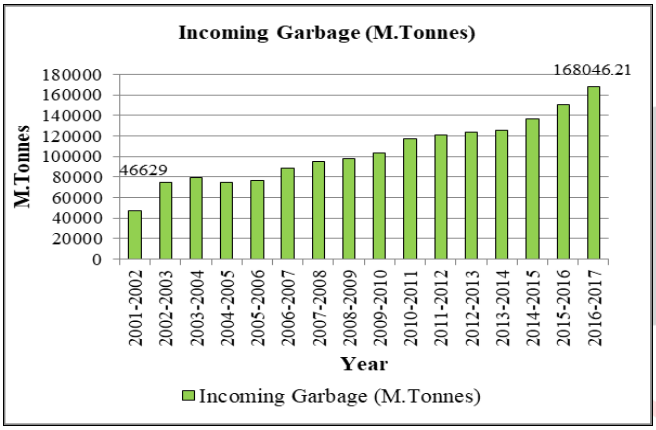


FIGURE IV.1 WASTE COLLECTED (2001-2017)

Based on the above values, the population as well as the waste that will be generated was forecasted using the combination of Geometrical Progression and Incremental Increase methods as waste using CPHEEO guidelines. Table IV.1 represents the population and waste forecasted for operational period (2018-2048) and Fig. IV.1 represent the forecasted waste generation.

TABLE IV.2 FORECASTED POPULATION & WASTE (2018-2048)

| Year | Population | Waste MT/day | Waste MT/year |
|---|---|---|---|
| 2018 | 1999121 | 545 | 199202 |
| 2019 | 2051608 | 570 | 206679 |
| 2020 | 2104095 | 590 | 214271 |
| 2021 | 2156582 | 610 | 221977 |
| 2022 | 2209069 | 630 | 229799 |
| 2023 | 2261556 | 650 | 237735 |
| 2024 | 2314043 | 675 | 245786 |
| 2025 | 2366530 | 695 | 253952 |
| 2026 | 2419017 | 720 | 262234 |
| 2027 | 2511033 | 750 | 274683 |
| 2028 | 2603049 | 790 | 287314 |
| 2029 | 2695065 | 825 | 300126 |
| 2030 | 2787081 | 860 | 313120 |
| 2031 | 2879097 | 895 | 326295 |
| 2032 | 2971113 | 930 | 339652 |
| 2033 | 3063129 | 970 | 353189 |
| 2034 | 3155145 | 1005 | 366909 |
| 2035 | 3247161 | 1045 | 380809 |
| 2036 | 3339177 | 1080 | 394891 |
| 2037 | 3455457 | 1130 | 411039 |
| 2038 | 3571737 | 1170 | 427347 |
| 2039 | 3688017 | 1215 | 443818 |
| 2040 | 3804297 | 1260 | 460449 |
| 2041 | 3920577 | 1310 | 477242 |
| 2042 | 4036857 | 1355 | 494196 |
| 2043 | 4153137 | 1400 | 511311 |
| 2044 | 4269417 | 1450 | 528588 |
| 2045 | 4385697 | 1495 | 546026 |
| 2046 | 4501977 | 1545 | 563625 |
| 2047 | 4618257 | 1600 | 581386 |
| 2048 | 4734537 | 1650 | 599307 |
| **Total** | **98272635** | **31415** | **11452958** |

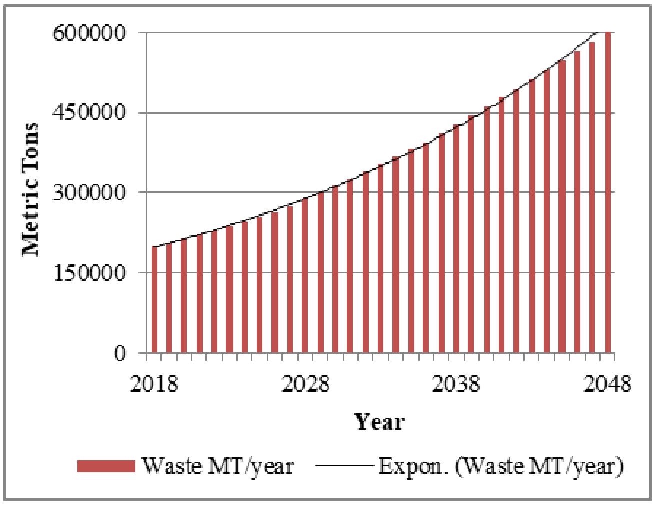


FIGURE IV.2 FORECASTED WASTE MT/YEAR (2018-2048)

Based on the guidelines provided by CPHEEO Manual, the average daily biogas emissions are calculated to be 1584 $m^3$/day. In order to study the biogas emission difference between the theoretical value and practical values. the emissions were measured at the Nashik Waste Management facility for a period of 60 days. Table IV.2 illustrates the emissions from biogas plant per day.

TABLE IV.3 BIOGAS PLANT EMISSIONS (60 DAYS)

| Day No | Per day Emission | Day No | Per day Emission |
|---|---|---|---|
| 1 | 1542 | 31 | 1422 |
| 2 | 1748 | 32 | 1614 |
| 3 | 1446 | 33 | 1760 |
| 4 | 1646 | 34 | 1762 |
| 5 | 1580 | 35 | 1756 |
| 6 | 1558 | 36 | 1754 |
| 7 | 1558 | 37 | 1544 |
| 8 | 1702 | 38 | 1634 |
| 9 | 1254 | 39 | 1346 |
| 10 | 1730 | 40 | 1318 |
| 11 | 1318 | 41 | 1706 |
| 12 | 1676 | 42 | 1422 |
| 13 | 1792 | 43 | 1602 |
| 14 | 1288 | 44 | 1720 |
| 15 | 1506 | 45 | 1510 |
| 16 | 1690 | 46 | 1702 |
| 17 | 1818 | 47 | 1724 |
| 18 | 1408 | 48 | 1574 |
| 19 | 1414 | 49 | 1668 |
| 20 | 1374 | 50 | 1470 |
| 21 | 1524 | 51 | 1626 |
| 22 | 1626 | 52 | 1490 |
| 23 | 1606 | 53 | 1610 |
| 24 | 1812 | 54 | 1678 |
| 25 | 1464 | 55 | 1456 |
| 26 | 1678 | 56 | 1658 |
| 27 | 1700 | 57 | 1478 |
| 28 | 1706 | 58 | 1574 |
| 29 | 1478 | 59 | 1662 |
| 30 | 1668 | 60 | 1500 |
| **Total practical site biogas-reading for 60 days** | | | **95050** |

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# V. DATA ANALYSIS & DISCUSSION

As per the site information available, there is an existing landfill which will be capped and closed by 2018 where vegetation will be laid. Another three landfills have been proposed for future waste disposal which cannot be processed in the Waste Management Facility. So the waste disposal to the landfill was divided into three phases, viz, Proposed Landfill 1 for phase 1 (2019-2029), Proposed Landfill 2 for phase 2 (2029-2039), Proposed Landfill 3 for phase 3 (2040-2048).


FIGURE V.1 PROPOSED LANDFILL SITES BY NASHIK WASTE MANAGEMENT

Based on the above collected data, the emissions from the Landfill were analyzed using LandGEM V.3.02. in terms of $m^3$/year, Megagram/year, and in terms of short tons/year. The growth in the emissions of different phases i.e. from 2000-2048 is depicted in following table as well as the fig. in $m^3$/year, Mg/year and short tons/year respectively.

TABLE V.1 PHASE-WISE EMISSIONS IN M3/YEAR

| Year | Total LFG | Methane | Carbon Dioxide |
|---|---|---|---|
| | *($m^3$/year)* | *($m^3$/year)* | *($m^3$/year)* |
| 2000-18 | 2.503E+07 | 1.252E+07 | 1.252E+07 |
| 2019-29 | 3.650E+07 | 1.825E+07 | 1.825E+07 |
| 2030-39 | 5.118E+07 | 2.559E+07 | 2.559E+07 |
| 2040-48 | 6.607E+07 | 3.303E+07 | 3.303E+07 |

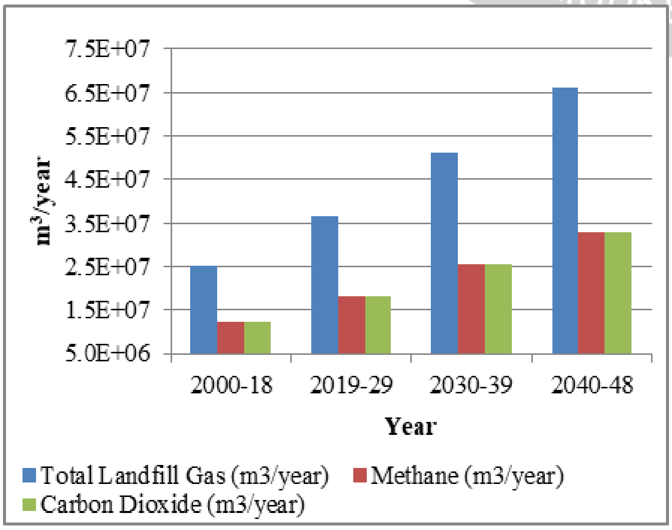


FIGURE V.2 PHASE-WISE EMISSIONS ($M^3$/YR)

TABLE V.2 PHASE-WISE EMISSIONS IN MG/YEAR

| Year | Total LFG | Methane | Carbon Dioxide |
|---|---|---|---|
| | *(Mg/year)* | *(Mg/year)* | *(Mg/year)* |
| 2000-18 | 3.126E+04 | 8.350E+03 | 2.291E+04 |
| 2019-29 | 4.559E+04 | 1.218E+04 | 3.341E+04 |
| 2030-39 | 6.392E+04 | 1.707E+04 | 4.685E+04 |
| 2040-48 | 8.251E+04 | 2.204E+04 | 6.047E+04 |

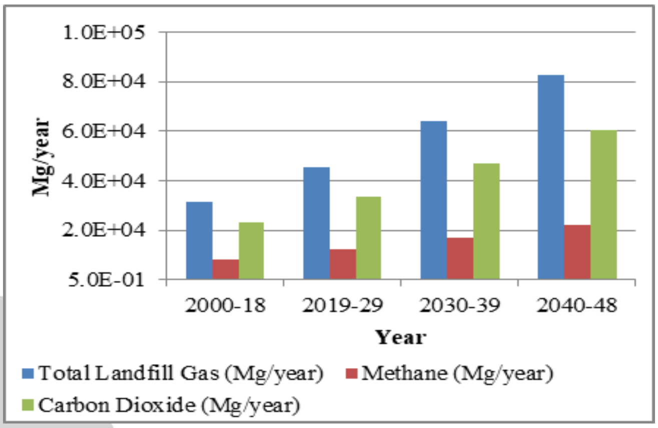


FIGURE V.3 PHASE-WISE EMISSIONS (MG/YR)

TABLE V.3 PHASE-WISE EMISSIONS IN SHORT TONS/YEAR

| Year | Total LFG | Methane | Carbon Dioxide |
|---|---|---|---|
| | *(short tons/year)* | *(short tons/year)* | *(short tons/year)* |
| 2000-18 | 3.439E+04 | 9.185E+03 | 2.520E+04 |
| 2019-29 | 5.014E+04 | 1.339E+04 | 3.675E+04 |
| 2030-39 | 7.031E+04 | 1.878E+04 | 5.153E+04 |
| 2040-48 | 9.076E+04 | 2.424E+04 | 6.651E+04 |

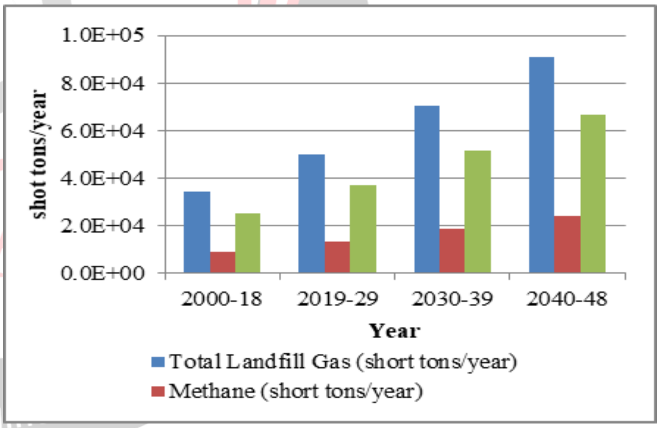


FIGURE V.4 PHASE-WISE EMISSIONS (SHORT TONS/YR)

In the waste management facility, the landfill emissions i.e. methane and carbon dioxide are main contributors for the increase in greenhouse gases. As crediting period for the project is estimated to be 30 years, the forecasted Emissions can be taken into consideration so as to avail the clean technologies so that there will an increase in the Net Power Generation (NPG). The property of methane and carbon dioxide is that its production in landfill will decrease in course of time, but if Clean Development Mechanism alternatives like Biogas, landfill gas etc. are recovered potentially so as to produce electricity, it can save the energy cost, decreasing load on the electric grid as well as functioning of various components of the waste management facility. The biogas emissions that were

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measured at the facility for duration of 60 days indicate that the theoretical value estimated and the practical readings had much difference as per daily emissions, but the summing up of total theoretical & practical emission for the 60 days duration shows a difference of only 10 $m^3$ between them. Fig. V.4 shows the fluctuation between the theoretical value and actual readings from the Biogas plant at Nashik Waste Management for 60 days.

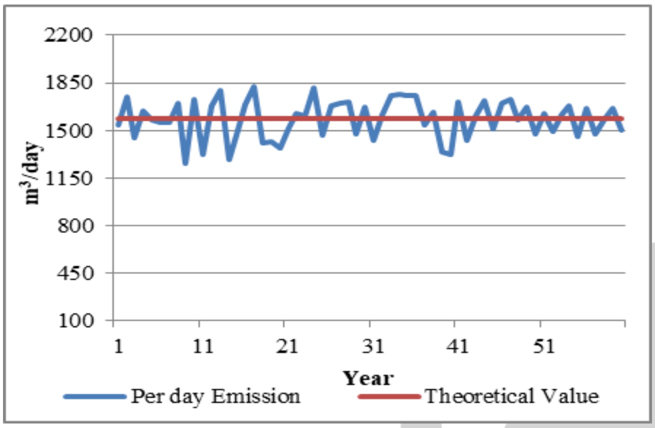


FIGURE V.5 THEORETICAL & PRACTICAL EMISSION COMPARISON

## VI. CONCLUDING REMARKS

The most practical and economic way to manage waste in the majority of urban communities and therefore reduce carbon emissions is to segregate waste at collection points i.e. by door to door collection, compost the remaining biogenic carbon waste in windrows, using the maturated compost as a substitute fertilizer and dispose the remaining fossil carbon waste in controlled landfills (R. Couth, 2010)[9]. It is crucial to set up system boundaries and assumptions when establishing a GHG emission inventory (Braschel and Posch, 2013)[10]. The LFG, $CH_4$ and $CO_2$ emissions in m3/year, Mg/year, and in terms of short tons/year for three phase-wise landfills have been estimated. According to IPCC default good practice guidelines, 1996, at a collection efficiency of seventy percent and varying difference with respect to time, 0.07 tons of $CH_4$ can be recovered, multiplied with the GWP for $CH_4$ (i.e., 21), using gas yield methodology. The waste generation is increasing day by day along with increase in emissions but these be used to generate power for the operation of waste management facility along with reduction in power rates as compared to earlier consumptions. The distribution of methane gas to customer can be a difficulty, but will not be in practise until the near decade. The Certified Emission Reductions CERs can estimated based on the accuracy of the estimated emissions which will be studied for the future project work. The CERs will be a stepping stone towards the happening of a clean, environmental and sustainable development to the Nashik Waste Management as well the employees working in the facility.

Although landfills represent the largest source of GHGs as compared to other methods but still landfills remain the leading waste disposal method in most parts of the world especially in developing countries. The biogas collection projects over landfills have established a strong point to introduce and ripen activities in the renewable energy sector in developing countries. Such Projects will also help in achieving greenhouse effect reduction, environmental protection, energy security and decline in dependency over conventional fossil fuels. The FOD model developed by IPCC to estimate the landfill GHG emissions is a viable tool that gives modest results if used properly. If MSW generated is managed appropriately by various schemes especially landfilling, it can improve the environment by reducing carbon emissions. Future estimates of solid waste production indicate that the current situation could worsen unless a dedicated national policy framework and an integrated action plan is adopted along with a concerted effort to improve the collection and disposal system.[11]

## VII. RECOMMENDATIONS

To reduce the volume of MSW that reaches the landfill, source reduction should be prioritized. Mass media like advertisements on radio stations and pamphlets can play a significant role in urging the public to segregate the waste. However, Nashik Waste Management is taking efforts in the city by playing the audios related to waste segregation on Garbage Vehicles called Ghanta-Gadi. Labeling the products as recyclable or non-recyclable by manufacturing organizations can help in better understanding of the public. Treatment technologies for MSW should be developed based on the type of waste generated and suiting the local needs. For developing countries, an integrated system for solid waste management as proposed by Shekdar (2009)[12] suits perfectly.[4]

In order to achieve Clean Development in the waste management facility, the following alternative measures can be taken so as to reduce the emission of Greenhouse gases up to some extent. Some recommendations can be listed as:-

a. Waste Water & Leachate Management
b. Water Quality Management
c. Odour Control
d. Alternative Technologies like:
    i. Bio-methanation
    ii. Vermi-Composting
e. Aerobic Composting Methods like:
    i. Indore Method
    ii. Rapid Composting
f. Anaerobic composting Methods like:
    i. Bangalore Method
    ii. Pyrolysis
    iii. Gasification
g. Occupational Health & Safety Management.
h. Community Health & Safety Management.

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## VIII. Limitations

The accurate facility's sector-wise estimation of emissions and its energy recovery potential is difficult due to the limitations on availability of input data as well as resources. The different technologies for recovering useful energy from Municipal Solid Wastes already exist and are being extensively utilised in different countries for their multiple benefits. It is necessary for the success of these technologies in India to evolve an Integrated Waste Management system, coupled with necessary legislative and control measures. Pollution standards to be improved which will increase the importance for emission reductions. Theoretical and practical emissions estimation will have vast differences which can/cannot be relied upon. The recommendations provided may or may not be practised due to financial or site conditions where climate also plays an important part. The public participation in solid waste management is not enough which affects the present as well as, will the affect the future generations to come in.

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