Assessing solid waste as ‘green energy economy’ in India using renewable energy technologies for sustainable development

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Abstract

During latest time, solid waste production and controlling are main issues for all world nations. Yet, the conversion technologies are using to create different by-products like light, heat energy, fertilizer and biogas etc. Energy is an important matter for world. Energy gain could show a factor for minimization the effect of urban Waste on the atmosphere with more advantage to provide an energy source. The waste disposal is more challenge and highest dependent on liquid fuel has impelled world to continue efforts in forwarding energy formation technology ensuring suitable changes on one side and energy flexibility on the other side.

In India waste generation rate per person is 0.3 – 0.6 kgs/day, which is estimated to increase at 1.33% annually. As per estimates, about 275000 tons of Municipal Solid Waste (MSW) is generated per day and this figure could be twice as much by 2030. Estimation exist a power for producing approx. 1500 MW energy from the municipal solid waste in India and this potential is likely to increase further with economic development. The power production from the specified MSW-RDF gasifier and system maximization for energy production from fuel with increased ability to promote extremely minimizing the costing of energy use.

The opportunity of power production in the effective manner of better and mass composition of solid waste current WTE practices and research trends in India well as world, with anaerobic digestion (AD), gasification, heat-based biofuel combined heat and power (CHP) production, and incineration with the defined approaching of Indian WTE application.
1.0-Introduction
Urban development has shown rapid growth in solid waste in another countries of world with producing with importance in local body to completely solid waste restraint. The most population country India with proper solid waste management scene principally based on ground filling, with increase in atmosphere control on landfilling creating pollution. It is gradually focusing most cost usefulness technologies. There are few operational energy thermal plants of approximate 93.5 Megawatt capacity and extra around 45 waste to energy conversion dealings in pipelines. Developed country Japan is leader in the world for getting power from solid waste around 80% waste to energy conversion and rest 20% is send for landfilling and other use. Due to development of people life per person income of the India is prominently influenced the solid waste generation practice.

WTE strategy promotes very good options to fossil fuel energy combustion [1] solid waste burns practically more safe as energy source other than fossil fuels. Radiations and emissions like harmful chemicals and other particulars from the solid wastetoenergy produced less mass and volume in the atmosphere rather than fossil fuel burning [2]. The solid waste is collected from residential, factories, offices, shops, civil division and public sources [3] latest conversion technologies has digested the biofuel recovery and utilized solid waste as fuel to produce electrical energy, heat energy, mixed energy fuels. The offshoot of waste to energy formation are very fruitful in a lot of states like fertilizer or residual, charcoal and slags material. [4]

Fossil fuel can be replaced by solid waste conversion energy as per present statues and requirement of future energy. Energy recovered from waste streams residual is combined with energy to steam cycle, is known energy cycle plant. Concise change for optimization of molecule or atom simulation process is being used to make a good model of atomic interactions and configuration of carbon nano-tubes particles [5]

This analysis of waste to energy conversion efficiency for solid wastetoenergy direction on local area on technology acceptance, different challenges of every technology, generally using decision support tools. In India 15% of solid waste is using for energy recoveries and 52% is landfilling. In India only 80 waste to energy plants uses combustible technology and Refuse-Derived technology and situated in north and south states of India. Country has many solid waste landfilling occupied with gaseous fuel regain, is supplied to houses or utilized for electricity production.

2.0- Approach and methodology
The object of this paper is to defend the Waste for energy creation in India and for interpretation the highest level of energy. These Waste to energy plants can be established for heat energy production. The heat energy power is calculated on solid waste formation, accumulation proportion, solid waste components and another pertinent factors.
India is a fast commercialization growing country with changeable properties in weather, geographical, atmosphere, civil, behavioral and education. The mass and volume of municipal solid waste is dependent on living standard of people, food culture, market activities and people space per square kilometer area.

2.1. Opportunity of energy gain from solid waste

The world population growth has increased from 2.55 billion in 1955 to approximately 8.25 billion in 2019 and it is estimated to grow up to 11.3 billion by 2030 and up to 18.3 billion by 2050.[6] World civil urban population also greatly expanded from 1.1 billion in 1955 to 3.4 billion in 2015 and it is estimated 5.45 billion in 2030 and 7.64 billion in 2050 with a population share increasing from 32% in 1965 to 72% in 2050[7]. At present, world solid waste production is estimated approx. 1.33 billion tons per year, and it is increased to approximate 3.12 billion tons per year by 2030. A magnificent growth in solid waste production per person has been also estimated, from the present 1.15 kg per person per day to 1.52 kg per person per day by 2025 [7].

2.2. Categorization of Waste to energy technologies

Suitable waste to energy technologies for solid waste processing, getting the experience from past, it is examined important to recognize useful technological process or combined technology process for all solid waste components. There are many technologies presently being recommended to process of solid waste all world. These important technologies can be categories:

1. Bio-chemical conversion of environmental municipal solid waste
2. Thermal transforming of municipal solid waste.

First Group has been covered these technologies like composting and bio methanation, while second group includes technologies like as gasification, pyrolysis, incineration and mass burning. Refuse Derived Fuel (RDF) can be processed from burnable municipal solid waste and can be utilized as a material for Waste to Energy plants. production technology for syngas also contains merits and other consideration besides conventional Waste to Energy technologies.

There are various several wastes to energy technologies available based on the variety, mass and features of raw materials, requirement of the energy, commercial situations, atmospherically standards and specifically some others factors. The generally used waste to energy technologies are thermal, bio-chemical and chemical technologies[8]

2.3 Thermal technologies

Thermal technology includes the Incineration, pyrolysis, gasification and RDF of waste to energy process. Thermal conduction and specific heat of the fluids are measured at various temperatures for various carbon Nano particle.[9] Various end-products are produced in these waste to energy which can be assigned to various energy generation and natural resource recovery treatment process[10].

2.3.1 Incineration
This is mostly used waste treatment technology, by incineration process waste can be minimized by 75% and solid waste volume is minimized up to 92%. This process is very useful for solid waste of higher calorific value. In this process, energy is converted in electricity generated form[11].

The incineration process contains mainly three phases 1- incineration, 2- energy recovery, 3- control of air pollution. In first phase burning process, solid waste is directly burned at 750-1050°C in the ignition compartment by applying flue gas and preheated air. Extra warm steam is originated after burning of solid waste and produced steam is utilized to produce heat energy. Mechanical Turbine is joined to generator to produce energy, heat and bottom dust. Bottom dust mainly contains of Si, Fe, Ca, AL, Na and K. Heat and energy are regained in second phase of incineration process. The huge problem of this process is the creation of greenhouse gases. So, this is essential of main concern for installation this radiation control equipment with the incinerator, that is the third phase of incineration process.

This technology of solid waste conversion is not advantageous because it involves more biodegradable organic components, water moisture content or inert content and lower calorific value (range 820-1120 kcal/kg). Generally, in India small scale incinerators plant are using for combustion of hospital waste. Yet, a medium size-based incinerator plant was established to dispose of 300 tons solid waste at Delhi, India in 1987. But this plant has been remained out of order at present, because of non-availability of solid waste having necessary calorific value for burning[12].

### 2.3.2 Pyrolysis

Pyrolysis is thermal type of waste to energy process. It uses the power heat as energy at 350-840°C to crack down organic component in the anaerobic atmosphere. This process constitutes the combination of different gases like methane, carbon dioxide, hydrocarbons, hydrogen and carbon mono-oxide, is called syngas. This syngas can be used in many power operations as in heat engines, steam boilers, power turbines, superheat pumps. Pyrolysis based small application apparatus can be used to produce the artificial diesel fuel from segregated plastic waste with care finding these dependency of most critically simulation specification [9]. At present, no pyrolysis plant in working condition is functional in India.

### 2.3.3 Gasification

This process mainly contains a little portion of burning of waste to produce energy. Gasification is adapted by giving high temperature range more than 750°C with a little bit of air, i.e. fractional burning. Charcoal, coal tar and syngas are main product of this process. The main advantage of this process is high energy content and clean gas through turbine or engine to produce more energy and high heat. Gasification process can minimized up to 75% mass and 95% volume of waste[13].

In India agro-based gasifiers have been installed to burn bio-based material. Only two projects of gasification at present is existing. The one is installed in Rajasthan by Navreet Energy Research and Information by using agro-biomass, sawmill dust and wood dust to burn. Other gasifiers installed in New Delhi by Tata Energy Research
Institute. Considering the enhancement was seen in gasification properties of heat transfer and friction above the fine layers.[9]

2.3.4. Refuse-derived Fuel (RDF)

This is latest waste to energy technology, provides safe and green-friendly disposal of solid waste. RDF can be used in boilers as an alternative fuel instead of fossil fuels. Only few plants based on RDF have been set up in India[14]. RDF particulate are used for pulp, paper, wood industry and saw-mill industry.

[Image: Figure 1. Refuse derived fuel process]

2.4. Biological technologies

2.4.1 Fertilizing

This process contains disintegration of biodegradable municipal solid waste by bacterium under controlled specific conditions in air presence under with humid and warm environment. Fertilizing is divided in two processes i.e. aerobic and anaerobic fertilization. Humus or compost is end product of this process that is excessive rich nutrients nano-particle into a vegetable oil mixed water complexion. [15] This end product of this process is being used to fertilize crops and burnable gas, carbon dioxide mixture and methane. Biogas is used to produce heat or electric energy. This complete process is illustrated in Figure 2.

[Image: Figure 2. Fertilizer process]
2.4.2 Anaerobic digestion

This is another form of bio methanation method. Biodegradable organic waste material is disintegrated by Bactrian in the anaerobic atmosphere. This process minimizes the amount of solid wastes and produces biogas combination of carbon dioxide and methane causing the production of heat and electricity. At present in India, many Anaerobic digestion plants are in working condition to produce energy from vegetables and residual municipal food waste.

3. Waste to energy plants status in India

In India, solid waste conversion to energy status is very considerable. The main reason behind this situation is lack of right vision and selection of suitable collection techniques of solid waste with proper treatment and disposal of waste. Various functional design issues are insufficient infrastructure, poor awareness, insufficient fund problem, inadequate monitoring and little technical knowledge. The experiment approaches to the waste material specialization is generally very costly and provides an importance for the process. [15]

There are various treatment plants of solid waste. It mainly divided into STP, CTEP and PTEP Plants in Indian states. 210 fertilizer plants, 208 composting plants, 80 biogas plants and 50 Refuse Derived fuel plants under construction condition. In India 7 gasification plants with 78.5 MW capacity working trial run stage. In Delhi only two plants in working in Ghazipur and Okhla. About fifty-five Waste to Energy plants are under different stages of manufacturing or tendering proposal to manufacturing 410 MW. There are several Waste to Energy projects in many states of in India. About 75 MW of 7 projects for electrical generation from solid waste. Reduction in solid waste to produces energy with process. [16]
3.1. MSW Generation and its Composition

In India, solid waste generation per person is 475 gram per day rather than to western countries of 1.1 kg to 2.25 kg per person per day. In Indian small towns, this rate varies from 250-325 gm/person, in medium towns 325-425 gm/person, and in metro cities, this rate varies from 450-675 gm/person. [17]

The data shows that solid waste generation in India is approximately 1.55 lakh metric tons per day. From this solid waste data, approximately 1.21 lakh metric tons (78%) is collected only, and 22% is littered to and fro. Only 0.15 lakh metric tons (10%) is treated.

Yet, the present 56.5 million tons per year solid waste generation will continue to dump in the land without procurement then approximate 3.4 million cubic meter of landfilling per day. The expected solid waste rate of generation of 155 million tons by year 2030, the landfill for these solid waste for 20 years (like 10-meter high solid waste heap) can be as high as 76,000 hectares of land, that cannot wear this effect of land use.

3.2 Role of Waste to Energy technology in Waste Management Hierarchy

From solid waste, the conversion to energy is not the easiest way to produce the electricity. It may be only a route to recover by-product of solid waste management. Interested literature has shown a path waste-to-energy as an optional case of our
fossil energy issue but that may not be completely fulfilled. Yet these processes are to be implemented to world emission standards system, that can be a route to scientific and reliable disposal method of urban solid waste, considering the inadequacy of city land in the country, which can also generate more required electricity.

3.3 Perceived Conflict between Waste to Energy and Recycling

Nowadays RDF based or Incineration based waste-to-energy conversion technologies have appeared in India as the important plan for controlling the enhanced problem of solid waste in India. The main requirement of these technologies is: perfect quality and quantity waste with chain supply, high calorific value solid waste and low moisture/water content to be feasible. Indian administration and Industrial organization had proposed that Waste to energy and recycling are appropriate systems for controlling the waste with some drawback also. So, the planner and management should have to plan the future perspective view these WtE policy while confirming the strategies for solid waste management policy for future.

The main object of zero waste is to stop the landfills by the suitable technology of waste treatment. In India according to the estimates, waste to energy plan can be produced around 38290 tons of RDF per day that can presently provide 82 power plants of 5 MW each in coming time of 5-10 years basis on incineration, gasification or pyrolysis technologies. The energy plants may increase to 210 in number by 2030 and 550 energy power plants by year 2050 generating 2,870 MW power. This estimation is based on the data of municipal solid waste of country and different waste to energy technology with its nature of working.

The other general object is unavailability of less capital involvement and plan for which small cost cutting edges technology can be developed, requisition of items and assistance can be accumulated and these costs can be minimized and funding projects can be developed. Waste to Energy in every Municipal corporation can find the support of these developed technology. Solids waste are necessary to produce 440 MW of energy from 38290 Tons per day of combustible solid wastes with RDF.

New technology emerging in India for transformation of polymeric wastes to liquid fuel called "catalytic transformation of unused plastic to liquid fuel" and integrated fragment plastic waste with liquid bitumen for increasing the strength and life of roads. Usable plastic wastes can be used the latest technology profitably that cannot be recycled.

3.4 Operational Plants in India:

At present only 8 working Waste to Energy thermal plants of capacity of 95.4 MW. The areal allocation is given in different states: of India. There are few private renowned companies operating these plants. Along with the object of high use of collected of waste, the administration should plan for next ten years to finish the running projects of approx. 400 MW in the pipe line which are delayed due to various reasons – legally complications, shortage of financial support, non-availability of land etc. The Waste to energy plants may include the plan of working, which are hold up at different stages. Tariff policy gives a profitable tariff to energy from solid waste and this PPP partnership has an affection for investors. Approx. 50 projects have already been started, will help to
convert the solid waste of many cities and towns. That will ensure the fully utilization of solid waste of about 35000 MT per day for power generation of 400 MW, four times time i.e. 1200 MW of solar.

Fig. 4. Waste-to-Energy technologies based on applied conversion process

4.0- The Energy Content of Waste

The calorific value of coal fuel 30 MJ kg⁻¹, and oil has the calorific value is about 40 MJ kg⁻¹. The different values compared with waste category. Solid waste calorific value has modified about 20% since 1970, as the decreasing quantity of ash in waste from coal fires and the increasing proportion of dry pack material. A solid waste incinerator may consist of many separate streams, every stream consumes 15 tons of waste per hour. About 75% of total energy can be used to produce electricity and distinct heating/cooling. It is clear that most energy-efficient incineration of solid waste can produce more quantity of the energy to the city population.

4.1-Estimated Costs

Capital values for Thermal Technology may be assumed a 15 MW output for a following: Burning of mass and RDF varies from $7,500 to $10,500 per kW.
Pyrolysis varies from $8,500 to $11,000 per kW.

natural Gasification varies from $7,000 to $11,500 per kW.

Plasma Arc Gasification varies from $8,500 to $11,000 per kW

Technology Costs for waste to energy will be changed as per technology process because of every technology have specific design characteristics, differentiation in tools costing, specialsolid waste specialized characteristics and site requirements. Some another important factors which can adversely affect the construction cost.

5.0 Conclusions

Many waste to energy technologies are presented in this paper with end user impact. though mostly units have combustible and RDF have been installed all over the world, the fewer using technologies (Pyrolysis, Gasification and Plasma Arc), they have the compatibility of variation the landscaping of the WTE time era. These three technologies provide the systems with lesser pollution emissions than mass burning and RDF system purely because of system specialties. Plasma Arc technology has proved its lesser emissions rather than of any other technologies in the paper, but not having the data of different system units in the world. Bio fuels are produced by the Pyrolysis technology in the world but this technology will not be able to produce electrical energy for the industry.

The capex costs are more and much high in comparison to other energy technologies, I have to see the other possible revenue system. The revenue system for all these technologies is; Electrical Energy Sale target, Indian Government Subsidy planning, Renewable Energy Costs, Sale of Recyclables products and tipping fees for this waste transportation. though, Waste to Energy technology has many ways to produce the fund revenue in comparison to other power generation technology. Plasma Arc is only technology That could not adopt revenue stream with the system because this might not have a reusable fund revenue stream due to their full burning of solid waste and is depended on the final design.

Latest Waste to energy technologies are providing the clean and green eco-friendly disposal of solid waste. It produces electrical and heat resolving the of solid waste problem. From this study it is seen in India waste to energy system has long back and unsuccessful due to many reasons like lack of significant and logistic plan, inadequate funding, unsuitable technical consideration and improper resources management. At presently government and civilian are trying to take different actions for waste management system and for generation energy from solid waste.

References: -

[1] S. Sakai et al., “World trends in municipal solid waste management,” Waste Management. 1996, doi: 10.1016/S0956-053X(96)00106-7.

[2] E. Daskalopoulos, O. Badr, and S. D. Probert, “An integrated approach to municipal solid waste management,” Resour. Conserv. Recycl., 1998, doi: 10.1016/S0921-3449(98)00031-7.
[3] J. Cleary, “Life cycle assessments of municipal solid waste management systems: A comparative analysis of selected peer-reviewed literature,” *Environment International*. 2009, doi: 10.1016/j.envint.2009.07.009.

[4] B. Mendecka and L. Lombardi, “Environmental evaluation of Waste to Energy plant coupled with concentrated solar energy,” in *Energy Procedia*, 2018, doi: 10.1016/j.egypro.2018.08.045.

[5] P. K. Singh, K. Sharma, A. Kumar, and M. Shukla, “Effects of functionalization on the mechanical properties of multiwalled carbon nanotubes: A molecular dynamics approach,” *J. Compos. Mater.*, vol. 51, no. 5, pp. 671–680, May 2016, doi: 10.1177/0021998316649781.

[6] N. Scarlat, V. Motola, J. F. Dallemand, F. Monforti-Ferrario, and L. Mofor, “Evaluation of energy potential of Municipal Solid Waste from African urban areas,” *Renewable and Sustainable Energy Reviews*. 2015, doi: 10.1016/j.rser.2015.05.067.

[7] J. E. Santibañez-Aguilar, J. M. Ponce-Ortega, J. Betzabe González-Campos, M. Serna-González, and M. M. El-Halwagi, “Optimal planning for the sustainable utilization of municipal solid waste,” *Waste Manag.*, 2013, doi: 10.1016/j.wasman.2013.08.010.

[8] G. Ionescu, E. C. Rada, M. Ragazzi, C. Mǎrculescu, A. Badea, and T. Apostol, “Integrated municipal solid waste scenario model using advanced pretreatment and waste to energy processes,” *Energy Convers. Manag.*, 2013, doi: 10.1016/j.enconman.2013.08.049.

[9] F. Graphene, E. Resin, and M. D. Simulation, “Molecular Dynamics Simulation of Glass Transition Behavior of Polymer based Nanocomposites,” vol. 77, no. October, pp. 592–595, 2018.

[10] H. D. Beyene, A. A. Werkneh, and T. G. Ambaye, “Current updates on waste to energy (WtE) technologies: a review,” *Renewable Energy Focus*. 2018, doi: 10.1016/j.ref.2017.11.001.

[11] K. L. Oung and C. P. Wong, “A review of the current and future technologies for solid waste,” *Environ. Prot. Bull.*, 2001.

[12] C. A. C. Haley, “Energy recovery from burning municipal solid wastes: a review,” *Resour. Conserv. Recycl.*, 1990, doi: 10.1016/0921-3449(90)90035-3.

[13] P. S. Nigam and A. Singh, “Production of liquid biofuels from renewable resources,” *Progress in Energy and Combustion Science*. 2011, doi: 10.1016/j.pecs.2010.01.003.

[14] M. Ragazzi and E. C. Rada, “RDF/SRF evolution and MSW biodrying,” *WIT Trans. Ecol. Environ.*, 2012, doi: 10.2495/WM120191.

[15] A. Sharma, A. Tiwari, A. Dixit, and R. Singh, *Investigation into Performance of SiO 2 Nanoparticle Based Cutting Fluid in Machining Process*, vol. 4. 2017.

[16] A. Saravananakumar, T. B. Reed, and M. R. Sudha, “Experimental Analysis of Municipal Solid Waste Blended with Wood in a Downdraft Gasifier,” *J. Environ. Eng. Sci.*, 2020, doi: 10.1680/jenes.20.00007.
[17] C. Mukherjee, J. Denney, E. G. Mbonimpa, J. Slagley, and R. Bhowmik, “A review on municipal solid waste-to-energy trends in the USA,” Renew. Sustain. Energy Rev., vol. 119, no. October 2019, 2020, doi: 10.1016/j.rser.2019.109512.