City based analysis of MSW to energy generation in India, calculation of state-wise potential and tariff comparison with EU

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Abstract

Techno-economic feasibility of the best available Waste to Energy (WTE) technologies across the world were studied for 75 Indian cities. Secondary data on Municipal Solid Waste (MSW) characteristics for all cities were compiled from three well-known authentic databases, viz. NEERI (National Environmental Engineering Research Institute, Nagpur), NSWAI (National Solid Waste Association of India) and CPCB (Central Pollution Control Board, New Delhi). We observed a definite relationship between the calorific value of waste generated and the biodegradable and paper fractions present in waste. The authors made an attempt to calculate WTE potential from MSW for a majority of Indian cities, along with the state-wise potential. Tariff charged by EU countries were compared with some states and operating plants in India. The authors also recommend what needs to be done in terms of policy modifications and rules that need to be adhered to for MSW management in order to make WTE a success for India.

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Keywords: Municipal Solid Waste (MSW); Techno-Economic feasibility; Waste-to-Energy (WTE)

1. Introduction

Municipal Solid Waste (MSW) in India is firstly defined as the non-industrial, non-hazardous solid waste. As per the Municipal Solid Wastes (Management and Handling) Rules, 2000, “Land-filling shall...
be restricted to non-biodegradable, inert waste and other waste that are not suitable either for recycling or for biological processing”. This is factual in an emerging economy like India because of two important reasons: (a) Unavailability of land for disposal of MSW due to rapid growing population; and (b) Disorganized way of MSW disposal which results into generation of greenhouse gases (mainly methane). Since energy is the key for any sustainable economic development, India is losing prospective organic resource by way of improper MSW disposal. It is therefore necessary to harness the locked energy resource from the organic fraction of MSW. Adoption of environment-friendly waste-to-energy (WTE) technologies is one such effective alternative which will help in reducing the space required and will allow treatment and processing of wastes before their disposal.

The Indian municipal solid waste to energy market could be growing at a compound annual growth rate of 9.7% by 2013, according to a report by market analysts Frost and Sullivan (Indian WTE market 2011). Hence there is a need to find out which is the appropriate technology/technologies to be used and how the calorific value content of the fuel varies with from the city source that it originates.

Some of the reasons why the MSW to energy route makes a lot of sense in India are due to the fact that there are huge volume reductions (80-90%) that can be achieved, the consumption of the waste can happen on a daily basis, all the processes are pathogen free, various technologies can be used for different types or MSW, these WTE technologies are capable to treat non-putreciable organic matters such as wood, rubber, plastic, etc, and finally there is a ready market for energy which makes WTE from MSW commercially viable (Pillai, 2005).

2. Methodology

Data pertaining to the physical and chemical composition of the MSW has been compiled for 75 cities from various renowned databases. An attempt has been made to establish a relation between the Calorific Value and the biodegradable and paper fractions of the MSW generated in various cities. The cities have been classified on the basis of population, i.e. cities having a population of over 20,00,000 are classified as Tier 1 cities, between 5,00,000 to 20,00,000 as Tier 2 cities, between 1,00,000 to 5,00,000 as Tier 3 cities and less than 1,00,000 as Tier 4 cities. Also, the state wise potential of MSW to Energy has been calculated using values of various MSW to WTE technologies taken from literature reviews of several papers. Using the projected population figures (Census) for the years 2011, 2015 & 2020 along with the scenarios stating which types of technologies could be used for waste generation to energy conversion as proposed by the authors, the projected MSW to Waste potential for India for the given years has been calculated.

3. MSW to energy technologies

3.1. Energy recovery potential from various technologies

3.1.1. Biomethanation / Anaerobic Digestion (AD)

In biomethanation, organic biodegradable fraction is decomposed (enzymatically) by microbial action and this method is very useful for wastes containing high percentage of organic biodegradable matter (>35%) and high level of moisture (>45%) along with C/N ratio of 20-30%. The power produced from MSW by biomethanation method can be determined by using mathematical relationship given below in equation 1 (Rao et al 2000):

Net Power Generation Potential (kW) = P x Q

(1)
Where, \[ P = X \times Y \times Z \times L \times W_1 \times 10^3 \] (2)

\[ Q = W_2 \times CV \times h \] (3)

\( X = \) Biogas produced (m\(^3\) per kg of volatile solids per day)
\( Y = \) Digester efficiency (%)
\( Z = \) Total organic fraction (%)
\( L = \) Organic biodegradable fraction (%)
\( W_1 = \) Total Waste generated everyday (tones)
\( h = \) Conversion efficiency (%)
\( CV = \) Calorific Value of MSW (kcal/m\(^3\))

Operating parameters shown in Table 1 are required for the determination of the power generation potential of the MSW. The average of values of these parameters reported in the literature by various researchers have been compiled in this table and the power generation potential has been calculated for various operating conditions using equations (1), (2)& (3) (Rao et al 2000).

Table 1: Power Generation Potential of MSW (for one ton) with given range of operating parameters (Rao et al 2000)

| Sr. No | X   | Y   | Z   | L   | CV  | h   | POWER   |
|--------|-----|-----|-----|-----|-----|-----|---------|
| Minimum| 0.2 | 45% | 40% | 35% | 3,500| 25% | 5.34 kW |
| Maximum| 0.8 | 70% | 60% | 60% | 5,000| 35% | 17.09 kW |

In general, 100 tonnes of raw MSW with 40-60% organic matter can generate about 0.534-1.71 MW power depending on the waste characteristics.

3.1.2. Incineration based technologies:

The various Incineration based technologies can be broadly classified as Mass Burn/RDF incineration technology, Gasification technology, pyrolysis technology and plasma arc gasification technology. The first three mentioned have been around for quite some time and are in an evolved state of employment in various locations in Europe and the U.S. Plasma arc gasification technology is a revolutionary new WTE technology that can generate energy from MSW and is in its pilot stage of development. [Plasma arc gasification is a high-temperature pyrolysis process whereby the organics of waste solids (carbon-based materials) are converted into syngas and inorganic materials and minerals of the waste solids produce a rock like glassy by-product called vitrified slag. (Gary.C.Young 2010)]

The thermal efficiency of each thermal process technology was determined by URS Corporation U.S, which reported the net energy production of electricity to the Grid per ton of MSW (see Table 2)

Table 2: Thermal Process Technology and Net Energy to Grid

| Type of Thermal Process Technology | Net Energy Production to Grid (calculated) | Net Energy Capacity to Grid (calculated) |
|----------------------------------|------------------------------------------|----------------------------------------|
| Mass burn (Incineration)         | 544 kWh/ton MSW                          | 2.267 MW/100 ton MSW                   |
| Pyrolysis                        | 571 kWh/ton MSW                          | 2.379 MW/100 ton MSW                   |
| Conventional Gasification        | 685 kWh/ton MSW                          | 2.854 MW/100 ton MSW                   |
| Plasma Arc Gasification          | 816 kWh/ton MSW                          | 3.40 MW/100 ton MSW                    |

3.2. Comparison of MSW to energy Technologies-Scenario for India:

From the data presented in Table 3 we can see that it is there is sufficient energy generation potential per 100Tons Per Day (TPD) of MSW as calculated by Lal& Reddy (Lal & Reddy 2009). This helps us
have a more meaningful comparison as to which technology is more suitable for recovering energy from
the MSW generated in India. It is also evident that the preferred technology at the present moment in
India would be Mass Burn Incineration where there is no need for source separated waste at all and which
also has a low capital cost requirement per MW of energy generation followed by Biомethanation.

Table 3. Comparison of WTE technologies in India (Lal & Reddy 2009; *MSW Manual 2000; **Matt Crowe et al
2002)

| Description                              | Plasma Gas Vitrification | Biомethanation                     | Mass Incineration | Gasification / Pyrolysis |
|------------------------------------------|--------------------------|------------------------------------|-------------------|--------------------------|
| MSW Treatment Capacity (TPD)             | 500                      | 300                                | 500               | 500                      |
| Quantity of Final MSW treated (TPD)      | 165                      | 300                                | 160               | 500                      |
| Land Requirement (acres)                 | 24.71 for 22.7 MW High   | -                                  | 9-10 / MW Moderate | 10 / MW Moderate         |
| Level of Automation                      | 22.7MW (4.5)             | 5.6MW (1.9)                        | 6MW (1.2)         | 11MW (2)                 |
| Power Generation Capacity (MW/100TPD)    |                          |                                    |                   |                          |
| PLF %                                    | 90%                      | -                                  | 70%               | 90%                      |
| Capital Cost in crores (million Rs/MW)   | 187 (82.3)               | 76 (135.71)                        | 25 (141.6)        | 11 (10)                  |
| Cost of Power Generation (Rs/kWh)        | 4.11                     | -                                  | 2.6 – 2.8         | -                        |
| Land Required for 300TPD plant*          | 2 hectares               | 0.8 hectares                       | 0.8 hectares      | 0.8 hectares             |
| Waste Acceptance**                       | All waste is acceptable  | Source separated waste only        | All Waste since air cleaning technology is good | Source separated dry waste only unless combined with better cleaning technology |
| Water Requirement**                      | High                     | High                               | Medium-High       | Medium-High              |

4. Global tariff comparison for energy generation from MSW:

As seen in Table 4 below, the tariff, subsidies, taxes and capital costs for MSW to Energy Plants for
several European Union Countries has been listed. The conversion rate used for calculation purposes has
been 1Euro = 65.53 INR (as of 10 June 2011).

In comparison to the EU, M/S Solapur Bioenergy Systems Pvt. Ltd. (SBSPL) in Solapur, Maharashtra
had a tariff of Rs.4.88/unit calculated for their Biомethanation plant (MERC 2009) which is comparable
to the average tariff of several EU countries as shown in Table 4.

5. MSW characteristics of selected Indian cities

Tables 5 to 8 give the physical & chemical composition of 75 Indian cities. The Sources of data for this
database are as listed: [NSWAI (National Solid Waste Association of India) & NEERI 1996
database], (* Data taken from CPCB Report (1999) - Characteristics of MSW by Metro Cities), (#:Data
taken from combined NEERI & CPCB Report (2004-05) - Characteristics of MSW by Metro Cities].

The variation in values seen on a city to city basis is very large. On sorting all the cities based on ascending values of Calorific value, Table 9 has been prepared to find if there is a correlation between calorific value of the waste and the value of biodegradable fraction and paper content in the waste
Table 4. Tariff, Subsidies and investment cost for WTE plants in 14 EU countries & the US (prices in INR)

| Country | Market Price (Rs/kWh) | Subsidy or Market Instrument | Price including subsidy or market instrument (Rs/kWh) | Investment for Flue Gas Treatment Cost (% of Total Cost) | Avg Investment Cost (Rs Cr/MW) |
|---------|-----------------------|-----------------------------|-----------------------------------------------------|-------------------------------------------------------|-------------------------------|
| Belgium** | 3.604 | Green Certificate – Rs.3931 per certificate | 4.58 to 8.51 | 25 | 34.73 |
| Denmark | 2.883 | Depends on Spot price or market price | Subsidy disappears when market price exceeds Rs.2.75 | 20 | - |
| Finland | 3.735 | NA | NA | 10 – 20 | 8.51 |
| France | 3.227 | Feed-in-tariff | 3.27 + 20 paise (Energy Efficiency Premium) | NA | NA |
| Germany | 5.242 | NA | NA | NA | NA |
| Hungary* | 3.604 | Feed-in-tariff | 5.24 | NA | NA |
| Italy | 5.898 | Green Certificate | NA | NA | 7.86 |
| Netherlands* *** | 9.173 | Subsidy | NA | 50 | NA |

Country | Market Price (Rs/kWh) | Subsidy or Market Instrument | Price including subsidy or market instrument (Rs/kWh) | Investment for Flue Gas Treatment Cost (% of Total Cost) | Avg Investment Cost (Rs Cr/MW) |
|---------|-----------------------|-----------------------------|-----------------------------------------------------|-------------------------------------------------------|-------------------------------|
| Portugal*** | 4.16 | Feed in Tariff | 4.914/kWh – average value of all plants operating | NA | NA |
| Spain | 3.512 | NA | NA | 15 | NA |
| Sweden | 3.047 | Green Certificate | 1.96 | NA | NA |

Note: Sources of data taken are as follows – Confederation of European Waste to Energy Plants, * Hungary Country Report on Electricity produced from RES, **Belgium Country Report on Electricity produced from RES, *** Portugal Country Report on Electricity produced from RES, **** Netherlands Country Report on Electricity produced from RES, Data compiled by authors

Table 5. Quantity of MSW generated from Tier 1 cities along with physical & chemical characteristics

| Sr. No | City/Town | Total MSW (T/day) | Physical Characteristics (in % composition) | Calorific Value (Kcal/kg) | C/N Ratio | Moisture % |
|--------|------------|------------------|-----------------------------------------------|--------------------------|-----------|-----------|
|        |            |                  | Biodegradable/Compostable | Recyclables | Inert, ash, debris |
| 1      | Hyderabad*# | 2187            | 40                             | 10                      | 50        | 1969      | 25.9      | 46 |
| 2      | Delhi*#    | 5922            | 31.78                          | 16                      | 51.82     | 1802      | 34.87     | 49 |
| 3      | Ahmedabad*# | 1683            | 40                             | 10                      | 50        | 1180      | 29.64     | 32 |
| 4      | Surat*#    | 1000            | 40                             | 15                      | 45        | 990       | 42.16     | 51 |
| 5      | Bangalore*# | 1669            | 45                             | 28                      | 27        | 2386      | 35.12     | 55 |
| 6      | Mumbai*#   | 5320            | 40                             | 16                      | 44        | 1786      | 39.04     | 54 |
| 7      | Nagpur#    | 504             | 30.4                           | 16                      | 53.4      | 2632      | 26.37     | 41 |
| 8      | Pune*#     | 1175            | 55                             | 20                      | 25        | 2531      | 35.54     | 63 |
| 9      | Jaipur#    | 904             | 42                             | 11                      | 47        | 834       | 43.29     | 21 |
| 10     | Chennai#   | 3036            | 49.06                          | 14                      | 36.9      | 2594      | 29.25     | 47 |
| 11     | Lucknow*#  | 1010            | 40                             | 11                      | 49        | 1557      | 21.41     | 60 |
| 12     | Kanpur*#   | 1100            | 40                             | 13                      | 47.5      | 1571      | 27.64     | 46 |
| 13     | Kolkata*#  | 2653            | 40                             | 25                      | 35        | 1201      | 31.81     | 46 |

Average Values | 2166 | 41 | 16 | 43 | 1772 | 32 | 47 |
Table 6. Quantity of MSW generated from Tier 2 cities along with physical & chemical characteristics

| Sr. No | City/Town  | Total MSW (T/day) | Physical Characteristics (in % composition) | Calorific Value (Kcal/kg) | C/N Ratio | Moisture % |
|--------|------------|------------------|---------------------------------------------|---------------------------|-----------|------------|
|        |            |                  | Biodegradable/Compostable | Recyclables | Inert, ash, debris |                |            |
| 14     | Vijaywada# | 374              | 59.43                        | 17           | 23.17                  | 1910          | 33.9       | 46        |
| 15     | Vishakapatnam*# | 584       | 35                            | 15           | 50                      | 1602          | 41.7       | 53        |
| 16     | Guwahati#   | 166              | 53.69                        | 23           | 23.03                  | 1519          | 17.71      | 61        |
| 17     | Patna*#     | 511              | 45                            | 20           | 35                     | 819           | 18.62      | 36        |
| 18     | Raipur#     | 184              | 51.4                         | 16           | 32.29                  | 1273          | 22.35      | 29        |
| 19     | Rajkot#     | 207              | 41.5                         | 11           | 47.3                   | 687           | 52.56      | 17        |
| 20     | Vadodara*#  | 357              | 40                            | 11           | 49                     | 1781          | 40.34      | 25        |
| 21     | Faridabad#  | 448              | 42.06                        | 23           | 34.63                  | 1319          | 18.58      | 34        |
| 22     | Srinagar#   | 428              | 61.77                        | 18           | 20.47                  | 1264          | 22.46      | 61        |
| 23     | Ranchi#     | 208              | 51.49                        | 10           | 38.65                  | 1060          | 20.23      | 49        |
| 24     | Jamshedpur# | 338              | 43.36                        | 16           | 40.95                  | 1099          | 19.69      | 48        |
| 25     | Mangalore   | 220              | 60                            | 0            | 40                      | NA            | NA         | NA        |
| 26     | Kochi#      | 400              | 57.34                        | 19           | 23.3                   | 591           | 18.22      | 50        |
| 27     | Bhopal*#    | 574              | 45                            | 20           | 35                     | 1421          | 21.58      | 43        |
| 28     | Jabalpur#   | 216              | 58.07                        | 17           | 25.32                  | 2051          | 28.22      | 35        |
| 29     | Indore*#    | 557              | 43                            | 8            | 49                     | 1437          | 29.3       | 31        |
| 30     | Aurangabad  | 300              | 60                            | 22           | 18                     | NA            | NA         | NA        |
| 31     | Bhiwandi    | 320              | 40                            | 23           | 37.39                  | 626.8         | NA         | NA        |
| 32     | Nashik#     | 200              | 42.62                        | 31           | 26.28                  | 2762          | 37.2       | 62        |
| 33     | Navi Mumbai | 520              | 40                            | 44           | 15.95                  | NA            | NA         | NA        |
| 34     | Pimpri      | 310              | 32                            | 28           | 40                     | NA            | NA         | NA        |
| 35     | Solapur     | 350              | 78                            | 6            | 16.5                   | NA            | NA         | NA        |
| 36     | Bhubaneswar#| 234              | 49.81                        | 13           | 37.5                   | 742           | 20.57      | 59        |
| 37     | Amritsar#   | 438              | 65.02                        | 14           | 20.98                  | 1836          | 30.69      | 61        |
| 38     | Ludhiana*#  | 735              | 40                            | 11           | 49                     | 2559          | 52.17      | 65        |
| 39     | Chandigarh# | 326              | 57.18                        | 11           | 31.91                  | 1408          | 20.52      | 64        |
| 40     | Coimbatore*#| 530              | 35                            | 15           | 50                     | 2381          | 45.83      | 54        |
| 41     | Madurai*#   | 275              | 45                            | 9            | 46                     | 1813          | 32.69      | 46        |
| 42     | Tiruvanantapuram# | 171 | 72.96                        | 14           | 12.68                  | 2378          | 35.19      | 60        |
| 43     | Agra#       | 654              | 46.38                        | 16           | 37.62                  | 520           | 21.56      | 28        |
| 44     | Allahabad#  | 509              | 35.49                        | 19           | 45.29                  | 1180          | 19         | 18        |
| 45     | Meerut#     | 490              | 54.54                        | 11           | 34.5                   | 1089          | 19.24      | 32        |
| 46     | Varanasi*#  | 425              | 48                            | 17           | 35                     | 804           | 19.4       | 44        |
|        | Average Values | 381    | 49                            | 17           | 34                     | 1426          | 28         | 45        |
Table 7. Quantity of MSW generated from Tier 3 cities along with physical & chemical characteristics

| Sr. No | City/Town     | Total MSW (T/day) | Physical Characteristics (in % composition) | Calorific Value (Kcal/kg) | C/N Ratio | Moisture % |
|--------|---------------|-------------------|--------------------------------------------|---------------------------|-----------|------------|
|        |               |                   | Biodegradable/ Compostable Recyclables Inert, ash, debris |                           |           |            |
| 47     | Gandhinagar#  | 44                | 34.3                                       | 13                        | 52.5      | 698        | 36.05      | 24         |
| 48     | Shimla#       | 39                | 43.02                                      | 37                        | 20.34     | 2572       | 23.76      | 60         |
| 49     | Jammu#        | 215               | 51.51                                      | 21                        | 27.41     | 1782       | 26.79      | 40         |
| 50     | Dhanbad#      | 77                | 46.93                                      | 16                        | 36.91     | 591        | 18.22      | 50         |
| 51     | Achalpur      | 25                | 42.3                                       | 5                         | 52.49     | NA         | NA         | NA         |
| 52     | Akola         | 120               | 29                                         | 57                        | 14        | NA         | NA         | NA         |
| 53     | Barsi         | 30                | 63                                         | 6                         | 31        | NA         | NA         | NA         |
| 54     | Kolhapur      | 165               | 45                                         | 16                        | 39.5      | NA         | NA         | NA         |
| 55     | Malegaon      | 65                | 40                                         | 36                        | 24        | NA         | NA         | NA         |
| 56     | Navghar       | 35                | 32.1                                       | 11                        | 56.8      | NA         | NA         | NA         |
| 57     | Ulhasnagar    | 236               | 45                                         | 11                        | 43.7      | NA         | NA         | NA         |
| 58     | Yavatmal      | 24                | 49.23                                      | 6                         | 45.07     | NA         | NA         | NA         |
| 59     | Imphal#       | 43                | 60                                         | 19                        | 21.49     | 3766       | 22.34      | 40         |
| 60     | Shillong#     | 45                | 62.54                                      | 17                        | 20.19     | 2736       | 28.86      | 63         |
| 61     | Aizwal#       | 57                | 54.24                                      | 21                        | 24.79     | 3766       | 27.45      | 43         |
| 62     | Pondicherry#  | 130               | 49.96                                      | 24                        | 25.75     | 1846       | 36.86      | 54         |
| 63     | Ajmer         | 131.16            | 48.18                                      | 7                         | 44.495    | NA         | NA         | NA         |
| 64     | Agartala#     | 77                | 58.57                                      | 14                        | 27.75     | 2427       | 30.02      | 60         |
| 65     | Dehradun#     | 131               | 51.37                                      | 20                        | 29.05     | 2445       | 25.9       | 60         |
| 66     | Asansol#      | 207               | 50.33                                      | 14                        | 35.46     | 1156       | 14.08      | 54         |
|        | Average Values| 95                | 48                                         | 19                        | 34        | 2162       | 26         | 50         |

Table 8. Quantity of MSW generated from Tier 4 cities along with physical & chemical characteristics

| Sr. No | City/Town     | Total MSW (T/day) | Physical Characteristics (in % composition) | Calorific Value (Kcal/kg) | C/N Ratio | Moisture % |
|--------|---------------|-------------------|--------------------------------------------|---------------------------|-----------|------------|
|        |               |                   | Biodegradable/ Compostable Recyclables Inert, ash, debris |                           |           |            |
| 67     | Port Blair#   | 76                | 48.25                                      | 28                        | 24.09     | 1474       | 35.88      | 63         |
| 68     | Itanagar#     | 12                | 52.02                                      | 21                        | 27.42     | 3414       | 17.68      | 50         |
| 69     | Silvassa#     | 16                | 71.67                                      | 14                        | 14.36     | 1281       | 35.24      | 42         |
| 70     | Daman#        | 15                | 29.6                                       | 22                        | 48.4      | 2588       | 22.34      | 53         |
| 71     | Panjin#       | 32                | 61.75                                      | 17                        | 20.81     | 2211       | 23.77      | 47         |
| 72     | Kavaratti#    | 3                 | 46.01                                      | 27                        | 26.79     | 2242       | 18.04      | 25         |
| 73     | Alibaug       | 50.55             | 50.7                                       | 18                        | 31.78     | NA         | NA         | NA         |
| 74     | Kohima#       | 13                | 57.48                                      | 23                        | 19.85     | 2844       | 30.87      | 65         |
| 75     | Gangtok#      | 13                | 46.52                                      | 16                        | 37        | 1234       | 25.61      | 44         |
It can be seen from the data presented in the tables 5-8 that the average biodegradable matter varies from 41-52% for all types of cities, but there is huge variation in data seen on a city to city basis. Similarly the average calorific value for Tier 3 & 4 cities is seen to be higher than Tier 1 & Tier 2 cities.

Table 9. Calorific Value vs Average Biodegradable fraction & Paper content (calculated by author)

| Range of Calorific Values (kcal/kg) | 500-999 | 1000-1499 | 1500-1999 | 2000-2499 | 2500-2999 | >3000 |
|------------------------------------|---------|-----------|-----------|-----------|-----------|-------|
| Average Value of Biodegradable Fraction (as % of total waste) | 44.66   | 48.84     | 45.49     | 53.59     | 45.52     | 51.57 |
| Average Value of Paper Content (as % of total waste) | 10.18   | 13.45     | 11.13     | 15.23     | 13.23     | 17.76 |

From the graph shown in Fig 1, we can see that there is some relation between the calorific values of the MSW waste generated in the cities and the amount of biodegradable fraction and paper content in the waste. This could prove to be decisive in choosing the right technology for MSW to energy generation along with the moisture content of the waste. However detailed city wise analysis has to be carried out.

5.1. State wise calculation of MSW to energy generation potential in India

The basis of calculating the WTE generation potential of each state is done on the basis of projected MSW generation figures given in Table 11 and the energy generation potential for the technology mix in Table 10. For Biomethanation the energy generation potential is 1.9 MW/100TPD, for Mass Burn Incineration 1.2MW/100TPD, for RDF plants 3MW/100TPD, for Gasification and Pyrolysis plants it is 2MW/100TPD and for Plasma Arc Gasification it is 4.5 MW/100TPD. The projections made for waste generation have been done on the basis of the waste generated per person per day as of 2001 and the census projections for 2011-20 given by the census of India website (Census)

Table 10. Combination of Technologies predicted to be used for waste to energy generation

Scenario for 2011 & 2015 - 50% Bio + 20% Mass Burn + 20% RDF + 5% from Gasification + 5% Pyrolysis
Scenario for 2020 - 25% Mass Burn + 35% Bio + 20% RDF + 8% Gasification + 7% Pyrolysis + 5% Plasma Arc Gasification

Table 11. State wise MSW generation & Energy Generation from 2011(p) to 2020(p) (NEERI 1996; NSWAI; Census website 2011)

| State/Union Territory | Total MSW(T/day) (2011) p | Total MSW(T/day) (2015) p | Total MSW(T/day) (2020) p | Energy Potential 2011 (p) (MW) | Energy Potential 2015 (p) (MW) | Energy Potential 2020 (p) (MW) |
|------------------------|---------------------------|---------------------------|---------------------------|-------------------------------|-------------------------------|-------------------------------|
| Maharashtra            | 22434.35                  | 23627.56                  | 25033.24                  | 446.44                        | 470.19                        | 523.19                        |
| Uttar Pradesh          | 13651.39                  | 14597.03                  | 15736.25                  | 271.66                        | 290.48                        | 328.89                        |
| West Bengal            | 12069.24                  | 12504.27                  | 13031.28                  | 240.18                        | 248.84                        | 272.35                        |
| Tamil Nadu             | 9501.77                   | 9725.21                   | 9948.80                   | 189.09                        | 193.53                        | 207.93                        |
| Andhra Pradesh         | 9998.97                   | 10344.37                  | 10732.24                  | 198.98                        | 205.85                        | 224.30                        |
| Karnataka              | 8296.02                   | 8628.03                   | 8992.86                   | 165.09                        | 171.70                        | 187.95                        |
| Delhi                  | 11873.06                  | 13304.83                  | 15326.68                  | 236.27                        | 264.77                        | 320.33                        |
| Gujarat                | 7930.91                   | 8342.24                   | 8805.97                   | 157.83                        | 166.01                        | 184.04                        |
| Madhya Pradesh         | 4633.63                   | 4925.32                   | 5271.18                   | 92.21                         | 98.01                         | 110.17                        |
| Punjab                 | 4645.00                   | 4841.02                   | 5051.64                   | 92.44                         | 96.34                         | 105.58                        |
| Rajasthan              | 4671.89                   | 4957.24                   | 5286.89                   | 92.97                         | 98.65                         | 110.50                        |
| Haryana                | 2184.78                   | 2325.63                   | 2490.78                   | 43.48                         | 46.28                         | 52.06                         |
| Bihar                  | 1956.78                   | 2057.14                   | 2170.08                   | 38.94                         | 40.94                         | 45.35                         |
| Kerela                 | 1689.02                   | 1733.49                   | 1779.28                   | 33.61                         | 34.50                         | 37.19                         |
| Chhattisgarh           | 1077.02                   | 1134.61                   | 1201.69                   | 21.43                         | 22.58                         | 25.12                         |
| Jharkhand              | 942.55                    | 994.39                    | 1056.53                   | 18.76                         | 19.79                         | 22.08                         |
| Orissa                 | 839.25                    | 867.83                    | 901.28                    | 16.70                         | 17.27                         | 18.84                         |
| Jammu & Kashmir        | 746.24                    | 782.60                    | 820.75                    | 14.85                         | 15.57                         | 17.15                         |
| Uttarakhand            | 424.00                    | 447.71                    | 474.58                    | 8.44                          | 8.91                          | 9.92                          |
| Assam                  | 341.73                    | 358.51                    | 378.49                    | 6.80                          | 7.13                          | 7.91                          |
| Goa                    | 221.92                    | 245.28                    | 272.54                    | 4.42                          | 4.88                          | 5.70                          |
| Pondicherry            | 185.66                    | 217.02                    | 259.47                    | 3.69                          | 4.32                          | 5.42                          |
| Tripura                | 137.90                    | 144.31                    | 151.90                    | 2.74                          | 2.87                          | 3.17                          |
| Andaman & Nicobar Islands | 105.46               | 115.92                    | 128.30                    | 2.10                          | 2.31                          | 2.68                          |
| Himachal Pradesh       | 71.53                     | 74.10                     | 76.98                     | 1.42                          | 1.47                          | 1.61                          |
| Mizoram                | 64.37                     | 67.39                     | 70.91                     | 1.28                          | 1.34                          | 1.48                          |
| Manipur                | 61.03                     | 63.87                     | 67.23                     | 1.21                          | 1.27                          | 1.41                          |
| Meghalaya              | 54.25                     | 56.78                     | 59.76                     | 1.08                          | 1.13                          | 1.25                          |
| Dadar & Nagar Havelli  | 25.75                     | 30.11                     | 35.35                     | 0.51                          | 0.60                          | 0.74                          |
| Daman & Diu            | 25.63                     | 30.09                     | 37.12                     | 0.51                          | 0.60                          | 0.78                          |
| Nagaland               | 14.52                     | 15.38                     | 16.18                     | 0.29                          | 0.31                          | 0.34                          |
| Sikkim                 | 14.71                     | 15.38                     | 16.17                     | 0.29                          | 0.31                          | 0.34                          |
6. Conclusion:

From the data presented in the above paper, we have seen that there is potential to generate close to over 3000MW of energy from MSW in India by 2020. There is also an indication that there is some correlation between the calorific value of the MSW and the paper and biodegradable fraction content present in the waste. This shows that the presence of these two fractions have a direct impact on the calorific value of the waste and a more detailed analysis on a city wise basis will enable generators who are willing to enter this business, to make more informed choices regarding the selection of appropriate WTE technologies. The country also urgently needs a separate policy that lays down the roadmap for WTE from MSW and there has to be a much stricter enforcement of existing MSW segregation rules.

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