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REVIEW ARTICLE

Comparison of the Effectiveness of Electrical Energy Production from Livestock Manure by Optimization using Combined Heat and Power (CHP) Method: A Literature Review

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Abstract

Livestock manure is a potential source of renewable energy. This study compares the effectiveness of electrical energy production from livestock manure with and without optimization using the Combined Heat and Power (CHP) method. Using the CHP method can improve energy efficiency by utilizing the heat generated from burning livestock manure to produce electricity and heat. The literature shows that CHP can significantly improve energy efficiency. The energy efficiency of CHP systems can reach 80%, compared to 30-40% for conventional systems. In addition, CHP can produce lower greenhouse gas emissions compared to traditional systems. The study also shows that CHP can be an economical solution to generate electrical energy from livestock manure. CHP systems can generate significant economic benefits in the long run.

Keywords: Livestock manure, CHP, renewable energy, energy efficiency

1. Introduction

As the population increases and people's energy consumption increases, the need for available energy is also increasing, this is due to the use of various electronic devices that support daily comfort [1]. The energy used today mainly comes from fossil fuels such as coal, oil, natural gas, and other types of energy [2]. Renewable energy is energy obtained from solar heat, water, wind, geothermal, ocean waves, and biomass [3].

Biogas is a gas produced by anaerobic processes or fermentation of organic matter, including urban waste, biological waste, or organic waste that decomposes under anaerobic conditions [4]. The main components of biomass are methane (CH_4) and carbon dioxide (CO_2). Biogas plays an important role in the global energy transition as the global energy system needs to move from on-site to low-carbon energy generation. [5]. Cow manure is a substrate that is considered the most suitable source of biogas production because the substrate contains methane-producing bacteria found in the stomachs of ruminants [6]. The presence of bacteria in the large intestine of ruminants helps the fermentation process, so that the process of biogas formation in the digestive tank can be carried out more quickly [7].

Table 1. The Samples for Substance Characterization

Substrate	C	H	N	S	VS (%)	TS (%)	C/N ratio
Grass clippings Chicken	19.10	1.04	0.93	0.00	64.08	87.88	20.54
Chicken Manure	63.67	0.85	3.11	2.25	11.75	18.74	20.47
Cow dung	14.87	1.65	0.84	3.66	78.72	91.55	17.70
Pig dropping	42.26	0.70	2.62	0.00	55.70	76.80	16.16

The researchers studied the biogas production potential (bio-methane potential) and speed of decomposition (biochemical kinetics) of different manure sources (cow dung, pig manure, and chicken manure) when digested together with grass clippings. The experiment was conducted under ideal conditions: a temperature of 37°C and an initial pH of 7. Additional details on the composition of each material used (substrate characterization) are presented in Figure 1 [6]. Conventional combined heat and power plants produce both heat and electricity. Although they are efficient in using waste heat for heating, their ability to regulate electricity production is limited because heat and electricity output are interconnected. Simply put, the amount of electricity a CHP plant can generate depends on the amount of heat it produces [8].

2. Research Methodology

This study adopted a literature review design. Library research is a method of collecting information or sources related to a topic from various sources such as journals and research articles, reference books, and reliable websites. Literature studies provide a comprehensive review of the literature related to a theme, theory, method and synthesize previous research to strengthen the knowledge base [9]. This literature study research is designed not based on direct research but sourced directly from journals and books which usually contain summaries of references to several journal articles or books.

Table 2. Literature Study Analysis

No.	Source	Research design	Research results
1	[10]	The research discusses energy efficiency in the power industry using the Combined Heat and Power method. Cogeneration systems utilize livestock manure to produce biogas as fuel. The system generates electrical energy and steam with an efficiency of 46.7%, higher than the minimum efficiency considered good for a power plant (35%)	The combined use of electricity and heat in the biogas industry is the energy efficiency achieved by the combined head and power is 46.7%, which is calculated based on the combustion of biogas for the production of electricity and steam used in production process. In addition, the use of biogas as fuel in cogeneration of electricity and heat can also reduce CO_2 emissions by 178,685,782 tons and create a clean and healthy environment. Thus, it offers great advantages in terms of energy efficiency, emission reduction and environmental sustainability.
2	[11]	The research aims to understand and improve the applicability of CHP technology in various energy contexts. The main focus is on energy efficiency, economic aspects, environmental impacts, optimal operational strategies, and integration with renewable energy sources. With a comprehensive approach, this research is expected to make a valuable contribution to the development and application of CHP to achieve sustainability goals in the energy sector.	Research on Combined Heat and Power (CHP) in biogas utilization shows that this technology improves the efficiency of energy production. Biogas, which is produced from organic materials such as livestock waste and food industry waste, contains methane (55- 75%), which has a high heating value. CHP utilizes biogas for various purposes, including cooking, lighting, and vehicle fuel, as well as supporting the natural gas grid. The benefits of CHP include renewable energy production, reduced greenhouse gas emissions and sustainable waste management.

3	[12]	Current management of livestock waste, optimization of anaerobic digestion technology for biogas production, establishment of anaerobic digestion experiments with different types of livestock waste and analysis of the environmental impact and economic benefit of increasing biogas production. The expected results are to find out the possibilities of biogas production from livestock waste, optimization strategies to improve the yield and quality of biogas, and views on the environmental benefits and economic benefit of using livestock waste in biogas production.	Through optimized anaerobic digestion technology, it is seen that biogas yield and quality can be improved, leading to increased energy output from organic waste. The natural benefits of actualizing biogas generation from animals fertilizer are apparent, with diminished nursery gas outflows and way better squander administration hones. In expansion, the financial achievability of scaling up biogas generation has too been illustrated, appearing the potential for cost-effective renewable vitality era within the animals industry. Overall, this study highlights the importance of sustainable energy development and the positive impact of utilizing livestock manure for biogas production in China.
4	[13]	Data collection and livestock statistics to identify bioenergy potential in each district. Furthermore, the research focused on the mathematical estimation of livestock waste and biogas production using parameters such as biogas yield, availability coefficient, and total solids. This research is expected to provide an understanding of the renewable energy potential of livestock waste, as well as its contribution to environmental sustainability and reduction of greenhouse gas emissions.	This study demonstrates the huge potential for decentralized green bioenergy production in Haryana, India. Estimates show that 52.29 million tons of livestock manure per year can produce approximately 5464.11 million m^3 of biogas, which is equivalent to 106.11 GJ of heat and 9.84 TWh of electricity. The biomass dissemination, control thickness, and power potential per capita are anticipated to be 27.41 kton/km^2, 0.59 W/m^2, and 387.96 kWh/capita, separately. Uncertainty analysis was conducted for various scenarios. Although the potential for bioenergy is large, there are barriers such as biomass availability, logistics, bioenergy policy, and institutional support. This ponder can serve as a demonstrate for worldwide agrarian locales to assist approach producers arrange for vitality security and climate alter moderation.
5	[14]	Research on Combined Heat and Power (CHP) includes analysis of energy efficiency, economic feasibility, environmental impact, operational optimization, and integration with renewable energy. The goal is to improve the implementation of CHP technology	Research shows that biogas from livestock manure in CHP systems is favorable for sustainability, despite its low efficiency. Using livestock manure for biogas plants is economically and environmentally better than applying it directly to the soil, and covering the manure reduces methane emissions. Storing manure without cover for

		to achieve sustainability in the energy sector.	extended periods leads to substantial quality degradation and environmental pollution. Covering and composting manure can significantly reduce methane emissions to 0.86 Mg, compared to 4.87 Mg when left uncovered. To enhance biogas production, mixing manure with other agricultural waste is advised. Investing in biogas CHP technology can help farms address future energy and environmental challenges.
6	[15]	Potential research involves understanding the dynamics and load response of biogas CHP systems in the power grid. The focus is on comparing the environmental impact of biogas CHP with conventional energy sources, efficiency, and emissions during startup and shutdown. Integration of biogas with CHP could improve sustainability, while evaluation of hybrid systems with photovoltaics holds promise for renewable energy research.	The findings show that biogas CHP systems are more flexible in partial load operation than natural gas CHP. This is important for balancing intermittent power sources such as photovoltaic (PV). The catalytic method in flue gas purification affects the flue gas composition, with biogas CHP systems using oxidation catalysts resulting in low CO emissions. Biogas CHP systems can enhance the stability of the electricity grid, particularly in rural regions. In general, biogas CHP systems provide a dependable source of renewable energy, benefiting both the environment and grid stability.
7	[16]	The research plan includes the examination of energy issues, the collection of data on the bioenergy of livestock waste and the analysis of the potential of biomass for energy production. The results of this study not only identify the potential of using electrical energy from animal waste biomass in the Bali region, but also contribute to the development of new and renewable energy and the achievement of new and renewable energy goals.	A biogas plant in the province of Bali has demonstrated the potential of using livestock waste as a source of electrical energy. From the analysis of livestock population data from 2013 to 2017, information was obtained that the total biogas that could be produced reached 246,130.81 m^3, equivalent to 1,156,814.81 kWh/day or about 1.16 GWh/day from an average total livestock population of 19,183,779 livestock. These results show the great potential in generating electrical energy through the utilization of livestock manure in Bali Province. Therefore, this research will contribute positively to the development of renewable energies and the achievement of new energy goals in the region.
8	[17]	This research investigates the potential for sustainable biogas production from livestock waste in the Canary Islands by researching literature on biogas technology,	The study found that biomass production using animal waste has great potential as a sustainable energy source for the Canary Islands. The study found a great opportunity to

		renewable energy, and livestock farming, and analyzing data on livestock populations, manure production, and current biogas facilities. The research will assess the technical and economic feasibility of biogas projects on selected farms, and evaluate the environmental impacts and benefits of biogas production.	produce renewable energy from manure and showed that bioenergy projects can be implemented on many farms. Challenges include the need for improved manure management and infrastructure investment. Recommendations include the development of cost-effective biogas generation models, as well as the exploration of co-digestion with agro-industrial waste for higher efficiency. This research emphasizes the importance of biogas production as a renewable energy strategy and sustainable agricultural practice in the Canary Islands.
9	[18]	This study evaluates the technical and economic feasibility of replacing fossil-fueled technologies on animal farms with biogas-fired CHP units. Through sensitivity analysis and regional economic modeling, the study assessed the use of biogas from livestock waste in CHP systems for heat and electricity. The results show that the use of biogas can reduce primary energy consumption and operating costs, and provide environmental benefits such as reduced greenhouse gas emissions and dependence on fossil fuels.	The results show that using biogas-based CHP technology is superior to conventional technology, both economically and environmentally. The use of biogas results in annual savings of $73,159.31, a profitability index of 60.99%, and a payback period of 28.5 months. In addition, CO2 emissions were reduced by 529.65 tons per year. Sensitivity analysis showed variations in the profitability of the biogas CHP unit due to changes in the prices of diesel fuel, electricity, and electricity buyback. Biogas technology also significantly reduces primary energy consumption and operating costs.
10	[19]	The aim of this research is to create a model to analyze the technical and economic feasibility of investing in a biodigester system that uses cow dung to produce electricity and biofertilizers on grassland. This model consists of two parts: technical feasibility analysis (TFA) and economic feasibility analysis (EFA).	In the TFA phase, the researchers evaluated factors such as the type and amount of substrate, the influence of external temperature, the hydraulic residence time (HRT) of the system, the amount of energy produced and energy cost savings. Three types of bioremediation systems were compared: cow dung digester (Project A), cow dung/corn digester (60:40 - Project B) and cow dung/sorghum digester (60:40 - Project C), every 10 power levels (100-1000 kWe). In the EFA phase, the researchers assessed the economic feasibility using net present value (NPV), expanded multivariate index methodology (EMIM) and Monte Carlo simulation (MCS). EMIM evaluates three aspects: return on

	investment, risk and sensitivity. MCS is used to analyze topics with high sensitivity.

3. Results and discussion

Based on the analysis of the literature study on 10 journal articles that met the screening criteria, the research articles had the main topic of biogas. The results of the review of the 15 research articles are presented in the following explanation:

3.1 Effectiveness of Electrical Energy Production from Biogas Generated from Livestock Waste with Conventional Methods

Numerous variables, including the volume of biogas generated, its energy content, its cost-effectiveness, and its environmental impact, may be used to evaluate how successful biogas made from animal waste using conventional methods. Anaerobic digestion without further purification takes place in basic digesters as part of conventional biogas generation processes. Technically speaking, biogas made from livestock waste typically contains between 50 and 70 percent methane (CH_4), which offers a high enough heating value to be utilized as a fuel. Although it would need to be further purified for some uses, including automotive fuel, this content is high enough to be used as an alternative fuel [20]. The effectiveness of producing biogas can be impacted by temperature fluctuations and changes in waste content, which could threaten the stability of conventional methods despite their relative simplicity and ease of use. The effectiveness of biogas generation is influenced by several parameters, including the kind of animal waste, pH, temperature, and digester retention time. The amount of methane and other impurities including carbon dioxide (CO_2), hydrogen sulfide (H_2S), and water vapor also affects the quality of biogas; purifying biogas can increase the fuel's efficiency [21].

Several studies and experimental initiatives have exhibited the efficacy of producing biogas from livestock waste. For instance, the use of biogas from cow dung has effectively decreased reliance on LPG and wood fuel in some parts of India, while also improving public health by lowering interior pollution [22]. Large farms in Germany employ biogas facilities to sell excess power to the national grid and produce heat and electricity for use on the farm [23]. Conventional techniques of converting biogas to electricity provide 2.4 m^3/kWh of electricity [24].

Overall, biogas produced from livestock waste is a successful renewable energy. Using this methods can result in lower energy expenses and greenhouse gas emissions, but it also improves waste management and produces organic fertilizer, among other advantages. Effective management, policy support, and local circumstances are necessary for successful implementation.

3.2 Effectiveness of Electrical Energy Production from Biogas from Livestock Waste with CHP (Combined Heat and Power) Method

Utilizing the CHP (Combined Heat and Power) technology to produce biogas from livestock waste is an extremely effective integrated approach to harnessing renewable energy resources. Using anaerobic digestion in a digester, this technique not only produces methane-rich biogas but also makes use of the heat produced to produce both heat and electricity at the same time. Because of its relatively high methane concentration, between 50%-75%, the biogas generated can serve as a viable alternative fuel to replace fossil fuels [25].

In addition to increasing energy efficiency, using the heat produced for industrial operations or space heating also drastically lowers greenhouse gas emissions. Furthermore, the CHP process lowers pollution levels in the environment, improves the management of animal waste, and generates digestate, which may be turned into nutrient-rich organic fertilizer. Even though CHP installations might have high upfront costs, waste treatment plants and livestock producers find it to be a desirable investment due to its long-term benefits of lower operating costs and energy savings as well as considerable environmental benefits. [23]

The efficacy of CHP in optimizing energy extraction from livestock waste has been proved by several case studies and deployments on farms and in waste treatment facilities. When biogas is used in conjunction with CHP techniques, these examples frequently demonstrate notable increases in energy efficiency, financial savings, and environmental advantages [26]. With an efficiency of 46.7%, the system generates steam and electrical energy, above the minimum 35 percent efficiency deemed satisfactory for a CHP plant [10].

Research on the energy production supply chain from anaerobic digestion and agricultural and animal waste sources reveals a biogas-to-energy conversion rate of around 5.5 kWh per cubic meter. CHP is a common method for producing energy efficiently, and it may be used to convert biogas into electricity [27]. All things considered, the CHP technique is a comprehensive strategy for producing high biogas output and using the heat produced for other uses, so improving the energy recovery from livestock waste. CHP is a desirable alternative for farms and waste treatment facilities searching for effective and sustainable energy management solutions because of its substantial economic and environmental advantages.

3.3 Comparison of the Effectiveness of Electrical Energy Production from Biogas from Livestock Manure with conventional and CHP (Combined Heat and Power) Methods

Several main parameters may be used to compare the efficacy of biogas from livestock waste produced using traditional and CHP (Combined Heat and Power) technologies, including energy efficiency, by-product usage, environmental impact, and operational costs. In the conventional method, the typical approach is simple anaerobic fermentation in digesters, which generates biogas that is immediately utilized for burning or heating. The energy conversion efficiency is fairly high, but the energy consumption of biogas is frequently suboptimal because the heat created is not fully utilized. This process yields digestate that may be utilized as organic fertilizer, however heat energy consumption is frequently suboptimal. The conventional approach decreases greenhouse gas emissions by avoiding direct dung burning, although the reduction is not considerable when compared to more modern systems. Although the basic technology utilized reduces operational expenses, low energy efficiency can raise long-term operational costs [28].

CHP, on the other hand, refers to the utilization of engines or turbines that may generate both electricity and heat from biogas. CHP systems have a substantially better energy conversion efficiency than conventional techniques since the energy generated is used for both electricity and heat, with total efficiency ranging from 75 to 80% [29]. In addition to generating electricity, the heat produced may be utilized for space heating, water, or other industrial activities, and the digestate can be used as organic fertilizer. CHP decreases greenhouse gas emissions considerably due to improved energy efficiency and more efficient use of heat, lowering reliance on fossil fuel sources. Although the initial cost of CHP installation is greater, increased energy efficiency can save operational expenses in the long term. Additional financial benefits can be obtained through power sales to the grid or internal consumption [30].

When it comes to energy efficiency, byproduct use, environmental impact, and operating costs, CHP systems are often more successful than conventional techniques in utilizing biogas from livestock waste. Because heat is used more effectively in CHP energy generation, the energy produced is more optimized, and the environmental impact is less harmful because greenhouse gas emissions are reduced more significantly. When considering a longer time frame, the return on investment (ROI) for CHP is greater since, despite its larger initial investment, it has lower long-term running expenses than conventional techniques [31].

4. Conclusions

The study concludes that biogas can be produced from livestock manure using both conventional and CHP methods, with CHP being more effective. Conventional methods yield biogas with 50-70% methane, while CHP methods produce 50-75% methane and achieve higher energy conversion efficiency by generating both electricity and heat. CHP systems reach 75-80% overall efficiency and utilize by-products like digestate as organic fertilizer. Environmentally, CHP reduces greenhouse gas emissions and fossil fuel dependence due to its optimal efficiency. Although CHP installation costs more initially, its superior energy efficiency results in lower long-term operational costs, making it the most sustainable solution for renewable energy from livestock waste.

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