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Article

Artificial Intelligence (AI) in Biological Waste Management and Bio Fuels Production

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Abstract: A dynamic aspect of environmental sustainability is the biological waste management, in which handling of biological waste and appropriate disposal is essential formed from diverse sources. The waste that comes from biological processes is the biological waste together with wastes from animals, plants, household, municipal solid waste and hospitals waste. Collection of waste from waste producing sources, processing, transport, recycling or disposal is the biological waste management. Industrialization, urbanization, altering the living styles and patterns of consumption of the community worldwide has caused in increased production of biological waste. Soil health and biodiversity are affecting by the production of biological waste, in case of industrial liquid waste discharge into the fields it affects crop productivity. It also affects human health and contributes to climate change and global warming. Here in this article, in biofuels production and biological waste management the role of artificial intelligence (AI) is examined using neural network (ANN), smart bin system, sensor-built monitoring of waste and waste sorting robots etc. Furthermore, bioenergy technologies are studied to chemically or thermally convert the waste into bioenergy products.

Keywords: Waste management; Biological waste; Climate change; Artificial intelligence

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1. Introduction

A wide range of sources of biological waste or bio-waste is coming from plants, animal, domestic, construction, biomedical, radioactive, commercial, industrial and liquid wastes (Chattopadhyay and Singha 2011). From the waste generation source, the gathering of waste is the biological waste management then transport, processing, disposal, recycling and intensive care and in case of unsafe nature of wastes e.g. radioactive wastes the sensing of waste materials (Demirbas 2011). Greenhouse gases such as methane and Carbon dioxide gas by the discarding of wastes at disposal sites that contributes straight towards climate change and global warming (Huang and Koroteev 2021).

As the awareness about waste has been increasing gradually biological waste management is gaining consideration worldwide due to increasing human population worldwide, changing in their living styles and consumption patterns, food grain production, urbanization, industrialization and economic growth (Chattopadhyay and Singha 2011; Kumar et al. 2021). Over the past few years worldwide population rises, rapid industrialization and urbanization have increased the amount of waste produced. Conferring to the current statistical data, worldwide (2.01 billion tons) of municipal solid waste (MSW) was formed in the year 2016. This figure might be increased by the year (2050) to 3.4 billion tons (Lin et al. 2022).

One-third is lost every year approximately from the food produced, from the food chain as waste resulting in economic loss, increasing hunger, inequality and inflation among people (Bhatia et al. 2018; Xu et al. 2018). Moreover, soil health, soil biodiversity, human health, crop productivity is affecting by the generation of biological waste as in case of discharge of industrial liquid waste into the fields, and contributes to climate change and global warming (Chattopadhyay and Singha 2011). Improper waste disposal may affect environment and may cause serious health issues, such as contamination of groundwater, land degradation, enhanced cancer probabilities, infants' fatality, and by-birth abnormalities and disabilities (Triassi et al. 2015). An enormous percentage of the street garbage left unprocessed due to poor infrastructure, financial constraints and deprived regulatory policies of the developing countries and thus they are major contributors towards increasing global warming and climate change (Sharma and Jain 2020). However, the revolution of artificial intelligence will definitely help achieving sustainability and profitability in area of biological waste management.

Biological waste should be managed or treated properly for the justifiable development of human society and environmental conservation, Secondly, in both environmental and economic terms best deal with waste is to avoid generating it in the place of production (Huang et al. 2021). To produce renewable bases of energy and to recover other nutrients the waste produced can be recovered or recycled like biogas, biodiesel, and biofuels. Waste reutilization, followed by recycling, waste reduction and recovery for energy the efficient waste management is required (Huang et al. 2021). Fossil fuels like petroleum products and coal are non-renewable sources of energy. Due to high dependence of public in today`s era the energy production is going to use up soon in near future. On the environment the usage of fossil petroleum has harmful outcome due to emissions of oxides of carbon, nitrogen and Sulphur and various other destructive gases which are mainly accountable for global warming, climate change, depletion of ozone layer and several negative impacts on health (Meena et al. 2021b).

The developed countries have earlier started to acquire artificial intelligence technologies to enhance use of resources, their efficiency, and recycling opportunities all over the process of biological waste management process (Soni et al. 2019). In various industries, especially in biological waste management the rapid advancement of AI is achieving high importance (Abdallah et al. 2020). Urban waste treatment plants are designed by incorporating robotics, machine learning and AI in their operation and strategy to manage the waste effectively and efficiently (Yigitcanlar and Cugurullo 2020; Mukherjee et al. 2021). In biological waste management AI technologies, especially for sensing, sorting and processing solid waste, are highly useful (Andeobu et al. 2022). Thus, artificial intelligence is important in efficient waste management models developing more sustainable, specifically for moving towards to a “zero waste circular economy” while taking into consideration all other factors such as; social, environmental and economic factors (Osman et al. 2023).

To suppose what is on a transport line easily new technologies aided by AI system uses artificial sorters, sensors and equipment (Meena et al. 2021b). As compare to traditional optical solutions AI detectors are an important improvement. The suggested framework incorporates neural networks and machine learning (Zhou et al. 2018). By using the neural network, the waste produced has been predicted. Based on unpredictable sustainable energy markets and energy costs an enhanced and improved machine learning algorithm further improves the waste collection (Ahmad and Kim 2020; Qiu et al. 2021; Yu et al. 2020). This article gives an outline of waste types, artificial intelligence in biological waste management, its production, and AI model for waste management process and bioenergy production technologies for the useful conversion of waste into biofuels, i.e. a renewable source of energy.

2. Classification and Generation Mechanisms of Waste Materials

A serious environmental problem is the potential of waste to harm or negatively impact on air, soil, and water. Human activities are primarily responsible for its formation (Fang et al. 2023). By 2050, the quantity of CO_2 released by the use of energy sources that are not renewable will have increased by around 50%, making it the most prevalent greenhouse gas and the one with the worst environmental impact (Chen et al. 2023). This could result in resource loss, environmental contamination, health concerns, financial losses, and increased expenses for waste management. Additionally, public education and awareness initiatives can aid in lowering trash production and influencing people to adopt more sustainable lifestyles. Depending on the trash's type, state, or source, categorization may be done according to several waste classification principles. According to study, industrial waste is the main source of waste, which is supported by the waste sources. These materials contain many harmful components, including radioactive materials, heavy metals, and organic contaminants, which severely pollutes the environment (Fang et al. 2023). Water is a natural resource that must be present on earth's surface in order to support life. It is necessary for all industrial, agricultural, and human endeavors as well as for human activity (Osman et al. 2023). The waste states categorize waste into four categories.

2.1 Solid Waste

Human operations including production, farming, and digging are main sources of solid waste, and treatment options include recycling etc. (Fang et al. 2023). Getting rid of solid waste is a big problem for environmental conservation (Jha et al. 2022). Construction, residential, hazardous, medicinal, and agricultural waste are all examples of solid waste (Fang et al. 2023). Due to its simplicity of execution among the various management choices, landfilling is the preferred method of garbage disposal worldwide (Peng et al. 2023). The most frequent issues with incorrect solid waste management include the spread of infections, fire hazards, nuisances, air and water pollution, aesthetically offensive issues, and financial losses (Fenta 2017).

2.2 Hazardous Waste

According to statistics by the United Nations Environment Programmed, there are created around 400 million tons of hazardous trash worldwide each year, or roughly 60 kg for each person on the planet (Akpan and Olukanni 2020). Mostly derived from electronic and biomedical waste, hazardous waste includes poisonous, flammable, combustible, radioactive, and caustic trash (Fang et al. 2023).

2.3 Liquid Waste

Liquid waste includes waste including heavy metals, cyanide, mercury, hexavalent chromium, corrosive and alkaline liquids, and mercury. Particularly, 12.4% of the total is made up of corrosive and alkaline liquid waste, 32.2% is made up of organic liquid waste, and 47.9% is made up of heavy metal liquid waste (Fang et al. 2023).

2.4 Recyclable Waste

To make new things like paper, glass bottles garbage that can be recycled includes trash that can be taken out of the garbage stream and utilized as a raw material. Techniques for recycling garbage include biological reprocessing, and physical reprocessing (Fang et al.

2023). Numerous nations have conducted in-depth study on waste sorting and recycling and implemented practical technology. Based on picture recognition, some researchers used techniques to conduct related research on garbage classification (Zhang et al. 2021).

3. Management of waste with artificial intelligence (AI)

Categorization robots, intelligent garbage cans, are just a few examples of artificial intelligence-based technology that help waste processing facilities run more professionally. The use of AI has the power to transform municipal trash management through improved processing, collection and classification efficiency. Municipalities may cut expenses, increase security, and lessen the effects of waste management on the environment by utilizing artificial intelligence.

3.1 Smart Bin Systems

People must perform manual checks to gauge the amount of trash present in commonplace garbage cans that only contain rubbish and sanitation. Routine waste disposal inspections cannot be conducted effectively using this method. In addition, since the containers are filled often, insects and germs that causes sickness tend to breed there (Fang et al. 2023). The current methods of trash management are insufficiently effective and efficient to deal with the increase in waste levels (Noiki et al. 2021). Therefore, creating smart cities requires inventing garbage bin monitoring systems that can effectively manage waste. The focus of several studies on intelligent trash cans is automatic waste sorting and monitoring. These studies provide a possible way for cities to develop a successful rubbish collecting system. Additionally, by introduction an ultrasonic device at the bin's edge a trash level can be determined (Fang et al. 2023). The main issues facing waste managers are garbage overflow and the danger posed by biodegradable wastes in terms of how they damage public health and the aesthetics of the environment (Ogunwolu et al. 2020).

In conclusion, the study on intelligent trash cans primarily focuses on automatically detecting the degree of waste filling and alerting users in advance. Most of the time, sensors gather the data, which is then sent across the network. But because installing smart trash cans is expensive, it is difficult to spread awareness about them. To resolve this delinquent, the government should think about sponsoring programs that would lower the price of smart trash cans, hence increasing public access to them. Furthermore, environmental variables like humidity and temperature might have an impact on how these bins function on a regular basis. As a result, committed staff must frequently inspect and maintain the trash cans. Therefore, it will be vital to concentrate on creating and promoting intelligent trash cans in the future.

3.2 Waste Sorting Robots

For the treatment and discarding of waste, robots are being used for this purpose. We know that in few years' science and technologies are make advances day by day which make the human life very much easier. So many industries and environmental communities are using robots for sorting waste either waste is in liquid or solid matter. For classification of garbage the advanced visualization and splendid skills are developed to operate, by which robots are need; functions are varied, intricate, and incalculable industrial environments.

Recently many researchers are pivoted on enhancing the efficiency of garbage classification robots, and accuracy which needed for developing high quality sensors and cameras which further helps for the identification of different types of waste, or also incorporate for improving the artificial intelligence algorithms for classification of generated waste (Huang and Koroteev 2021). To trace the target area of interest, hyper spectral images are used that is promising approaches to identified the exact location of waste. Many new fundamental techniques are being developed for managing the waste by the help of robots in many industrial or environmental cleaning industries. Using robots to sort waste before it is sent down to landfills for disposal purposes scientists are currently demonstrating many methods of incorporating waste-sorting robots into existing waste management systems. By adding localization and technology of map locality robots can cope with complexities field conditions of waste generation and for the ongoing segmentation methods simultaneously many more ways have been discovered. In this regard, studies have suggested a parallel robot model which means that at the same time waste is being sort out and then clean water or recycling process are further goes with the concept to initial revolving around a gripper that is fully integrated to robot structure. Furthermore, new advances are on in way for solving the waste by more reliable robotic system.

3.3 Sensor Based Monitoring

This is very advanced and more reliable method, because sensors are developed for the proper monitoring of waste material when it runs or drive from the sensor operator. In a specific area of different industries this is the new waste monitoring management technology that characterized or using sensors to trace and locate the amount of waste generation, identify the causes of waste, and determine the effect of waste management tactics.

There is a network which is composed by self- operating machine, a wireless sensor network, which have no wire connection sensors install in the network by means to locate or monitored physical or environmental limiting factor of the system. By construction, typical wireless sensor network includes various sensors, for the treatment of solid matters like the optimum condition; humidity, pH, temperature and odor, sound sensors and infrared which increases waste management efficacy (Shreyas et al. 2022). In real time quality, sensors can be used to monitoring parameters, it faster identified the generations of waste from the large amount of discarded or recycle bins, thus classified controlled system have shown the waste treatment process results in better signification. Those sensors are very useful for the management of generations of waste and further many researchers developed new more fundamental techniques.

4. Models to Predict Waste Generation

Recently, its secure increasing consideration, and many advance models have been suggested to predict better the amount of waste generation. To resolving the harmful waste substances, it is important to first evaluate the waste generations. For the prediction of waste generation, many investigators are developing new more accurate methods.

For more consistent prediction of waste generations, the most innovative models are considered as AI algorithm. The main reason is that it possessed an extraordinary quality like data input, learning, and prediction. These capabilities defined the data accurately and gives the proper enlisted substances/compounds and types of matter. On small datasets, machine learning algorithms for instance, artificial neural network which contain multilayer perceptron and supporting the regress vector algorithms, algorithms of tree, linear regression algorithms, and genetic algorithms can be used for developing the models with better form mainly of unequivocal variables or predictive performance (Kshirsagar et al. 2022). On the basis of predictable generation, it is important to predict the generation of waste for destroying its harmful impact. AI systems commonly used in waste management more aggressively at both large and small scale. Due to the rapid development of artificial intelligence, it has been extensively used in waste generation prediction models. In waste generation prediction applications, artificial neural networks have been widely applied more reliable and followed by support vector machines. ANN gives more accurate, fast and detailed information about generation of waste which has to be predicted.

4.1 AI Model for Waste Management System

AI models are intricate mathematical and computer structures that mimic human thought and action (Pennachin and Goertzel 2007). These models are made to process and analyze data, learn from it, and then come up with choices or predictions depending on what they have discovered (Van et al. 2022). They serve as a key building block of artificial intelligence (AI) systems and are employed in a wide range of tasks, including natural language processing, speech and picture recognition, and game play (Woodruff 1997). To create AI models, machine learning techniques are frequently used over time which entail the training model on big datasets to enhance its performance (Van Der Aalst 2016).

As mentioned in the figure 1 (AI) models can significantly contribute to the sustainability, cost-effectiveness, and efficiency improvements of waste management systems (Kamali et al. 2021).

Figure 1. Waste management system model plan

5. Biofuels Production and AI

It is possible to convert biomass into bioenergy there are two different methods:

(1) Thermo-chemical Conversion technology.
(2) Biochemical Conversion technology (Meena et al. 2021b).

Use of AI in biomass conversion method optimize the biomass conversion by predicting the optimal conditions for conversion such as temperature, pressure and catalyst and increases the efficiency of bioconversion (Hansen & Mirkouei 2018). Additionally, AI is used to develop new and more efficient conversion method by identifying new catalyst or enzymes that can break biomass more efficiently.

6. Waste to Energy

Electricity is generated by biogas, which is taken from the biodegradable waste of human and animals this biogas is a maintainable basis of energy (Farghali et al. 2023). According to the IEA, double energy increase in the energy utilization as in 2020, 29.47% energy endow is from the oil, 23.68% from the gas 9.8% from fuels, 26.80% from the coal. (Farghali et al. 2023). Producing power from the sustainable resources is the main source of growth energy production from biogas is the most effective ecofriendly bioenergy production technologies. In Europe biogas produced by the heavy exertion of human and animal wastes 20% growth rate increases by the use of 6 million tons of oils, (Chiu et al. 2022). Due to not proper access to deep learning and neural network of machine learning there are low chances of generation of methane. On the basis of proper knowledge of machine learning you can notice any error in the inside burning engine power production and can easily set their system (Vickers 2017).

6.1 Biochemical Processing and Conversion Techniques

This method incorporates both fermentation and anaerobic digestion (AD). In its suitable raw material and microorganisms are there for production. AD produces biogas, whereas fermentation produces bioethanol, bio butanol and other products (figure 2). AD employs microorganisms to convert basic material into natural gas which is widely spread in whole world. Yeast are used during the fermentation of the feedstock to convert the sugar contained into it ethanol. End result will be ethyl alcohol then it will be disinfected and further uses for procedure staging and gives a high herb growth costly.

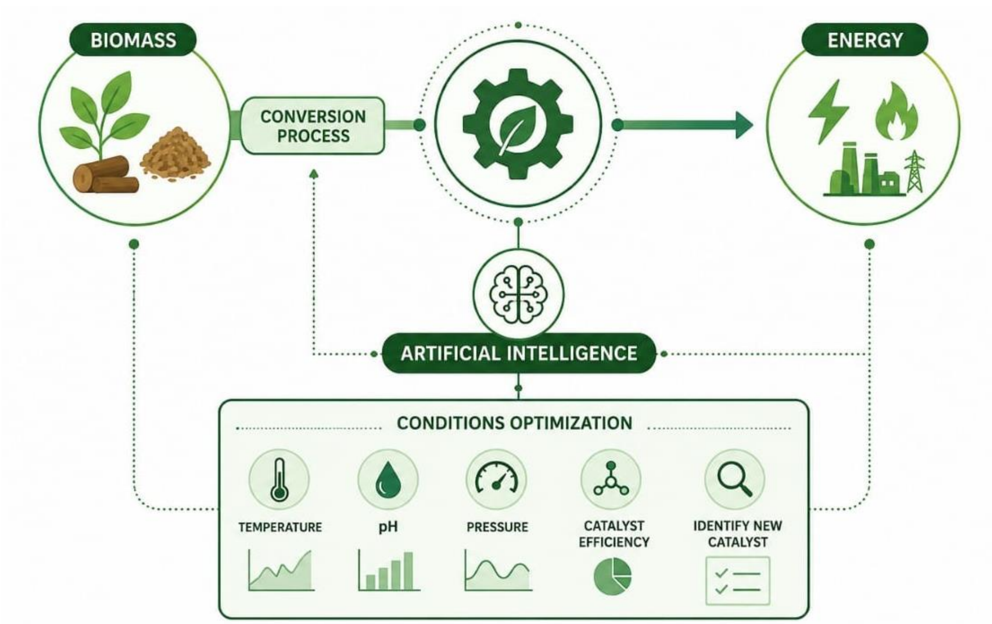

Figure 2. Increase bioconversion efficiency with the use of AI.

6.1.1 Artificial Intelligence Applications in Biochemical Conversion Technologies for Bioenergy Production

By microbial treatment AD is a well-established method for producing bio methane from organic wastes. The process is dependent on the specific communities of microbes and is susceptible to process interruption, which may reduce bio methane yield (Cruz et al. 2021). (Weinrich and Nelles 2021) monitoring of process is a potential technique for process efficiency, assuring a high bio methane production. Monitoring techniques could be very helpful in monitoring several conditions such as "pH, alkalinity, methane yield concentrations of fatty acid (VFAs), composition of biogas, some transitional metabolites concentrations and enzyme activity (Aghbashlo et al. 2022). Furthermore, AI is important for the structure and functioning of AD method and microbial absorption of dietary wastes is recognized to be the best possible cycle to deal. As it enables waste modification and aids in the improvement of both biogas and fertilizer. Furthermore, absorption cycle, to improve the AD process the use of zero-valent iron (ZVI) is frequently promoted, as it increases generation of methane as well as strength of framework. Instead of time laborious and tedious experiments, accurate ZVI-based AD reactor modeling is useful in projecting methane output capacity, optimizing the strategy for operation, and gather the reference knowledge for industrial design (Liu et al. 2021).

6.2 Technology for Thermochemical Conversion

By several methods thermochemical conversion method alters biomass into fuel such as torrefaction, pyrolysis, liquefaction, gasification, and combustion, the first stage of all thermochemical processes is called pyrolysis. Thermochemical processes generate intermediate products in the liquid or gas state that can be transformed into higher amount of energy (Meena et al. 2021b). A chemical reaction pyrolysis occurs in the absence of oxygen and product generated may be in the form of gas, liquid or solid. Gasification involves the process in which biomass is semi-oxidized to produced syngas-controlled supply of oxygen is provided during this reaction (He et al. 2021). For the production of liquid product solved medium such as acetone, water and ethanol are used while organic materials are thermally converted with the combustion process.

6.2.1 Bioenergy Production Bioenergy Production Using AI in Thermochemical Conversion

Process optimization of thermochemical transformation of sources such as biomass is critical for companies and research because it can provide a relationship in between biomass pieces, parameters of operations, and long-term utilization of biomass. Pyrolysis is a more appealing method of producing liquid fuel goods from waste. The grade of pyrolysis final products is greatly influenced by rate of warming, residence duration, temperature, particle size of feedstock, and biomass content of water. (Sajjadi et al. 2018) Several chemical and physical alterations occur during the process, resulting in a large variety of intermediate products (Couto et al. 2013). In order to enhance the manufacturing of the byproducts of pyrolysis researchers have explored various optimization and observation techniques such as bio-oil, bio char, pyrolysis gases, enhanced method parameters, and provide more efficient system for monitoring that improves dependability by presuming continuous checking and data documentation mechanisms. Recently, a mathematical technique based on AI was published, with the authors focusing on predicting desirable operating conditions in order to achieve desired yields of biological char, biological-oil, and pyrolysis gasses (Thiruvengadam et al. 2021).

The gasification of biomass is a paramount thermochemical technique for providing helpful biofuel products by converting biomass (such as farming waste, poultry production waste, solid municipal waste, and forest garbage) into helpful energy form carriers (such to be the gas monoxide, hydrogen, methane, and hydrocarbons) using inexpensive vaporizing methods (Sikarwar et al. 2016). To frame the active behavior of gasified and combustion processes AI based methods are useful; it can aid in the design of profitable handles that are cost related with tedious processes and have greater effectiveness of conversion of carbon to minimize process time; and it can show an important role in the industrialization gasification of biomass.

7. Machine Learning Algorithm and Optimization

The generation of bioenergy is primarily determined by feed quality, time to reaction, temperatures, catalyst, and mixing ratio. Deeper investigation into feed quality and liquefaction operation conditions is required to improve the whole process. (Singh et al. 2020) created a machine learning algorithm built Tunable decision-support system for enhancing operational parameters and estimating output of yield, and discovered a high efficacy (94%) between estimated and experimental outcomes. A few additional studies used (ML) algorithms for optimization and feature anticipating to get the favorite results. AI has numerous uses in microalgae pretreatment (growing, screening, strain identification, and conversion). (Hu et al. 2020), This aids in improving quality of feed for increased bio-crude production during the process of liquefaction Lignocellulose biomass is an important source of production of bioenergy, and preparation of biomass containing lignocellulose can increase the manufacturing or conversion efficiency of biofuels.

Mass spectrometry, thermo gravimetric (TG), and turn infrared spectrum analysis can give a solution and process monitoring for determining these parameters. The thermochemical qualities of feedstock, blend proportion, combustion temperatures, rate of heating, and operational technique parameters all have a significant impact on the viability and usability of combustion technology (Chang et al., 2020). AI can also be utilized in the combustion process to model the boiler wall under different operating conditions, simulate defect detection, automate the generating process, and estimate output energy (Shubham et al. 2021a). As input variables that affect the amount of moisture in feedstock content of moisture in biomass has a significant effect on biomass characteristics to the combustion procedure established a Fuzzy logic (FL-ANN) centered model for forecasting for predicting the thermal properties of carbon dioxide, they thought about weight, the environment temperatures, days of stay, feedstock handling, and so on. The crew built the FL-ANN system, which demonstrated 92.88% reliability based on 20 distinct farm study data. (Tan et al. 2009). They tested 108 specimens with this artificial structure and discovered that the average moisture level is 30.16%. Researchers conduct another study in which an (ANN) method was used to anticipate the process of combustion. The genetic algorithm method was used to optimized parameters of combustion such as combust temperatures, feed flow rate, catalyst, and so on. Furthermore, numerous investigators worked on the deployment of AI to increase the effectiveness of knowledges of bioenergy production in order to obtain the highest energy output.

8. Conclusions

Different sources produced biological waste which comes like plants, household, agriculture, hospitals, paper pulp industry, animal waste, construction sites, industrial liquid and municipal solid waste. Solid waste required appropriate supervision and handling to confirm the clean and safe atmosphere. To produce different valuable products the waste can be used such as biofuels, heat, electricity, biogas and biodiesel. Neural network the proposed technique of AI predicts the amount of waste. In improving treatment efficacy, lessen environmental hazards, and give computational solutions for efficient waste management artificial intelligence can help. Different AI models for efficient waste management were analyzed. Although they have some limitations but, in the future, artificial intelligence will better able to manage the problem of waste in a more efficient way.

References

Abdallah, Mohammed, Manar Abu Talib, Sainab Feroz, Qasim Nasir, Hadeed Abdalla, and Bayan Mahfood. 2020. Artificial intelligence applications in solid waste management: A systematic research review. *Waste Management* 109: 231–246. https://doi.org/10.1016/j.wasman.2020.04.057

Aghbashlo, Murtaza, Homa Hosseinzadeh-Bandbafha, Hossein Shahbeik, and Meisam Tabatabaei. 2022. The role of sustainability assessment tools in realizing bioenergy and bioproduct systems. *Biofuel Research Journal* 9: 1697–1706. https://www.biofueljournal.com/article_155564.html

Ahmad, Imran Shabbir, and Do Hyeun Kim. 2020. Quantum GIS based descriptive and predictive data analysis for effective planning of waste management. *IEEE Access* 8: 46193–46205. *IEEE Access* 8: 46193–46205. https://www.semanticscholar.org/paper/Quantum-GIS-Based-Descriptive-and-Predictive-Data-Imran-Ahmad/6301d9e3411866886e8154a5f466c5037334b31c

Akpan, Victor E., and David, O. Olukanni. 2020. Hazardous waste management: An African overview. *Recycling* 5: 1-24. https://www.mdpi.com/2313-4321/5/3/15

Andeobu, Lynda, Santoso Wibowo, and Srimannarayana Grandhi. 2022. Artificial intelligence applications for sustainable solid waste management practices in Australia: A systematic review. *Science of the Total Environment* 834: https://doi.org/10.1016/j.scitotenv.2022.155389

Bhatia, Shahshi Kand, Hwang Soo Joo, and Yung Hun Yang. 2018. Biowaste-to-bioenergy using biological methods: A mini-review. *Energy Conversion and Management* 177: 640–660. https://doi.org/10.1016/j.enconman.2018.09.059

Chang, Haixing, Yajun Zou, Rui Hu, Haowen Feng, Haihua Wu, Nianbing Zhong, and Jianjun Hu. 2020. Membrane applications for microbial energy conversion: A review. *Environmental Chemistry Letters* 18: 1581–1592. https://link.springer.com/article/10.1007/s10311-020-01032-7

Chattopadhyay, S., and Singha, R. 2022. Bio-waste: An introduction to its management. Agric. Food E-Newsl, 4, 379-381.

Chen, Lin, Lepeng Huang, Jianmin Hua, Zhonghao Chen, Lilong Wei, Ahmed I. Osman, and Sameer Fawzy et al. 2023. Green construction for low-carbon cities: A review. *Environmental Chemistry Letters*: 1–31. https://link.springer.com/article/10.1007/s10311-022-01544-4

Chiu, Ming Chiu, Chih Yua Wen, Hsin Wei Hsu, and Wei-Chen Wang. 2022. Key wastes selection and prediction improvement for biogas production through hybrid machine learning methods. *Sustainable Energy Technologies and Assessments* 52. https://www.sciencedirect.com/science/article/abs/pii/S2213138822002752

Couto, Allan Motta, Thiago De Protásio, Trugilho, Paulo Fernando Trugilho, Thiago Andrade Neves and Vania Aparecida de Sa. 2013. Multivariate analysis applied to evaluation of Eucalyptus clones for bioenergy production. *Cerne* 19: 525–533. https://scispace.com/pdf/multivariate-analysis-applied-to-evaluation-of-eucalyptus-4sdukrl6bt.pdf

Cruz, Larissa P., Vinicius Pacheco, Luciano M. Silva, Rafael L Almeida, Rafael L. Almeida, Marcela T. Miranda, Maria D. Pissolato, Eduardo C. Machado and Rafael V. Ribeiro. 2021. Morpho-physiological bases of biomass production by energy cane and sugarcane: A comparative study. *Industrial Crops and Products* 171. https://doi.org/10.1016/j.indcrop.2021.113884

Demirbas, Ayhan. 2011. Waste management, waste resource facilities and waste conversion processes. *Energy Conversion and Management* 52: 1280–1287. https://www.sciencedirect.com/science/article/abs/pii/S0196890410004279

Fang, Bingbing, Jiacheng Yu, Zhonghao Chen, Ahmed I. Osman, Mohamed Farghali, Ikko Ihara, and Essam H. Hamza et al. 2023. Artificial intelligence for waste management in smart cities: A review. *Environmental Chemistry Letters* 21: 1959-1989. https://doi.org/10.1007/s10311-023-01604-0

Farghali, Mohamed, Ahmed I. Osman, Isra M. A. Mohamed, Zhonghao Chen, Lin Chen, Ikko Ihara and David W. Rooney. 2023. Strategies to save energy in the context of the energy crisis: A review. *Environmental Chemistry Letters* 2003-2039. https://link.springer.com/article/10.1007/s10311-023-01591-5

Fenta, Biruk Abate. 2017. Waste management in the case of Bahir Dar City near Lake Tana shore in Northwestern Ethiopia: A review. *African Journal of Environmental Science and Technology* 11: 393–412. https://academicjournals.org/journal/AJEST/article-full-text/60C213665187

Hansen, S., and Mirkouei, A. 2018. Past infrastructures and future machine intelligence (MI) for biofuel production: A review and MI-based framework. *American Society of Mechanical Engineers*:1-10. https://asmedigitalcollection.asme.org/IDETC-CIE/proceedings-abstract/IDETC-CIE2018/51791/V004T05A022/274971

He, Zhang Wei, Wen-Jing Yang, Yong-Xiang Ren, Hong-Yu Jin, Cong-Cong Tang, Wen-Zong Liu, Chun-Xue Yang Ai-Juan Zhou and Ai-Jie Wang. 2021. Occurrence, effect, and fate of residual microplastics in anaerobic digestion of waste activated sludge: A state-of-the-art review. *Bioresource Technology* 331. https://www.sciencedirect.com/science/article/abs/pii/S09608524 21003746

Hu, Bin, Yilun Zhang, Yi Li, Yanguo Teng, and Weifen Yue. 2020. Can bioenergy carbon capture and storage aggravate global water crisis? *Science of the Total Environment* 714. https://www.sciencedirect.com/science/article/abs/pii/S00489697 20303661

Huang, Juera, and Dmitry D. Koroteev. 2021. Artificial intelligence for planning of energy and waste management. *Sustainable Energy Technologies and Assessments* 47. https://www.sciencedirect.com/science/article/abs/pii/S2213138821004367

Jha, Rupali, Shipra Dwivedi, and Bharat Modhera. 2022. Measurement and practices for hazardous waste management. *Hazardous waste management*: 89–115. https://www.sciencedirect.com/science/chapter/edited-volume/abs/pii/B9780128243442000112

Kamali, Mohammadreza, Liza Appels, Xiaobin Yu, Tejraj M. Aminabhav, and Raf Dewil. 2021. Artificial intelligence as a sustainable tool in wastewater treatment using membrane bioreactors. *Chemical Engineering Journal* 417. https://www.sciencedirect.com/science/article/abs/pii/S1385894720341875

Kshirsagar, Pravin R., Neeraj Kumar, Ahmed H. Almulihi, Fawaz Alassery, Asif Irshad Khan, Saiful Islam,Jyoti P. Rothe, D. B. V. Jagannadham, Kenenisa Dekeba. 2022. Artificial intelligence-based robotic technique for reusable waste materials. *Computational Intelligence and Neuroscience* 2022, 1–10. https://onlinelibrary.wiley.com/doi/10.1155/2022/2073482

Kumar, M. Iniya, S. Naveen, and A. Ramalakshmi. 2021. Valorization of biowastes into food, fuels, and chemicals: Towards sustainable environment, economy, and society. *Sustainable Bioeconomy*: 85–100. https://doi.org/10.1007/978-981-16-3797-9_5

Lin, Kunsen, Zoucai Zhao, Jia-Hong Kuo, Hao Deng, Feifei Cui, Zilong Zhang, Meilan Zhang, Chunlong Zhao, Xiaofeng Gao Tao Zhou, Tao Wang. 2022. Toward smarter management and recovery of municipal solid waste: A critical review on deep learning approaches. *Journal of Cleaner Production* 346. https://www.sciencedirect.com/science/article/abs/pii/S0959652622005807

Liu, S., Cao, L., Xu, F., Yang, L., Li, Y., and Inalegwu, O. S. 2021. Integration of algae cultivation to anaerobic digestion for biofuel and bioenergy production. *Advances in Bioenergy* 6: 199–300. https://doi.org/10.1016/bs.aibe.2021.02.003

Meena, Manish, Shubham Shubham, Kunwar Paritosh, Nidhi Pareek, and Vivekanand Vivekanand. 2021. Production of biofuels from biomass: Predicting the energy employing artificial intelligence modelling. *Bioresource Technology* 340. https://www.sciencedirect.com/science/article/abs/pii/S0960852421009834

Mukherjee Anirban Goutam, Uddesh Ramesh Wanjari, Rituraj Chakraborty, Kaviyarasi Renu, Balachandar Vellingiri, Alex George, Sundara Rajan C. R., Abilash Valsala Gopalakrishnan. 2021. A review on modern and smart technologies for efficient waste disposal and management. *Journal of Environmental Management* 297. https://www.sciencedirect.com/science/article/abs/pii/S0301479721014092

Noiki, Ayodeji, Sundar A. Afolalu, Abioye, A. Abioye, Christian A. Bolu, and Moses E. Emetere. 2021. Smart waste bin system: a review. *IOP Conference Series: Earth and Environmental Science* 655. https://doi.org/10.1088/1755-1315/655/1/012036

Ogunwolu, Ladi, Henry Mbom, Abubakar Raji and Abolade Omiyale. 2020. Design and Implementation of an IoT Based Smart Waste Bin for Fill Level and Biodegradability Monitoring. *Journal of Engineering Research* 25: 84-95. https://www.researchgate.net/publication/348140087

Osman, Ahmed I., Lin Chen, Mingyu Yang, Goodluck Msigwa, Mohamed Farghali, Samer Fawzy, David W. Rooney and Pow-Seng Yap. 2023. Cost, environmental impact, and resilience of renewable energy under a changing climate: A review. *Environmental Chemistry Letters* 21: 741–764. https://doi.org/10.1007/s10311-022-01532-8

Osman, Ahmed I., Mohamed Hosny, Abdelazeem S. Eltaweil, Sara Omar, Ahmed M. Elgarahy, Mohamed Farghali, and Pow-Seng Yap et al. 2023. Microplastic sources, formation, toxicity and remediation: A review. *Environmental Chemistry Letters*, 21: 2129–2169. https://link.springer.com/article/10.1007/s10311-023-01593-3

Peng, Xiaoxaun, Yushan Jiang, Zhonghao Chen, Ahmed I. Osman, Mohamed Farghali, David W. Rooney, and Pow-Seng Yap. 2023. Recycling municipal, agricultural and industrial waste into energy, fertilizers, food and construction materials, and economic feasibility: A review. *Environmental Chemistry Letters* 21, 765–801. https://doi.org/10.1007/s10311-022-01539-1

Pennachin, Cassion, and Ben Goertzel. 2007. Contemporary approaches to artificial general intelligence. *Artificial general intelligence*: 1–30. https://doi.org/10.1007/978-3-540-68677-4_1

Qiu, Linrun, Dongbo Zhang, Yuan Tian, and Najla Al-Nabhan. 2021. Deep learning-based algorithm for vehicle detection in intelligent transportation systems. *The Journal of Supercomputing* 77: 11083–11098. https://doi.org/10.1007/s11227-021-03757-z

Sajjadi, Baharak, Wei-Yin Chen, Abdul Aziz Abdul Raman, and Shaliza Ibrahim. 2018. Microalgae lipid and biomass for biofuel production: A comprehensive review on lipid enhancement strategies and their effects on fatty acid composition. *Renewable and Sustainable Energy Reviews* 97: 200–232. https://doi.org/10.1016/j.rser.2018.08.050

Sharma, K. D., and Jain, S. 2020. Municipal solid waste generation, composition, and management: The global scenario. *Social Responsibility Journal* 16: 917–948. https://doi.org/10.1108/SRJ-06-2019-0210

Shreyas Madhav, AV., Raghav Rajaraman, S. Harini, S., and Cinu C, Kiliroor. 2022. Application of artificial intelligence to enhance collection of E-waste: A potential solution for household WEEE collection and segregation in India. *Waste Management & Research* 40: 1047–1053. https://doi.org/10.1177/0734242X221090758

Sikarwar, Vineet Singh, Ming Zhao, Peter Clough, Joseph Yao, Xia Zhong, Mohammed Zaki Memon, Nilay Shah, Edward J, Anthony and Paul S. Fennell. 2016. An overview of advances in biomass gasification. *Energy & Environmental Science* 9: 2939–2977. https://pubs.rsc.org/en/content/articlelanding/2016/ee/c6ee00935b

Singh, Anamika, Sabeela Beevi Ummalyma, and Dinabandhu Sahoo. 2020. Bioremediation and biomass production of microalgae cultivation in river water contaminated with pharmaceutical effluent. *Bioresource Technology* 307. https://doi.org/10.1016/j.biortech.2020.123233

Soni, Umang, Akashdeep Roy, Ayush Verma, and Vipul Jain. 2019. Forecasting municipal solid waste generation using artificial intelligence models-a case study in India. *SN Applied Sciences* 1. https://doi.org/10.1007/s42452-019-0167-8

Tan, R. R., Ballacillo, J.-A. B., Aviso, K. B., and Culaba, A. B. 2009. A fuzzy multiple-objective approach to the optimization of bioenergy system footprints. *Chemical Engineering Research and Design* 87: 1162–1170. https://doi.org/10.1016/j.cherd.2009.02.004

Thiruvengadam, Sudharsan, Mathew Edmund Murphy, and Jei Shian Tan. 2021. Mathematically modelling pyrolytic polygeneration processes using artificial intelligence. *Fuel* 295. https://doi.org/10.1016/j.fuel.2021.120488

Triassi, Maria, Rosella Alfano, Maddalena Illario, Antonio Nardone, Oreste Caporale, and Paolo Montuori. 2015. Environmental pollution from illegal waste disposal and health effects: A review on the "Triangle of Death." *International Journal of Environmental Research and Public Health* 12, 1216–1236. https://doi.org/10.3390/ijerph120201216

van Cranenburgh, Sander, Shenhao Wang, Akshay Vij, Francisco Pereira, and Jaan Walker. 2022. Choice modelling in the age of machine learning: Discussion paper. *Journal of Choice Modelling* 42. https://doi.org/10.1016/j.jocm.2021.100340

Van Der Aalst, Wil. 2016. Process mining: Data science in action. *second edition*: 3-23. https://doi.org/10.1007/978-3-662-49851-4_1

Vickers, Neil J. 2017. Animal communication: When I'm calling you, will you answer too? *Current Biology* 27: R713–R715. https://doi.org/10.1016/j.cub.2017.05.064

Weinrich, Soren, and Michael Nelles. 2021. Systematic simplification of the Anaerobic Digestion Model No. 1 (ADM1): Model development and stoichiometric analysis. *Bioresource Technology* 333. https://doi.org/10.1016/j.biortech.2021.125124

Woodruff, Robert B. 1997. Customer value: The next source for competitive advantage. *Journal of the Academy of Marketing Science* 25: 139–153. https://doi.org/10.1007/BF02894350

Xu, Fuqing, Li, Yangyang, Xumeng Ge, Liangcheng Yang, and Yebo Li. 2018. Anaerobic digestion of food waste: Challenges and opportunities. *Bioresource Technology* 247, 1047–1058. https://doi.org/10.1016/j.biortech.2017.09.020

Yigitcanlar, Tan, and Federico Cugurullo. 2020. The sustainability of artificial intelligence: An urbanistic viewpoint from the lens of smart and sustainable cities. *Sustainability* 12. https://doi.org/10.3390/su12208548

Yu, L., Q. W. Li, S. W. Jin, C. Chen, Y. P. Li, T. R. Fan,and Q. T. Zuo. 2020. Coupling the two-level programming and copula for optimizing energy-water nexus system management: A case study of Henan Province. *Journal of Hydrology* 586. https://doi.org/10.1016/j.jhydrol.2020.124832

Zhang, Q., Zhang, X., Mu, X., Wang, Z., Tian, R., Wang, X., and Liu, X. 2021. Recyclable waste image recognition based on deep learning. *Resources, Conservation and Recycling* 171. https://doi.org/10.1016/j.resconrec.2021.105636

Zhou, Y., Sun, Q., and Liu, J. 2018. Robust optimisation algorithm for the measurement matrix in compressed sensing. *Cyber-Physical Systems Theory and Applications* 3, 133–139. https://doi.org/10.1049/cps2.12008