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Waste to Energy – Technical, Financial & Economical Analysis for Sustainable Solutions

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ABSTRACT *Waste Management has become a major problem in developing countries. Changing lifestyle, increasing population, urbanization & smaller open lands in the metro cities pose big challenges. Although the*

Keywords: *Waste Management, Clean India Mission, Swachh Bharat Mission, Waste Management Pyramid, Financial viability*

I. INTRODUCTION

There have been several efforts on the part of the policy makers in making the cities clean and green by adopting sustainable technologies including for waste management. A distinct effort towards making the urban localities clean and sustainable, the Govt. of India launched the Swachh Bharat Mission (Clean India Mission) in 2014, covering 4041 statutory towns, to clean the streets, roads and infrastructure of the country. The Clean India Mission(CIM) recommends preparation of 'city sanitation plan' and 'state sanitation strategy' and highlights the importance of few of the project that are finically unviable as on date. Such as improvisation of the waste collected from the door steps, waste form the sanitation & C&D waste are the few major waste sources that need to be target for the Clean India Mission"2019".

Urban India generates 188,500 ton per day (68.8 million ton per year[1]) of municipal solid waste (MSW) Collection is the basic part that cover the one side of the coin other side is the disposal in most effective environmental friendly manner. Most metropolitan cities have the fairly good collection system in the city but the waste goes to the dump site where the pile of heaps is piling up. As per the survey Delhi alone generate the more that 8000 MT of waste per day & same has being growing at the higher pace due the change in the lifestyle of the society. Same is adding the stress on the land. Waste landfills in the India are highly un-organized & don't abide the international stringent norms. Thus same is stressing the environment too. Waste in these land fill over the time generates the methane & leachate as two most deadly substances. Methane is having

[1]http://swmindia.blogspot.in/2012/01/municipal-solid-waste-msw-generation-in.html

the almost 100 times higher global warming potential than carbon dioxide. Leachate on other hand is highly carcinogenic – if not treated will lead to the numerous of the diseases, as landfills are not monitored this has tendency to seep in the ground water bed that can led to the ecological balance.

II. CLEAN INDIA MISSION

There have been several efforts and initiatives on the part of the policy makers in India for making the cities clean and green by adopting sustainable technologies including that of waste management. Adistinct effort towards making the urban localities clean and sustainable, the Government of India launched the Clean India Mission –Urban (CIM-U) in 2014, covering 4,041 statutory towns, to clean the streets and roads of the country. There is need to bring about a paradigm shift in the approach to promote WtE project development in India and help in meeting the CIM's goal to make India litter free and open-defecation-free by 2019- the 150thbirth anniversary year of Mahatma Gandhi.

The Mission aims at improving cleanliness covering about 1.04 Crore households, 5.10 Lakh communities and public toilets across the country. The modern and scientific solid waste management is estimated to cost over Rs. 62,000 crore which will be shared between Centre and State/ULBs in the ratio of 75:25 in all the states except the North Eastern Region where the ratio will be 90:10.

The CIM-U recommends preparation of 'city sanitation plan' and 'state sanitation strategy' and also highlights the need for taking necessary measures in wake of the few unviable projects that have been developed till date. These measures may include improvement in waste collection from doorsteps as well as waste from sanitation and construction & demolition (C&D) waste.

III. INITIATIVE BY GOI FOR MSW

MSW, street waste and green waste can be disposed by i) Combusting after processing to generate power & ii) Gasification to generate fuel gases (Methane, CNG, Syngas) Both types of projects are highly capital intensive with somewhat lower internal rate of return (IRR). Thus, in order to cater to the problem of waste management, the government has allocated attractive financial benefits for setting up combustive as well as gasification projects. Government has created the Swachh Bharat Cess (SBC) under CIM to generate INR 10,000 Crs., which may increase year-on-year as per growth of service revenue, and will be used to provide financial grant to the projects. This will make the projects more attractive and will increase the interest of the promoters.

Govt. of India has released INR 100 Crs. fund for Delhi under CIM for promoting sanitation, promotion of collection facilities of household waste & promotion of projects to dispose the waste. Similarkinds of initiatives are being taken at the Central and state levels for promotion of solid waste management (SWM) projects.

IV. TECHNOLOGIES IN WTE

Emerging technologies [2] like incineration, gasification, pyrolysis, plasma gasification, thermal de-polymerization are being developed globally for achieving higher conversion efficiencies. Gasification, plasma gasification, fuel cell and pyrolysis are all non-combustible technologies [3][4][5]. There is little or no involvement of air in these processes as compared to incineration technologies in which combustion takes place in presence of excess of air

Electricity from waste: A great idea!

Incinerating waste generates lots of heat. Heat can be used to generate energy in the form of electricity. In this way, one can achieve the following:

1. Disposal of waste
2. Electricity generation.

Electricity generated from waste is also referred to as green electricity, just like electricity that comes from renewable sources like sun, wind, water, biogas or biomass. So, it is an intelligent move to make use of this smart, reliable and clean technology for this purpose. When the waste is incinerated, the heat is released, which is used to produce steam. The steam, thus generated, is used to drive a turbine, which is linked to an alternator to generate electricity. Approximately, 1 Lakh ton [6] of waste would generate enough electricity to power over 20,000 households all year round. Moreover, it cuts back on the fuel costs. If the same amount of energy is generated at a conventional power station, there would be a requirement of about 30,000 ton of coal or 18,000 ton of oil.

Limitation of incineration is the emissions, but there exist solutions to curb these emissions. However, all these solutions ultimately boil down to increasing the cost of the project. This calls for financial support from the

system so that the waste can be eliminated in most eco-friendly and sustainable manner.

Text Box 1. Electricity from waste

Non-thermal technologies such as anaerobic digestion, fermentation are also being developed and deployed in some countries, which are considered to be better options from the perspective of environmental pollution. However, among all the available technologies in WtE, incineration is still by far the most commonly used technology. In the low-oxygen environments, the production of dioxins and furans from waste can be significantly reduced when compared with incineration. In this case, the emissions potentially fall even below detection limits [7].

The cost for plants based on incineration technology is considerably high when compared to other technologies. The comparative cost of project based on different technologies is summarized in the following table [8].

TABLE 1.COMBUSTION TECHNOLGIES COMPARISION FOR MSW

Environmental Issues	**Comparative Performance**			**Remarks**
	Incineration	Pyrolysis	Plasma Arc	
Landfill	1	2	3	Incineration reduces the volume by about 80% compared to 95% in case of plasma-vitrified ash from plasma gasifier, which can be used productively
SPM	1	2	3	Plasma arc operates under vacuum condition and as such there would be zero emission
Acid gases	1	2	3	Plasma arc operates practically under zero oxygen condition
Dioxin, furan	1	2	3	Plasma arc operates at the highest temperature ensuring total destruction
Heavy metals	1	2	3	Gets vitrified in case of plasma system
GHG emission	1	2	3	Higher specific energy output for plasma

Note: 3 is best while 1 is worst

The emerging technologies, however, offer better financial return compared to incineration. Plasma gasification/fuel cell is financially the most attractive option among all, but since these technologies are still in nascent stages, incineration is the most preferred option as on date. [9]

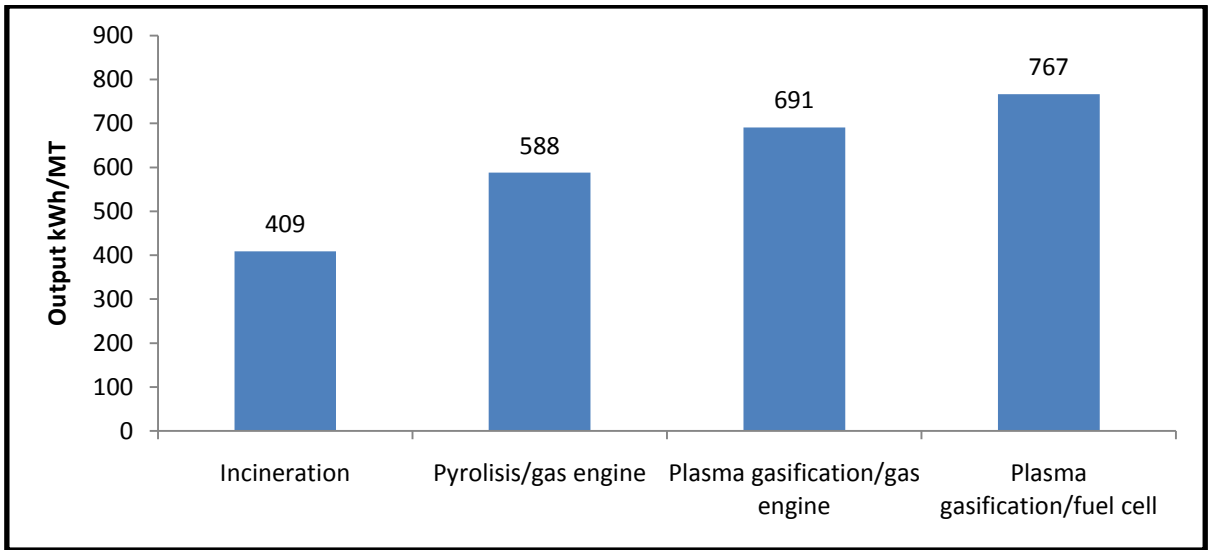

Fig. 1Power output by using different technologies

As per Table 1, Incineration affects environment less as compared to other technologies, however, the power generation potential is less in comparison. Environment policy is the top priority for a power plant, that's why incineration is the most suitable technology for combustion of MSW.

There would be requirement of different kinds of pre-processing facilities for different technologies depending upon the quality and quantity of waste. The normative pre-processing requirement for different technologies is mapped in the figure below.

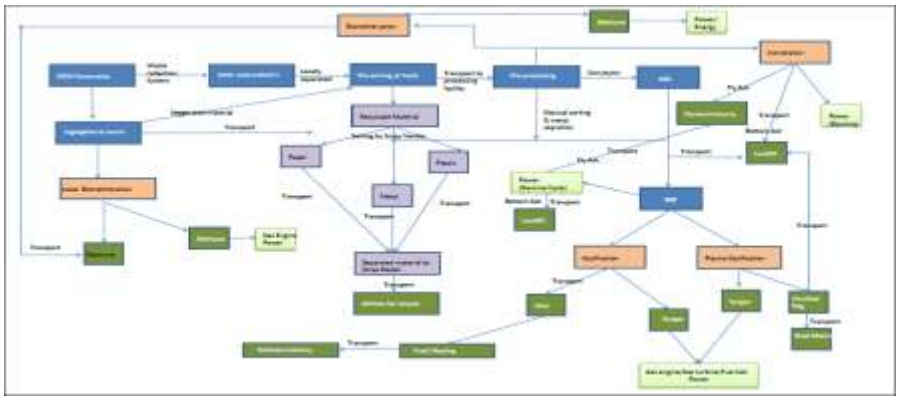

Fig. 2 Spectrum of present technologies & pre processing requirements [12] [13] [14]

Text Box 1: Plasma arc gasification

Plasma technology appears to be one of the most probative technologies for processing of waste in waste-to-energy plants and can be easily adapted to the treatment of various wastes (municipal solid wastes, heavy oil, used car tires, medical wastes …). Thermal gasification allows processing of all kinds of wastes (domiciliary and industrial wastes) by adjusting the energy input with the plasma, independent of the oxidizing agent ratio, the LHV and the moisture of the waste.

About the comparison of chemical efficiency of thermal versus auto-thermal gasification processes: (i) the values of cold gas efficiency (energy efficiency) are in the same order of magnitude, (ii) the main difference is on the net electrical efficiency of the overall process.

This value is based on the theoretical electrical conversion performances of the end-use devices which are strongly dependent of the tar content in the Syngas, key parameter for the performances of the overall process.

Waste Gasification by Thermal Plasma: A Review-FrédéricFabry et el, *MINES ParisTech (2013)*

V. WASTE CHARACTERISATION IN INDIA

Municipal solid waste (MSW) management is a major challenge in urban areas worldwide. Per capita generation of waste is increasing sharply with the economic development and changing lifestyle. Similarly, characteristics of wastes are changing dramatically. MSW management policies and practices are also changing with increasing emphasis on sorting and segregation of waste at sources.

Municipal Solid Waste: Urban India generates about 188,500 ton of municipal solid waste (MSW) per day (70 million ton per year [15]). MSW collection is the basic part in the waste management cycle, however, that covers only one side of the coin. The other side of the coin is the disposal of waste in the most effective environment friendly manner. Most metropolitan cities have a fairly good collection system, but the same could not be said about the disposal of the collected waste. The waste collected in the cities goes to the dump sites where it keeps on piling with every passing day.

Other major problems include lack of an adequate sanitation plan, and the same requires top priority. The metropolitan cities in India produce around 15,644 million liters per day (MLD) of waste, out of which only 8,040 MLD (51%) is treated in Sewage Treatment Plants. Nearly 80% of total sewage generated in urban India flows untreated into its rivers, lakes and ponds, thereby polluting the water sources.The below figure shows the growth of per capita waste generation, which mandates for urgent action to manage the present scenarios and to address the same in the future.

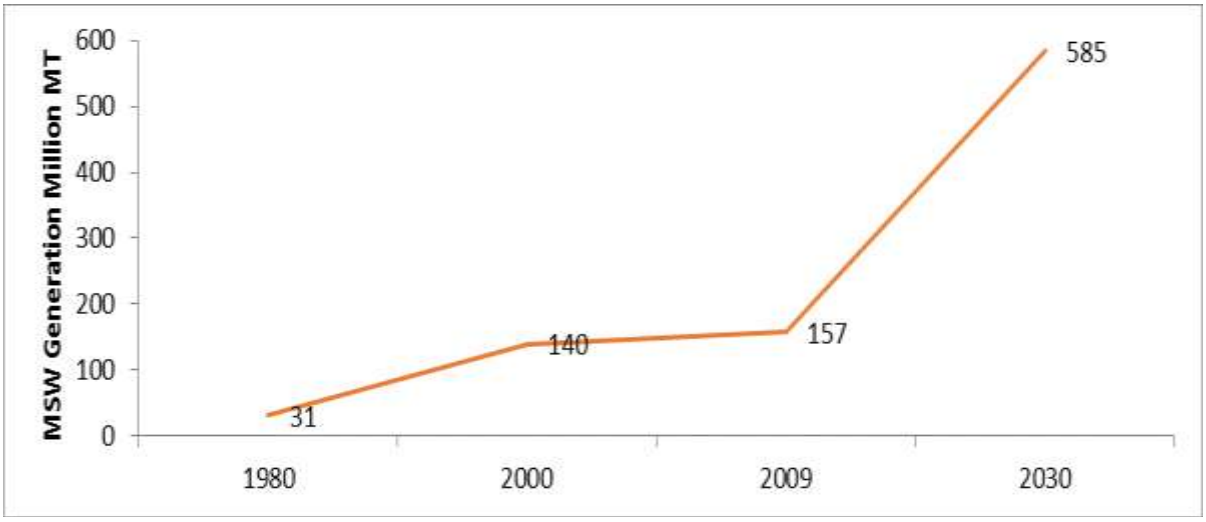

Fig. 3 Waste generation pattern in India

From Figure 4, it is clear that waste generation increased in India in the last decade which shows huge potential of power generation units and GHG reduction. Figure 5 shows MSW quality that is available in India which could be termed as worse when compared to other countries. This will affect generation potential, land requirement and environmental policies as per SWM Rule 2016.

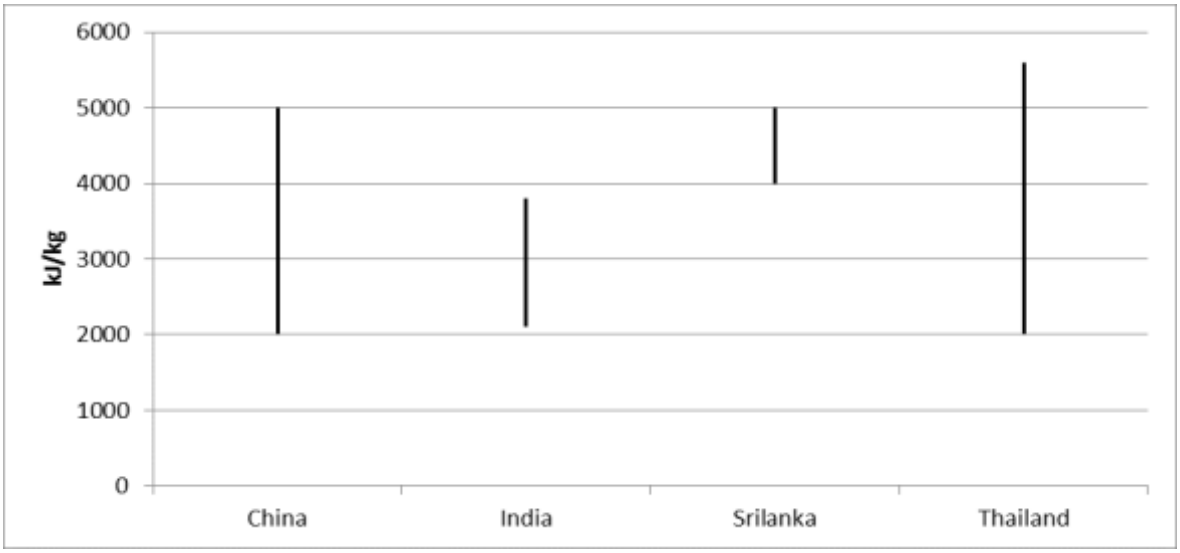

Fig. 4 Comparison of MSW quality country wise

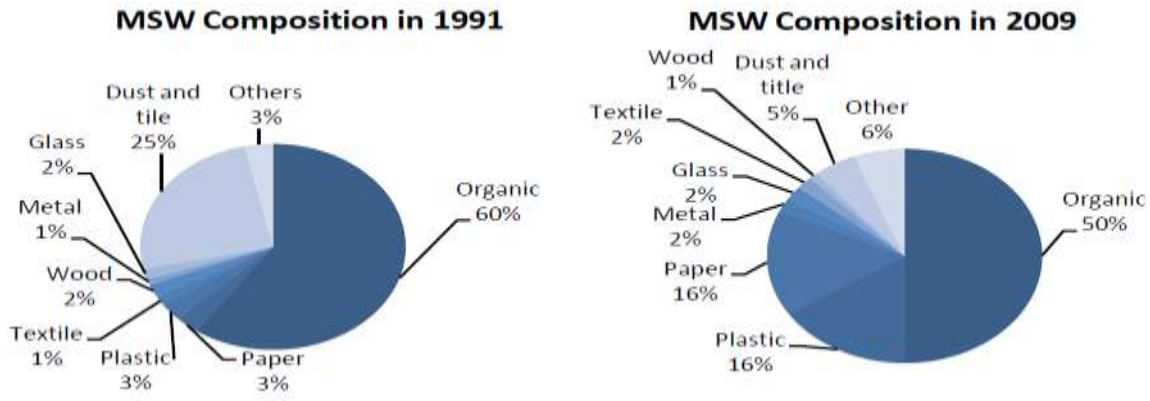

Fig. 5 Comparison of MSW composition

The above figure 5 shows that there is variation in composition of waste with changing times dependent on our life style. Plastic composition increased in MSW drastically which promotes formation of dioxin furans in flue gas. That will lead to difficulty inburning MSW having high plastic content. At the same time, organic content is reduced which directly represent GCV of MSW. So, power generation will be affected due to lesser quantity of organic content in MSW in later stages.

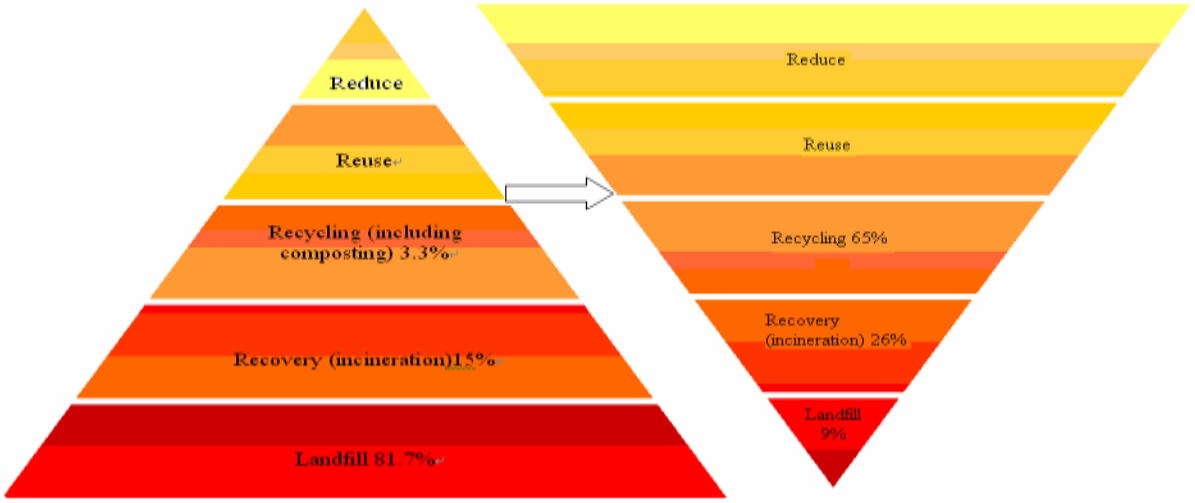

Fig. 6 Effect of 4'R

Typical proximate analysis of processed MSW suggested for different technologies has been depicted in the table below.

TABLE 3.TECHNOLOGIES SUGGESTED AS PER COMPOSITION OF MSW

Parameters	**Requirement (%)**			
	Bio-methanation	Incineration	Gasification	Plasma
Moisture	>50%	<50%	<20%	<10%
Volatile/organic	>40%	>40%	>40%	>40%
Fixed carbon	<15%	<15%	<15%	<15%
Total inert	<5%	<30%	<10%	<10%
GCV (kcal/kg)	NA	>1200	>2000	>2000
C/N ratio	25-30	NA	NA	NA

VI. ESTIMATION OF FUNDS

As there is requirement of funds to cater to any project, an initiative like Clean India Missionthat aims for a "Clean & hygiene India" would also require huge funds to achieve the mission targets. The government has incorporated 'Swachh Bharat Cess' (SBC) on services besides funding from the Ministry of Urban Development (MoUD), Government of India, and other agencies to promote this campaign. Present fund scenario is tabulated in the table below.

TABLE 4. ESTIMATION OF FUNDS

S.N.	**Particulars**	**UOM**	**Value**
1	Net service revenue	Bn INR	15,651[17]
2	Growth of revenue	%	27
3	Swachh Bharat Cess	%	0.5
4	Net revenue target	Bn INR	100
5	Grant MoUD	Bn INR**	564[18]
6	Total fund	Bn INR	664

*** Converted from UDS to INR at exchange rate: 1 USD = 60 INR*

VII. FUNDS AVAILABILITY

A total fund of INR 664 billion will be available during 2016-17 that will go to the economy as Swachh Bharat Fund. In the year 2016-2017, INR 100 Billion will be accrued from SBC besides grant of MoUD for the projects. CIM talks about subsidizing waste-to-energy projects through the central government grant in various forms such as viability gap funding (VGF) or providing generation based incentives (GBI) [19].

Fund in this mission is almost 4-5% of the GDP of India. The fund is expected to not only promote the projects for sanitation but will also fund the projects for eco-friendly solutions to dispose the waste. At the same time, a significant portion of this fund will be pumped into the market, which will boost the economy due to multiplier effect (Macroeconomic variable). As these projects will lead to development of machinery, plants, employment to the citizens, they will generate the potential income streams for the industries like metal, heavy machinery, etc. On the other hand, the waste-to-energy projects will reduce the stress on the landfills, thereby reducing health & environmental issues. Thus, the multiplier effect will lead to overall development of the society. A healthy &working society will ultimately lead to welfare of the nation.

VIII. WASTE TO ENERGY STATUS

There are several projects that have already been promoted by the promoters in India. However, barring one or two, almost all the other projects are not performing up to the expectations. Presently, operating waste to energy plants have low power sale tariff, thus lower revenue. A few of them have been declared as Non-Performing Assets (NPAs).Since this market is still in its nascent stage, the NPAs in this economic melt-down period has definitely not given positive signals for the WtE segment.

All the projects for municipal solid waste (MSW) to power, sewage treatment plant (STP), Construction & Demolition (C&D) require high investment with lower rate of returns. All the projects have been promoted by the promoters during the past 4-5 years, when the banking & financial sector globally was in stress. As these projects were executed for the first time in India, there were numerous problems that included technological issues, lack of financial support or lack of different funding schemes from the government. All these factors led to projects becoming financially unviable. Most of the projects ended in loss making ventures prompting the promoters to declare them NPAs. All these created a negative perception about the WtE industry.

Financing has become a major challenge for the upcoming projects, as many financial institutions & banks are reluctant in financing these projects or are not having attractive financing measures to promote the promoter's interest.
Text Box 2. Financing of the project

Presently, there are consultants like DESL [20] that have delivered the best design solutions taking into account the technological requirements in the Indian context. There is huge variation in the quality and nature of waste which results from collection methods, geographical specifics, living & eating habits of the communities in different regions. Thus, addressing all these factors in a proper manner will lead to successful projects. One of the best examples in India is the Waste-to-Energy project at Okhla in New Delhi that is running successfully [21].

TABLE 5. OVERALL WTE Efficiency

Particulars	**Units**	**Values**
Ranking heat rate	kcal/kWh	2,952
Incineration efficiency	%	65
Gross heat rate	kcal/kWh	4,542
Auxiliary consumption	%	16
Net heat rate	kcal/kWh	5,407
Overall WTE efficiency	%	16

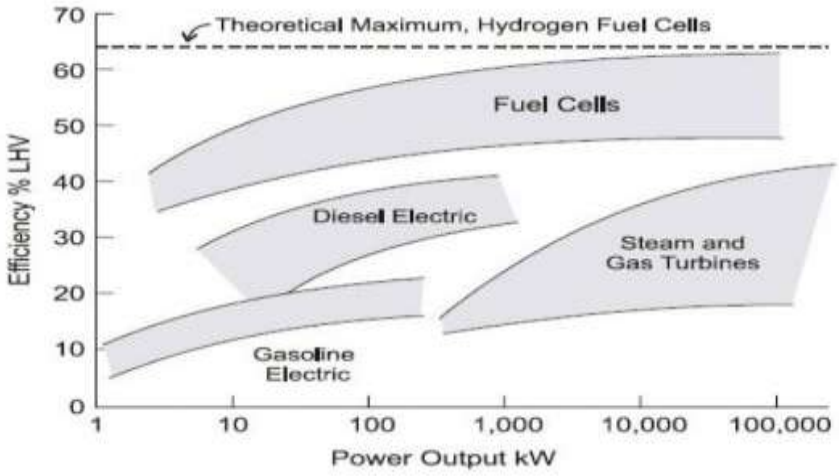

Fig. 7 COMPARISION OF EFFICIENCY FOR VARIOUS GENNERATORS

TABLE 5.IVESTMENT-COST RDF

Cost	Capacity t/d	Investment		Remarks
A	700	120	177710	Without dryer
B	1200	410	345730	Automated sorting & segregation facility
C	750	250	331730	Automated sorting & segregation facility-Import from Holland

IX. BENEFITS

Waste-to-energy and gasification[2] projects will lead to generation of circular economy where the waste that was the problem for the government to dispose off can be most optimally used to produce green energy, provide employment to the masses and help in serving the society. Under this scheme, Indian Oil Corporation Ltd. (IOCL[3]) and other petrochemical companies in India are planning to generate CNG from waste with a target to reduce crude oil import by 10%. All these will have circular impact on the financial economy of the country. The benefits:

- Reduction in import of Oil & Gas- reducing the burden of subsidies
- Improvement in hard currency reserves, as Oil is traded in USD
- Employment generation
- Projects under 'Make in India' will develop technologies which could be sold to other countries
- Besides generating electricity from MSW, there are several byproducts from waste-to-energy projects that are used for various purposes. Ash from the plant is used for brick making that adds to the revenue stream. These bricks are mainly used for making footpaths for similar type of activities thus generating the cycle of employment, adding back to the economy and improving the financial level of the society.
- By products of Gasification:
- Compost is the byproduct of gasification process that can be treated and used as manure for agriculture purpose. This compost is organic in nature which can reduce the consumption of the chemical fertilizers, thereby reducing burden on the government for subsidies and import of fertilizers
- Thus, it is pertinent to make these projects financially viable through grants or special funding schemes, as these have multiplier effect in the financial economy. Same will reduce the burden from the government, improve the hard currency reserves, and will lead to returns by multiplier effect in multiple dimensions.

X. FINANCIAL VIABILITY STUDY OF THE PROJECTS

Globally, there are over 2,000 projects running for disposal of waste that are primarily funded by government and other agencies. However, in India there are very few waste-to-energy plants catering to huge waste generation in the country. India has one seventh of the world's population, but still there are negligible waste processing facilities which account for 0.001% of those facilities. The country has maximum mountains

[2] ROCKHEM- Pune
[3] Project under implementation

of waste heaps which could be seen in and around all the cities and metros. The national capital alone has six big mountains of waste in its periphery.

The only point to ponder is the difference in strategies of financing to make this business model highly attractive. The next step should be valorization of this waste in most eco-friendly manner and then allthe big players with government can tackle this situation.

Presently, financing and other financial measure have only IRR of 4-5% for these projects and the government doesn't have funds to promote these projects. On an average, the cost of these projects is INR 100-200 Crs. for 1,000 ton/day of waste. The country requires more than 100 projects to cater to 188,500 t/d of the urban waste being generated as of now.

Case Study for MSW to Energy Plants in Indian context

A number of financial case studies were taken into account to figure out the impact of various financial measures on the project "IRR & NPV". Financial spread sheets and financial models have been worked upon the following cases:

a. Present case with free land for the waste projects
b. Tax holiday for the industry for life cycle
c. Tax holiday for first half life of the project, MAT tax
d. Moratorium period of 2 years
e. Tipping fee for the waste
f. Government grant to the projects
g. Higher tariff rate for sale of power
h. Lower Interest rate for the debt
i. Combined impact of the all (excluding tax holiday, for life of project)

Conclusion summary of the cases is summarized below.

Cases[22]	NPV (Mn INR)	IRR	PI
Base case	40	13%	1.021
Debt at 10%	967	17.46%	1.506
Mat (10 years)	693	17.28%	1.368
Mat (25 years)	744	17.48%	1.394
With tipping fee	637	17.04%	1.338
Tax holiday (25 years)	1,256	20.46%	1.666
Government grant	1,497	30.73%	2.322
Government grant with MAT	1,616	30.38%	2.428
Combined together (Except Debt @10%)	2,091	31.96%	2.823

Text Box 3: Case Study

XI. REVENUE ESTIMATION OF GOI

Front end benefit to government is that there is circular economy; the money pumped will have multiplier effect. Also, there are tax streams that will generate revenue for the government. Revenue estimation has been analyzed from the government's perspective and IRR calculation has been done accordingly. This is computed using the financial modeling, thermodynamic modeling & data for the same is taken from the database of previous projects done by DESL in the past 5 years in this field

TABLE 5: REVENUE ESTIMATION & IRR CALCULATION

Particulars ↓/ Years	UOM	0	5yrs	10yrs	15yrs	20yrs	25yrs
Grant	Mn INR	(848)					
Revenue from corporate Taxes	Mn INR		87.39	98.39	119.21	186.21	185.75
Revenue from Income taxes	Mn INR	2	2.65	3.50	4.64	6.14	8.12
Revenue from the Tax on machinery	Mn INR	-	-	-	-	-	26
Revenue from	Mn INR	-	-	-	-	-	-

multiplier effect							
Revenue from the tax on machinery made in India	Mn INR	19.08	-	-	-	-	-
Revenue from the O&M taxed	Mn INR	-	2.20	2.91	3.85	5.10	6.75
Expense as tipping fee	Mn INR	-	(9.13)	(12.09)	(16.00)	(21.17)	(28.02)
Revenue	Mn INR	826.92	83.10	92.71	111.69	176.27	172.59
NPV	Mn INR	280.1					
IRR	%	10%					
PV	Mn INR	1,126.9	58.98	46.69	39.92	44.71	31.07
PI		1.33					

It is clear from the table that even if government provides 40% grant to the WtE projects, the same will lead to payback with profitability index of 1.33. However, same values may increase as there will be other revenue streams due to the multiplier effect of the monetary market.

XII. WAY FORWARD

To make the projects viable, there will be requirement of grant. Swachh Baharat Cess is a step in that direction in India under Clean India Mission where grant is generated and can be used for financially supporting waste-to-energy projects. This may encourage the promoters to invest for the yield of 30%+, which will give out positive signals to the banks & financial institutions for financing such projects.
Some of the steps that could propel the sector in India could be:

- Import duty exemption (presently machinery is imported)
- Special permissions for the projects (saving time)
- Investment in R&D under 'Make in India' scheme
- Incentive to the promoters from Clean environment cess
- Making MAT for these projects to 15 from present of 10 years
- Increasing the moratorium period to 2 years for higher IRR for projects
- Special interest rate for project finance
- Exploring the Clean development management fund
- Involving the Municipalities for the STP to power & upgrading the capacities
- Creation of the E-waste treatment facility with Venture capital funds

Clean India Mission and SBC are seen as proponents of growth for such projects that are still struggling to find a foothold in India. SBM and SBC could be the one point source for a number of projects in India in the next few years. With more projects coming up in future, the economy is bound to have a positive effect due to multiplier effect in circular economy. Livelihood of these projects lies on the financial policies and how the corpus that is generated by the SBC is utilized by the government in achieving the goals of Clean India Mission as well as viability of these projects. This is an upcoming sector backed by the financial policies, Government policies, Monitory policies & development of the technology under *"Make in India drive*" to promote the new avenue for generation of green power by cleaning waste from India. Present demonetization process is touted as a blessing in disguise, as the rate of interest for loans is expected to come down. So, all moves are on track and working on a sustainable financial model is likely to give a major push to this sector.

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