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REALIZING GREEN ECONOMY: SYNERGIES BETWEEN WASTE MANAGEMENT AND ECONOMIC GROWTH IN THE OIL AND GAS SECTOR IN INDONESIA

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ABSTRACT

The implementation of a green economy is a key strategy in promoting sustainable development, especially in strategic sectors such as oil and gas in Indonesia. Green economy aims to improve human welfare in a sustainable manner by minimizing risks and pressures on the environment. This study aims to analyze the causality relationship between Gross Regional Domestic Product (GRDP), waste generation, population density, and energy use. The method used is panel data analysis with the Vector Error Correction Model (VECM) approach, which is able to identify long-term and short-term relationships between variables. The results show that there is a unidirectional causality relationship between waste generation and GRDP, as well as between population density and GRDP. In the long run, there is a significant relationship between population density and regional economic growth. Meanwhile, in the short term, there is a relationship between GRDP and population density. These findings emphasize the importance of waste management and population planning as an integral part of green economic development strategies in the oil and gas sector. This research contributes to the strengthening of environment-based policies that support the integration between economic development and ecosystem sustainability.

Keywords: Green Growth; Waste Generation; Population Density; Energy Consumption

A. INTRODUCTION

Low emission economic activities are a key focus in Indonesia efforts to achieve zero emissions by 2060. The implementation of a green economy is becoming increasingly important in the context of sustainable development and environmental conservation. The green economy is a mechanism that can result in the improvement and development of human welfare, while significantly reducing environmental risks and constraints (Lumbanraja & Lumbanraja, 2023). In this case Indonesia is experiencing rapid progress with a growth rate that is among the highest in the world with an increase in Gross Domestic Regional Product (GDP) reaching IDR 5,638.9 trillion (Badan Pusat Statistik, 2024). With increasing economic growth, the amount of waste generation has also increased globally. Effective waste management is one of the solutions in dealing with environmental degradation and social activities in a region (Muis et al., 2024).

Growing awareness of the impact of waste on the environment has prompted a range of activities aimed at controlling waste generation (Sidik, 2022). The high level of consumption and goods coupled with increasing population growth and high living standards leads to high levels of waste generation that pose a serious threat to the environment if not disposed of or recycled effectively (S. Nanda, Berruti, 2021). In this regard, it is important to know the impact of waste production on environmental damage in economic growth (Shah et al., 2023). Consequently, solid waste management is divided into two categories: organic waste and inorganic waste (Ali et al., 2020). This requires measurable management or a series of activities that suggest implementation, planning and monitoring to achieve set goals (Karundeng el al., 2018).

The rapid increase in population accompanied by industrial development has led to the production of large amounts of waste, causing socio-economic and environmental problems. According to Sira (2022), in environmental protection, waste management plays an important role, as waste affects people's daily lives and business activities. Knowing about this Manea (2024), explains that there is a link between economic and environmental factors for sustainable development. Sustainable development also has a relationship with the circular economy, which prioritizes environmentally friendly waste management to increase economic growth. Therefore, there is an urgent need to link high energy demand and rising waste levels for sustainable development growth.

Recent research conducted by Boloy (2021) showed that combustion, anaerobic digestion, and pyrolysis are Waste to Energy (WtE) technology management methods that turn solid waste into energy sources. Waste to Energy (WtE) technology is becoming a major focus in addressing energy and waste management issues in developed countries (Ali et al., 2020), This technology utilizes waste as a renewable energy source, which helps reduce dependence on fossil fuels and addresses the environmental concerns of inefficient waste disposal (Muis et al., 2021).

While renewable, the production and utilization of waste involves economic issues and also generates environmental impacts that need to be adequately identified and measured so that they can be managed more efficiently. Some previous researchers have identified that economic variables as factors that generate waste output (Zambrano et al., 2021). Accordinig to Cheng (2020), attributes the increase in waste generation to population growth and rapid urbanization, which tend to be followed by increased economic growth. Recognizing this Soukiazis (2020), explained that how waste production follows the same progression of population density, urbanization rate, and economic growth.

Among the methods used in this study, there are many ways to justify the contribution of waste generation, population density, energy use to economic growth (Boubellouta & Kusch, 2021). This study examines the relationship between waste generation, population density, and the use of energy sources on economic growth. Therefore, this review examines sustainability by applying WtE technology with economic growth in a correlation model (VECM). This review highlights ways to solve problems and issues related to renewable energy demand by applying WtE technology to support alternative fuels while reducing dependence on fossil energy sources (Pradhan et al., 2018).

B. METHODS

This research uses a quantitative approach method. The type of data used in this study is panel data, which is a combination of time series and cross section data. The samples used in this study were 34 provinces in Indonesia during the period 2019 to 2023. The independent variables used are the amount of waste generation, population density, installed capacity of electricity, while the dependent variable used is Gross Domestic Product (GDRP), implementing the VECM correlation model.

The relationship between Gross Domestic Regional Product (GDRP) and waste generation is due to the increase in people's consumption activities. This is because consumption is very influential on economic stability (Zambrano et al., 2021). While population density makes a significant contribution to economic growth (Chen et al., 2023). This implies that an increase in population density can boost economic activity and increase productivity.

The panel regression is used as an econometric model to analyze these variables. This analysis model is applied because the data operated in this study is panel. Numberically, the model looks as shown in the first equation.

$$GDRP = \alpha + \beta1WG + \beta2PD + \beta3AES + eit \quad (1)$$

Description:

GDRP = Gross Domestic Regional Product

WG = Waste generation

PD = Population density

AES = Application of energy sources

e = error term

i = cross section

t = time series

To interpret the coefficient estimates predicted through panel regression as the elasticity of each dimension with respect to the independent variables, all variables are transformed into logarithms. Thus equation 1 is modified into equation 2.

$$LogGDRPit = \alpha + \beta1LogWGit + \beta2LogPDit + \beta3LogAESit + eit \quad (2)$$

Description:

GDRP = Gross Domestic Regional Product

WG = Waste generation

PD = Population density

AES = Application of energy sources

e = error term

i = cross section

t = time series

Assertion on the significance of one of the variable dimensions refers to the p-value generated through statistical calculations. When a dimension has a p-value < 0.05, it indicates that this dimension has a significant effect. Conversely, it does not have a significant effect if it has a p-value > 0.05. Furthermore, justification regarding the significance of the influence of independent variables (simultaneously) on the dependent variable, is based on the statistical value of the F test. In this case, the p-value generated through the statistical test is also used as the basis for this justification, provided that if the p-value < 0.05 it is interpreted that simultaneously the independent variable is significant to the dependent variable. The opposite interpretation is given if the p-value > 0.05.

Cointegration test; This research uses first differences on all stationary variables, which is to estimate the long-run and short-run relationships between indicators. Cointegration testing can improve the accuracy and reliability of model results. Therefore, this research to see the amount of cointegration between variables can be known by comparing the t-statistic value with the critical value (Dhealika el al, 2021).

Granger panel causality test: This research uses the Granger causality test which was introduced to investigate the causal dynamics among variables and the reciprocal relationship between variables. The causality test is in line with Teklie (2024) explains the dependence between variables or has a causal relationship between variables.

C. RESULT AND DISCUSSION

Data analysis result

Panel data was analysed with descriptive statistical model estimation by showing that the amount of waste generation, population density, installed capacity of electricity in Indonesia during the analysis period fluctuated from year to year. On the other hand, Gross Domestic Regional Product (GDRP) also fluctuates from year to year. Using data for the period from 2019 to 2023, statistical tests show that the amount of waste generation tends to increase from year to year. Summarising the results of the descriptive statistical parameters of the independent variables and the dependent variable as in table 1.

Tabel 1. Results of Multiple Linear Regression Analysis and Partial Test

	GDRP (Billion)	WG (Ton)	PD (Km^2)	AES (Megawatt)
Mean	347.457,00	959.466,50	7.512.976	1.732.360
Median	139.379,50	457.352,70	1.015.000	4.626.800
Maximum	2.050.466,00	6.117.220,00	16.146,00	13.543,39
Minimum	26.597,55	16.834,53	9	0.6
Std. Dev	492.227,60	1.356.179,00	2.708.537	2.921.318
Observations	168	168	168	168

Source: Calculation results using E-views 12, 2024

Based on table 1, the average GDRP is IDR 347,457.00, while the minimum GDRP is IDR 26,597.55 and the maximum is IDR 2,050,466.00. Furthermore, the average level of waste generation is 959,466.50 tonnes, while the minimum amount of waste generation is 16,834.53 tonnes and the maximum amount of waste generation is 6,117,220.00 tonnes. The average population density reached 7,512,976 km2, then the minimum population density reached 9 km2, and the maximum value of population density was 16,146.00 km2. Furthermore, the average amount of installed power generation capacity is 1,732,360 megawatts, at the minimum average value of 0.6 megawatts, and at the maximum value on the amount of installed power generation capacity of 13,543.39 megawatts.

Correlation coefficient (r) was used to analyse the relationship between waste generation, population density, installed power generation capacity and gross regional domestic product (GDRP). Waste generation positively correlates with gross regional domestic product (r = 0.870). This is consistent with the estimation results (Table 2) which provide statistical information that the estimated coefficient of waste generation on gross domestic product. This can be explained in Table 2.

Tabel 2. Correlation Matrix Result

Variabel	Log (GDRP)	Log (WG)	Log (PD)	Log (AES)
Log (PDRB)	1			
Log (JTS)	0.870	1		
Log (KP)	0.613	0.691	1	
Log (KTPL)	0.552	0.475	0.254	1

Source: Calculation results using E-views 12, 2024

Table 2 above shows the estimation results of the correlation matrix that shows the relationship between the variables. The GRDP value is positively related to the amount of waste generation, population density, and installed capacity of power plants. This is shown by the correlation coefficient values of 0.870, 0.613, and 0.552, respectively. As GRDP increases, the level of waste generation, population density, and installed capacity of power plants also increases. The increase in GRDP to the amount of waste generation is indicated because the increasing GRDP in an area, the more waste is generated. The increase in GRDP is also significant to population density, this occurred due to migration to an area to find job opportunities. Similarly, the increase in GRDP is also significant for the installed capacity of power plants, with the increase in GRDP, the demand for energy also increases. The relationship of waste generation is also positive to population density and installed capacity of power plants with a correlation coefficient of 0.691 and 0.475. Likewise, the population density has a positive relationship with the installed capacity of the power plant.

This research also conducted a granger causality test. The granger causality test aims to determine the relationship between two economic variables that mutually affect each other (Adhitya el al, 2019).

Tabel 3. Granger Causality Test Result

Null Hypothesis	Obs	F-Statistik	Prob	Description
WG does not Granger Cause GDRP	102	0.02514	0.9752	There is no causality between WG and GDP
GDRP does not Granger Cause WG		2.45386	0.0913	
PD does not Granger Cause GDRP	102	0.00316	0.9968	There is no causality between PD and GDRP
GDRP does not Granger Cause PD		1.73106	0.1825	
AES does not Granger Cause GDRP	102	0.08937	0.9146	There is bidirectional causality between AES and GDRP
GDRP does not Granger Cause AES		6.48568	0.0023	
PD does not Granger Cause WG	102	2.70629	0.0718	There is bidirectional causality between PD and WG

WS does not Granger Cause PD		8.83962	0.0003	
AES does not Granger Cause WG	102	3.18554	0.0457	There is bidirectional causality between AES and WG
WS does not Granger Cause AES		13.5541	6.E-06	
AES does not Granger Cause PD	102	1.26930	0.2857	There is bidirectional causality between PD and AES
PD does not Granger Cause AES		5.87193	0.0039	

Source: Calculation results using E-views 12, 2024

The results of the Granger Causality Test between Gross Regional Domestic Product (GDRP) and installed capacity of power plants (AES) in Indonesia show that there is bidirectional causality. This indicates that GDRP affects the power plant, and conversely the installed capacity of the power plant can increase GDRP. The existence of a two-way relationship between economic growth and installed power plants can increase productivity, and increase competitiveness in the global market. This relationship is in accordance with the findings of Yang and Kim (2020) that the effect of energy sources through power generation can increase investment in renewable energy projects and conversely. Furthermore, the results of the Granger Causality Test between the amount of waste generation (WG) and population density (PD) also show that there is a two-way causality between the amount of waste generation and population density. This is that there is a relationship caused by increasing the amount of consumption which is influenced by increasing population density. The installed capacity of the power plant (AES) and the amount of waste generated (WG) also show a two-way causality through the Granger Causality Test results. This linkage creates solutions and opportunities to effectively manage waste as well as provide a sustainable source of renewable energy.

Granger Causality Test results between population density (PD) and installed capacity of power plants (AES). This is due to the high demand for energy, including electricity consumption, which is mostly used by households and industries for daily activities. This conclusion shows consistency with the VECM results which show that there is a short-term and long-term relationship between population density and electrical energy consumption. Table 3 above shows that there is no two-way causality between the amount of waste generation (WG) and gross regional domestic product (GDRP) and the population density variable (PD) and gross regional domestic product (GDRP).

Cointegration Test Result

The cointegration test results in this study use Johansen's cointegration test. An equation is said to be cointegrated based on the comparison if the probability value < 0.05. Conversely, if the probability value > 0.05, it is interpreted that the equation is not cointegrated. Johansen's cointegration test results can be seen in Table 4.

Tabel 4. Cointegration Test Result

No. of CE(s)	Eigenvalue	Statistik	Critical Value	Prob
None	0.626853	54.51249	47.85613	0.0104
At most 1	0.333871	20.99587	29.79707	0.3579
At most 2	0.179265	7.182607	15.49471	0.5565
At most 3	0.013605	0.465743	3.841465	0.4950

Source: Calculation results using E-views 12, 2024

The results in table 4 above show that in the long run there is cointegration in the model. In econometrika, variables that are cointegrated with each other are said to be in a long run equilibrium condition or commonly called long run equilibrium. This research also applies the VECM (Vector Error Correction Model) estimation test because there is cointegration when the cointegration test is carried out to see long-term and short-term analysis. The results of the VECM estimation test, namely:

Tabel 5. Long-term Vector Error Correction Estimates test results

Cointegrating Eq;	CointEq1
D(GDRP(-1))	1.000000
D(WG(-1))	-0.040844
	(0.015859)
	[-2.57100]
D(PD(-1))	1209.209
	(243.070)
	[4.97473]
D(AES(-1))	-2.914162
	(20.9550)
	[-0.13907]
C	-14212.49

Source: Calculation results using E-views 12, 2024

Tabel 5. Long-term Vector Error Correction Estimates test results

Error Correction:	D(GDRP,2)	D(WG,2)	D(PD,2)	D(AES,2)
CointEq1	-4.047358	6.380531	-0.000451	0.079932
	(8.21377)	(8.02001)	(0.00014)	(0.02426)
	[-0.49275]	[0.79558]	[-3.16648]	[3.29509]
D(GDRP(-1),2)	3.660895	-3.898110	0.000525	-0.078058
	(8.92101)	(8.71056)	(0.00015)	(0.02635)
	[0.41037]	[-0.44752]	[3.39663]	[-2.96274]
D(GDRP(-2),2)	3.374489	-2.327764	0.000404	-0.083936
	(7.18596)	(7.01644)	(0.00012)	(0.02122)
	[0.46959]	[-0.33176]	[3.24147]	[-3.95502]
D(WG(-1),2)	-0.160666	-0.716789	-1.710005	0.000468

	(0.30256)	(0.29542)	(5.20006)	(0.00089)
	[-0.53102]	[-2.42632]	[-3.25150]	[0.52377]
D(WG(-2),2)	-0.139230	-0.071094	-1.200005	-0.001205
	(0.22286)	(0.21760)	(3.90006)	(0.00066)
	[-0.62475]	[-0.32671]	[-3.09885]	[-1.83069]
D(PD(-1),2)	6427.030	-15220.93	-0.363324	-203.1487
	(13174.0)	(12863.2)	(0.22846)	(38.9073)
	[0.48786]	[-1.18329]	[-1.59034]	[-5.22136]
D(PD(-2),2)	120.3088	-2586.560	-0.054790	5.372606
	(2586.86)	(2525.84)	(0.04486)	(7.63987)
	[0.04651]	[-1.02404]	[-1.22135]	[0.70323]
D(AES (-1),2)	-66.37978	-231.3033	-0.016950	-2.216846
	(114.426)	(111.727)	(0.00198)	(0.33794)
	[-0.58011]	[-2.07025]	[-8.54186]	[-6.55989]
D(AES(-2),2)	-27.27282	-71.09942	-0.014202	-1.702766
	(105.360)	(102.874)	(0.00183)	(0.31116)
	[-0.25885]	[-0.69113]	[-7.77309]	[-5.47228]
C	3454.103	118269.3	-5.863765	820.1007
	(133815.)	(130658.)	(2.32054)	(395.199)
	[0.02581]	[0.90518]	[-2.52689]	[2.07516]
R-squared	0.032516	0.832317	0.949059	0.956773
Adj. R-squared	-0.330291	0.769435	0.929957	0.940563
S.E. equation	304979.1	297784.7	5.288786	900.7047
F-statistic	0.089624	13.23632	49.68178	59.02317

Source: Calculation results using E-views 12, 2024

The application of the Vector Error Correction Model (VECM) test is intended to see the long-term and short-term relationship between variables, where the number of t tables is 1.974357764. Referring to table 5, population density has a long-term relationship with a cointegration value of 4.97473, while WG and AES are not influenced in the long term as indicated by the variable t statistic value of -2.57100 and -0.13907, respectively. In the short-term application in Table 6, there is a relationship between t-1 GDRP and PD with a t statistic value of 3.39663, and there is also a relationship between t-2 GDRP and PD with a t statistic value of 3.24147. Broadly speaking, it can be concluded that there is long-run and short-run cointegration among the variables. The results of this study are in line with the research of Annicchiarico (2024) that there is a relationship between short-term and long-term economic growth. This research examines the relationship between waste generation, population density, and installed capacity of power plants to gross regional domestic product per capita simultaneously in 34 provinces in Indonesia. Based on the panel regression results through the fixed effect model approach, it shows that there is a relationship between the independent variables and the dependent variable.

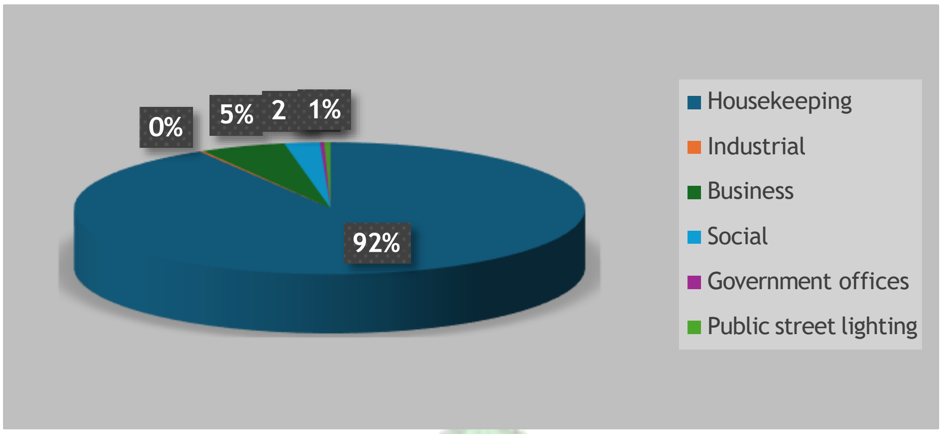
DISCUSSION

This study contributes to the literature by examining the relationship between the amount of waste generation, population density, and installed capacity of power plants to gross regional domestic product with the aim of sustainable economic development in Indonesia. The time period covers 2019-2023 and 34 provinces, using the Vector Error Correction Model (VECM) method, Granger Causality Test and cointegration test. This finding has a positive contribution to the implementation of the green economy on long-term economic growth. Based on the panel regression results through the fixed effect model approach, it shows that there is a relationship between the independent variable and the dependent variable. The granger caucality test results also concluded that there is bidirectional causality between Gross Regional Domestic Product (GDRP) and installed capacity of power plants (AES), Waste Generation (WG), with population density (PD), installed capacity of power plants (AES) with total waste generation (WG), population density (PD) with installed capacity of power plants (AES). Based on this, it can be concluded that the relationship between GDRP can encourage the amount of waste generation, and vice versa, the amount of waste generation can encourage GDRP. Additionally, the amount of waste generation can affect population density, otherwise population density can affect the amount of waste generation. The installed capacity of power plants can also encourage the amount of waste generation, conversely waste generation can encourage the installed capacity of power plants. Similarly, with population density, an increase in population density can drive the installed capacity of the power plant, which is a two-way causality relationship between density and power generation. This study confirms that there is a two-way hypothesis regarding the relationship between these variables.

Economic growth of the oil and gas industry sector

Economic growth, which indicates the increase in the production of products and services in an economic region during a specific time period, is a good indicator of a nation's economic development (Achmad et al., 2022). Energy is needed by the industrial sector to generate commodities and services. The oil and gas industry is currently the most widely used energy source. It is evident that the oil and gas industry serves as a basic and supporting material in certain industries in addition to being a source of energy (Mohamed et al., 2022). Fuel oil and common gas are the most drivers of transportation and versatility.

Long-term expansion to boost the economy's output capability in order to satisfy societal demands is also referred to as economic growth. Additionally, sustained economic expansion raises employment and national income, which raises living standards. According to Mohamed (2022) asserts that a number of factors affect economic growth, including: (1) Amount of physical capital, whereby the manufacturing process produces more goods and services when more tools are available. Since physical capital was initially believed to be the main driver of economic growth, industrial production in terms of capital accumulation became important as a source of sustainable development. (2) The Human resources: The amount and caliber of human resources that directly support the economy are among the most crucial elements causing economic progress. The ability to innovate and give education, training, and skills is the most crucial of the qualities that determine the quality of human resources. If there is a shortage of skilled human resources, this will limit economic progress. (3) One of the elements that affects a nation's economic development is its natural resources. All resources that exist on or within the earth's surface, such as water resources and terrestrial plants, are considered natural resources and are significant. Minerals, oil, and gas are examples of natural resources found on Earth. (4) Technological development, which encompasses the application of a collection of industrial and scientific techniques, is a significant and impactful factor in economic growth. Technology is also a collection of practices, knowledge, and experience that help to meet anticipated social and economic needs.



Source: PT PLN, 2024

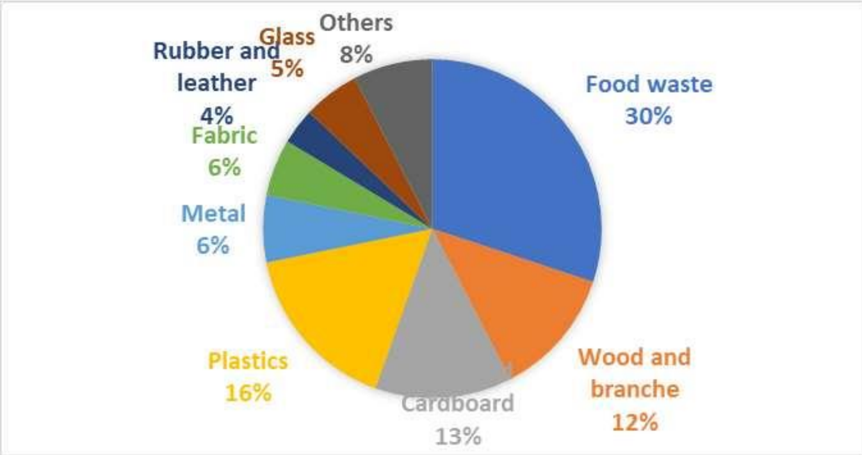
Figure 1. Number of state electricity company customers in 2024

National Electricity Company (PLN) distributes most of the customers coming from the household category, which reaches 92% of the total customers. This shows that the need for electricity for household needs is a top priority. On the other hand, customers from the business category accounted for 6%, indicating a considerable contribution to the productive sector. Meanwhile, customers from the social category only accounted for 3%. Overall, this data indicates that PLN's electricity services are dominated by household needs, which are then followed by other sectors with smaller portions. In this sense, advancement in technology has played a vital influence in economic growth, as well as generating creative energy opportunities. One of the good benefits of technical innovation is the diversification of energy sources concurrently and with the same devices, thereby contributing to the decrease of pollution. Apart from creating comparable substitutes using more economical, efficient, and less polluting materials, it also helps to make manufacturing systems more flexible and lowers production costs (Mohamed et al., 2021).

Oil and gas sector transformation in waste management

Within the context of developing countries, which have gone through the transition from agrarian to industrialized societies, the application of their economies does not focus on knowledge (creativity and dissemination) and the use of science of technology compared to developed countries with lower quality of life and low per capita income (Rasheed et al., 2021).

In addition, technology is increasingly driving economic expansion and generating new energy opportunities. In addition, technology is increasingly driving economic expansion and generating new energy opportunities. Diservitalising pollution reduction is one of the benefits of technical progress. It also helps lower production costs and increase the flexibility of production systems by creating comparable alternatives from more affordable, more efficient, and less polluting materials. Furthermore, by following guidelines and regulations created based on the idea of waste that is not harmful to the environment, the marketing of contemporary technology results in better production accuracy (Broughel & Thierer, 2019).



Source: PT PLN, 2024

Figure 2. Waste composition based on type in 2024

Composition of waste types is dominated by food waste at 30%, which makes it the largest component that mostly comes from organic household waste. Plastic waste also comes in second at 16% which is a major concern because it is difficult to decompose. Followed by paper and cardboard waste at 13% which has a high potential to be recycled, and also wood and branches at 12% which are also categorized as organic waste. Overall, this data shows the importance of waste management that focuses on reducing organic and plastic waste, as well as optimizing recycling to create renewable energy.

The following is a Waste to Energy Technology management technique to convert waste into energy:

Thermal Conversion Method

Within this review, the organic matrix found in municipal solid waste (MSW) is thermally processed in this study to produce gas, which is then used as a fuel oil and energy source For MSW with a lower water concentration (dry waste) and a higher percentage of non-degradable organic matter, thermal treatment is an appropriate solution. Combustible materials (RDF) with greater calorific value are often treated using thermal treatment technologies (Azam et al., 2019). Refuse Derived Fuel (RDF) is used to create alternative fuels generated from waste management, especially non-combustible and recyclable materials (Rezaei et al., 2020). High temperatures are used to break down organic materials in thermal waste treatment techniques using gasification, incineration, and pyrolysis methods.

Pyrolysis: Pyrolysis is the process of thermally breaking down solid materials at high temperatures without oxygen to create solid, liquid, and gaseous products (Sipra et al., 2018). Pyrolysis can reduce the volume of solid waste by 80-90% (Jamilatun et al., 2023). Pyrolysis is a sophisticated process that uses temperatures between 400 and 8000 C and doesn't require air or oxygen. The heating rate, sushu, particle size, and waste composition all have a major impact on how much char, oil, and pyrolysis gas are created during the process (Jamilatun et al., 2022). High quality products can be obtained by selecting raw materials such as waste wood, waste plastic electronic equipment waste electricity and waste rubber (Nanda et al., 2023).

Incineration; Incineration is the process of burning organic materials at temperatures between 750 and 1000 degrees Celsius to produce trash. Certain materials' composition and rate of recovery allow for the reduction of about 70% of the total waste mass and 90% of the total waste volume (Kumar & Samadder, 2017). Besides gas, incineration produces bottom ash and fly ash containing organic and inorganic substances (Wang et al., 2019).

Developments in the field of environmental technology and air pollution control, incineration is nowadays deliberately taken as an attractive technique for waste treatment, especially in developing countries (Iyamu et al., 2020). According Dong (2018) suggested that municipal waste incineration is far better than all other techniques because of its efficient flue gas cleaning system. Accordingly, researchers have reported a number of additional benefits in addition to volume reduction and electricity generation in a number of other papers. These benefits could include recovering ferrous and nonferrous elements and using fly ash and other leftovers and by products from incinerator facilities to make cement and build roads (Rasheed et al., 2021). On the other hand, in underdeveloped nations, incineration is thought to be the most cost-effective and dependable method of burning waste without first treating it in order to produce electricity. This method's primary benefit is the mineralization breakdown of organic materials and living things into innocuous by products (Yu & Dong, 2020).

Gasification; Whereas pyrolysis is mainly used for converting waste into solid, liquid, and gaseous phases without an oxidiser, gasification aims to produce gaseous fuels with high calorific value through controlled oxidation (Sharma et al., 2020). The produced gas is the main output of the gasification methodology, the gas produced is then used for energy production through the combustion process. Liquid fuel and chemical feedstock are other products of this process.

In case of coordinate gasification, combination of steam and oxygen is used to partially oxidize the waste and provide energy to keep the temperature high enough for the oxidation reaction (Nobre et al., 2020). Uniform carbon-based feedstock with a high calorific value is required for efficient gasification (Abdelrahim et al., 2020). On the other hand, in indirect gasification, heat energy is provided by an external source by using a heated bed material through charcoal burning or the use of a plasma torch. The gasification reaction occurs between the devolatilised solid waste (charcoal) and a gas other than oxygen (Yang et al., 2019).

D. CONCLUSION

Based on the research findings, it can be concluded that there is a mutually beneficial causal relationship between energy efficiency and economic growth, particularly in the green economy framework in the oil and gas sector. This relationship indicates that efforts to reduce waste generation and control population density through a sustainable approach can significantly increase GRDP, both in the short and long term. Therefore, energy efficiency strategies not only impact environmental conservation, but also directly contribute to sustainable economic development. The government, through relevant institutions, needs to develop green technology-based policies and innovations that strengthen the synergy between economic development and environmental sustainability. Emphasis on energy transition and optimizing waste management are crucial aspects in accelerating the realization of a green economy in Indonesia. Theoretically, these findings contribute to the sustainable development literature by emphasizing the importance of integration between ecological and economic aspects in national development planning. In the context of Islamic basic education, the results of this study can be utilized to develop a curriculum that instills ecological awareness and environmental ethics from an early age, as part of Islamic values-based character education.

Practically, the green economy approach can be used as an interdisciplinary learning model that links science, economics, and religious teachings in shaping the personality of students who care about the environment. This research has limitations on sectoral data coverage and has not considered the socio-cultural dimension in depth. Therefore, future research is recommended to integrate qualitative and participatory approaches to explore the contextual dimensions of green economy implementation in society and education.

REFERENCE

Abdelrahim, A., Brachi, P., Ruoppolo, G., Fraia, S. Di, & Vanoli, L. (2020). Experimental and Numerical Investigation of Biosolid Gasification: Equilibrium-Based Modeling with Emphasis on the Effects of Different Pretreatment Methods. *Industrial and Engineering Chemistry Research*. https://doi.org/10.1021/acs.iecr.9b03902

Achmad, Y., Syahnur, S., & Seftarita, C. (2022). The Effect of the Exploration and Exploitation of Oil and Gas on Indonesian Economic Growth. *International Journal of Quantitative Research and Modeling*, *3*(3), 104–112. https://doi.org/10.46336/ijqrm.v3i3.342

Adhitya Wardhono, Yulia Indrawati, Ciplis Gema Qoriah, M. A. N. (2019). *Analisis Data Time Series dalam Model Makroekonomi*. Pustaka Abadi.

Ali, J., Rasheed, T., Afreen, M., Anwar, M. T., Nawaz, Z., Anwar, H., & Rizwan, K. (2020). Modalities for conversion of waste to energy — Challenges and perspectives. *Science of the Total Environment*, *727*, 138610. https://doi.org/10.1016/j.scitotenv.2020.138610

Annicchiarico, B., Pelloni, A., & Valenti, F. (2024). Short-run fluctuations and long-run growth with recursive preferences. *Macroeconomic Dynamics*, *2024*, 1–16. https://doi.org/10.1017/S1365100524000336

Azam, M., Jahromy, S. S., Raza, W., Jordan, C., Harasek, M., & Winter, F. (2019). Comparison of the combustion characteristics and kinetic study of coal, municipal solid waste, and refuse-derived fuel: Model-fitting methods. *Energy Science and Engineering*, *7*(6), 2646–2657. https://doi.org/10.1002/ese3.450

Badan Pusat Statistik. (2024). In *5 november*.

Boloy, R. A. M., da Cunha Reis, A., Rios, E. M., de Araújo Santos Martins, J., Soares, L. O., de Sá Machado, V. A., & de Moraes, D. R. (2021). Waste-to-Energy Technologies Towards Circular Economy: a Systematic Literature Review and Bibliometric Analysis. *Water, Air, and Soil Pollution*, *232*(7). https://doi.org/10.1007/s11270-021-05224-x

Boubellouta, B., & Kusch-Brandt, S. (2021). Cross-country evidence on Environmental Kuznets Curve in Waste Electrical and Electronic Equipment for 174 Countries. *Sustainable Production and Consumption*, *25*, 136–151. https://doi.org/10.1016/j.spc.2020.08.006

Broughel, J., & Thierer, A. D. (2019). Technological Innovation and Economic Growth: A Brief Report on the Evidence. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.3347294

Chen, L., Yu, L., Yin, J., & Xi, M. (2023). Impact of Population Density on Spatial Differences in the Economic Growth of Urban Agglomerations: The Case of Guanzhong Plain Urban Agglomeration, China. *Sustainability (Switzerland)*, *15*(19). https://doi.org/10.3390/su151914601

Cheng, J., Shi, F., Yi, J., & Fu, H. (2020). Analysis of the factors that affect the production of municipal solid waste in China. *Journal of Cleaner Production*, *259*, 120808. https://doi.org/10.1016/j.jclepro.2020.120808

Dhealika Syamputri, Mutia Luthfiany Khairunnisa, R. N. (2021). *Ekonometrika Terapan Pada Bidang Riset Ekonomi Dan Keuangan Islam* (M. S. Dr. Hj. Aas Nurasyiah (Ed.)). UPI Press.

Dong, J., Tang, Y., Nzihou, A., Chi, Y., Weiss-Hortala, E., & Ni, M. (2018). Life cycle assessment of pyrolysis, gasification and incineration waste-to-energy technologies: Theoretical analysis and case study of commercial plants. *Science of the Total Environment*, *626*, 744–753. https://doi.org/10.1016/j.scitotenv.2018.01.151

Iyamu, H. O., Anda, M., & Ho, G. (2020). A review of municipal solid waste management in the BRIC and high-income countries: A thematic framework for low-income countries. *Habitat International*, *95*(October 2019). https://doi.org/10.1016/j.habitatint.2019.102097

Jamilatun, S., Pitoyo, J., Amelia, S., Ma'arif, A., Hakika, D. C., & Mufandi, I. (2022). Experimental Study on The Characterization of Pyrolysis Products from Bagasse (Saccharum Officinarum L.): Bio-oil, Biochar, and Gas Products. *Indonesian Journal of Science and Technology*, *7*(3), 565–582. https://doi.org/10.17509/ijost.v7i3.51566

Jamilatun, S., Pitoyo, J., & Setyawan, M. (2023). Technical, Economic, and Environmental Review of Waste to Energy Technologies from Municipal Solid Waste. *Jurnal Ilmu Lingkungan*, *21*(3), 581–593. https://doi.org/10.14710/jil.21.3.581-593

Karundeng, Thessa Natasya Mandey, S. L., & Sumarauw, J. S. B. (2018). Analisis Saluran Distribusi Kayu (Studi Kasus Di Cv. Karya Abadi, Manado). *Jurnal EMBA: Jurnal Riset Ekonomi, Manajemen, Bisnis Dan Akuntansi*, *6*(3), 1748–1757.

Kumar, A., & Samadder, S. R. (2017). A review on technological options of waste to energy for effective management of municipal solid waste. *Waste Management*, *69*, 407–422. https://doi.org/10.1016/j.wasman.2017.08.046

Lumbanraja, P. C., & Lumbanraja, P. L. (2023). Analisis Variabel Ekonomi Hijau (Green Economy Variable) Terhadap Pendapatan Indonesia (Tahun 2011-2020) dengan Metode SEM-PLS. *Cendekia Niaga*, *7*(1), 61–73. https://doi.org/10.52391/jcn.v7i1.836

Manea, E. E., Bumbac, C., Dinu, L. R., Bumbac, M., & Nicolescu, C. M. (2024). Composting as a Sustainable Solution for Organic Solid Waste Management: Current Practices and Potential Improvements. *Sustainability (Switzerland)*, *16*(15), 1–25. https://doi.org/10.3390/su16156329

Mohamed, M. M. A., Liu, P., & Nie, G. (2021). Are technological innovation and foreign direct investment a way to boost economic growth? An egyptian case study using the autoregressive distributed lag (ardl) model. *Sustainability (Switzerland)*, *13*(6). https://doi.org/10.3390/su13063265

Mohamed, M. M. A., Liu, P., & Nie, G. (2022). Causality between Technological Innovation and Economic Growth: Evidence from the Economies of Developing Countries. *Sustainability (Switzerland)*, *14*(6), 1–39. https://doi.org/10.3390/su14063586

Muis, R., Anggraini, N., Ariani, F., Yunus, S., & Zulkifli. (2021). Survey of Environmental Baseline in the Nunukan Agriculture Area, Indonesia. *Nature Environment and Pollution Technology*, *20*(1), 237–242. https://doi.org/10.46488/NEPT.2021.V20I01.025

Muis, R., Anggraini, N., Radde, H. A., Rachman, I., & Matsumoto, T. (2024). Current Update Waste to Energy in Developing Country; A Review and Bibliometric Analysis. *Journal of Community Based Environmental Engineering and Management*, *8*(8), 35–44. https://doi.org/10.23969/jcbeem.v8i1.12000

Nanda, M. A., Sugandi, W., Wijayanto, A. K., Imantho, H., Sutawijaya, A., Nelwan, L. O., Budiastra, I. W., & Seminar, K. B. (2023). The Waste-to-Energy (WtE) Technology to Support Alternative Fuels for Agriculture in the Context of Effective Solid Waste Management in the Jabodetabek Area, Indonesia. *Energies*, *16*(24). https://doi.org/10.3390/en16247980

Nanda, S., & Berruti, F. (2021). Municipal solid waste management and landfilling technologies: a review. *Environmental Chemistry Letters*, *19*(2), 1433–1456. https://doi.org/10.1007/s10311-020-01100-y

Nobre, C., Longo, A., Vilarinho, C., & Gonçalves, M. (2020). Gasification of pellets produced from blends of biomass wastes and refuse derived fuel chars. *Renewable Energy*, *154*, 1294–1303. https://doi.org/10.1016/j.renene.2020.03.077

Pradhan, R. P., Arvin, M. B., & Bahmani, S. (2018). Are innovation and financial development causative factors in economic growth? Evidence from a panel granger causality test. *Technological Forecasting and Social Change*, *132*(February 2017), 130–142. https://doi.org/10.1016/j.techfore.2018.01.024

Rasheed, T., Anwar, M. T., Ahmad, N., Sher, F., Khan, S. U. D., Ahmad, A., Khan, R., & Wazeer, I. (2021). Valorisation and emerging perspective of biomass based waste-to-energy technologies and their socio-environmental impact: A review. *Journal of Environmental Management*, *287*(February), 112257. https://doi.org/10.1016/j.jenvman.2021.112257

Rezaei, H., Panah, F. Y., Lim, C. J., & Sokhansanj, S. (2020). Pelletization of refuse-derived fuel with varying compositions of plastic, paper, organic and wood. *Sustainability (Switzerland)*, *12*(11), 1–11. https://doi.org/10.3390/su12114645

Shah, W. U. H., Yasmeen, R., Sarfraz, M., & Ivascu, L. (2023). The Repercussions of Economic Growth, Industrialization, Foreign Direct Investment, and Technology on Municipal Solid Waste: Evidence from OECD Economies. *Sustainability (Switzerland)*, *15*(1). https://doi.org/10.3390/su15010836

Sharma, S., Basu, S., Shetti, N. P., Kamali, M., Walvekar, P., & Aminabhavi, T. M. (2020). Waste-to-energy nexus: A sustainable development. *Environmental Pollution*, *267*, 115501. https://doi.org/10.1016/j.envpol.2020.115501

Sidik. (2022). *Peningkatan Kapasitas Pemerintah Daerah dalam Pengelolaan Sampah melalui Implementasi Pengurangan dan Penanganan Sampah*. In sipsn.menlhk.go.id

Sipra, A. T., Gao, N., & Sarwar, H. (2018). Municipal solid waste (MSW) pyrolysis for bio-fuel production: A review of effects of MSW components and catalysts. *Fuel Processing Technology*, *175*(February), 131–147. https://doi.org/10.1016/j.fuproc.2018.02.012

Širá, E., Kravčáková Vozárová, I., Kotulič, R., & Dubravská, M. (2022). EU27 Countries' Sustainable Agricultural Development toward the 2030 Agenda: The Circular Economy and Waste Management. *Agronomy*, *12*(10). https://doi.org/10.3390/agronomy12102270

Soukiazis, E., & Proença, S. (2020). The determinants of waste generation and recycling performance across the Portuguese municipalities – A simultaneous equation approach. *Waste Management*, *114*, 321–330. https://doi.org/10.1016/j.wasman.2020.06.039

Teklie, D. K., & Yağmur, M. H. (2024). The Role of Green Innovation, Renewable Energy, and Institutional Quality in Promoting Green Growth: Evidence from African Countries. *Sustainability (Switzerland)*, *16*(14). https://doi.org/10.3390/su16146166

Wang, P., Hu, Y., & Cheng, H. (2019). Municipal solid waste (MSW) incineration fly ash as an important source of heavy metal pollution in China. *Environmental Pollution*, *252*, 461–475.

https://doi.org/10.1016/j.envpol.2019.04.082

Yang, G., Yin, Y., & Wang, J. (2019). Microbial community diversity during fermentative hydrogen production inoculating various pretreated cultures. *International Journal of Hydrogen Energy*, *44*(26), 13147–13156. https://doi.org/10.1016/j.ijhydene.2019.03.216

Yang, M., & Kim, J. (2020). Revisiting the relation between renewable electricity and economic growth: A renewable-growth hypothesis. *Sustainability (Switzerland)*, *12*(8). https://doi.org/10.3390/SU12083121

Yu, S., & Dong, H. (2020). Uncover cost-benefit disparity of municipal solid waste incineration in Chinese Provinces. *Sustainability (Switzerland)*, *12*(2). https://doi.org/10.3390/su12020697

Zambrano-Monserrate, M. A., Ruano, M. A., & Ormeño-Candelario, V. (2021). Determinants of municipal solid waste: a global analysis by countries' income level. *Environmental Science and Pollution Research*, *28*(44), 62421–62430. https://doi.org/10.1007/s11356-021-15167-9