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Abstract. The development of the batik industry, especially in Yogyakarta, has not only a positive impact but also a negative impact. The process of making batik produces solid, liquid, and gas waste, pollution due to waste affects the environment and human health in the long term. Indonesia is one of the countries committed to the Sustainable Development Goals (SDGs), even the government realized it with the promulgation of Presidential Regulation of the Republic of Indonesia No.59/2017 concerning the Implementation of Achieving Sustainable Development Goals—research on Batik Akasia by applying eco-effectiveness with the descriptive-analytical method. Eco-effectiveness is a principle in green ergonomics related to dealing with environmental problems. Human factors and ergonomics could contribute to sustainable development. Green ergonomics, developed by Thatcher, emphasizes the reciprocal relationship between HFE (human factors and ergonomics) and nature. Green ergonomics examines how humans can preserve and restore natural systems and vice versa. Batik Akasia's use of some chemicals exceeds the usage limits for green industry standards. In dealing with environmental issues, Batik Akasia can optimize the use of natural dyes, and replace firewood with gas. The application of eco-effectiveness in Batik Akasia thus becomes an effort to achieve Goal 6 Clean Water and Adequate Sanitation and Goal 12 Responsible Consumption and Production in the Sustainable Development Goals.

Keywords: Eco-effectiveness, Green Ergonomics, Sustainable Developement.

1 Introduction

UNESCO officially recognizes batik as an intangible cultural heritage increasing interest in batik, so the batik industry is thriving in Indonesia [22]. The development of the batik industry, especially in Yogyakarta, has not only a positive impact but also a negative impact. Making batik produces industrial waste in solid, liquid, and gas waste, negatively impacting the environment [1]. Batik industry waste generally comes from wax splashes, residual dyeing water, and residual pelorodan water. Using dyes and chemicals as supporting materials, such as caustic soda, soda ash, sulfuric acid, nitrite, naphthol, indigosol, lime water, and citric acid [10]. Pollution due to batik industry waste not only causes environmental damage but will interfere with human health if it occurs in the long term.

Indonesia is one of the countries committed to Sustainable Development Goals (SDGs), and even the government realized it with the promulgation of Presidential Regulation of the Republic of Indonesia No.59/2017 concerning the Implementation of

Achieving Sustainable Development Goals. One of the efforts in developing sustainable development is applying green ergonomics [14]. The principles of green ergonomics include eco-efficiency, eco-effectivity, and eco-productivity. Effectiveness in ergonomics refers to the ability of a system to achieve goals, while eco-effectiveness consists of the ecosystem in its achievement. Eco-effectiveness means examining a system's capacity to convert resources and energy without harming other systems [26]. At CV Batik Akasia, there needs to be more aware of waste management, including liquid, solid, and gas waste and energy use.

2 Batik

Batik comes from the Javanese word "amba," which means writing, and "tik" from the word dot, which refers to making a dot. The development of Batik in Indonesia can be seen from the use of Batik, which was initially only widely used by the palace circles. Now it has developed a lot in the community [18]. Batik is registered as a UNESCO intangible cultural heritage to protect cultural heritage by motivating people to understand the importance of Batik as a cultural heritage and as an Indonesian identity in foreign countries. It cannot be claimed by other countries [28].

Batik is defined as pictorial fabric by writing wax on a piece of fabric, the pattern produced by the wax is applied on the fabric to prevent the entry of dyes. Based on the making of batik, there are two ways: written and stamped. Written batik is done using canting; canting is a tool made of copper which is formed to accommodate wax by having an end in the form of a small channel to remove the wax and create it on the fabric. Meanwhile, stamped batik is done using a stamp which is a tool made of copper shaped according to the desired image, the stamp is usually 20x20 and has a handle [25]. Another difference between printed batik and written batik is the processing time, the process of working on written batik takes longer than printed batik. So the price of written batik is relatively higher than printed batik [30].

3 Green Ergonomics dan Eco-effectiveness

Achieving a better life for people is known as a main driving force and encourages us to focus on sustainability and ecological improvement; in long term action needs some effective procedures, and green ergonomics plays a critical role [21]. Green ergonomics is an ergonomics intervention focusing on nature, especially the relationship between humans and nature. Green ergonomics recognizes that the world is a closed system; if one system is disrupted, other systems will be affected. Green ergonomics studies a two-way relationship where humans affect the health of the natural environment. The green ergonomics approach focuses not only on nature, but also on social and economic issues. Green ergonomics includes the principles of eco-efficiency,

eco-effectiveness, and eco-productivity. In ergonomics, efficiency and effectiveness refer to the work system. In contrast, eco-efficiency, eco-effectiveness, and eco-productivity in green ergonomics refer to understanding how energy flows, nutrient cycles, and resource flows extend from the work system to the ecosystem [26, 27]. The explanation of each principle is as follows:

1. Green ergonomics recognizes that efficiency is important, but humans must expand their understanding of efficiency to include the cyclical flow of energy and other raw materials. Eco-efficiency can be achieved if the system requires the use of exergy or energy to maintain the system, realize the output and minimize energy or residual energy such as waste [27].
2. Eco-effectiveness in green ergonomics incorporates the wider ecosystem. Eco-effectiveness can only be achieved if energy flows consistently impact the ecosystem with no recovery. Eco-effectiveness examines the capacity of systems to transform energy, materials, resources, and information without wasting or causing harm to other systems. Eco-effectiveness also involves using appropriate materials and non-renewable energy, as well as using resources with rational use [27].
3. Productivity in ergonomics refers to the output of a product or service in a given period. Eco-productivity is extended through eco-effectiveness, in ergoecology the balance between inputs is considered in the long run. Eco-productivity is achieved when the system is in balance over a long enough period. McDonough and Braungart (2002), in their cradle-to-cradle philosophy suggest that a product should be designed as a biological element (which will quickly and efficiently return to the natural cycle) or a technical element (which is almost infinitely and efficiently recycled) [27].

According to McDonough & Braungart (2009), eco-effectiveness is a more comprehensive approach similar to that of natural systems and more helpful for achieving sustainability targets. Eco-effectiveness implies a situation where changes are improved to provide the same or even better results without negative environmental impacts and minimize company costs [7]. The steps for implementing eco-effectiveness are:

a) Free of

At this stage, the industry understands the impact of each material used on the environment and health. In the application of eco-effectiveness, a substitute for a substance known to be harmful is found, and the toxic substance is eliminated or replaced with a better one. Still, the substitute is certainly better than before [2].

b) Personal preferences

After eliminating unwanted substances, then choose the substances that will be included in the product. The industry must understand the substance to be used and how it will impact the environment, if the impact on the environment cannot be avoided, then the substance to be included is adjusted to the needs based on the best information.

Although the substances or raw materials used to adjust the requirements are not always effective for the environment, they should be better than the previous product [2].

c) The passive positive list

This step systematically assesses each ingredient or substance in the product to be classified according to its hazard characteristics and environmental impact. Criteria that should be examined include human and aquatic hazards. The assessment of the ingredient or chemical according to the classified criteria is used to determine the additional optimization required for a product. [2].

d) The active positive list

The fourth step involves the optimization of the classified ingredient list. While the previous step identifies the ingredients or substances that need to be optimized, this step implements the optimization to the maximum extent. This stage is said to be achieved if the substance or material used in the product is positively defined as non-hazardous [2].

e) Reinvention

This step discusses the ecological, social, and economic properties of substances or materials used to manufacture products. The reinvention of substances or materials in products can still meet customer needs, so customer desires are aligned between customers and the industry [2].

4 Sustainable Development

Sustainable development is a system of maintaining stability by balancing technology, economic, social, environmental, and technical support responsibilities without compromising future generations' needs [8]. Sustainable development is popularized as a concept based on three pillars of sustainability arranged in a balanced ecological, social, and economic pillar. The achievements required by the concept of sustainable development are :

1) Ecological sustainability: maintaining the quality of the environment needed for economic activities and quality of life, such as environmental protection, reducing emissions, rational use of natural resources, etc.
2) Social sustainability: preservation of community and cultural identity, respect for cultural, racial, and religious diversity, preservation of social values, rules and norms, and protection of human rights.
3) Economic sustainability: maintaining the natural, social, and human resources needed to achieve income and living standards.

The interrelationship between the three pillars is organized in a sustainability framework called the Triple Bottom, proposed by John Elkington (1994) [15]. The Sustainable Development Goals (SDGs) consist of 17 goals. The goals are again divided into four pillars, namely the pillars of social development, economic development, environmental development, legal development, and governance [29]. Sustainable

development goals, when linked to the batik industry, the batik industry produces liquid waste, which will have a negative impact. Waste awareness will create a batik industry through goal 6 related to Clean Water and Sanitation, and goal 12 related to Responsible consumption and Production [20].

5 Methodology

The research was conducted using the descriptive analytical research method, this method presents directly the nature between the researcher and the object of research by analyzing the thing of research to obtain in-depth data [24]. The data used are primary and secondary data, primary data obtained by conducting observations, interviews, and data related to the use of dyeing materials and supporting materials for the batik making process, as well as energy use. Secondary data is obtained from journals, books, and related articles. Data analysis was carried out with the eco-effectiveness approach.

6 Result and Discussion

6.1 Batik Making Process

Batik based on the method of making is divided into written batik, stamped batik, and a combination of written and stamped batik. Making batik generally begins with dicing, dyeing, and pelorodan. Mencanting is creating motifs on fabric using wax with a tool called canting. In stamped batik, the tool inscribes the wax as a stamp tool with a motif. The dyeing process in Batik Akasia is divided into synthetic dyes and natural dyes, with chemicals as supporting materials. Before the fabric goes through the dyeing process, the fabric is dipped in TRO. TRO is used to wet the fabric before dyeing. The following is Table 1. Substances and Supporting Materials for Synthetic Dyeing and Table 2. Substances and Supporting Materials for Natural Dyeing

Table 1. Substances and Supporting Materials for Synthetic Dyeing

No	Substances Name	Description
1	Naphthol	dyes
2	Napthol Salt	dyes
3	Indogosol	dyes
4	Remasol	dyes
5	Sodium Hydroxide/Caustic	Supporting Materials
6	Sodium Nitrite	Supporting Materials
7	HCL	Supporting Materials
8	Sodium Silicate/ Waterglass	Supporting Materials

Source: Batik Akasia

Table 2. Substances and Supporting Materials for Natural Dyeing

No	Substances Name	Description
1	Tingi Natural Color	dyes
2	Akasia Natural Color	dyes
3	Jalawe Natural Color	dyes
4	Indigofera Paste	dyes
5	Alum	Supporting Materials
6	Lime	Supporting Materials
7	Conifers	Supporting Materials

Source: Batik Akasia

The dyeing technique consists of two methods, namely dipping and coletan. Dyeing by dipping gives color to the material that has been provided wax by dipping, while coletan provides color to the fabric by brush or dicoletkan in certain parts. The fabric that has gone through the dyeing process is then dried in the sun by spreading the fabric and avoiding folds or bends. Color fixation is carried out for fabrics that have gone through the dyeing process. Color fixation aims to strengthen the dyeing results and not quickly fade. The shades of color stains on textiles also depend on the factors of duration, types, and mordanting techniques applied [19]. Here is the dose of dye and fixation

Table 3. Indigosol dyeing rate

No	Name	Amount	m^2
1	Indigosol Brown IRRD	12 gr	6 gr
2	Sodium Nitrite	24 gr	12 gr
3	Hot Water	500 ml	250 ml
4	Water	2500 ml	1250 ml

Source: Batik Akasia

Table 4. Remasol dyeing rate

No	Name	Amount	m^2
1	Remasol	40 gr	20 gr
2	Baking Soda	10 gr	5 gr
3	Paal	10 gr	5 gr
4	Water	1000 ml	500 ml

Source: Batik Akasia

Table 5. Indigosol fixation rate

No	Name	Amount	m^2
1	HCl	15 ml	7,5 ml
2	Sodium Nitrite	15 gr	7,5 ml
3	Water	1000 ml	500 ml

Source: Batik Akasia

Table 6. Remasol fixation rate

No	Name	Amount	m^2
1	Waterglass	1000 gr	500 gr
2	Costic	5 gr	2,5 gr
3	Ash Soda	10 gr	5 gr
4	Water	250 ml	125 ml

Source: Batik Akasia

The fabric has been colored and has gone through the fixation process, the next process is pelorodan, which removes wax from the fabric. Pelorodan is done by boiling the fabric in water mixed with soda ash to remove wax. The fabric is then rinsed using clean water and repeat until there's no wax attached.

6.2 Eco-effectiveness

The increase in the batik industry in Yogyakarta has resulted in negative impacts in the form of environmental problems. The batik making process produces solid, liquid, and gas waste. It is estimated that water use in the batik making process averages approximately 25-50m2 [18]. The solid waste generated from the batik making process comes from the splattered wax during the dicanting and stamping process. Liquid waste is generated during the dyeing and pelorodan process, clean water is contaminated by the chemicals and dyes used. Liquid waste has high characteristics of temperature, acidity, Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), and Total Suspended Solid (TSS), causing the dissolved oxygen content in water to decrease and kill organisms [18]. If wastewater is discharged without treatment, it will cause pollution of aquatic ecosystems. In addition, water used daily for the batik making process reaches 50 liters/day.

Waste gas from the batik-making process comes from burning firewood to do pelorodan. The staining process at Batik Akasia uses firewood and is in the same area as other activities. Exposure to smoke from burning firewood affects the environment and the health of workers who are still in the same place.

Humans and nature have a needy relationship, with natural systems providing resources that support human well-being and health. Meanwhile, humans need conservation ethics to ensure the preservation and restoration of the natural environment. In this case, green ergonomics ensures the relationship between biological systems and human well-being. Green ergonomics involves eco-efficiency, eco-effectiveness, and eco-productivity [26]. Eco-effectiveness is a principle in green ergonomics related to dealing with environmental problems. In implementing eco-effectiveness, Braungart and McDonough have defined a stepwise strategy to achieve the following:

1. Step 1 : *Free of*

The first step to implementing eco-effectiveness is to find a substitute for the toxic substance. However, substance replacement is only required if the replacement substance is better than the substance to be replaced. In the batik industry, chemicals

support the batik making process. The following is Table 7. Substances and Supporting Materials and Hazardous Impacts

Table 7. Substances and Supporting Materials and Hazardous Impacts

No	Name	Description	Impacts
1	Naphthol	Synthetic Dyes	Skin Irritation
2	Naphthol Salt	Synthetic Dyes	Skin Irritation
3	Indigosol	Synthetic Dyes	Skin Irritation
4	Remasol	Synthetic Dyes	Skin Irritation
5	Sodium Hydroxide/ Caustic	Synthetic Dyes Support Materials	Skin Irritation
6	Sodium Nitrite	Synthetic Dyes Support Materials	Skin Irritation
7	HCl	Synthetic Dyes Support Materials	Skin Irritation
8	Sodium Silicate/ Waterglass	Synthetic Dyes Support Materials	Skin Irritation
9	Alum	Natural Dyes Support Materials	Skin Irritation
10	Arbor	Natural Dyes Support Materials	Skin Irritation
11	Lime	Natural Dyes Support Materials	Skin Irritation
12	TRO	Wetting Substance	Skin Irritation
13	Chlorine	Waste Purifier	Skin Irritation

Source: Dewi Lusyana Sari [3]

Batik Akasia produces batik with natural dyeing, which can be one of the efforts to replace synthetic dyeing as a form of eco-effectiveness. The production of batik with natural dye is less than synthetic dyeing batik because the variety of natural colors is less than synthetic dyeing. Synthetic dyeing and other supporting materials can still be used with a note of use in quantities below the rules set by Government Regulation No. 39/2019 concerning Green Industry Standards for the Batik Industry. The following is Table 8. Limitation of the Use of Dyes and Supporting Materials for Green Industry

Table 8. Limitation of the Use of Dyes and Supporting Materials for Green Industry

No	Name	Limit Value
1	Indigosol (Dark Color)	2,4 gr/m^2
2	Nitrite (Dark Color)	4,8 gr/m^2
3	HCl (Dark Color)	6 cc/m^2
4	Indigosol (Light Color)	1,2 gr/m^2

No	Name	Limit Value
5	Nitrite (Light Color)	2,4 gr/m^2
6	HCl (Light Color)	3 cc/m^2
7	Remasol (Dark Color)	16 gr/m^2
8	Caustic (Dark Color)	2 gr/m^2
10	Ash Soda(Dark Color)	4 gr/m^2
11	Waterglass (Dark Color)	400 gr/m^2
12	Remasol (Light Color)	8 gr/m^2
13	Caustic (Light Color)	1 gr/m^2
15	Ash Soda (Light Color)	2 gr/m^2
16	Waterglass (Light Color)	200 gr/m^2

Source: Permenperin Nomor 39 Tahun 2019 [16]

Based on the above limitations, Batik Akasia in some chemicals exceeds the use limit for green industry standards. The amount used in indigosol and remasol dyeing and fixation by Batik Akasia exceeds the limit, dyes and supporting materials that exceed the limit are Indigosol, Sodium Nitrite, HCl, Remasol, Waterglass, Caustic, and Soda Ash. The use of dyes and supporting materials is optional to be replaced, if the replacement is not better than what has been used. However, use exceeding the limit and long-term exposure to dyes and supporting materials will interfere with health, especially skin health, and also impact the environment.

Not only focusing on the dyeing process, but the identification of hazardous substances is also seen from canting and pelorodan. In the process of dicanting, the waste produced is the solid waste from the liquid wax that falls when dicanting or stamping. Wax is the primary substance or material in the batik making process, it cannot be replaced with anything else. The effort is to reprocess the scattered wax with the condition that the wax can still be reprocessed, thereby reducing waste and environmental impact.

Pelorodan is the process of removing wax by boiling the fabric in a container. The Pelorodan process is still traditional by using firewood; in terms of cost, it is relatively cheaper. However, the smoke generated from the burning process disturbs the comfort and health of workers still in the same area as the pelorodan process. Not only does the smoke affect humans, but it also affects the environment. Firewood used for the pelorodan process can be replaced with gas, in terms of cost, a long pelorodan process will require a large amount of gas so the price will be relatively more expensive. However, it does not produce burning smoke that will disturb human comfort and health, and the environmental impact is not more dangerous than the smoke from burning firewood.

2. Step 2: Personal preferences

The second stage starts with choosing substances to replace with better ones, but still according to needs and desires. It is identifying the substance or material and its impact on ecological and human systems.

Orders for synthetic color batik cap dominate sales of Batik Akasia products, consumers prefer synthetic color batik cap because it is relatively cheaper and fast processing. In promoting its products, Batik Akasia emphasizes that the featured product is the natural color batik. The dyeing process with natural colors is not entirely natural, but using chemicals in natural dyeing is less than synthetic dyeing. Natural dyeing not only reduces the impact on the environment, but also on human health in the long run. Natural dyes are an alternative in considering the environmental impact of dyes compared to synthetic dyes [30].

Wax, which is the primary substance, is not found to be an appropriate substitute, efforts are made to protect the environment by reprocessing wax waste. The quality of the reprocessed wax is similar to the wax obtained from the wax manufacturer. The reprocessing of wax not only reduces solid waste, but also reduces the cost of purchasing wax. Unlike wax, for which no substitute can be found, firewood as a supporting material can be replaced with gas. The smoke from burning firewood that becomes waste gas pollutes and disrupts human health, especially breathing. The use of gas minimizes the impact on the environment.

3. Step 3: The passive positive list

In this stage, each substance or ingredient used in the product is assessed and classified according to the hazard level to the environment or humans. The assessment is done for additional optimization required for a product.

The impact of the batik-making process on human health is dominated by skin irritation and respiratory problems. Skin irritation is caused by continuous exposure to chemicals during the dyeing and dyeing process. Meanwhile, respiratory issues are caused by smoke from wax heating and when burning firewood used for pelorodan. The impact on the environment from the batik making process is the solid waste from wax, liquid waste which pollutes the surrounding water from the dyeing and pelorodan process, and gas waste in the form of carbon dioxide from burning firewood. The classification results are used to perform additional optimization required in the batik making process. Substances or materials that need to be optimized include wax, natural dyes and supporting materials for the natural dyeing process, and the use of gas. Natural dye derives from using natural resources from the surrounding by involving the extraction, and mordanting process applied [8].

4. Step 4 : The active positive list

This stage is advanced, in the third stage, knowing the substances or materials that need to be optimized, then in the fourth stage implementing optimization. Reprocessing wax can be a form of optimizing the use of wax without disturbing the environment. Substances and materials that can be optimized for use are natural dyes. In the natural dyeing process, chemicals are still used as supporting materials for the dyeing process. Using natural dye is considered the best strategy to achieve an environmentally friendly

industry the aim of [5]. Optimizing the use of gas will also have a significant effect on the environment, the environment will be free from smoke from combustion.

5. Reinvention

The fifth stage re-engages the product and customer relationship by addressing ecological, social, and economic properties. The reinvention strategy views the product from the perspective of the service it provides and the needs it fulfills for the customer. One of the advantages of such a system from the customer's perspective is that the customer is no longer faced with the responsibility of potential hazards contained in the product, and the customer's interests are aligned with the industry providers.

Batik Akasia provides products in the form of printed and written batik with natural and synthetic colors. Batik Akasia provides batik products, and customers who buy batik as product users. In the concept of reinvention, Batik Akasia can make products that not only have a negative impact, but can also have a positive impact. Natural dyes are limited in color variation, this can be pursued by finding plants or fruits that produce the colors needed. Using gas as a substitute for firewood in the pelorodan process reduces the environmental impact.

The use of natural dyes is one way to reduce pollution [17], this is proven by Martuti [11] who has explored natural dyes using plant and fruit parts. Water from making batik with natural dyes is biodegradable and safer for the environment. Optimizing dyes can be a recommendation to develop a sustainable batik industry, promote natural dye batik, and provide training on using natural dyes to other batik industries [5]. The treated wax can be used in batik making [12].

6.3 Eco-effectiveness dan Sustainable Development Goals

Environmental problems have become one of the main issues in various countries, evidenced by the World Environment Conference in Stockholm in 1972. Environmental problems are a concern for the world, including Indonesia. The United Nations (UN) in 215 provided a joint agreement for human peace and prosperity in the present and future, namely 17 Sustainable Development Goals (SDGs) [13]. The implementation of SDGs in Indonesia itself is regulated in the Presidential Regulation of the Republic of Indonesia No.59/2017. In implementing the achievement of SDGs goals, the government needs help to achieve it. Still, stakeholders who want to involve themselves in SDGs must understand the goals and targets of their respective roles.

The issue of batik coloring is due to the need for more awareness and implementation of synthetic batik dyes that impact the environment. Also, there still needs to be more information about natural dyes in the community regarding natural dyes and implementing green batik [8]. Therefore, the introduction of alternative material such as natural dyeing need to be referred to as one of the knowledge materials and biodegrade for a biological system, and technical nutrient tend to continually circulate and give valuable nutrient to vicinity communities and the environment (13). The wastewater from natural dyeing is biodegradable and provides biological nutrients towards the environment [9]

Ergonomics can contribute to sustainable development by designing sustainable work systems, designing sustainability-oriented products, and ergonomics help solve social problems [23]. Green ergonomics, developed by Thatcher, emphasizes the reciprocal relationship between HFE (human factors and ergonomics) and nature. Green ergonomics examines how humans can preserve and restore natural systems and vice versa. Humans can benefit from resources derived from nature. The principles in green ergonomics are eco-efficiency, eco-effectiveness, and eco-productivity [6].

Eco-effectiveness is a principle in green ergonomics related to the impact on the environment of a working system. The implication of using natural dyes leads to eco-effectiveness practices and drives awareness toward sustainable development [9]. The targets in Sustainable Development Goals to be achieved by the application of eco-effectiveness in Batik Akasia are Goal 6 Clean Water and Sanitation, which is to ensure the availability and sustainable management of clean water and sanitation for all and Goal 12 Responsible Consumption and Production, which is to ensure sustainable production and consumption patterns.

7 Conclusions

Eco-effectiveness is a principle in green ergonomics that deals with environmental problems. The problems at Batik Akasia related to the environment are the use of synthetic dyes and supporting materials that exceed the limits of green industry standards for the batik industry. The firewood used for the pelorodan process affects the environment and disrupts the health and comfort of other employees in the same area. The use of gas fuel can be a substitute for firewood; the smoke produced is not like burning firewood. Batik Akasia has batik with natural colors; the dyeing process with natural colors can be optimized because it dramatically reduces waste. Optimizing the use of natural dyes can be done by adding color variations and using the right mordant for natural dyeing fastness.

Green ergonomics is one of the efforts to realize sustainable development goals. The goals achieved by implementing eco-effectiveness are goal 6 related to ensuring the availability and sustainable management of clean water and sanitation for all, and goal 12 related to providing sustainable production and consumption patterns.

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