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Circular Economy Transitions: Evaluating the Economic and Environmental Impacts of Waste-to-Resource Systems

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Abstract

This study quantitatively investigates the relationship between the implementation of waste-to-resource systems and the economic and environmental performance of circular economy transitions. Using survey data from 350 respondents, the research employs regression analysis to test its hypotheses. The key finding is that adopting waste-to-resource systems has a significant positive correlation with both economic gains and environmental sustainability, with effectiveness being moderated by technological, regulatory, and socio-cultural factors.

Keywords

Circular Economy, Waste-to-Resource Systems, Economic Performance, Environmental Sustainability, Technological Factors, Regulatory Factors, Socio-Cultural Factors, Sustainable Development

1. Introduction

1.1. Background

The classical linear economic approaches that are generally referred to as the take-make-dispose systems have remained dominant in industrial and consumer behavior over decades (Pacheco-Lopez et al., 2021; You, 2022). The inherent flaw of the linear models has caused the adoption of the alternative paradigms that reconcile economic growth and environmental care, such as the concept of the circular economy (CE).

Circular economy assumes the infinite utilization of resources, and it pays specific attention to such processes as reuse, repair, remanufacturing, and recycling

(Ng et al., 2024; Pacheco-Lopez et al., 2022). The other economic opportunity that CE strategies bring about is the innovation and cost savings and availability of new markets of secondhand materials (Shah et al., 2024).

The implementation of waste-to-resource technologies, which involve transforming waste into an economically valuable input, is one of the most interesting issues of the implementation of the circular economy. They are structures comprising of many technological, managerial, and policy interventions to recover materials, energy, or any other products within garbage that lessen the addiction to landfill and environmental burden (Fritz, 2025; Donkor et al., 2025). In such a way, the waste-to-resource systems may be viewed as the meeting point of environmental and economic interests, and it provides a decent alternative to apply the postulates of the circular economy and offers a financial stimulus to the stakeholders at the same time (Tathavadekar & Mahankale, 2025; Santos et al., 2025).

It is true that the waste-to-resource systems have potential regardless of the issues (Bekchanov & Gondhalekar, 2022; Pacheco-Lopez et al., 2021). This way, it is noteworthy to focus on the economic and environmental performance of such systems and have in place interventions that could enhance the optimal sustainability performance and stakeholder engagement (Ng et al., 2024; You, 2022).

The re-use of metals, plastics and organic resources have been seen to decrease the cost of the production process and has resulted in creating employment opportunities and also in industrial revolution (Shah et al., 2024; Donkor et al., 2025). The investments in the infrastructures, and the secondary markets of the materials (Pacheco-Lopez et al., 2022; Fritz, 2025).

On the environmental aspect, the systems reduce emission of greenhouse gases, manage the pollution and reduce the impact that production and consumption has on the environment. The waste-to-resource systems hold that the system conserves on methane gas and other pollutants and conserves on energy and water than production of virgin resources by channeling the waste out of landfills and incineration. This streamlines the transformations into the circular economy to the global climate goals (Ng et al., 2024; Tathavadekar & Mahankale, 2025).

The implementation of the circular economy has not been applied equally worldwide as countries are not equally endowed with the economic potential, technology, governance and culture (Bekchanov & Gondhalekar, 2022; Pacheco-Lopez et al., 2021). The transitions are only successful when they are based on cross-sector collaboration, alignment of policies, knowledge sharing ability, and creation of powerful evaluation systems, which consider flows of materials, energy use, emissions, and socio-economic impacts (Ng et al., 2024; You, 2022).

To sum up, the waste-to-resource systems may be used as an alternative option to make a step to the circular economy and to trade-off the economic development and ecology. These systems have been applied to minimize the effects of the environment, maximize use of resources, create new innovations and come up with economy by converting waste into useful products.

1.2. Problem Statement

The contemporary global economy relies mostly on a linear production-consumption model which is sometimes referred to as a take-make-dispose. It is based on the removal of virgin resources and the creation of large amounts of waste, which lead to worsening the environment, depleting resources, and socio-economic inefficiencies (Pacheco-Lopez et al., 2021; You, 2022). As a result, it is becoming less viable and more expensive to use the conventional approaches to managing waste, including landfills and incineration (Shah et al., 2024; Fritz, 2025).

Circular economy models provide a solution with potential as they focus on the reuse of waste into resources (Ng et al., 2024; Pacheco-Lopez et al., 2022). Nonetheless, there are major problems with the adoption of waste-to-resource systems. They are technological barriers, high costs capital, and regulatory gaps (Bekchanov & Gondhalekar, 2022; Tathavadekar & Mahankale, 2025). Also, although many studies have demonstrated the theoretical benefits of the practice of a circular economy, there is still a gap between the theoretical benefits and the practical evidence, both economically and environmentally, to assess the impact of waste-to-resource systems in the real world (Santos et al., 2025; Donkor et al., 2025).

The issue is thus a two-fold. First, it is strongly urgently required to find and use viable solutions to change the linear to the circular economic frameworks, especially through converting the waste resources into useful resources. Second, the critical knowledge gap is associated with the quantitative results of these transitions (Leong et al., 2023; Amaral et al., 2023).

Waste-to-resource initiatives can be ineffective, not used to their full extent, or not meet their sustainability goals without a systematic evaluation of both economic and environmental effects. Thus, to ensure that these systems are effective in practice, properly assess the obstacles and the drivers of successful implementation and give evidence-based recommendations to support the decision-making process during the transition to a low-carbon, circular economy, it is crucial to carry out thorough research (You, 2022; Pacheco-Lopez et al., 2021).

1.3. Research Questions

Main Question:

What is the relationship between waste-to-resource systems and the economic and environmental performance of circular economy transitions?

Sub-Questions:

1) How do waste-to-resource systems influence economic performance in circular economy transitions?

2) How do waste-to-resource systems affect environmental sustainability in circular economy transitions?

3) What are the key factors that enhance or hinder the effectiveness of waste-to-resource systems in achieving circular economy objectives?

1.4. Research Objectives

Main Objective:

To examine the relationship between waste-to-resource systems and the economic and environmental performance of circular economy transitions.

Sub-Objectives:

1) To analyze the impact of waste-to-resource systems on economic performance in circular economy transitions.

2) To investigate the effect of waste-to-resource systems on environmental sustainability in circular economy transitions.

3) To identify the factors that enhance or hinder the effectiveness of waste-to-resource systems in achieving circular economy objectives.

1.5. Research Hypotheses

Main Hypothesis:

- H1: There is a statistically significant relationship between the implementation of waste-to-resource systems and the economic and environmental performance of circular economy transitions.

Sub-Hypotheses:

- H1a: There is a statistically significant relationship between waste-to-resource systems and economic performance in circular economy transitions.
- H1b: There is a statistically significant relationship between waste-to-resource systems and environmental sustainability in circular economy transitions.
- H1c: The effectiveness of waste-to-resource systems in circular economy transitions is influenced by key technological, regulatory, and socio-cultural factors.

2. Literature Review

2.1. The Concept of the Circular Economy and Its Formation

The field of CE has been extended to include industrial symbiosis, eco-design, sustainable production and consumption patterns and combination with technology advances (Kristensen & Mosgaard, 2020; Atif, 2023).

Lamba, Kumar, and Dhir (2023) in their article have pointed out that the notions of the circular economy (CE) are not limited to the reduction of environmental footprints but also the production of economic value because of the waste streams through the implementation of innovative business models and industrial practices. The systemic logic, which forms the central part of circular business models, was also emphasized by Fehrer and Wieland (2021) in their study.

The implementation of the principles of CE has been developed to a significant extent as a result of policy interventions (European Commission, 2020; European Commission, 2019). Until the final goal of the transition to a circular system is reached, the following strategies focus on ending the material loops, a longer lifespan of goods and the stimulation of the secondary raw materials. Meanwhile, academic research has been moving towards defining more and more how CE can be used to meet the goals of sustainability and evaluating the efficacy of the policy initiatives undertaken (Corvellec, Stowell, & Johansson, 2022; Johansson, Velis, & Corvellec, 2020).

CE has also come under criticism and this has created identification of potential limitations and challenges despite being a widely accepted one. Corvellec et al. (2022) did not reject the possibility of CE to, in fact, balance economic growth and environmental sustainability or not. The policy contradictions were also outlined by the Johansson et al. (2020) such as contradiction between non-toxic materials cycles and non-toxic recovery objectives in the sector. They also observed relevance of joint governance systems in the search to find solutions to these problems. That leads to the necessity of realistic methods that can be observed to attain the successful passage between the linear and the circular models (Kumari et al., 2020; Castro et al., 2023).

Dynamic interaction between theory and policy and the improvement of technology has led to a great extent to the concept of a circular economy developing. Originally concentrated on minimization of waste and recycling of materials, CE has evolved to be a multifaceted system in which the elements of environmental sustainability, creation of economic value and the social responsibility are integrated. It also applies the most appropriate technologies and the integrated business strategies in the process of making a systemic change. To say the least about the contemporary studies on the waste-to-resource systems discussed in the proper context, one will have to possess a fair understanding of this conceptual development, in fact. It sheds light on the theoretical foundations, practical challenges and prospects of innovation that are associated with the transition to a truly circular economy (Chen et al., 2018; Diao et al., 2024).

2.2. Microalgae Application within the Plants of Waste to Resource Conversion

According to Abdelfattah et al. (2023), Bhatt et al. (2022), and Bellido-Pedraza, Torres, and Llamas (2024) such photosynthetic microorganisms possess peculiarities that enable them to absorb nutrients, trap pollutants, and produce valuable biomass simultaneously. Due to it, they can be applied extremely to the long-term environmental management and to the restoration of the industrial resources. The importance of microalgae being a dual agent, a bioremediation agent and a bioresource to bio-based products puts microalgae in a central position in the creation of closed-loop and zero-waste systems that would accord with the objectives of the circular economy (Bandh & Malla, 2023; Braun & Colla, 2023).

Integration of different modern growing techniques has also contributed immensely towards the effectiveness and the usage of the micro algae systems. Chia et al. (2023) authors investigated the use of microalgae-bacteria consortia as a source of bioenergy. They determined that symbiotic relationships of the species improve uptake of nutrients, increase the rate of pollutant elimination, and increase biomass usability. Greene et al. (2025) investigated how to optimize the production of renewable diesel and sustainable aviation fuel produced by microalgae in a geographically resolved manner. Their findings demonstrated the fact that specific culture strategies can be used to maximize the environmental performance, and even the economic performance (Kholssi et al., 2021).

To illustrate a case in point, Encarnação et al. (2023a, 2023b) presented the evidence that confirms the fact that the recycling of wastewater produced by lenses worn in the eyes is possible by the introduction of microalgae. It is an example of circular solutions based on sectors which the researchers developed. Bhatt et al. (2022) also highlighted the cleaning up of the pollutant with the help of microalgae as an example of a circular urban water management approach. Specifically, they focused on the compatibility of these systems and low-carbon and regenerative conservation endeavors. Microalgae technologies can also be aligned to the global sustainability targets, such as the Sustainable Development Goals (SDGs) of United Nations by promoting clean water supply, renewable energy, and sustainability industrial operation (Kuech et al., 2023).

It is required that the methods of research and technical innovation should be conducted continuously in order to address the issues of light penetration, nutrient variability, contamination, costs, and optimization of the processes (Abdelfattah et al., 2023; Chong et al., 2024; Imamoglu, 2024). With artificial intelligence, machine learning, and process automation, maximum cultivation, growth monitoring, and new spheres of resource efficiency can be introduced (Bradley et al., 2023; Costa et al., 2023).

2.3. An Evaluation of the Waste-to-Resource Systems regarding Eco-Friendly and Cost-Effective Factors

Environmental and economic footprints of waste-to-resource systems are critical elements of the process of determining the possibility or impossibility of waste-to-resource systems, their sustainability, and their suitability to the goals of the circular economy. Ng, Mah, and Zhao (2024) make it known that the waste-to-resource systems, particularly those that are based on microalgae technologies, could offer numerous possibilities for waste stream valorization. Such wastes are municipal wastes and industrial wastes and even agro-industrial wastes (Kirchherr et al, 2017). These wastes can be transformed into useful bioproducts that involve biofuels, biofertilizers, and bioplastics among other high-value chemicals. The complete evaluation is necessary to target quantifying of trade-offs, resource efficiency maximization, and policy and investment decision-making. Despite the fact that these systems will have enormous impacts on the environment and financial benefits, there is a need to assess them (Cheirsilp et al., 2023).

In Arashiro et al. (2022), the life cycle assessment (LCA) of microalgae systems that had been coupled with wastewater treatment was performed. They unveiled that microalgae systems of waste management and biofuel production reduce greenhouse gases significantly, the possibility of eutroffication as well as the energy consumption intensity and simultaneously recover useful nutrients as compared to traditional waste management and biofuel production systems (Kirchherr et al., 2023; Chourasia et al., 2022).

2.4. Integration of the Systemic Technologies with the Advanced Technologies

Besides, digital tools, artificial intelligence (AI), machine learning, and industrial automation have become a necessary scale facilitator of these systems and achieve precise and data-driven control over the processes (Chong et al., 2024; Imamoglu, 2024). This is despite the fact that biotechnological methods of microalgae provide the biological foundation of reclaiming resources (Dini, 2021).

3. Methodology

3.1. Research Design

The research design adopted by the paper is a quantitative, descriptive-analytical study, but with the addition of the elements of the exploratory analysis in examining the effect of waste-to-resource systems on the economy and the environment in the broader context of the processes of a circular economy transition.

3.2. Population and Sample

The target population of the proposed study consists of industrial organizations and enterprises that are or intend to implement waste-to-resource systems as one of the components of their circular economy strategies.

3.3. Research Hypotheses

The research hypotheses will seek to find quantifiable and testable relations between the implementation of the waste-to-resource systems and the economic and environmental benefits of the implementation of the circular economy. The research hypothesis is the following: The positive impact of the adoption of waste-to-resource systems on economic performance and environmental sustainability is statistically significant.

3.4. Research Instrument

A structured questionnaire is the major data collection tool to be used in this research, as it will be used to collect quantitative data about the participants on the policies of waste-to-resource systems and their performance.

3.5. Data Collection Procedure

Data collection was carried up to a target population of 350 valid responses. Ambiguities were clarified by using follow-up communications, participation was encouraged and incomplete or inconsistent submissions were eliminated.

3.6. Data Analysis

Analysis has been conducted in such a way that it has not only established the strength and direction of relationships, but also the moderating factors of the effects such as technological capability, compliance to regulations, and organizational culture. Conventional levels of confidence were also tested to make sure that the results are strong and sound.

3.7. Reliability and Validity

Reliability and validity of the research instrument is important to ensure that the data obtained is correct, consistent and is in fact representative of the constructs under measurement. Reliability of the questionnaire was determined in this research by using the Cronbach's Alpha coefficient, which measures the internal consistency between the items of every construct.

4. Data Analysis

4.1. Demographic Data Analysis

Table 1 illustrates how the study respondents will be divided according to gender. Among all the 350 respondents, 152 (43.4) were male and 198 (56.6) were female. The marginally bigger percentage of the female respondents shows that their views on waste-to-resource systems and transitions to the circular economy are well-represented. This gender balance is especially important in situations when environmental decision-making and the implementation of sustainable practices may be affected by the differences in the points of view and priorities between the male and female genders.

Table 1. Distribution of the study sample according to gender.

Gender	Frequency	Percentage
Male	152	43.4%
Female	198	56.6%
Total	350	100%

Table 2 indicates the sample of respondents by age groups. The highest percentage (33.7) is in 25 - 34 age group, which is made up of early-career professionals who usually form the main workforce in the uptake of new technologies and innovative practices in the organizations. They are essential in assessing the operational and economic consequences of the waste-to-resource systems since they are the ones that are mostly open to new approaches and sustainable measures.

Table 2. Distribution of the study sample according to age group.

Age Group	Frequency	Percentage
Less than 25	68	19.4%
25 - 34 years	118	33.7%
35 - 44 years	92	26.3%
45 years & above	72	20.6%
Total	350	100%

Table 3 shows the educational qualification of the respondents. Most of them possess a bachelor's degree (43.4%), which means that most of the participants have the academic qualification required to know and evaluate the technical, managerial, and environmental properties of waste-to-resource systems. Postgraduate respondents (22.3) have more developed knowledge and analytical abilities that add strategic and policy-oriented information regarding the transition towards the circular economy.

Table 3. Distribution of the study sample according to educational qualification.

Qualification	Frequency	Percentage
High School	46	13.1%
Diploma	74	21.1%
Bachelor's Degree	152	43.4%
Postgraduate Degree	78	22.3%
Total	350	100%

Table 4 depicts the professional experience of the respondents. The highest population (34.6) is 5 - 10 years old, as they are mid-career professionals and can shape operational implementation, introduction of waste-to-resource-technologies, and sustainability activation.

Table 4. Distribution of the study sample according to years of experience.

Experience	Frequency	Percentage
Less than 5 years	74	21.1%
5 - 10 years	121	34.6%
11 - 15 years	78	22.3%
More than 15 years	77	22.0%
Total	350	100%

Table 5 indicates the distribution of respondents according to job position. A majority of the respondents (52.6) are employees and this gives them operational-level insights into how waste-to-resource systems are implemented. Supervisors (22.3%) are also important in converting organizational policies into practice and assisting teams in adopting the practices of a circular economy.

Table 5. Distribution of the study sample according to job position.

Job Position	Frequency	Percentage
Employee	184	52.6%
Supervisor	78	22.3%
Manager	62	17.7%
Director	26	7.4%
Total	350	100%

The income distribution of the participants is demonstrated in **Table 6**. Most of them are making about 5000 - 10,000 SAR per month (35.7%), which is the primary work force that might be engaged in day-to-day activities of the waste-to-resource systems. Greater incomes (>15,000 SAR) and positions tend to be on managerial or directorial level, providing information on the strategic decision making and investment on sustainability efforts.

Table 6. Distribution of the study sample according to monthly income.

Monthly Income (SAR)	Frequency	Percentage
Less than 5000	72	20.6%
5000 - 10,000	125	35.7%
10,001 - 15,000	95	27.1%
More than 15,000	58	16.6%
Total	350	100%

4.2. Survey Statements Analysis

Table 7 provides a clear picture of the perceptions of the respondents on the general effects of waste to resource systems. The table shows that most of the items had scores that lie between Agree and Strongly agree, a fact that shows that the respondents positively perceive the implementation of such systems in facilitating the process of transitions to the circular economy.

Table 7. Overall impact of waste-to-resource systems.

No.	Statement	Mean	Std. Deviation	Direction	Rank
1	Implementation of waste-to-resource systems positively impacts overall economic and environmental performance in circular economy transitions.	4.32	0.61	Strongly Agree	2
2	Organizations adopting waste-to-resource systems achieve better balance between economic growth and environmental sustainability.	4.45	0.58	Strongly Agree	1
3	Waste-to-resource systems enhance organizational capacity to meet circular economy objectives.	4.21	0.64	Agree	3
4	The use of waste-to-resource systems results in measurable improvements in both economic efficiency and environmental outcomes.	4.12	0.69	Agree	4
5	Adoption of waste-to-resource systems encourages innovation and resource optimization that support sustainable business practices.	4.05	0.72	Agree	5
6	Implementation of these systems facilitates long-term resilience of organizations in the context of environmental and economic pressures.	3.98	0.75	Agree	6

Continued

7	Waste-to-resource systems support strategic decision-making by providing reliable data on resource usage.	3.95	0.77	Agree	7
	Total	4.16		Agree	

Table 8 shows the economic aspect of waste-to-resource systems. The table indicates that the respondents have a positive relationship that is very strong about the application of these systems and economic performance.

Table 8. Economic performance.

No.	Statement	Mean	Std. Deviation	Direction	Rank
1	Implementation of waste-to-resource systems improves overall economic efficiency in organizations.	4.38	0.63	Strongly Agree	2
2	Adoption of these systems reduces operational and production costs.	4.47	0.57	Strongly Agree	1
3	Waste-to-resource systems create new business opportunities and revenue streams.	4.12	0.69	Agree	4
4	These systems contribute to efficient utilization of raw and secondary materials.	4.18	0.66	Agree	3
5	Waste-to-resource systems enhance competitiveness and economic sustainability of organizations.	4.05	0.71	Agree	5
6	The use of waste-to-resource systems reduces dependency on expensive virgin materials.	3.95	0.74	Agree	6
7	Organizations that adopt these systems can achieve long-term financial stability.	3.92	0.76	Agree	7
	Total	4.16		Agree	

Table 9 illustrates the perceived beneficial aspects of waste-to-resource systems to the environment. The ratings of respondents on items were mainly between the Agree and Strongly Agree scale with the mitigation of greenhouse gas emissions being ranked the most strongly.

Table 9. Environmental sustainability.

No.	Statement	Mean	Std. Deviation	Direction	Rank
1	Waste-to-resource systems reduce environmental pollution, including air, water, and soil contamination.	4.41	0.59	Strongly Agree	2
2	Adoption of these systems lowers greenhouse gas emissions.	4.50	0.55	Strongly Agree	1
3	The use of waste-to-resource systems minimizes reliance on landfills and incineration.	4.30	0.62	Agree	3
4	These systems support sustainable use of renewable and non-renewable resources.	4.15	0.68	Agree	4

Continued

5	Waste-to-resource systems enhance environmental quality and ecosystem protection.	4.08	0.71	Agree	5
6	Implementation of these systems aligns with global climate goals and sustainability standards.	3.97	0.73	Agree	6
7	Organizations using these systems are perceived as environmentally responsible by stakeholders.	3.92	0.75	Agree	7
	Total	4.20		Agree	

Table 10 discusses the success of waste-to-resource systems by indicating technological, regulatory, and socio-cultural issues. The items rated highest are associated with regulatory support and technological access, which proves that the effectiveness of the systems is determined by the combination of the policy, technology, and stakeholder involvement.

Table 10. System effectiveness.

No.	Statement	Mean	Std. Deviation	Direction	Rank
1	Availability of advanced technology significantly affects the success of waste-to-resource systems.	4.35	0.61	Strongly Agree	2
2	Organizational policies and regulations support or hinder the implementation of these systems.	4.48	0.54	Strongly Agree	1
3	Socio-cultural awareness and attitudes toward recycling impact system effectiveness.	4.12	0.68	Agree	4
4	Skilled human resources and training are critical for successful adoption.	4.18	0.65	Agree	3
5	Financial incentives and funding support improve the efficiency and adoption of these systems.	3.98	0.73	Agree	6
6	Collaboration between stakeholders enhances the overall effectiveness of waste-to-resource systems.	3.95	0.75	Agree	7
7	Continuous monitoring and evaluation of systems improve overall performance.	3.96	0.74	Agree	5
	Total	4.17		Agree	

4.3. Proving Hypotheses

4.3.1. Hypothesis One (H1)

H1: There is a statistically significant relationship between the implementation of waste-to-resource systems and the economic and environmental performance of circular economy transitions.

The model summary of the regression analysis to test the main hypothesis H1 is in Table 11. A positive association between the application of waste-to-resource systems and the overall economic and environmental performance in the transitions of the circular economy is moderate and has the value of 0.412. $R^2 = 0.170$ indicates that about 17 percent of the change in the economic and environmental performance can be accounted by the introduction of the waste-to-resource systems which is statistically significant as represented by the Sig. F Change = 0.000.

Table 11. Model summary for hypothesis one (H1).

Model	R	R-Square	Adjusted R-Square	Std. Error of the Estimate	Change Statistics	R-Square Change	F Change	df1	df2	Sig. F Change
1	0.412a	0.170	0.168	0.382	0.170	71.234	1	348	0.000	

a. Predictors: (Constant), waste-to-resource systems.

Table 12 of H1 ANOVA tests the significance of the regression model as a whole. The significance of F-statistic (71.234) is extremely high ($p = 0.001$), which confirms that the regression model can be used to predict the economic and environmental performance of the circle economy transitions with high reliability.

Table 12. ANOVA for hypothesis one (H1).

Model	Sum of Squares	df	Mean Square	F	Sig.
Regression	12.356	1	12.356	71.234	0.000b
Residual	60.347	348	0.173		
Total	72.703	349			

b. Predictors: (Constant), waste-to-resource systems; a. Dependent variable: Economic & environmental performance.

Table 13 shows the regression coefficients of H1. The non-standardized coefficient B = 0.398 means that with every unit increase in the adoption of the waste-to-resource systems, the summative economic and environmental performance increases by 0.398 units. The *p*-value of less than 0.001, and t-value of 8.443 indicate the statistical significance of the predictor. The standardized Beta coefficient of 0.412 reveals a medium effect size which proves the relevance of this variable on the results.

Table 13. Coefficients for hypothesis one (H1).

Model	Unstandardized Coefficients (B)	Std. Error	Standardized Coefficients (Beta)	t	Sig.
(Constant)	1.102	0.085	-	12.970	0.000
Waste-to-Resource Systems	0.398	0.047	0.412	8.443	0.000

a. Dependent variable: Economic & environmental performance.

4.3.2. Hypothesis Two (H1a)

H1a: There is a statistically significant relationship between waste-to-resource systems and economic performance in circular economy transitions.

Table 14. Model summary for H1a.

Model	R	R-Square	Adjusted R-Square	Std. Error of the Estimate	Change Statistics	R-Square Change	F Change	df1	df2	Sig. F Change
1	0.378a	0.143	0.141	0.389	0.143	58.123	1	348	0.000	

a. Predictors: (Constant), waste-to-resource systems.

Table 14 shows that waste-to-resource systems are moderately positively correlated with the economic performance (R = 0.378). The R^2 of 0.143 implies that these systems can explain the variation of 14.3% of the economic performance. The statistical significance ($p < 0.001$) proves that the implementation of waste-to-resource systems has a positive impact on economic performance, cost savings, and the establishment of new sources of money.

Table 15. ANOVA for H1a.

Model	Sum of Squares	df	Mean Square	F	Sig.
Regression	10.423	1	10.423	58.123	0.000b
Residual	62.407	348	0.179		
Total	72.830	349			

b. Predictors: (Constant), waste-to-resource systems; a. Dependent variable: Economic performance.

Table 15 shows that the F-statistic of 58.123 and p of less than 0.001 indicate that the regression model is really significant.

Table 16. Coefficients for H1a.

Model	Unstandardized Coefficients (B)	Std. Error	Standardized Coefficients (Beta)	t	Sig.
(Constant)	1.145	0.088	-	13.011	0.000
Waste-to-Resource Systems	0.352	0.046	0.378	7.626	0.000

Table 16 shows that the coefficient is positive and significant, which proves that better waste-to-resource systems lead directly to a better economic performance, which proves H1a.

4.3.3. Hypothesis Three (H1b)

H1b: There is a statistically significant relationship between waste-to-resource systems and environmental sustainability in circular economy transitions.

Table 17. Model summary for H1b.

Model	R	R-Square	Adjusted R-Square	Std. Error of the Estimate	Change Statistics	R-Square Change	F Change	df1	df2	Sig. F Change
1	0.397a	0.158	0.156	0.381	0.158	65.781	1	348	0.000	

a. Predictors: (Constant), waste-to-resource systems.

Table 17 shows that the waste to resource systems are strategic in ensuring environmental sustainability as shown by a moderate positive relationship (R = 0.397). The value of R^2 0.158 shows that these systems explain 15.8 percent of the variation in environmental sustainability.

Table 18. ANOVA for H1b.

Model	Sum of Squares	df	Mean Square	F	Sig.
Regression	11.456	1	11.456	65.781	0.000b
Residual	60.254	348	0.173		
Total	71.710	349			

b. Predictors: (Constant), waste-to-resource systems; a. Dependent variable: Environmental sustainability.

Table 18 shows that the results of ANOVA indicate that the model is very significant. The sub-hypothesis H1b is proven as the waste-to-resource systems are implemented to enhance the performance of the environmental system through resource conservation and minimization of emissions, which has a scientific foundation.

Table 19. Coefficients for H1b.

Model	Unstandardized Coefficients (B)	Std. Error	Standardized Coefficients (Beta)	t	Sig.
(Constant)	1.198	0.086	-	13.930	0.000
Waste-to-Resource Systems	0.384	0.047	0.397	8.115	0.000

4.3.4. Hypothesis Four (H1c)

Table 19 shows that H1c: The effectiveness of waste-to-resource systems in circular economy transitions is influenced by key technological, regulatory, and socio-cultural factors.

Table 20. Model Summary for H1c.

Model	R	R-Square	Adjusted R-Square	Std. Error of the Estimate	Change Statistics	R-Square Change	F Change	df1	df2	Sig. F Change
1	0.431a	0.186	0.183	0.378	0.186	79.342	1	348	0.000	

a. Predictors: (Constant), technological + regulatory + socio-cultural factors.

Table 20 shows that the correlation coefficient R =0.431 demonstrates that the waste-to-resource systems have a moderate to strong correlation, meaning that these factors determine their effectiveness. $R^2 = 0.186$ demonstrates that 18.6 percent of the changes in effectiveness is explained, which is statistically significant with $p = 0.001$ and this proves H1c to be valid.

Table 21. ANOVA for H1c.

Model	Sum of Squares	df	Mean Square	F	Sig.
Regression	13.245	1	13.245	79.342	0.000b
Residual	58.065	348	0.167		
Total	71.310	349			

b. Predictors: (Constant), technological + regulatory + socio-cultural factors; a. Dependent variable: System effectiveness.

Table 21 shows that ANOVA proves the model to be significant. Technological availability, legal policies, and social-cultural values are some of the major determinants that can influence the effectiveness of these systems towards the realization of the circular economy.

Table 22. Coefficients for H1c.

Model	Unstandardized Coefficients (B)	Std. Error	Standardized Coefficients (Beta)	t	Sig.
(Constant)	1.103	0.084	-	13.131	0.000
Key Factors	0.431	0.048	0.431	8.905	0.000

Table 22 shows that the positive coefficient supports the fact that the effectiveness of waste-to-resource systems is improved with the improvement in technology, regulatory support, and socio-cultural awareness. H1c is thereby justified and it is important to note that multi-dimensional interventions are needed in order to implement the circular economy successfully.

5. Conclusion

The present study has explored the impacts of the implementation of waste-to-resource systems on the economic and environmental performance of the changes to the circular economy. The findings confirm the argument that the adoption of such kind of systems is significantly correlated with improved performance in the economic and environmental scales. Specifically, it was possible to accept the primary hypothesis (H1) that indicates the fact that the organizations adopting the waste-to-resource programs not only enhance their potential to act efficiently and be cost-effective, but they also achieve the direct impact on environmental sustainability, e.g., reducing the rate of waste production and maximizing the use of resources. Sub-hypotheses H1a and H1b also show that the positive effects are two-fold because they consist of both the economic performance indicators of the reduction in costs and rise in revenues, as well as the environmental performance indicators of the reduction in emissions and the enhanced waste management behavior.

6. Suggestions for Improvement

1) The methodology should specify the geographic region and industrial sectors from which the 350 respondents were sampled. This context is essential for assessing the generalizability of the findings.

2) The literature review dedicates significant space to microalgae applications (Section 2.2), yet the survey and analysis address waste-to-resource systems in general. The manuscript should explicitly state whether microalgae is a specific case study or an illustrative example to justify this narrow focus within a broader review.

3) The study would benefit from a dedicated limitations section. A brief discussion of potential constraints, such as the cross-sectional nature of the data, reliance on self-reported perceptions, or potential sampling bias, would add important context to the results.

4) The population is defined as "industrial organizations", but the data is collected from individual employees. The methodology should briefly justify using individual perceptions as a proxy for organizational-level performance.

5) The recommendations are sound but could be strengthened with more specific examples. For instance, when suggesting investment in technology, mentioning a specific type of resource recovery or digital monitoring technology discussed in the literature would provide a more actionable insight.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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Appendix

Demographic Data

1) Gender

☐ Male

☐ Female

2) Age

☐ Less than 25

☐ 25 - 34

☐ 35 - 44

☐ 45 and above

3) Educational Qualification

☐ High School

☐ Diploma

☐ Bachelor's Degree

☐ Postgraduate Degree

4) Years of Experience

☐ Less than 5

☐ 5 - 10

☐ 11 - 15

☐ More than 15

5) Job Position

☐ Employee

☐ Supervisor

☐ Manager

☐ Director

6) Monthly Income (SAR)

☐ Less than 5000

☐ 5000 - 10,000

☐ 10,001 - 15,000

☐ More than 15,000

Questionnaire Table

Dimension	Item	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
Economic Performance	1) The implementation of waste-to-resource systems improves overall economic efficiency in organizations.					
	2) Adoption of these systems reduces operational and production costs.					

Continued

	3) Waste-to-resource systems create new business opportunities and revenue streams.
	4) These systems contribute to efficient utilization of raw and secondary materials.
	5) Waste-to-resource systems enhance competitiveness and economic sustainability of organizations.
	6) The use of waste-to-resource systems reduces dependency on expensive virgin materials.
Environmental Sustainability	1) Waste-to-resource systems reduce environmental pollution, including air, water, and soil contamination.
	2) Adoption of these systems lowers greenhouse gas emissions.
	3) The use of waste-to-resource systems minimizes reliance on landfills and incineration.
	4) These systems support sustainable use of renewable and non-renewable resources.
	5) Waste-to-resource systems enhance environmental quality and ecosystem protection.
	6) Implementation of these systems aligns with global climate goals and sustainability standards.
System Effectiveness	1) Availability of advanced technology significantly affects the success of waste-to-resource systems.

Continued

	2) Organizational policies and regulations support or hinder the implementation of these systems.	
	3) Socio-cultural awareness and attitudes toward recycling impact system effectiveness.	
	4) Skilled human resources and training are critical for successful adoption.	
	5) Financial incentives and funding support improve the efficiency and adoption of these systems.	
	6) Collaboration between stakeholders enhances the overall effectiveness of waste-to-resource systems.	