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Production of energy from waste materials in India

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Abstract
Renewable waste materials from agriculture, (crop debris, livestock wastes, abattoir wastes, bulk forest wastes, etc.) industries (paper and pulp, bagasse, press mud, contaminated petroleum or synthetic oil, water in oil, oil in water, tarry residue waste, coal tar, heavy metals, a metallic chemical element both lethal and dangerous) and domestic sources(bottles, cans, clothing, compost, disposables, food packaging, food scraps, newspapers and magazines and yard trimmings) are convertible to useful energy forms like bio-hydrogen, biogas, bio-alcohols, etc., through WTE routes for sustainable growth of the world. Total solid wastes are produced annually by products through industry, municipal, agricultural, mining and other processes in the country. China and India play a vital role to add to worldwide waste generation. The cumulative of renewable energy in India as of 31.12.2018 was 74.08166 GW, and the WTE have contributed 0.18% only. Wind energy contributed 47.43%, solar 34.03%, biomass power/cogeneration 12.25%, small hydro 6.098%. Biomass power/cogeneration and WTE are classified as bio power category in India. The plants can be constructed in the area of waste availability if needed. The expected capacity is 20 MW, and the financial support of 81791 Million USD (60 Million INR).

Keywords: renewable waste, industries, sustainable growth, WTE, agricultural, mining and energy

Introduction

The present pattern of living has changed with a major increase within the number of industries and substantial expansion within the population living within the geographical region. Urban, municipal and industrial wastes could even be beneficial sources of energy when guaranteed safe disposal. A number of the foremost forms of solid wastes include municipal solid waste (MSW), hazardous wastes, industrial wastes, agricultural wastes, and bio-medical wastes. The growing waste generation and its unscientific disposal methods are heading to the discharge of GHG (methane, CO2, etc.) within the atmosphere. Safe waste management is crucial for the green economy and sustainability intentions of both government and also the private sectors. The energy demand specifically, the electricity generation, has resulted within the creation of fuel based power plants that allow abundant greenhouse gas/carbon emission into the environment which has resulted in heating and changes in weather conditions [1]. Renewable waste materials from agriculture, (crop debris, livestock wastes, abattoir wastes, bulk forest wastes, etc.) [2, 3] industries (paper and pulp, bagasse, press mud, contaminated petroleum or synthetic oil, water in oil, oil in water, tarry residue waste, coal tar, heavy metals, a metallic element both lethal and dangerous) [4, 5] and domestic sources(bottles, cans, clothing, compost, disposables, food packaging, food scraps, newspapers and magazines and yard trimmings) [6] are convertible to useful energy forms like bio-hydrogen, biogas [7], bio-alcohols, etc., through WTE routes for sustainable growth of the planet. Total solid wastes are being produced annually as by products through industry, municipal, agricultural, mining and other processes within the country [8]. The general public health concerns include infections within the lungs, nose, throat, sinuses, chronic lung disease, and breathing difficulties, infections because of a bacteria, hemoglobin deficiency, decreased resistance to diseases and allergies leading to poor health among the general public [9]. The biomedical wastes are managed by various technologies like incineration, autoclaving, etc. WTE is anticipated to determine robust growth and positive policy support by the government going ahead as conventional fuel power projects are meeting increasing transition uncertainties. There is an ever-increasing need for energy despite the increasing costs of oil & other fossil fuels with depletion of fossil fuels. The country is bestowed with several types of renewable energy sources like solar, biomass, small hydro, wind, and biogas. Hence we are going analyse the assembly of energy from the waste materials in India.

Objectives

Analysis of the waste generation
Analysis of waste management and energy production

Result

Population Growth and Waste Generation

As of November 2017, the waste generation was around 53 Million metric tons per year and 145626 tons per day in India. The country produced 31.63 Million MT in the year 2001, 47.30 Million MT in the year 2011 and 71.15 Million MT by 2021, which is shown in Table -1

Table 1: Predicted Population increase and overall impact on waste production [10]

Year	population (Billion)	per capita generation (Gram per day)	Total waste generation (Million MT per year)
2001	0.1973	439	31.63
2011	0.2601	498	47.30
2021	0.3428	569	71.15

State-wise Solid Waste Generation in Urban Areas

The state wise solid waste production (Table-2) in urban regions, as of November 2017. It shows that Maharashtra (8.238 MT/annum) generates the highest waste, followed by Tamilnadu (5.675 MT/annum), Uttar Pradesh, Gujarat, and New Delhi. In Maharashtra, the critical industries generating wastes, which have tremendous potential for power production, include sugarcane press mud, paper & pulp, distilleries, poultry, dairy industry waste, abattoir, etc. The total estimate of energy potential from industrial wastes are 350 MW (MNRE estimation was 287 MW).

Table 2: State-wise Solid Waste Generation in urban areas, MNRE, November 2017 [11]

No	State	Total waste generation per day metric ton per day (MT/D)	Total waste generation per day million MT /annum
1	Andhra Pradesh	6525	2.382
2	Andaman & Nicobar Islands	115	0.042
3	Arunachal Pradesh	181	0.066
4	Assam	1134	0.414
5	Bihar	1192	0.435
6	Chandigarh UT	340	0.124
7	Chhattisgarh	1959	0.715
8	Daman & Diu	23	0.008
9	Dadra & Nagar Haveli	58	0.021
10	NCT of Delhi	10500	3.833
11	Goa	240	0.088
12	Gujarat	10145	3.703
13	Haryana	4514	1.648
14	Himachal Pradesh	342	0.125
15	Jammu & Kashmir	1792	0.654
16	Jharkhand	2451	0.895
17	Karnataka	10000	3.650
18	Kerala	1576	0.575
19	Madhya Pradesh	6424	2.345
20	Maharashtra	22570	8.238
21	Manipur	176	0.064
22	Meghalaya	268	0.098
23	Mizoram	201	0.073
24	Nagaland	342 5	0.12
25	Odisha	2460	0.898
26	Puducherry UT	495	0.181
27	Punjab	4100	1.497
28	Rajasthan	6,500	2.373
29	Sikkim	89	0.032
30	Tamil Nadu	15547	5.675
31	Telangana	7371	2.690
32	Tripura	421	0.154
33	Uttar Pradesh	15500	5.658
34	Uttarakhand	1400	0.511
35	West Bengal	8675	3.166
	Total/ Average	145626	53.153

The state-wise WTE potential

The state-wise WTE potential (Table-3) of the country, the estimated potential of WTE is 2.554 GW as per MNRE annual report 2016-17. Highest potential of WTE state is Maharashtra (0.287 GW) least is Himachal Pradesh (0.002 GW).

Table 3: State-wise Waste to Energy Potential in India:

No.	State/Union Territory	Potential (GW)
1	Andhra Pradesh	0.123
2	Assam	0.008
3	Bihar	0.073
4	Chandigarh	0.024
5	Delhi	0.131
6	Gujarat	0.112
7	Haryana	0.024
8	Himachal Pradesh	0.002
9	Jharkhand	0.010
10	Kerala	0.036
11	Madhya Pradesh	0.078
12	Maharashtra	0.287
13	Manipur	0.002

14	Meghalaya	0.002
15	Mizoram	0.002
16	Orissa	0.022
17	Pondicherry	0.003
18	Punjab	0.045
19	Rajasthan	0.062
20	Tamil Nadu	0.151
21	Tripura	0.002
22	Uttar Pradesh	0.176
23	Uttarakhand	0.005
24	West Bengal	0.148
25	Others	1.022
	Total	2.554

Maharashtra produces more waste, and the possibility of WTE is high. The state is second populated in the country with 9% of the total population next to Uttar Pradesh with 16%. Maharashtra stands first in a large number of industries such as textile, food processing, cement, chemical, steel industries next to Punjab, Tamilnadu and West Bengal. The WTE potential of this state is 0.287 GW followed by Uttar Pradesh with 0.176 GW and Tamilnadu with 0.148 GW. The state-wise potential (Table - 4) of energy from urban and industrial wastes. There is a potential of about 1700 MW (1.7 GW) from urban waste as per MNRE estimation. Out of this 1700 MW of potential, 1500 MW (1.5 GW) is from MSW and 225 MW (0.225 GW) from sewage and about 1300 MW from industrial waste.

Table 4: Energy Recovery Potential from Urban and Industrial Wastes: MNRE 2011 [12]

No.	State/Union Territory	From Liquid Wastes* (GW)	From Solid Wastes (GW)	Total (GW)
1	Andhra Pradesh	0.016	0.107	0.123
2	Assam	0.002	0.006	0.008
3	Bihar	0.006	0.067	0.073
4	Chandigarh	0.001	0.005	0.006
5	Chhattisgarh	0.002	0.022	0.024
6	Delhi	0.02	0.111	0.131
7	Gujarat	0.014	0.098	0.112
8	Haryana	0.006	0.018	0.024
9	Himachal Pradesh	0.0005	0.001	0.0015
10	Jharkhand	0.002	0.008	0.01
11	Karnataka	0.026	0.125	0.151
12	Kerala	0.004	0.032	0.036
13	Madhya Pradesh	0.01	0.068	0.078
14	Maharashtra	0.037	0.25	0.287
15	Manipur	0.0005	0.0015	0.002
16	Meghalaya	0.0005	0.0015	0.002
17	Mizoram	0.0005	0.001	0.0015
18	Orissa	0.003	0.019	0.022
19	Pondicherry	0.0005	0.002	0.0025
20	Punjab	0.006	0.039	0.045
21	Rajasthan	0.009	0.053	0.062
22	Tamil Nadu	0.014	0.137	0.151
23	Tripura	0.0005	0.001	0.0015
24	Uttar Pradesh	0.022	0.154	0.176
25	Uttaranchal	0.001	0.004	0.005
26	West Bengal	0.022	0.126	0.148

Energy recovery from MSW- State wise estimated potential

The solid waste generated from the towns and cities in the country has present potential to create the power of approximately 500 MW (0.5 GW, the State-wise potential for power generation from MSW is shown in Table -5 [13].

Table 5: The State-wise potential for power generation from MSW: MNRE 2014. [14]

No.	State/Union Territory	Power Equivalent (GW)
1	Andaman & Nicobar	0.001
2	Andhra Pradesh	0.043
3	Arunachal Pradesh	0.001
4	Assam	0.002
5	Bihar	0.006
6	Chandigarh	0.001
7	Chhattisgarh	0.007
8	Delhi	0.028

9	Goa	0.001
10	Gujarat	0.031
11	Haryana	0.013
12	Himachal Pradesh	0.006
13	Jammu & Kashmir	0.007
14	Jharkhand	0.017
15	Karnataka	0.035
16	Kerala	0.006
17	Madhya Pradesh	0.019
18	Maharashtra	0.062
19	Manipur	0.001
20	Meghalaya	0.001
21	Mizoram	0.002
22	Nagaland	0.001
23	Orissa	0.009
24	Pondicherry	0.002
25	Punjab	0.015
26	Rajasthan	0.019
27	Sikkim	0.000
28	Tamil Nadu	0.053
29	Tripura	0.001
30	Uttar Pradesh	0.072
31	Uttaranchal	0.005
32	West Bengal	0.032
	Total	0.500

Electricity Generation from Waste to Energy Sources

The generation of electricity (Table -6) (MU) from WTE sources, with the help of suitable technology, India can generate electricity every month using WTE. Table -7 shows the comparison of Electricity generation from various renewable energy sources for the year 2018 (April 2018-Dec 2018). It is observed that wind generate (45478.90) more electricity than other renewable sources followed by solar.

Table 6: The generation of electricity (MU) from waste to energy sources [15]

MU	2014-2015	2015-2016	2016-2017	2017-2018	2018-2019
April	35.220	22.450	15.750	34.610	38.640
May	32.770	28.280	16.350	27.270	39.030
June	37.440	23.480	15.590	27.900	36.720
July	37.110	23.640	18.000	31.290	30.650
August	31.250	22.350	11.830	28.610	32.530
September	20.250	19.410	14.360	24.320	32.16
October	22.270	20.140	13.640	26.520	34.87
November	22.090	18.640	16.070	32.060	37.29
December	32.140	19.600	16.070	32.240	36.69
January	18.330	21.430	16.330	29.330	-
February	29.750	25.840	23.31	31.190	-
March	29.300	23.280	36.020	33.120	-

Table 7: Electricity generation using WTE (April 2018- Dec 2018) [16]

MU	18-Apr	18-May	18-Jun	18-Jul	18-Aug	18-Sep	18-Oct	18-Nov	18-Dec	Cumulative 2018	Cumulative 2017
Wind	3322.74	4441.09	8336.94	11365.27	11771.66	6093.34	2822.78	2181.03	2789.24	53124.09	45478.90
Solar	3178.88	3322.72	3012.37	2553.02	2635.79	3209.96	3452.61	3140.99	3078.3	27584.65	17334.68
Biomass	255.43	253.59	285.86	225.1	185.61	177.17	206.31	199.72	247.01	2035.81	2598.46
Bagasse	1263.94	728.01	393.48	319.56	218.28	231.36	426.26	1558.8	2311.49	7451.18	5991.84
Small	384.14	472.04	761.27	1193.6	1530.91	1001.29	872.37	678.16	515.62	7409.38	6592.22
WTE	38.64	39.03	36.72	30.65	32.53	32.16	34.87	37.29	36.69	318.58	264.81

Ministry provides financial support to projects based on bio-methanation technology utilizing wastes of the vegetable markets, the dung of the cattle, scraps after slaughtering cows, sheep, and hens. It is expected to show 250kW project capacity concerning energy generation from cattle dung. Similarly, biogas (12000 cu.m /day) as an end product of the plant, the financial support is limited to 0.1359 Million USD/MWeq (INR 10 Million. M Weq).

The plants can be constructed in the area of waste availability if needed. The expected capacity is 20 MW, and the financial support of 81791 Million USD (60 Million INR) is given after the evaluation of the project. Every day the country is producing more than 500 tons of biomedical waste. The biomedical wastes are infectious, toxic radioactive and hazardous. This waste contains blood and microorganisms which spreads infections in the surroundings. The biomedical waste also contains plastic and combustion of these wastes produces toxic elements such as dioxins and furans. Poisonous elements and compounds of mercury are also discharged during the incineration process which poisons and pollutes the environment which affects the people in the surroundings.

Discussion

Disposing of waste through landfills raises health hazards 30-fold, compared with using WTE, which produces several types of energy, example: steam, electricity, by combusting MSW. The benefits [17] of WTE are the bulk of waste that may usually go in landfill sites can be re-used. There will be an honest source of fuel from the wastes as the current landfill sites may be mined out, and also the landfill materials may be used as fuel. The WTE helps in decreasing waste to provide heat and energy. WTE also helps in protecting groundwater from contamination. Harmful pollutants and toxins emitted show the negative influence on human health because it contaminates the air, water, and therefore the land. The lake, river, and pools are incredibly affected thanks to the continual emission of toxic hazardous pollutants which affect the creatures living within the water and also affect the people eating fish and beverage from the lake or river. Waste management is showing more advantages like reducing greenhouse gases, reducing wastes, income from energy sale, reuse of waste materials. China and India play an important role to feature to worldwide waste generation [18]. It is observed that there will be arise of a minimum 4 to 6 times compared to the year 1999. The cumulative installed capacity of WTE is 0.1383 GW. It shows that only 5.4 % it had been achieved until the date. The cumulative of renewable energy in India as of 31.12.2018 was 74.08166 GW, and therefore WTE have contributed 0.18% only. Wind energy contributed 47.43%, solar 34.03%, biomass power/cogeneration 12.25%, small hydro 6.098%. Biomass power/cogeneration and WTE are classified as biopower category in India [19]. Residential, industrial and commercial areas create solid wastes like waste developed during construction work, biowastes from farming, horticulture cultivation lands, deforestation, forest related activities, hazardous wastes from battery sources, paints, tints, chemical solvents, bleaching agents and pesticides employed in the agriculture lands. These solid waste should be managed effectively through WTE to get energy because solid wastes also are blame for creating unsanitary conditions within the environment and develop pollutions [20, 21].

Indian Renewable Energy Development Agency (IREDA) estimates show that the country has up to now realized only about 2% of its WTE potential [22]. MSW is growing attention in recent years. The MSW management includes the gathering, transportation, handling and conversion to power through biological and thermal routes [23]. Between April 2018-Dec 2018, wind-generated 53124.09 MU cumulative electricity, solar generated 45478.9 MU, biomass 2035.81 MU, bagasse 7451.18 MU, SHP 7409.38 MU [24]. The cumulative for WTE in 2018 (April –Dec) was 318.58 MU, and 2017 (April –Dec) was 264.81 MU. Suitable waste management techniques which incorporate conventional collection, separation, storage, packaging, labeling, transportation and selecting proper WTE technologies or proper disposal techniques [25]. The biomedical waste management and handling rules of India were released in 2016. Ministry of Health (MoH) in India imposed severe laws, rules, and regulations that ought to be followed by any health care sector concerning biomedical waste. This guideline covers various possibilities of doing away with biomedical wastes like plastics through WTE which may be then used for laying roads and within the production of diesel [26]. The disposal of liquid wastes like physical structure fluids are into the sewage and drains. Slid and organic wastes which don’t seem to be possible to be recycled or reused are treated using incineration methods [27]. Very low dioxins and furans are released in this method with effective eradication of pathogens. During this method, biomedical wastes are pyrolyzed into hydrocarbons, H2 and CO as an example. For example, polyethylene with water and warmth are pyrolyzed to make CH_4, CO, and H2. Exothermic reactions occurring during the combustion of CO and H_2. Recently Plasma gasification is taken in to account as sustainable management of medical wastes. It uses plasma torches which converts biomedical wastes into a syngas (synthesis gas) which consists of H_2 and CO which may bewas liquid fuels, electricity, and warmth [28]. Another recent method includes anaerobic digestion of biomedical waste leading to the assembly of biogas. Biogas consists of CH_4, CO_2, H_2O, and other gases within the oxygen-free anaerobic digester. The biogas is combusted to come up with heat and electricity [29]. Nowadays biological fuel cells are would be convert biomedical waste like blood and saliva to energy using biocatalyst during which the organic matter is converted into electricity.

Recommendations

1. Waste stream can be assessed appropriately for energy generation, reuse and recycle. A particular portion of the waste is more suitable for WTE and can be treated with proper technology.
2. Municipal Corporation plays a vital role in collaboration with WTE plants, and they should be financially strong and supported by the concerned government to collect waste and supply to the WTE plant regularly without any delay or issues.
3. Proper planning of backup and emergency capacity should be the higher priority. Legal security for the WTE plant should be ensured, and the vision of the WTE plant should be transparency, trust to provide clean energy to the people through WTE technologies which are environmentally and public health friendly.
4. WTE market can be standardized and enhance the current plant. To manage, develop, monitor, examine, and inspect the operation of the plant-specific administrative agencies can be established. Legal liability concerning pollutant discharge contamination outflows needs to be considered. Severe penalties can be imposed on the plants which are not following acceptable standards and creating problems to the environmental and public health.
5. The policymakers need to understand the long-term result of the WTE policy in their long-term waste management policies/strategies.
6. Pricing tool for Bio-CNG and model document for purchase/sale agreement with oil and gas marketing companies. This will assist in promoting a market for WTE, which is very nascent at this step.

Conclusion

Waste management is showing more advantages such as reducing greenhouse gases, reducing wastes, income from energy sale, reuse of waste materials.

The cost of energy from conventional energy sources is becoming very high and harnessing power from waste is becoming more important nowadays.

The waste management techniques are cost-effective, environmentally friendly and accepted socially.

The WTE technology is controlled and maintained by the MNRE of India which has a multilevel governance system which builds strategies, policies, plans, outlining and implementing.

The partnership and MoU between the WTE sector, companies, and educational institutions should be healthy to have steady growth in this sector. There should be an efficient method to explore WTE potential.

The investigation should include efficient waste management techniques and technology following environmental impact studies.

The system should frame SOP for biomedical waste segregation, transportation, disposal methods and choosing suitable WTE technology.

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