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Comparative Analysis of The Economic and Environmental Performance of Virgin and Recycled Polyester in Supporting The Transition from a Linear to a Circular Economy in The Indonesian Polyester Industry

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ABSTRACT

The polyester industry in Indonesia has experienced significant growth under a linear economic model based on virgin polyethylene terephthalate (vPET), which relies heavily on fossil-based resources and contributes to high energy consumption, greenhouse gas (GHG) emissions, water use, and waste generation. The transition toward recycled polyethylene terephthalate (rPET) represents an important pathway for implementing circular economy principles and improving industrial sustainability. This study aims to compare the economic and environmental performance of vPET and rPET, evaluate future development trends, and identify strategic factors influencing the transition from a linear to a circular economy model in Indonesia's polyester industry. A mixed-methods approach was employed, combining quantitative comparative analysis, Simple Linear Regression (SLR) for projection analysis, and PESTEL analysis to assess external factors affecting rPET development. The results indicate that vPET maintains stronger economic performance in terms of production, revenue, and operating profit; however, rPET demonstrates superior environmental performance through substantially lower energy consumption, GHG emissions, and water usage. Projection results for 2025–2030 show that rPET has greater growth potential, supported by increasing sustainability demands, regulatory pressure, technological advancement, and ESG commitments. Nevertheless, challenges related to feedstock availability, recycling infrastructure, and investment requirements remain significant barriers. This study concludes that a gradual transition through a hybrid economic approach is the most feasible strategy, enabling Indonesia's polyester industry to balance economic competitiveness with environmental sustainability while supporting circular economy implementation and net-zero emission targets.

INTRODUCTION

The global industrial development has driven substantial economic growth, enhanced living standards, and expanded employment opportunities, it has simultaneously contributed to significant environmental degradation. Such industrial expansion has been associated with escalating greenhouse gas (GHG) emissions, increasing levels of air and water pollution, and the accelerated depletion of natural resources (Saxena 2025; Wang et al. 2024). These conditions have further exacerbated the global climate crisis, as evidenced by rising global temperatures, the loss of biodiversity, and the disruption of hydrological systems (Mehta 2024; Nile et al. 2025; Upadhyay 2020).

At present, economic systems continue to be largely shaped by a linear model, in which natural resources and the environment are primarily treated as inputs to support economic activities. Following production and consumption processes, products often become environmental burdens in the form of waste and pollution (Hadipuro, 2022). This linear model, commonly referred to as 'take–make–dispose', places greater emphasis on economic gains than on long-term sustainability (Aiguobarueghian et al. 2024; Kulwant et al. 2025).

The origins of this approach can be traced back to the Industrial Revolution, a period marked by significant improvements in human welfare and the widespread belief that natural resources were abundant and effectively unlimited. As a result, it became widely assumed that nature could continuously provide the inputs required for economic systems, while environmental considerations were often given less priority compared to economic performance (Barbier 2019; Hajirasouli et al. 2016; Hardt et al. 2017; Sanchez 2022).

In practice, this linear approach has resulted in substantial resource losses throughout the production cycle. However, its continued dominance has been reinforced by historically low costs of raw materials and labor, as well as the relative ease of accessing new resources and disposing of waste at minimal cost (Hasbi, 2022).

As a solution to these problems, the transition from a linear economic model to a circular economic model is becoming increasingly urgent and unavoidable (Ellen MacArthur Foundation, 2019). The circular economic model emphasizes extending the life cycle of materials through reuse, recycling, and regeneration so that industrial growth can remain in harmony with ecological balance (Geissdoerfer et al., 2017).

In an industrial context, the textile and textile products (TPT) sector is one of the industries with the most significant environmental impact (Niinimäki et al., 2020). According to global sustainability reports, the textile industry contributes approximately 10% of total global CO_2 emissions, surpassing even the combined emissions of the aviation and international maritime transport sectors (UNEP, 2019). This impact is closely related to the use of raw materials, particularly synthetic fibers (Niinimäki et al., 2020). Polyethylene terephthalate (PET), commercially known as polyester, dominates global fiber consumption due to its durability, cost efficiency, and production scalability (Textile Exchange, 2024). However, over 85% of global polyester production still relies on virgin PET (vPET), while recycled PET (rPET) accounts for less than 15% (Textile Exchange, 2024).

The heavy reliance on virgin polyester poses a number of complex environmental challenges. First, its production process relies heavily on non-renewable fossil resources, such as oil and natural gas (IEA, 2022; PlasticsEurope, 2021). This dependence not only accelerates resource depletion but also increases the industry's vulnerability to fluctuations in global energy prices (IEA, 2022).

Second, the vPET production process is known to be highly energy-intensive, particularly during the polymerization stage, which requires large amounts of thermal and electrical energy input (Franklin Associates, 2020). This directly contributes to increased greenhouse gas emissions and accelerated global warming (Shen et al., 2010; IPCC, 2021).

Furthermore, the use of polyester exacerbates the global waste problem. Its difficult-to-decompose nature causes polyester textile waste to persist in the environment for a long time (Ellen MacArthur Foundation, 2017). The growth of the fast fashion industry further exacerbates this situation by generating large amounts of post-consumer waste, much of which ends up in landfills (Ellen MacArthur Foundation, 2017). This pattern further emphasizes that vPET use remains within a linear economic framework that generates ongoing environmental pressures (OECD, 2022).

As an alternative, recycled polyester (rPET) is gaining increasing attention as a more sustainable solution. rPET is generally produced from post-consumer PET bottle waste through mechanical and chemical recycling processes (Muthu, 2020). Research shows that rPET production can reduce energy consumption by 40–85% and reduce GHG emissions by 25–75% compared to virgin PET (Muthu, 2020). This demonstrates that rPET is not only an alternative material but also a concrete example of implementing a circular economy model in the textile industry (Fatima et al. 2025; Islam 2026; Massoud et al. 2025; Mohtaram et al. 2025).

This study demonstrates that the linear economic model represented by virgin polyester (vPET) continues to impose significant environmental pressures on the Indonesian textile industry. The production of vPET relies heavily on fossil-based resources and is associated with high energy consumption, greenhouse gas emissions, water usage, and waste generation. These findings indicate that the traditional take-make-dispose model is increasingly incompatible with sustainability objectives and long-term environmental commitments.

The comparative analysis reveals that recycled polyester (rPET), as a representation of the circular economy model, provides clear economic and environmental advantages over vPET. The use of recycled feedstock reduces dependence on virgin petrochemical resources, lowers production-related emissions and energy requirements, and offers opportunities for cost efficiencies. In addition, the growing recycling industry and increasing market demand for sustainable materials strengthen the economic attractiveness of rPET within the textile sector.

The study further finds that the transition from vPET to rPET has the potential to deliver sustained improvements in both environmental performance and economic resilience over the 2025–2030 period. Increasing demand for sustainable textile products, combined with stricter environmental regulations and stronger ESG commitments, is expected to accelerate the adoption of recycled materials. As a result, rPET can contribute to resource efficiency, emission reduction, and long-term competitiveness in the Indonesian textile industry.

Finally, the successful transition toward a circular economy depends on addressing several key challenges, including feedstock availability, recycling infrastructure, investment requirements, and material quality consistency. Government policies, industry collaboration, and stakeholder participation will play a critical role in overcoming these barriers. Overall, this study concludes that rPET represents a viable and strategic pathway for transforming Indonesia’s textile industry into a more sustainable, resilient, and competitive circular economy system.

METHOD

Research Process Design

This study uses a mixed-methods approach with a primary focus on quantitative comparative analysis. The research compares two polyester production models: Virgin PET (vPET) representing the linear economy and Recycled PET (rPET) representing the circular economy. The analysis is based on a functional unit of one ton of polyester fiber. The research process begins with a literature review and data collection, followed by environmental and economic analyses. The results are then compared to evaluate sustainability performance and to develop conclusions and recommendations for the implementation of rPET in the textile industry.

Data Collection Method

The study utilizes both primary and secondary data. Primary data were obtained through interviews with industry stakeholders, sustainability personnel, and practitioners involved in polyester recycling and circular economy implementation. Secondary data were collected from company reports, sustainability reports, scientific journals, government publications, and industry databases. The analysis focuses on key indicators including raw material cost, operational cost, energy consumption, water consumption, greenhouse gas (GHG) emissions, and wastewater generation, as these indicators are widely used in sustainability and circular economy assessments.

Data Analysis Techniques

For RQ1, Trend Analysis and Intensity-Based Environmental Assessment are used to evaluate the environmental impact of vPET production from 2020–2024 through energy consumption, water consumption, and GHG emissions per ton of product. For RQ2, comparative analysis is conducted to evaluate the economic and environmental performance of vPET and rPET using indicators such as raw material costs, operational costs, energy use, water use, and carbon emissions. Standard sustainability metrics and intensity calculations are applied to ensure objective comparison.

Future Projection and Strategic Analysis

For RQ3, Simple Linear Regression (SLR) is used to project future trends of vPET and rPET from 2025–2030 based on historical data from 2020–2024. Forecast accuracy is evaluated using Mean Absolute Deviation (MAD), Mean Squared Error (MSE), and Mean Absolute Percentage Error (MAPE). For RQ4, a PESTEL Analysis is conducted to identify political, economic, social, technological, environmental, and legal factors influencing the transition from vPET to rPET, as well as the role of government policies and stakeholders in supporting a circular economy in Indonesia’s textile industry.

RESULTS AND DISCUSSION

Projection of Economic and Environmental Performance

Future economic and environmental performance projections for virgin polyester (vPET) and recycled polyester (rPET) were conducted for the 2025–2029 period using the Simple Linear Regression (SLR) method based on historical data from 2020–2024. The analysis covered six key variables: production, revenue, operating profit, energy consumption, greenhouse gas (GHG) emissions, and water consumption. Regression coefficients, intercepts, and R^2 values were calculated using Microsoft Excel to identify historical trends and estimate future performance. The projection results were then used to compare the long-term development of vPET and rPET from both economic and environmental perspectives. This approach provides insight into the potential impacts of transitioning from a linear economy model to a circular economy model, particularly in terms of profitability, resource efficiency, and environmental sustainability within Indonesia’s polyester industry.

1. **Projection of Production**

a. Hasil Regresi dan Proyeksi Produksi vPET dan rPET

The following are the data on the regression results and projections of vPET and rPET production from 2020-2030:

Table 1. 60 Regression Equation

Polyester Type	Regression Equation
Virgin PET (vPET)	Y = 293.817,8 – 1.322,6X
Recycled PET (rPET)	Y = 6.866,8 + 5.544,6X

Where:

- Y = Production (tons)
- X = Year number (2020 = 1, 2021 = 2, and so on)

Table 2. 61 Summary Regression Statistics

Parameter	vPET	rPET
Multiple R	0,079	0,950
R Square	0,006	0,902
Adjusted R Square	-0,325	0,869
Standard Error	30.639	3.341
F Statistic	0,019	27,545
Significance F	0,900	0,013
Production Trend	Decreasing	Increasing

Table 3. Projection of vPET and rPET Production

Year	X	Predicted vPET Production (tons)	Predicted rPET Production (tons)
2020	1	292.495	12.411
2021	2	291.173	17.956
2022	3	289.850	23.501
2023	4	288.527	29.045
2024	5	287.205	34.590
2025	6	285.882	40.134
2026	7	284.560	45.679
2027	8	283.237	51.223
2028	9	281.914	56.768
2029	10	280.592	62.313
2030	11	279.269	67.857

b. Analisis Regresi Produksi vPET dan rPET

Based on the simple linear regression results, the regression equation for virgin polyester (vPET) production was obtained as:

$$Y_{vPET} = 293.817,8 - 1.322,6X$$

while the regression equation for recycled polyester (rPET) production is:

$$Y_{rPET} = 6.866,8 + 5.544,6X$$

These equations show that vPET production has a tendency to decline by 1,322.6 tons per year, while rPET production experiences an increase of 5,544.6 tons per year.

The statistical test results show that the vPET regression model has a coefficient of determination (R^2) of 0.006, which means that only 0.6% of the variation in production can be explained by changes in time. A significance value of 0.900 (>0.05) indicates that the relationship between time and vPET production is not statistically significant. This indicates that the vPET production pattern during the observation period fluctuated relatively and did not have a strong linear tendency.

Conversely, the rPET production regression model shows a coefficient of determination (R^2) of 0.902, which means that 90.2% of the variation in production can be explained by changes in time. A significance value of 0.013 (<0.05) indicates that the regression model is statistically significant. Therefore, rPET production has a consistent growth pattern and can be projected with a relatively high level of reliability.

Based on the projection up to 2030, vPET production is estimated to decline from around 292 thousand tons in 2020 to 279 thousand tons in 2030. Conversely, rPET production is projected to increase from around 12 thousand tons to almost 68 thousand tons in 2030. This trend shows a gradual shift from the virgin-polyester-based business model toward recycled polyester.

In general, the regression results indicate that the vPET business has entered a maturity phase with relatively stagnant growth, while the rPET business is in a growth stage. Increasing demand for environmentally friendly products, the application of circular economy principles, the decarbonization targets of the global textile industry, and the ESG commitments of various international brands are the main factors driving rPET growth. Therefore, from the perspective of sustainability and long-term prospects, the rPET business model shows better potential than the virgin polyester business model.

These findings support the research hypothesis that the transition from virgin polyester to recycled polyester not only provides environmental benefits, but also shows more promising and sustainable business growth prospects in the long term.

2. Projection of Revenue

a. Regression and Projection Results of vPET and rPET Revenue

The following are the regression and projection results of vPET and rPET revenue from 2020 to 2030.

Table 4. 63 Revenue Regression Equation

Polyester Type	Regression Equation
vPET	Y = 3.186.490.000.000 + 443.129.000.000X
rPET	Y = 427.130.000.000 + 29.101.000.000X

Where:

1) Y = Revenue (Rp)
2) X = Year number (2020 = 1, 2021 = 2, and so on)

Table 5. 64 Summary Regression Statistics

Parameter	vPET	rPET
Multiple R	0,758	0,660
R Square	0,575	0,436
Adjusted R Square	0,434	0,247
Standard Error	$6{,}95\times10^{11}$	$6{,}05\times10^{10}$
F Statistic	4,062	2,315
Significance F	0,137	0,225
Revenue Trend	Increasing	Increasing

Table 6. 65 Projection of vPET and rPET Production

Tahun	X	Revenue vPET (Rp Trillion)	Revenue rPET (Rp Billion)
2020	1	3,63	456,2
2021	2	4,07	485,3
2022	3	4,52	514,4
2023	4	4,96	543,5
2024	5	5,40	572,6
2025	6	5,85	601,7
2026	7	6,29	630,8
2027	8	6,73	659,9
2028	9	7,17	689,0
2029	10	7,62	718,1
2030	11	8,06	747,2

b. Analisis Regresi Revenue vPET dan rPET

Based on the results of simple linear regression, a virgin polyester revenue regression equation (vPET) is obtained as follows:

$$Y = 3.186.490.000.000 + 443.129.000.000X$$

while the regression equation for recycled polyester (rPET) revenue is:

$$Y = 427.130.000.000 + 29.101.000.000X$$

These equations show that vPET revenue experiences an average increase of IDR 443.13 billion per year, while rPET revenue increases by IDR 29.10 billion per year.

The statistical test results show that the vPET revenue regression model has a coefficient of determination (R^2) of 0.575, which means that 57.5% of the variation in revenue can be explained by changes in time. A significance value of 0.137 (>0.05) indicates that the relationship between time and revenue is not yet statistically significant.

The rPET revenue regression model has a coefficient of determination (R^2) of 0.436, which means that 43.6% of the variation in revenue can be explained by changes in time. A significance value of 0.225 (>0.05) indicates that this relationship is also not yet statistically significant.

Nevertheless, both vPET and rPET revenue show an increasing tendency during the observation period. This increase in revenue is not entirely influenced by production volume, but also by fluctuations in the polyester selling price, changes in product mix, global market conditions, currency exchange rates, and the dynamics of textile industry demand.

3. Projection of Operating Profit

a. Regression and Projection Results of vPET and rPET Operating Profit

The following are the regression and projection results of vPET and rPET revenue from 2020 to 2030.

Table 7. 66 Regression Equation Operating Profit

Type Polyester	Regression equations
vPET	Y = 130,73 + 47,88X
rPET	Y = 143,04 + 12,37X

Where:

1) Y = Operating Profit (Rp)
2) X = Year number (2020 = 1, 2021 = 2, and so on)

Tabel 8. Nilai Koefisien Determinasi Model Regresi Variabel vPET dan rPET

Parameter	vPET	rPET
Multiple R	0,917	0,736
R Square	0,840	0,541
Adjusted R Square	0,787	0,388
Standard Error	38,1	20,8
F Statistic	15,80	3,54
Significance F	0,028	0,157
Profit Trend	Increasing	Increasing

Tabel 9. Perkembangan Operating Profit vPET dan rPET Periode 2020–2025

Year	X	Operating Profit vPET (Rp Trillion)	Operating Profit rPET (Rp Billion)
2020	1	178,61	155,41
2021	2	226,49	167,78
2022	3	274,37	180,15
2023	4	322,25	192,53
2024	5	370,12	204,90
2025	6	418,00	217,28
2026	7	465,88	229,65
2027	8	513,76	242,02
2028	9	561,64	254,39
2029	10	609,52	266,76
2030	11	657,40	279,13

b. Analisis Regresi Operating Profit vPET dan rPET

Based on the simple linear regression results, vPET operating profit follows the equation:

$$Y = 130,73 + 47,88X$$

while rPET operating profit follows the equation:

$$Y = 143,04 + 12,37X$$

vPET operating profit shows an increase of IDR 47.88 billion per year with a coefficient of determination (R^2) of 0.840 and a significance value of 0.028 (<0.05), which indicates that the regression model is statistically significant.

Conversely, rPET operating profit experiences an increase of IDR 12.37 billion per year with an R^2 value of 0.541 and a significance value of 0.157 (>0.05), so this relationship is not yet statistically significant.

These results show that the profitability of the vPET business is still relatively stable and able to generate a larger operating profit than rPET. Nevertheless, the increase in operating profit in rPET shows positive growth potential in line with rising demand for environmentally friendly products.

4. Projection of Energy Consumption

a. Regression and Projection Results of vPET and rPET Energy Consumption

The following are the regression and projection results of vPET and rPET energy consumption from 2020 to 2030

Tale 10. Energy Consumption Regression Equation

Jenis Polyester	Regression equations
vPET	Y = 1.020.538,9 – 15.743,5X
rPET	Y = 7.620,6 – 654,8X

Notes:

1) Y = Operating Profit (Rp)
2) X = Number (2020 = 1, 2021 = 2, and so on)

Table 11. Regression Equation of vPET and rPET Energy Consumption Projection (2020–2030)

Parameter	vPET	rPET
Multiple R	0,317	0,974
R Square	0,101	0,950
Adjusted R Square	-0,199	0,933
Standard Error	85.983	276
F Statistic	0,335	56,46
Significance F	0,603	0,0049
Tren Profit	Downward	Downward

Table 12. Regression Statistics of vPET and rPET Energy Consumption Models

Tahun	X	vPET (GJ)	rPET (GJ)
2020	1	1.004.795	6.966
2021	2	989.052	6.311
2022	3	973.308	5.656
2023	4	957.565	5.001
2024	5	941.821	4.347
2025	6	926.078	3.692
2026	7	910.334	3.037
2027	8	894.591	2.382
2028	9	878.847	1.727
2029	10	863.104	1.072
2030	11	847.360	417

b. Regression Analysis of vPET and rPET Operating

Based on the simple linear regression results, vPET energy consumption follows the equation:

$$Y = 1.020.538,9 - 15.743,5X$$

Meanwhile, rPET energy consumption follows the equation:

$$Y = 7.620,6 - 654,8X$$

vPET energy consumption shows a tendency to decline by 15,743.5 GJ per year. However, an R^2 value of 0.101 and a significance value of 0.603 (>0.05) indicate that the relationship between time and energy consumption is relatively weak and not statistically significant.

Conversely, rPET energy consumption shows a decline of 654.8 GJ per year with an R^2 value of 0.950 and a significance value of 0.0049 (<0.05). This indicates that the regression model has a very strong and significant relationship.

The continuous-process characteristics of vPET production cause the base-load energy requirement to remain high even though production fluctuates. Conversely, the simpler rPET production process, which mostly uses electrical energy, allows for greater improvements in energy efficiency. Therefore, from the perspective of sustainability and the decarbonization of the textile industry, rPET shows a better advantage than vPET in the energy consumption aspect.

5. Projection of GHG Emission vPET dan rPET

a. Regression and Projection Results of vPET and rPET GHG Emission

The following are the regression and projection results of greenhouse gas emissions (GHG Emission) for vPET and rPET from 2020 to 2030. Tabel IV.3.XX Regression Equation GHG Emission

Table 13. Projected Energy Consumption of Virgin PET (vPET) and Recycled PET (rPET) from 2020 to 2030

Jenis Polyester	Regression Equation
Virgin PET (vPET)	Y = 57.251,9 – 882,9X
Recycled PET (rPET)	Y = 1.798,8 – 154,6X

Keterangan:

1) Y = Greenhouse Gas Emissions (tCO_2e)
2) X = Year number (2020 = 1, 2021 = 2, and so on)

Table 14. Regression Equation of vPET and rPET Greenhouse Gas (GHG) Emission Projection (2020–2030)

Parameter	vPET	rPET
Multiple R	0,317	0,974
R Square	0,100	0,950
Adjusted R Square	-0,200	0,933
Tren Emisi	Downward	Downward
The Power of Relationships	Weak	Sangat Kuat
Significance of the Model	Insignificant	Significant

The GHG regression statistics follow the same pattern as energy consumption because emissions are calculated based on energy consumption multiplied by the emission factor.

Table 15. Regression Statistics of vPET and rPET Greenhouse Gas Emission Models

Tahun	X	GHG Emission vPET (tCO_2e)	GHG Emission rPET (tCO_2e)
2020	1	56.369	1.644
2021	2	55.486	1.490
2022	3	54.603	1.335
2023	4	53.720	1.180
2024	5	52.837	1.026
2025	6	51.954	871
2026	7	51.071	717
2027	8	50.188	562
2028	9	49.306	407
2029	10	48.423	253
2030	11	47.540	98

b. Regression Analyzes GHG Emission vPET dan rPET

Based on the simple linear regression results, the regression equation for virgin polyester (vPET) greenhouse gas emissions (GHG Emission) was obtained as:

$$Y = 57.251,9 - 882,9X$$

while the regression equation for recycled polyester (rPET) GHG Emission is:

$$Y = 1.798,8 - 154,6X$$

These equations show that vPET GHG emissions have a tendency to decline by 882.9 tCO_2e per year, while rPET GHG emissions decline by 154.6 tCO_2e per year.

The statistical test results show that the vPET GHG Emission regression model has a coefficient of determination (R^2) of 0.100, which means that only 10.0% of the variation in emissions can be explained by changes in time. This shows that the relationship between time and vPET GHG emissions is relatively weak and not statistically significant. This condition indicates that GHG emissions in the virgin polyester production process are still strongly influenced by the continuous-process characteristics of plant operation, so the base-load energy consumption remains high even though the production volume fluctuates.

Conversely, the rPET GHG Emission regression model shows a coefficient of determination (R^2) of 0.950, which means that 95.0% of the variation in GHG emissions can be explained by changes in time. Therefore, the decline in GHG emissions in rPET shows a strong and consistent pattern, indicating an improvement in energy efficiency and environmental performance during the observation period.

Based on the projection up to 2030, vPET GHG emissions are estimated to decline from around 56 thousand tCO_2e to around 47 thousand tCO_2e. Meanwhile, rPET GHG emissions are projected to experience a more significant decline, from around 1,644 tCO_2e to only around 98 tCO_2e in 2030.

In general, the regression results show that recycled polyester technology has a better advantage than virgin polyester in the decarbonization aspect. The significant decline in energy consumption in the rPET production process directly contributes to the reduction of greenhouse gas emissions, thereby supporting the achievement of net zero emission targets and the implementation of circular economy principles in the textile industry.

These findings support the research hypothesis that the transition from virgin polyester to recycled polyester not only provides economic benefits, but also provides environmental benefits through the sustainable reduction of energy consumption and greenhouse gas emissions

6. Projection of Water Consumption

a. Regression and Projection Results of vPET and rPET Water Consumption

The following are the regression and projection results of water consumption (Water Consumption) for vPET and rPET from 2020 to 2030.

Table 16. Water Consumption Regression Equation

Jenis Polyester	Persamaan Regresi
Virgin PET (vPET)	Y = 21.122.299,5 + 761.554,1X
Recycled PET (rPET)	Y = 238.553,8 – 34.103,6X

Keterangan:

1) Y = Water Consumption (m^3)
2) X = Year number (2020 = 1, 2021 = 2, and so on)

Table 17. Regression Equation of vPET and rPET Water Consumption Projection (2020–2030)

Parameter	vPET	rPET
Multiple R	0,882	0,942
R Square	0,777	0,887
Adjusted R Square	0,703	0,850
Water Consumption Trend	Increasing	Decreasing
Kekuatan Hubungan	Kuat	Very Strong
Signifikansi Model	Relatif Signifikan	Signifikan

Table 18. Regression Statistics of vPET and rPET Water Consumption Models

Year	X	Water Consumption vPET (m^3)	Water Consumption rPET (m^3)
2020	1	21.883.854	226.349
2021	2	22.645.408	167.623
2022	3	23.406.962	124.134
2023	4	24.168.516	91.927
2024	5	24.930.070	68.077
2025	6	25.691.624	50.414
2026	7	26.453.178	37.334
2027	8	27.214.732	27.648
2028	9	27.976.286	20.475
2029	10	28.737.840	15.163
2030	11	29.499.394	11.231

b. Regression Analyzes Water Consumption vPET dan rPET

Based on the regression results, the water consumption equation for virgin polyester (vPET) was obtained as:

$$Y = 21.122.299,5 + 761.554,1X$$

while the water consumption equation for recycled polyester (rPET) follows an exponential model:

$$Y = 305.649,9(0,7406)^X$$

These equations show that vPET water consumption has a tendency to increase by 761,554 m³ per year. Conversely, rPET water consumption experiences an exponential decline with a rate of decrease of around 25.9% per year. The exponential model was used because it provides more realistic results than simple linear regression, which produces negative values over the long-term projection period.

The statistical test results show that the vPET regression model has a coefficient of determination (R^2) of 0.777, which means that 77.7% of the variation in water consumption can be explained by changes in time. Meanwhile, the rPET regression model has a coefficient of determination (R^2) of 0.887, which shows that 88.7% of the variation in water consumption can be explained by changes in time. Therefore, both models show a strong relationship between time and water consumption.

Based on the projection up to 2030, vPET water consumption is estimated to increase from around 21.9 million m³ in 2020 to around 29.5 million m³ in 2030. This increase occurs even though the production volume tends to be stagnant or declining. This condition shows that the continuous-process characteristics of virgin polyester production **continuous process** cause the utility water requirement, such as cooling water, cooling tower make-up, boiler feed water, and other supporting systems, to remain high even though the production level fluctuates.

Conversely, rPET water consumption is projected to keep declining from around 226 thousand m³ in 2020 to around 11 thousand m³ in 2030. This decline reflects the improvement in water-use efficiency through optimization of the washing process, the application of reuse-recycle water systems, and increased process productivity.

In general, the regression results show that recycled polyester technology has a better advantage than virgin polyester in the water resource conservation aspect. In addition to having a far lower water requirement, the declining trend in rPET water consumption shows an improvement in resource-use efficiency that supports the implementation of circular economy principles and the sustainability of the textile industry.

These findings support the research hypothesis that the transition from virgin polyester to recycled polyester not only provides economic benefits and a reduction in greenhouse gas emissions, but also provides environmental benefits through the sustainable improvement of water-use efficiency. In addition, the lower water consumption characteristics of rPET reinforce the position of recycled polyester as a more environmentally friendly alternative in supporting decarbonization targets and natural resource conservation in the Indonesian textile sector.

7. Strategic Implications of the Transition from a Linear Economy Model toward a Circular Economy

Based on the comparative projection results between virgin polyester (vPET) and recycled polyester (rPET) up to 2030, significant differences in characteristics were obtained, both in the economic and environmental aspects. The projection results show that vPET still dominates in terms of production, revenue, and operating profit. In 2030, vPET production is projected to reach 279,269 tons with revenue of IDR 8.06 trillion and operating profit of IDR 657.4 billion. However, this economic achievement is accompanied by high energy consumption of 847,360 GJ, greenhouse gas emissions of 47,540 tCO_2e, and water consumption of 29.50 million m³.

Conversely, the recycled polyester (rPET) business is projected to generate production of 67,857 tons with revenue of IDR 747.2 billion and operating profit of IDR 279.1 billion. Although its economic contribution is still smaller than that of vPET, the rPET business model shows far better environmental performance with energy consumption of 417 GJ, greenhouse gas emissions of 98 tCO_2e, and water consumption of 11,231 m^3.

Table 20. Comparative Projection of vPET and rPET for 2030

Parameter	vPET	rPET
Production (tons)	279.269	67.857
Pendapatan (Rp)	Rp8,06 triliun	Rp747,2 miliar
Laba Operasi (Rp)	Rp657,4 miliar	Rp279,1 miliar
Energy Consumption (GJ)	847.360	417
GHG Emission (tCO_2e)	47.540	98
Water Consumption (m^3)	29.499.394	11.231
Outlook Bisnis	Mature Commodity Business	High Value Circular Business

These results show that virgin polyester (vPET) represents a linear-economy-based business model that follows the take-make-dispose concept, namely using petrochemical-based resources, processing them into products, having them used by consumers, and ultimately becoming waste. This business model still generates large economic value, but has a high dependence on fossil resources and generates relatively high intensities of energy consumption, greenhouse gas emissions, and water use.

On the other hand, recycled polyester (rPET) represents a circular-economy-based business model that applies the collect-sort-recycle-produce-use-collect principle. Through this approach, post-consumer PET bottle waste is reused as raw material so that it is able to reduce the use of primary resources, lower carbon emissions, and improve energy and water-use efficiency.

In general, the regression results show that the vPET business has entered the mature commodity business phase, characterized by relatively stagnant production growth and limited long-term growth opportunities. Conversely, the rPET business is in the growth market phase, with a significant production growth trend, supported by increasing demand for sustainable products, ESG commitments, Net Zero Emission targets, and the implementation of the circular economy in the global textile industry.

Nevertheless, the results of this study do not indicate that the Indonesian textile industry must carry out a full replacement of virgin polyester with recycled polyester. Given that vPET still makes a large economic contribution to the textile industry, a total halt to the linear business model in the short term is not a realistic option.

Conversely, the results of this study show that the Indonesian textile industry needs to carry out a gradual transition from the linear economy model toward the circular economy. In other words, the future of the textile industry is not about choosing between a linear economy versus a circular economy, but rather about creating a balance through a hybrid economy approach, namely linear and circular business models operating side by side during the transition period.

Table 21. Comparison of the Characteristics of Linear and Circular Economy Business Models

Aspek	Linear Economy (vPET)	Circular Economy (rPET)
Material Source	Virgin Petrochemical	Post-Consumer PET Bottle
Konsep	Take-Make-Dispose	Reduce-Reuse-Recycle
Tahap Bisnis	Mature Market	Growth Market
Production Growth	Tends to be stagnant	Increasing
Pendapatan	High	Growing
Profitabilitas	Stabil	Potentially increasing
Energy Consumption	High	Very low
GHG Emission	High	Very low
Water Consumption	High	Very low
Dependence on Fossil Raw Materials	High	Low
Alignment with ESG	Moderat	Very high
Alignment with Net Zero Emission	Low	Very high
Long-Term Prospects	Limited	Very promising

Based on these results, it can be concluded that the shift toward a circular economy is a strategic necessity, not merely an environmental option. However, this transformation should be carried out gradually through a hybrid economy approach, namely utilizing the economic advantages of the established virgin polyester business while simultaneously increasing the contribution of recycled polyester as a future business model that is lower in carbon, more resource-efficient, and more sustainable.

Therefore, the main finding of this study shows that the transformation from virgin polyester to recycled polyester is not merely a change in production technology, but a transformation of the business model from a linear economy toward a circular economy that has higher competitiveness and is able to support the achievement of Net Zero Emission targets as well as the future sustainability of the Indonesian textile industry.

The key finding of this study shows that the future of the Indonesian textile industry is not a linear economy versus a circular economy, but rather a linear to circular transition, namely a gradual transition from a fossil-resource-based business model toward a more sustainable, low-carbon, and long-term competitive circular-economy-based business model. This approach enables the creation of a balance among economic sustainability, the environment, and the competitiveness of the Indonesian textile industry in facing global market demands and the future decarbonization agenda.

PESTEL Analysis of Indonesia's rPET Industry 2025–2030

Based on the results of a comparative analysis between virgin polyethylene terephthalate (vPET) and recycled polyethylene terephthalate (rPET) from economic, environmental, and market trends, rPET shows superior potential in supporting the industrial transition to a circular economy model. Although vPET still has advantages in terms of technological maturity and relatively stable production costs, rPET offers more significant benefits in reducing natural resource consumption, greenhouse gas emissions, and post-consumption plastic waste generation. In addition, the increasing commitment of governments, industry players, and consumers to sustainable practices further strengthens the position of rPET as a strategic material alternative in the future.

Considering various external factors that can affect the development of the rPET industry in Indonesia until 2030, a more comprehensive analysis is needed to understand the opportunities and challenges that will be faced. Therefore, PESTEL (Political, Economic, Social, Technological, Environmental, and Legal) analysis is used to evaluate external factors that have the potential to encourage or hinder the growth of the rPET industry. This analysis is expected to provide an overview of the readiness level and prospects of rPET as the most relevant solution in supporting the transformation from a linear economic model (take-make-dispose) to a circular economy (reduce-reuse-recycle) in Indonesia.

1. Political Aspect

From a political perspective, the prospects for the development of the recycled polyethylene terephthalate (rPET) industry in Indonesia until 2030 show a very positive direction. This is supported by the government's increasingly strong commitment to encouraging sustainable waste management and the implementation of the circular economy as part of the national development agenda. Through Presidential Regulation Number 12 of 2025 concerning the 2025–2029 National Medium-Term Development Plan (RPJMN), the government has set a target of solving 100% of the waste problem by 2029. This target reflects the government's seriousness in improving the national waste management system while encouraging the reuse of resources through recycling activities.

This commitment is strengthened by the Ministry of Environment which emphasizes that the achievement of the 100% waste management target by 2029 will be carried out through strengthening the implementation of the circular economy and increasing collaboration between stakeholders, including the government, the private sector, recyclers, academics, and the community. This approach provides a great opportunity for the rPET industry because recycled materials are one of the important elements in supporting a circular economy system that aims to reduce dependence on primary raw materials while minimizing waste generation.

In addition, government policies related to waste reduction by producers through the Regulation of the Minister of Environment and Forestry Number 75 of 2019 concerning the Roadmap for Waste Reduction by Producers are also a significant driving factor. This regulation adopts the principle of Extended Producer Responsibility (EPR), which requires producers to be responsible for the packaging of their products after they become waste. The implementation of EPR encourages companies to increase the use of recyclable materials and expand the use of recycled raw materials such as rPET in their product packaging.

The effectiveness of these various policies is starting to be seen from the increasing performance of the national recycling industry. Based on the results of the Recycling Rate Index (RRI) study conducted by Sustainable Waste Indonesia (SWI) and Indonesian Plastic Recyclers (IPR) in 2025, the recycling rate of PET bottles in Indonesia has reached 71%, with the economic contribution of the plastic recycling industry reaching around IDR 19 trillion per year. This achievement shows that the PET collection and recycling ecosystem in Indonesia has developed quite well and has a strong foundation to support the increased use of rPET in the future.

With the support of national policies, the implementation of EPR, the strengthening of the circular economy, and the development of the domestic recycling industry, political factors can be categorized as one of the key drivers of the growth of the rPET industry in Indonesia. This condition shows that politically, the business environment until 2030 will increasingly support the use of rPET as a strategic material in the transition from a linear economy model to a more sustainable circular economy.

2. Economic Aspect

From an economic perspective, the recycled polyethylene terephthalate (rPET) industry shows very attractive growth prospects until 2030. The results of a study by Sustainable Waste Indonesia (SWI) and Indonesian Plastic Recyclers (IPR) show that the PET recycling rate in Indonesia has reached 71%, making it the type of plastic with the highest recycling rate in Indonesia. In addition, the plastic recycling industry has made a significant economic contribution with a value of Rp19 trillion per year.

The growth prospects are also supported by global market developments. The rPET market is projected to increase from US$14.3 billion in 2026 to US$25.9 billion by 2033 at a compound annual growth rate (CAGR) of 8.9%. This growth was driven by increasingly stringent regulations related to the content of recycled materials in packaging, the company's increasing commitment to ESG, and the development of increasingly efficient recycling technology. This condition shows that the demand for rPET will continue to increase and open up great economic opportunities for the recycling industry in Indonesia.

In line with the results of this study, the increasing demand for PET-based products and the growing national recycling ecosystem strengthen the potential of rPET as an alternative that not only provides environmental benefits, but is also able to create long-term economic value. Therefore, economic factors can be categorized as opportunities that support the development of the rPET industry and accelerate the transition from a linear economy to a circular economy in Indonesia.

3. Social Aspect

From an economic perspective, the recycled polyethylene terephthalate (rPET) industry shows very attractive growth prospects until 2030. The results of a study by Sustainable Waste Indonesia (SWI) and Indonesian Plastic Recyclers (IPR) show that the PET recycling rate in Indonesia has reached 71%, making it the type of plastic with the highest recycling rate in Indonesia. In addition, the plastic recycling industry has made a significant economic contribution with a value of Rp19 trillion per year.

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development of the rPET industry and accelerate the transition from a linear economy to a circular economy in Indonesia.

4. Technology Aspect

From a technological perspective, the development of the recycled polyethylene terephthalate (rPET) industry is supported by advances in recycling technology that are increasingly able to produce high-quality products and meet various industrial needs. The mechanical recycling technology that is currently the most widely used has developed so that it is able to process post-consumption PET bottles into rPET resin that can be reused in various applications, including packaging and textiles. In addition, the development of bottle-to-bottle recycling technology allows rPET to be reused as a raw material for food-grade packaging, thereby increasing the added value and competitiveness of recycled products.

On the other hand, the development of chemical recycling technology such as depolymerization and glycolysis opens up greater opportunities in utilizing PET waste that was previously difficult to recycle through conventional methods. This technology is able to return PET to the shape of a monomer so that the quality of the material produced is close to virgin PET (vPET). In addition to improving product quality, the application of this technology also has the potential to expand the source of raw materials and increase the efficiency of the use of plastic waste in a circular economy system.

Technological developments also occur in waste sorting and treatment systems, such as the use of artificial intelligence (AI) for the sorting process, contaminant detection technology, and increasing the efficiency of the washing and pelletizing process. These innovations help improve the quality of rPET while reducing operational costs in the long run. In addition, in the textile industry, technological advances allow the use of rPET as a raw material for recycled polyester fibers that have quality equivalent to conventional polyester so that they are increasingly accepted by the global market.

With the development of recycling technology and increasing investment in rPET processing facilities, technology factors can be categorized as opportunities that greatly support the growth of the rPET industry until 2030. Technological advances not only improve the quality and efficiency of production, but also expand the application of rPET in various industrial sectors, thereby strengthening its role in supporting the transition to a circular economy.

5. Legal Aspect

From a legal and regulatory perspective, the development of the recycled polyethylene terephthalate (rPET) industry in Indonesia is supported by the growing strength of government policies that encourage the reduction of plastic waste and the implementation of a circular economy. One of the main regulations is the Regulation of the Minister of Environment and Forestry Number 75 of 2019 concerning the Roadmap for Waste Reduction by Producers which adopts the principle of Extended Producer Responsibility (EPR). This regulation requires manufacturers to reduce waste generation from their products and packaging through more environmentally friendly designs, post-consumption packaging recollection, and increased use of recyclable materials.

In addition, the government through the 2025–2029 RPJMN has also set a target of solving 100% of waste problems by 2029 which will be achieved through strengthening the circular economy and increasing the national recycling rate. The policy provides certainty in the direction of the development of the recycling industry, including increasing the use of rPET as an alternative raw material that supports the achievement of national waste reduction targets.

In terms of the global market, various countries have implemented regulations that require the use of recycled content in packaging. The European Union, for example, has set a target of a minimum recycled content on PET bottles of 25% by 2025 and increasing to 30% by 2030. Similar regulatory trends are also starting to develop in various Asian and North American countries. This condition provides an opportunity for Indonesia's rPET industry to meet the needs of the global market that increasingly demands the use of recycled materials and products that meet sustainability standards.

However, regulatory developments also require the rPET industry to meet various requirements for increasingly stringent quality, food-grade, traceability, and sustainability reporting. Therefore, companies need to continue to improve the quality of their processes and management systems in order to be able to meet national and international standards.

Overall, legal and regulatory factors can be categorized as opportunities for the development of the rPET industry until 2030. National regulatory support for the circular economy and increasing obligations to use recycled materials in various countries are expected to drive the growth in rPET demand and accelerate the transition from a linear economy to a circular economy.

CONCLUSION

This study concluded that recycled polyethylene terephthalate (rPET) offers significant advantages over virgin polyethylene terephthalate (vPET) in supporting the transition from a linear to a circular economy in Indonesia’s textile industry. The findings indicate that vPET production generates substantial environmental impacts through high energy consumption, greenhouse gas emissions, resource depletion, and waste generation, whereas rPET demonstrates superior environmental performance and greater resource efficiency. Economically, rPET provides opportunities for cost savings, reduced dependence on fossil-based raw materials, and enhanced competitiveness amid growing demand for sustainable products. The projected analysis for 2025–2030 further shows that wider adoption of rPET can deliver long-term economic and environmental benefits while strengthening industry resilience to evolving market and regulatory requirements. Although challenges remain, including feedstock availability, recycling technology investment, and waste management infrastructure, supportive government policies, industry collaboration, and technological advancements can accelerate the transition. Overall, rPET serves as a strategic enabler for creating a more sustainable, competitive, and circular textile industry in Indonesia.

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