Research Article

Marine Waste Reduction in the European Union: The Potential of Bioplastic Policy

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Abstract

The accumulation of marine plastic waste represents a significant global environmental pollution issue. The European Union is a regional organisation that has implemented a marine plastic waste management strategy. This is due to the amount of waste on European beaches, which is dominated by about 50% of single-use plastics. The policy implemented by the European Union is to pay attention to the use of recyclable plastics including plastic processing strategies through the EU Plastic Strategy in 2018. Thus, this research aims to explain the EU's opportunity to implement bioplastics through single-use plastic policies that can reduce marine plastic waste. This research will be explained through analysis of the diffusion of innovation theory from Everett M. Rogers. Based on the implementation, the European Union can be a benchmark in plastic waste management to achieve a balance of sustainable development in the economic, environmental and social sectors. This is because the European Union has qualified policy development through the Single Use Plastic policy and the EU Policy Framework of Biobased, Biodegradable and Compostable Plastics.

Keywords: Bioplastics; European Union; Marine Plastic Waste; Single-Use Plastic

Introduction

Marine pollution caused by plastic waste has become one of the most pressing environmental issues in the world. A recent estimate shows that by 2030, around 53 million metric tons of plastic per year could enter the oceans; however, only about 20 percent is recycled and recovered. The majority of the remaining plastic waste is simply discarded (UNEP, 2021).

This unmanaged plastic waste pollutes marine ecosystems, endangers marine life, disrupts the food chain, and negatively impacts ocean-based economic sectors such as fisheries and tourism. The high intensity of plastic waste in the oceans has even led to phenomena such as the Great Pacific Garbage Patch, an accumulation zone of marine debris whose size exceeds that of several countries.

Global awareness of the importance of the blue economy is reflected in various initiatives adopted by countries and international organizations. The European Union (EU), as a pioneer in environmental policy, has integrated blue economy principles into its maritime and environmental policies. The EU publishes Directive (Eu) 2019/904 of the European Parliament and of the Council about regulation of single use plastic to reduce the impact of certain plastic products on the environment (EUR-Lex, 2019). The commitment of the EU for plastic waste management is also evident from the EU policy framework on biobased, biodegradable and compostable plastics (European Commission, 2022).

One strategic measure to address marine plastic waste is the development and implementation of biodegradable plastics, which are plastics that can naturally decompose through the action of microorganisms under specific environmental conditions. The use of this type of plastic is expected to reduce the accumulation of conventional plastic waste, which is difficult to degrade. Therefore, this study aims to analyze how the European Union implements biodegradable plastics as part of its efforts to tackle marine plastic waste. The focus of this research is not only on policy but also on the implementation aspects and challenges faced in applying environmentally friendly plastic technologies in EU maritime regions.

Literature Review

The Concept of Bioplastics

The utilization of plastic has become ingrained in daily activities, including the use of water bottles, coffee cups, shopping bags, and various other items. Conventionally, plastics are derived from petrochemical compounds such as Poly Ethylene Terephthalate (PET), Poly Butylene Terephthalate (PBT), Polypropylene (PP), Polystyrene (PS), and Polyvinyl Chloride (PVC). However, plastics produced from these chemical constituents are environmentally unfriendly due to their non-biodegradability, with an annual production exceeding 34 million tons. Out of the many types of plastics used, merely 7% undergo recycling, while the remaining 93% inevitably find their way to landfills or even marine environments. In response to this predicament, Bioplastics emerge as an alternative solution to conventional plastic use.

Bioplastics are a category of plastics derived from renewable sources that have a biodegradability nature. According to the findings of Manali Shah et al (2021), there exist three classifications of bioplastics: bio-based and biodegradable, fossil-based and biodegradable, and bio-based yet non-biodegradable. For further detail, the classification of plastics is described in the following table.

Table 1. Bioplastic Classification

	Bio-based	**Petroleum based**
Biodegradable	Bioplastic: Starch, Cellulose, Polyhydroxy alkanoate, Polylactic acid	Bioplastic: Polycaprolactone, Polybutylene succinate, Polybutylene adipate Terephthalate
Non-biodegradable	Bioplastic: Bio-polyethylene, Biopolypropylene	Conventional plastic: PVC, PET, PP, PBT, PS

Source: Shah et al., 2021

Bioplastics are typically derived from essential starches found in crops such as corn, potatoes, wheat, rice, barley, oats, and others. The management of bioplastics commences with the collection of raw materials, followed by extraction, refining, manufacturing, disposal, composting, and eventual reformation. This cycle makes bioplastics have a more sustainable life cycle compared to conventional plastic. The intricate phases of the bioplastic cycle are further explicated in the diagram below.

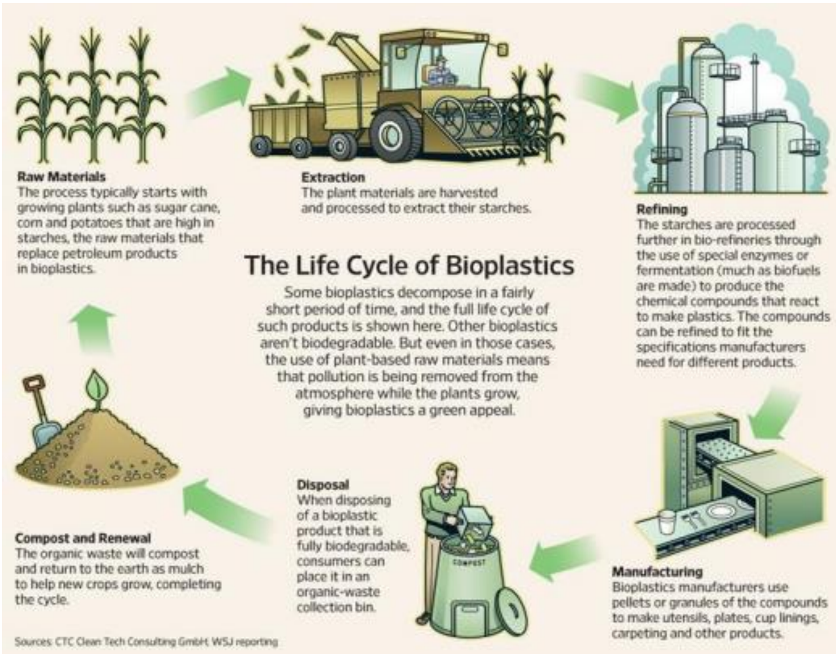

Figure 1. The Life Cycle of Bioplastics
Source: Pathak et al., 2014

According to Taofeeq D. Moshood et al.'s article titled "Biodegradable plastic applications towards sustainability: A recent innovation in the green product" (2022), the role of biodegradable-based bioplastics is said to be a sustainable solution. The solution offered by bioplastics indirectly addresses the massive issue of plastic waste at present. Bioplastics are often misunderstood due to the narrow definition that focuses solely on the source of bio-based plastics. However, environmentally friendly solutions extend beyond that, with the ideal bioplastic being based on biodegradability. Biodegradable plastics are easily decomposed by the activities of living organisms such as microbes in water. The application of biodegradable plastics can replace non-degradable plastics, resulting in several advantages, such as minimizing the pressure from reduced waste disposal availability and plastic pollution. Additionally, the use of biodegradable plastics can reduce greenhouse gas emissions (Moshood et al., 2022).

The use of bioplastics is also vital to achieve a sustainable economy. The issue of widespread plastic use not only impacts environmental damage but also affects economic growth. Ideally, sustainable economic activities should consider aspects of social justice and environmental sustainability. According to Jan-Georg Rosenboom et al. (2022) in their article titled "Bioplastics for circular economy," the classification of bioplastics applicable to a circular economy includes bio-based aliphatic (degradable) polyesters (PLA), bio-based aromatic (durable) polyesters (PEF), bio-based polyurethanes, bio-based polyolefins, fossil-derived biodegradable polymers, and various types of non-synthetic bioplastics, offering alternatives to conventional plastic use. Additionally, in the effort to achieve a circular economy, the use of bioplastics must be based on a life cycle assessment of the bioplastic itself. Assessments based on international standards such as ISO 14040 and EN 16760 can serve as references in implementing environmentally friendly bioplastic production. To achieve a circular economy for bioplastics, considerations should include end-of-life scenarios, recycling mechanisms, chemical recycling, biodegradation and composting, biological recycling, incineration, disposal sites, anaerobic digestion, industrial application and marketing of bioplastics, as well as policies and regulations to be considered in the use of bioplastics on both macro and micro scales (Rosenboom et al., 2022).

From the various literatures mentioned above, it can be seen that each has its own focus of discussion. The first literature explains the definition of bioplastics and its classification. The second literature suggests that bioplastics can be a solution to environmental issues. Meanwhile, the third literature provides a detailed explanation of bioplastics as a form of circular economy. However, none of these literatures delve into the specific details of how bioplastics are applied by international actors, such as regional organizations. Therefore, this research will focus on exploring the opportunities for implementing bioplastics at the regional level.

Diffusion of Innovation Theory

Diffusion of Innovation theory by Everett M. Rogers (1971) is a process of an innovation that communicated through certain channels over the time among the social system. There are four main elements such as innovation, communication channel, time, and social system.

Innovation

Innovation refers to an idea, practice, or object that is perceived as novel by individuals or other entities of adoption. The novelty of an innovation does not necessarily depend on the introduction of new knowledge. It is possible for someone to be aware of an innovation for a period of time without having formed a positive or negative attitude toward it, or without having made a decision to adopt or reject it. The element of "newness" in innovation can relate to one's awareness, the process of persuasion, or the decision-making stage regarding adoption. Innovations typically possess certain attributes, including relative advantage, compatibility, complexity, trialability, and observability.

a. Relative advantages refers to the extent to which an innovation is viewed as superior to the idea it replaces. While this advantage can be evaluated in terms of economic benefits, other factors such as social prestige, convenience, and user satisfaction also significantly influence perception. Innovations perceived to offer greater benefits are generally adopted more rapidly.
b. Compatibility denotes the extent to which an innovation aligns with the existing values, prior experiences, and needs of prospective users. Innovations that conflict with the cultural norms and values of a social group tend to experience slower adoption compared to those that are more aligned.
c. Complexity describes how difficult an innovation is perceived to be in terms of understanding and use. Innovations that are simple and easy to grasp are more likely to be adopted quickly, while those perceived as complex may face delays in acceptance.
d. Trialability pertains to the extent to which an innovation can be tested or experimented with on a limited scale. Innovations that allow for partial implementation or experimentation tend to be adopted more readily than those requiring full commitment from the outset.
e. Observability concerns the visibility of an innovation's outcomes to others. When the results are easily noticeable, potential adopters are more likely to be influenced and encouraged to adopt the innovation themselves.

Communication Channel

Communication is defined as the process by which individuals exchange and construct meaning with one another to achieve shared understanding. Diffusion represents a specific form of communication focused on the transmission of new ideas. It centers on the exchange of information where one party introduces an innovation to others. The diffusion process fundamentally involves four key elements: (a) the innovation itself, (b) a person or group with existing knowledge or experience of the innovation, (c) a person or group without such knowledge, and (d) a communication channel that links them. Communication channels serve as the medium through which messages are transmitted. The nature of the relationship between the information source and the receiver influences both the likelihood of transmission and the potential impact of the innovation being shared.

Time

Time plays a crucial role in the diffusion process. Unlike much of behavioral science research, which tends to overlook the temporal dimension, diffusion studies explicitly recognize its importance. Although time is inherently present in all forms of communication, it is often not directly addressed in general communication research. This may be due to its foundational nature, as time may not be reducible to more basic concepts. Rather than existing independently, time is intrinsically linked to and reflected in all human activities.

Social System

A social system refers to a collection of interconnected units that collaborate in addressing shared problems to achieve a collective goal. These units may include individuals, informal groups, organizations, or subsystems. In diffusion research, the social system under study might range from peasants in an Asian village, to high schools in Wisconsin, medical professionals within a hospital, or consumers across the United States. Each unit within the system is identifiable and distinct from others, yet all members participate—at least minimally—in efforts to resolve a common issue. It is this pursuit of a shared objective that unifies and sustains the system.

The four elements of innovation diffusion theory can be applied in analyzing policy implementation. This research elaborates on the European Union's policy on plastic waste management through the Single-Use Plastic Directive and how it relates to biodegradable plastic innovation in the European Union. If examined based on these four elements, the Single-Use Plastic Directive will be seen from what innovations are created from the policy, what communication channels are used to implement the policy, how the decision stage and the speed of distribution of the policy reach member countries, and what social systems play a role in the implementation of the policy seen from norms, the role of figures, and structures that overshadow the adoption of EU policies.

Methods

This article will employ qualitative research with case study design. Descriptive research aims to systematically and accurately examine the facts and elements of an issue or problem. Meanwhile, qualitative research aims to understand social issues or problems based on descriptions derived from words. Therefore, the qualitative descriptive method involves reviewing data from various secondary sources and interpreting this data using selected theories (Silalahi, 2006). This study examines the issue through the lens of Rogers' diffusion of innovation theory. By analyzing the policy through its four key elements, the Single-Use Plastic Directive is explored in terms of the innovation it introduces, the communication channels employed for its implementation, the decision-making process and the speed at which the policy spreads across member states, as well as the social system involved in its adoption—taking into account prevailing norms, influential actors, and the structural framework supporting the European Union policy implementation.

Result and Analysis

The EU has increasingly recognized the potential of bioplastics to address environmental concerns, reduce fossil resource dependence, and support climate neutrality goals by 2050. Over the past several years, the EU has initiated multiple legislative measures and funding programs to integrate bioplastics into its sustainability framework. These efforts aim to enhance bioplastic innovation, establish regulatory clarity, and promote responsible labelling and recycling. However, challenges remain in ensuring bioplastics reach their full potential in contributing to the circular economy and sustainable materials management.

Regulatory Conditions and Bioplastics Programs in EU

Since 2018, the EU has adopted a range of high-level strategies that reflect a growing policy focus on sustainable materials. In this context, this paper analyzes the implementation of bioplastics and biodegradable plastics policies within the EU, with the objective of promoting more sustainable alternatives to conventional plastics.

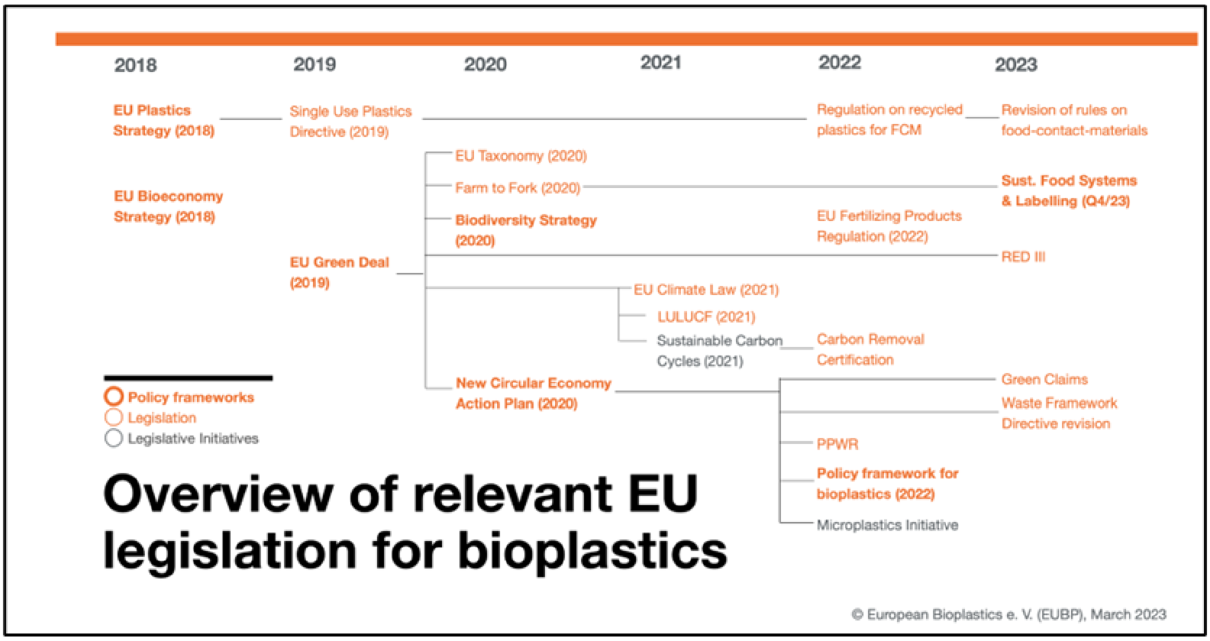

Figure 2. Overview of Relevant EU Legislation for Bioplastics
Sources: Europeans Bioplastics, 2018

As part of this broader effort, the Single-Use Plastics Directive, introduced in 2019, targeted a wide range of commonly used disposable plastic items including–cotton bud sticks, cutlery, plates, straws and stirrers, balloons and sticks for balloons, food containers, cups for beverages, beverage containers, cigarette butts, plastic bags, packets and wrappers, wet wipes and sanitary items.

For other single-use plastic products not explicitly banned, the EU has adopted additional measures aimed at limiting their environmental impact. These include (the European Union, 2024):

a. Promoting reduced consumption by implementing educational campaigns and awareness-raising initiatives.
b. Enhancing environmental sustainability through the introduction of product design standards aimed at improving ecological performance.
c. Mandating product labelling to provide consumers with information regarding plastic content and proper disposal practices.
d. Assigning waste management responsibilities to producers, including obligations for clean-up efforts and the enforcement of Extended Producer Responsibility (EPR) schemes.

These measures represent a preventative policy approach intended to enhance societal capacity to adapt to the restrictions and facilitate the effective implementation of the Single-Use Plastics Directive.

One key regulation in this regard is the Revision of Rules on Food Contact Materials (FCM), which underwent amendments in 2023 and will take effect on March 16, 2025 (SGS, 2025). These revisions reflect the EU's commitment to improving material safety standards while considering the environmental impact of packaging and food contact substances.

Additionally, the Packaging and Packaging Waste Regulation (PPWR), introduced in 2022, highlights the EU's efforts to improve packaging sustainability (European Bioplastics, 2022). Under the PPWR, specific packaging materials—such as tea bags, coffee filter pods and pads, and fruit stickers—are mandated to be compostable. These provisions establish foundational steps toward material recycling and reinforce the EU's dedication to reducing packaging waste. By implementing such regulations, policymakers aim to support investment, innovation, and job creation, ensuring that the transition toward sustainable materials aligns with broader economic and environmental objectives.

Recognizing the importance of funding in driving bioplastic advancements, the EU supported research and development through Horizon 2020, its research funding program from 2014 to 2020. With a budget of nearly €80 billion, Horizon 2020 provided crucial financial backing for projects focused on developing and scaling bioplastics. As part of these efforts, several bioplastic-related initiatives emerged has been mentioned by EU (European Commission, 2020), such as:

a. Converting side-streams from biorefineries into biodegradable polymers.
b. Developing 100% natural and biodegradable bio-based plastics for food packaging.
c. Producing custom bio-based polymers from plant sugar waste for fire-resistant applications.

By investing in these projects, the EU facilitated technological progress in bioplastics, reinforcing their potential as alternatives to conventional petroleum-based plastics. In parallel with regulatory efforts, the EU has implemented a policy framework to regulate the labelling of biodegradable and compostable plastics, ensuring clarity for consumers and industries. However, despite these advancements, the framework has faced criticism for failing to promote the key advantages of biobased plastics, which include reducing fossil dependency and lowering greenhouse gas (GHG) emissions.

The policy framework seeks to standardize the labelling of bioplastics to prevent misleading environmental claims. By providing clear definitions and applications, the EU aims to facilitate informed decision-making regarding compostability, biodegradability, and recyclability. Establishing proper disposal methods and ensuring the effectiveness of recycling infrastructure remain key priorities for policymakers.

At the local level, the implementation of sustainable plastic product management is commonly categorized into five key options–reuse, mechanical recycling, chemical recycling, organic recycling, and energy recovery (Figure 3). Among these, reuse holds the highest position in the EU waste hierarchy, offering significant opportunities for the development and promotion of reusable products. The importance of reuse is explicitly emphasized in the PPWP, which identifies it as a central strategy in the EU's broader efforts to enhance sustainability.

The remaining options—mechanical recycling, chemical recycling, organic recycling, and energy recovery—are increasingly recognized as complementary solutions. However, their successful implementation requires continued advancements in technological infrastructure, material science, and waste management systems. Bridging existing knowledge gaps and investing in innovation are essential to ensuring these methods can effectively support the EU's transition toward a circular economy.

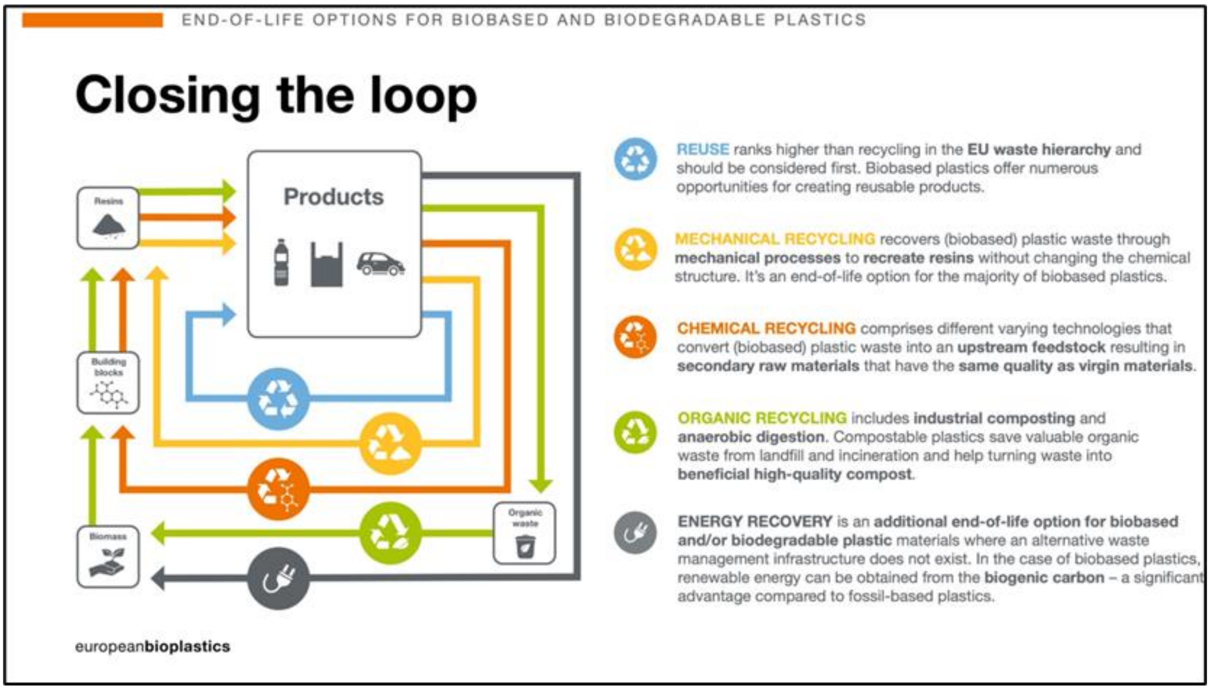

Figure 3. End of Life Options for Biobased and Biodegradable Plastics
Sources: European Bioplastics, 2022

On a global scale, bioplastics present a viable tool to help the EU achieve its climate neutrality target by 2050. By fostering the transition away from fossil-based plastics, bioplastics contribute to carbon footprint reduction and sustainable material development. The EU's commitment to climate neutrality aligns with its policies supporting investment in sustainable technologies and strengthening the circular economy.

Beyond regulatory enforcement, policymakers must clearly articulate a vision for bioplastics integration across industries. The success of bioplastics depends on effective recycling programs, improved infrastructure, and cross-sector collaboration. Moving forward, continuous refinement of policies will be necessary to bridge gaps between environmental objectives, market adoption, and regulatory compliance.

While significant progress has been made, challenges persist in scaling up bioplastics production, optimizing recycling systems, and ensuring long-term investment viability. Industry stakeholders highlight the need for greater incentives to accelerate innovation and commercialization. Additionally, bioplastics must be integrated seamlessly into established sustainability frameworks, guaranteeing that they align with broader waste management strategies.

To solidify its leadership in bioplastics innovation, the EU must continue refining policies to enhance recycling efficiency, investment attractiveness, and job creation. Addressing existing barriers will be essential in ensuring that bioplastics emerge as a cornerstone of Europe's commitment to environmental sustainability and circular economic principles.

To consolidate its leadership in bioplastics innovation, the EU must continue to refine and adapt its policy framework with a focus on enhancing recycling efficiency, improving investment attractiveness, and fostering job creation within the green economy. Overcoming existing technical, regulatory, and economic barriers will be critical to ensure that bioplastics can fulfil their potential as a foundational element of the EU's long-term strategy for environmental sustainability and the transition toward a circular economy.

In parallel, bioplastics innovation is facilitating the localization of the Single-Use Plastics (SUP) Directive across EU Member States. National-level implementation efforts are increasingly shaped by the availability and scalability of bioplastic alternatives, enabling more context-specific approaches to phasing out conventional plastics. This decentralized adaptation process not only supports compliance with EU-wide regulations but also encourages innovation at the regional level, fostering alignment between environmental objectives and local economic development.

Implementation of the SUP Directive Across Europe

Table 1. Analysis of the Diffusion of Innovations Theory by Everett M. Rogers

Rogers' Elements	**Implementation**
Innovation	Regulation banning Single-Use plastic in the European Union
Relative Advantage	To prevent and reduce the impact of plastic on the environment, especially the marine environment, and on human health. To promote the EU's transition to a circular economy which will also contribute to the efficient functioning of the internal market.
Communication Channel	National public awareness campaigns Mandatory product labeling Digital engagement Educational initiatives Extended Producer Responsibility (EPR) schemes
Time Period	Formally adopted in July 2019 and the latest implementation report was published in September 2022.
Adopter Categories	Correct Implementation of the Single-Use Plastics Directive in the EU by 2022: Cyprus, Denmark, France, Greece, Latvia, Luxembourg, Portugal, Slovenia, and Sweden. Implementation underway or incomplete: Austria, Belgium, Czech Republic, Estonia, Germany, Ireland, Italy, Lithuania, Malta, Netherlands, and Spain. No implementation or incorrect implementation: Bulgaria, Croatia, Finland, Hungary, Poland, Romania, and Slovakia.
Social System	Forming a norm that single-plastic use is no longer acceptable.

Source: Authors' Analysis

The following segment is an analysis of the implementation of the EU's Single-Use Plastics Directive based on the innovation diffusion theory by Everett M. Rogers. As detailed in the table above, the innovation of the EU to reduce marine plastic waste is through establishing a policy which bans single-use plastics. The advantage of this policy is that it will be able to prevent and reduce the impact of plastic on the environment, especially the marine environment, and on human health. In addition, this policy is able to promote the EU's transition to a circular economy which will also contribute to the efficient functioning of the internal market (European Commission, 2024).

According to the Single Use Plastics Directive Implementation Assessment Report: September 2022, EU member states employed several communication channels to carry out this policy. One primary tool was national public awareness campaigns, which aimed to inform both citizens and businesses about the environmental impacts of single-use plastics, promote reusable alternatives, and encourage correct disposal behavior. These campaigns were disseminated through various media, including television, print, online platforms, and public signage. However, their ambition and consistency varied significantly among member states.

Another means of communication was mandatory product labeling. Article 7 of the Directive requires clear, legible, and indelible labels on selected high-polluting items such as wet wipes, sanitary products, plastic-lined cups, and tobacco filters. These labels inform consumers about the presence of plastic in the product, appropriate disposal methods, and the consequences of environmental mismanagement, making them an effective communication tool to promote awareness.

Digital engagement also played a key role. Civil society organizations launched platforms like the Single-Use Rebellion (S.U.Re) campaign, allowing citizens to report non-compliant products still being sold. The collected data was then used to advocate for stronger enforcement by EU institutions. Educational initiatives were another vital communication channel. In countries like Romania and Spain, the Directive's goals were integrated into school programs, educating students about plastic pollution and sustainable alternatives. Lastly, some countries assigned awareness-raising responsibilities to plastic producers under extended producer responsibility (EPR) schemes. However, these industry-led campaigns often focused narrowly on anti-littering rather than promoting reduction or reuse of plastics (Copello et al., 2022).

The Directive (EU) 2019/904 on the reduction of the impact of certain plastic products on the environment was formally adopted by the EU in July 2019. EU member states were required to transpose it into national law by July 2021 (European Commission, 2024). Though most countries have implemented key parts of the Directive, especially the bans, there is a lack of full and consistent implementation across the member states. Furthermore, though this policy remains in place today, this paper shall only analyze the implementation until the year 2022 during which the Single-Use Plastics Directive Implementation Assessment Report was published.

Based on the innovation diffusion theory, the implementation of the policy by the EU's member states can be divided into three categories: 1) countries with correct implementation of the Single-Use Plastics Directive in the EU by 2022, 2) countries with implementation underway or incomplete, and 3) countries where there was no implementation or incorrect implementation. Among the countries in the European Union that correctly implemented the Single-Use Plastics Directive by 2022 were Cyprus, Denmark, France, Greece, Latvia, Luxembourg, Portugal, Slovenia, and Sweden. Meanwhile, most countries experienced big delays in implementing the directive. In January 2022, 16 states received a formal notice for lack of transposition; Belgium, Cyprus, Croatia, Czechia, Estonia, Finland, Ireland, Latvia, Lithuania, Luxemburg, Malta, Poland, Portugal, Slovakia, Slovenia and Spain. The Czech Republic missed the adoption deadline, the law coming to effect in October 2022. The Poland legislation was also slow in its process due to legislation bureaucracy (Copello et al., 2022).

Several member states adopted ambitious measures and have used the SUP Directive to handle plastic pollution in their countries. For instance, France established national reduction targets aiming for a 20% decrease in plastic packaging, the complete elimination of unnecessary single-use plastic packaging, and a 50% reduction in plastic bottles on the market by 2030. Similarly, Greece introduced national reduction goals of 30% by 2024 and 60% by 2026 for all single-use plastic beverage cups and food containers. Nevertheless, several member states failed to fully implement key provisions of the directive. Others either did not adopt all required measures or introduced measures that conflict with the Directive's stipulations. For instance, Romania and Italy altered the list of prohibited items and even proposed specific exemptions.

Based on the SUP Directive Implementation Assessment Report, it is reasonable to argue that a new social norm around single-use plastics (SUP) is emerging in the EU, though it is still in progress and varies across Member States. There is Spain's Waste Law, which began to charge cups for beverages and food containers and the prices would be visible to consumers on their receipts. Ireland has also put in place "latte levy tax" on single-use coffee cups within the Irish Circular Economy bill. The SUP Directive has not only spurred legal bans and regulatory frameworks but has also been accompanied by several communication channels. These efforts have aimed to influence consumer perception and behavior, especially by emphasizing the environmental harms of SUP and promoting reusable alternatives. Moreover, the report notes that some countries and regions have gone beyond the minimum requirements and adopted SUP reduction into national circular economy strategies. This reflects a norm shift towards plastics.

Unfortunately, assessing the impact of the Single-Use Plastics Directive (SUPD) on marine plastic waste in the EU remains challenging. A study by Kiessling et al (2023) involving a comparison of litter data before and after the policy was enacted shows no definitive reduction in banned items. This is not surprising, as environmental waste is unlikely to vanish within just six months of a regulation taking effect. Furthermore, the continued legal distribution of remaining stock means that such products are still in circulation and likely to end up as litter during the transition period. These factors make it difficult to attribute short-term changes in pollution levels directly to the SUPD.

Despite difficulties in calculating litter data, many estimation studies are optimistic that the SUPD remains the best solution to reduce marine plastic pollution. Scenario-based projections reinforce this optimism. In a "best case" scenario—assuming complete elimination of all SUPD-regulated items from the environment—litter levels in marine environments have a potential to drop by more than 40% overall, and plastic litter specifically could decline by as much as 46% to 81%. Although this scenario is admittedly unrealistic due to its assumption of total compliance, it underscores the significant potential impact of the SUPD if fully and effectively implemented. The directive addresses a substantial proportion of marine waste—between 42% and 58% of identifiable items—suggesting that targeted regulatory measures can be highly influential (Kiessling et al., 2023).

Challenges in the Implementation of Bioplastics to Reduce Marine Plastic Waste in the EU

Now we turn to the question of whether bioplastics can be a potential solution to reduce marine plastic waste in the European Union. The fact is, the SUPD does not see bioplastics as an adequate solution. All forms of bioplastics, if they are single-use plastics, are still banned by the SUP Directive. In fact, when the member state Italy made an exception from Article 5 pertaining to biodegradable and compostable plastic as long as it was in compliance with European standard UNI EN 13432, Italy was condemned to have breached the SUP Directive by allowing single-use biodegradable and compostable plastic (Copello et al., 2022).

The reason for this is because bioplastics in the European Union still face a complex set of challenges spanning environmental, economic, and regulatory domains that make it an inadequate solution to address marine plastic waste. Although presented as a sustainable alternative to fossil-based plastics, their actual environmental performance is mixed. Recent studies conducted in the EU have discovered that many bioplastics are chemically modified and do not degrade easily in natural environments, including marine settings, thereby contributing to persistent pollution. Moreover, their production often relies on food-based biomass, raising concerns about land use, food security, and water resource exploitation (Beghetto et al., 2023).

From a regulatory standpoint, the EU has struggled with the harmonized classification and labeling of bioplastics. Terms like "biobased," "biodegradable," and "compostable" are inconsistently used, leading to consumer confusion and improper disposal. The lack of standardized infrastructure for separate collection and treatment of bioplastics further exacerbates this issue, often resulting in contamination of existing recycling streams and higher operational costs for waste management systems. Moreover, EU and national legislations offer fragmented guidance—only a few explicitly define disposal pathways for biodegradable plastics, and many national source separation guidelines contradict legislative directives. Addressing these challenges requires harmonized regulations, improved consumer education, investments in sorting and processing infrastructure, and clearer product labeling. Without these, the promise of biodegradable plastics to contribute to sustainable development remains limited by systemic inefficiencies and policy gaps (Mhaddolkar et al., 2024).

Economically, bioplastics remain expensive to produce and often lack scalability. EU directives such as the Single-Use Plastics Directive (SUPD) and the Packaging and Packaging Waste Regulation (PPWR) impose strict limitations on both fossil and chemically modified biobased plastics, creating uncertainty for manufacturers. These policies, although environmentally motivated, may unintentionally disadvantage innovative materials and industries already transitioning to greener alternatives.

Conclusion

Human activities have increasingly demonstrated detrimental effects on the environment, particularly within marine ecosystems. A major contributing factor to environmental degradation is the excessive production and mismanagement of plastic waste. In response, the European Union introduced the Single-Use Plastic (SUP) policy as a measure to mitigate the accumulation of plastic debris in marine environments. One proposed alternative to conventional plastics is the use of bioplastics, which are promoted within the EU's broader policy framework on biobased, biodegradable, and compostable materials. This article analyzes the SUP policy through the lens of Everett M. Rogers' Diffusion of Innovations theory, examining key elements such as innovation, relative advantage, communication channels, time, adopter categories, and the social system. Several member states, such as Italy, have adopted the policy with context-specific adjustments. However, the findings reveal both progress and stagnation in the implementation process. Notably, bioplastics may not represent a viable long-term solution to marine plastic pollution due to challenges such as the uneven management of marine litter and the gradual pace of societal adaptation. Despite these limitations, the European Union continues to pursue a comprehensive and robust policy approach aimed at balancing environmental sustainability with economic and social development objectives.

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