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Closed-Loop Sustainability: Leveraging Canteen Food Waste for Maggot Cultivation and Decorative Fish Feeding in an Automotive Spare Parts Manufacturing Facility in Bekasi, Indonesia

Adi Nugroho
Master Management Technology, President University, Indonesia,
email : adi.nugroho.lestanto@gmail.com

ABSTRACT

An automotive spare parts manufacturing plant in Bekasi Regency, Indonesia, has created a closed-loop sustainability project to address the essential issue of food waste management. With a canteen that serves 3,500 employees every day, the facility creates a lot of food waste, which has traditionally caused environmental and financial problems. The activity-integrated approach highlights the potential for novel waste management strategies to promote sustainability in industrial settings. The research frequently treats waste management and resource production (such as decorative fish ponds) as distinct domains, with a scarcity of studies focusing on sustainability practices within facilities catering to large employee populations with internal systems (such as canteens) that generate significant waste. As a result, it closes the gap by offering a case study of how an internal waste stream. The major goal is to create and execute a closed-loop system that converts food waste into a useful resource, maggots, for feeding decorative fish. Similarly, examine the economic benefits of eliminating the need for commercially supplied fish feed, as well as the environmental impact of decreasing food waste through an integrated waste management approach. This study employs a case study technique to analyze the deployment and consequences of a closed-loop sustainability system at an automotive spare parts manufacturing facility. The method provides for a thorough analysis of the procedures, obstacles and triumphs that come with repurposing food waste for maggot cultivation and fish feeding. The adoption of the closed-loop system successfully diverted a significant volume of food waste from the canteen, decreasing the environmental impact of typical trash disposal methods. Furthermore, the project resulted in significant cost savings by eliminating the need to buy commercial fish feed. As a result, the closed-loop technology helped to reduce the facilities overall carbon footprint by reducing waste and the requirement for externally supplied feed ingredients, which generally demand significant resources to produce and deliver. The discovery establishes a feasible approach for deploying closed-loop sustainability systems in industrial settings. It demonstrates how merging waste management and resource generation can improve sustainability while reducing operational expenses. Furthermore, demonstrated financial benefits, such as cost savings and potential profitability, can pique the interest of industry stakeholders for sustainable and economically viable solutions. The study also emphasizes the environmental benefits of reducing waste and reducing reliance on commercially produced feed, which contributes to a lower carbon footprint and reduces the environmental impact of manufacturing processes. Finally, the effort contributes to the

company's CSR profile, demonstrating a commitment to environmental stewardship and appropriate resource management, which improves the companies reputation and employee morale.

Keywords: *Close-Loop Sustainability, Food Waste Management, Maggot Cultivation, Environment Impact Reduction.*

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1. Introduction

Food waste is a massive issue globally for a number of reasons. Firstly when food goes to landfill, it releases methane which is 30 times more harmful than Co2 emissions to the planet which contributes to climate change. Secondly, food production uses a massive amount of water, land and energy. Whenever food is thrown out, there resources have been squandered and could have been allocated elsewhere. Lastly, there are people around the world starving, so we really shouldn't be wasting precious life giving food. (Laura Baker, 2019).

When food is wasted, it creates environmental harms at the point of disposal-for example, it contributes to global warming by releasing methane when it breaks down, it takes up space in landfills, and it generates landfill leachate. But to fully account for the environmental impacts of food waste, a whole-of-lifecycle approach is needed. When food is produced, processed, manufactured, packaged, transported, stored, and cooked, limited resources are used, emissions occur, and environmental harms are produced. If that food is wasted, the environmental toll of every step in the food supply chain is still felt, without delivering the benefits of nourishing the growing global population. (Office of the Prime Minister's Chief Science Advisor Kaitohutohu Mātanga Pūtaiao Matua ki te Pirimia, 2022).

The sources of food waste and the extent to which the environment, global economy and society are bearing the burden of food wasted and lost. The lifecycle of the food we eat begins in the farms where it is grown and harvested or the sea, rivers and lakes it is fished from. It continues through handling and storage stages and, often, processing prior to distribution and consumption. Throughout the food cycle, losses and wastage occurs, at farms, processing plants, distribution centres, storage houses, supermarkets, restaurants and households. (Jain, Sarika & Newman, David, 2018).

Currently, the author works at the automotive spare parts manufacturing facility in Bekasi, Indonesia, which has 3500 employee. During it is production activities, the company provides canteen facilities where employees can eat during work breaks from catering services. Organic food waste disposal is a major issue in everyday life facility activity, despite the fact that there are already collaborative waste management company, but we are working to apply sustainable concepts inside. Furthermore, each employee rest area has a garden that includes a decoratives fish pond, which adds to the beauty while also costing money to maintain, including fish food. For this reason, they try to collaborating on food waste management solutions here.

The study goal is to create and execute a closed-loop sustainability system in an industrial setting, specifically in a automotive spare parts manufacturing factory facility in Bekasi, Indonesia. The technique attempts to convert food waste from the facilities canteen into a valuable resource-maggots (the black soldier fly)-which are then fed to decorative fish scattered throughout the factory. This research is also develop an effective, sustainable system for managing food waste by repurposing it as a resource for maggot cultivation and fish feeding, with environmental, economic, and operational advantages. This show that such a system is feasible for industrial operations, providing a model for sustainability that can

be replicated in other situations. Finally the author clearly state the objectives is for waste reduction, cost saving and environment benefits.

This research also fills a gap by offering a detailed case study of how a non-food industrial facility may establish a closed-loop sustainability system by converting food waste from its canteen into a profitable resource for maggot cultivation and fish feeding. It is not only tackles the underutilized potential for waste management in non-food businesses, but also exhibits the integration of food waste management, animal feed production, and environmental sustainability into a single, self-contained system. This integrated strategy might be broadly applied to other large-scale facilities, emphasizing new prospects for sustainability in industries not traditionally linked with food waste management. the gap occurs due to a lack of focus on how non-food businesses, which have major internal waste-generating processes, might benefit from integrated waste management approaches. This study broadens the area of sustainability research by applying circular economy principles to industrial settings where food waste management has historically been overlooked.

2. Literature Review

a. Automotive Spare Part Manufacturing in Bekasi, Indonesia

Bekasi Regency is one of the outer ring zones of the Jakarta Metropolitan Area (JMA) that is directly affected by its metropolitan core (Indraprahasta, 2013), (Pravitasari, et al., 2015) and that undergoes industrialization process to support JMA's economic activities (Rustiadi, 2002). The industrialization process contributed to the increase in the Bekasi Regency GDP, where foreign capital played an essential role in the speed and significance of the industrialization process in Bekasi Regency.

The industrialization process in Bekasi Regency was also caused by the shifting of industrial manufacturing area from a crowded city center to a more "open" space in the outskirts or fringe areas of the metropolitan, which is commonly referred to as "industrial suburbanization" which occurs in urban regions of developed countries since the 1990s (Lewis, 2012).

The industrial suburbanization process in Bekasi Regency is driven by the private sector (Firman, et al., 2017), (Winarso, 2015), (Firman, 2004), it is only oriented towards developing residential and industrial estates without paying attention to agricultural areas. These estates increasingly threaten food security in the JMA (Pribadi, 2015, 2016), where 46.34% of agricultural land has been converted into a built-up area during 2000–2015 (Santosa, 2015)]. This type of development will only orient itself towards the upper-middle-class society and will lead to spatial and social segregation between the poor and rich in suburban areas. (Firman, 2017; Pribadi, 2015), (Zhu, 2015). This segregation is commonly referred to as dualism of urbanization in suburban areas, which lacks government intervention in the development process in suburban Bekasi.

The area of Bekasi-Karawang is a strategic location for car manufacturers as it is conveniently located near Indonesia's capital city of Jakarta where car demand is highest. Although infrastructure development in Indonesia is generally insufficient, there exists good access from the Bekasi-Karawang area to Jakarta through a toll road. Access to Jakarta is also important for exports from Tanjung Priok. The port of Tanjung Priok in North Jakarta is the busiest and most advanced Indonesian seaport, handling more than 50 percent of Indonesia's trans-shipment cargo traffic.

In the future exporting will be made easier for those businesses in the Bekasi-Karawang area. A new port, the Patimban Seaport, will be constructed in Subang (West Java). through Presidential Decree No. 47/2016, signed by Indonesian President Joko Widodo, the government declared this project a national strategic project, implying that all ministers, government agencies and governors need to support

its development. The Patimban seaport is envisaged to become an international seaport with a 7.5 million twenty-foot equivalent units (TEU) capacity. (Indonesia Investment Report, Aug 2024).

b. Environment Sustainability

Environmental sustainability is the recognition of linkages between humans to the ecosystems for life-supporting services. In return, it expresses the human's impacts on ecosystems. The concept of sustainability is increasingly disgraced as a useful practice for the conservation of natural resources, biodiversity, and other life-supporting systems. Environmental sustainability is a system of interconnections of living organisms to the ecosystems that they inhabit and depend on air, water, soil, and other environmental resources. It is also closely linked to the socioeconomic condition of living beings. Because it is difficult to have a sustainable society without a sustainable productive environment that provides the base for resources. Similarly, a sustainable economic system is also dependent on the sustainable flow of energy, material, and environmental resources. Hence, a sustainable environment can stand alone as a sustainable system and is not dependent on social or economic systems. While humans are completely dependent on the flow of ecosystem services as:

1. Provisioning services: include food, fiber, water, biochemical, pharmaceutical, medicines, and energy resources.
2. Supporting services: include soil formation, photosynthesis, nutrient cycling, seed dispersal, hydrological cycle.
3. Regulating services: include water purification, waste treatment, regulation of air quality, disease, pest, erosion, water, pollination, climate, and natural hazards.

Cultural services: include all nonmaterial benefits obtained from the environment such as cognitive development, recreation, reflection, and esthetic values. (Khan, Nazish Huma, et al, 2021).

Environmental sustainability is a conservation concept which is the meeting of services and resources of present and future generations without affecting the health of the ecosystems that provide them. The principles for Strategy of environmental sustainability are given below as:

1. Biodiversity conservation: this is the preservation of biodiversity and energy resources.
2. Social needs: the availability of basic needs, products, and services for present and future generations. Support local employment, fair trade and environmental attributes of raw material.
3. Regenerative capacity: protect the depletion of natural resources and keep the harvest rate of renewable resources within the capacity of regeneration.
4. Reuse, recycling: support the reuse, recycling practices to reduce waste, emissions, and cost and improve product efficiency.
5. Limitations of nonrenewable resources and waste generation: the human economic system should be within the carrying capacity, the emissions should be within the assimilative capacity of the ecosystem, prioritize low-impact transportation, and effective decisions with consideration of environmental quality (Morelli, 2011).

c. Food Waste Management

Food waste management refers to the systematic approach and the strategies implemented to handle and redirect food and agricultural products for better purposes such as human consumption, animal feed, industrial application, and other environmental benefits. As the name implies, food waste is when edible food is thrown away, lost, or left uneaten while it is still valid for consumption. It includes many forms of waste such as food that is intentionally thrown away, expired food, kitchen trimmings, etc.

Significant amounts of food waste are generated in different stages including the primary production, distribution, and sale of food products, and the preparation and serving of food in commercial and domestic environments. While it may not be possible to completely eliminate food waste, the food

industry can highly reduce it and contribute to a more sustainable and responsible food system. A significant amount of unnecessary loss can be avoided with better management systems throughout the food supply chain.

The waste management hierarchy is an approach that focuses on prioritizing waste management practices with the goal to achieve sustainable waste management. It establishes the order of waste management options, from the most preferred to the least preferred one: prevention, minimization, reuse, recycling and disposal.

Figure 1: Waste Management Hierarchy
Source: https://pecb.com/article/waste-management-in-food-industry, 2023

Besides many other actions that can be taken, the simplest most preferable practice, and often the least costly option, is the prevention of waste at the source. A good example regarding food service establishments is reducing portion sizes at restaurants and cafeterias, this will consequently reduce the amount of food waste in this sector. If waste generation cannot be completely prevented, the next step is to minimize the amount of waste produced.

Reusing products or materials that are still in good condition is another preferred option. This can involve repairing, refurbishing, or repurposing items to extend their lifespan and avoid the need for new production. Recycling involves the processing of waste materials to create new products. It is an important method to recover valuable resources from waste. Various recycling technologies and processes are utilized to convert waste into raw materials for manufacturing. Lastly, despite the fact that it is the least preferable waste management option, disposal or landfilling is the option used when none of the above methods could be used. Food waste generated from leftover perished produce and spoiled food is the number one material taking up landfill space. Proper landfill management practices are essential to minimize environmental impacts. (Vlerë Hyseni, 2023).

d. Maggot (The Black Soldier Fly) Cultivation

Another potential useful species is the black soldier fly (BSF), *Hermetia illucens*. It is considered a non‐pest species native to North and South America ranging from 40 degrees north to 40 degrees south (McCallan 1974). The species is not considered a disease vector or a nuisance to humans (Furman et. al. 1959); however there have been reported cases of intestinal myiasis in humans (Lee et. al. 1995). Myiasis is the parasitic consumption of tissue by fly (Diptera: two‐winged) larvae. These reports appear limited to cases where infection occurred in equatorial zones. The likelihood of disease transfer from BSF to humans in a waste management facility is not known, but with the use of adequate personal

protective equipment, the incidence of such transfer is not expected to be significantly worse than current disease vectors present at a landfill.

The adult flies are not believed to congregate around human residences as a disease spreading organism (Furman et. al. 1959). This is mostly likely because studies suggest that the flies do not need to consume food during the adult phase of their life cycle (Sheppard et. al. 2002, Furman et. al. 1959) and this significantly reduces the opportunity to spread disease. Instead, the adults are pre-occupied with mating, egg-laying and when necessary, acquiring water.

The BSF has five stages in its lifecycle: egg, larvae, prepupal, pupae and adult. These are shown in Figure:

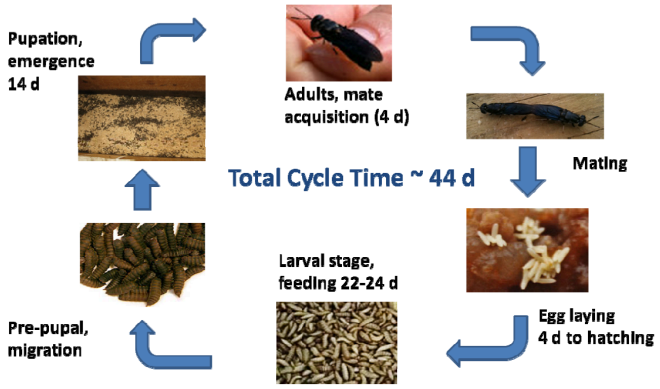

Figure 2: Maggot (Black Soldier Fly) Life Cycle
(Source: https://scholar.uwindsor.ca/etd/402/)

The larval stage is further divided into phases called *instars*. An instar is defined as the period between each moulting of their exoskeleton. The number of instar stages varies for different fly species: *Hermetia illucens* has five instar stages. All of the adult fly's nutritional requirements are obtained during its larval stage and adult flies survive on their fat reserves obtained as maggots. When this fat reserve is depleted the adult dies (Myers et. al. 2008).

The larvae have a wide ranging diet: they can consume animal feces, rotten and fresh flesh, fruits, restaurant waste, kitchen waste, cellulose and possibly a variety of other organic wastes (Nguyen 2010, Holmes 2010, Sheppard et. al. 2002, Tomberlin et. al 2002). They have been observed to consume restaurant waste left at 30oC for 3 weeks contaminated with mould. However, the maggots appeared lethargic after doing so based on observations in this research. (Luis, Alvarez, 2012).
Soldier flies, from egg to adult, have an estimated life cycle of 40 days but this length depends on the environmental conditions present and the rearing diet. Waste consumption rates appear to depend on the size of the maggot and the type of food being consumed (Diener et. al. 2009).

3. Research Method

In a non-empirical article, the discussion would center on the phenomena of waste repurposing in industrial facilities, particularly in areas that are not typically linked with food production. The article would investigate the broader sustainability difficulties confronting these non-food companies, where waste generation is frequently viewed as a disposal issue rather than an opportunity. A primary subject would be the potential for merging waste management and resource development through new

technologies such as closed-loop systems. These systems take a transformative approach, converting waste-such as food waste from employee canteens-into valuable resources like maggots for animal feed.

Key discussion would focus on the economic benefits of this method, notably in terms of reducing trash disposal costs while creating internal resources to offset operational expenses, such as removing the need to purchase commercial fish feed. The article would also emphasize the environmental benefits of reducing waste transported to landfills, which helps to reduce the facility's overall carbon footprint by reducing emissions connected with traditional waste disposal methods as well as the creation of external feed sources.

To address sustainability issues, the article could recommend a number of approaches. One of these is pushing industries to implement internal waste repurposing systems, which can convert waste into a resource within the facility itself. Furthermore, investing in technology that convert food waste into sustainable resources, such as maggots for animal feed, would be viewed as a significant step forward. Finally, fostering cooperation between waste management experts and industry managers is critical for developing specialized solutions customized to the specific needs of various businesses, assuring both environmental and economic sustainability.

4. Results and Discussion

In the context of this article, canteen food waste generated at the automotive spare parts manufacturing factory in Bekasi Regency is critical to the sustainability initiative. With a canteen that serves 3,500 employees daily, the facility generates a lot of organic waste from uneaten meals, kitchen trash, and food preparation residues. Traditionally, this waste would add to environmental and financial burdens due to trash disposal costs and the environmental impact of dumping organic waste in landfills, where it decomposes and emits greenhouse gasses such as methane.

According to the findings of monitoring canteen activities, the average amount of food waste recovered per week was 150 kg.

Figure 3 : Canteen Food Waste
(Source : Automotive Spare Part Manufacturing Factory Canteen in Bekasi Indonesia, 2024)

Instead of following traditional waste management techniques, the plant has repurposed this food waste as a source of maggot cultivation. The food waste is collected and fed to black soldier fly larvae, which develop into nutrient-rich maggots. These maggots are then caught and used as a sustainable feed for the decorative fish that roam the manufacturing grounds, essentially closing the waste-to-resources cycle. This novel use of food waste not only reduces the amount of waste transported

to landfills, but also removes the need to purchase external fish feed, making the waste management procedure both environmentally and economically beneficial to the institution.

As a first step in using food waste from the canteen, a modest non-permanent facility was erected to cultivate maggots within the factory.

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Figure 4 : Maggot Cultivate Facility Area
(Source: Automotive Spare Part Manufacturing Factory Maggot Facility in Bekasi Indonesia, 2024)

The second stage is to make the cage or box for maggot rearing from used wooden pallets, which are frequently used by the factory in their production activities.

Figure 5 : Maggot Cultivate Wooden Box
(Source: Automotive Spare Part Manufacturing Factory Maggot Facility in Bekasi Indonesia, 2024)

In several areas of the company include fish ponds that require care, one of which is the necessity for ornamental fish feed.

Figure 6 : Decorative Fish Ponds
(Source: Automotive Spare Part Manufacturing Factory Fish Ponds in Bekasi Indonesia, 2024)

The plant requires fish feed because of the facilities decorative fish, which are strategically positioned throughout the grounds to improve the working atmosphere. Traditionally, feeding these fish required purchasing commercial fish feed, which can be expensive and resource-intensive to create and deliver. The following is the monthly data on the overall required to purchase fish food.

Table 1: Monthly Fish Feeding Cost

No	Departemen	Per Month	Cost	
1	PGA	10 Kg	Rp	100,000.00
2	MCH R4	5 Kg	Rp	50,000.00
3	GDC	3 Kg	Rp	30,000.00
4	MCH R2	2 Kg	Rp	20,000.00
5	RECEIVING	2 Kg	Rp	20,000.00
6	DELIVERY	3 Kg	Rp	30,000.00
7	CASTING 1	5 Kg	Rp	50,000.00
8	CASTING 2	5 Kg	Rp	50,000.00
9	CASTING 3	5 Kg	Rp	50,000.00
10	PAINTING F2	5 Kg	Rp	50,000.00
11	PAINTING KCW	6 Kg	Rp	60,000.00
TOTAL		51 Kg	Rp	510,000.00

(Source: Automotive Spare Part Manufacturing in Bekasi Indonesia General Affair Internal Data, 2024).

As a result, food waste from the canteen was used to cultivate maggots with existing facilities.

Figure 6 : Maggot Cultivation
(Source: Automotive Spare Part Manufacturing Factory Maggot Cultivation in Bekasi Indonesia, 2024)

The harvesting phase of maggot cultivation is an important component in the closed-loop sustainability system. When the larvae are ready for harvest, the substrate is screened or sifted to gather them efficiently, reducing waste and increasing productivity. The gathered maggots are then rinsed to remove any remaining food waste, assuring their cleanliness and suitability for usage as feed. After cleaning, the maggots can be stored for immediate feeding to decorative fish or further processed as needed. This harvesting technique not only allows for the efficient use of food waste, but it also

underlines the necessity of preserving sanitation and quality throughout the maggot production cycle, adding to the overall sustainability of the closed-loop system.

Figure 7: Maggot Harvesting
(Source: Automotive Spare Part Manufacturing Factory Maggot Cultivation in Bekasi Indonesia, 2024)

Following the provision of suitable facilities and equipment, cultivation activities can begin. Starting in May 2024, canteen food waste was collected and sorted before being fed to maggots. Following several months of operation, data on the use of canteen food waste relative to harvest yields were as follows.

Table 2. Comparing the amount of canteen food waste and the harvest of maggot cultivation.

No	Activity	PIC	2024																			
			MAY				JUN				JUL				AGT				SEP			
			W1	W2	W3	W4	W1	W2	W3	W4	W1	W2	W3	W4	W1	W2	W3	W4	W1	W2	W3	W4
1	Food Waste	Farros	150 Kg	150 Kg	150 Kg	150 Kg	150 Kg	150 Kg	150 Kg	150 Kg	150 Kg	150 Kg	150 Kg	150 Kg	150 Kg	150 Kg	150 Kg	150 Kg	150 Kg	150 Kg	150 Kg	150 Kg
2	Maggot Harvesting	Farros		2 Kg		2 Kg		5 Kg		7 Kg		7 Kg		6 Kg		15 Kg		15 Kg		15 Kg		

(Source: Automotive Spare Part Manufacturing in Bekasi Indonesia General Affair Internal Data, 2024)

It was discovered that cultivation activities, which began in May 2024 with the harvest of maggot cultivation, exceeded the internal need for fish food by the second week of July 2024. These findings show that by July 2024, the usage of canteen food waste will be able to cover and even eliminate the expense of purchasing conventional decorative fish food.

5. Conclusion and Implications

The article makes a compelling case for implementing a closed-loop sustainability system in an automotive spare parts manufacturing facility in Bekasi, Indonesia, which would effectively convert a significant amount of canteen food waste into a valuable resource for maggot cultivation and fish feeding. The findings highlight the potential for creative waste management solutions to not only reduce the environmental implications of food waste, but also provide significant economic benefits by lowering dependency on commercially supplied fish feed. By successfully integrating waste management and resource production, the facility demonstrates that companies, including those unrelated to food production, may contribute to sustainability initiatives while boosting operating efficiency.

This article contributes to the expanding body of literature on non-food sustainability practices by emphasizing the link between waste management and resource development. It challenges prevailing paradigms that perceive these areas as distinct, giving a framework for understanding how closed-loop systems can be used effectively in a variety of industrial scenarios. This finding stimulates additional research into integrated waste management solutions, particularly in settings with large internal waste streams.

Also, the study provides useful information about the practical implementation of closed-loop sustainability systems. This article can help industrial facility managers understand the methods, challenges, and triumphs involved in repurposing trash into useful resources. Companies that invest in comparable efforts can not only improve their sustainability profiles, but also save money and boost employee morale by implementing ecologically responsible practices. This technique is consistent with corporate social responsibility (CSR) aims and can improve a company reputation among stakeholders.

Future study could build on this work by investigating the scalability of closed-loop systems in industries other than automotive spare parts manufacture. Furthermore, longitudinal studies examining the long-term environmental and economic implications of such efforts would provide further information about their success. Investigating the potential for technical breakthroughs in waste transformation processes, as well as the importance of employee participation in promoting sustainability initiatives, could help to improve our understanding of integrated waste management techniques. Finally, comparative examinations of firms that have and have not implemented closed-loop systems may reveal best practices and areas for improvement, enabling a more sustainable industrial landscape.

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