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Sustainable Municipal Solid Waste Management - A case study of Kanpur, India

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Abstract

Municipal solid waste generation and disposal is a problem not only in India but all over the world. Presently majority of such waste is being dumped indiscriminately over vacant lands causing problems of odor, methane generation leading to air pollution, leaching effect polluting ground water and runoff polluting water bodies. Technological options are available to treat this solid waste and convert it into usable products but the biggest problem is its segregation preferably at the source of generation or even at the disposal area. Municipal solid waste generated in India consists of 15 percent non biodegradable which has high calorific contents and can be converted into power generation. Remaining 85 percent is degradable which can either be converted into compost or bio fuels. Under the present context, sustainable municipal waste management strategy needs to be evolved and put in place with effective implementation to address the issue of environmental pollution. An attempt has therefore been made by the authors of the present paper to take up a case study of Kanpur, India for managing such wastes having sustainable approach. The authors have worked out trends of population starting from the year 1951 and projected to 2051. Similarly waste generation trends established on the lines of population. An effort has also been made as to how much compost, bio fuel and power can be generated along with economic value to make it sustainable on a time scale.

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Introduction

The increase in population and resulting modernization and urbanization throughout the world has resulted in the drastic increase in the production of waste. The management of the solid waste has become a universal issue due to the rate at which dumping sites are getting piled up with waste. The openly dumping of wastes or burning the waste has lead to a lot of greenhouse gases emission and climatic changes. Moreover, the unmanaged dumped waste not only effects the environment but also creates an impact on the human health. Kaza et al (2018) predicted that by the year 2050, the annual production of the waste would account upto 3.40 billion tons which is approximately 1.7 times present day annual production of waste [1].

India is the second most populated country in the world and the amount of waste generation has increased substantially over a decade. As per the reports, 277 million tonnes of the waste is produced in our country in the year 2016. It is expected that around 387.8 and 543.3 million tonnes waste will be produced by the year 2030 and 2050 respectively. There are various existing technologies which can be used for the conversion of the waste to the usable products. But, there is a need of certain guidelines that needs to be followed within the country which must include the proper collection, segregation, disposal of the municipal solid waste[2]. Proper system is thus mandatory as it not only reduces the dependence on landfills but also lead to the reduction in utilization of the energy resources, health issues and environmental impacts [3].

Henry et al (2006) studied the MSWM of Kenya, which is a low-income developing country. The improper and unplanned dumping of the wastes by the citizens of the country on the river banks and roads has resulted in the environmental and economic problems to the nearby places. The increasing urbanization, inadequate availability of the collection vehicles and poor management of waste disposal are certain factors which have made the planning of the waste management the need of an hour in such developing nations [4].

Mumbai is one of the largest metropolitan cities in India and hence the amount of waste is proportional to the population of the city. Sarika (2006) suggested two major alternative methods that can be incorporated for a better management in the disposal of waste. Public private partnership and community participation are the two suggested alternatives out of which the most viable and the economic is the one which involves community participation in the management of the waste (5).On the other hand various developed nations such as Japan and USA have analysed the problem and found pragmatic solutions to it in comparison the developing and the under-developed nations. The changes in the strategy over a time period and adoption of recycle, reuse and renew policy have resulted in this change. Nevertheless, India yet has to develop some comprehensive structure for the management of the solidwaste [6].The present study gains importance as it considers the enormous waste production in the Kanpur city and hence, the need of the sustainable and economic waste management system in the city.

Transformation of Waste into Usable Products

There are several technological options available and presently in use to transform waste into usable products in the form of compost, bio fuels, and energy. Some of these technologies in brief are described hereunder**:**

Transformation of Waste to Compost

There are various technological options available for the conversion of the waste produced into the usable products. This conversion of the huge amounts of waste produced in the city is mandatory as it causes environmental as well as health issues. The various technologies available for composting are as follows:

- Closed Bins method
- Pit Composting Method
- Open Bins Method
- Tumblers Method
- Piling Method
- Vermicomposting Method

Out of the above listed methods, one method of vermi composting is being briefly described as under:

Vermicomposting Method

This is one of the most used methods in India and is an easy method to covert the waste into compost. This method involves burying of the food waste in a pit which is enriched with earthworms. The composting can also be done at our homes by placing the 15-gallons container underneath the sink in our kitchens. Red Wigglers are good for composting in our houses. Then, for harvesting the manufactured compost, move the entire waste to one side of the container and then add new waste to be composted in the same bin. On doing so, the insects migrate to the fleshly added waste over a period of few weeks [7]. Figure 1 shows the finished product after Vermicomposting.

Advantages

- It is one an easiest method of composting.
- It is also best suited for the small spaces.
- Materials used are tidy and do not create a mess.

Disadvantages

There might be fruit flies in the area if the waste is not buried properly.

Transformation of Waste to Energy

The production of energy from waste involves the usage of the waste material as a fuel. It is usually done in a closed area and is properly mixed before the waste is combusted. Then, the negative air flow is given in order to remove the dust particles from the combustion chamber. After the preparation, the mixed waste is added to the chamber and the waste is exposed to the ample ample of oxygen and fire so that it burns up completely. The burning waste (fuel) results in the formation of steam that in turns rotates the turbine to generate electricity. This is very advantageous as it would reduce the dumped waste to an extent of 90% and also decrease in the greenhouse gas emission upto one ton for the same amount of waste(8). The waste to energy cycle is depicted in the Figure 2.

Sustainable Waste Management-Case Study of Kanpur

An attempt has been made to workout sustainable municipal solid waste management for the city of Kanpur, India. In the present context, the population trends with forecast of population for the year 2051 were estimated along with solid waste generation. An effort has also been made to estimate the quantity of compost, bio fuel and energy that can be produced from the generation of solid waste during different years. In order to have sustainability, economic dimension in terms of the possible financial cost of compost, bio fuel and energy were also estimated. The salient steps taken are as under**:**

Population Trends and Projections of Kanpur

The population of India is increasing at an alarming rate and the statistics reveal that our country is the second most populated country in the world. This increasing rate has made the population forecasting an important tool. The population data from the year 1951 to 2011 was collected and was then forecasted for 2021, 2031, 2041 and 2051. Arithmetic mean, geometric Mean and incremental Increase are the three methods that have been used for projecting the population of Kanpur city. The population calculated from the arithmetic mean method is assumed to be underestimated whereas over-estimated when calculated using Geometric mean method. Thus, an Average value is calculated which will be further used for calculating the waste generation in the city. Table 1, Figure 3 and Figure 4 clearly shows the population trends till 2051.

Solid Waste Generation Trends and Projections of Kanpur

The generating of the waste in the cities depends on various factors such as living standards, eating habits and extent of commercial activities. For the prediction of solid waste generated in Kanpur, the waste production assumed is 1 kg/capita/day for the year 2021. This is higher than the general value assumed as it takes into consideration the migrant laborers. Due to the migrations, changes in the lifestyle and increasing urbanization the waste production in kg/capita/day have increased by 0.1for the coming decades. The solid waste generation over past decades and for the upcoming decades is mentioned in Table 2 and depicted in Figure 5.

Transformation Waste to Compost and Energy- A Case Study of Kanpur

Various reports were analyzed and the following deductions were made for the calculations of the compost, bio-fuel and energy produced from 1000 tons of waste. In India, The amount of highly calorific value waste accounts to only 15% of the total waste which can be incinerated inorder to produce energy.

Figure 1. Vermicomposting

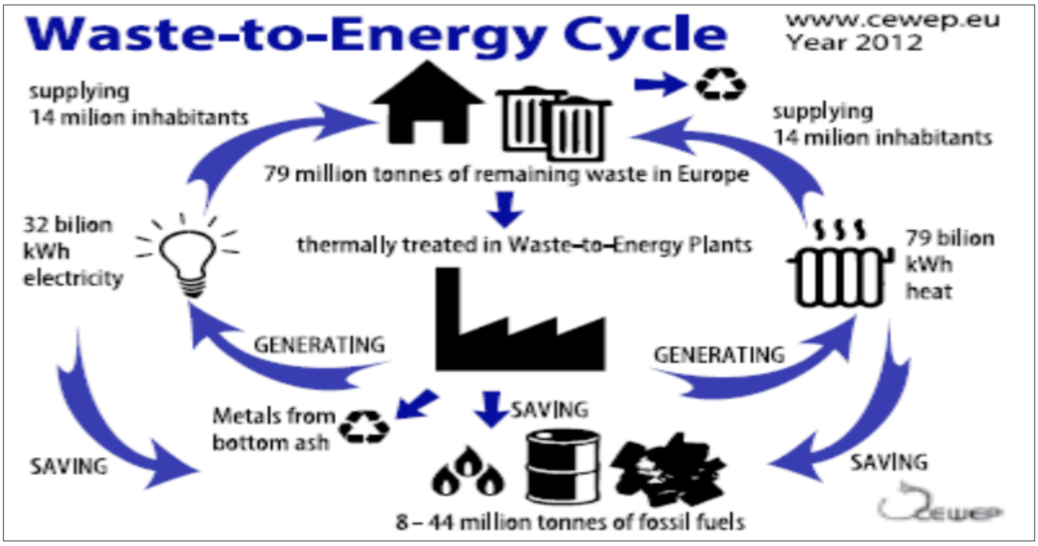

Figure 2. Waste-to-Energy Cycle

Table 1. Population trends and forecasting of Kanpur

Year	Arithmetic Mean	Geometric Mean	Incremental Increase	Average
1951				1,325,778
1961				1,647,150
1971				2,099,164
1981				2,665191
1991				3,253,572
2001				4,167,999
2011				4,581,268
2021	5,123850	5,640,513	5,142,229	5,302,197
2031	5,666,431	6,944,669	5,721,570	6,110,890
2041	6,209,013	8,550,361	6,319,289	7,026,221
2051	6,751,595	10,527,310	6,935,389	8,071,431

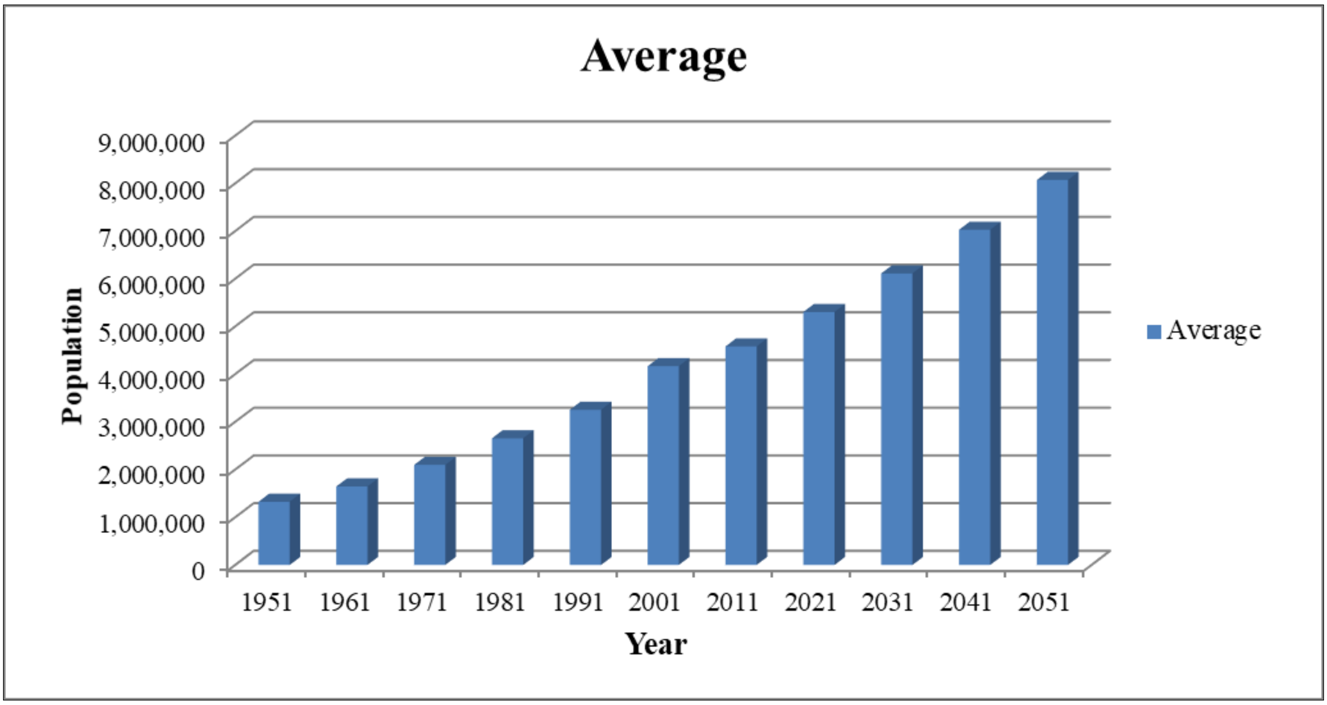

Figure 3. Showing population trends and forecasting

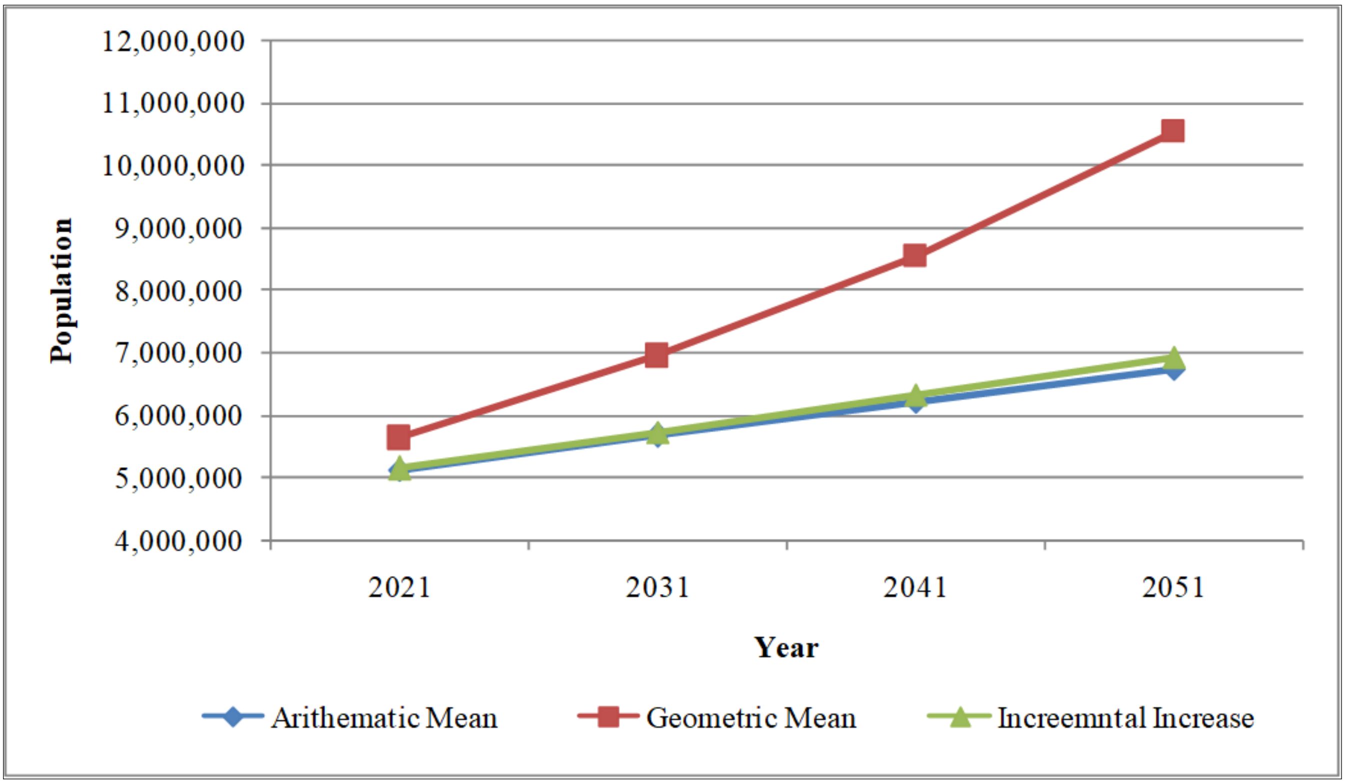

Figure 4. Population forecasting trends

Table 2. Showing solid waste generation trends and forecasting

Year	Population	Assumed Waste Production (kg/per/capita/day)	Waste Produced per day (in kg)	Waste Produced per day (in tones)	Waste Produced per Year (in tones)
1951	13,25,778	0.3	3,97,733	398	1,45,173
1961	16,47,150	0.4	6,58,860	659	2,40,484
1971	20,99,164	0.5	10,49,582	1,050	3,83,097
1981	26,55,191	0.6	15,93,115	1,593	5,81,487
1991	32,53,572	0.7	22,77,500	2,278	8,31,288
2001	41,67,999	0.8	33,34,399	3,334	12,17,056
2011	45,81,268	0.9	41,23,141	4,123	15,04,947
2021	53,02,197	1	53,02,197	5,302	19,35,302
2031	61,10,890	1.1	67,21,979	6,722	24,55,522
2041	70,26,221	1.2	84,31,465	8,431	30,77,485
2051	80,71,431	1.3	1,04,92,860	10,493	38,29,894

Figure 5. Showing solid waste generation trends and forecasting

Accordingly, based on assumptions, following can be produced from 1000 tons of waste

- BIO GAS PRODUCTION =21.43 m^3
- 100 tons per day= 1mw power generation
- 1000 tons per day=10 mw power generation
- Compost = 81.43 tons

Figure 6, 7 and 8 clearly depicts the compost, bio-fuel and energy that can be produced for the coming decades. Table 3 shows the waste to compost, energy and bio-fuel production.

Economic Dimensions

The following assumptions have been made in order to calculate the total economic value.

Per ton cost of compost production as Rupees 10 which would increase in upcoming decades due to the increase in the waste generation, Hence, Rs. 5 increase have been taken per decade.

- Cost of bio-fuel per liter = Rs. 45
- Cost of per unit Power = Rs. 4

Table 4 shows the economic value calculation on converting waste to compost, energy and bio-fuel. Figure 9 and Figure 10 depicts the revenue generation from compost, bio-fuel and energy production.

With the emerging problem of indiscriminate disposal of municipal solid waste and consequential environmental pollution to a great extent, there is an urgent need to demonstrate environmentally sustainable management of municipal solid waste. Such a management strategy should be formulated for the next 30 years to make sustainable on a time scale. The present paper highlights a case study of Kanpur wherein trends of population and solid waste generation from 1951 to 2051 were estimated. Technological options were also briefly described for transformation of waste to usable products. Accordingly, it has been estimated that how much quantity of compost, bio fuels and energy that can be produced from waste generated in Kanpur on a time scale coupled with economic value likely to be generated from such products. However, segregation of waste preferably at source or otherwise at the disposal site should be carried out to make best use of degradable and non degradable wastes separately. Moreover, effective strategy formulation, commitments, use of best technological options and implementation would surely achieve environmentally sustainable management of municipal waste.

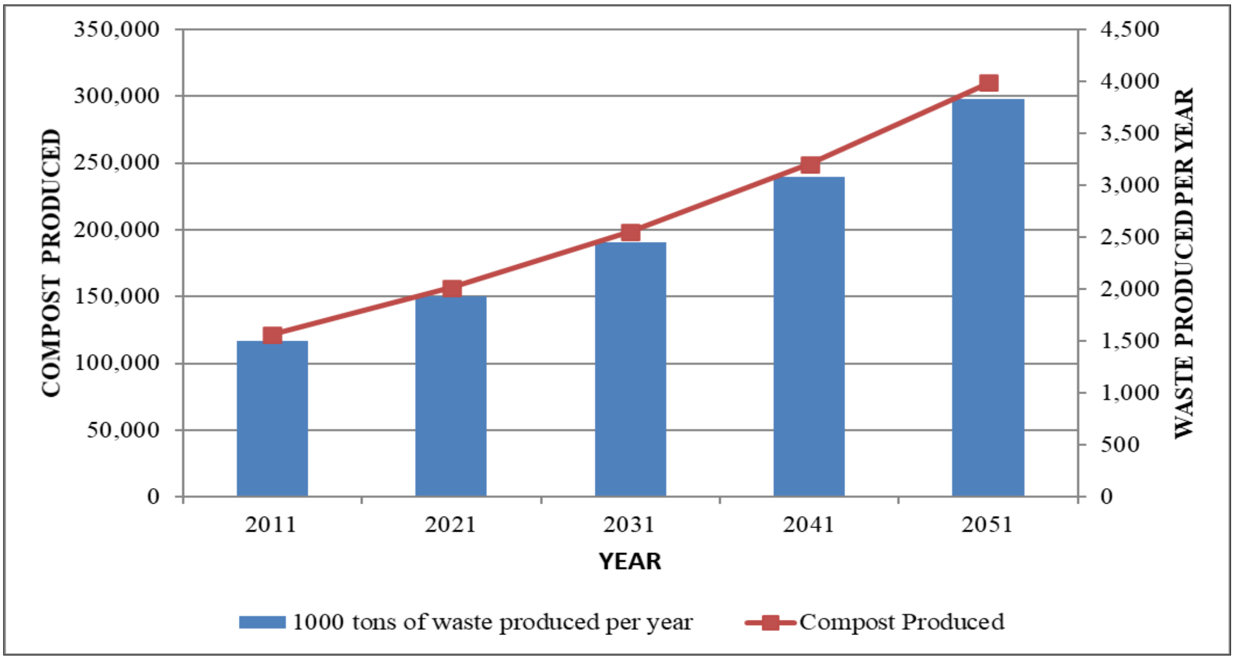

Figure 6. Showing waste to compost production

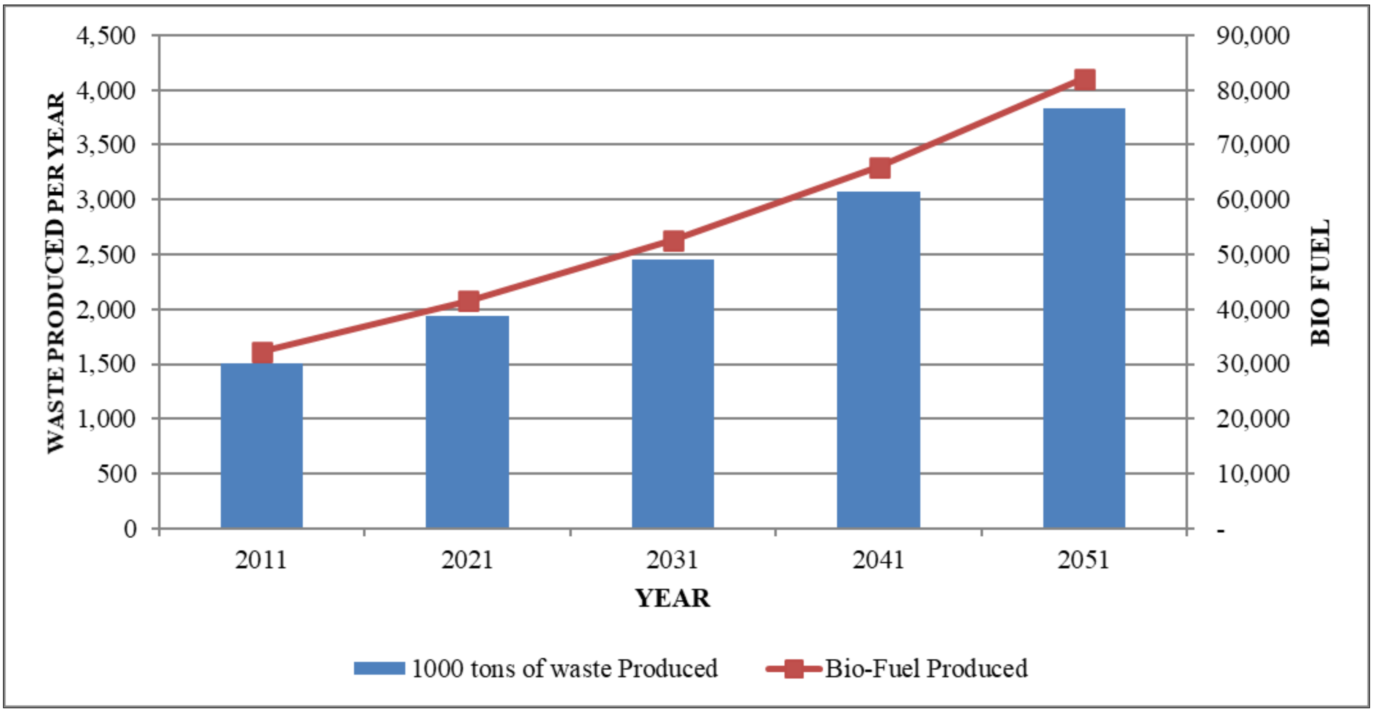

Figure 7. Showing waste to bio-fuel production

Table 3. Showing Waste to Compost, Bio-fuel and Energy Production

Years	Waste quantity in 1000 tons/day	Waste quantity in 1000 Tons/year	Compost production in tons /year	Bio fuel production in m^3/ year	Energy production in MW/day
2011	4	1,505	1,21,901	32,252	6
2021	5	1,935	1,56,759	41,467	8
2031	7	2,454	1,98,735	52,589	11
2041	8	3,077	2,49,276	65,940	12
2051	10	3,830	3,10,221	82,077	15

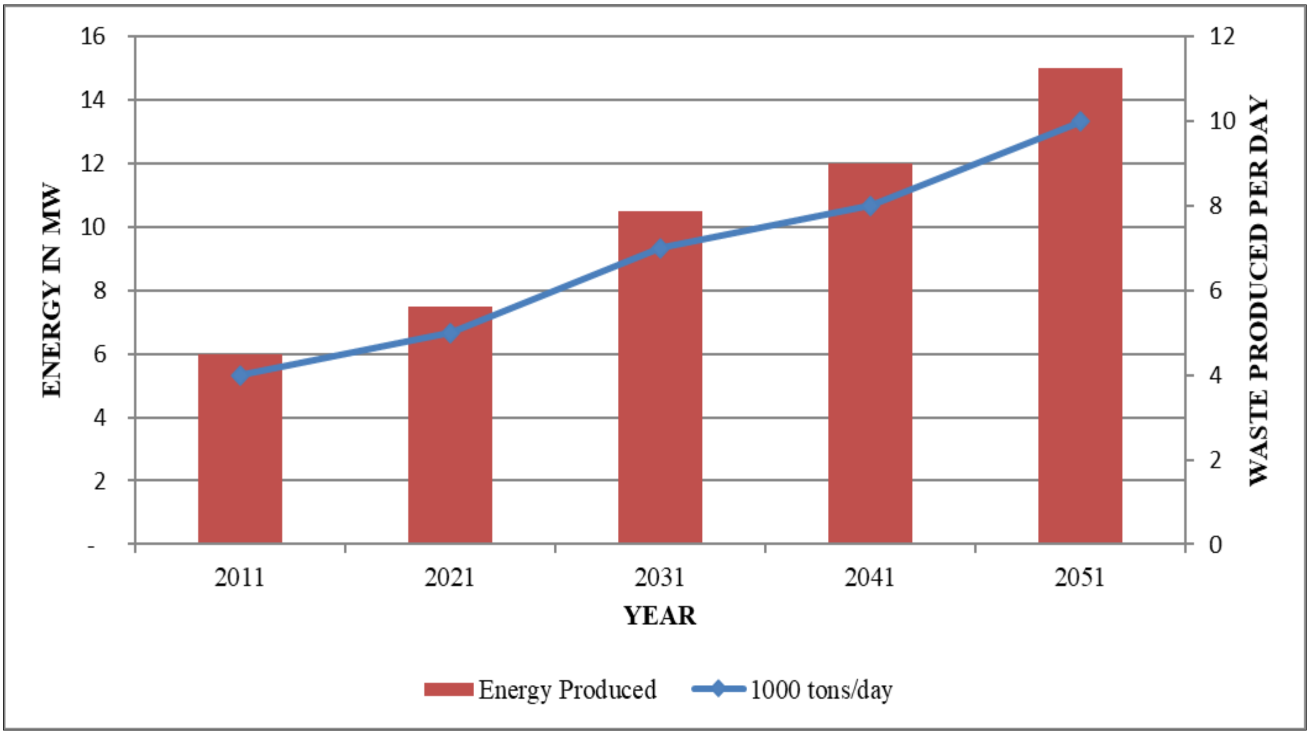

Figure 8. Showing waste to energy production

Table 4. Showing the Economic Value generation from waste

Years	Compost quantity in tons/year	Value in rupees	Bio fuels quantity in m^3/year	Value in rupees	Power generation in MW/day	Value in rupees
2011	121,901	12,19,007	32,252	14,51,347	6	24
2021	156,759	15,67,595	41,467	18,66,077	8	53
2031	198,735	29,81,030	52,589	23,66,515	11	74
2041	249,276	49,85,525	65,940	29,67,307	12	84
2051	310,221	77,55,535	82,077	36,93,461	15	105

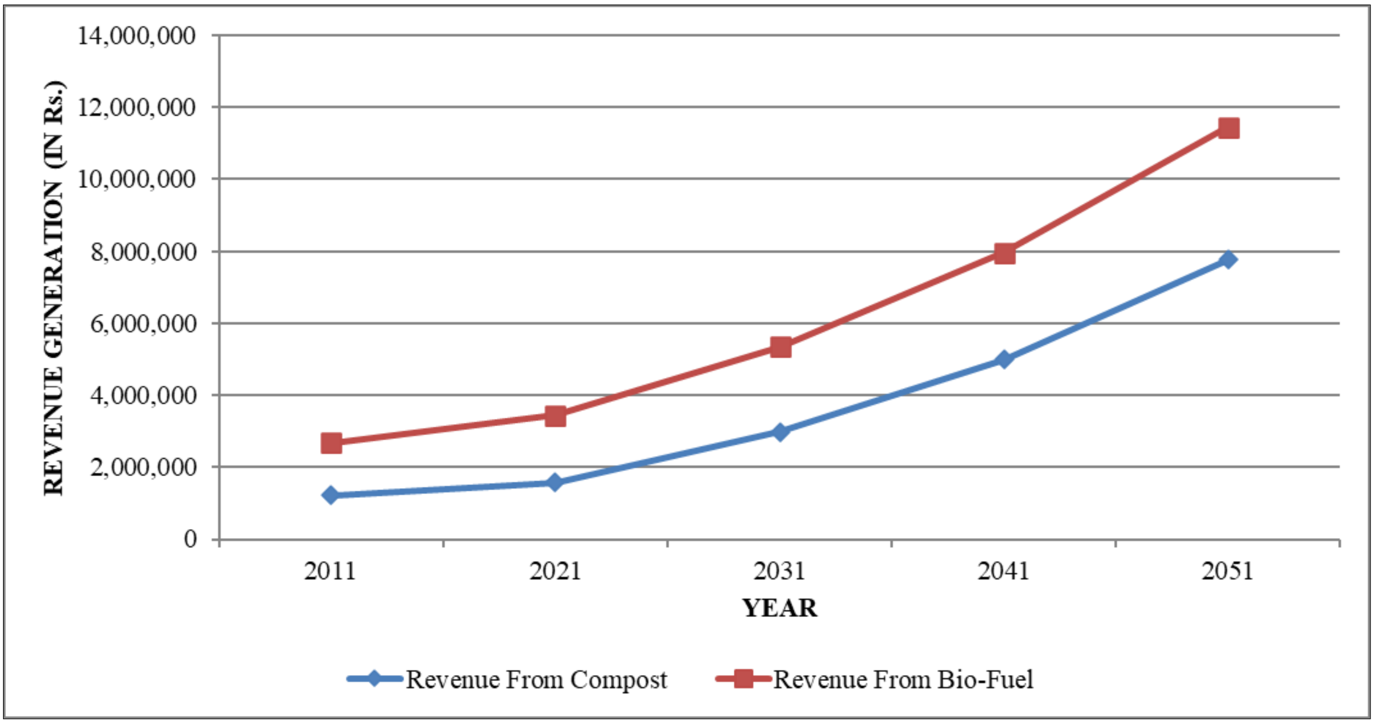

Figure 9. Revenue Generation from Compost And Bio-Fuel Production

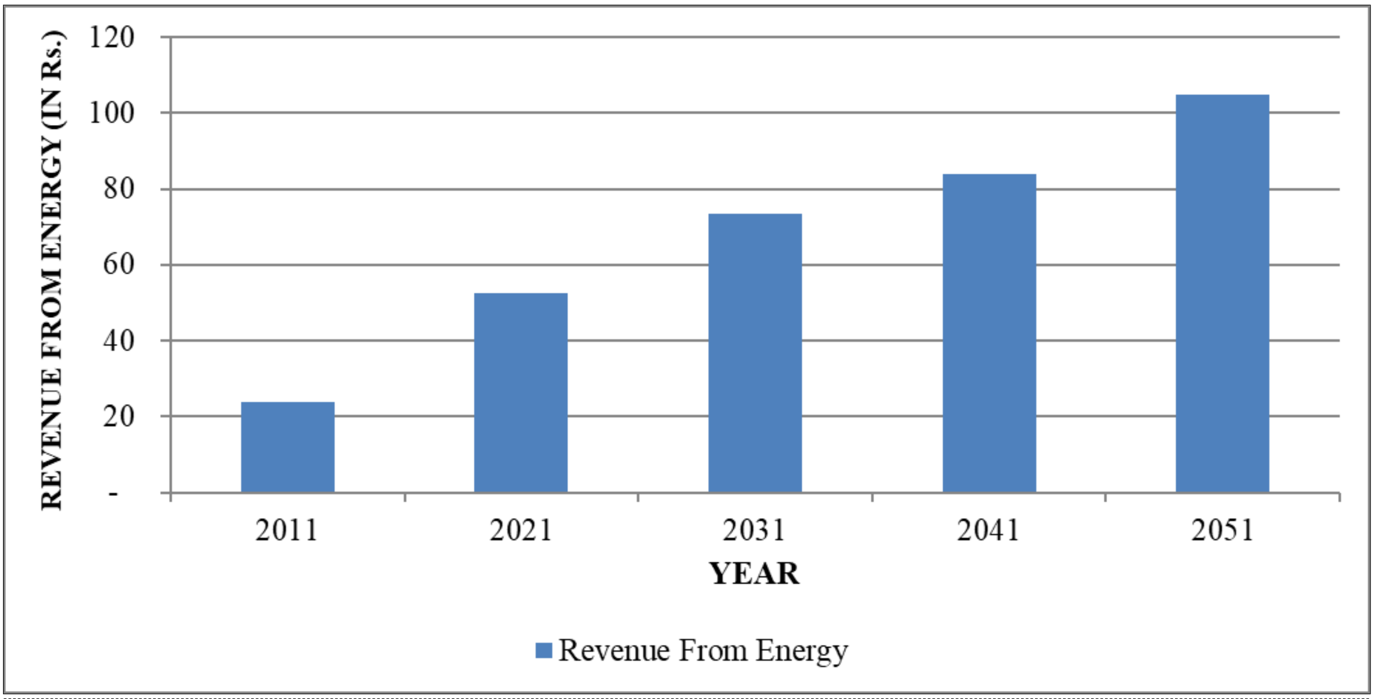

Figure 10. Revenue Generation from Energy Production

Conclusion

With the emerging problem of indiscriminate disposal of municipal solid waste and consequential environmental pollution to a great extent, there is an urgent need to demonstrate environmentally sustainable management of municipal solid waste. Such a management strategy should be formulated for the next 30 years to make sustainable on a time scale. The present paper highlights a case study of Kanpur wherein trends of population and solid waste generation from 1951 to 2051 were estimated. Technological options were also briefly described for transformation of waste to usable products. Accordingly, it has been estimated that how much quantity of compost, bio fuels and energy that can be produced from waste generated in Kanpur on a time scale coupled with economic value likely to be generated from such products. However, segregation of waste preferably at source or otherwise at the disposal site should be carried out to make best use of degradable and non degradable wastes separately. Moreover, effective strategy formulation, commitments, use of best technological options and implementation would surely achieve environmentally sustainable management of municipal waste.

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