International Journal of Arts Humanities and Social Sciences Studies
Volume 6 Issue 12 ǁ December 2021
ISSN: 2582-1601
www.ijahss.com

Bio-Waste Management and Need for Energy Policy in Urban India – Taking Delhi as a Case

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Abstract*: Waste management is a serious concern in cities over the world. Incompetent ways of handling waste have only snowballed it. Therefore efficient smart-city waste management is the immediate requirement. Indian government is doing immense efforts in this concern. However, understanding the ongoing course in waste management and renewable energy needs, India can do much better with efficient strategy. Concerning the nature of bio-waste, and the economy's requirements; India needs a model that can take care of its simultaneous requirements for --'sanitation, landfill issues, clean energy, organic urban agriculture, employment and investment opportunities, and healthy environment'. India needs a model which can offer a long term sustainable solution to green, healthy and self-sufficient cities. Not only India, the world cities need it. For this, it is needed to think about a policy solution which is more efficient and sustainable. In this concern, this manuscript proposes a 'three stepped smart- city model for handling bio-waste' for cities in general and for Delhi in particular. The model is based on multi-target approach and it presents a smart- city model for handling bio-waste through well-established anaerobic digestion technique. In this effort, the manuscript presents a case of Delhi for need of 'smart-city model for bio-waste management' and explains the model by presenting Delhi's case. As waste management and energy are universal issues, the model will also be helpful for all Indian cities and cities in the world.*

Keywords*: bio-waste, biogas, centralised, decentralised, segregation.*

I. Introduction

In Delhi, Incompetent waste management has created many problems regarding sanitation, landfill related issues, serious environmental concerns, and loss of resources. Lack of efficient interventions is perpetually festering the situation. The situation is less or more same in other Indian cities too. Its management is required on priority basis because of all these problems.

If we look from the perspective of waste management in Delhi and other Indian cities, most of their waste finds its way to landfills. World atlas reports that out of world's 50 biggest landfills, 3 landfills ('Deonar' in Mumbai; 'Mandur' in Bengaluru; 'Ghazipur' in Delhi) are in India; and about 8.6 million people living within 10 kilometre of these dumpsites are at health risk. 'Ghazipur' landfill site is reported to be about 65 meter i.e. 213 feet high (only 17 feet short of 'Quatab Minar') which is more than double its permissible limit of 25 meters. The situation would have been different if it had been taken care in the starting and waste treatment and segregation what would have been practiced to divert the waste from landfills. The situation is less or more same for all the landfills.

Other landfills in the country are also on the same path. Planning commission projections, based on 0.45 kg /capita/day/capita, reveals that till 2030 land requirement for landfill will be 1175 hectare per year. Situation may be more critical in future because World Bank 1999 publication shows that Waste generation in urban areas of India will be 0.7 kg per person per day in 2025, approximately four to six times higher than in 1999.

In India, very-often open dumps are taken as landfills; while in actual, landfills are technically engineered sites which is meant to receive only waste left after waste reuse and recovery. Presently there is no sanitary landfill operating in India. Delhi's 3 landfills are also huge dumps. However, Delhi's 4th landfill in 'Narela-Bawana' is a sanitary landfill but it also has waste management concerns.

Mostly mixed waste is dumped in the Indian landfills. It contains organic, inorganic, and other dangerous things like batteries, bottles or packaging containing chemical leftover, broken glasses and tubes etc. These dumps are dangerous for health, environment, and economy. Mixed waste contaminates the overall waste with dangerous heavy metals. It further festers the problems regarding leachate, landfill burning, aerosol and other sanitation

related issues. The result is land, air and water pollution which causes health issues. Many studies show that the leachate from these dumps contains heavy metals which threatens to contaminate the nearby soil and groundwater. Studies have found concentrations of heavy metal in groundwater surround the dumpsite. Heavy metals are known to be reason for harm to the central nervous system, anaemia, kidney and liver dysfunction, psychological and developmental changes in young children, and stomach and intestinal irritation and in human body.

Many studies presents the bad effect of lachating due to dumps. (Ghosh, Pooja et al, 2014-15) present the leachate issues about Delhi's 3 landfill sites. Delhi landfills poses serious threat for contamination of nearby groundwater by very dangerous elements. Yamuna's water has contamination risk because of its proximity to the sites (Ghosh, Pooja et al, 2014-15; Mor et al. 2006). In Kolkata, "Studies on Environmental Quality in and around Municipal Solid Waste Dumpsite" by Biswas A.K., et al. found concentrations of heavy metal in groundwater surround the dumpsite. The groundwater quality was significantly affected by leachating (Annepu, R.K., 2012, page 62; Biswas, A. K. et.al, 2010). Recently, the NGT is hearing petition about water contamination due to landfill lechating in the area near these 3 dumping zones (Okhla, Bhalswa and Ghazipur) (ANI, 2020).

Open burning of Wastes and landfill fires are also common in India (Annepu, R.K., 2012, page 56). These fire emissions are very harmful and can even cause to cancer. Landfill fires and open burning of MSW in Mumbai releases 10,000 grams of dixons/furons in the atmosphere, which are carcinogenic agents and its long term exposure can cause cancer (Annepu, R.K., 2012, page 62; NEERI, 2010). A NEERI study in 2010 in Mumbai reports that 2% of uncollected waste, and 10 % of total MSW is burnt in streets and in landfills respectively. Open burning causes 19% of Mumbai air pollution. As compared to road-transport, open burning of MSW emits more than double particulate matter in Mumbai (Annepu, R.K., 2012, page 58; NEERI, 2010). Health studies led in Kolkata presents exposure of landfill fire emissions caused "Chromosome Break" incidence within regularly and for longer period exposed waste- pickers, which was 12 times higher than the control population. Chromosome Break often leads to cancer. Municipality workers were also affected with Chromosome Break but less than that of waste pickers (Annepu, R.K., 2012, page 62)**.**

Because of serious waste management concerns, the government of India has made excellent improvements through waste management rules, 2016. The rules make it mandatory to source segregate and handle the waste by its stakeholders as per their responsibilities mentioned in the waste management rules, 2016. However, compliance of the rules is still awaited.

In the context of landfill concerns, in July 2019, NGT ordered to start and complete the project regarding bio-mining and bioremediation of the 3 landfills (Okhla, Bhalswa and Ghazipur) in Delhi within a period of one year (1 October 2019 to 1 October 2020). NGT has also directed the Delhi government and civic bodies to deposit 250 crore to an escrow account for the purpose. All the municipal corporations in the country are also directed by the NGT to carry out similar projects from 1 November 2019 - a month after starting of the Delhi project. Though, great safeguards are needed because of many apprehensions about its risks (Sidharth Ravi, 2019).

However, it would have been wise to treat the waste initially but not to look for landfill mining or bioremediation after creating massive heaps of dumps because at one side it has cost us a lot in various ways, while on another side its toxic dump become risky to dig. A lot of money also get spent even after harming the environment and resource loss. This money could otherwise be used for resource recovery from waste and keeping the environment clean.

In this scenario, NGT's (National Green Tribunal) worries are clear by its various orders regarding compliance of waste management rules. NGT order in 2018 (NGT, 2018), NGTs order dated 18/10/2019 (India environmental portal, 2019), and NGT's order dated 7/1/2020 (India environmental portal, 2020) are all regarding compliance of solid waste management rules and hence present the serious concerns. In March 2020, the NGT has directed all the states and UTs to set up 'Environment Monitoring Cell' for ensuring the compliance of solid waste management rules (ANI, 2020).

Due to various waste related issues, waste rules' compliance is the immediate requirement. Though, despite of NGT's continuous calls, it is still much far from reality. It seems that efficient strategy is still to be deciphered. Therefore, overall scenario presents that in contemporary times, waste management is the immediate concern in Delhi and all-over India. If the current waste management picture does not improve, cities will soon be buried in their own muck. Hence, efficient and sustainable waste management is the need of the hour.

II. *A NEED FOR* 'WHAT IS?' TO 'HOW TO?

The manuscript covers a journey from 'what is?' to 'how to?' 'What is?' part (explained in section 3.1) does the contemporary situation analysis of bio-waste management concerns, available bio-waste management techniques and their use in solving issues, and present policy perspectives. 'How to?' part (explained in section 3.2) offers solution of bio-waste management issue through the proposed model. In this journey, the paper uses analytical, and descriptive approaches. Both inductive and deductive ways are used for result and discussions.

III. Discussions

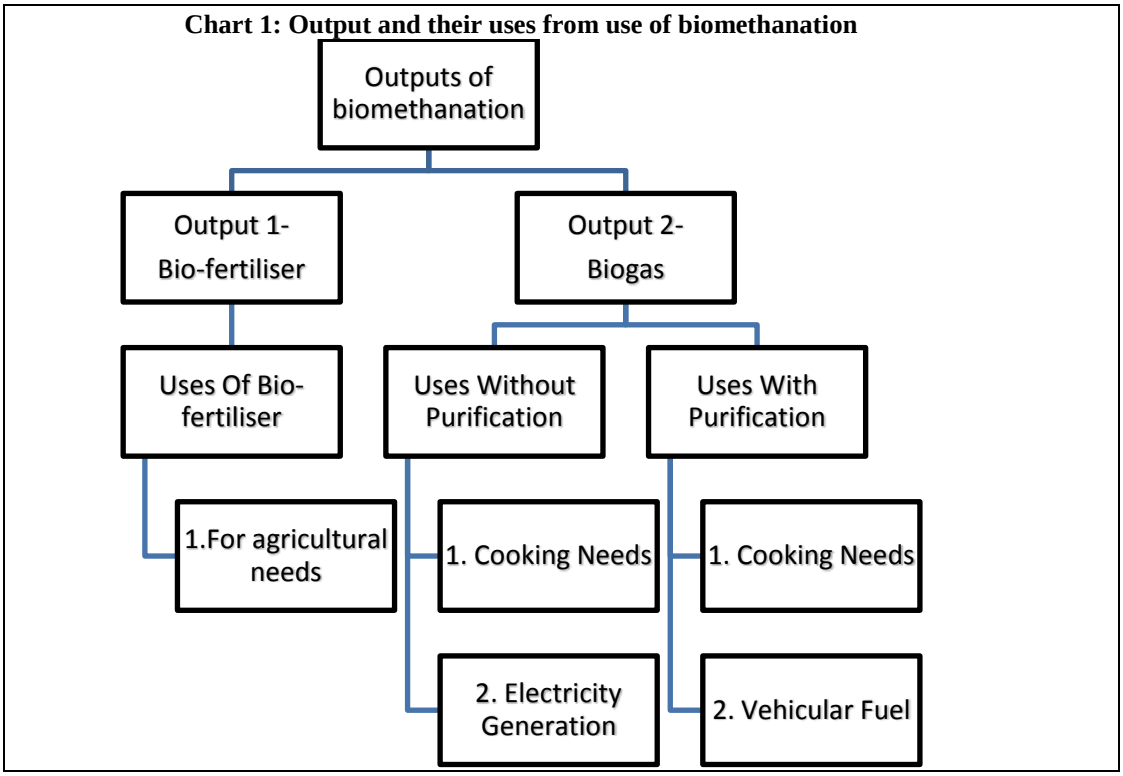
3.1. 'What is?' scenario: This section deals with the situation analysis of bio-waste management concerns, available bio-waste management techniques and their uses in solving issues, and present energy policy perspectives as solution. The 'What is?' scenario is explained in 3 sub parts. Section 3.1.1 explains about b*io*-waste management options scenario; section 3.1.2 explains about bio-waste management scenario in Delhi; while section 3.1.3 explains about need of policy integration for bio-waste management and clean energy in Delhi.

3.1.1 Bio-Waste Management Options: In India, and so in Delhi, bio-waste holds about more than 50% share in total municipal waste. Therefore, this paper focuses on effective city bio-waste management and its importance for energy production. For effective management, initially we should ponder upon municipal bio-waste handling options. After that, we can choose the desirable option. There are two options of Municipal bio-waste handling– either dumping in landfills or resource recovery. Resource recovery is the desired option as because of dangers associated with dumping. Various recourse recovery methods offers various output options. Besides famous and popular options of compost and energy, some other options are - commodity chemicals, bio-plastics, bio-pesticides, proteins, lipids, chitin, and animal protein by use of black soldier fly. Though these other options are still to be established properly. India's immediate requirements are sanitation, energy, and more agricultural production. Therefore, for municipal bio-waste, presently India needs to focus on biomethanation for the recovery of bio-fertiliser and energy. Other options should be tried in the future, as and when required. However, because of large amount of agricultural waste, agriculture produce markets should be checked for animal food possibilities.

There are different options for resource recovery of municipal bio-waste. Passive composting (in dumps), and some active composting (aerobic digestion, and vermicomposting) methods offer only compost but not energy. One active composting (biomethanation through anaerobic composting) method offers compost and energy altogether. The method which can offer compost and energy altogether is the preferred option. Initially, biomethanation provides 2 outputs- biogas, and bio-fertiliser**.** Now, biogas has energy in it which can be used for different possible options.

Chart 1 presents the output and their uses from use of biomethanation technology.

Chart 1: Output and their uses from use of biomethanation



Biogas can provide energy in two ways - without purification, and with purification **(Chart 1).** The simple and easy method is using biogas directly (without purifying and compressing) for cooking gas needs, and also for electricity generation with the help of a generator. The other way is purifying the biogas to get and compress the methane (CBG) for energy requirements of vehicular fuel (for replacing CNG), and also for cooking needs. Purifying provides a chance to store carbon-dioxide part of biogas. CO_2 can be captured for different uses (like in - greenhouses, fire extinguisher, hospitals, beverages, and in refrigeration and cold storages) and can be an extra source of income. CO_2 is also used in slaughterhouses to stun the animals pre-slaughtering. Though CO_2's use in stunning animals is controversial in the context of animal rights, and is hardly used in India for animal stunning.

3.1.2. Bio-Waste management in Delhi: This section deals with bio-waste management scenario in Delhi. It is further explained through 2 sub-sections. Section 3.1.2.1 explains about bio-waste management and concerned bodies in Delhi. Section 3.1.2.2 explains about bio-waste management efforts in Delhi.

3.1.2.1 Bio-Waste management and Concerned Bodies in Delhi: Delhi generates about 10000 TDP of solid waste out of which about more than 50% is bio-waste. In Delhi; 5 local bodies – 3 municipal corporations (which are trifurcated from the Municipal Corporation of Delhi (MCD) in 2010) covering 1397.30 square kilometre area, New Delhi Municipal Council (NDMC) covering 42.74 square kilometre area, and the Delhi Cantonment Board (DCB) covering 42.97 square kilometre area are responsible for solid waste management of the city. Municipalities manage almost 95 % of the city area (which has 98% of the city population) in this concern. Waste generation in the local bodies' areas are given in Table 1.

Table1: Solid waste generation in Delhi

Local Body	**Existing Generation for 2001 (in TDP)**	**Projected* Generation in 2021 in TDP**
Municipal Corporation of Delhi (MCD)	6300	**15100**
New Delhi Municipal Council (NDMC)	400	**550**
Delhi Cantonment Board (DCB)	100	**100**

Source: Public Health Department of MCD, NDMC, and DCB
*700 g per capita per dayfor calculation of projected generation in 2021 as per CPEHHO Manual on solid waste management
Cited from- (Dept. of Urban Development, Govt. of Delhi. Page 12-3).
https://ccs.in/sites/default/files/files/Ch12_Solid%20Waste%20Management.pdf 23/4/2020

Table 1 present that Municipal Corporation caters substantially huge share of waste generation in Delhi.

Now the municipal corporation is divided in to three parts [North Municipal Corporation of Delhi (North MCD), South Municipal Corporation of Delhi (South MCD), and East Municipal Corporation of Delhi (East MCD)]. The 3 municipal corporations are further divided in to 12 MCD zones (Business Standard, 2017).

North MCD has 6 zones (Karol Bagh, Civil Lines, Narela, Rohini, Keshav Puram, City – Sadar Paharganj, and keshav Puram) which are spread over 104 wards (Urban Development Department, 2017). South MCD has 4 zones (Central Delhi, South Delhi, west Delhi, and Najafgarh) which too are spread over 104 wards (Elections.in – South Delhi Municipal Corporation Wards List 2017- webpage). East MCD has 2 zones (Shahdara North, and Shahdara South). The zones are spread over 64 wards (Elections.in – East Delhi Municipal Corporation Wards List 2017- webpage)

Map 1 presents the zonal areas under the three MCDs. However, this map shows zones before changes done by North MCD in 2017. After the changes City-Sadar Paharganj has become one zone (Earlier City, and Sadar Paharganj were two different zones), and a new zone keshavpuram is made. Map 1 provides insight about geographical spread and locations of the three MCDs and their zones.

Map 1: Zonal areas under the three MCDs

Source: **(Sharma, Mohit; 2017)**

3.1.2.2. Bio-Waste Management Efforts in Delhi

Due to lack of bio-waste resource recovery, biodegradables are having about 62% of total landfill waste in Delhi (**Dept. of Urban Development, Govt. of Delhi, page 12-5)**. About 90% waste is dumped in landfills. Waste management rules, 2016 are an excellent efforts towards better and sustainable waste management. However, rule compliance is still to be achieved. A few resource recovery facilities have been installed in Delhi till now. Sections 3.1 to 3.4 shed light on these treatment facilities.

Composting Plants in Delhi: 5 windrow composting plants, based on mixed waste, have been installed in Delhi till now. Table 2 presents the briefs about these composting plants. Presently, 2 centralised composting plants at Okhla and Bawana, with 1200 TDP capacity, are functional **(NCT, Recommendations for Long Term Action Plan for Solid Waste Management in Delhi, 2018, page 21).** The rest is dumped in three dumpsites (Bhalsawa, Okhla, and Ghazipur).

Table 2: Compost facilities in Delhi

Facility with Capacity and year of installation	Remarks
Okhla (South MCD) – 150 TDP – 1981 & 2008	Closed in 2000 as there was insufficient revenue from sale of compost. Rehabilitated by IL&FS (MCD signed a concession agreement with IL&FS) and the plant was set up in 2008 with 200 metric tons capacity. Media reports present that the plant is not getting takers for compost (Urban Update, 2018).
Okhla (NDMC) – 200 TDP – 1985	(NDMC and IL&FS, 2007, Page 10-3) presents that the plant is closed now. At the time of processing it was reported to handle 50 tonnes garbage per day and had remained shut from time-to-time because of various reasons.
Bhalswa – 500 TDP – 1999	Closed in 2014 because Delhi pollution control committee served a notice to Bhalswa plant for closure due to violating pollution norms. The plant was operated by a private enterprise 'Excel Industries Ltd' (Suraksha.P, 2015; Halder, Ritam et al 2017; Adak, Baishali 2018)
Tikri Khurd (APMC)- 125 TDP – 2001	Closed after dispute between APMC and spiral services (Delhi high court, 2017)
Narela-Bawana- 400 TDP – 2011	Working

Compost Quality: The quality of compost obtained from these working, and non-working plants are highly compromised upon. The compost quality has been observed a main reason of discontinuing the closed plants. Because of the bad quality, Bawana and Okhla composting plants are also facing problems for not having takers.

Besides, many studies show that compost from MBT (Mechanical Biological Treatment) facilities, which are using mixed waste, is laden with heavy metals. The most important but ignored fact regarding MBT compost is - entering heavy metals in food supply chain through soil and crops produced with the MBT compost. If heavy metals are introduced in food chain through use of this contaminated compost, it leads to "biomagnification". It generates the health risks associated with consumption of heavy metals. Heavy metals are known to be responsible for harming to the central nervous system, anaemia, kidney and liver dysfunction, psychological and developmental changes in young children, and stomach and intestinal irritation and in human body (Annepu, R.K., 2012, page 66). Because of the danger of contamination, mixed waste composting is not an option for sustainable waste management.

(Annepu, R.K., 2012, page 85) presents that if all MSW is composted as mixed waste in the next decade, in India, 73000 tons of heavy metals would introduce in to agricultural soil. A study by IISS, Bhopal, presents that compost produced from MSW in India, is contaminated with heavy metals and contains low nutrient value (Saha, J.K., et al, 2010; Annepu, R.K., 2012, page 84).

Despite of known dangers of mixed waste composting, it is annoying that the main concern observed is towards sale of compost, but not towards its quality. While the main concern should be towards production and sale of good-quality compost.

Latest moves regarding bio-waste treatment through biomethanation/compost in Delhi: Under 'Swachh Bharat Abhiyaan', Yasasu Green technology was positioned as a nodal agency for setting up 10 decentralized biomethanitation plants (4 South MCD, 4 North MCD, and 2 East MCD) by Municipal Corporation of Delhi for treating organic waste (Business Standard, 30/4/2019; Singh Paras, times of India, 16/7/2018). One plant costs 1.74 crore rupees. The plants are of capacity 5 metric ton each (Amar Ujala**.** 31 December 2019).

South MCD's 3 biomethanation plants – in Punjabi Bagh (started in February 2019), Dwarka sector 14, and Sarita Vihar have been started operating. It is reported that soon, the 4th planned biomethanation plant will also operate in Vasant Kung.

East MCD has initiated the trial run of its first biogas plant in Geeta colony in December 2019. The plant will consume 5,000kg of bio-waste on daily basis, and will generate 250-300 units of electricity, along with 750kg of compost. It is spread over 600 sq metres area. The civic agency aims to establish another 5-tonne plant at Shastri Park and a 10-tonne facility at Yamuna Vihar. 10 more plants (each of 1-tonne capacity) have been established in various colonies. Because of their size they can only convert waste into compost (Positive News corner, 2019).

Therefore, it is clear that almost all recently installed and planned biomethanation plants are of 5TDP capacity. 20 such plants will cater only 100 TDP. Therefore, keeping in view the amount of Delhi's bio-waste, which is about 5000 TDP (If we take 50% of total waste 10000 TDP), the initiatives are just an introduction of biomethanation to Delhi.

Biomining and Bioremediation: The three landfills host about 28 million tonne of waste (Ghazipur -14 million tonnes, Bhalswa -8 million tonnes, and Okhla -6 million tonnes) in Delhi. As per NGTs order of biomining and remediation of the legacy waste at these landfills, Delhi Corporations have planned to install 33 trommel machines (11 trommel machines per landfill) at these landfills. It will process 9,000 metric tonnes of waste daily. This plan was recently submitted to the NGT during a hearing on waste management. As per media reports, South MCD has installed one trommel machine (300 metric tonne capacity) at Okhla landfill. East MCD has installed a trommel machine (600 tonne capacity) at Ghazipur landfill, and the North MCD claims to have installed 11 machines (Three of them are operational). These machines are helping in biomining of 900 tonnes of waste per day (Thakur Monika 2019).

3.1.3. Need of Smart-City Model for Bio-Waste Management in Delhi: As per above mentioned solid waste manage scenario in Delhi, most of the solid waste has made Delhi's landfills exhausted and dangerous. Waste processing (through composting, biomethanation, and WTE plants) is very low. Mixed waste feeding has been the main reason behind discontinuation of various facilities (composting, and WTE plants). Mixed waste has been a main reason for shutting down various composting facilities (as explained in sections 3.1, and 3.2). Mixed waste feeding has also been the reason behind shutdown of various WTE plants (mixed waste with less calorific and high moisture content is unsuitable quality of feed for WTE plants). Timarpur waste to energy WTE plant, the first WTE plant of India, was constructed by a Denmark's company with a cost of 20 crore rupees. It started commissioning in 1987 and got shut down within 21 days of trial operations. Since inception of first WTE plant till now, failure of WTE plants (out of 15 installations, 8 has been shut down) in India is mainly because of feeding mixed waste which is unsuitable for this technology. The presently working WTE plants are also under scrutiny for violating environmental norms. Currently, there are 40-odd WTE plants at various stages of construction. Various subsidies/incentives take care of about 40% of the project cost. (Bhushan, Chandra; 2019). The remaining operating facilities are also reported to be in mire due to mixed waste feeding. The irony is that in spite of these problems, the behaviour pattern of waste management seems the same. Mixed waste dumping, and mixed waste treatment is still here as ever.

Though, government's waste management rules and NGTs continuous pressure to comply the rules has resulted in some moves (very recent start of small size biomethanation plants, and bioremediation and biomiming of three landfill sites). However, the moves (opting small size and much decentralised plants) don't seem to present far-sightedness from long-run smooth sustainability and efficient resource recovery point of view (explained in section 5.1. – 'Model Approach - decentralised-cum-centralised'). Besides, an organised and well planned system, based on multi target approach, for the city as a whole, will work better. Participants of NGT meeting (regarding waste management) have also felt that procedural delay can be curtailed by - "standardization of technologies and cost breakup and identification of service providers and placing them on GeM Portal will go a long way in tackling the situation by curtailing the procedural delay. This requires coordination among the concerned authorities and clarifying the existing CVC guidelines, if necessary." (India environmental portal, 2019).

In the present scenario, when officials are trying to comply with the waste management rules; the most important thing is to ensure that not just complying but it also needs the use the bio-waste resource for the developments needs of our country. Bio-waste can simultaneously contribute towards - 'sanitation, landfill issues, renewable energy, organic urban agriculture, employment and investment opportunities, and healthy

environment'. Therefore, to do swift, if they lose best and multi target strategy; then they will lose the motive behind waste management rules. Incompetent ways can't solve the problem but will only snowball it. 'Self-reliant India" mission also demands efficient strategy for India.

Moreover, working on an organised waste management will not be costly than spending government's /public money in biomining, discontinuing plants, and other related losses. Besides, as per its multi-target approach, the working on this model will directly provide sanitation, landfill issues, environmental benefits, energy, investment and employment opportunities at various levels, and urban organic agriculture. It will create a chain of works. Besides, the model works on a smart well organised system which will makes cities smart.

Indian prime minister's call for 'Aatmnirbhar Bharat Abhiyan (Self-reliant India Mission)' on his 12 May 2020 speech in COVID times declares that India also strives for self-reliance. This 5 pillar based mission demands efficient projects. Working on this well-organised system based model will generate a high-tech bio-waste management infrastructure. All this will help in bringing quantum jump in Indian economy. In recent times, the model is important for COVID affected economies', where providing employment opportunities are important (blue and white collar jobs), working on this model will increase demand and supply both. Instant increase in demand (which is due to income generation because of increased employment opportunities) will be followed by increase in supply in terms of increased outputs. However, supply will take some time. And hence, at present situation, this model will work for solving present problem (employment, demand, and supply mainly due to COVID effect) by solving another important contemporary issues of bio-waste management and energy.

Keeping in view the above discussed scenario, it is clear that Delhi needs a good model to process its bio-waste efficiently. Not only Delhi, but all the Indian cities need it. Without it, the grim situation is unlikely to improve and can become grimmer. Therefore, a well-co-ordinated integrated waste management system, based on multi target approach, is required for long term sustainable solution to green, healthy and self-sufficient cities. This smart city model for bio-waste management offers itself for service.

3.2. 'How to?' scenario*:* This part offers solution of bio-waste management issue through the proposed model. The section 3.2 is further divided in to two sections. Section 3.2.1 presents the model in general, and section 3.2.2 presents the model in Delhi case.

3.2.1. The Model

With decided optimum number of biogas plant sites with optimum locations, a smart-city model based on biomethanation is required for optimal use of bio-waste in a city. Initially the model is explained in general. In the next section, the model is explained for Delhi city in particular. The model proposes the bio-waste management system for city as a unit. The model works as per its approach, and prerequisites

3. 2.1.1. The Model's Aim

Keeping attention towards multi-targeting potential of efficient bio-waste management, the model aims at **multi-targeting**.

3.2.1.2. The Model's Approach

As efficient bio-waste management can help for realising the targets for --'sanitation, solution of landfill issues, transportation and other fuels, organic urban agriculture, employment and investment opportunities, and healthy environment because of less pollution'. Therefore, to get optimum bio-waste management scenario, this model works with "multi-target approach". This multi-target approach is approached through **"decentralisation-cum-centralisation**".

The model is not about 'centralised versus decentralised' but the model is about "decentralised-cum-centralised" approach. These two approaches complement each other in the model. The fact is that there is a trade-off between centralisation and decentralisation. More centralisation means less decentralisation and vice-versa. Now the point is to choose the optimum position.

Decentralised approach benefits with relatively less transportation costs. On another side, over-decentralisation debars to get the possible benefits of scale, and division of labour. Highly decentralised approach can ruin the chances of commercial operations based on expert handling, and hence of entrepreneur possibilities. Centralised approach supports benefits with large scale plants and hence offers - less scattered efforts, benefits of return to scale, technical efficiency, and entrepreneurial opportunities. However highly centralised plants demand greater transportation requirements. Therefore, unnecessarily highly centralised or highly decentralised plants can get

less benefits and more costs. So, for optimum sustainable results, an optimum level of decentralisation or centralisation is required.

As both approaches have their own benefits and own limitations; therefore, to get the benefits of both these approaches, and to curtail the limitations of both, the model supports the mix approach through adopting – **'centralisation via decentralisation'**. It supports decentralisation from the city perspective (upper level), while it supports centralisation from zonal point of view (lower level). Besides, the two major resource-recovery processes work as per "centralisation via decentralisation approach"- the first process of biogas plants are decentralised while the process of "Central CBG (Compressed biogas plants)" is centralised. The details given below in the general model, and in the case of Delhi, clarifies it more.

3.2.1.3. Three prerequisites for successful operation of this model

There are 3 essential requirements for successful operation of this model. These requirements are-

Requirement 1- source segregation: Source segregated waste is the utmost requirement for implementation of this model. Lack of waste segregation has been the main reason of plant failures (of compost plants as well as waste to energy plants). Source segregation is not achieved yet but it can be achieved easily because of certain available but unused strengths. These strengths are - already established collection and transportation mechanisms, more aware people, already available media base to communicate and inform the masses, and waste act compliance requirements.

The important thing to be taken care is that other than entry-point segregation should strictly not be taken as an option as it allows the bio-waste to contaminate and get mixed with other wastes. It also deteriorates the quality of other waste (which is or can be sent for resource recovery through waste to energy plants and other recycling ways). The first and most important segregation requirements is towards waste collectors. Separate section for source segregated bio-waste in waste collecting vehicles and accepting only segregated waste is the most important requirement. This is not even their moral duty but for them it is also mandatory as per law. The same responsibility lies to the waste generators too.

It is also important to note that if people's source segregated waste got mixed by the waste collectors by putting all waste in some common collecting unit, then it is very difficult to encourage people for source segregation. In the same manner, if waste collectors' source segregated collection is to be dumped at a common place where all type of waste is dumped, then it is very difficult to keep them driven for source segregation. Therefore, source segregation is useful only in the presence of waste processing facility. Without it, source segregation will be just only waste of efforts.

Besides, whenever possible, vehicular transport mechanism should be replaced by automatic waste collection system based on IoC (Internet of things). However, in the presence of already established transport system, the initial focus should be towards setting up a resource-recovery (treatment) mechanism.

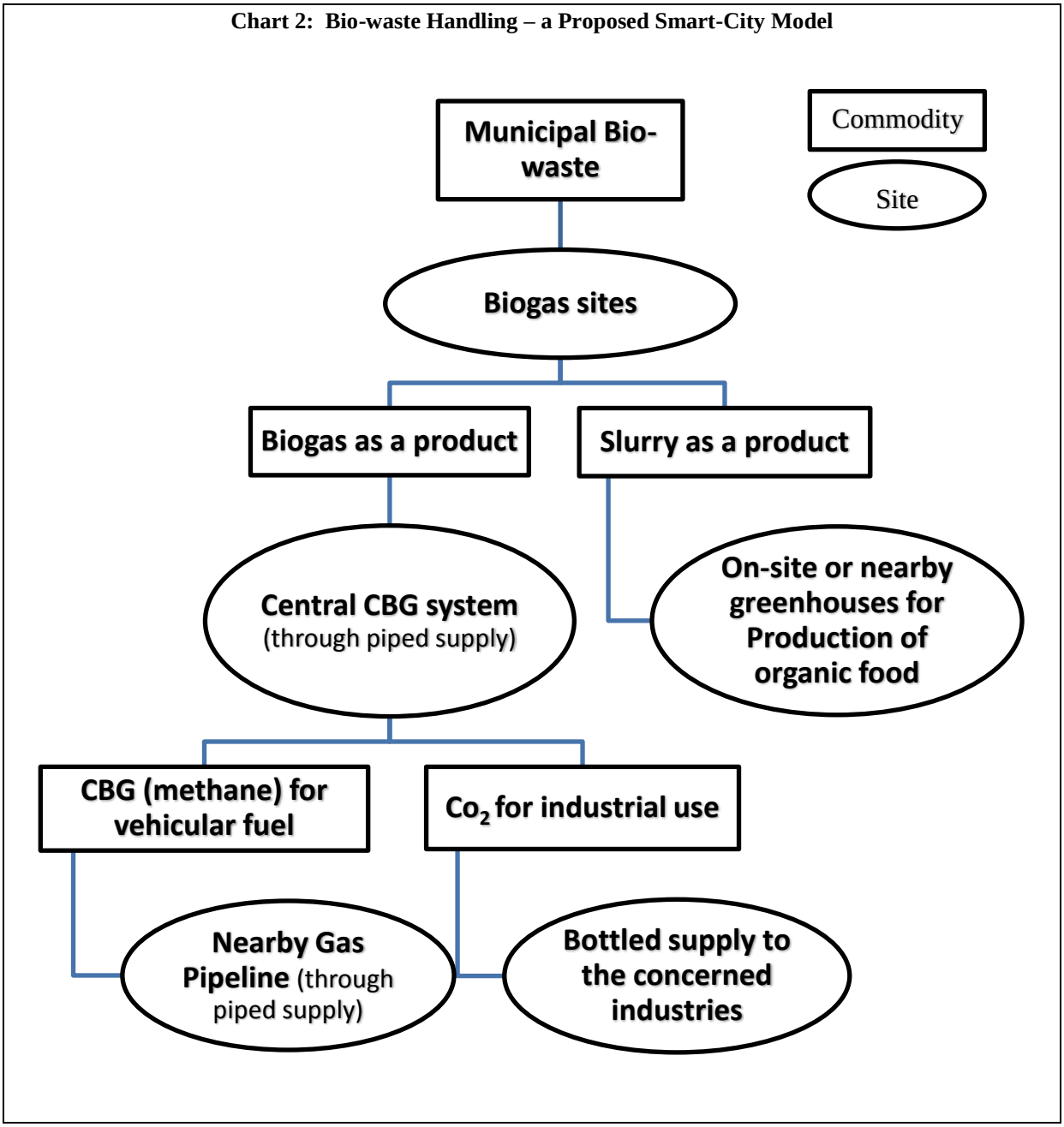
Requirement 2- Choosing optimum location for treatment plants: When it is decided that treatment will be done, the most appropriate facility location among specific possible available sites (when we have options to choose), should be recognised on the basis of geographic information system (GIS) based models because transportation cost is the main cost to be taken care in this case.

Requirement 3- Efficient management: Efficient technical and non- technical management, based on expert knowledge, is required for optimum and long term sustainable solutions. It is required both in planning (before establishing) and commissioning (after establishing) periods of the system.

3.2.1.4. Bio-waste Handling - a Proposed Smart-City Model

Chart 2 presents the process of bio-waste handling in this smart city model. In further section, the model clarifies the process more with the explanation of smart-city model in the case of Delhi.

Chart 2: Bio-waste Handling – a Proposed Smart-City Model



Explanation**:** The model is presented in 3 major steps –

Step 1 (source to facility 1): Source segregated municipal bio-waste should be transferred to chosen biogas sites (which are decentralised from city point of view but centralised from zonal context). Biogas plants will provide two products – biogas and bio-fertiliser.

Step 2 (facility 1 to facility 2): Now biogas will be supplied to a common biogas refining centre, which will cater the needs of a few biogas plants (the exact number of biogas plants will be decided as per city requirements). The supply of biogas from "Biogas Plants" to "Central CBG system" will be done through piped supply. Central CBG plant can or cannot be attached with any of the biogas plant. The piped supply needs one time investment and hence curtail the daily transportation needs which are required in the absence of piped supply option. Besides, through setting one refining plant for many biogas plants, biogas plants can be focussed only on efficient biogas generation (otherwise the plants have to focus on both the processes) while refining centre can focus on refining process. It will rule out the problem of unnecessary scattered efforts and investment; and will provide the benefits of scale, and benefits of division of labour.

Step 3 (facility 2 to demand point): Now central CBG system will purify the gas and will capture compressed bio-methane, and CO_2. Bio-methane will be supplied (through piped supply) to the nearest natural gas pipeline or station. CO_2 will be bottled and supplied to the concerned industries.

Digested slurry (bio-fertiliser) from the biogas plants should be used in on-site or nearby green-houses to produce organic vegetables and fruits. The greenhouse can also help interested people to have their own kitchen gardens in pots, by making available them plants and bio-fertiliser. Greenhouses operations based on expert knowledge and techniques will provide professional output. These greenhouses offer a chance for making cities self-sustainable by supplying of organic food. It will also increase our total output of fruits and vegetable which can further increase the supply of supply of fruits and vegetables for processing industry as presently only about 2 -3 % of fruits and vegetables are processed in India. The main reason behind this meagre processing is that due to large population, almost all the amount got demanded in the markets for consumer use, and hence only a small fraction is left for processing. However, establishing greenhouses can be done in 2nd shift if it is not possible to take it simultaneously with bio-methane system in the city. But simultaneous functioning of greenhouses is the part of the model as it will use bio-fertiliser in efficient way without the fear for lack of takers, and will introduce the useful concept of organic urban agriculture.

Resource recovery services can be used either through internal appointments or via outsourcing. Though there are many examples in the world where owner-developer agreements are doing well; however, for sustainability and optimality, costs and risks of outsourcing (disputes, disruptions in switching the outsourcing company) can't be ignored. The same can be done for green-houses too. Besides, in the case of green-houses, skills can be imparted to the people who are interested in this investment opportunity. Local people can be turned and supported towards greenhouse entrepreneurships. However, for sustainable efficient functioning, regular expert observation and guidance is highly important for CBG system as well as for greenhouses.

3.2.2. The Model in Delhi

This model for Delhi is based on assumed optimum locations but not actual optimum locations as actual optimum locations depends upon available places which further depends upon many factors and needs to be decided at the time of implementation of model.Now the smart-city model for bio-waste handling in Delhi is explained below with the help of an imaginary example**.**

Let's assume that 14 sites are recognised for biogas plants and thereafter 4 sites are recognised for central CBG plants in Delhi, and these plants cater all the Delhi for their municipal bio-waste treatment. The model presents that from 14 assumed biogas plants sites - 6 assumed locations are in North MCD area, 4 assumed locations are in South MCD area, and 2 assumed locations are in East MCD area, 1 in NDMC area, and 1 in DCB area. Now there are 4 identified optimum assumed sites for Central CBGs. These 4 assumed CBGs cater the purifying and compressing need of 14 assumed biogas plants. Every CBG supplies its purified and compressed methane to nearby natural gas pipeline. The 14 Biogas plants supply it bio-fertiliser to onsite or nearby greenhouses for organic farming.

Therefore, this model proposes the framework of smart-city model for bio-waste management system in general, and for Delhi in particular.

IV. Conclusion

The paper concludes that when countries' are in the mire of waste management, and are trying to work actively towards it; the proposed model can change the bio-waste management perspective in the world cities by presenting better and doable policy perspective for a long term sustainable solution to green, healthy and self-sufficient cities. (Manisha, 2021), titled "Biogas perspectives from Bio-Waste Management in Rural India – Part I", presents the perspectives for rural India.

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