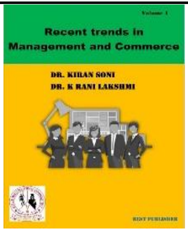
Recent trends in Management and Commerce
Vol: 1(2), 2020
REST Publisher
ISBN: 978-81-936097-6-7
Website: http://restpublisher.com/book-series/rmc/



Waste-to-energy technologies' technological and economic viability for investment in India: A COPRAS Method

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Abstract

In the Vellore District of Tamil Nadu State, small-scale power generation has recently been recognised as a feasible option for energy access because to unprofitable phase extension in remote rural areas (India). Possibility of creating an Integrated Renewable Energy System to satisfy the electricity and cooking needs of rural hamlets (IRES). Techno-Economic Research on This article conducts Technologies for converting waste into energy (WtE) has been acknowledged as one solution to India's persistent problem with unannounced power outages and load shedding. Which of the four potential WtE technologies—pyrolysis, gasification, plasma arc gasification, and anaerobic digestion—will have the highest techno-economic return on investment? MCDA, or multi-criteria decision analysis, is employed in the current study. The four solutions were assessed using 10 chosen techno-economic criteria by five academic and business professionals. According to the current analysis, gasification, also known as anaerobic digestion, is the third most practical WtE technology for investment in India after pyrolysis and plasma arc gasification. The annual energy production and initial investment are, respectively, the most important technical and economic factors. In this paper, based on COPRAS set theory It is suggested to use a multi-criteria decision-making (MCDM) paradigm. Alternative processes include anaerobic digestion, pyrolysis, gasification, and plasma arc gasification. Net present value, internal rate of return, and Transformative capacity, generational capacity, Annual Energy Generation, Initial Investment, Operations and Maintenance, balanced energy expenditure, repayment period, and Cost of Electricity is taken for evaluations parameters. As a result the Remanufacturing is in 1st rank and Refurbishing are last rank. The results of sensitivity analysis are more robust, Showing stability and consistency. According to the present analysis, Anaerobic digestion and gasification should be integrated rather than used separately, Because it balances well as a WtE technology. The results of this study will help potential WtE technology investors in India make decisions. .

Keywords: waste-to-energy, Anaerobic digestion, Gasification, Plasma arc gasification, Pyrolysis, COPRAS Method.

Introduction

Some of the most significant socioeconomic issues that many developing nations, including India, face include poor waste management and a power shortage. Many "waste-to-energy" (WtE) technologies are developed in modern economies like the United States, the United Kingdom, and China to produce Electric energy from their waste products and other consumables. Adoption of these technologies in the Indian context is still in its infancy, In the literature that it simultaneously reduces the amount of waste pollution Despite what many publications claim and increase the nation's power generating capacity. Despite recent reports indicating a conscious endeavor by the Government of India To adopt these WtE technologies, there are few studies on the most practicable technology for investment in India. Existing debris and to solve electrical problems The government is making continuous efforts. it is essential to have a wide range of works in this area to serve as a reference for future consultants and other important stakeholders. Therefore, our present analysis, Very inventive to invest in India and by identifying economical WtE technology contributes to the body of literature. A country's electricity sector has Sporadic power outages and When characterized by resistance, Lasting hours not days, it is argued that power generation and distribution issues exist. According to reports, Many variables, including But not just supply shortages, high transmission and distribution system losses, and a higher reliance on thermal and water resources for electricity production, are to blame for the nation's seemingly endless power problem. Ghana loses an average of US$2.1 million per day in productivity as a result of severe power supply problems. Additionally, India has fallen short of its 2020 goals for both universal access to power and renewable energy. At the end of 2019, Ghana's rural parts still lack access to power, and the country's urban areas that do have access to electricity continued to experience frequent blackouts. Any society's ability to sustain its economy and expand economically depends on having access to clean, inexpensive energy. Excessive uses of fossil fuels have negative effects on the environment, It lacks resources, and These include climate change and global warming. As of 2020, carbon-rich fuel-fired thermal power plants accounted for the majority of Ghana's electricity needs. Like the solar, wind, and hydro intermittent nature of non-conventional energy sources, one of its drawbacks is, Because they are weather dependent. However, for waste-to-energy technology when used as a primary ingredient, While addressing environmental challenges To generate reliable and scalable power MSW is one of the most promising avenues. India's current electrical crisis is sufficient evidence of the need for future sustainable energy alternatives, such as WtE technology. Depending on the composition and moisture content of the waste, using biochemical or thermochemical processes MSW contains energy that can be recovered and used to produce power or heat. To create a Circular Economy System (CES), associated with waste management, energy usage, and greenhouse gas emissions WtE supply chain to solve problems simultaneously offers a solution (Trindade et al., 2018). technological innovation, Plenty of technical and

Due to scientific data, and official support The practice of many WtE programs is evident in developed countries; In these developed nations, WtE presently provides 5% of the energy needed (Brunner &Rechberger, 2015). German MSW was converted to WtE at a rate of 31% in 2018 according to European waste-to-energy facilities, compared to more than 50% in Sweden, Finland, Norway, and Denmark during the same year. For instance, in the United States, contemporary, regulated landfills gather roughly 2.6 million tonnes of methane, which can be used to power turbine generators up to 50 MW with heat and electricity (Moya et al., 2017). The largest developing nation in the world, China, has achieved significant advancements in WtE development over the previous ten years. China now has 259 WtE mass-fired plants with a 280,000 TPD capacity (Rogoff, 2019). Anaerobic digesters, which have a Technology Readiness Level (TRL) 9 grade, are commonly utilized in the United Kingdom. Therefore, depending on the aforementioned variables, all stakeholders need to choose the appropriate WtE methods. It poses a multi-criteria decision-making dilemma since multiple criteria, some of which may be in conflict, must be taken into account at the same time. These criteria include technological, environmental, economic, political, and social factors. At this point, to make a decision Multi-criteria decision-making/analysis (MCDM/MCDA) models are required. The application of MCDM or MCDA tools, which are tried-and-true techniques to help decision-makers compare and assess technology, is especially valued in the waste management industry. COPRAS was originally developed by Zavatskas and Kaklauskas (1996) introduced. COPRAS method with a better resolution rate determines a solution. Adequately describe the values and weights of alternative methods and criteria Significance of versions examined in the criterion setting This approach is direct and takes utility and proportional dependence into account. In conventional cobras, weights of scales and estimates of Soft's alternatives as numerical data are taken into account. However, under many conditions, real-world decision-making problems Smooth data is not enough to handle. On the other hand, accurate knowledge is not easily obtained. These also make the results accurate. Alternative methods and criteria values and calculate the weights adequately Significance of versions examined in descriptive criteria setting this method is direct and proportional bias and considers usability. Determining the importance, order of priority, and extent of use of alternatives is carried out in five steps: 1. Weighted normal decision matrix D. 2. Weighted normalized describing the alternative Calculating sums of symbols. 3. Advantages S+j and disadvantages S -j of substitutes Describe and determine the Qj values of the compared alternatives. Degree of application of alternative aj 5. Determining the priority order of alternatives. For pre-qualification of the bidder’s five-window replacement versions Results of multi-criteria assessment, based on utilization degree equal to 100% the first alternative shows that it is better, and The third version is basically the second best Usage rate equals 100%. The next step is the final selection of the contractor. Satisfied pre-qualification requirements considering bids of candidates. After completing the technical assessment, for the final exam of the final short-listed contractors to award the contract Price proposals will be linked to the technical score. Show table 1 gives in evaluation parameters.

Materials & Methods

You Finding the optimum technology for India's waste-to-energy programme is the study's main objective. MCDM techniques and waste management and in energy planning About their applications The approach began with a review of the literature. The second step was to study WtE technology in order to develop appropriate evaluation criteria for the selection process. Several technological and financial factors are among the criteria taken into account in our investigation. Measuring weights quality May be quantity or a combination of both. Scale weights numerically Since it reflects the properties of alternatives, they are excellent for case study themes when there is a wealth of readily available survey data. Comparatively, qualitative weights are more appropriate for case study regions like Ghana where research data are scarce because they are based on decision-makers' perceptions and judgements of the qualities of options. The current study employs a qualitative deliberative process to achieve the intended outcomes. Economics and Features of MSW Five participants with substantial expertise and background are given a survey on WtE technology for emerging nations like India (see supplementary file). In order to a final ranking for WtE exams initially, various experts determine the effect of assigned weights A sensitivity study was conducted. Due to the MSW present there, both types of WtE conversion techniques can be applied in Ghana (Miezah et al., 2015; see the supplemental file for information on Ghana's waste). selective anaerobic digestion, Plasma Arc Gasification, pyrolysis, and gasification processes are taken into consideration for this study. Filling gas to power, Like plasma therapy Fuel derived from other technologies, Thermal de-polymerization, Hydrothermal Carbonization, Combustion, etc. were denied. were largely ignored due to their lack of information in the indian context and the technological immaturity of the majority of them. In the part that follows, it will be made obvious why these technologies were chosen.

Anaerobic digestion: Anaerobic digestion (AD) is Uses litter to break down organic matter is a technique biologically with the aid of microorganisms to produce digestate and biogas. The biological process of digestion occurs with little oxygen in a regulated setting. Producing biogas requires: a natural gas replacement that produces energy and heat, methane, carbon dioxide, and water must be added. Digestate is another byproduct of AD that contains several nutrients and can be used as a biofertilizer. High methane (CH4) and low carbon dioxide (CO2) content are characteristics of AD (Francoli and Bolton, 2019). Pre-treatment, digestion, and post-treatment are the typical steps in an AD system's operation. To maximise biogas production, pre-treatment divides, categorises, and reduces waste volume in order to produce organic matter. The environment is then maintained at 6.7 pH and 55–60 C to encourage microbial digestion. The remainder of the filth was then removed. AD technology has a few benefits, such as the following: In addition to taking up less space than landfills, recovering resources and redirecting them from them also reduces GHG emissions, may be carried out on a smaller scale, and permits trapped gas generated for closed system use. The fundamental flaw with this approach is that it cannot be used to treat wastes with low quantities of organic matter, necessitating waste separation in order to improve the efficiency of digestion (Doslu et al., 2016).

As sewage sludge and livestock manure are used in the majority of AD plants deployed globally, municipal solid waste (MSW) is a material that is difficult and underdeveloped.

Gasification: With the aid of gasification agents, carbonaceous waste (MSW) is converted into energy during the thermochemical process known as gasification at high temperatures (usually between 550 and 1000 °C). Through a variety of heterogeneous processes, a gasifying agent (another gaseous chemical) aids in converting the input into gas quickly. This process produces syngas, sometimes referred to as producer gas, which is primarily composed of hydrogen, carbon monoxide, carbon dioxide, and methane. Depending on whether ambient air or air with lots of oxygen is used, the gasification process can create between 25% and 40% of the heat content of natural gas. Instead of just creating heat and power, the materials created by gasification can be used to make high-value consumer goods including transportation fuels, chemicals, fertilisers, and natural gas substitutes, just like when waste is burned in a waste-to-energy facility.

Plasma arc gasification (PAG): During PAG operation, an arc is created in an electric arc gasifier by passing a very high voltage current between two electrodes. The complex feedstock's organic component might be turned into syngas (CO, H2) by the plasma arc, which has a maximum operating temperature of 13,900 C, while the inorganic component may be transformed into vitrified slag. A steam turbine can be powered by the recovered heat from a combined cycle design, and the recovered sludge can be further processed or burned in a gas turbine. Inorganic substances such as silica, soil, asphalt, glass, gravel, and other inorganic substances are electrified into a glass and emptied to the bottom of the furnace at this temperature since there are no tars or purans present. Metals all melt at this temperature. The main benefits of plasma arc gasification over conventional gasification and incineration include better handling of a variety of waste compositions and heating values, fewer pollutant emissions due to higher temperatures, and efficient power generation due to integrated cycle design.

Pyrolysis: MSW pyrolysis produces solid residues at low temperatures (less than 450 °C) when the heating rate is slow, while most gases are produced at high temperatures (more than 800 °C) when the heating rate is fast. In gas turbines and diesel engines, bio-oil can be utilised as a liquid fuel to produce energy. The majority of MSW is made up of materials like paper, textiles, rubbish (such as fallen branches and leaves), food waste, plastics, and to a lesser extent, leather and rubber, along with metals, glass, ceramics, earthy materials, and other things. Glass, metals, and inert items are mechanically removed from municipal waste before the remaining waste is treated in a pyrolysis reactor. The three types of pyrolysis reactors most frequently used are rotating reactors, rotary hearth reactors, and fluidized bed reactors. Pyrolysis is becoming a more appealing option to incineration because of its ability to reduce CO2 pollution (Doslu et al., 2016). Using an example case, the techno-economic performance of four WtE alternatives—pyrolysis, gasification, plasma arc gasification, and anaerobic digestion—is examined in order to determine the viability and effectiveness of the suggested framework for WtE technology investment in India. The three technical criteria (T), conversion efficiency, production efficiency, and annual power generation, are made up of seven economic components, including initial investment, O & M cost, LCOE, NPV, IRR, payback period, and electricity cost. Data Language-based descriptions of the relative weights of options and selection criteria are provided in Table 1. Each WtE alternative is rated using the relative importance of the ten criteria, which are independently determined by five experts.

Identifying This section discusses the results of using the COPRAS approach theory to choose the best WtE technology for investment in India. The most crucial elements that determined the project's choice are listed in Table 8, which also demonstrates that gasification is the WtE technology that India can use that is both technologically and economically feasible, beating out the least desirable options of anaerobic digestion, pyrolysis, and plasma arc gasification. Figure 1 displays the ranking of WtE possibilities for each criterion.

Result and discussions

Table 1 Alternative

A1	Anaerobic digestion
A2	Pyrolysis
A3	Gasification
A4	Plasma arc gasification

Alternative methods are presented in Table 1. Alternative methods for A1(anaerobic digestion), A2(pyrolysis), A3(gasification) and A4(plasma arc gasification).

Table 2 Evaluation parameters Criteria for segmental attractiveness

C1	Net present value
C2	Internal rate of return
C3	Conversion efficiency
C4	Generation capacity
C5	Energy generation per annum
C6	Initial investment
C7	Operations and Maintenance
C8	Levelized cost of energy
C9	Payback period
C10	Cost of electricity

Table 2 presents the evaluation parameters. Parameters for evaluating practices are net present value (C1), internal rate of return (C2), conversion efficiency (C3), generation efficiency (C4), energy generation per year (C5), initial investment (C6), operations and maintenance (C7), balanced Energy cost (C8), payback period (C9), and electricity cost (C10).

Table 3 given a data set

	C1	C2	C3	C4	C5	C6	C7	C7	C8	C10
A1	53.12	56.72	65.13	68.43	58.43	29.15	17.45	24.13	12	36.43
A2	46.10	68.43	79.43	61.34	65.39	33.69	16.31	11.69	18	27.30
A3	58.72	49.12	59.16	81.24	81.67	29.18	19.37	19.73	10	23.10
A4	69.45	77.28	35.69	79.13	39.46	24.60	22.43	34.36	9	17.59

Table 3 appears. a set of data. The data collection has high values for annual energy generation. The data set has low values for cannibalization. The data set for the techno-economic viability using the COPRAS method is shown in Table 3 for the Net present value, Internal rate of return, Conversion efficiency, Generation capacity, Annual Energy Generation, Initial Investment, Operations and Maintenance, Levelized Cost of Energy, Payback period, and Cost of Electricity.

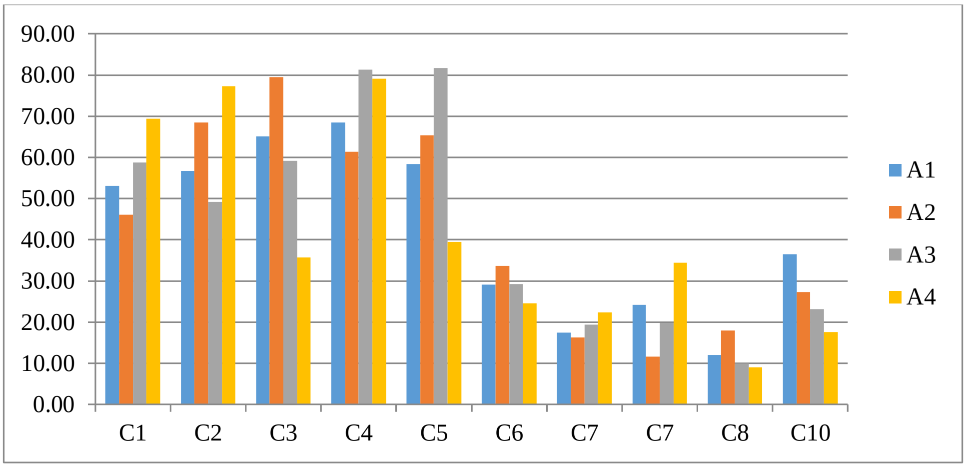

Figure 1. Give a data set graph

Figure 1 shows the data set for the Net present value, Internal rate of return, Conversion efficiency, Generation capacity, Annual Energy Generation, Initial Investment, Operations and Maintenance, Levelized Cost of Energy, Payback period, and Cost of Electricity.

Table 4 Normalized Data

	C1	C2	C3	C4	C5	C6	C7	C7	C8	C10
A1	0.2336	0.2255	0.2720	0.2359	0.2385	0.2500	0.2309	0.2684	0.2449	0.3489
A2	0.2027	0.2720	0.3318	0.2114	0.2670	0.2889	0.2159	0.1300	0.3673	0.2614
A3	0.2582	0.1953	0.2471	0.2800	0.3334	0.2502	0.2564	0.2194	0.2041	0.2212
A4	0.3054	0.3072	0.1491	0.2727	0.1611	0.2109	0.2969	0.3822	0.1837	0.1685

Table 4 shows the normalized data which is calculated from the data set each value is calculated by the same value on the data set divided by the sum of the column of the above tabulation seeing figure 2.

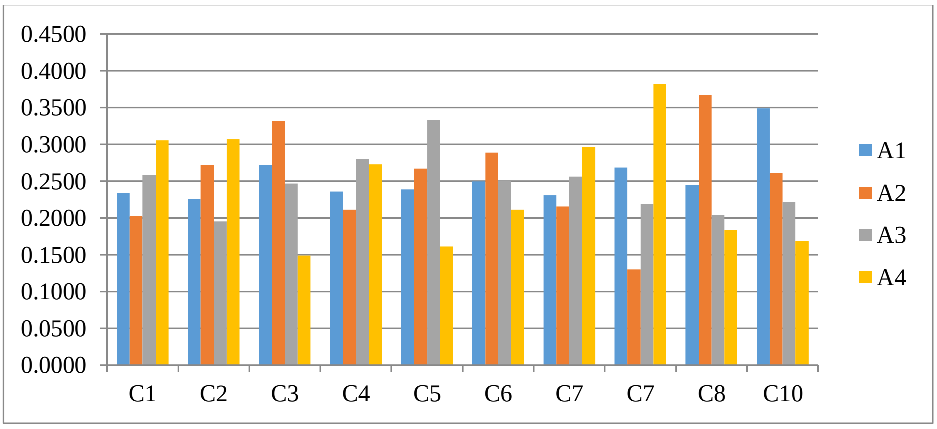

Figure 2 gives the normalized data

Table 5 Gives Weight Matrix

	C1	C2	C3	C4	C5	C6	C7	C7	C8	C10
A1	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
A2	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
A3	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
A4	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25

Table 5 gives the weight of the data set equal to all values in the data set in Table 1.

Table 6 Normalized decision matrix with weights

	C1	C2	C3	C4	C5	C6	C7	C7	C8	C10
A1	0.06	0.06	0.07	0.06	0.06	0.06	0.06	0.07	0.06	0.09
A2	0.05	0.07	0.08	0.05	0.07	0.07	0.05	0.03	0.09	0.07
A3	0.06	0.05	0.06	0.07	0.08	0.06	0.06	0.05	0.05	0.06
A4	0.08	0.08	0.04	0.07	0.04	0.05	0.07	0.10	0.05	0.04

To obtain the following value, multiply the weight by the previous table. The weighted normalisation choice matrix, shown in Table 6, is created by multiplying the performance value and weight from Tables 4 and 5.

Table 7 Bi and Ci

	Bi	Ci
A1	0.301	0.336
A2	0.321	0.316
A3	0.329	0.288
A4	0.299	0.311

Table 7 show the value of Bi and Ci. The Bi is calculated from the sum of the Specific strength, Specific Modulus, Corrosion resistance. The Ci is calculated from the sum of cost category.

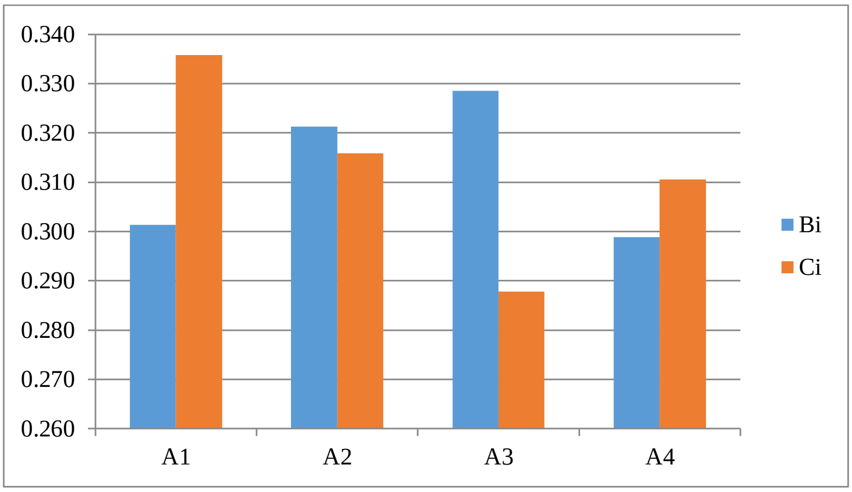

Figure 3 Bi and Ci

Table 8 Min(Ci)/Ci, Qi and Ui

	Min(Ci)/Ci	Qi	Ui
A1	0.8572	0.591353	88.6889
A2	0.9112	0.629445	94.4018
A3	1	0.666772	100
A4	0.9269	0.61243	91.8499

The value of Min(Ci)/Ci, Qi, and Ui is shown in Table 8. The Bi and Ci are used to calculate Qi, which is then used to determine the Ui. The A1 is on 88%, the A2 is on 94%, the A3 is on 100%, and the A4 is on 91%, according to Table 8.

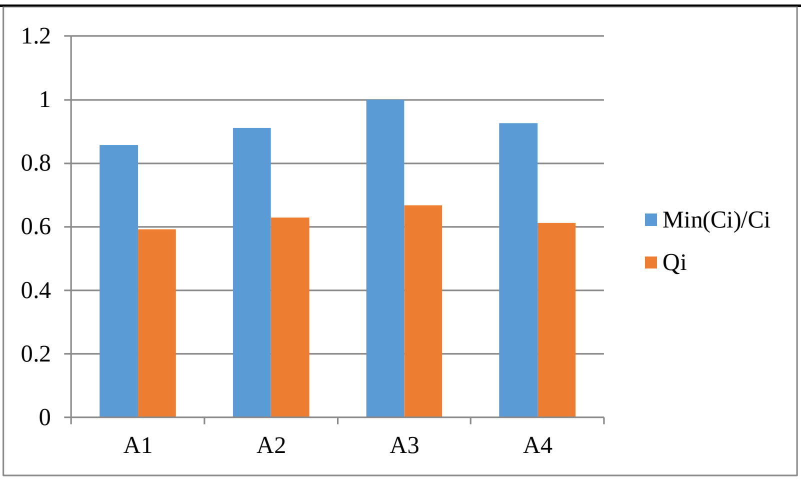

Figure 4 Min(Ci)/Ci and Qi

Figure 4 showing Qi values all most same values.

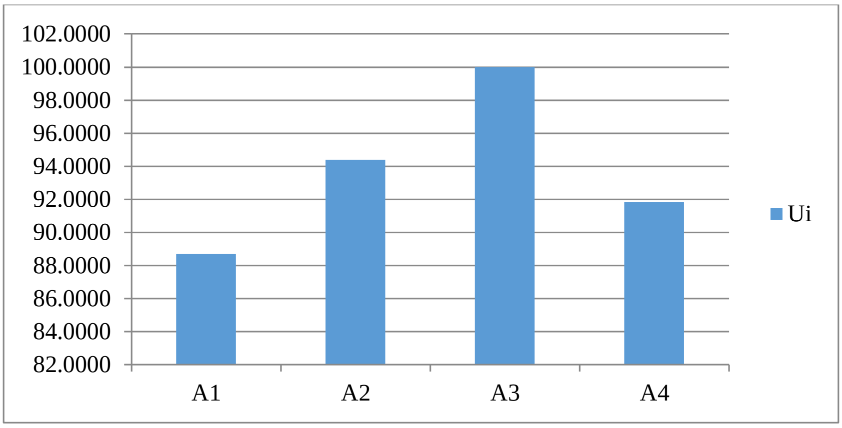

Figure 5 Ui value

Figure 5 showing Ui values the A1 is on 88%, the A2 is on 94%, the A3 is on 100%, and the A4 is on 91%, according to Table 8.

Table 9 Ranking

A1	Anaerobic digestion	4
A2	Pyrolysis	2
A3	Gasification	1
A4	Plasma arc gasification	3

Table 8 shows that the Gasification is in 1st rank, Pyrolysis is in 2nd rank, Plasma arc gasification is in 3rd rank and Anaerobic digestion are last rank. Figure 6 shown in ranking.

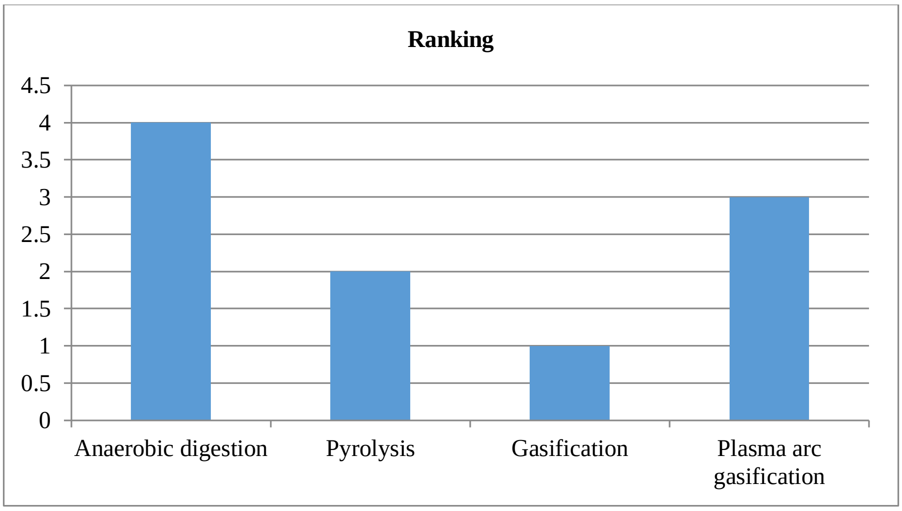

FIGURE 6 shown in ranking

Conclusion

India and other developing countries lack practical waste-to-energy system knowledge. Nearby landfills and open warehouses the volume of municipal solid waste is increasing. Which is leading to severe health and environmental issues, as well as the current electrical crisis, these waste-to-energy technologies provide It has forced the government to work on alternatives and adapt. For waste-to-energy development in India Possibilities has been explored. By giving a multi-criteria analysis, we add to the literature. Making decisions is based on a variety of technical and financial factors that examine numerous waste-to-energy options concurrently. Anaerobic digestion, gasification, pyrolysis, and plasma arc gasification are the four WtE solutions that have been evaluated using techno-economic standards. Income, payback period, power cost, and net present value. After the waste-to-energy alternatives had been examined by five carefully picked experts based on all the selection criteria, the alternatives were ranked using the COPRAS multicriteria decision model. Anaerobic digestion is ranked first in terms of annual power generation, production efficiency, conversion efficiency, NPV, and LCOE O&M costs, IRR, repayment period, and initial investment Gasification comes in first place in terms of power cost. According to overall ranking statistics in India, gasification has proven to be a superior waste-to-energy technology based on the proportional weights of the important criteria. This is followed by pyrolysis, Plasma arc gasification, and anaerobic digestion. The results of the sensitivity analysis, Very reliable despite changes in the early stages and showed that a stable result was still reached. Combining anaerobic digestion and gasification The results also proved to significantly improve waste management. Decision makers in India's waste-to-energy sector And research provides relevant information to potential investors.

References

1. Chauhan, Anurag, and R. P. Saini. "Techno-economic feasibility study on Integrated Renewable Energy System for an isolated community of India." Renewable and Sustainable Energy Reviews 59 (2016): 388-405.
2. Li, Chong, Xinfeng Ge, Yuan Zheng, Chang Xu, Yan Ren, Chenguang Song, and Chunxia Yang. "Techno-economic feasibility study of autonomous hybrid wind/PV/battery power system for a household in Urumqi, China." Energy 55 (2013): 263-272.
3. Aui, A., Y. Wang, and M. Mba-Wright. "Evaluating the economic feasibility of cellulosic ethanol: A meta-analysis of techno-economic analysis studies." Renewable and Sustainable Energy Reviews 145 (2021): 111098.
4. Liu, Hangyue, Donald Azuatalam, Archie C. Chapman, and Gregor Verbič. "Techno-economic feasibility assessment of grid-defection." International Journal of Electrical Power & Energy Systems 109 (2019): 403-412.
5. Patel, Martin, F. Marscheider-Weidemann, J. Schleich, B. Hüsing, G. Angerer, O. Wolf, M. Crank, and M. Patel. "Techno-economic feasibility of large-scale production of bio-based polymers in Europe." Techncial Report EUR 22103 (2005).
6. Crank, Manuela, M. Patel, F. Marscheider-Weidemann, J. Schleich, B. Hüsing, and G. Angerer. Techno-economic feasibility of large-scale production of bio-based polymers in Europe (PRO-BIP). Final report. No. NWS-E--2004-111. Department of Science, 2004.
7. Mahmoud, Marwan M., and Imad H. Ibrik. "Techno-economic feasibility of energy supply of remote villages in Palestine by PV-systems, diesel generators and electric grid." Renewable and sustainable energy reviews 10, no. 2 (2006): 128-138.
8. Mamaghani, Alireza Haghighat, Sebastian Alberto Avella Escandon, Behzad Najafi, Ali Shirazi, and Fabio Rinaldi. "Techno-economic feasibility of photovoltaic, wind, diesel and hybrid electrification systems for off-grid rural electrification in Colombia." Renewable Energy 97 (2016): 293-305.
9. Saqib, Najam Ul, Hari Bhakta Sharma, Saeid Baroutian, Brajesh Dubey, and Ajit K. Sarmah. "Valorisation of food waste via hydrothermal carbonisation and techno-economic feasibility assessment." Science of the Total Environment 690 (2019): 261-276.
10. Das, Barun K., Najmul Hoque, Soumya Mandal, Tapas Kumar Pal, and Md Abu Raihan. "A techno-economic feasibility of a stand-alone hybrid power generation for remote area application in Bangladesh." Energy 134 (2017): 775-788.
11. Kazem, Hussein A., M. H. Albadi, Ali HA Al-Waeli, Ahmed H. Al-Busaidi, and Miqdam T. Chaichan. "Techno-economic feasibility analysis of 1 MW photovoltaic grid connected system in Oman." Case Studies in Thermal Engineering 10 (2017): 131-141.
12. Spoelstra, Simon, Willem Gerrit Haije, and J. W. Dijkstra. "Techno-economic feasibility of high-temperature high-lift chemical heat pumps for upgrading industrial waste heat." Applied Thermal Engineering 22, no. 14 (2002): 1619-1630.
13. Kumar, Y. V., and Bhimasingu Ravikumar. "Integrating renewable energy sources to an urban building in India: challenges, opportunities, and techno-economic feasibility simulation." Technology and Economics of Smart Grids and Sustainable Energy 1, no. 1 (2016): 1-16.
14. Purohit, Ishan, and Pallav Purohit. "Techno-economic evaluation of concentrating solar power generation in India." Energy policy 38, no. 6 (2010): 3015-3029.
15. Kumar, Shalander, K. L. Sharma, K. Kareemulla, G. Ravindra Chary, C. A. Ramarao, Ch Srinivasa Rao, and B. Venkateswarlu. "Techno-economic feasibility of conservation agriculture in rainfed regions of India." Current Science (2011): 1171-1181.
16. Rad, Mohammad Amin Vaziri, Roghaye Ghasempour, Parisa Rahdan, Soroush Mousavi, and Mehrdad Arastounia. "Techno-economic analysis of a hybrid power system based on the cost-effective hydrogen production method for rural electrification, a case study in Iran." Energy 190 (2020): 116421.
17. Ara, Syed Raahat, Santanu Paul, and Zakir Hussain Rather. "Two-level planning approach to analyze techno-economic feasibility of hybrid offshore wind-solar pv power plants." Sustainable Energy Technologies and Assessments 47 (2021): 101509.

18. Mousavi-Nasab, Seyed Hadi, and Alireza Sotoudeh-Anvari. "A comprehensive MCDM-based approach using TOPSIS, COPRAS and DEA as an auxiliary tool for material selection problems." Materials & Design 121 (2017): 237-253.
19. Zolfani, Sarfaraz Hashemkhani, I-Shuo Chen, Nahid Rezaeiniya, and Jolanta Tamošaitienė. "A hybrid MCDM model encompassing AHP and COPRAS-G methods for selecting company supplier in Iran." Technological and economic development of economy 18, no. 3 (2012): 529-543.
20. Ayrim, Yelda, Kumru Didem Atalay, and Gülin Feryal Can. "A new stochastic MCDM approach based on COPRAS." International Journal of Information Technology & Decision Making 17, no. 03 (2018): 857-882.
21. Pitchipoo, P., D. S. Vincent, N. Rajini, and S. Rajakarunakaran. "COPRAS decision model to optimize blind spot in heavy vehicles: A comparative perspective." Procedia Engineering 97 (2014): 1049-1059.
22. Vytautas, Bielinskas, Burinskienė Marija, and Palevičius Vytautas. "Assessment of neglected areas in Vilnius city using MCDM and COPRAS methods." Procedia Engineering 122 (2015): 29-38.
23. YDIN, Yüksel. "A hybrid multi-criteria decision making (MCDM) model consisting of SD and COPRAS methods in performance evaluation of foreign deposit banks." Equinox Journal of Economics Business and Political Studies 7, no. 2 (2020): 160-176.