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Abstract
Plastic pollution is rising as a global issue. Consequently, enormous amounts of plastic marine litter are observed worldwide ~~in the oceans~~. To tackle the issue on a European level, the European Commission introduced the Single-Use Plastic Directive in 2019, a directive specifically aimed at targeting the most frequently found plastic items located on European beaches. Norway implemented the directive in 2019 through membership in EEA. The Single-Use Plastic Directive introduces complete and partial product bans, informational measures informing the consumer of correct waste disposal methods and plastic content in the items, while also requiring the producer to cover all costs arising from single-use plastic waste. This Thesis assesses the effects of the Single-Use Plastic Directive on marine litter numbers in Norway through Norwegian beach litter data, particularly focusing on the externalities and inefficiencies arising from overconsumption of single-use plastics and the lack of responsibility commitment amongst agents in the market. Production and consumption data on single-use plastics in Norway are currently unavailable, making it impossible to conclude whether Norwegian marine litter numbers are affected by the directive or other market trends efforts. Nevertheless, a downward sloping trend is identified for almost all items covered by the directive through 2016 to 2022.

> *'Single-use plastic product' means a product that is made wholly or partly from plastic and that is not conceived, designed or placed on the market to accomplish, within its life span, multiple trips or rotations by being returned to a producer for refill or re-used for the same purpose for which it was conceived* [emphasis added]. (Directive (EU) 2019/904, 2019, Article 3, definition 2)

1 Introduction

1.1 Motivation

Environmental degradation and carbon emissions has emerged as a pressing issue with severe consequences for our planet. Plastic, once hailed as a revolutionary material for its versatility and convenience, has now become a major environmental challenge. Most plastic is manufactured from petroleum and is not degradable, lasting forever when placed in landfills or the oceans. In 2019, global plastic production reached a record high of 460 million tonnes (OECD, 2022a), and it is estimated that by 2050, there could be more plastic than fish in the ocean by weight (Ellen MacArthur Foundation, 2016).

The widespread use of plastic has led to alarming levels of pollution in our oceans, rivers, and land, causing detrimental impacts on ecosystems, wildlife, and human health. Plastic waste has been found in all corners of the planet, from the deepest oceans to the remotest areas. Wildlife, including marine animals, birds, and terrestrial species, often ingest or become entangled in plastic debris, leading to injuries, deaths, and disruption of ecosystems.

To address the issue, various countries and regions have implemented regulations and policies, such as the *Single-Use Plastic (SUP) Directive* introduced by the European Commission in 2019. The directive sets forth measures such as bans, restrictions, and extended producer responsibility schemes, with the goal of mitigating plastic pollution and transitioning towards a circular economy for plastics.

The EU alone generates approximately 53 million tonnes of plastic waste annually, with single-use plastic items, such as straws, cutlery, and disposable cups, being a significant portion of the waste stream (OECD, 2022b). These items are often used for just a few minutes but persist in the environment for centuries.

Plastic litter is also witnessed at Norwegian beaches, rivers and in the city landscape. Norwegian numbers on plastic litter reveal the magnitude of the issue. Numbers from *Grønt Punkt Norge* shows that only 19% of household plastic waste were recycled (Grønt Punkt Norge, 2023), while the rest is sent for incineration or to landfills. The issue has gained attention from policymakers, businesses, and communities, leading to efforts to reduce plastic pollution and promote sustainable waste management practices within the country. As a result, Norway implemented the SUP Directive through EEA in 2021(Stortinget [The Parliament], 2021).

The goal of this Master Thesis is to assess the effect of introducing environmental legislation in a country. Specifically, the effect from the SUP Directive in Norway. The Directive and its measurements will be thoroughly discussed in the context of economic theory. By evaluating the environmental and economic impacts of the SUP Directive in Norway, this thesis aims to contribute to the understanding of the effectiveness of such environmentally friendly policy measures in mitigating plastic pollution and promoting sustainable waste management practices.

1.2 Background

The global use of plastic has steadily increased since 1950, as shown in figure 1 (Handelens Miljøfond, n.d.). Plastic is a ubiquitous material in our daily lives. Its versatility, affordability, and convenience have revolutionized numerous industries, from packaging to healthcare. Its minimal weight has drastically reduced transportation costs, and its flexibility and durability have extended the shelf life of food, contributing to reduced food waste. Moreover, its disposability has played an important role in enhancing hygiene standards worldwide, especially in hospitals. Its importance is recognized by the SUP Directive, which still allows hospitals to continue using single-use plastic items that are subject to bans and consumption reduction measures (Directive (EU) 2019/904, 2019, ANNEX PART B, (1) & (4)). Consumption reduction measures will be further discussed in 2.5.1.

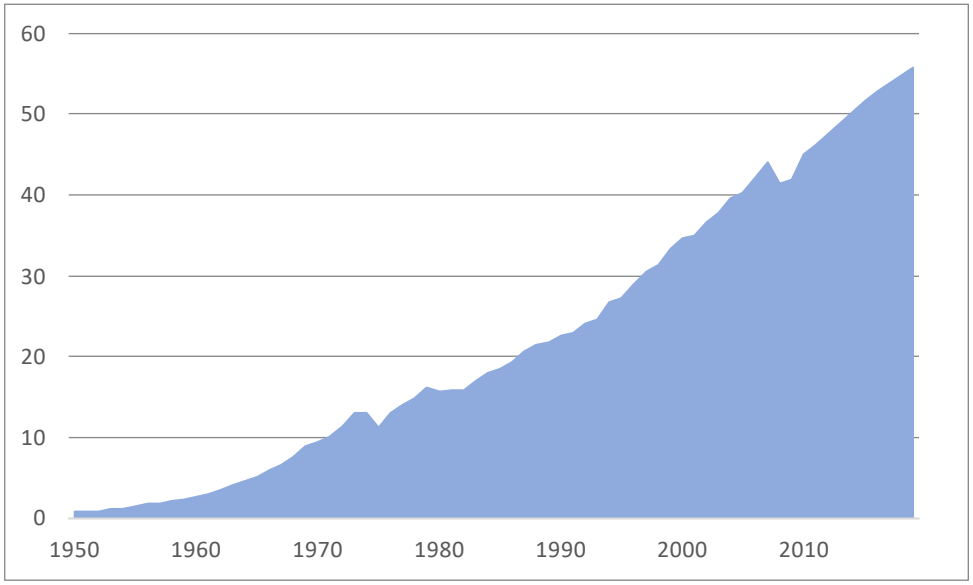

Figure 1 Timeline of global annual plastic consumption per capita. Based on numbers from (Handelens Miljøfond, n.d.)

However, the production of plastic is intrinsically linked to the extraction and refining of oil, further exacerbating our reliance on fossil fuels. While plastic has revolutionized industries, it is imperative that we acknowledge its detrimental environmental consequences. The non-degradable nature of plastic means that once created and misplaced in nature, it sticks around for a very long time. While recycling may seem like a solution, the reality is less optimistic. Plastics come in 7 different polymer types, Polyetylentereftalat (PET), High-density polyethylene (HDPE), Polyvinyl chloride (PVC), Low-density polyethylene (LDPE), Polypropylene (PP), Polystyrene (PS) and others, some which are not even recyclable (Abbasi et al., 2023).

All recyclable plastics – even the bottle you return in the Norwegian deposit system, are melted into plastic pellets. The process disrupts the plastic polymer chains, making them weaker each time. After 2 – 3 rounds of recycling, the chains are completely broken down, and the recycled plastic material ends up as microplastics. As a result, pure recycled plastic has poorer quality, compared to virgin plastics, and can only be recycled a set number of times.

Alongside with the increased volume of plastic consumption, the problems of plastic have been amplified. Mismanaged waste exacerbates the problem;

overflowing landfills and plastic-laden oceans bear witness to this negligence. Marine animals mistake plastic debris for food, ingesting it and suffering fatal consequences. Recent examples include the discovery of the Cuvier's Beaked Whale with 40 plastic bags in its stomach (now known as the "Plastic whale" at Sotra) (Lislevand, 2021), the Costa Rican turtle with a plastic straw through its nostril (Faltin, 2023), or the fact that 90% of the Norwegian bird "Havhest" has plastic in its stomach (Nerland et al., 2014). The pictures are disturbing.

Further, even tinier pieces of plastic, microplastics, have been found in waterways and ecosystems, causing pollution at a microscale, with far-reaching consequences for aquatic life and potentially our own health. By global media coverage and outrages on social media, the incidents visualize the true negative externalities of our plastic consumption.

1.2.1 Marine litter

Marine litter is a global issue, affecting all countries and nations worldwide. Large numbers of plastic marine litter are found everywhere on the earth, from the Arctics to remote island in the Pacific's. A survey conducted by the Tara Oceans Circumpolar Expedition found that hundreds of thousands of plastic pieces per square kilometer in the Atlantic region had travelled all the way from Europe and North America (Cózar et al., 2017). Plastic waste can travel enormous stretches, and unfortunately, the example is just one amongst many.

Projections from OECD Global Plastics Outlook shows that unless drastic actions are taken right now, plastic consumption will triple in size within the next forty years (OECD, 2022b). While plastic consumption continuously increases, one main category is driving mismanaged plastic waste numbers. Plastic packaging does and will continue to dominate the plastic market. Currently, packaging constitutes 40% of all consumed goods within the plastic market (Plastics Europe, 2023), and is expected to increase, as shown in figure 2.

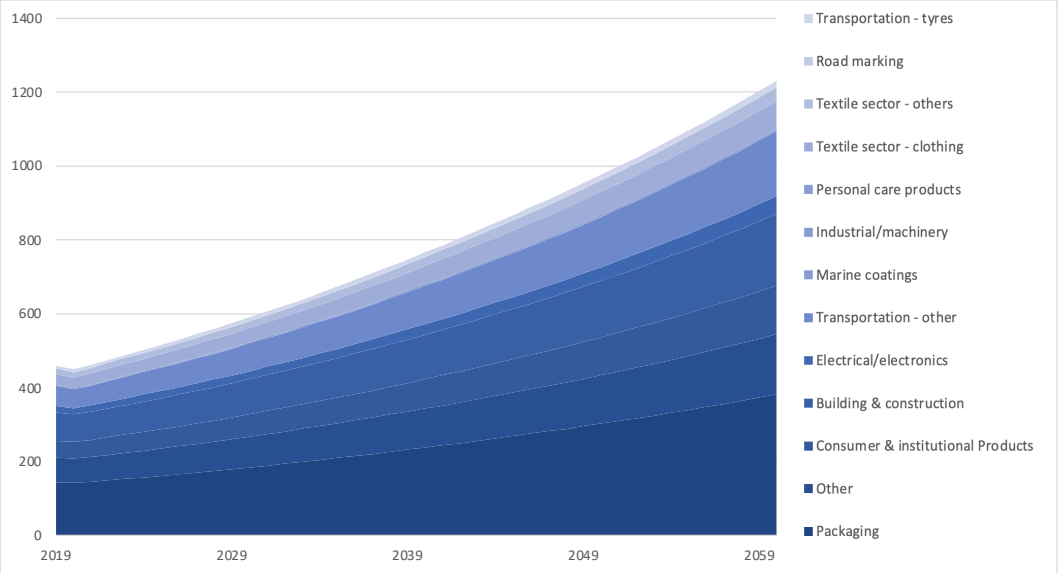

Figure 2 Plastic consumption projections by category (mega tonnes). Based on numbers from (OECD, 2022a).

While other categories also drive waste numbers, plastic packaging is generally linked to on-the-go consumption and a high risk of littering. In total, 99.55% of all plastic packaging becomes waste and will through different waste streams find its way to the marine environment (OECD, 2022a, 2022b). As plastic consumption is predicted to drastically increase throughout the next decade, it is important to study the main drivers of the marine plastic waste flows and accumulation.

A 2016 marine litter study shows that single-use plastics single-handedly covers approximately half of all littered items found on beaches in Europe (Addamo et al., 2017). These single-use plastic items are all targeted by the SUP Directive, which places restrictions on beverage containers, cups and lids, bottles, take away food containers, food packets and wrappers, cutlery, plates, straws, stirrers, sanitary towels, pads, tampons and applicators, wet wipes, cotton bud sticks, tobacco products with filters and filters, balloons and balloon sticks, lightweight plastic bags and all oxo-degradable products.

1.3 Research question

The SUP Directive aims at mitigating plastic marine litter on a global scale, and has introduced 7 distinct measures to combat the issue. As a directive newly adopted by Norway through EEA, it presents a valuable opportunity to explore the effectiveness of green policies, with Norway serving as a focal point for the analysis. Within this context, the primary research questions emerge:

1. *What is the current magnitude of single-use plastic littering in Norway?*

2. *Can we expect that the SUP Directive will successfully reduce marine litter in Norway?*

To address these critical questions, this Thesis will draw from economic theory, recent literature, data extracted from reports evaluating the SUP Directive's effectiveness, as well as data from Norwegian beach litter clean ups during the past 10 years.

It must be noted that while the SUP Directive addresses marine litter arising from both single-use plastics and fishing gear containing plastic, the scope of this Master Thesis will only cover single-use plastic items. A previous data analysis, Addamo et al. (2017) shows that while fishing-related plastic items represent around 15% of the total amount of plastic marine litter found on European beaches in 2016, single-use plastic items represented above three times the amount.

Further, the behavior of consumers within the two distinct markets varies greatly. While single-use plastics are littered due to poor infrastructure or faulty consumer behavior on the go, plastic fishing gear will mainly be littered due to heavy weather at the sea or destruction of fishing nets and ropes within the industry. Not only will the different waste streams vary greatly, but so will market characteristics and incentives targeting the arising problems. As a result, this Thesis will only focus on exploring the single-use plastic market, and the different waste streams within.

2 Framing the analysis

2.1 The Marine Litter issue in Norway

In 2020, SBB reported that Norway generated a total of 248.000 metric tonnes plastic packaging waste. Due to the short lifespan of plastics, the amount of plastic waste is assumed to equal the amount of plastic packaging put on the market (Berge et al., 2023.). Out of the total 248.000 tonnes plastic packaging waste generated, it is estimated that approximately 6% is recycled (Grønt Punkt Norge, 2022b), while 5% of the total litter stock in Norway ends up in the marine environment (Briedis et al., 2019). The majority of the marine waste originates from mismanaged plastic waste that either has been directly littered or is subject to poor infrastructure.

	Plastics	Percentage
Norwegian plastic waste	248000	
Sent to material recovery	151000	60.89%
Incineration	80000	32.26%
Landfill	13000	5.24%
Other disposal	4000	1.61%
Household plastic waste	61000	24.60%
Plastic sent for recycling	32330	13.04%
Recycled plastic	15372	6.20%
Recycled plastic sent to incineration	16958	6.84%
Incineration	16785	6.77%
Landfill	2661	1.07%
Litter	9224	3.72%
Collected litter	8301	3.35%
Uncollected litter	922	0.37%
Terrestial litter	461	0.19%
Marine litter	461	0.19%

Table 1 Norwegian waste numbers 2021. Based on numbers from (Berge et al., 2023; Briedis et al., 2019; Grønt Punkt Norge, 2022b).

2.2 The lifecycle of plastic

The life cycle of plastics can be divided into three stages. The first stage (Stage 1) is the production stage, which includes the process of product designs, extraction of raw materials, manufacturing and distribution to the consumers. The first stage is extremely energy and material heavy. Numbers from Plastic Europe shows that the greenhouse gasses from European plastic production is estimated to equal 140 metric tonnes, or 3% of all greenhouse gas emission within the EU (Plastics Europe, 2023).

The second stage (Stage 2) evolves around consumer consumption of the plastic products. Consumption patterns are particularly important, especially overconsumption, which is further exaggerated by the low prices and convenience of most plastic products.

In the final stage (Stage 3), we find plastic disposal, where disposal methods and waste stream are crucial in evaluating the total impact that plastic consumption and production has on the marine environment. I will discuss stage three and the different waste streams in more detail in section 2.3. While recycling will somewhat reduce the overall impact, littering and incineration of plastics will drastically increase it.

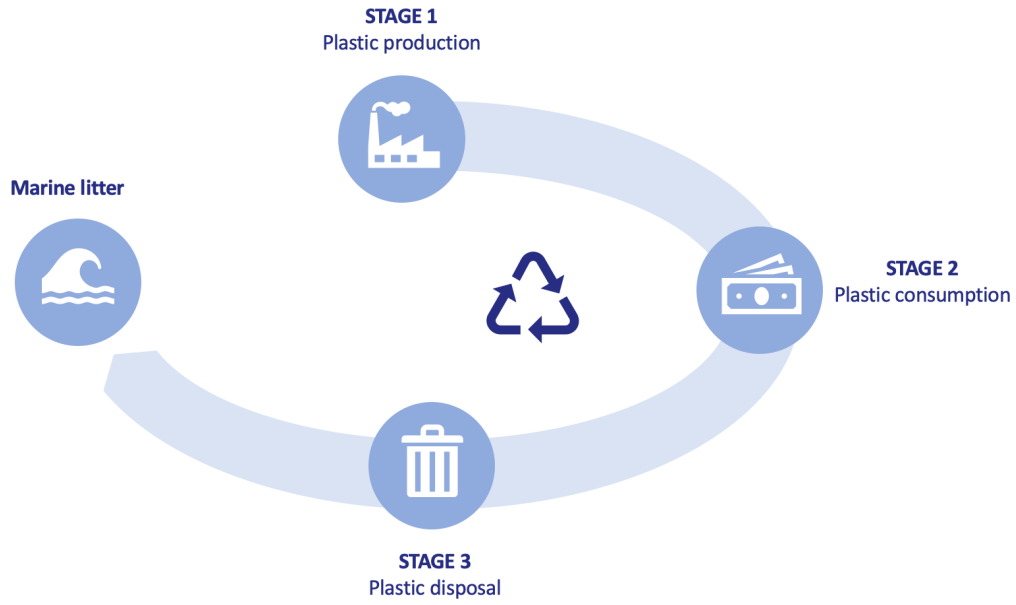

Figure 3 The lifecycle of plastic

2.3 Stage 3: Waste streams

There are mainly three waste streams driving litter numbers in Stage 3 of the single-use plastics lifecycle. These are recycling, disposal and littering. The streams and their path towards marine litter is shown in figure 4. While recycling will lead to some material recovery, waste is generated in every stage, regardless, as correct disposal does not imply circularity or complete recovery.

While the waste stream of correctly disposed plastics is rather straight forward, further explanation of the different waste streams of single-use plastic through recycling and littering will be explained below.

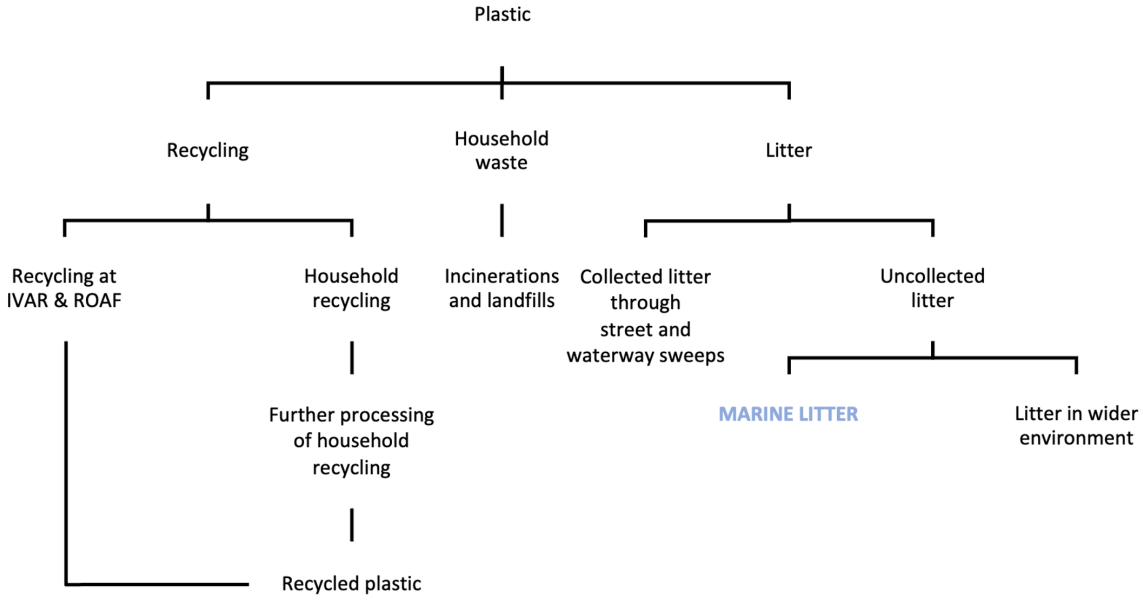

Figure 4 Plastic waste streams

2.3.1 Recycling

Plastic packaging is either recycled or disposed of with ordinary waste. In Norwegian municipalities where plastics should be disposed with ordinary household waste, plastics are later separated from household waste at IVAR and ROAF sorting plants. All household recycling is then sent for further processing to remove pollutants, and later to Germany where plastics are further processed and separated by polymer type and non-recyclables removed (Grønt Punkt Norge, n.d.b).

2.3.1.1 Polymer types

The seven different polymer types have different levels of recyclability. For example, PET-bottles are easily recyclable, especially through the Norwegian deposit scheme, where a total of 92.8 % PET-bottles are returned and recycled annually (Infinitum, 2023). However, plastics made from PS, such as foam cups, PVC and LDPE, have chemical and physical properties that makes recycling harder and less likely to occur. If a product contains several polymer types, it must be sorted as mixed plastic, and will have a lower quality after recycling. Further contamination of other non-plastic materials will decrease its chances of successful recycling additionally (Grønt Punkt Norge, 2022a).

Table 2 shows the different polymer types and their recyclability. The polymer type of a plastic item can easily be identified. A triangular recycling symbol can

be seen on all plastic items, and the number inside the triangle will tell what polymer the plastic item is constructed of.

	Polymer type	Recyclability	Typical products	Recycled waste	Percentage
	PET	Easy	Beverage bottles, beverage containers, condiment boxes, fleece	1628	7%
	HDPE	Easy	Detergent and soap bottles, furniture, toys	910	4%
	PVC	Recyclable	Roof covering, gutters, cables, flooring, pipes, windows	NA	NA
	LDPE	Recyclable	Plastic foil, shopping bags, bubble wrap	9516	41%
	PP	Recyclable	Bottle caps, straws, take away containers, butter and ice cream containers, sports clothes	1755	8%
	PS	Recyclable	Cups, take away boxes, single-use plastic cutlery, insulation	95	0%
	Other	Difficult	Multi use plastic products, carbon black plastic items, cheese and cold cut packaging, nylon	9176	40%

Table 2 Recyclability of plastic polymers. Based on numbers from (Antalis, 2022; Deloitte, 2019; Emballasjeforeningen, 2019; Grønt Punkt Norge, 2022a; PVC Forum Norge, 2018; Zaman & Newman, 2021)

2.3.1.2 Single-use plastics recycling

The minority of single-use plastics items can be properly recycled. Neither plastic cotton buds, balloons, balloon sticks, EPS-packaging, wet-wipes, cigarette filters, coffee cups with a plastic film, crisp packets, sweet wrappers, sanitary pads or tampons are recyclable (Grønt Punkt Norge, 2019; Sortere, n.d.b). In order to recycle a coffee cup, the plastic lining on the inside must be removed. While it is possible to separate the plastic film and paper, these machines do not exist in Norway, and paper coffee cups can therefore not be recycled with ordinary plastic packaging waste (Tingstad, n.d.).

Packaging made from EPS, for example take away boxes, is not suitable for recycling because the material contains a lot of air. EPS sticks to the recycling machine when melted, causing them to break. As a result, consumers are advised against recycling EPS together with plastic packaging waste (Sortere, n.d.b). Furthermore, crisp packets and sweet wrappers can only be recycled if they do not contain a coat or film made from other materials than plastic on the inside (Sortere, n.d.a). The film is usually there to ensure food safety and has been hard to get rid of. The linings can frequently be seen on the inside of coffee bags, crips packets or other food bags. However, the industry is taking action to improve the recyclability of plastic packaging. In 2019, *Sørlandschips* released their first chips bag constructed without an aluminum foil on the inside, and as a result, the bag is now recyclable for the first time (Grønt Punkt Norge, 2019).

Lightweight plastic carrier bags and other fast-food packaging can be recycled. Recycling of plastic straws, stirrers, cutlery, cigarette plastic packaging, sanitary packaging and tampon applicators is also possible, but due to their small size, recycling is less likely to occur. Sorting machines utilize air to ensure that the plastic items are sorted correctly, and as a result, the items will most likely fall through the sieve in the sorting plant due to their size and weight. Fragmented single-use plastics or lightweight items that are lost within the recycling system, will then get discarded with general waste. The same fate will be suffered by bottle caps not properly attached to the plastic bottle(Grønt Punkt Norge, n.d.b).

Furthermore, fast food packaging made from the color "Carbon Black", cannot be recycled due to limitations in the technology of existing sorting facilities, as the machines are not able to detect items of this color (Grønt Punkt Norge, 2017). This color can frequently be observed in microwavable food and sushi trays. Further use of dark and bright color may also deteriorate the quality of the recycled plastic. As a result, we see that despite the recycling efforts of consumers, insufficient technology and material choices in the design process means that full material recovery cannot be obtained. Simply because a product is recyclable, does not mean that it will or can be recycled.

2.3.2 Littering of single-use plastics

The majority of littered plastic items are single-use plastic items (Addamo et al., 2017, p. 36). Littered single-use plastic items have a source, a means of release and a transport mechanism. The different transport mechanisms are pictured in figure 5. Single-use plastic items are usually littered due to three reasons: the purchase of the item itself (source), faulty consumer behavior and/or the lack of proper infrastructure (means of release). While the purchase of single-use plastic items rarely is intentional, the low cost and absence of alternatives incentives the purchase. Due to the items short period of use, they are highly likely to be discarded of within a short period of time. While some consumers are highly aware on how to properly dispose of single-use plastic items, others are not, or do simply not care. A combination of the convenience of single-use plastic items, faulty consumer behavior and lack of proper infrastructure exacerbates the marine litter problem.

The path towards marine litter will vary from item to item. The majority of litter that ends up in the marine environment will be released through disposal in the sewage system, littering in urban or rural areas, beaches or directly into the marine environment (European Commission, 2018b, p. 11). However, items correctly disposed of in trash bins can also end up in the oceans. Overflowed trash cans filled to the brim allows wind and weather to lead the trash towards water ways. While trash collection frequency can be improved in areas with high pressure, the externality that stems from consumer behavior due to cultural norms and lack of awareness is harder to correct.

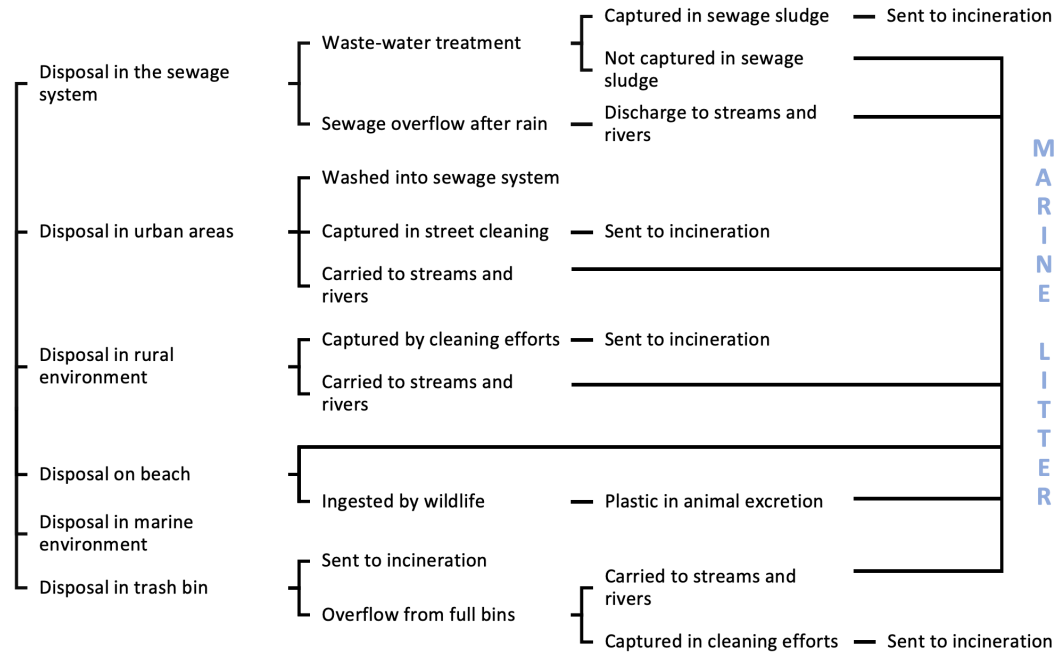

Figure 5 Marine litter transport mechanisms

While on the go consumption and convenience is the main driver for the initial purchase (source), food containers, drink cups, bottles, cutlery, straws, plates and lightweight plastic bags are mainly transferred to the marine environment through poor waste management (European Commission, 2018b, p. 25). The items might be correctly disposed of in a trash bin, but the lack of proper infrastructure in urban areas will lead the items on a path towards the marine environment, as overflowed trash bins will allow wind to carry the items away. In rural areas, overfilled trash bins, or the non-existence of trash cans, means that trash will be placed besides the bin or directly littered in nature. This is typical in recreational areas, beaches or tourist hotspots where trash collections are not conducted according to the required frequency. Full trash bins or the lack of available trash bins might lead to direct littering in the environment, and items will find its way towards the oceans through sewer systems, rivers or animal ingestion.

Cigarette butts, balloons and balloon sticks are on the other hand mostly littered due to faulty consumer behavior. The majority of cigarette butts are disposed of directly onto the streets or in the rural environment, where it is transported towards the ocean by rivers or sewer systems (European Commission, 2018b, p. 25). Furthermore, balloons and balloon sticks are usually left floating in the open air. When they break, they fall down and enter the environment, getting transported towards the ocean by rivers or wind. Due to the festive nature of the items, correct trash disposal might not be the first thought consumers have in mind.

The waste stream of sanitary single-use plastic items stands out. These items are usually not littered directly, but rather improperly disposed of in the sewer systems. Wet wipes, tampons, sanitary pads, tampons and cotton buds are all items frequently flushed down the toilet (Briedis et al., 2019, p. 44). Convenience, faulty consumer behavior and lack of proper infrastructure are the main drivers. However, consumers will choose to flush these items due to laziness or unawareness, even when the necessary infrastructure is in place. Items incorrectly disposed of through the sewer systems are captured in a sewage sludge, but small items like single-use plastics will easily escape and pass through. When heavy

rains occur, these items are discharged into the marine environment during sewer overflows.

2.3.3 Single-use plastics recycling and litter rates

Miljødirektoratet has estimated the recycling, litter and marine litter rates of single-use plastic items. Single-use plastic items in Norway have litter rates ranging from 15 – 0.5% of total consumption, where approximately 5% of all littered items will end up in the marine environment and become marine litter (Briedis et al., 2019, pp. 44 - 45). See table 3 for the estimates.

Initially, the numbers do not appear as big. However, by looking at consumption rates for certain single-use plastic items, the picture changes. While a total of 11.600 tonnes lightweight plastic bags are consumed annually in Norway, a litter rate of only 5% (marine litter rate of 0.25%) implies that a total of 29 tonnes lightweight plastic bags will enter the marine environment yearly (Briedis et al., 2019, p. 55). And this is only in within Norway. Multiplying the waste numbers by 46 European countries, leads to more than 1.000 tonnes of littered lightweight plastic bags entering the marine environment each year.

	Consumption volume (million items)	Recycling rate	Litter rate	Marine litter rate
Beverage bottles, caps and lids	632	87%	3%	0.2%
Cotton bud sticks	631	1%	7%	0.4%
Very lightweight plastic bag	263	38%	3%	0.2%
Balloon sticks	0.3	2%	2%	0.1%
Fast food packaging, plates and trays	137	5%	3%	0.2%
Beverage cups and lids	106	3%	6%	0.3%
Fast food packaging (EPS)	122	0%	3%	0.2%
Straws and stirrers	526	1%	1%	0.1%
Lightweight plastic bags	770	38%	5%	0.3%
Wet wipes	599	0%	3%	0.2%
Sweet wrappers	126	9%	3%	0.2%
Cutlery	455	1%	1%	0.1%
Drink cartons	1 361	56%	1%	0.1%
Sanitary towels, tampons and tampon applicators	478	0%	15%	0.8%

Table 3 Estimated litter, recycling and marine litter rates of single-use plastics. Based on numbers from (Briedis et al., 2019).

Different policy responses are required to tackle the waste problem related to single-use plastics. While the SUP Directive tries to correct faulty consumer behavior by placing information labels on items that frequently are incorrectly disposed of, and inform consumers of proper waste disposal methods, the overproduction and constant availability must be corrected by another measure.

The measures, and their effectiveness in correcting the externalities will be further discussed in section 4.

2.4 The Single-Use Plastic Directive

> *"The objectives of this Directive are to prevent and reduce the impact of certain plastic products on the environment, in particular the aquatic environment, and on human health, as well as to promote the transition to a circular economy with innovative and sustainable business models, products and materials, thus also contributing to the efficient functioning of the internal market* [emphasis added]. (Directive (EU) 2019/904, 2019, Article 1)"

The SUP Directive was implemented in the European Union on June 25, 2019 (Directive (EU) 2019/904, 2019). The directive is a part of EUs circular economy plan "Closing the loop – An EU action plan for the Circular Economy", an action plan introduced in the union in 2015 to promote a more circular economy where efforts were focused towards sustainability, low carbon emissions and resource efficiency (European Commission, 2015). Subsequently, in 2018, EU adopted a strategy primarily targeting plastics, the "Plastics Strategy", as a part of the action plan. It builds upon existing measures to reduce plastic waste, protect the environment, reduce marine litter, greenhouse gas emissions and the dependency on fossil fuels (European Commission, 2018a).

Through EU and EEA implementation, the SUP Directive was also introduced in Norway in 2019, (Directive (EU) 2019/904, 2019). However, the majority of the directive's requirements were not enforced until two years later, on July 3, 2021. The enforcement of certain provisions, such as the implementation of Extended Producer Responsibility (EPR) schemes and production requirements stated in Article 8 and Article 6.1, is scheduled for later stages, respectively 2023 and 2024 (Directive (EU) 2019/904, 2019, Article 17.1).

The main objective of the SUP Directive is to reduce the quantity of marine litter generated within the European Union. The directive focuses on promoting sustainable practices, giving priority to reusable products and reuse systems, as in accordance with the hierarchy of the Waste Directive (Directive (EU) 2019/904, 2019, (2)). According to the Waste Directive, prevention as a measure should be given the highest priority, followed by preparation for reuse, recycling and other recovery. Ultimately, disposal as a measure ranks the lowest (Directive 2008/98/EC, 2008, Article 4.1).

The SUP Directive specifically targets single-use plastic products intended for one-time use before disposal. However, as follows from the single-use plastics definition, products only need to contain some plastic to qualify as a single-use plastic product. One example is paper coffee cups, an item that usually contains a thin plastic lining on the inside to ensure warmth and safety (BASF, 2023). Because the product contains some plastic, it is categorized as a single-use plastic item by the SUP Directive and so are all other single-use items that contains some plastic but is primarily made of a non-plastic material.

Based on a 2016 European beach litter dataset, it is estimated that by focusing efforts on the top ten most commonly found single-use plastic items, the SUP Directive will cover approximately 86% of all the observed single-use plastic items in 2016 (European Comission, Directorate-General for Environment et al., 2018, p. 130). The items in question are drink bottles, caps and lids, cigarette

buds, cotton bud sticks, crisp packets and wrappers, sanitary applications, lightweight plastic bags, cutlery straws and stirrers, drink cups and lids and food containers. In addition, all oxo-degradable plastic items are included. A further explanation of oxo-degradable plastic and the issues related to the material can be found in section 4.1.1.3.5.

Products covered by the Directive are addressed by one or several measures, depending on availability of suitable and more sustainable alternatives, feasibility of changing consumption patterns, and the extent to which the products already are covered by existing legislation.

In total, there are 7 different measures introduced. These are:

1) Consumption reduction measures
2) Product bans
3) Design requirements
4) Marking requirements
5) Extended Producer Responsibility (EPR) schemes
6) Separate collection targets
7) Awareness raising measures

	Consumption reduction	Product ban	Design requirement	Marking requirement	EPR scheme	Collection target	Awareness raising
Plastic cups, incl covers and lids	x			x	x		x
Plastic take away food containers	x				x		x
Cotton bud sticks		x					
Plastic cutlery		x					
Plastic plates		x					
Plastic straws		x					
Plastic stirrers		x					
Plastic balloon sticks		x					
EPS takeaway food containers		x					
EPS beverage containers, incl caps and lids		x					
EPS cups, incl covers and lids		x					
Oxo-degradable plastic products		x					
Plastic beverage containers			x		x		x
Plastic beverage bottles, incl caps and lids			x			x	
Sanitary towels, tampons and applicators				x			x
Wet wipes				x	x		x
Tobacco products with filters and filters				x	x		x
Food packets and wrappers					x		x
Lightweight plastic bags					x		x
Balloons					x		x

Table 4 Measures introduced by the SUP Directive, (Directive (EU) 2019/904, 2019).

Each measure is covered by one article in the Directive, addressing the different stages within the life cycle of single-use plastic items. While certain items are completely banned, others are subject to consumption reduction measures. The

extended producer responsibility scheme requires producers to cover certain costs related to waste generation from single-use plastic items and the introduction of awareness raising measures. These measures are introduced to educate the population on the consequences of single-use plastic consumption, how waste can be avoided and other available options that are not single-use plastic. Further explanation of the articles follows below.

2.4.1 Article 4: Consumption reduction measures

Article 4 in the SUP Directive introduces a consumption reduction measure directly targeting stage 2 in the life cycle of plastic. The main goal is to reduce the consumption of plastic cups, covers and lids and plastic take away food containers. Because the items are deemed to be single-use items where no good multi use or non-plastic single-use alternatives are currently available, they are only targeted by a consumption reduction measure, and not a complete ban. This is done to avoid substitution towards items of a worse environmental impact (European Commission, 2022).

Countries are free to choose which consumption reduction measures they wish to implement, as long as a substantial decrease in consumption is achieved. To document the decrease, each country is obliged to yearly report the introduced measures, the number of plastic cups and take away food containers currently in the marked, and the consumption of such items. The number of items can be measured by count or weight of the items within each country but must be reported as a percentage change compared to 2022.

2.4.1.1 Consumption reduction measures in Norway

There are currently no officially introduced measures that single handedly targets consumption reductions of single-use plastic cups and takeaway food containers in Norway. However, other initiatives to reduce plastic production are encouraged within the private sector.

"Plastløftet" is one such plastic initiative from the private sector, where companies can "take the pledge" to increase the use of recycled plastic, avoid unnecessary use of plastic and design their items to improve recycling. Companies that are a part of the plastic pledge must report their numbers and results annually to *Grønt Punkt Norge*. *Grønt Punkt Norge* reports that companies a part of "Plastløftet" decreased their plastic production by 2 905 tonnes in 2022, while 3 888 tonnes of plastic packaging were replaced by other materials and 3 752 tonnes of plastic packaging were designed for better recycling due to design improvements (Grønt Punkt Norge, n.d.a).

2.4.2 Article 5: Product bans

Article 5 introduces a command-and-control measure directly targeting stage 1 in the life cycle of plastics. The article prohibits cotton bud sticks, plastic cutlery, plastic plates, plastic straws, plastic stirrers, plastic balloon sticks, EPS take away containers, EPS beverage containers, EPS cups and all oxo-degradable plastic products from being placed on the market. These are all items with great difficulties in recycling, high litter rates, and where it is deemed that the items have sufficient and suitable alternatives to the single-use plastic items. By directly targeting the first stage, the total volume of plastic units in the market are reduced,

substantially reducing the amount of single-use plastic items that may find its ways towards the marine environment.

Figure 7 EPS take away food container. From Styrofoam container Hamburger Large, by Bagstar, n.d., Bagstar (https://bagstar.pl/en/styrofoam-container-hamburger-large-q-155x140x80mm-hb6-125-pieces.html). Copyright 2021 by Bagstar.

Figure 6 Oxo-degradable plastic in a compost facility. From Oxo-Degradable Plastics, by Natur-Tec, n.d., Natur-Tec (https://naturbag.com/oxodegradable-plastics/). Copyright 2023 by Natur-Tec.

2.4.2.1 Product bans in Norway

Article 5, with all its bans, was implemented by Norwegian law in 2021, as a part of *"Produktforskriften",* banning all single-use cotton bud sticks, plastic cutlery, plastic plates, plastic straws, plastic stirrers, plastic balloon sticks, EPS take away containers, EPS beverage containers and cups and all oxo-degradable plastic products (Produktforskriften [Product Regulation], 2004, §2b-3 and 4).

2.4.3 Article 6: Design requirements

Article 6 introduces another measure directly targeting stage 1 in the life cycle of plastics. In accordance with Article 6.1, plastic beverage containers up to three liters with plastic lids or caps can only be sold in the market if the caps and lids remains attached to the containers during the products' intended usage time. Article 6 directly targets bottle caps and lids as these items are among the single-use plastic items most frequently found in European marine litter surveys (Addamo et al., 2017).

Furthermore, Article 6.5 (a) states that all PET beverage bottles up to three liters must meet a requirement of minimum 25% recycled plastic content, while all other beverage bottles up to three liters must contain 30% recycled plastic. The requirement must be met and reached within 2025, and reported yearly to the European Commission from 2023.

These measures are directly targeting the design process in stage 1, and limits the producers availability to freely choose how to design his products. Article 6.1 aims at reducing the number of caps and lids that will reach the marine environment, while Article 6.5 aims at increasing demand for recycled plastic, by enforcing a minimum amount within all plastic bottles.

Bottles are only required to contain some recycled plastic, as bottles made 100% from recycled PET plastic, rPET, will be of lower quality. By diluting the amount of virgin plastic within the bottle, the bottles lifecycle will increase, and it will be possible to recycle many more times (Grønt Punkt Norge, 2022c).

2.4.3.1 Design requirements in Norway

As opposed to almost non-existent deposit and recycling schemes in Europe, 98% of all Norwegian plastic bottles are returned within the deposit system *with* their

cap or lid attached. However, implementation of the SUP Directive through EEA has resulted in that the majority of plastic bottles sold in the Norwegian market now have their caps and lids attached to the bottle (Coca Cola, 2022; Ringnes, 2023).

Currently, 30 - 40% of the Norwegian PET-bottles on the market contains rPET (Emballasjeforeningen, n.d.). The largest Norwegian producer, Ringnes, has already introduced recycled PET in 80% of its portfolio (Ringnes, 2022), and Coca Cola only offers bottles made from 100% recycled plastic in Norway (Coca Cola, 2021). No regulation is in place regulating the amount of recycled plastic in Norwegian beverage bottles. However, the industry has asked the government to introduce a virgin plastic tax in order to enforce use of recycled plastic. A draft from the Commission currently under work (D092953/01 (Draft Implementing Act), 2023).

2.4.4 Article 7: Marking requirements

Article 7.1 imposes a marking requirement on single-use plastic cups, sanitary towels, pads, tampons, tampon applicators, wet wipes and tobacco products with filters. The measure is targeting the transition and consumer behavior between stage 2 and 3 in the life cycle of plastic, and the specific items are targeted due to their frequent inappropriate disposal through the toilet. As a result, the items end up as marine litter, if not captured in the sewer sludge (Directive (EU) 2019/904, 2019, Recital 20).

The informational label is intended to inform consumers of correct waste disposal methods and that these items do contain plastic. The mark is standardized and does not allow for any flexibility or changes in its design. However, the information can be translated to the local language. The label must be placed horizontally on the external front or top surface of the product, but not such that it will be torn when the packaging is opened. For cups, the mark cannot be placed underneath the cup, nor close to the rim, to ensure visibility and hinder destruction (Commission Implementing Regulation (EU) 2020/2151, 2020).

Figure 8 Marking label to be placed on single-use plastic cups. From Marking specifications for single-use plastic products, by European Commission, n.d., European Commission (https://environment.ec.europa.eu/topics/plastics/single-use-plastics/sups-marking-specifications_en#gallery).

2.4.4.1 Marking requirements in Norway

The marking requirement from Article 7 was implemented by Norwegian law in 2021, as a part of "*Produktforskriften*" (Produktforskriften [Product Regulation], 2004, § 2b-5). The label can now be seen on all single-use plastic cups, coffee cups, sanitary towels, pads, tampons, tampon applicators, wet wipes, tobacco products with filters and tobacco filters.

2.4.5 Article 8: Extended producer responsibility schemes

Article 8.1 introduces an extended producer responsibility scheme on additional single-use plastic items where no suitable sustainable alternatives are available. It is a measure that covers all stages of the plastics lifecycle. One could think of it as a property rights allocation, where the whole responsibility and cost of the waste management process is put on the producer.

Because sustainable substitution for the covered items is deemed as impossible, the article requires the producer to have and cover the costs of waste management for his items. Article 8 states that that producers must cover:

(a) The cost of awareness raising measures, as further explained in 2.5.7.
(b) The cost of waste collection for production of single-use plastic items that are disposed of in public waste collection systems.
(c) The cost of cleaning up, transporting and correctly treating litter arising from production of single-use plastic items.
(d) The cost of data gathering and reporting in accordance with the previous version of the Waste Directive legislation (Directive 2008/98/EC, 2018, Article 8a (1), point c).

Producers of single-use plastic take away food containers, food packets and wrappers for immediate consumption, plastic beverage containers, plastic cups and lightweight plastic bags must cover costs a, b and c. Producers of wet wipes and balloons are subject to costs a, c and d, while producers of tobacco products with filters and filters are subject to costs a, b, c and d.

2.4.5.1 Extended producer responsibility schemes in Norway

Several EPR-schemes are in place in Norway. One is the tax on single use plastic bags, which were introduced more than 20 years ago. It requires plastic bag producers to pay a fixed tax of their produced units to *"Handelens Miljøfond"*, and should cover the waste management costs of the plastic bag producers. The money invested in the plastic bag fund is then invested in environmental improving practices.

Most plastic bags sold in Norway are subject to the fee, which has recently been raised from 0.20 NOK to 4.25 NOK per bag. The government's objective is to decrease the number of plastic bags available in the market. As the tax facing the producers are levied on the final market price facing the consumers, numbers show that the tax increase should decrease consumer consumption of plastic bags (Handelens Miljøfond, 2023).

After the implementation of the Waste and SUP Directives, a further extension of the existing Norwegian EPR scheme has been under development. Drafts altering "*Avfallsforskriften*" chapter 7 and 18 (Avfallsforskriften [Waste Regulation], 2004) to include the required EPR measures, as established by the directives, are in work (Ministry of Climate and Environment, 2023a, 2023b).

The new producer responsibility scheme requires that the producer is responsible for ensuring that product designs comply with appropriate reuse and recycling requirements, collection, trash treatment and recycling of the product and sufficient levels of recycled material for each product category. All plastic producers are required to be a part of the scheme, and must be registered at a producer responsibility portal (Miljødirektoratet, n.d.). All members must cover

the cost of cleaning up litter from production, and production and waste numbers must be reported for each item.

Furthermore, "*Forurensningsloven*" and "*Produktkontrolloven*" (Forurensningsloven [Pollution Control Act], 1983; Produktkontrolloven [Product Control Act], 1977) were updated in 2019, assigning the authority to issue penalty charges for non-compliance by the EPR-schemes (Miljødirektoratet [The Norwegian Environemental Agency], 2022).

2.4.6 Article 9: Separate collection requirement

Article 9.1 establishes a separate collection requirement for plastic beverage bottles, requiring 77% and 90% of the waste generated from plastic bottles to be collected separately for recycling by 2025 and 2029. The article specifically targets stage 3 in the lifecycle of plastics by promoting enhancements in recycling infrastructure and mandating a shift in consumer disposal habits towards recycling. It is further encouraged that countries introduce deposit refund schemes and separate collection targets, similar to the one established in Norway, as a mean to achieve the targets.

2.4.6.1 Separate collection requirement in Norway

Norway has a well-established deposit system for PET bottles. In 2022, Infinitum reported that 92,8 % of all PET-bottles placed on the Norwegian market were returned by its members (Infinitum, 2023, p. 37). As a result, Norway has already met the 2029 goal of a 90% separate collection rate.

There are strong incentives in place for all the involved agents to ensure a high return level of PET-bottles within the country. Norwegian plastic bottle producers are subject to an environmental tax that must be paid to the Norwegian government, equaling 3.91 NOK per unit (Stortingsvedtak om særavgifter for 2023 [Parliamentary Decision on Special Taxes for 2023], 2022). If the producer has a return rate between 25 and 95% through an approved deposit scheme, the environmental tax is decreased, and if the return rate is above 95%, the whole tax is waived (Skattedirektoratet, 2023, Section 1.2).

There are strong financial incentives in place for the consumers as well. By depositing a plastic bottle, 2.5 or 3 NOK are given back to the consumer (Infinitum, n.d.). The great success of the deposit system is deeply rooted in Norwegian culture, and as the numbers show, bottles are rarely disposed of outside the deposit system.

2.4.7 Article 10: Awareness raising measures

Article 10 introduces awareness raising measures for all single-use plastic items covered by the Directive. As opposed to article 7, which only covers single-use items frequently flushed in the toilet, article 10 covers all single-use plastic item categories, except those subject to a production ban. This means that all plastic cups, take-away containers, sanitary items, cigarette filters, food packets and wrappers, lightweight plastic bags and balloons, are subject to the awareness raising measures.

To reduce littering, countries are required to inform consumers of:

(a) The availability of other multiuse substitutes and systems to the single-use plastic items.
(b) The impact of inappropriate waste disposal through flushing single-use plastic items in the toilet.
(c) The impact of littering and other inappropriate waste disposal methods, and particularly the effect it has on the marine environment.

The awareness raising measure is a measure directly targeting consumer disposal behavior in stage 2, 3 and in between, in the plastics lifecycle. Its goal is to influence consumers to make more sustainable choices, but also to educate consumers towards appropriate disposal methods and the effect that inappropriate disposal methods have.

2.4.7.1 Awareness raising measures in Norway

No particular measure targeting only those items mentioned in Article 10 has been introduced in Norway yet. On the other hand, a commission draft from *Miljødirektoratet* reveals that the agency is suggesting the implementation of annual nationwide informational marine litter campaigns through TV, cinemas, social media, purchasing platforms and physically in stores (Miljødirektoratet, 2023). However, the Norwegian law "*Tobakksskadeloven*" prohibits tobacco producers from performing such behavior changing measures (Tobakksskadeloven [Tobacco Damage Act], 2004).

The awareness raising measure is a rather vague measure. Various sustainable campaigns, workshops, educational activities and theme days are hosted each year to improve sustainability and reduce littering. Cities do for example host many arrangements on *Verdens klimadag* each year.

Another Norwegian awareness raising measure is the concept *"Sneipfritt"* (https://www.sneipfritt.no). This is a private initiative, and not initiated by tobacco producers. "Sneipfritt" places yellow trash bins intended for cigarette disposal, concealed as voting ballots, in public areas. Fun questions or dilemmas are asked, and the smoker can vote for his preference by disposing his cigarette in one of the two alternatives on the box. By doing so, the company intends to reduce litter from cigarettes, and bring awareness to the consumers. It acts as a reminder of correct waste disposal.

3 Analysis

3.1 Economic theory

3.1.1 Market failures and the first fundamental welfare theorem

According to the first fundamental theorem of welfare economics, a perfectly competitive market will be efficient. A market is said to be Pareto-efficient if no feasible allocation is Pareto-improving to it. A Pareto-improvement is a reallocation of resources, making at least one agent better off, without making others worse. In order for a market to be perfectly competitive, it must satisfy some strict criteria:

a) Absence of market power. No agent should have the market power to influence prices. Hence, competitive markets often involve a large number of buyers and sellers, where all agents are price takers and the market clearing price will equal marginal costs.
b) All agents are rational and profit maximizing. We can expect utility and profit maximizing behavior from consumers and producers within the market.
c) Property rights are well defined.
d) All agents have perfect information. There is no information asymmetry regarding prices or goods within the market.
e) All goods are private. Hence, there are no public goods alloctions.
f) No externalities. Prices are correct, and all goods have a market price.

A market failure is said to occur when the first fundamental theorem of welfare economics is violated. This happens when a competitive market fails to achieve a Pareto-efficient allocation in its equilibrium, and one or several of the above criteria fails.

The existence of market failures requires government intervention. Single-use plastic consumption (stage 2) introduces two main market failures, specifically public goods and externalities, leading to an inefficient market allocation. Mismanaged plastic waste (stage 3) introduces two additional market failures. These are the lack of properly defined property rights and asymmetric information between agents in the market.

3.1.2 Public goods

A pure public good is defined as a good which is non-excludable and non-rivalrous (Ostrom & Ostrom, 2019). Where exclusion is infeasible, anyone, regardless, can derive benefits from the good. To satisfy the non-excludability constraint, a pure public good must be free. Therefore, no agent will have an incentive to supply the good within the market, as there are no profits. As a result, a public good must be provided by the government.

Non-rivalry on the other hand, implies that one agent's consumption of the good does not diminish another agent's use. Consequently, the supply of the resource will be unlimited, and all agents will consume the good until their maximal marginal utility is obtained.

Several goods have some public good characteristics, but not all. Common pool resources and toll goods are examples of such goods (Ostrom & Ostrom, 2019, p. 11). Common pool goods bear the characteristics of a public good, but also traits of rivalry. The use of a common pool resource by one agent means that it might preclude the use from another agent.

In relation to the marine litter issue, several dimensions have public goods-characteristics. The single-use plastic item in itself is a private good. However, the use of the deep sea and oceans as a dumping place for plastic waste can be seen as a public good. There are no physical barriers excluding trash from entering the ocean, and dumping waste in the ocean is free – i.e. you do not have to pay for the service. If you are caught in action and fined, it will be another case.

The act of littering is not rival, as long as there is room for more waste in the ocean. However, as the stock of plastic waste in the oceans continues to accumulate, littering will eventually become rivalrous. As the oceans fill up, there will less and less space for more trash, and one can imagine an exceptional scenario where the ocean is full, and there is no more space for litter.

3.1.2.1 The Tragedy of Commons

There are mainly two issues that arise with public goods provision. The first is known as open-source exploitation, or "The Tragedy of Commons". The tragedy of the commons is a situation where individuals act in their own individual profit maximizing self-interest and have an incentive to overuse or deplete a public good resource. While each agent has his own private marginal utility from consumption of the public good, $MRUS_1$, the total cost of consuming the resource until all agents marginal utility is satisfied, is unsustainable. Total combined demand for consumption will greatly override the sustainable provision of the good in the market.

Hardin argues that "The rational man finds that his share of the cost of the wastes he discharges into the commons is less than the cost of purifying his wastes before releasing them. Since this is true for everyone, we are locked into a system of "fouling our own nest," so long as we behave only as independent, rational, free enterprisers"(Hardin, 1968, p.1245).

In the case of single-use plastics, Hardin's argument implies that consumers will continue their faulty behavior and litter the oceans as the cost of littering or wasteful behavior is lower compared to other more sustainable waste management actions. Locating a trash can, carrying waste home with you after a picnic on the beach or ensuring that the trash cans are not too full is inconvenient, and allocates more costs on the individual consumer. As a result, the wasteful behavior will continue, and the quality of the public good will diminish, unless a change in course of actions occur.

The availability of waste-free oceans can also be categorized as a public good. As wasteful behavior amongst the agents continues, and marine pollution increase, the quality level of the environment, oceans and land, will deteriorate. Figure 9 illustrates the public good provision when each agent, i, acts individually within the market. The individual agent will choose a market allocation where his marginal rate of utility substitution, $MRUS_i$, equals the marginal rate of technical substitution, $MRTS$, within the market.

The $MRUS_i$ is assumed to be decreasing for each individual agent in the market. Cleaning up and ensuring good waste management practices requires time and effort, an effort that can be a monetarized, and which is reflected in the $MRUS_i$. While the first unit will be relatively cheap for the agent, the last unit will be perceived as very costly. At this point, the agent is already acting extremely sustainable, and is doing almost everything correctly. Providing the last additional quality level of the public good, q, in the market and achieving perfect sustainability will be very costly for the agent.

When the individual agent makes decisions in a public goods market by himself, the cost of cleaning up, ensuring good waste management practices or retrieving information beyond point q^{low} is regarded as excessively high, compared to the utility received from consumption of the public good. The agent will therefore choose a market allocation where the quality level of the public good is q^{low}. Consequently, an efficiency loss occurs in this market, primarily due to the individual agents relatively low valuation of the public good of high quality, compared to the perceived costs.

However, because we are looking at a public goods market, the collective social marginal rate of utility substitution of all individual agents in the market can be summarized as $\sum MRUS_i$. The optimal quality allocation of the public good in the market will be where $\sum MRUS_i = MRTS$, and $q = q^{high}$, which will be a market allocation where collective or governmental action is taken to ensure a high quality provision of the public good. As shown in figure 9, the optimal quality level of the public good will create additional social surplus within the market.

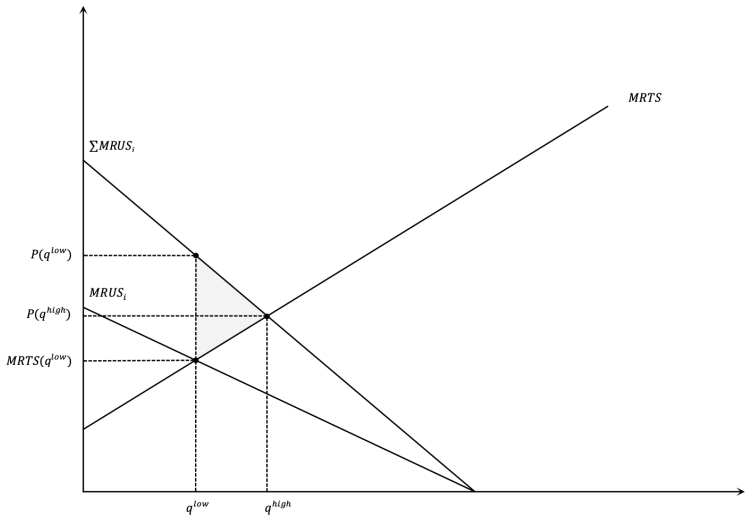

Figure 9 The quality level, q, of public good provision

3.1.2.2 Free riding

The second issue with public goods is free riding. No agent can hinder others from enjoying the benefits from his actions. This means that if one, or some, agents perform actions that will reduce the accumulation of litter within the marine environment, e.g., beach litter clean-up efforts, then there is no way the agent(s) can prevent others that did not participate in the actions from deriving benefits from the actions. Because the utility derived from the efforts do not

depend on any agent's contribution towards or in the action, an incentive for free riding is created.

There will exist several reasons behind free riding amongst consumers within the single-use plastics market. While some will straightforward utilize the efforts of others by continued littering, while being well aware of the consequences, others might free ride unintentionally due to informational asymmetry and unawareness. Nevertheless, regardless of the reasoning behind such behavior, free riding will further reduce agents wish to contribute to actions that will reduce marine litter and benefit the overall society.

Further accumulation of stock pollution in the marine environment will eventually decrease each individuals obtained utility of consumption. When each agent acts individually, a large-scale prisoners' dilemma is created. No agent will change his behavior, unless he sees that a sufficient number of others do so as well. As this will be true for all agents in the market, a need for collaborative action is created.

To avoid exploitation, free riding and reliance on private agents' efforts, rules and legislation such as the SUP Directive is introduced by the government in the market. Collective and coordinated efforts will reduce costs, and as coordination occurs, the marked will adjust towards a more socially optimal market allocation, taking all agents needs into consideration.

3.1.3 Externalities

Externalities are defined as spillover effects caused by consumption or production of a good or service that negatively or positively affects an agent not directly involved in the transaction. While negative externalities impose additional costs on others, positive externalities create additional value in the market. The inefficiencies created from negative externalities in a market result in market failures and thus, non-optimal market allocations. To restore efficient markets, the government can introduce corrective policies and incentives.

To explain the concept of externalities, let's consider a simplified marked for single-use plastic, Q. In this market, there are n identical single-use plastic producers. Each firm is a price taker, and the inverse demand function equals $D(Q) = P$. I assume a linear cost-economy, where the marginal cost of production, MPC, is constant because the production of single-use plastic materials is not restricted or limited today. As the marine litter stock pollution increases, more efforts and resources must be diverted towards clean-up efforts and correct disposal. Further, integration of wasteful behaviors amongst consumers in the market will increase the costs associated with behavioral changes. Combined, the negative externalities are assumed to give rise to a linear upwards sloping marginal external cost, MEC.

To obtain optimality in a market, the market price, P, should equal social marginal cost, SMC. The price of single-use plastic items should therefore cover both the marginal cost of production and the additional negative externality it imposes in the market (Hasson et al., 2007). Even though production of single-use plastic items is relatively inexpensive, the negative externality from consumption and production is not accounted for in the market price. This is due to the fact that

the marginal external cost, MEC, is not a cost directly affecting the firms pricing decision. The producer will therefore set the price where $P = MPC$. The quantity is given by Q^N, with equilibrium price $P(Q^N) = MPC$. However, the market allocation at Q^N is inefficient, and aggregated social welfare is not maximized. As shown in figure 10, the efficiency loss will equal $\frac{1}{2}(Q^N - Q^*)(MSC(Q^N) - P(Q^N))$. By not setting the correct market price, the producer disregards his social responsibility, and indirectly allows waste to accumulate over time. The negative externality will then grow, which again should have been reflected in the market price through SMC.

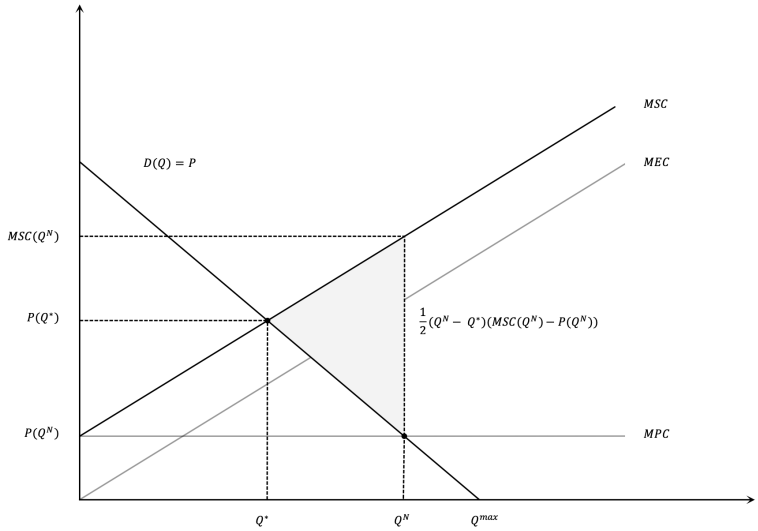

Figure 10 Externalities in a single-use plastic market where P = MPC, based on Hasson et al., (2007).

Single-use items like straws, plastic cups or tableware are given away for free at most restaurants and coffee shops. While the restaurant and coffee shops can cover their market clearing price by increasing coffee or meal prices, consumers are left experiencing a zero-price. As a result, the consumer is not facing the true economic cost of his actions and will overconsume the goods in question. It is a well-known phenomenon. When cutlery and napkins are free, you take a couple more, just to be sure you have enough, or to use for a later occasion. Furthermore, cutlery, straws, containers and napkins are usually expected to be free. The restaurant or coffee shop could therefore loose costumers, simply by setting a market price on these items. As result, the incorrect price will create an additional externality in the market.

By providing single-use plastic items for free, additional overconsumption occurs, and Q will increase substantially, until maximum market demand is met, as illustrated by $Q = Q_{max}$. In this case, the efficiency loss will equal $\frac{1}{2}(Q^{max} - Q^*)MSC(Q^{max})$ and the social marginal costs of production is completely disregarded by the firms, as shown in figure 11.

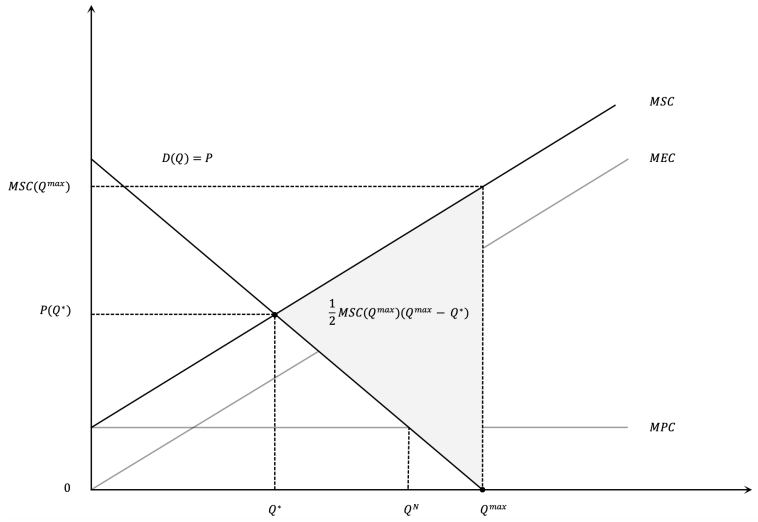

Figure 11 Externalities in a single-use plastic market where P = 0.

To maximize aggregated social welfare, both MPC and MEC needs to be taken into account when determining the market price. P would therefore need to cover the social marginal cost, $MSC = MPC + MEC$, for firms to fully internalize the negative externality plastic production and consumption creates. No welfare loss occurs in the socially optimal allocation, Q^*, with social optimal price $P(Q^*) = MSC(Q^*)$. From both these scenarios, it can be inferred that some firms do have a higher acceptance for plastic waste than the aggregated society overall, which is another argument in favor of government intervention.

3.1.4 Property rights

Property rights are a fundamental concept in economics that refer to the legal rights agents have to use, control, and dispose of property, goods, or resources. In theory, well-defined property rights will create efficient market allocations, known as the Coase theorem. The Coase theorem states that inefficiency caused by externalities can be corrected by private transactions if property rights are well defined and there are no transaction costs (Coase, 1960). Allocation of property rights will allow the parties involved in a transaction to negotiate and reach an efficient outcome that maximizes the utility of each party, regardless of which agent is allocated the initial property right.

Nonetheless, transaction costs are usually present in every market. In the single-use plastic market, transactions costs can be seen in the form of time spent researching single-use plastic substitutes or correct waste disposals, locating a trash can or even the inconvenience of bringing trash back from an outdoor gathering. Further, in the presence of public goods, it is not possible, nor desirable, to introduce property rights.

The absence of property rights is evident within the single-use plastic market. No agent is assigned the responsibility for the adverse effects of plastic pollution and mismanaged waste, and as a result, both consumption and production may grow rapidly uninterrupted. The long-term consequences will eventually affect the involved parties, but the lack of property rights defers these concerns to future generations. One could think of it as free riding on the next generation. Unassigned property means that no agent will take on the responsibility for the externalities within the market, and the market allocation will be non-optimal.

The Coarse theorem is rarely seen in practice when solving environmental issues and is usually used to explain the need for government intervention. In itself, the theorem cannot resolve market inefficiencies. However, by assigning responsibility for ensuring waste free oceans to consumers or assigning the financial responsibility for the whole life cycle of plastics to a producer, negotiation may begin, and the different agents can reach a more optimal agreement, reducing inefficiencies, as attempted by the introduction of EPR schemes by the SUP Directive.

3.1.5 Information asymmetry

In a perfectly competitive market, the assumption of full information transparency prevails. All agents are fully informed about costs and prices, facilitating optimal market outcomes. However, real-world scenarios often deviate from this ideal. In the case of single-use plastic items, there are often information asymmetry amongst both consumers and producers within the market.

Consumers often have varying levels of knowledge regarding plastic content in single-use items and the environmental impact of purchasing such items. While some consumers know that cigarette filters and most paper coffee cups contain plastic, others may lack such awareness and therefore choose to improperly dispose of the items, for example through littering in the urban and marine environment. Furthermore, other consumers might not be aware that items flushed down the toilet can escape the sewer sludge and end up in the marine environment, and that items will not degrade when flushed.

As illustrated in figure 12, the information asymmetry arising from unawareness of the consequences from externalities caused by consumption of single-use plastic items will give rise to an unnaturally high demand, the uninformed demand, $D_{uninformed}(Q)$. As a result, an inefficient market allocation, $Q_{uninformed}$, occurs, where efficiency losses are created. The information disparity means that consumers are not fully considering the external costs of their actions, which leads to suboptimal decision-making due to information asymmetry.

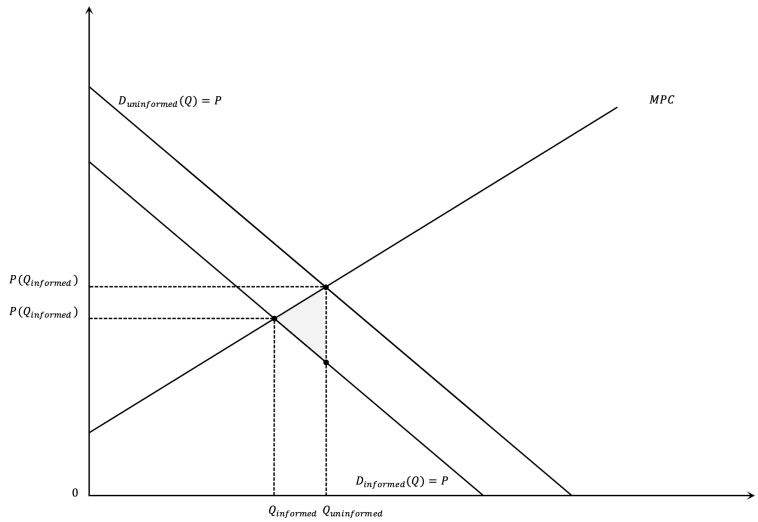

Figure 12 Uninformed demand in the single-use plastic market.

Information asymmetry is also evident in pricing decisions. To establish an optimal market price, it is necessary to assign a monetary value to externalities that accurately reflects their negative effects. However, producers and industries may not possess full knowledge about these costs. Government entities and other organizations might have a more detailed understanding, but it is ultimately only the individual firms that have complete information about their production processes. The information disparity between agents will complicate the task of setting an optimal price in the market that fully accounts for all negative external costs.

3.1.3 Government intervention

In the presence of market failures, the government can carry out appropriate corrective policies to restore a Pareto efficient market allocation. We can consider three broad categories of environmental regulation:

(a) Economic incentive instruments, like taxes, subsidies and tradeable emission quotas.
(b) Command-and-control policies, like production ban, technology requirements or emissions standards.
(c) Other institutional approaches, like information, awareness campaigns and responsibility placements.

In the following I will give a brief review of the main policy tools discussed in the theory of environmental economics, namely the Pigou tax and command and control.

3.1.3.1 Pigouvian tax

The preferred approach in the literature is the use of market-based instruments (Cropper & Oates, 1992). These typically internalize the value of the externality into the private price paid for the good, thereby shifting effective demand. A Pigouvian tax, t, is an example of a market-based instrument. It is a charge levied on a product, where the goal is to achieve an optimal level of output, Q^* (Pigou, 1932). In order for the Pigouvian tax to be optimal, it must equal the marginal damage that stems from single-use plastic production and consumption in the optimal market allocation, $t^* = MEC(Q^*)$, and must be attached directly to the pollution activity, i.e., the production of single-use plastics (Cropper & Oates, 1992, p. 680).

The introduction of an optimal Pigouvian tax will raise the private marginal costs for the producer. His total cost will now include the cost of production *and* the tax levied on his items. The market price will therefore increase and eventually cover the total social marginal cost in the optimal market allocation, $P^* = t^* + MPC(Q^*) = MSC(Q^*)$. As a result, the producer is forced to internalize the damage he is causing in the market.

Graphically, it can be shown as follows. In a single-use plastic market where the producer is not accounting for the marginal external cost, MEC, when setting the market price, the optimal Pigouvian tax, t^*, would have to equal the negative externality, $t^* = MEC(Q^*)$ in the optimal market allocation. As a result, the effective market price will change from $P(Q^N)$ to $P(Q^*) = P(Q^N) + t^*$. The increased price will shift the supply curve, and the consumers will adjust accordingly to the higher market price. As a result, demand falls from Q^N to Q^*, and the efficiency loss is reduced to 0. The Pigouvian tax is forcing all agents to

socially adjust their behavior towards optimality. Consumers with a higher marginal cost than benefit of consumption, will no longer purchase the product. However, consumers with a higher willingness to pay, might continue their unsustainable behavior.

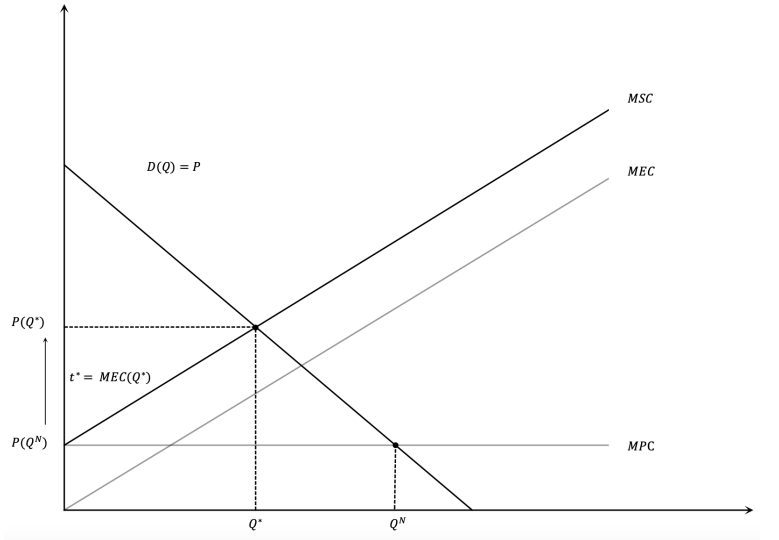

Figure 13 The optimal Pigouvian tax.

The Pigouvian tax is known to achieve cost efficiency. It is targeting the flow pollution and might limit further plastic littering in the future, by reducing current consumption. However, limited knowledge of environmental damage in accurate monetary terms makes it hard to estimate the optimal tax precisely. While the Pigouvian tax is the preferred instrument in the literature, the SUP Directive explores other options.

3.1.3.2 Command-and-control measures

Command-and-control regulations are commonly used as a policy measure in the fight against environmental change. The measures sets forth defined emission standards, production quantities, or requires introduction of specific environmental friendly technologies. While command-and-control regulations can be effective in addressing environmental challenges and ensuring compliance with established standards, they are known to be cost inefficient. Critics argue that the measures are inflexible, defer innovation and that monitoring costs are too high.

However, compliance must be monitored to ensure effectiveness of command-and-control measures. If not, free riding will occur. Without a control function, agents will have no incentive to abide by the rules and production standards set forth by the measures, and as a result, the regulations will have no effects on the market.

The SUP Directive introduces monitoring requirements for several of its introduced measures. Waste numbers, production numbers, recycling numbers and material composition are just some amongst many indicators that countries are measured against. While monitoring requires high costs, the goal is to reduce the negative externality from production and consumption to a level where the market allocation will be optimal, and efficiency reduced. However, the result will strongly rely on the total cost curve.

In markets categorized by *very high* externalities, MEC_{HIGH}, such that social marginal cost will be above $P(Q)$: $MSC_{HIGH}(Q) > P(Q)$, command-and-control policies can yield the most efficient market outcome. By setting the price equal to the marginal cost, $P = MPC\ (Q^N)$, an efficiency loss equal to $\frac{1}{2}Q^N(P(0) - P(Q^N) + Q^N\big(MSC_{HIGH}(0) - P(0)\big) + \frac{1}{2}Q^N\big(MSC_{HIGH}(Q^N) - MSC_{HIGH}(0)\big)(Q^N)$ will occur in the market.

Because the externality is very high, the producer cannot choose any price level that will resolve the market inefficiency. Due to the high externality, a production ban will yield a better result than every price level the producer can choose, as illustrated in figure 14. As a result, a command-and-control policy completely banning the production from the market will yield a social surplus of 0.

While the efficiency loss is resolved, compliance costs are now introduced in the market. As long as the cost of introducing the command-and-control measure is lower that the externality arising from an unregulated single-use plastic market, the measure will be socially optimal. As the SUP Directive does introduce command-and-control measures, it can be interfered that the externalities are assessed to be very high, as illustrated in figure 14.

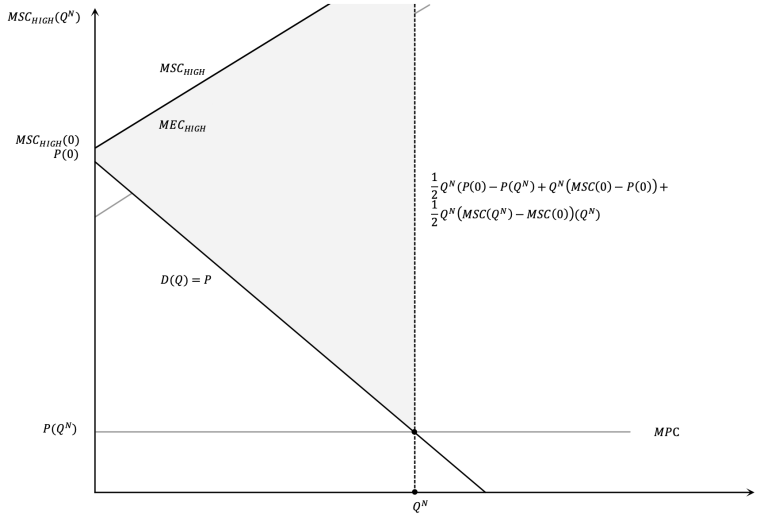

Figure 14 Command-and-control measure in a market with very high externalities.

3.2 Data

Measuring waste numbers arising from plastic consumption, and particularly single-use plastics, is a tedious task. While other global pollution issues can be quantified by greenhouse gas emissions, knowledge retrieval on plastic waste accumulation and the items that give rise to the issues, requires hands-on collection efforts in several geographic locations, repeatedly over time.

Marine litter data are collected through beach litter clean ups, where identified items are recorded and categorised based on different survey guidelines. While a standardisation on marine litter retrieval guidance is attempted, differences do exist, making data analysis and comparison harder.

Furthermore, plastic waste is accumulating unevenly and is spread geographically. As most beach litter clean-ups are done on a voluntarily basis, one can assume that not all beach clean-up efforts do result in data recording, depending on the objective of the efforts, and whether these are done to clean the beach or to retrieve data. As a result, beach litter clean up data are highly prone to fluctuations in litter spread, recording and retrieval, as well as human errors.

Most plastic items have been transported long stretches, where wind and weather has torn or demolished the items in question into smaller plastic fragments. As reflected in the data, large numbers of items are recorded as unidentified plastic fragments in beach litter surveys. These categories comprise numerous plastic items, making it an impossible task to retract the origin of the items. As a result, the identified plastic fragments have little value, besides displaying the volume of plastic items identified in general.

3.2.1 Data methodology

My data analysis is based on Norwegian beach litter data collected from OSPAR, International Coastal Cleanup (ICC), *Ryddenorge* and *Ryddeportalen*. While OSPAR data are retrieved from their online databank (OSPAR Commission, 2022), data from ICC, *Ryddenorge* and *Ryddeportalen* are retrieved through personal communication with ICC and *Hold Norge Rent*. *Hold Norge Rent* is the organization that manages the data portals *Ryddenorge* and *Ryddeportalen*. Through the communication, permission has been asked and provided for the use of the datasets in this Master Thesis.

Most of the surveys report the total weight of all items recorded in one survey in kilograms or pounds, as well as the number of recorded items within each category. Depending on the survey, numbers on several beach litter categories are reported, both plastic, non-plastic, fishing related items and others. Below, an example from ICC is shown, where each row represents a distinct survey, and the number of items identified within each category in that survey.

Rope (1 yard/meter = 1 piece)	Fishing gear (Clean Swell)	Other plastic/foam packaging	Tobacco packaging/wrap	Other packaging (Clean Swell)	Cigar tips	Cigarette lighters
2						
1						
			13			2
6			11			
13			8			
4						
			1			

Figure 15 ICC survey example.

As in accordance with Addamo et al. (2017), from which the SUP Directive is based, litter counts are applied in this analysis. While weight could be a good measure of the size of the issue, the marine litter results would have been dominated by heavier items, such as plastic tires etc.

To identify the dimension of the marine litter single-use plastic issue in Norway and analyze the effects of the SUP Directive on Norwegian data, categorizations have been conducted in accordance with the single-use plastic items covered by the SUP Directive. However, as my data stems from four different sources, which all contains slightly different categories, some categories have been merged for the sake of the analysis. An explanation of the category mergers and assumptions can be found in Appendix A.

Further processing is done in R and Excel. The R manuscript can be found in Appendix B. Duplicates have been removed from each dataset. However, in total, only 15 duplicates existed in the *Ryddenorge* dataset, and 3 duplicates in the ICC dataset. The remaining datasets did not have any duplicates. The four datasets were then combined into combined Norwegian marine litter dataset. However, it must be noted that *Ryddeportalen* data did not contain data on "crisps and cany wrappers" or "lightweight plastic bags", while ICC data did not contain any data on "wet wipes".

In total, 12 categories are a part of my analysis. An overview of the total identified observation within each of the categories from 2016 – 2022 can be seen below.

Single-use plastic item	Total observations	Percentage
Plastic beverage bottles and containers	256 397	24%
Plastic cotton bud sticks	238 831	22%
Cigarettes	215 158	20%
Lids and caps	137 128	13%
Plastic and EPS take away food containers	111 031	10%
Plastic straw and stirrers	30 576	3%
Plastic and EPS cups, plates and cutlery	26 733	2%
Crisp and candy wrappers	21 334	2%
Wet wipes	18 196	2%
Lightweight plastic bags	10 050	1%
Balloons	5 332	0%
Pads, tampons and tampon applicators	3 445	0%

Table 5 Total observations within each category from 2016 - 2022. Based on numbers from (OSPAR Commission, 2022, ICC & Hold Norge Rent).

The surveys and identified single-use plastic items are located all over the country. Below, figure 16 displays the geographical spread in single-use plastic observations within my defined categories. Coordinates from each deducted survey determine data point allocation, while circle size is decided by the number

of observations within that area. A darker color indicates several observations in the same area.

The dispersion between datapoints and smaller identified quantities in the northern part of the country reflects the same dispersion within the population. However, as previously discussed, marine litter is capable of travelling long distances, and as a result, marine litter accumulation in the north should be subject for further inspections, to ensure a complete evaluation of Norwegian marine litter data.

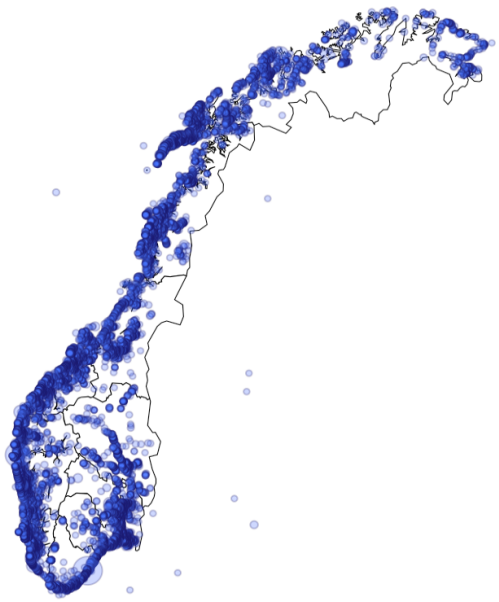

Figure 16 Norwegian single-use plastic beach litter clean-up observations, 2015 – 2023. Based on numbers from (OSPAR Commission, 2022, ICC & Hold Norge Rent).

Figure 17 illustrates the distribution within each surveyed category throughout 2016 – 2022. Due to the nature of logarithmic transformations, zero-values are omitted. As the boxplot shows, outliers within each category are present. However, these are all kept within the dataset. While they do represent observations of a much greater size than others, the outliers may exist due to spills and do consist of actually representations of marine waste numbers in Norway. Further graphics over the marine litter numbers within each surveyed category can be found in Appendix C.

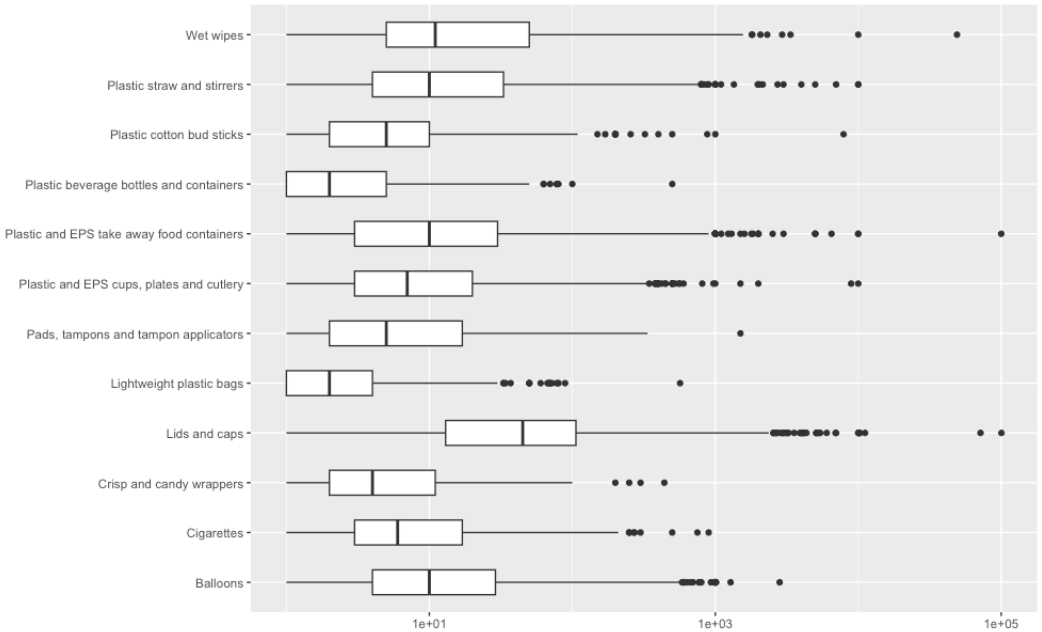

Figure 17 Outliers within each monitored single-use plastic category. Based on numbers from (OSPAR Commission, 2022, ICC & Hold Norge Rent).

In total, data are gathered from a period of six years. However, the number of recorded surveys within each year vary greatly. A further issue is the number of zero-observations within each survey. As shown below, only 23% of the surveys in 2016 does contain any data identifications within my specified categories. Due to category mergers and exclusion, what originally was an extensive dataset, has now become rather small.

year	n surveys	surveys with zero obs	surveys with obs	surveys with obs
2016	760	589	171	23%
2017	1 759	988	771	44%
2018	4 815	3 022	1 793	37%
2019	4 876	3 077	1 799	37%
2020	2 178	1 266	912	42%
2021	950	362	588	62%
2022	891	345	546	61%

Table 6 Combined dataset characteristics. Based on numbers from (OSPAR Commission, 2022, ICC & Hold Norge Rent).

3.2.2 Data results

mean	Plastic and EPS cups, plates and cutlery	Plastic and EPS take-away containers	Plastic cotton bud sticks	Plastic straw and stirrers	Plastic bottles and containers	Pads, tampons and tampon applicators
2016	13.80	134.24	149.96	11.55	108.66	3.00
2017	8.67	25.91	553.81	14.66	82.15	6.11
2018	20.35	31.33	58.95	29.42	37.41	4.33
2019	9.20	20.08	53.24	13.94	48.60	9.08
2020	10.69	31.99	38.44	9.41	40.68	4.54
2021	9.25	23.87	42.15	7.55	20.09	4.18
2022	6.66	13.93	36.08	5.49	14.54	4.77
trend	-1.0686	-13.012	-49.482	-1.8718	-14.399	0.0592
R^2	0.2547	0.4492	0.3177	0.2623	0.8447	0.0042

mean	Wet wipes	Cigarettes	Crisp and candy wrappers	Lightweight plastic bags	Balloons	Lids and caps
2016	20.00	45.48	1.00	0.00	6.14	41.90
2017	7.34	58.18	7.00	14.17	6.20	42.80
2018	12.70	133.27	10.40	26.50	6.70	30.39
2019	19.10	53.10	17.08	5.00	3.02	31.12
2020	16.62	45.56	22.95	18.22	2.88	33.55
2021	10.68	128.75	20.45	10.81	3.74	28.67
2022	7.69	74.49	12.24	6.01	2.95	20.85
trend	-0.9399	5.017	2.6133	0.1082	-0.6549	-3.1527
R^2	0.1511	0.0805	0.5334	0.0007	0.6581	0.7905

Table 7 Means of surveyed single-use plastic items from 2016 – 2022. Based on numbers from (OSPAR Commission, 2022, ICC & Hold Norge Rent).

median	Plastic and EPS cups, plates and cutlery	Plastic and EPS take-away containers	Plastic cotton bud sticks	Plastic straw and stirrers	Plastic bottles and containers	Pads, tampons and tampon applicators
2016	8.00	8.00	20.00	6.00	14.00	2.50
2017	5.00	6.00	10.00	6.00	12.00	4.00
2018	4.00	6.00	10.00	5.00	10.00	2.00
2019	5.00	10.00	10.00	8.00	20.00	2.00
2020	5.00	10.00	10.00	5.00	8.00	2.00
2021	4.00	8.00	6.00	3.00	6.00	2.00
2022	3.00	5.00	5.00	3.00	4.00	2.00
trend	-0.5714	-0.0357	-1.8929	-0.5357	-1.5714	-0.1964
R^2	0.6154	0.0015	0.7122	0.4261	0.398	0.3218

median	Wet wipes	Cigarettes	Crisp and candy wrappers	Lightweight plastic bags	Balloons	Lids and caps
2016	20.00	20.00	1.00	0.00	3.00	17.50
2017	5.00	10.00	7.00	8.00	2.00	10.00
2018	5.00	16.00	3.00	26.50	2.00	10.00
2019	7.00	12.50	5.50	5.00	2.00	10.00
2020	10.00	10.00	8.50	7.00	2.00	10.00
2021	3.00	18.00	7.00	3.00	2.00	8.00
2022	3.00	13.00	4.50	3.00	2.00	5.00
trend	-1.7857	-0.3929	1.088	-0.7321	-0.1071	-1.4821
R^2	0.4139	0.0475	0.2261	0.0323	0.375	0.7218

Table 8 Medians of surveyed single-use plastic items from 2016 – 2022. Based on numbers from (OSPAR Commission, 2022, ICC & Hold Norge Rent).

To account for outliers within each category, medians are calculated. As opposed to the mean, a median will be less affected by extreme outliers and functions well when the data distribution is skewed. Beach litter data does typically have a skewed distribution with weigh put on smaller observations. On the other side, calculating the mean value will give a good overview of the actual marine litter volume, and is usually a more precise measure statistically.

The best fitted linear trend has then been constructed to show the trend throughout the years for each category in question. To assess the fit of the trendline, R^2 is also calculated. While the power of the R^2 should not be exaggerated, it may be used as a tool to somewhat assess how well the linear trend fits the data.

Almost all single-use plastic categories show a declining trend in means and medians between 2016 and 2022. The greatest reductions can be seen for cotton bud sticks and plastic bottles. Observations within the two categories do make up almost half of all observations within the six monitored years. In 2016, the two items were top three most littered items, whereas they make up spot four and five in 2022. Both means and medians show great reductions, whereas the mean of plastic bottles and respectively median of cotton bud sticks show high explanatory powers in the R^2. A visual of the evolution in the means for all single-use items can be found in Appendix D

While Norway has a very good deposit return system, numbers still show that both plastic bottles, caps and lids are highly present single-use plastic items within marine litter surveys. Because plastic bottles are big, it could be expected that high numbers of bottles will be identified in surveys, due to the fact that the items are easily recognizable, and most likely do not demolish on the way towards the marine environment. As such, plastic bottles may be overrepresented in the data.

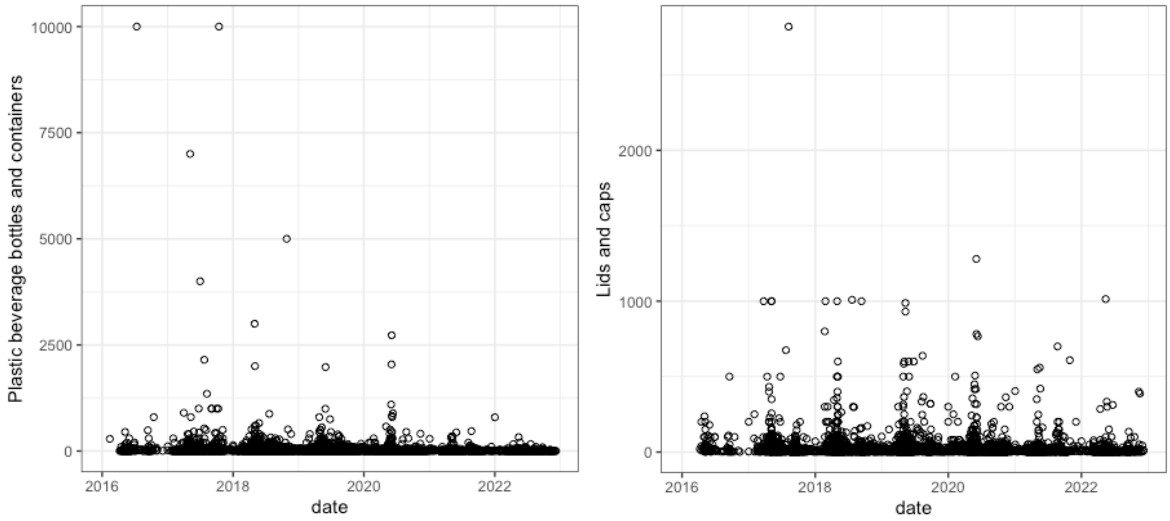

Figure 18 Plastic bottle, caps and lids observations in marine litter data. Based on numbers from (OSPAR Commission, 2022, ICC & Hold Norge Rent).

While the overall expectation would be low identified number of bottles, caps and lids, caps and lids do make up the fourth most observed single-use plastic item overall. Reductions in means and medians do exist, but these are not comparable to the ones within other categories, resulting in the item being listed as the second most frequently identified item in 2022. However, some of the volume could be

explained by potential spills. The items are lightweight, and seem to be prone to high numbers of outliers.

Furthermore, wet wipes, straws and balloons make up approximately 3% of all observed single-use plastic items. All categories show a decline in median and average numbers, and the low numbers are kept throughout the years. However, it can be interfered that both consumption and waste arising from the consumption of these items is not very high in Norway. While many straws very exchanged for paper straws several years ago, wet wipes are made from mostly degradable materials and balloons mostly consumed outside, and then prone to becoming marine litter, once a year, on the constitutional day.

Candy wrappers and lightweight plastic bags show an increase in the average observations each year. While there seems to be a reduction in the median of lightweight plastic bags, the median of crisps and candy wrappers are consistent with the average value. However, it must be noted that *Ryddeportalen* did not have any data on either of these categories, and such the trend in mean and medians do not reflect the actual movements in waste numbers within these categories from 2016 to 2022. As seen in the plots below, this results in nearly no observations between 2016 and 2020.

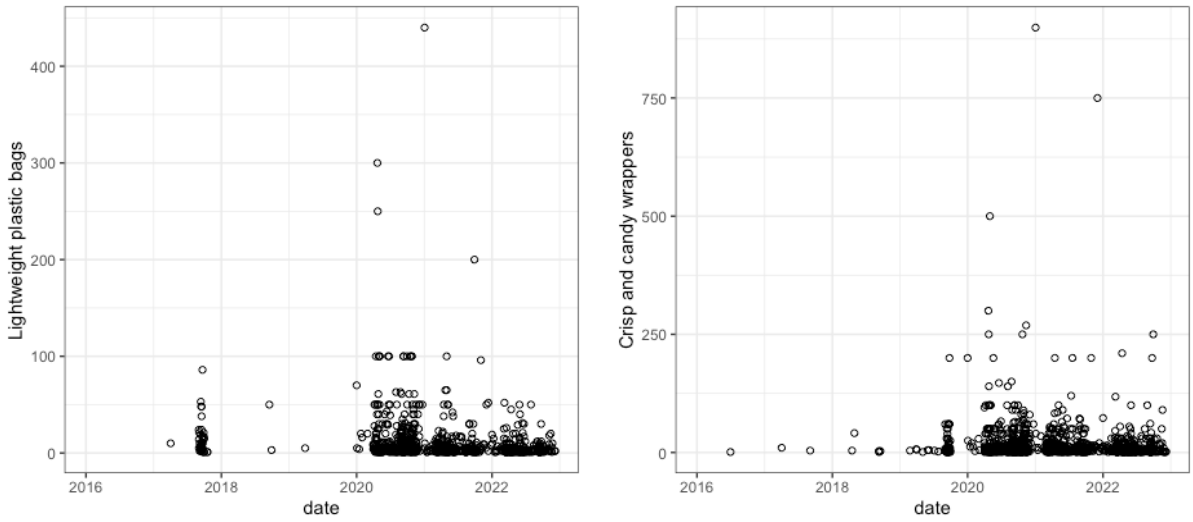

Figure 19 Lightweight plastic bags and crisps and cany wrappers observation in marine litter surveys. Based on numbers from (OSPAR Commission, 2022, ICC & Hold Norge Rent).

For cigarettes, the volume of observations increases drastically from 2.183 in 2016 to 12.738 observations in 2022, where it is the most frequently observed items in marine litter surveys. Cigarettes do have high average observations each year, however, based on the boxplot, it does not seem like the category is more prone to outliers than others. However, the item is in fact rarely disposed of in a correct manner, and the appearance of large number of cigarette butts in one area is deemed to be very likely.

While the total number of observations from pads, tampons and tampon applicators have increased by more than 300%, from 60 to 248, the total number of observations are diminishing compared to other surveyed categories. As seen from the mean and medians, the observed number of items stay relatively stable throughout all the six years, which could potentially be blamed on the items little plastic composition. As these items are mostly made from degradable materials,

they are less likely to persist in the environment for longer periods, and hence, less likely to appear in marine litter data.

Plastic and EPS cups, plates and cutlery and plastic and EPS take away food containers are categories covered by a complete and partial ban within the SUP Directive. Both mean and medians show a decline in waste numbers from 2016 to 2022. However, neither of the measurements do have an R^2 above 0.5, assigning little explanatory power to the trend lines.

2016			
1	Plastic beverage bottles and containers	16 842	38%
2	Plastic and EPS take away food containers	11 142	25%
3	Plastic cotton bud sticks	7 948	18%
4	Lids and caps	3 855	9%
5	Cigarettes	2 183	5%
6	Plastic and EPS cups, plates and cutlery	1 159	3%
7	Plastic straw and stirrers	751	2%
8	Balloons	264	1%
9	Pads, tampons and tampon applicators	60	0%
10	Wet wipes	40	0%
11	Crisp and candy wrappers	1	0%
12	Lightweight plastic bags	0	0%

2022			
1	Cigarettes	12 738	29%
2	Lids and caps	6 942	16%
3	Plastic and EPS take away food containers	5 517	13%
4	Plastic beverage bottles and containers	5 178	12%
5	Plastic cotton bud sticks	4 221	10%
6	Crisp and candy wrappers	3 697	8%
7	Plastic and EPS cups, plates and cutlery	1 544	4%
8	Lightweight plastic bags	1 256	3%
9	Plastic straw and stirrers	1 022	2%
10	Wet wipes	954	2%
11	Balloons	283	1%
12	Pads, tampons and tampon applicators	248	1%

Table 9 Comparison between 2016 and 2022 Norwegian single-use plastic observations. Based on numbers from (OSPAR Commission, 2022, ICC & Hold Norge Rent).

3.2.3 Discussion of data result

Even though the SUP Directive was implemented 2019, only two out of the seven introduced measures are active in Norway today. These are product bans and marking requirements, which were introduced in Norway in 2021. The five other measures are scheduled for a later introduction.

The production ban targets the first stage in the plastics lifecycle, namely the plastic production stage. However, we have no data or estimates on how long it takes from a single-use plastic item is produced, until it is purchased and incorrectly disposed of such that it ends up as marine litter. As a result, it is not possible to interfere from the data whether the Norwegian marine litter data stem from waste released into the environment before or after the introduction of a production ban introduced by the SUP Directive.

In order to assess the effect of production bans on marine litter numbers, both numbers on produced single-use plastic items in Norway, the time it takes until the items in question becomes marine litter and is recorded in a marine litter survey and precise marine litter numbers in that year would be required.

The same issue arises when analyzing the implementation of the marking requirement. While the measure was also implemented in Norway in 2021, interference of any significant effect on the data cannot be concluded. The marking requirement is a measure targeting stage 2 consumer behavior, introduced in stage 1. However, the effect of the mark on marine litter data is impossible to assess, unless production, consumption, time from purchase to marine litter and precise marine litter observations are in place.

While the basis for the SUP Directive is constructed in marine litter data, the analysis must combine consumption, production and litter data to conduct a thorough analysis.

Contrary to marine litter data, which falls victim to population dispersions within the country, mandatory reporting of production and consumption numbers will ensure a representative data source, reflecting the realistic market within the country. This is particularly important as marine litter is able to travel far. Low population densities will therefore reduce the data retrieval possible in such areas, where areas like the Northern part of Norway will have fewer marine litter observations compared to the south.

While it is still too early to conclude on the effects the SUP Directive has had on Norwegian marine litter numbers, it is reasonable to expect that a trend further enhancing the already existing trends seen in the data will be identified in the future. The market is already in the midst of a sustainable transformation, whereas many sustainable measures are already introduced. Even before the SUP Directive was introduced, producers started to swap plastic for other materials in order to appear more environmental friendly, a swap that initially will reduce the number of plastic items found in the marine environment.

4 Discussion: The marine litter problem

As previously discussed, the life cycle of plastics can be divided into three separate stages. During the first stage, the single-use plastic items are produced. Here, the extraction of fossil fuels, design choices and greenhouse gas emission occur. During this stage, the producer also decides what quantity he will provide in the market, and what his market price will be.

Nevertheless, producers and resellers rarely take the externality that results from production, consumption and disposal of the single-use plastic product into account when setting the market price. Consequently, efficiency losses are created in the market from overconsumption in the second stage, while production is kept above the socially optimal level in the first. In combination with very low prices, the utility retrieved from the items creates a high demand.

To correct the market failures, the SUP Directive introduces production bans on certain single-use plastics in an effort to amend the quantity of single-use plastics available within the market. To further reduce consumption, consumption reduction measures are introduced for most items not prone to a complete production ban.

Faulty consumer behavior further exaggerates the issue in stage three. In an attempt to educate consumers and reduce the number of items littered after consumption, marking labels targeting single-use plastics frequently incorrectly disposed of through toilets and general awareness raising measures are introduced.

However, the right to incorrectly dispose of plastic items in the marine environment bears the characteristics of a common pool good. Initially, no agent in the market is assigned the responsibility for ensuring good waste management practices and hinder the destruction of the ocean. By introducing EPR-schemes for the producer, the SUP Directive targets the non-existent responsibility allocation and places it on the producer.

Regardless of efforts diverted towards urban and rural clean-up efforts, some of the waste still finds its way towards the ocean, where it accumulates and degrades the local environment, attracting pests and causing loss of recreational value. And not only is the local environment a victim of single-use plastic pollution - as the waste travels far, marine animal wide and far are entangled in the plastic debris from single-use plastics.

While some consumers will incorrectly dispose of the items due to information asymmetry within the market, others simply do not care, and toilets, beaches and trash bins filled to the brim are chosen as disposal methods. Separate collection measures are introduced, which in combination with informational measures are the measures targeting stage 3 behavior.

A further discussion on the introduced measures by the SUP Directive follows below.

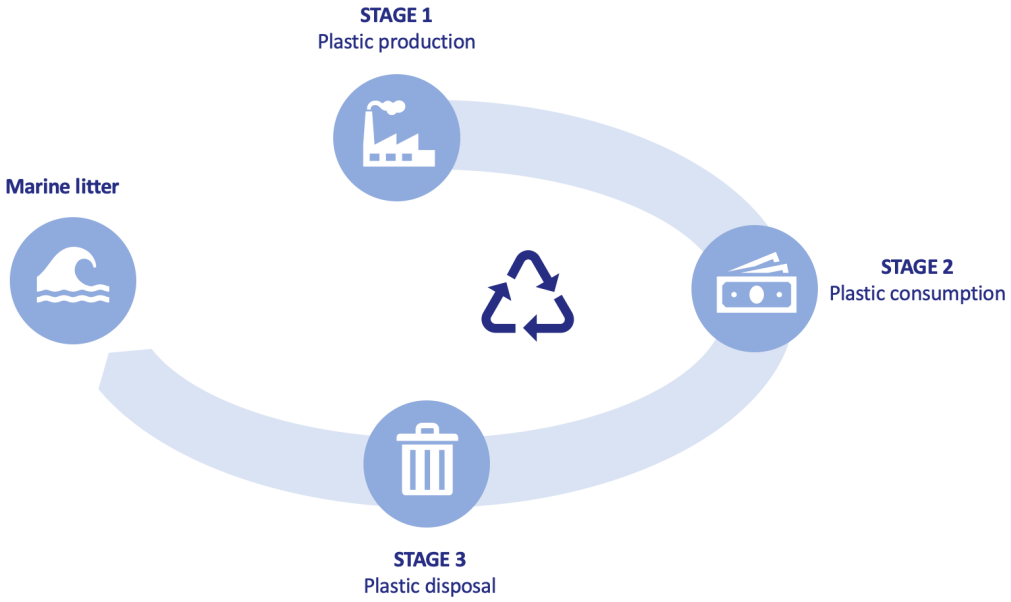

Figure 20 Lifecycle of single-use plastics.

4.1 Stage 1 in the life cycle of plastics

4.1.1 Product bans

Miljødirektoratet has anticipated that the ban of single-use plastic cotton bud sticks, cutlery, plates, straws, stirrers, balloon sticks, EPS food containers, EPS cups, EPS beverage containers, and oxo-degradable items will result in a significant consumption reduction of almost 2 billion units annually (Briedis et al., 2019, pp. 82 - 129). However, the impact of the ban will largely depend on the adaptation effects from consumers and the market, as well as substitution effects between non-plastic and multi-use alternatives. Notably, a report by Norwaste reveals that several Norwegian entities were already proactively addressing issues related to plastic, plastic waste, and recyclability as early as in 2019, even before the SUP Directive was implemented in Norway (Norwaste, 2020). Examples of actions taken towards some single-use plastic items in Norway is the removal, sale at a fee, or discreet placement of single-use plastic cutlery in eateries.

Cotton bud sticks, cutlery, plates, straws, stirrers, balloon sticks, EPS food containers, EPS cups, EPS beverage containers, and oxo-degradable products are all items with great difficulties in recycling, high litter rates, and where it is deemed that the items have sufficient and suitable alternatives to the single-use plastic items. The externalities that arise from production, consumption and improper waste disposal are deemed to be higher than the perceived consumer utility and producer surplus created within the market. As a result, the producer is not willing to price his product according to the total social marginal cost in the market, which is largely driven by the size of the externality, nor is the consumer willing to pay such a price. Consequently, the SUP Directive has covered all these items by a complete production ban in order to eliminate the efficiency loss and negative externalities within the market.

4.1.1.2 Economic impacts

4.1.1.2.1 Command and control measures

Production bans are generally costly in economic terms, as they eliminate all potential social welfare in a market. However, it is important to consider that excessive production and overconsumption of single-use plastic items generate significant negative externalities in the market, including marine litter, greenhouse gas emissions from production and cleanup expenses – which all contributes to social welfare costs. This, in turn, necessitates diverting resources from productive uses, towards litter cleanups, awareness campaigns, and recycling efforts.

Depending on the magnitude of the negative externalities and the practical difficulties with implementing cost-efficient regulations, a production ban can be justified, particularly for items where consumers' willingness to pay is lower than the externalities that come from production and consumption in monetary terms. As a result, the negative externality and efficiency loss created from the production, consumption and disposal of certain single-use plastic items covered by a production ban will be completely removed.

Introducing command and control measures are rarely associated with cost efficiency, as all goods, and not only the ones that will become marine litter, are targeted. If the reduction in externalities resulting from the consumption of single-use plastic items is less than the costs associated with monitoring and compliance with the ban, society will be in a Pareto-improving resource allocation, compared to before. In general, addressing the issue at its core will prove to be more efficient than continuously diverting resources toward addressing the consequences without tackling the underlying causes.

The effect of a command-and-control measure on a market categorized by lower ("normal") externalities, $MEC_{"normal"}$ compared to MEC^{HIGH} introduced in part 3.1.3.2, is ambitious. While a command-and-control measure requiring the implementation of the optimal quantity Q^* will be the most efficient, a complete ban on the product will lead to further efficiency losses in the market. When $P = MPC$, an efficiency loss of $\frac{1}{2}(Q^N - Q^*)(MSC_{"normal"}(Q^N) - P(Q^N))$ occurs. By completely banning production when the externality is "normal", an efficiency loss of $\frac{1}{2}Q^*(P(0) - P(Q^N))$ is created.

Figure 21 shows that the introduction of a partial ban requiring the optimal quantity, Q^*, to be produced in the market results in the most efficient market outcome with no efficiency losses. However, compared to a complete ban, it can be argued that administrative costs in terms of monitoring and compliance will be higher in a market categorized by a partial ban. It is practically infeasible to target only the plastic items that will become marine litter. Due to the high cost and resources needed to chase the optimal quantity, Q^*, a tradeoff between the benefit and associated costs occurs. In reality, the cost of banning only those items that would become marine litter is deemed as too high, and the government is therefore more prone to introduce a full than partial ban.

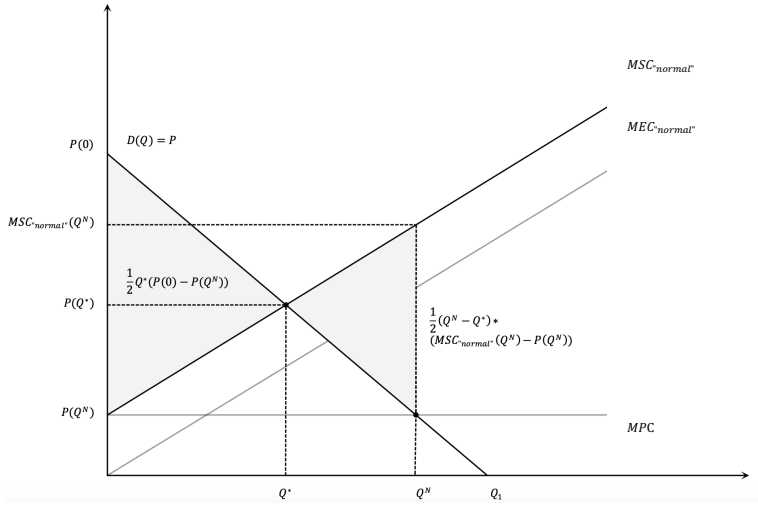

Figure 21 Command-and-control measure in a market with "normal" externalitites

Some of the single-use plastic products covered by the product ban is highly valued by the consumer. Their practicality, convenience on the go and perceived disposability yields a high level of utility. Some examples include the convenience of single-use plastic items for families with young children, field trips or big parties, as well as vulnerable groups more prone to diseases and transmission within. However, in the case of a complete ban, all social surplus generated from consumer consumption at $P = MSC_{"normal"}$ is lost, and a new efficiency loss is created. Whether the market allocation in $P = MPC$ or $Q = 0$ is more efficient, will depend on the market's characteristic, as illustrated in figure 21, which efficiency loss is greater, and the total costs related to the introduction of the ban. As a result, the social surplus generated through a ban might be lost due to high monitoring costs, reduced consumer utility and reduction in firms' profits.

The change from single-use plastics to other alternatives will be cost-effective and socioeconomically profitable if the cost of switching equals or is less than the social cost of the negative externality. The assessment should consider both the externality from mismanaged waste and the carbon emissions associated with a switch to both single-use non-plastic items and multiuse items. Implementing a production ban may be a suitable solution for certain items, provided that the ban will not lead to the substitution of single-use plastic items with alternatives of a worse environmental impact and greater associated externality.

Due to the nature of command-and-control regulations, non-compliance might result in fines or other punishments. As a result, firms will focus efforts towards ensuring that the defined limitation is not exceeded, rather than pursuing more environmental friendly or efficient production alternatives. The limitation does not foster innovation, and greatly reduces the firm's incentive to go beyond any requirement. As a result, the possibility of innovation and social surplus is lowered within the market. Therefore, many policymakers prefer market-based tools over command-and-control measures, as these will provide economic incentives to reduce the negative externality, while allowing the firm flexibility in how to do so.

4.1.1.2.2 Price sensitive consumers and elastic markets

Production of single-use plastic items is relatively cheap compared to other substitutes made from cardboard, wood, glass or metal. The shift from single-use plastic to other materials will therefore increase costs for most producers, as we can assume that both multiuse and single-use non-plastic alternative are more expensive to produce. Depending on the price elasticity of the consumers in the market, the cost increase will be split between the consumer and the producer through the price, which acts like an informational instrument.

All single-use plastic items covered by the product ban are deemed to have suitable alternatives available. As previously discussed, some swaps have already been made in anticipation of an anti-plastic legislation, while other swaps have been made in accordance with consumer expectations and the wish for producers to be promoted as sustainable. We live in a world where "sustainable" marketing from a brand is the expectation, and where the absence of this type of marketing will be negatively perceived by most consumers. As a result, it can be inferred that consumers of single-use plastic items covered by a product ban will have had some time to explore the different options, and adjust behavior according to their needs and requirements, before a complete production ban was introduced by the SUP Directive.

The availability of substitutes within a market will affect the price sensitivity of consumers and elasticity of demand within the market. If the consumer has many options of different prices, some time has passed, and he has already adjusted to product bans or swaps, his demand curve will be more elastic. For other items where a ban or price increase is introduced relatively sudden, the demand curve will be rather inelastic in the short run, as the consumer will need some time to adapt to the new market and figure out suitable substitutes. Inelastic markets will be further discussed in section 4.1.2.1.

Contrary to other single-use plastic items not covered by a production ban (plastic cups, takeaway food containers, beverage bottles, sanitary towels and tampons, wet wipes, tobacco filters, food packets, lightweight plastic bags and balloons), the market for single-use plastic substitutes is categorized by a more elastic demand curve. Consumers will chase the cheapest substitute that yields the highest perceived utility. As a result, firms and producers must be more competitive, and cannot uncritically raise their prices due to increased costs without expecting a loss in consumer mass. As shown in figure 22, an increase in the price due to increased costs for the producer will result in a relatively big decrease in demand. It is therefore important that producers operating within this market continues to innovate to increase consumers' willingness to pay, but also to continue to lower his marginal costs of production.

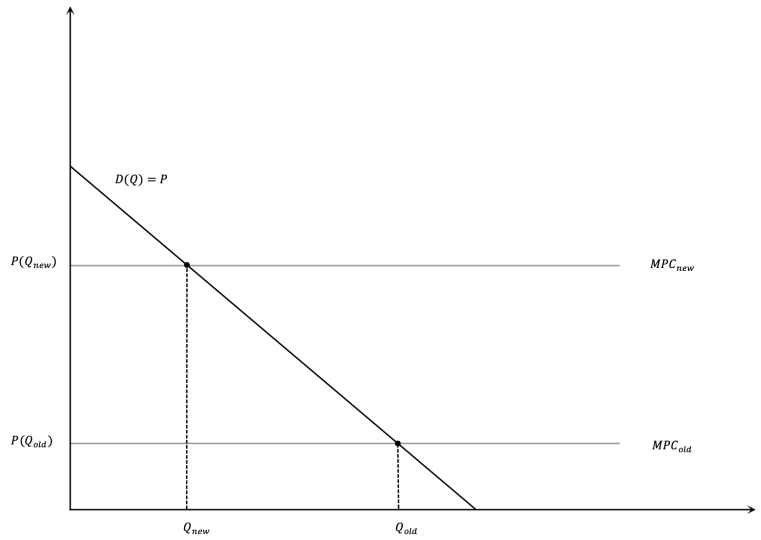

Figure 22 Elastic demand of single-use plastics and their substitutes.

While some producers of the targeted single-use plastic items may experience losses due to the production ban, others will experience gains – especially producers of the substituting alternatives. Importantly, for certain manufacturers, the ban could stimulate innovation within the market. Those who wish to continue must adapt, revamp their businesses, and explore new production areas.

4.1.1.3 Discussion

4.1.1.3.1 Plastic straws

Plastic straws are one of the items subject to a product ban. In Norway, there are mainly two different types of non-single use plastic straws. These are paper straws, which you will be given at coffee shops and restaurant, and multi-use straws made from metal, bamboo or hard plastic. These substitutes do not have the same consumption qualities as plastic straws, as they are either short-lived or difficult to clean. The reduced quality of the product might reduce the use of straws, and hence less littering potential. In addition, multi-use items are less prone to become litter due to their reusable nature, higher price and design features. Paper straws as a non-plastic substitute, is on the other hand still prone to become litter. Contrary to plastic, paper will degrade in nature after some time, and is therefore less likely to become *marine* litter. As a result, substituting single-use plastic straws with other non-plastic alternatives will likely lower the amount of waste entering the marine environment.

4.1.1.3.2 Cutlery, plates and EPS cups

Single-use plastic cutlery, plates and EPS cups are convenient items, but are all items with equally good substitutes The main non-plastic substitution alternative to single-use plastic cutlery in Norway, is wooden cutlery. While the substitution has been seamless, their wood-like taste and poor quality has been reported to provide disutility to the consumers. Only EPS cups, and not plastic cups, are subject to a product ban. Single-use plastic cups would be a substitute to EPS cups. For single-use plastic plates, the substitution of plastic to other materials is seemingly effortless. Compared to cutlery and cups, which goes into the mouth, the material a single-use plate consists of is not so important.

A multiuse alternative to single-use cutlery, cups and plates will be to bring your own metal cutlery, multiuse cup or plate. However, having to remember to always bring such items from home is hard, and most people will probably forget at some

point, or simply not undergo the hassle of carrying your own multiuse product, because the cost is perceived as too high. While bringing multiuse cutlery could be reasonable due to the small size of the products, carrying a cup or plate would be rather excessive, particularly when considering their size and the inconvenience. However, the consumption of some EPS cups can most likely be substituted with drinking straight from a bottle, or by bringing your own reusable water bottle, a quite common item to bring. As multiuse alternatives are less likely to become marine litter, and wooden utensils will degrade as some point, marine litter will most likely be reduced, even though the total litter number could be increased.

4.1.1.3.3 EPS takeaway food containers, EPS cups and EPS beverage containers
Single-use expanded polystyrene items are all banned as the material is particularly hard to recycle, fragments easily into smaller particles and microplastics and have several available substitutes. Other single-use plastic items, non-plastic and multiuse items are available substitutes within the market.

EPS takeaway food containers will most likely be substituted with paper takeaway boxes, plastic containers made from other plastic alternatives or multiuse alternatives from home. For EPS cups and containers, the most likely single-use substitute will we single-use plastic cups or paper cups with a plastic lining. There is also the option to bring multiuse cups from home, but this alternative is less likely to properly substitute the EPS cups.

One particular unintended consequence of the ban on EPS containers and cups, is the substitution of EPS to XPS materials. The SUP Directive does not impose any restrictions on Extruded Polystyrene (XPS). It is part of the foamed polystyrene family and can be used and substituted with EPS in disposable packaging and fast-food containers. As a result of the Directive not imposing any restrictions on XPS products, several European companies have announced that they are making a switch from EPS to XPS based products (Troya et al., 2022). As with EPS, the material cannot be properly recycled, and substitution to this material could potentially lead to no change in litter numbers for EPS takeaway containers covered by the SUP Directive.

4.1.1.3.4 Stirrers, cotton buds and balloon sticks
The substitution of these items is assumed to be effortless. Coffee stirrers have been made from wood in Norway for a long time, and are not as frequently consumed as in other countries. Cotton buds with a non-plastic cotton stick yields the same quality and utility as a plastic stick cotton bud, and there is no assumed difference in litter numbers. Paper cotton bud sticks will dissolve in the sewage system after a while. Balloon sticks are not frequently consumed in Norway, and the effect is assumed to be insignificant.

4.1.1.3.5 Oxo-degradable plastic items
The Single-Use Plastic Directive bans all oxo degradable plastic products. While these items are not specifically emphasized amongst the most commonly found items on European beaches, they are subject to a product ban due to the material's inability to properly biodegrade or compost, its negative effects on recycling, and its non-existent environmental benefit, compared to conventional plastics (Aldas et al., 2018; Directive (EU) 2019/904, 2019).

Oxo-degradable plastic is a plastic material mixed with additives, constructed such that it will oxidate and degrade into micro fragments over time. In order for oxo-degradable plastics to properly degrade, sufficient sunlight, oxygen and heat is required (Break Free From Plastic, 2022). However, studies show that these conditions are rarely in place in the real world, and as a result, oxo-degradable plastic usually persists in the environment for years (European Commission, Directorate-General for Environment et al., 2016;Thomas et al., 2012)On the other hand, when the conditions are in place, and fragmentation occurs, oxo-degradable plastic items will fragment into micro plastic particles, which are known for its harmful effect on human and wildlife health.

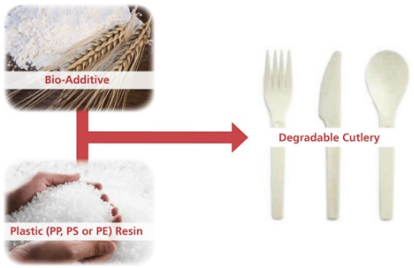

Figure 23 Illustration of oxo-degradable plastics. From Oxo-Degradable Plastics, by Natur-Tec, n.d., Natur-Tec (https://naturbag.com/oxodegradable-plastics/). Copyright 2023 by Natur-Tec.

Furthermore, oxo-degradable plastic items are commonly advertised as "compostable" or "biodegradable" by the industry, which is highly misleading (European Commission, 2018c). As a result, consumers might compost these items at home, or throw them out in nature due to its "degradable" nature. However, oxo-degradable plastics are not compostable. While compostable plastic can become organic matter if properly disposed of, oxo-degradable plastics will either not degrade or end up as microplastic if composted. A survey conducted in Germany underpins this point, as 58 % of respondents thought that all 'bioplastics' were compostable (Blesin et al., 2017, cited in European Environment Agency, 2020).

The presence of oxo-degradable plastic in Norway is minimal. Interviews conducted by Mepex indicate that oxo-degradable plastic is only used for chin supports for deceased individuals, waste bag dispensers for dog waste disposal, and oxo-degradable trimmer lines (Mepex, 2019). Although a limited number of oxo-degradable plastic bags were previously imported, their quantities are diminishing. Therefore, the overall impact of the ban on producers in this category is expected to be negligible. However, the ban of oxo-degradable plastic is expected to give rise to positive externalities from increases in material recycling and the reduction of micro plastic litter due to the fact that oxo-degradable plastic cannot be recycled with conventional plastic and will contaminate any plastic recycling that otherwise would have been recyclable.

4.1.1.4 Predicted effects from the product ban

It is predicted that the Directive will impose additional costs for consumers and retailers within the takeaway segment, however, the number is limited to a maximum of 80 NOK per costumer a year. *Miljødirektoratet* has estimated that a switch from single-use plastic items to multiuse plastic items will reduce the total number of waste entering the marine environment by 76 tonnes, while emissions of greenhouse gasses will decline by 228.000 tonnes CO_2. The total savings in external costs is calculated to equal 2.6 billion NOK annually and is achieved

even though multiuse food packaging and sanitary items require drastic increases in water consumption due to their need for washing. The net cost from the transition will equal 3.5 billion NOK in savings. The externality is calculated as the monetized value in 2018 real term NOK of the total change in greenhouse gas emissions from reductions in total production of items, additional washing of multiuse items, decreases in recycling numbers due to less disposal (recycling) and therefore less energy generated from items sent to incineration (EfW), and further decreases in terrestrial and marine litter. The total production costs consist of less land and more water required for production and cleaning and total number of employees required, while other costs are related to less sales due to multiuse, the operation of refill schemes, recycling and litter clean-up costs (Briedis et al., 2019, p. 59).

However, the report only views a 100% switch to multiuse items as possible for cotton buds, straws, stirrers, cutlery, balloon sticks, wet wipes, tampons and applicators and sanitary towels. EPS take-away containers could possibly be abandoned, and some lightweight plastic bags substituted with non-plastic or multiuse alternatives. However, for sweet wrappers, drink bottles with caps and lids and drink cartons, a switch to multiuse items is deemed unlikely, but a switch to single-use non-plastic possible. A switch to single-use non-plastic items will reduce the amount of plastic litter entering the marine environment by a total of 56 tonnes. Greenhouse gas emissions will be reduced by 950.000 tonnes and the total overall externalities by 2 billion NOK. A swap from single-use plastic to single-use non plastic will increase the costs for the consumer, especially when considering drink containers. As a result, a switch from single-use plastic items to single-use non-plastic items will reduce the externality less, compared to a complete switch to multiuse items (Briedis et al., 2019, p. 57).

4.1.1.5 Impact on marine litter:
The substitution from plastic to other single-use items made from alternative materials like paper or wood could potentially lead to increased littering because the materials may be perceived as organic and degradable. However, overall, a production ban is assumed to drastically reduce the number of marine litter entering the oceans.

On the other hand, while bans can be effective in reducing the quantity provided and consumed within the market, it may not necessarily be enough in itself to address the issue of littering occurring in stage 3 of the plastics lifecycle. To reduce littering, and then marine litter, other attitude changing measures must be implemented. A further discussion of measures targeting behavioral change appearing in stage 2 of the single-use plastics lifecycle can be found in section 4.2.2 and 4.2.3.

4.1.2 Design requirement

To reduce the number of littered bottle caps within the marine environment, the SUP Directive requires all PET bottles to be designed such that all caps will be attached throughout the bottle's whole life cycle. This is a measurement directly targeting stage 1 in the lifecycle process, namely the producers design stage, intended to adjust consumer behavior and waste numbers in stage 3. The design requirement is introduced to enforce consumers to internalize the externality that comes from wasteful consumer behavior. Bottle caps are very lightweight, and once lost or incorrectly disposed of, have an easy way towards the ocean and marine environment. As the cap is required to stay attached to the bottle throughout the whole lifecycle, the SUP Directive expects that marine litter numbers from disposal of bottle caps will be reduced.

4.1.2.1 Economic impact

To comply with the new bottle cap design requirements, it is to be expected that most bottle producers must invest in new technology, machines or allocate funds towards the design process, all which will constitute a significant cost increase for the producer. The design process, and the associated costs, are particularly important to ensure that the renewed design does not cause more disutility than necessary for the consumers within the market.

The cost increase of the design requirement will be split between the consumer and the producer, depending on the price elasticity within the market. In a market categorized by non-price-sensitive consumers, a greater share of the cost increase can be transferred to the consumer. The inelastic demand curve then allows the producer to increase his price in accordance with his increasing marginal costs of production, only experiencing a relatively small reduction in consumer demand. Consequently, he might be able to retain a profit, as illustrated in figure 24.

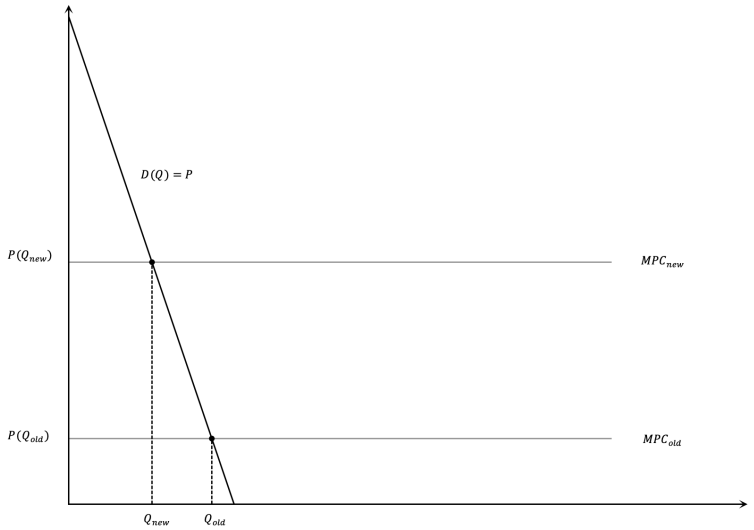

Figure 24 Inelastic demand of single-use plastic bottles.

In the short run, there will be few other alternatives to soda bottles with the attached caps. While some substitutes are available, like soda cans or soda bottles, the convenience of a soda bottles with a cap that can be closed, is currently irreplaceable in the same manner. However, over time, the market might adapt, and innovation occur. Reusable lids for bottles and cans already exist and might become more widespread in the long run. Further, consumers might start to bring

their own reusable water bottle, as a substitute to purchasing water bottles with the new cap. However, neither juice bottles, nor milk cartons etc. do have current appropriate substitutes. It is therefore assumed that while the market will adapt and become more elastic over time, the substitution effects within the market are inferior, and it is therefore assumed that the bottle market will stay relatively inelastic, also in the long run, if no drastic design innovation occur.

While a current inflation of 3.3% has led prices to increase in all sectors within the country, the price of mineral water, soft drinks and juice increased by 7% the last year (Statistics Norway, 2023a, 2023b). Though it is not possible to blame the price increase on design measures introduced by the SUP Directive, it might have affected the market price facing the consumer due to increased costs for the producer from the new design and compliance requirements. Because the market is relatively inelastic, the new price will be accepted by the consumer, due to their high valuation and utility from the product.

As a result, most of the financial burden from complying with the SUP Directive is shifted onto the consumer. As it is the consumer that litters plastic bottles and lids, placing the financial responsibility of ensuring that the cap stays attached to the bottle on the consumers, appears to be correct. placement of responsibility. However, consumers, regardless of their faulty disposal behavior and methods, are not to blame for improper infrastructure, for example in countries categorized by the lack of appropriate deposit return schemes.

4.1.2.2 Discussion

Within Europe, caps are found to be one of the most littered items in beach litter data. However, numbers from *Hold Norge Rent* shows that littered caps and lids only constitute about 3% of all waste in Norway in 2022. The waste numbers stem from both urban and marine litter clean ups. Norwegian beach litter data further emphasizes that point, showing that caps and lids only make up 9% of the littered targeted single-use plastic items within the marine environment in Norway. Compared to a European level of 5,26% in the marine environment in 2016, or 18,90% of the littered targeted single-use plastic items, the Norwegian numbers are small.

In Norway, marine litter estimates show that bottles entering the marine environment equals 38% of the total littered targeted single-use plastic items. European data, on the other hand, shows that plastic bottles equal a total of 6.15% of the total littered targeted single-use plastic items. It appears that even though Norway has a very well-functioning deposit system, where 92,8 % all PET bottles are recycled and 98% of the recycled bottles still have their cap attached when they are recycled, many bottles and loose caps still make their way towards the oceans.

As the issue is present, it must be tackled with global efforts. As bottle caps are extremely lightweight, the caps have a great opportunity to travel far, once transported to the marine environment.

The reduction of consumer utility from the new bottles' designs, is heavily debated on social media. See for example the comment section in godt.no (2022). While some consumers show their support towards an environmental policy aiming at reducing marine litter, the majority is expressing their utmost

dissatisfaction, with consumers even claiming that they will rip the cap off the bottle as soon as possible after the purchase. The design measure is comparable to the introduction of wooden spoons or paper straws. While these were annoying and yields less utility than the original single-use plastic spoon or straw, it has been possible for most people to get adjusted to the new cutlery over time. No substitutes yield no alternatives, and as a result, the desire for continued consumption means that the current alternative must be accepted amongst the consumers.

Further, if consumers experienced a utility decrease from the new bottle design where the market price would exceed the perceived marginal benefit from consumption, then no market would exist. As a marked does exist, it can be interfered that while the new design causes great disutility amongst the consumers, the majority will learn to adapt in the long run. However, for some consumers with navigation difficulties due to age or health, the disutility caused from the new designs could be tremendous.

4.1.2.3 Impacts on marine litter

It is evident that loose caps and lids is a problem in Europe and Norway. As the bottle cap now has to stay attached, the possibility for future loose caps is the marine environment is lowered.

However, the requirement does have potential to introduce further unintended negative consequences. While the design measure in itself is meant to reduce the number of caps and lids that are littered and ends up as marine litter, the new caps could be more prone to wasteful behavior, compared to a pre-legislation cap. Particularly because consumers report great disutility from the inconvenient design, resulting in consumers purposely ripping them off.

If the cap is detached from the bottle before disposal, it is further prone to become litter, and will not stay a part of the recycling loop. Caps that are not attached to the bottle when recycled in the deposit scheme, will most likely get lost in the recycling system, and as a result be sent for incineration. It can be assumed that a consumer ripping off a cap in affection will not be very cautious about where he disposes of it. If the bottle and cap is not recycled within the deposit system, a cap on the loose might easily fly away, and is thus more likely to become marine litter.

4.3.2 Extended Producer Responsibility schemes

In the single-use plastic market context, the act of dumping and littering the oceans can be regarded as a public good or right, leading to free riding and a lack of responsible consumption patterns amongst consumers within the market.

To resolve some of the issues related to overconsumption, the SUP Directive introduces consumption reduction measures (discussed in section 4.2.1) and product bans, reducing the quantity of single-use plastics in the market, but also the generated amount of marine litter that arises from consumption. In a further attempt to allocate responsibility for the lifecycle of single-use plastics, Extended Producer Responsibility (EPR) schemes targeting all three stages of the plastics lifecycle is introduced for the producers.

The introduction of an EPR scheme can be interpreted as a property rights allocation, where the producer is assigned the responsibility of the total costs arising from the negative externalities of production, consumption and mismanaged waste from single-use plastics. Specifically, the SUP Directive enforces the producer to cover the costs related to awareness raising, waste collection, clean up and data collection if he wants to provide his goods in the market.

4.3.2.1 Responsibility placement

While it is reasonable to place some of the responsibility on the producer, the responsibility for the externalities related to single-use plastics is two folded. First, there is the actual plastic production process that relies on fossil fuels, will release greenhouse gasses, produce non-recyclables and generate waste. Here, the responsible agent for the whole production process is the producer.

Furthermore, the producer sets an incorrect market price, selling items at a very low price, or giving them away for free. He does not cover the total social cost of single-use plastic items in the market, only his private production costs. However, it is expected that these items will be priced relatively cheaply, and as a result, consumers in the single-use plastic market have an accordingly low willingness to pay. If the producer wants to participate in the competitive market, he must set a low market price on his goods.

While the producer is responsible for choosing the correct market price, it is evident that consumer expectations within the market is driving the price down as well. Consumers are accustomed to retrieve the items for free or purchase them at a very low price. Because there is a price cap expectation, consumers will not purchase the product, unless it is within the expected price range. Thus, demand for pricier single-use plastics will fall, and producers must adapt by lowering the market price. As a result, we see that the set market price is determined by the market power between the agents in the single-use plastics market.

Secondly, there is consumer behavior. Consumers excessively overconsume the goods compared to the social optimal level, generating large numbers of marine litter in the process. While the overall society benefits from clean oceans, individual agents retrieve utility from the availability of oceans as a dumping spot, either by direct littering or indirectly by faulty wasteful behavior. One can even view the act of purchasing a single-use plastic item as a wasteful choice due to the

release of greenhouse gasses from production and the possibility the item has to become marine litter.

Participation in beach litter clean-ups, time spent exploring reuse alternatives, purposely lowered consumption or careful disposal of plastic items are all actions lowering the impact of consumption, and thus the negative externalities that follows from consumption. However, as with a public goods market, only some agents within the single-use plastic market take responsibility for the externalities they are causing in the market, while others choose to free ride on their efforts.

Some agents may choose to free ride on the efforts of other agents due to the high cost associated with taking the correct choice, or because they are unaware or uneducated due to information asymmetries in the market. Consumer costs related to allocation of the closest trash can, research on how to properly dispose and recycle a product, or the inconvenience of bringing trash home, may be perceived as very high for some, and in total, greater than the utility of taking the correct and environmentally correct choice. More information about asymmetry reducing measures is found in paragraph 4.2.2.

To reduce the perceived costs for the consumers, solutions could be to allocate more trash cans in the public space and ensure good waste collection management is areas with high activity during specific season, or all year around. This would particularly relate to recreational areas like park, the beach and other areas where consumers will gather, eat and drink together, particularly during the spring and summer season. While the SUP Directive does target waste infrastructure, the only objective of the measure is plastic bottles.

On the other hand, some consumers will unintentionally free ride on the sustainable actions of agents within the market. These will be consumers that have wasteful behavior because they lack complete information about waste disposal methods, recyclability and the effect that their individual actions will have on marine litter numbers.

In 2019, plastic production only represented 3.4% of the total global greenhouse gas emissions. While plastic production in itself does not contribute to major greenhouse gas emissions compared to other industries, plastic consumption and production does lead to enormous marine litter (OECD, n.d.)waste numbers, which is a correlated, but separate issue. However, it is reasonable to assume that some consumers will regard their efforts towards greenhouse gas emission and marine litter reductions as negligible in the big picture. As the issues are heavily intertwined, many might overlook the individual effect their actions have on marine litter numbers. This group will therefore free ride on the efforts of others, not purposely to avoid doing the work, but because they do not believe their actions have any effect or make any impact. Therefore, this group will be an important group for the government to target through awareness raising measures, attempting to alter consumer behavior, as discussed in section 4.2.3.

4.3.2.2 Introduction of an EPR scheme in the market

According to the Coase theorem, the introduction of property rights through the EPR scheme should resolve the inefficiencies within the single-use plastic market through bargaining between the agents (Coase, 1960). However, the introduction

of an EPR scheme is a mix between a property rights allocation and Pigou tax through the addition costs laid on the producer.

While the EPR scheme does not introduce an optimal Pigou tax, additional costs are laid on the producer, increasing his private cost of production. No firm will want to participate in a competitive market with many other players if the price of his product is below his marginal costs, unless he can gain any long-term benefits from the low price level. As a result, the introduction of additional costs through the EPR scheme will increase the producers' costs, and as a result, the price level of the targeted single-use plastic items (plastic cups, covers and lids, takeaway containers, beverage containers, wet wipes, tobacco products with filters and filters, food packets and wrappers, lightweight plastic bags and balloons).

It must be noted that the EPR scheme only requires the producer to cover costs related to cleaning up litter and distributing of information to the consumer. He is not required to take any actions towards the reduction of marine litter in itself but might experience a total cost reduction due to the cost-effectiveness of proactive action.

As the market price increases, consumer demand will drop. The final market price and demand will depend upon the elasticity within the specific single-use plastic item market, as discussed within section 4.1.1.2.2 and 4.1.2.1 Regardless, some of the additional costs from the EPR scheme will be transferred to the consumers through increased prices, more in markets with non-price-sensitive consumers and less in markets with price-sensitive consumers.

Firms have incentives to improve efficiency in the market if they can gain any profits from it. Increasing the cost of harmful products will initiate innovation and incentives to introduce more environmentally friendly items to gain profits and market shares in the continuously developing market that will replace single-use plastic items. Therefore, it might be valuable for the producer to shift his production from items covered by the EPR scheme, to other non-covered items which might yield greater profits due to total cost reductions.

A switch from the production of single-use plastic items to more sustainable options are in line with the responsibility placement from the EPR scheme on the producer. While the responsibility is transferred to the consumers through increased prices, producers are the first agents that have to deal with the cost increase, and such, the first respondent to the cost increase, shifting production towards more sustainable options.

4.3.2.3 Marine litter effects

In combination with awareness raising measures, production bans and consumption reductions, demand might permanently shift from consumption of single-use plastic items to other more sustainable options. Depending on the availability of other substitutes, and whether these are non-plastic single-use or multiuse items, waste numbers will therefore also decline, due to less consumption of on-the-go items, and the less wasteful nature of multiuse items.

However, to ensure a substantial and lasting reduction in waste numbers, consumption of single-use plastic items must not be substituted with products in other materials equally contributing to the waste problem. Further, to ensure free

riding within the single-use plastic market is diminished, measures targeting consumer behavior must be implemented. Agents must be explained why their behavior is bad, and how they can improve. However, it must be noted that informational campaigns will not resolve the issue of free riding altogether. To properly eradicate such harmful behaviors, systems and policies punishing faulty behavior and rewarding correct behavior should be considered, like the existing deposit scheme for plastic bottles.

4.2 Stage 2 in the life cycle of plastics

4.2.1 Consumption reduction measures

While other single-use plastic items are subject to a complete production ban (cotton bud sticks, cutlery, plates, straws, stirrers, balloon sticks, EPS food containers, cups, beverage containers, and oxo-degradable products), single-use plastic cups and takeaway containers are only subject to a partial ban, referred to as a consumption reduction measure in the SUP Directive. The items are not considered to have appropriate sustainable substitutes, and are therefore only subject to a measure requiring a consumption reduction. Regardless, consumption of the items comes with great externalities that are not accounted for within the market, and wasteful behavior that no agent is taking on the responsibility for too. Therefore, previous discussion regarding externalities in section 4.1.1 applies to partially banned single-use plastic cups and takeaway containers as well.

Particularly, the effect of increasing the plastic bag tax while inflation is high, and new waste disposal bags must be paid for. As a result, the substitution effects from consumer behavior can be observed in the market. The inconvenience, price and disutility from purchasing new bags is shown in the amount of wrong plastic bags used for disposal. Households are therefore substituting expensive grocery bags with free organic waste and recycled plastic bags.

Similar effects might be observed through the restrictions of single-use plastic items. While the SUP Directive is not imposing any tax on the consumer, price levels of substitutes are expected to be higher than single-use plastic prices, particularly because of more expensive materials, increased extended producer responsibility (EPR) schemes and specific design requirements. A further discussion around increased producer costs can be found in section 4.3.2.2.

Unintended consequences may appear from measures targeting sustainable behavior. A recent example shows that while the tax on plastic bags recently have been increased in Norway, a drastic increase within the number of organic waste and recycled plastic bags that are now incorrectly used to dispose of general household waste has been observed within the capital, Oslo. While the increased plastic bag tax is introduced to incentivize consumers to purchase less new plastic bags at the grocery store, the extent to which the bags have been reused as waste bags and the associated convenience these shopping bags constituted by always being available in the household after grocery shopping, may have been underestimated by policy makers.

4.2.1.1 Discussion

The SUP Directive does not put any restrictions on how the consumption reductions should be achieved. However, to achieve a substantial and persistent reduction, it is expected that the producer must use the market price as a tool to regulate overall demand. Single-use plastic cups and takeaway containers will therefore most likely experience a price increase in the short run. The result of the consumption reduction measures will highly depend on customers reaction to the price increase, and the substitution effects between the different single-use plastic, single-use non-plastic and multiuse items.

4.2.1.1.1 Coffee cups
Within the context of the SUP Directive, all single-use takeaway cups, paper or plastic, that partially consists of plastic are considered single-use plastic cups covered by the consumption reduction measure. This is due to the fact that paper cups usually will have a thin plastic coating or wax layer to hold hot beverages or keep dirt away. Immediately, single-use coffee cups are considered a necessity when purchasing take away coffee, or other drinks on the go. This means that the demand curve will be relatively inelastic in the short-term, as illustrated in figure 24 in section 4.1.2.1.

The price increase will therefore lead to a slight reduction in consumption of single-use cups at first. However, over time, consumers will adjust to the new market and find other alternatives, for example to bring their own multiuse cup. Demand for single-use plastic coffee cups is therefore expected to become more elastic over time, and demand to decrease.

Items that customers substitute with other multiuse items they already own will experience a decrease in demand. Typically, this will be seen for multi-use coffee cups. Several coffee shops have implanted schemes that gives out price deduction if you bring your own reusable cup from home. As a result, substitution effects will be strong for multiuse coffee cups, and a somewhat reduction in demand for single-use coffee cups will be seen. However, the multiuse coffee cup is big, and sometimes impractical to bring. Multiuse coffee cups will need to be washed between each use, and for some households, this will require that they do own an unreasonable number of multiuse coffee cups, if takeaway coffee is purchased daily. As a result, it is to be expected that these households will substitute some of the plastic single-use coffee cups for multiuse coffee cups, but not all.

4.2.1.1.2 Other cups
Single-use plastic cups meant for other consumption besides take away coffee, will experience a similar change in demand and consumption. Single-use plastic cups meant for picnics or outdoor activities might be substituted with other cups brought from home. However, there are currently no good single-use non-plastic substitute available. As the necessity of other single-use plastic cups is not a prominent as for coffee cups, demand is estimated to be more elastic, as illustrated in figure 22 in section 4.1.1.2.2. An increase in the market price will lower total demand in the market, as price-sensitive consumers turn to other substitutes. Because single-use paper (plastic) cups may be perceived as degradable in nature, a shift from single-use to other multiuse alternatives will reduce the amount of marine litter that might stem from outdoor activities – e.g., picnics or hikes.

4.2.1.1.3 Takeaway containers:
Substitutes to single-use plastic takeaway containers are paper takeaway boxes (without a plastic lining), multiuse plastic containers, or other food containers that households have at home. These could for example be lunch boxes, or reused ice cream containers. However, besides for bringing your own lunch, such containers are big and impractical to carry around. As the current substitutes that consumers can bring from home or purchase elsewhere are limited, demand for take away containers from restaurants and coffee shops will be high, and is not perceived to decline in the foreseeable future. Due to the high demand, innovations must occur within the industry.

One example of an innovative firm is the restaurant ASIA at Aker Brygge which introduced recyclable multiuse plastic take away containers in collaborations with *GRIN in 2021 (Yildirim, 2021).* When ordering take away, consumers had to pay 50 NOK per takeaway container, which were reusable and could be deposited in a box outside the restaurant. The money was then immediately returned to the customer. The multiuse boxes could be washed and reused approximately 200 times, which drastically reduced demand for new plastic takeaway containers. However, consumers did not to return the boxes, and the project was discontented.

4.2.1.2 Marine litter impact

As with single-use plastic items subject to a complete production ban, for items covered by a consumption reduction measure, significant decreases in marine litter are expected. However, the total marine litter impact will depend on the item that the consumer chooses as a substitute.

4.2.2 Marking requirements

While consumption reduction measures, product bans and EPR schemes target reductions in production and consumption, and assigns responsibility, informational measures must be implemented to adjust behavioral norms and habits amongst consumers within the single-use plastics market. As a result, the SUP Directive introduces marking requirements in the form of an information label that must be placed in certain single-use plastic items (cups, sanitary towels and pads, wet wipes and tobacco products with filters and filters). The mark informs consumers that the product contains plastic, and how incorrect disposal will harm marine animals. Cups, sanitary items, wet wipes and tobacco products all have to bear the mark because these items are frequently flushed down the toilet or improperly disposed of, and thus have a high likelihood of becoming marine litter.

The information label is introduced to amend faulty consumer behavior happening between stage 2 and 3 in the life cycle of plastics, in the moment where the consumer makes a decision about which disposal method he will use. In collaborating with the introduced awareness raising measure, the information label targets the asymmetry within the market. Informed consumers will make socially more optimal choices, compared to uninformed consumers.

Some agents will choose inappropriate waste disposal methods. This can happen because he finds it hard to understand what the appropriate disposal method is, because his whereabouts lack the required infrastructure, or because he might feel like one incorrect action (wrong disposal of a single-use item) does not matter in the big picture.

4.2.2.1 Discussion

Some public facilities lack the necessary infrastructure to ensure correct disposal, such as trash cans, toilet paper, a sink to wash your hands or soap. As a result, sanitary items might be flushed down the toilet, both because there are no other disposal options, but also because one might not want to deal with the item if there is no way to clean your hands afterwards. Carrying used sanitary items is also uncomfortable, and as a result, these items might get thrown away when used during outdoor activities and hikes if no appropriate disposal method is in place.

Furthermore, insufficient infrastructure is a critical issue contributing to marine litter, where even items properly placed in trash bins may find their way into oceans. In urban areas, overflowing bins exposed to wind and weather can direct debris towards waterways, eventually reaching the oceans. Similarly, in rural settings or recreational spots with irregular trash collections, litter is often left behind in nature, posing a threat to marine environments. The challenge extends beyond consumer behavior, as the market lacks the necessary infrastructure to handle waste streams effectively. Therefore, there is a pressing need for improved waste collections, availability of trash bins, and enhanced recycling infrastructure, particularly in high-activity public spaces. Governments play a pivotal role in addressing these challenges and should prioritize the establishment of effective waste management systems to mitigate the impact on marine litter.

4.2.2.2 Marine litter impact

Some items, like see through plastic cups, obviously contains plastic. However, to abide by the SUP Directive, the cups will need to have a mark informing

consumers about their plastic content, and a warning against incorrect disposal. For items like plastic cups, the informative mark will most likely not amend consumer behavior. However, the label can serve as a reminder of that plastic litter can hurt marine animals. The mark does show a picture of a turtle, which most likely is there to nudge the brain, and play on the consciousness. The mark might remind the agent about pictures of turtles and other marine animals with straws and other plastic debris through their nose.

Figure 25 See through single-use plastic cup with required plastic information label. From About SUP Labels, by Food Delivery Packaging, n.d. Food Delivery Packaging (https://www.fooddeliverypackaging.ie/pages/about-sup-labels). Copyright 2023 by Food Delivery Packaging.

As the idea to play on consumers consciousness through a turtle mark is good, the number of labels put on all consumer goods is high, and the probability of that the label will drown amongst other marks is high. As an unfortunate consequence, the information distribution from the informational label is low.

Plastic content of other single-use plastic cups is not always as obvious. One example is takeaway coffee cups, which do have a plastic lining on the inside. In that case, the plastic information label could lead to a change in consumer behavior, because consumers now are informed about the products plastic content. As a result, the amount of correct disposal may increase, mainly because the coffee cup will not be sorted for recycling (where it will deteriorate the quality of the recycled paper materials), but also through proper waste disposal. Consumers in urban areas, hikers or campers might not leave coffee cups in the urban environment or the wild, thinking that these will degrade fast due to them only consisting of paper.

Tampons and sanitary pads are items considered to be frequently flushed down the toilet, and therefore subject to the information label – if they contain plastic. Many tampons do have a plastic film to reduce fiber loss and make insertion and removal easier. While the mark could potentially help consumers realize that tampons and sanitary pads themselves contains plastic, these items are often carried outside their packaging, or used in a rather rushed setting. As the information mark should be plastic on the outside of the packaging, the likelihood of the consumer observing the mark during the short period of use, is small. However, because these items are frequently flushed, the consumer might choose the correct disposal method if the mark is observed.

One product that might benefit from the plastic information mark, is wet wipes. Wet wipes are also frequently flushed in the sewer system. Manufacturers even promote these as flushable. As wet wipes must be contained within their packaging to be usable, the likelihood of the consumer observing the mark before use is high. The plastic mark could therefore potentially ensure that some consumers choose to properly dispose of the items, particularly in a setting that is not rushed.

Cigarettes are a tobacco product with filters containing plastic, and also subject to the information label. However, these items do already bear a huge mark

informing the consumer about the consequences of consumption. While the number of smokers have decreased by 28 percentage points the last 20 years, 7% of the Norwegian population still smoke each day. It is therefore still an arguably significant part of the population that is used to ignore information on the cigarette packaging, or simply do not care about the label. The effect of placing another warning mark on the cigarette box is therefore arguably very small. Other measures, such as the extended producer responsibility scheme could therefore be considered to be more effective towards consumers that purposely will choose to ignore the provided information on the cigarette box.

4.2.3 Awareness raising measure

Awareness raising measures is another information measure implemented in an attempt to influence consumer behavior and amend the information asymmetry within the single-use plastic market. While the plastic in product label is aimed at informing customers about plastic content in the product, awareness raising measures are meant as a measure increasing general consumer knowledge about plastics, available alternatives to single-use plastic items, and also how incorrect disposal through the sewer system, in urban, rural or marine environments impacts the environment. As the information label, the awareness raising measure is vague, and it is hard to assess its potential effects. However, it is directly targeting the behavioral decisions taken by consumers between stage 2 and 3, by informing them about the consequences of choosing the different waste disposal methods and waste streams.

Information labels and information distribution to consumers are means introduced to tackle the externality related to consumer behavior and faulty disposal methods. Faulty behaviors might be learnt from a young age, by being surrendered by non-environmentalists, because you do not care or because you think your contribution towards the problem is too small. Therefore, the government is taking it upon themselves to turn around these bad habits and thought patterns by casually learning consumers about the consequences of their actions, and plastic in items. It could further be argued that informational and awareness campaigns to some extent will adjust behavior of agents through repeated exposure to information about the effect of incorrect waste disposal, the affected animals and the accumulation of waste stocks.

Informed consumers will take more socially optimal decisions, but the extent to which the information label and awareness raising measures are able to increase consumer knowledge, is debatable as the measures are very vague. The extent to whether the measures are measurable, is highly uncertain. Therefore, some reductions in marine litter numbers are expected, due to repeated exposure amongst consumers to informational campaigns etc.

4.3 Stage 3 in the life cycle of plastics

4.3.1 Separate collection

It is impossible for the government to enforce environmental friendly actions in the market without providing appropriate and required infrastructure. Product bans and behavioral adjusting measures are simply not enough in itself. If infrastructure is not in place, it does not matter whether the agents take the socially optimal action, as he does not have an appropriate waste disposal option. One could therefore assume that the SUP Directive enforces improvements in waste disposal infrastructure and waste collections, to retrieve the gains from product bans and market behavior adjustments. However, the only infrastructural target of the SUP Directive is PET-bottles, for which it does require a separate collection.

The separate collection requirement is a measure directly targeting stage 3 in the plastic bottle lifecycle. It is meant to reduce the numbers of bottles that are incorrectly disposed of, and therewithin, the number of littered loose bottle caps. The measure requires that 77% and 90% of all PET-bottles are collected within 2025 and 2029. However, with a 92.8% collection rate, Norway has already achieved both goals through its very well functioning deposit system. The measure is therefore not expected to make any impact on Norwegian marine litter waste numbers.

4.3.1.1 Discussion

In order to facilitate consumer actions that will internalize the externality of faulty consumer behavior, measures that rewards correct behavior or punishes faulty behavior should be in place. The Norwegian deposit system is one example of a rewards system where agents will receive a reward for participation, and the participation rate within the population is therefore extremely high. All agents must pay the deposit when purchasing soda, juice or beer cans. There is no way to opt out of the fee, as long as you purchase the good within Norway. Furthermore, no shop or kiosk can choose to not be a part of the deposit system, which makes the distance to a return point short. As a result, whether or not an agent chooses to participate in the game, he cannot be made worse off than he already is, but will on the other hand be rewarded for participating. Most agents will therefore regard the utility from participating in the game as higher than choosing not to partake in the deposit system.

While the deposit system works well for beverage bottles, no similar system has been established for the return of any other items or materials. It could therefore be discussed if a similar system should be implemented for other bottles like soap and detergent bottles, or just all plastic items in general. One possibility could be to use the existing deposit system, but rather have different barcodes for different polymer types, much like the deposit system was operated when both bottles and cans could be returned within the same system. This is further highlighted by the fact that the success of deposit systems relies on the fact the PET polymer is kept within the system, and not removed. The continued cycle allows the product to be recycled and reused many more times. By recycling, and sorting, other polymer types could be kept within the system and recycled many more times too, and not deteriorated by reuse outside a recycling system.

If different barcodes would require too much administration and monitoring, the different plastic items could all be disposed within the deposit system, and later sorted at one of the Norwegian deposit systems. One potential benefit could even be that the machine would inform you whether the plastic item is recyclable or not. If the machine accepts your waste regardless, high turnout rates amongst the population would most likely occur. Deposit return machines where you can dump a whole bag of plastic bottles already exist, as well as vacuum systems that will transport the deposited bottles into containers. As a result, the Norwegian system is capable of handling large number of waste, and does not require large numbers of additional human labor to ensure efficiency in the process (Infinitum, 2023, pp. 19 - 20).

If consumers could deposit plastic waste, correct waste disposal numbers would most likely be higher. For example, deposit system waste collection areas could be put in public areas. If consumers would be able to deposit plastic waste regardless of their whereabouts, participation would most likely increase due to decreased transactional costs for the consumer. The deposit system could be designed almost like the Norwegian bottle deposit system, and could for example work by weigh. However, it would be important to ensure that the costumer is using the system correctly. There should not be incentives for the consumers to dispose of other items or materials in order to obtain the deposit. As in the bottle deposit system, producers could receive a tax deduction if a certain amount of their items are returned in the system. However, as plastic items will break easily and single-use plastic items usually are consumed on the go, many return points should be allocated in the market to ensure efficiency, and that the producer will prefer the use of these over disposal in normal waste bins or by littering.

The world is filled with profit maximizing individuals on the hunt towards higher and higher utility levels. While some choose to take into account how their actions are affecting the world, some do not. Consumers will adjust where marginal benefit meets marginal utility. They will pay for what they like and expect, but not necessary anything more. It will therefore be important for decision makers to take this information into account. Consumers might need additional benefits for them to participate in a scheme that will benefit society as a whole. While giving away benefits to consumers might impose additional costs, the benefit generated from collective actions will hopefully overgo the cost, and permanently reduce single-use plastic marine litter.

4.7.3 Data sampling

The SUP Directive is solely based on a 2016 beach litter data constructed by Addamo et al. (2017). The dataset covers a total of 355 671 items, recorded from over 600 surveys and 277 European beaches. In total, 19 19 of the (at that time) European Union member states provided data from conducted beach litter surveys. Notably, data from Austria, Croatia, The Czech Republic, Hungary, Luxembourg, Malta, Romania, Slovakia or Slovenia are not included. Below, a map displaying the different beaches data were collected from is shown.

Figure 26 Map over European beaches where marine litter data has been collected. From: Top Marine Beach Litter Items in Europe, by Addamo et al., 2017, Publications Office, p. 25 (doi:10.2760/496717). Copyright 2017 by European Union.

While publications apply different calculation methods, Addamo et al. (2017) applies the "total abundance method". In particular, this method calculates the total number of items recorded for each litter type, for all observations from all surveys on all beaches during 2016. The report does recognize that the data rely heavily on monitoring programs, methodology and voluntary efforts, and thus do most likely vary greatly of quality. However, for the recorded items, the results have been normalized with transect lengths of 100 meters within each survey. The final list, for which the Single-Use Plastic Directive is based on, does not differ between items recorded in different seasons or seas. However, such divisions are available.

Out of all marine litter items identified, plastic materials were found to represent 84% of the total, including non-plastic items, while single-use plastic items represented 50 %, giving rise to the below ranking.

Rank	SUP-item	Marine litter	Percentage
1	Cigarette butts	21 854	22.05%
2	Caps and lids - other	16 125	16.27%
3	Food containers incl. fast food packaging	14 012	14.14%
4	Cotton bud sticks	13 579	13.70%
5	Wet wipes	8 101	8.17%
6	Drink bottles	6 095	6.15%
7	Other bags	4 429	4.47%
8	Cutlery	4 203	4.24%
9	Other bottles	3 011	3.04%
10	Caps and lids - drinks	2 605	2.63%
11	Shopping bags	2 520	2.54%
12	Cups and cups lids	1 995	2.01%
13	Straws and stirrers	566	0.57%

Table 10 Single-use plastic item ranking in Europe. Based on numbers from (Addamo et al., 2017).

Rank	Single-use plastic items	Observations	Percentage
1	Plastic beverage bottles and containers	16 842	38%
2	Plastic and EPS take away food containers	11 142	25%
3	Plastic cotton bud sticks	7 948	18%
4	Lids and caps	3 855	9%
5	Cigarettes	2 183	5%
6	Plastic and EPS cups, plates and cutlery	1 159	3%
7	Plastic straw and stirrers	751	2%
8	Balloons	264	1%
9	Pads, tampons and tampon applicators	60	0%
10	Wet wipes	40	0%
11	Crisp and candy wrappers	1	0%
12	Lightweight plastic bags	0	0%

Table 11 6 Single-use plastic ranking from 2016 Norwegian marine litter surveys. Based on numbers from (OSPAR Commission, 2022, ICC & Hold Norge Rent).

As Norway is not a part of the EU, Norwegian beach litter data was excluded from the dataset. Briedis et al. (2019) estimates the following raking of single-use plastic items in the Norwegian environment. Many single-use plastic items are the same as identified in EU. However, the list highlights certain Norway specific items that is not in scope of the European beach litter dataset. Amongst these are contact lenses, snus packaging and shotgun cartridges.

Rank	SUP-item	Marine litter (tonnes)	Percentage
1	Lightweight plastic carrier bags	28.9	37%
2	Sanitary towels (pads)	10.6	14%
3	Tampons and tampon applicators	10.2	13%
4	Drink cartons	7.5	10%
5	Drink bottles, caps and lids	7.2	9%
6	Beverage cups and lids	4.8	6%
7	Fast food packaging, plates and trays (non- EPS)	3.7	5%
8	Sweet wrappers	1	1%
9	Wet wipes	1	1%
10	Fast food packaging (EPS)	0.8	1%
11	Cotton buds	0.54	1%
12	Very lightweight plastic carrier bags (bags for fruit)	0.48	1%
13	Cutlery	0.31	0%
14	Straws	0.11	0%
15	Balloon sticks	0.002	0%
16	Stirrers	0.001	0%
17	Balloons	-	-
18	Cigarette filters	-	-
19	Cigarette plastic packaging	-	-
20	Contact lenses	-	-
21	Crisp packets	-	-
22	Shotgun cartridges	-	-
23	Snus packaging	-	-

Table 12 Single-use plastic waste estimates. Based on numbers from (Briedis et al., 2019).

Single-use contact lenses could be prone to becoming marine litter as the items might potentially be flushed in the toilet, just as any other plastic sanitory items. However, as the items only consist of plastic, the items are most likely not flushed due to information asymmetry as the plastic content should be obvious, but rather due to the choice of faulty disposal methods.

There are some discrapansies in the data showing typical Norwegian and European waste numbers and consumption patterns. Cigarettes are for example one of the most frequently littered times in Europe, contrary to Norway, where snus is way more popular. However, snus is not covered by the SUP Directive, as only tobacco products with filters are covered. Therefore, when performing an analysis on the SUP Directives effects on plastic marine litter numbers, snus should be in the scope in the future as a highly relevant single-use plastic item

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5 Conclusion

The SUP Directive will not resolve the worldwide issue of marine litter in itself. Neither will it hinder continued plastic production, greenhouse gas emissions or continuously increasing consumption patterns. However, what it can do, is to shed some light on the issue of plastic pollution and the current increasing consumption trends.

In the course of everyday life, realizations may have unfolded. The single-use plastic spoon, usually accompanying single serve yoghurts, is substituted by wooden alternatives. Similarly, the scenario unfolds when purchasing a to-go soda. The usual plastic straw is now substituted with a paper straw, which immediately crumbles.

You, as a consumer, is caused disutility. However, a question arises. Why do businesses swap perfectly good single-use plastic items for other non-plastic materials? It might be expectations from consumers and shareholders to become more sustainable. Or worse, green washing. The reality is that the numbers are clear. Our oceans are heavily polluted. And both animals and humans suffer the consequences. And therefore, anti-plastic pollution legislation is introduced.

Yet, consumers and businesses, the whole market, struggles to adapt, regardless of apocalyptic future projections. Just imagine an ocean where there is more plastic than fish. It is bizarre.

The whole market is stuck in a disarray. All agents free ride, hoping that someone else will take on the lead or responsibility for the current plastic pollution. And in the meantime, consumption of ridiculously cheap plastic items produced far, far away can persist.

Nevertheless, the utility retrieved from single-use plastics should not be understated. The items are extremely convenient, giving great support to a hectic lifestyle on the go. Their disposable nature reduces the amount of trash that must be carried and brought to the next location. Moreover, if disposal is no issue and the item can be dumped everywhere, transaction costs from correct disposal in the market can be lowered till a point where they no longer exist.

But while we wait, marine pollution increases. Consumption is kept above the social optimal level, causing enormous negative externalities and efficiency losses, diverting resources from productive to reactive measures, while a few agents make an attempt to carry the load. Some do clean up the oceans and organize urban sweeps, while the majority keeps on thinking “Someone else should fix this problem. I am not the biggest polluter; other pollute *way* more than me”. And while the point might be true, no change of action occurs.

The discovery of the “Plastic whale” opened the eyes of many (Lislevand, 2021). The consequences of continued plastic consumption and waste patterns were crystal clear. But the sad truth is that while the disturbing reality will amend consumer behavior in the short run, more powerful actions are required permanently alter behavior in the long run.

Producers are profit maximizing and will only stay in the market as long as they can gain any long-term benefits from it. So when the SUP Directive introduces

product bans and other regulatory burdens on single-use plastics producers, it simultaneously opens up an arena for innovation and further development of sustainable alternatives. The economic landscape is undergoing a transformation. Although initial adjustments may incur costs, the long-term benefits of a more sustainable and environmentally conscious economy cannot be overstated.

And while the SUP Directive enforces certain regulatory burdens on the producer, the consumer must reevaluate his options to identify the appropriate substitution. How can the usual single-use plastic coffee takeaway cup be substituted? It is up to the individual agent to decide whether or not bringing a reusable cup from home is a good solution, or if transaction costs will be too high. And while some will bring a cup from home, others might start a petition for innovations like reusable coffee cups, returnable at every coffee shop.

And such, the SUP Directive can be a push in the right direction. If it is able to revoke only one critical thought in each affected agent, a change is created. Discussions amends information asymmetry within the market. Consumers become more educated and take better actions through communication with other agents in the market. And such, producers must follow where demand goes.

However, one major question is left unanswered. The SUP Directive does not address the information disparity in pricing decisions, and each firm is left on its own to set a market price, regardless of what information he might have on the externalities and efficiency losses he is creating in the market.

Whereas economic theory states that the optimal price should cover the marginal damage it creates in the optimal market allocation, the SUP Directive does not target the price, nor pricing decisions or tax introductions. The market is left on its own to set the market price. As it is a crucial aspect of tackling the negative externalities arising from plastic production, future efforts should be focused on addressing this particular issue, such that cost efficiency is achieved in anti-plastic pollution policies.

The goal of the SUP Directive is to prevent litter in the future, and the evaluation should be based on whether the policy is meeting that target. Here, a further collection of production, consumption and waste numbers will be crucial, in line with the data reporting requirements in the SUP Directive.

Contrary to marine litter data, which falls victim to population dispersions within the country, mandatory reporting of production and consumption numbers will ensure a representative data source, accurately reflecting the market within the country. This is particularly important as marine litter is able to travel far.

Nevertheless, the SUP Directive only targets the last stage in the plastic life cycle, leaving other measures to correct for the market failures in the production process – like carbon emissions. The stock of plastic litter has already accumulated in the oceans and the issue must be solved with organized clean-ups.

While it is too early to conclude on any effects from the introduction of the SUP Directive, a decreasing trend seems to exist within most single-use plastic categories covered by the SUP Directive.

Ultimately, the SUP Directive serves as a catalyst for change, fostering a more resilient and sustainable economy throughout behavioral changes amongst consumers and the adaptations from producers within. As the information gap within the market decreases, information asymmetry is reduced, while inefficiency reductions follow tight. By internalizing the externalities from single-use plastic production and consumption, an example is set for others to follow, demonstrating that economic prosperity and environmental friendly markets can coexist. The success of the SUP Directive lies not only in its economic outcomes, but in its contribution to a more sustainable future for generations to come.

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Appendix A. Data category decisions

Plastic and EPS cups, plates and cutlery:
Single use cups, plates and cutlery have been merged into one category, due to different reporting specifications in the four surveys. *Ryddeportalen* and *Ryddenorge* only provide data on tableware, and not distinguish between cups, plates or cutlery in their survey categories, nor whether these items are plastic or not. ICC do report cups and plates as one category, while the OSPAR study only report data on cups and cutlery, however distinguished as two categories. None of the surveys report any data on "plastic plates" only.

Paper cups and plates will usually have a thin plastic coating. Paper cups and plates recorded in the OSPAR and ICC studies are therefore added to "Plastic and EPS cups, plates and cutlery". Tableware reported by Ryddenorge and Ryddeportalen is assumed to be made wholly or partially of plastic, even though material is not specified.

While both ICC and OSPAR do distinguish between plastic and EPS in their surveys, neither Ryddeportalen nor Ryddenorge do. As a result, "foam cups and plates" (EPS) from the ICC study have been added to "Plastic and EPS cups, plates and cutlery", as both the Ryddenorge and Ryddeportalens category "tableware" might contain EPS items. ICC report EPS and plastic as separated and aggregated numbers.

Plastic and EPS take away food containers:
All surveys report distinct numbers for "take away food containers". While both ICC and OSPAR surveys do specify that these numbers stem from plastic take away containers, Ryddenorge and Ryddeportalen simply reports "take away containers" and "food packaging". However, judging from an old Ryddeportalen registration form (Hold Norge Rent, n.d.), it seems like "food packaging" also consists of take away containers.

Neither Ryddenorge nor Ryddeportalen surveys report whether the recorded takeaway containers are plastic. However, as these types of containers frequently are made from plastic, at least partially, they categories are included as single-use plastics.

As neither Ryddeportalen nor Ryddenorge do record whether the surveyed food containers are made from plastic or EPS, plastic and EPS take away food containers are merged into one category. The ICC study has recorded "foam" food containers, while OSPAR do specify that they are made from EPS, both as a stand-alone category and as an aggregated plastic category.

Plastic cotton bud sticks:
All surveys report distinct numbers for cotton bud sticks, however, only OSPAR guidelines suggest that these are plastic items (Wenneker & Oosterbaan, 2010). Cotton buds usually have plastic sticks, and therefore all surveyed cotton buds stick categories are included in this category.

Plastic straw and stirrers:
Ryddenorge and Ryddeportalen has recorded straws as one distinct category in their survey. ICC has reported plastic straws and stirrers together, while OSPAR

reports no data on either of these categories. Drinking straws are commonly made of plastic, and while only ICC specifies that the recorded straws are plastic, it is assumed they all are.

Plastic beverage bottles and containers:
All four surveys report numbers on beverage bottles. Ryddeportalen do not specify whether these are plastic, but so is assumed. The ICC survey do report numbers for "beverage sachets/pouches", but none of the others do. Pouches, plastic containers, composite beverage cartons and flexible beverage containers made fully or partially of plastic are covered by the Single-Use Plastic Directive. As a result, "beverage sachets/pouches" are reported together with numbers for plastic beverage bottles, due to only one survey monitoring this category. Furthermore, OSPAR do report numbers in the category "Other bottles". However, judging by the OSPAR Marine Litter Guideline(Wenneker & Oosterbaan, 2010), these bottles are deemed to be non-beverage bottles, and thus excluded from the scope.

Pads, tampons and tampon applicators:
All four surveys report some numbers for sanitary towels, pads, tampons and tampon applicators. However, the ICC study does not report any numbers for "sanitary towels" or "pads". As a result, there is a possibility that these could be recorded under the category "diapers" in the study. As this category is out of the scope for the Single-Use Plastic Directive, it is not included. ICC is also the only study that do record "tampon applicators". Still, the reported numbers are all aggregated into one category, in accordance with the Single-Use Plastic Directive.

Wet wipes:
While Addamo et al. (2017) has recorded wet wipes as a part of several monitored categories, Briedis et al., (2019) do highlight wet wipes as a distinct category that should be covered by the Single-Use Plastic Directive, after contact with organizations in 8 Member States. As a result, wet wipes were distinguished as a separate category, even though most surveys do not record this item. This is also the case for Norwegian survey data. Only Ryddeportalen and Ryddenorge report data on wet wipes only, while ICC and OSPAR do provide number for "other sanitary items". As these are not covered by the Single-Use Plastic Directive, it is decided that these categories will not be included in this analysis, even though some of these recordings probably do consist of wet wipes.

Cigarettes:
All four surveys report numbers for cigarette butts, but no numbers for filters or other tobacco products with filters.

Crisp and candy wrappers:
Ryddenorge, ICC and OSPAR report numbers for crisp and candy wrappers. Only the OSPAR study specifies that these items are plastic, but so is assumed. As a result, all the three categories are included.

Lightweight plastic bags:
Lightweight plastic bags are defined in The Single-Use Plastic Directive by Article 3 (1)c. in the Waste Directive as a "plastic carrier bags' (…) with a wall thickness below 50 micron", i.e., "bags that are less frequently reused than thicker

plastic carrier bags" (Directive 2008/98/EC, 2008). This excludes normal shopping and grocery bags from the scope.

Data on "Small bags" from Ryddenorge, "Other bags (plastic)" from ICC and "Small plastic bags" from OSPAR are therefore included. The ICC survey only distinguishes between grocery bags and other bags, and it is therefore assumed that the latter fall into scope.

Balloons:
All four surveys report numbers for balloons.

Lids and caps:
While not a distinct category within the Single-Use Plastic Directive, each survey reports separate numbers for lids and caps. The ICC and OSPAR studies do specify that these are plastic items. However, Ryddenorge and Ryddeportalen do report numbers on "lids and corks", which potentially can include both metal caps from soda and beers or champagne bottles corks. However, it assumed that most of these caps and lids are plastic.

Appendix B. R Manuscript

```
#1:
#DATAPOINTS FROM RYDDEPORTALEN ARE IN A TWO-
DIMENTIONAL CARTESIAN COORDINATE SYSTEM (WKT)
#WKT MUST BE TRANSFORMED TO LONGITUDE AND LATITUDE

setwd("/Users/hedda/Library/Mobile
Documents/com~apple~CloudDocs/skole/master/data/rådata")
library("readxl")
library(sf)

read_excel("Data fra Ryddeportalen .xlsx")
ryddeportalen_data <- read_excel("Data fra Ryddeportalen .xlsx")

#CREATE SF OBJECT WITH UTM ZONE 33
utm_coordinates <- st_as_sf(ryddeportalen_data, coords = c("x_column",
"y_column"), crs = 32633)

#TRANSFORMING TO WGS84
wgs84_coordinates <- st_transform(utm_coordinates, crs = 4326)
ryddeportalen_df <- as.data.frame(wgs84_coordinates)

st_write(ryddeportalen_df, "ryddeportalen_coordinates.csv", layer_options =
"GEOMETRY=AS_XY")


#THE FOUR DATASETS WITH LONG AND LAT ARE COMBINED INTO:
"combined litter data copy.xlsx"




#2: CREATING FIGURE 16
#CREATING A MAP OVER NORWAY WITH THE OBSERVED BEACH
LITTER CLEAN-UP OBSERVATIONS.
#COORDINATES AND NUMBER OF OBSERVATIONS DETERMINE DATA
POINT ALLOCATION AND SIZE.
#A DARKER COLOR INDICATES SEVERAL OBSERSVATIONS IN THE
SAME AREA.

#source: https://cran.r-project.org/web/packages/csmaps/csmaps.pdf


setwd("/Users/hedda/Library/Mobile
Documents/com~apple~CloudDocs/skole/master/data/databehandling")
a <- read_excel("combined litter data copy.xlsx")


library("tidyverse")
library("csmaps")
library(ggplot2)
q <- ggplot(mapping = aes(x = long, y = lat))
```

```
q <- q + geom_polygon(
  data = csmaps::nor_county_map_b2020_default_dt,
  mapping = aes(group = group),
  color = "black",
  fill = "white",
  linewidth = 0.2
)
q <- q + theme_void()
q <- q + coord_quickmap() +
  geom_point(data = a, aes(x = lat, y = long, size = sum), colour = "midnightblue",
fill = "royalblue1", pch = 21, alpha = I(0.3), show.legend = FALSE)
q
```

#3: CREATING FIGURE 17

```
a <- read_excel("combined litter data.xlsx")

# Combine data into a single dataframe
data <- data.frame(
  Variable = rep(c("Plastic and EPS cups, plates and cutlery", "Plastic and EPS
take away food containers", "Plastic cotton bud sticks","Plastic straw and
stirrers","Plastic beverage bottles and containers","Pads, tampons and tampon
applicators", "Wet wipes", "Cigarettes", "Crisp and candy wrappers",
"Lightweight plastic bags", "Balloons", "Lids and caps"), each = length(a[[4]])),
  Value = c(a[[4]], a[[5]], a[[6]], a[[7]], a[[8]], a[[9]], a[[10]], a[[11]], a[[12]],
a[[13]], a[[14]], a[[15]])
)

# Create a horizontal boxplot with logarithmic scale on the y-axis using ggplot2
ggplot(data, aes(x = Value, y = Variable)) +
  geom_boxplot(width = 0.5) +
  scale_x_log10()
```

#4: CREATING PLOTS IN APPENDIX B AND C

```
ggplot(data = a, aes(x = `date`, y = `Plastic and EPS cups, plates and cutlery`)) +
geom_point(shape = 1) + theme_bw() +
  geom_smooth(data = a, method = "lm", color = "royalblue1", se = FALSE)


ggplot(data = a, aes(x = `date`, y = `Plastic and EPS take away food containers`))
+ geom_point(shape = 1) + theme_bw() +
  geom_smooth(data = a, method = "lm", color = "royalblue1", se = FALSE)
```

```
ggplot(data = a, aes(x = `date`, y = `Plastic cotton bud sticks`)) +
geom_point(shape = 1) + theme_bw() +
  geom_smooth(data = a, method = "lm", color = "royalblue1", se = FALSE)


ggplot(data = a, aes(x = `date`, y = `Plastic straw and stirrers`)) +
geom_point(shape = 1) + theme_bw() +
  geom_smooth(data = a, method = "lm", color = "royalblue1", se = FALSE)


ggplot(data = a, aes(x = `date`, y = `Plastic beverage bottles and containers`)) +
geom_point(shape = 1) + theme_bw() +
  geom_smooth(data = a, method = "lm", color = "royalblue1", se = FALSE)


ggplot(data = a, aes(x = `date`, y = `Pads, tampons and tampon applicators`)) +
geom_point(shape = 1) + theme_bw() +
  geom_smooth(data = a, method = "lm", color = "royalblue1", se = FALSE)


ggplot(data = a, aes(x = `date`, y = `Wet wipes`)) + geom_point(shape = 1) +
theme_bw() +
  geom_smooth(data = a, method = "lm", color = "royalblue1", se = FALSE)


ggplot(data = a, aes(x = `date`, y = `Cigarettes`)) + geom_point(shape = 1) +
theme_bw() +
  geom_smooth(data = a, method = "lm", color = "royalblue1", se = FALSE)


ggplot(data = a, aes(x = `date`, y = `Crisp and candy wrappers`)) +
geom_point(shape = 1) + theme_bw() +
  geom_smooth(data = a, method = "lm", color = "royalblue1", se = FALSE)


ggplot(data = a, aes(x = `date`, y = `Lightweight plastic bags`)) +
geom_point(shape = 1) + theme_bw() +
  geom_smooth(data = a, method = "lm", color = "royalblue1", se = FALSE)


ggplot(data = a, aes(x = `date`, y = `Balloons`)) + geom_point(shape = 1) +
theme_bw() +
  geom_smooth(data = a, method = "lm", color = "royalblue1", se = FALSE)


ggplot(data = a, aes(x = `date`, y = `Lids and caps`)) + geom_point(shape = 1) +
theme_bw() +
  geom_smooth(data = a, method = "lm", color = "royalblue1", se = FALSE)
```

#5: CREATNG PLOTS IN APPENDIX D

```
a <- read_excel("combined litter data.xlsx")

ggplot(data = a, aes(x = `date`, y = `Plastic and EPS cups, plates and cutlery`)) +
geom_point(shape = 1) + theme_bw()
ggplot(data = a, aes(x = `date`, y = `Plastic and EPS take away food containers`))
+ geom_point(shape = 1) + theme_bw()
ggplot(data = a, aes(x = `date`, y = `Plastic cotton bud sticks`)) +
geom_point(shape = 1) + theme_bw()
ggplot(data = a, aes(x = `date`, y = `Plastic straw and stirrers`)) +
geom_point(shape = 1) + theme_bw()
ggplot(data = a, aes(x = `date`, y = `Plastic beverage bottles and containers`)) +
geom_point(shape = 1) + theme_bw()
ggplot(data = a, aes(x = `date`, y = `Pads, tampons and tampon applicators`)) +
geom_point(shape = 1) + theme_bw()
ggplot(data = a, aes(x = `date`, y = `Wet wipes`)) + geom_point(shape = 1) +
theme_bw()
ggplot(data = a, aes(x = `date`, y = `Cigarettes`)) + geom_point(shape = 1) +
theme_bw()
ggplot(data = a, aes(x = `date`, y = `Crisp and candy wrappers`)) +
geom_point(shape = 1) + theme_bw()
ggplot(data = a, aes(x = `date`, y = `Lightweight plastic bags`)) +
geom_point(shape = 1) + theme_bw()
ggplot(data = a, aes(x = `date`, y = `Balloons`)) + geom_point(shape = 1) +
theme_bw()
ggplot(data = a, aes(x = `date`, y = `Lids and caps`)) + geom_point(shape = 1) +
theme_bw()
```

Appendix C. Plotted means of surveyed single-use plastics

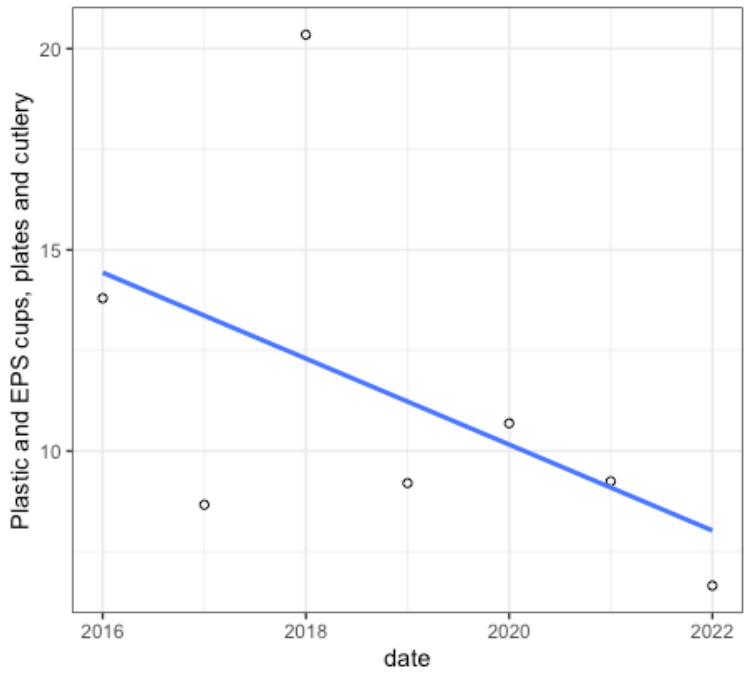

Figure C1 Mean of Plastic and EPS cups, plates and cutlery.

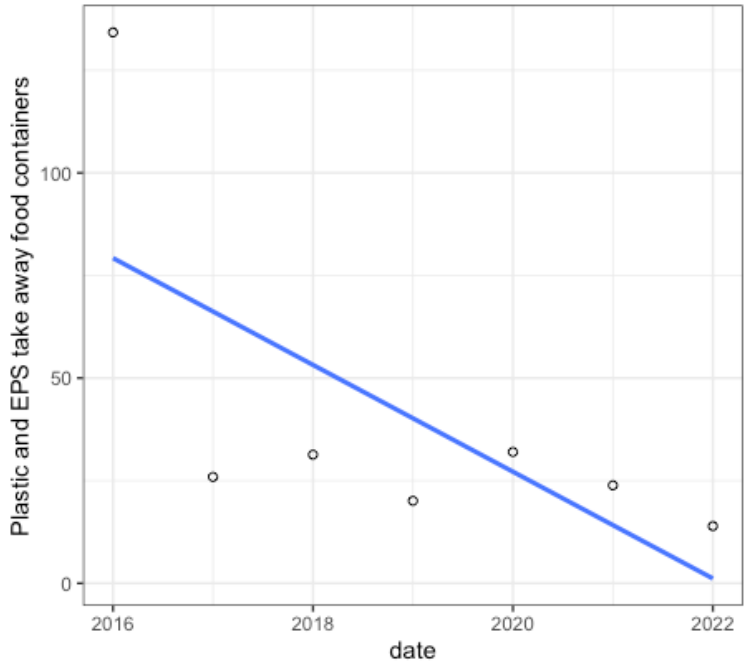

Figure C2 Mean of Plastic and EPS take away food containers.

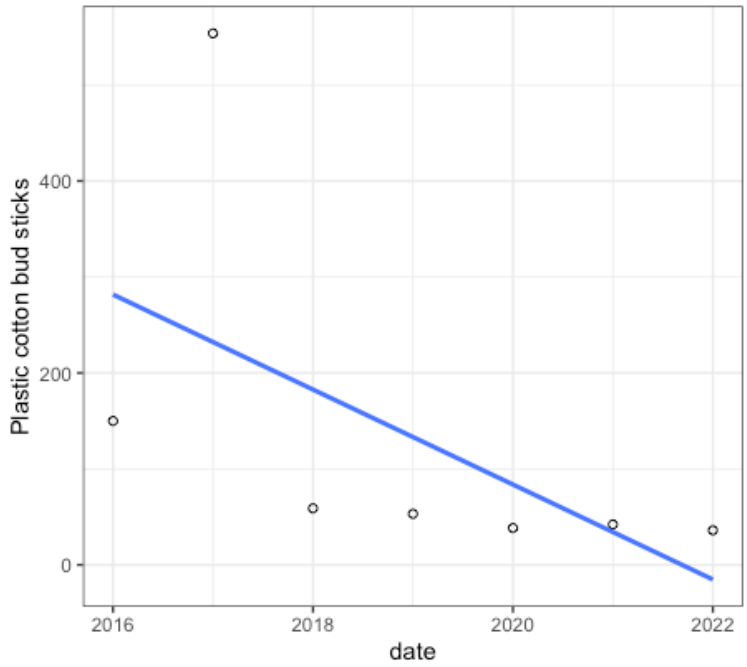

Figure C3 Mean of Plastic cotton bud sticks.

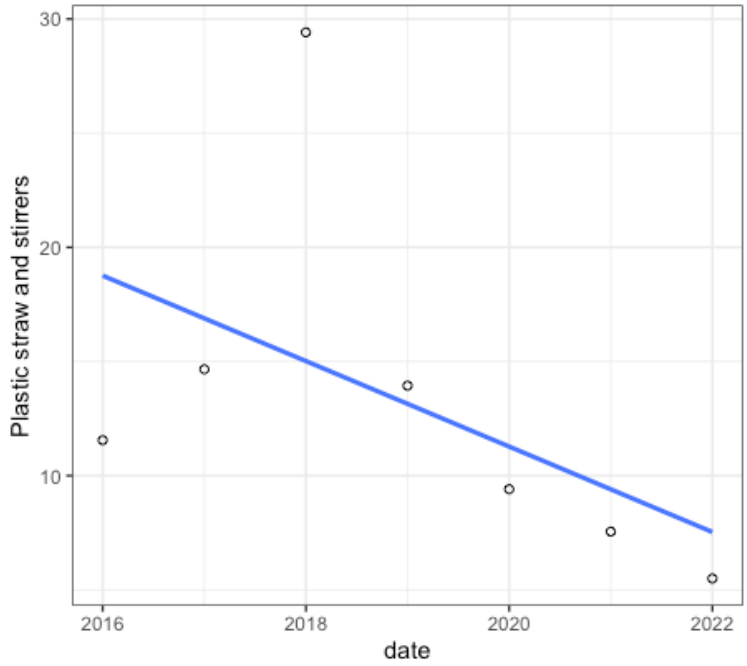

Figure C4 Mean of Plastic straw and stirrers.

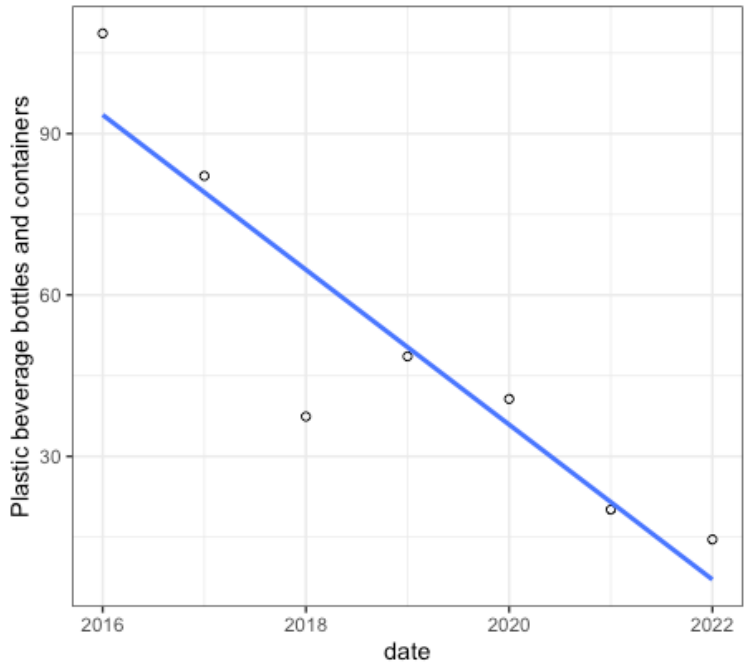

Figure C5 Mean of Plastic beverage bottles and containers.

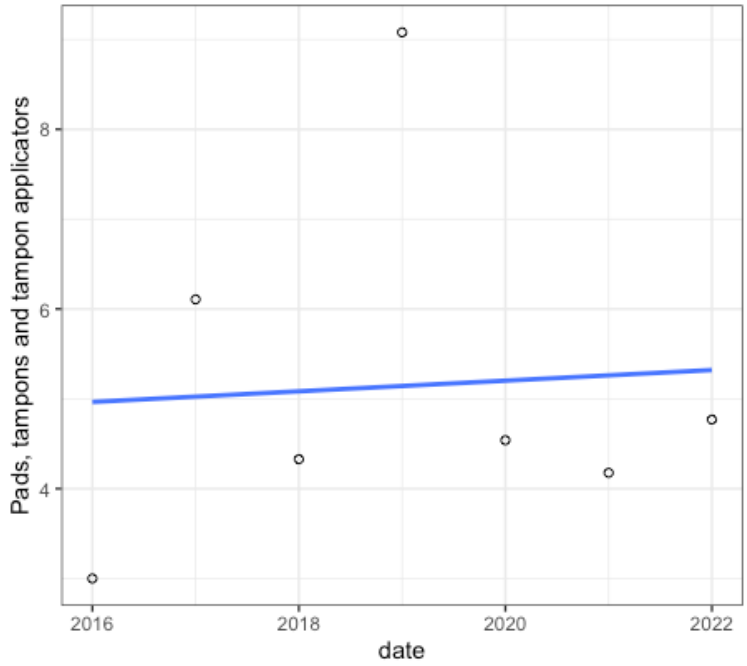

Figure C6 Mean of Pads, tampons and tampon applicators.

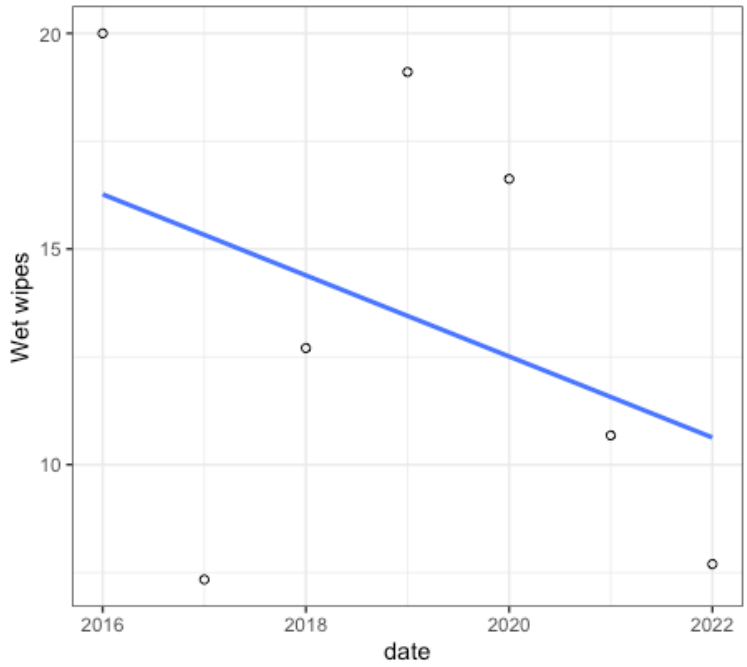

Figure C7 Mean of Wet wipes.

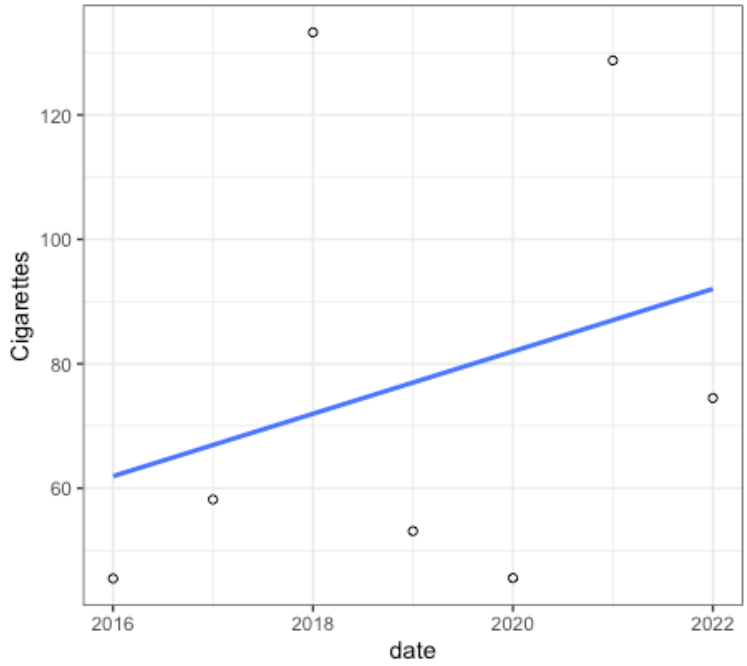

Figure C8 Mean of Cigarettes.

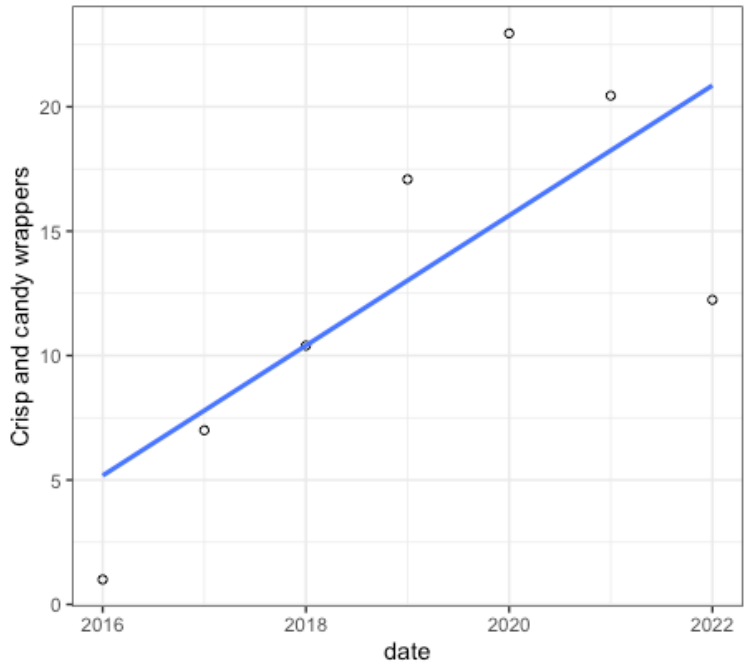

Figure C9 Mean of Crisp and candy wrappers.

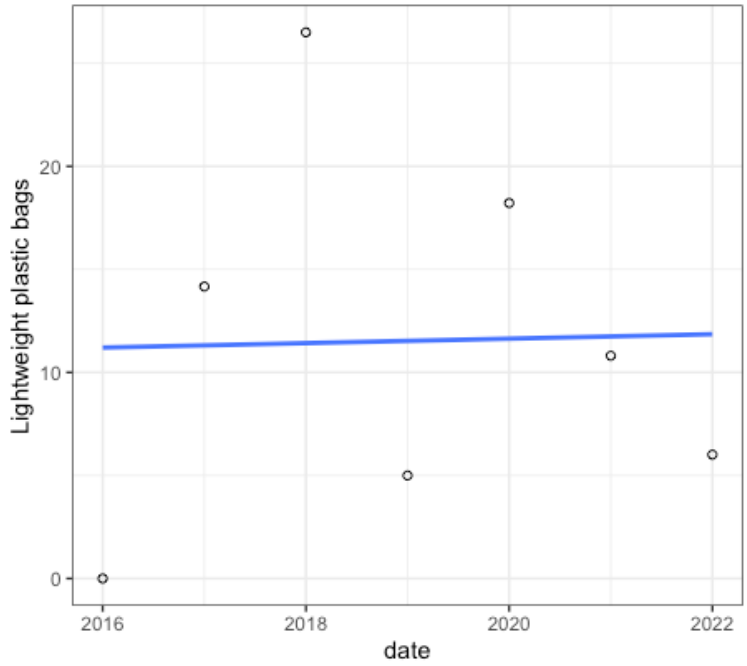

Figure C10 Mean of Lightweight plastic bags.

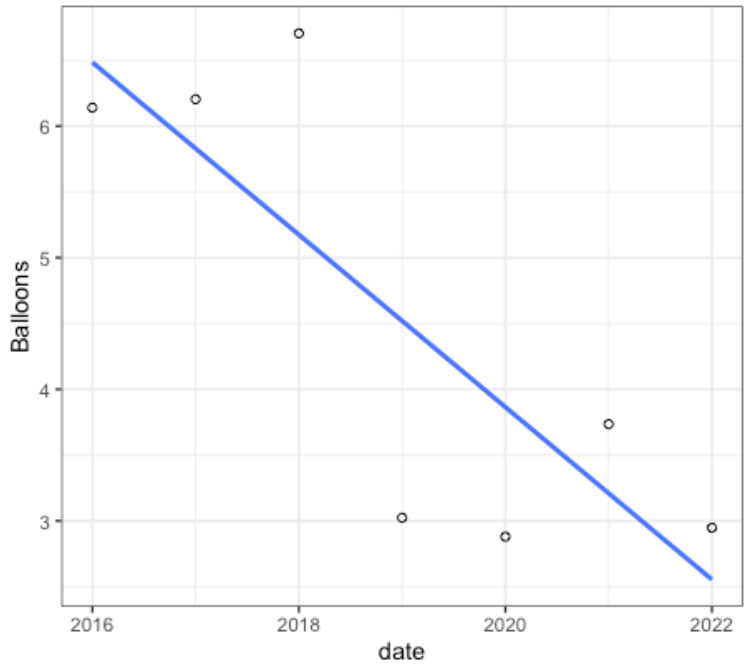

Figure C11 Mean of Balloons.

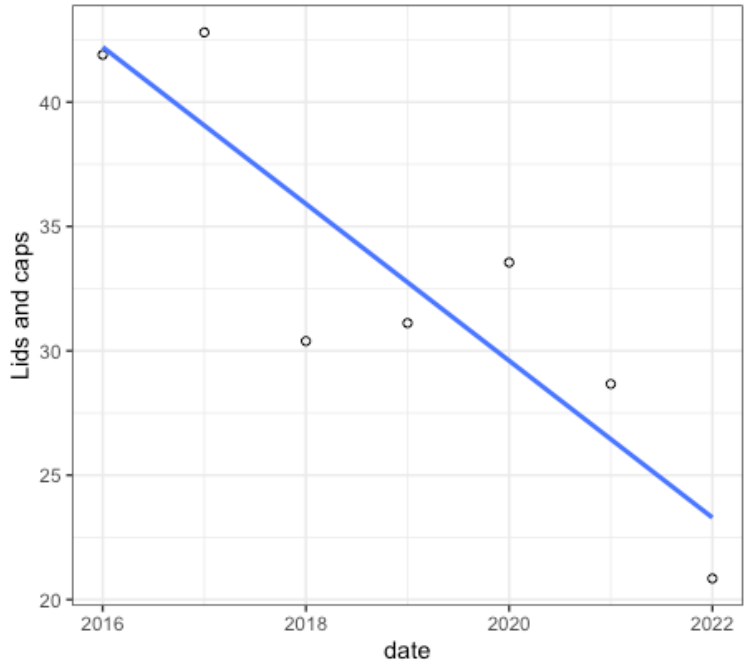

Figure C12 Mean of Lids and caps.

Appendix D. Plotted medians of surveyed single-use plastics

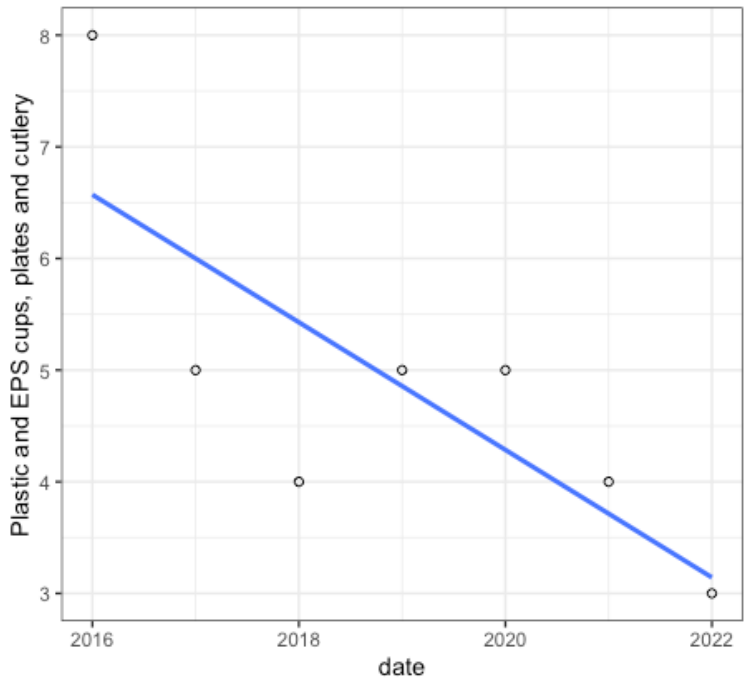

Figure D1 Median of Plastic and EPC cups, plates and cutlery.

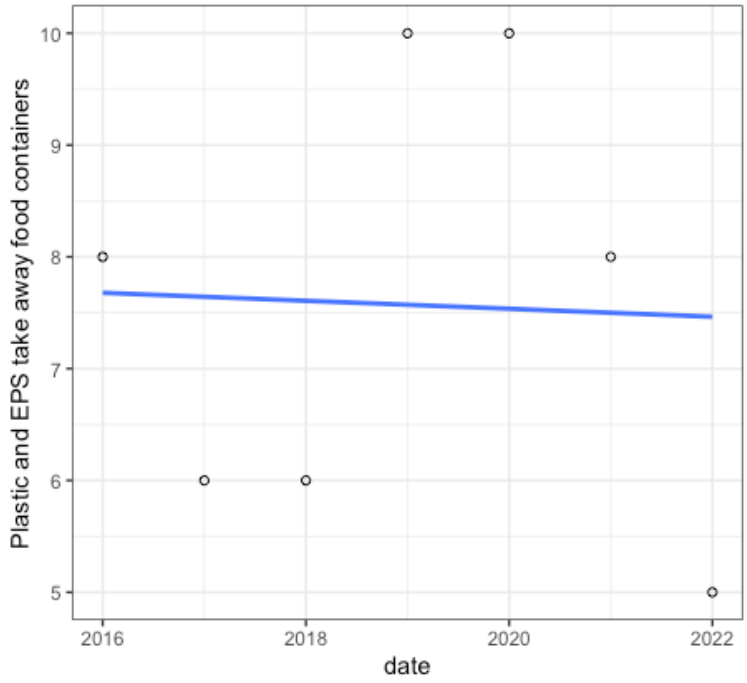

Figure D2 Median of Plastic and EPS take away food containers

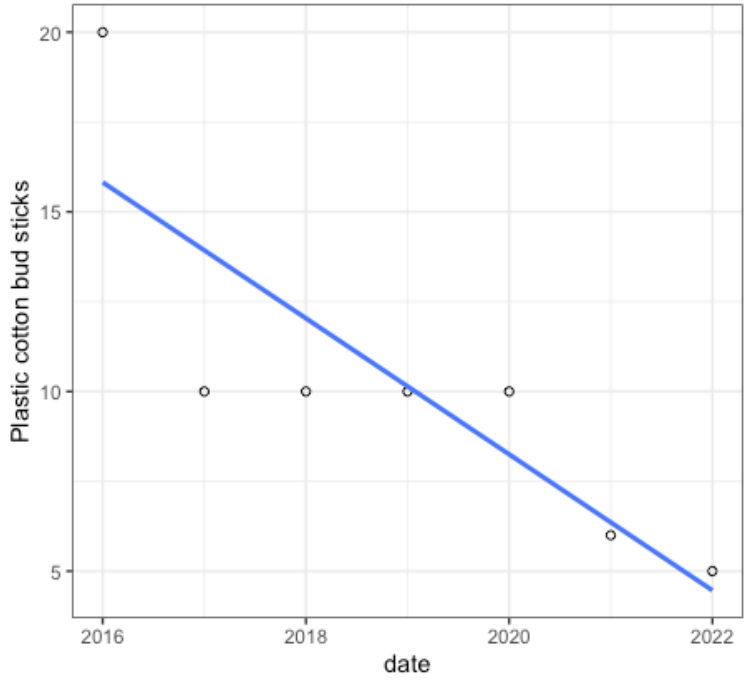

Figure D3 Median of Plastic cotton bud sticks.

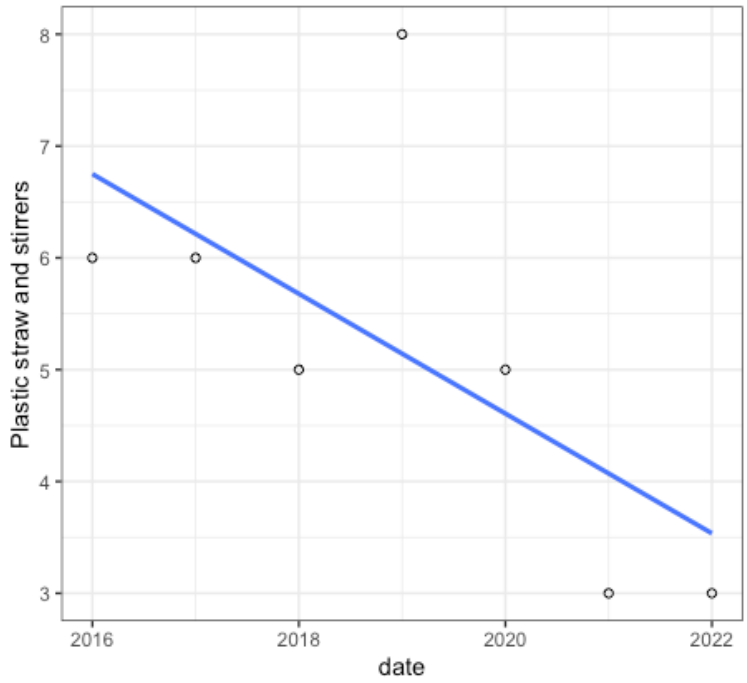

Figure D4 Median of Plastic straws and stirrers

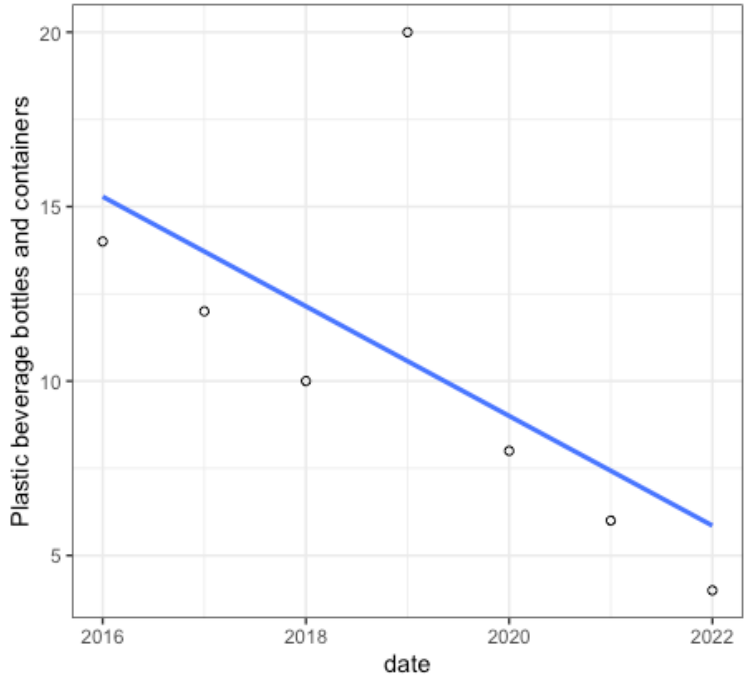

Figure D5 Median of Plastic beverage bottles and containers.

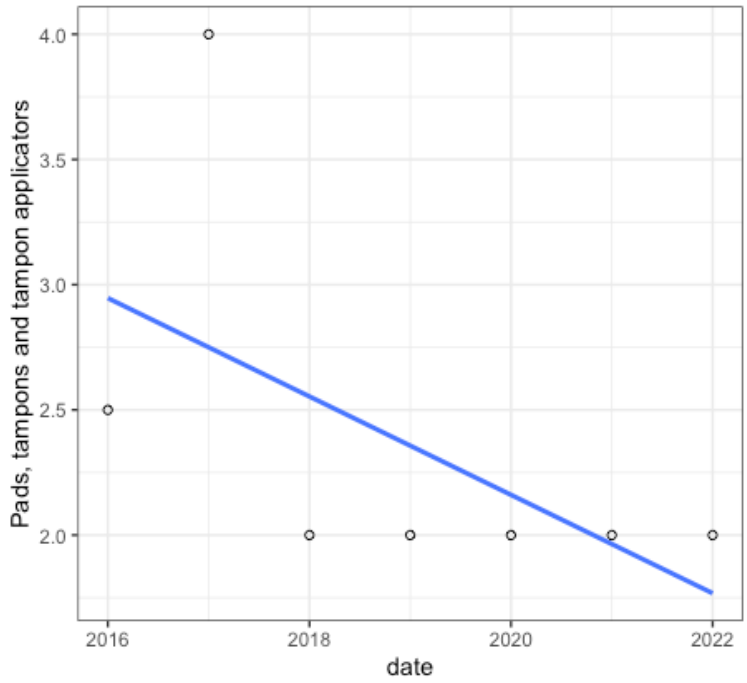

Figure D6 Median of Pads, tampons and tampon applicators.

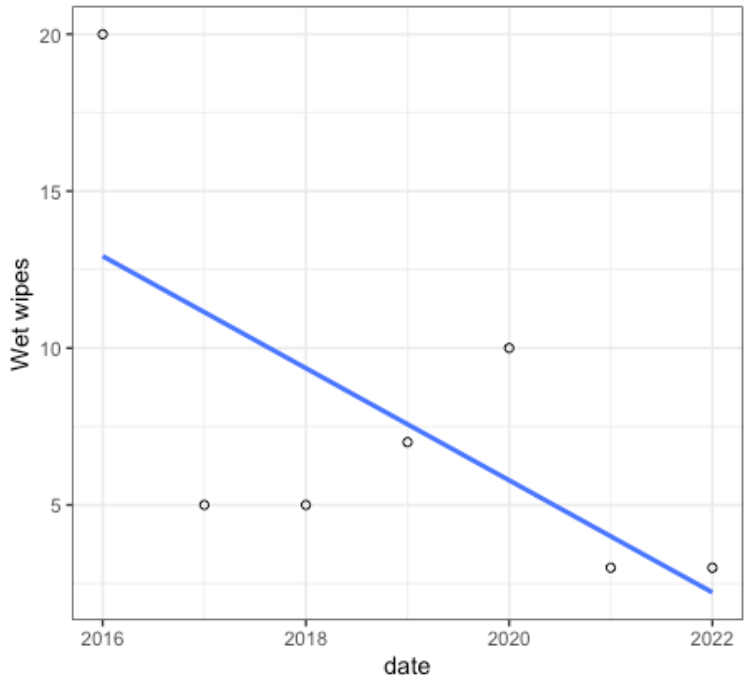

Figure D7 Median of Wet wipes.

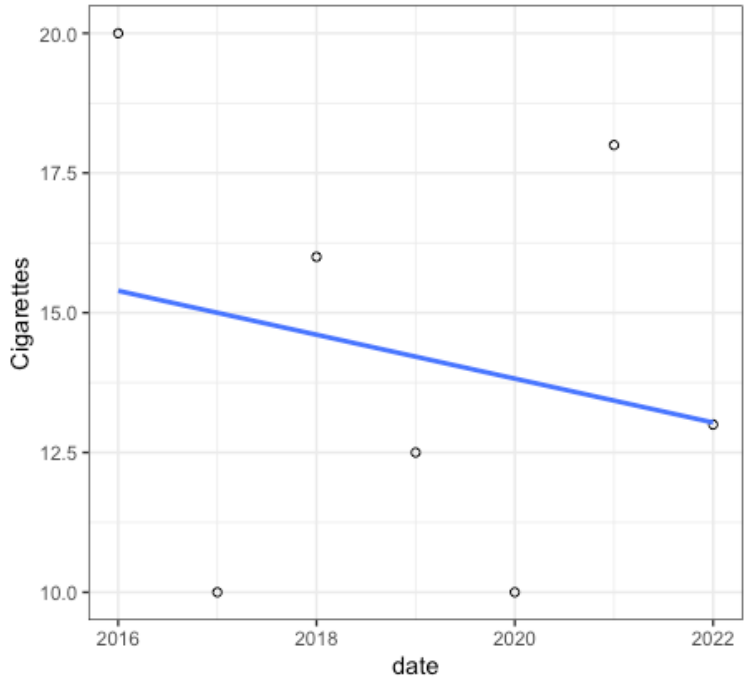

Figure D8 Median of Cigarettes.

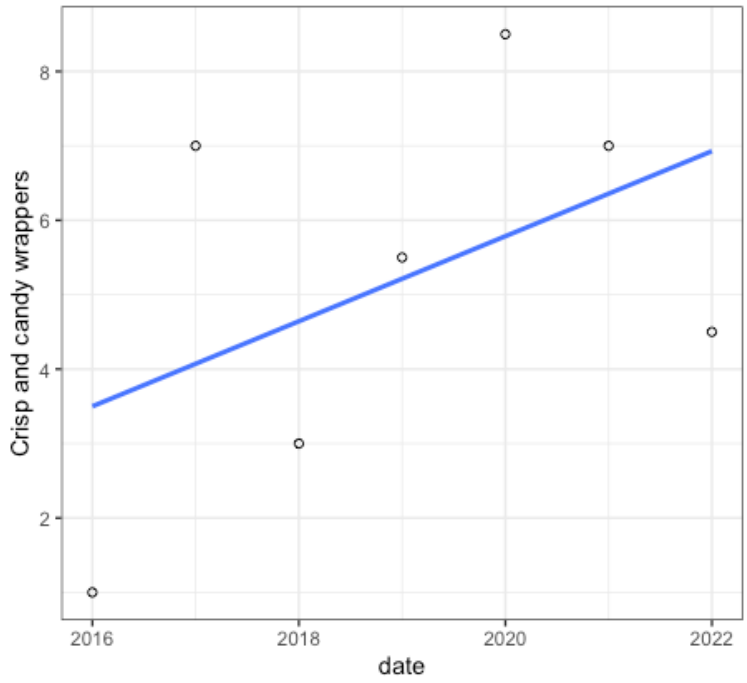

Figure D9 Median of Crisp and candy wrappers.

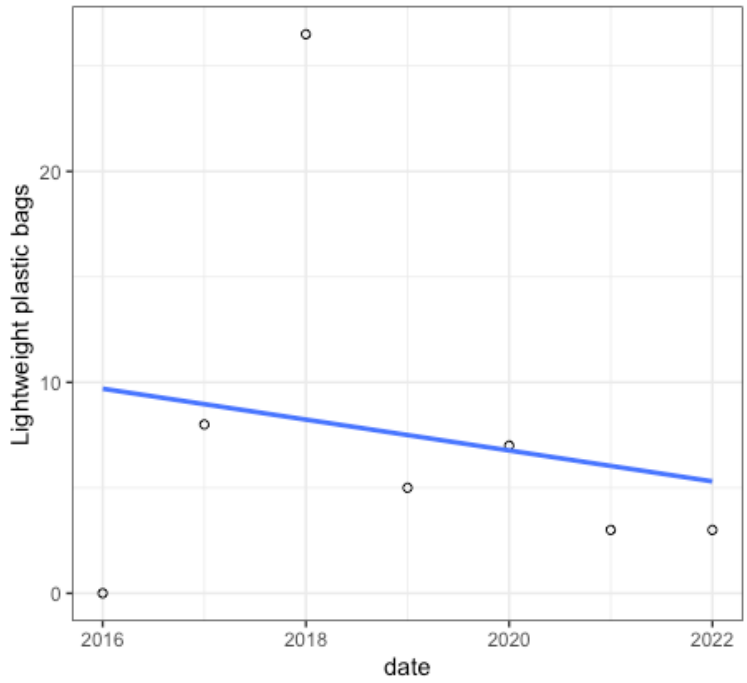

Figure D10 Median of Lightweight plastic bags

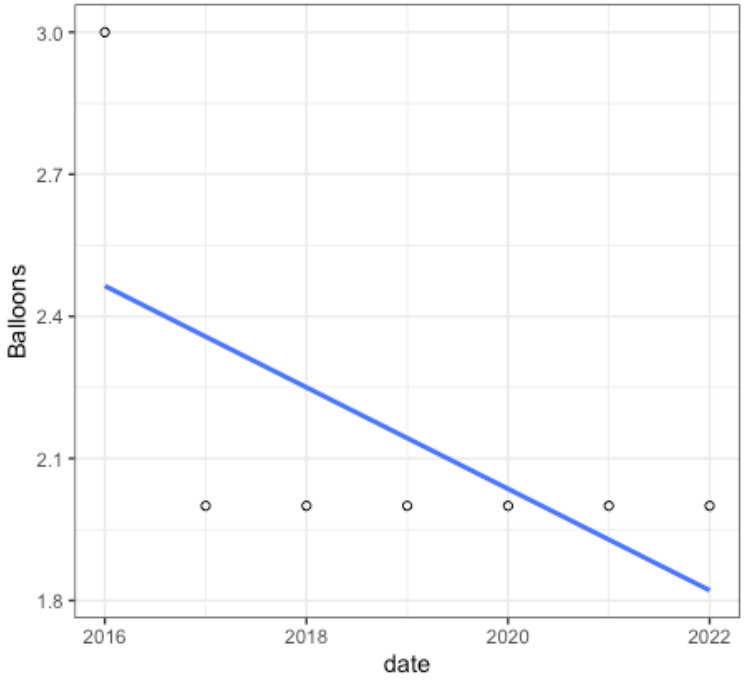

Figure D11 Median of Balloons.

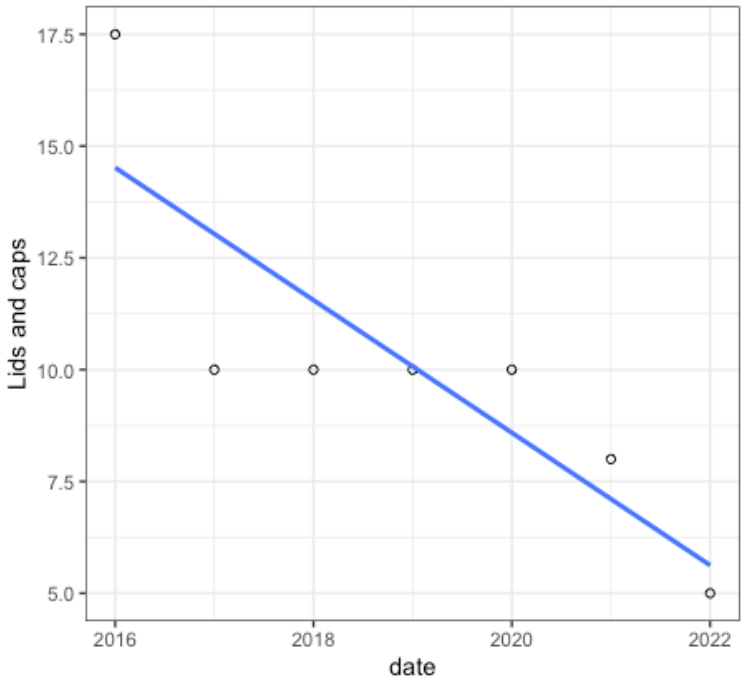

Figure D12 Median of Lids and caps.

Appendix F. Plots of surveyed single-use plastic categories

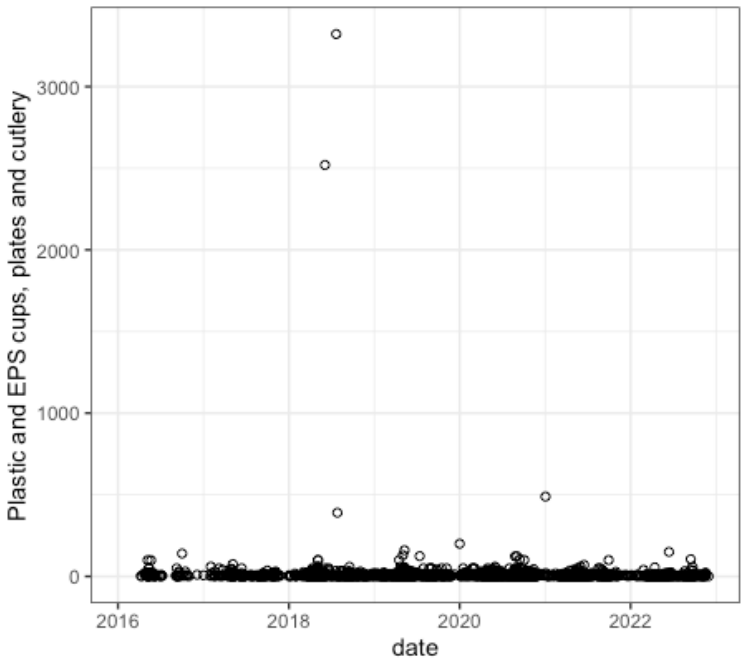

Figure F1 Plot of Plastic and EPS cups, plates and cutlery.

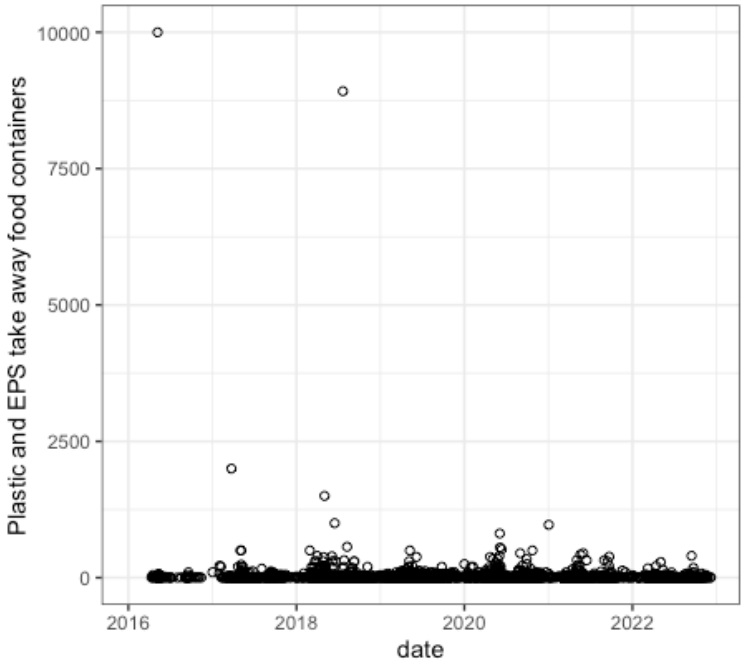

Figure F2 Plot of Plastic and EPS take away food containers.

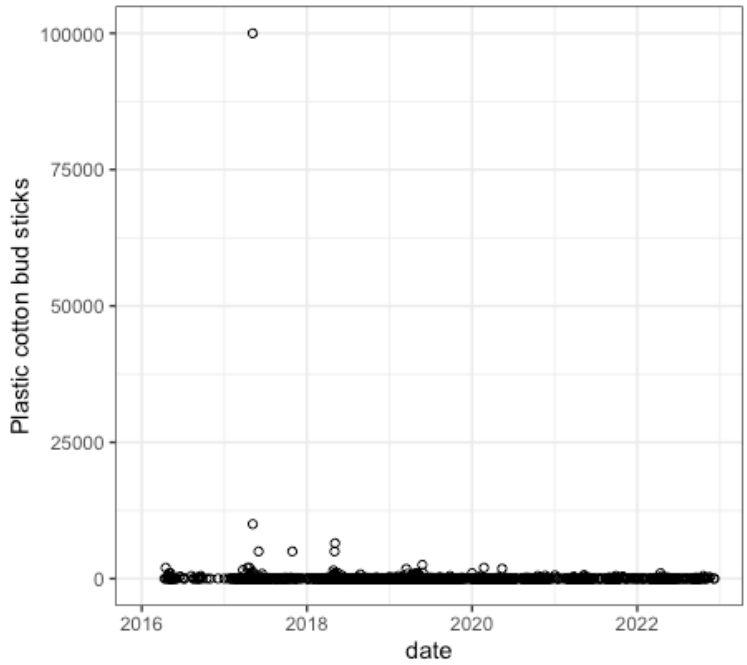

Figure F3 Plot of Plastic cotton bud sticks.

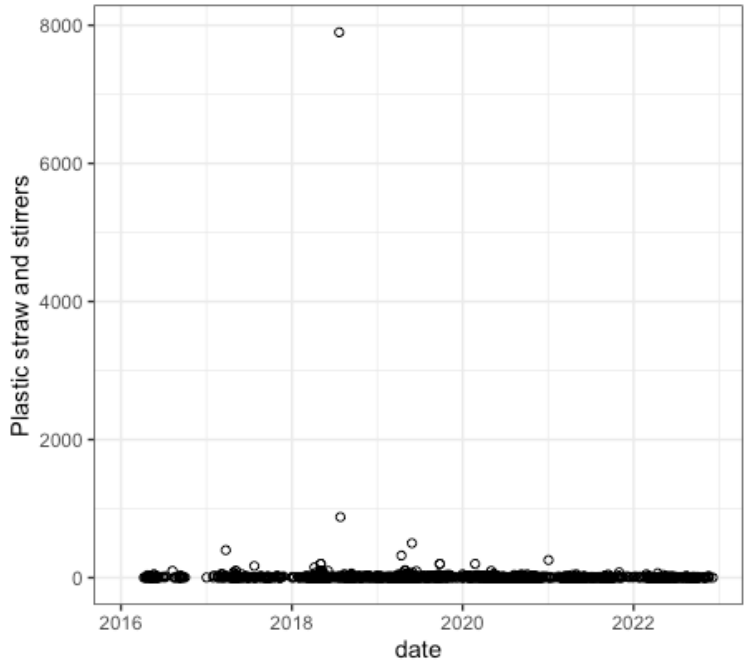

Figure F4 Plot of Plastic straw and stirrers.

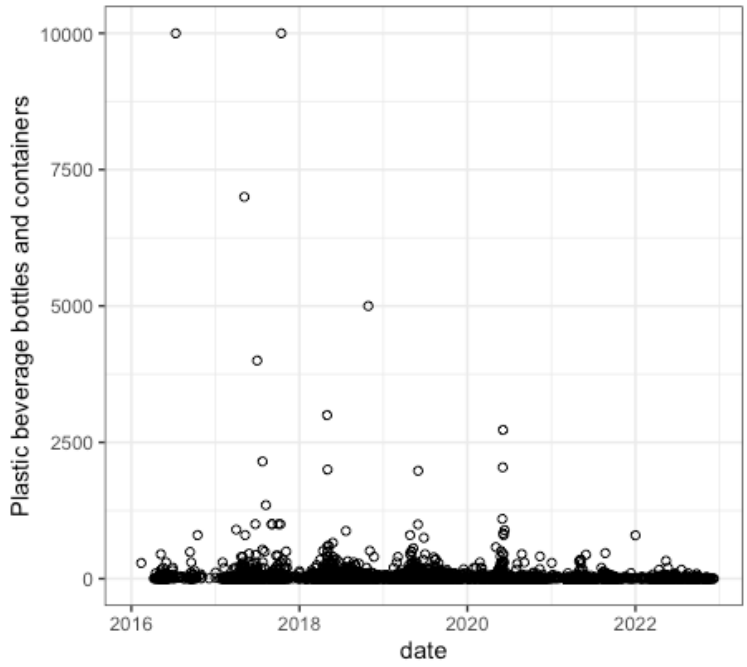

Figure F5 Plot of Plastic beverage bottles and containers.

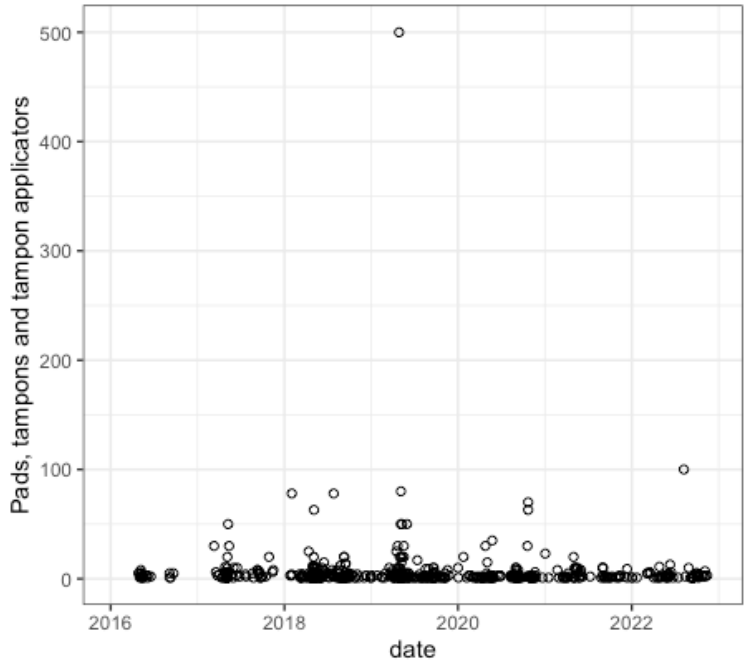

Figure F6 Plot of Pads, tampons and tampon applicators.

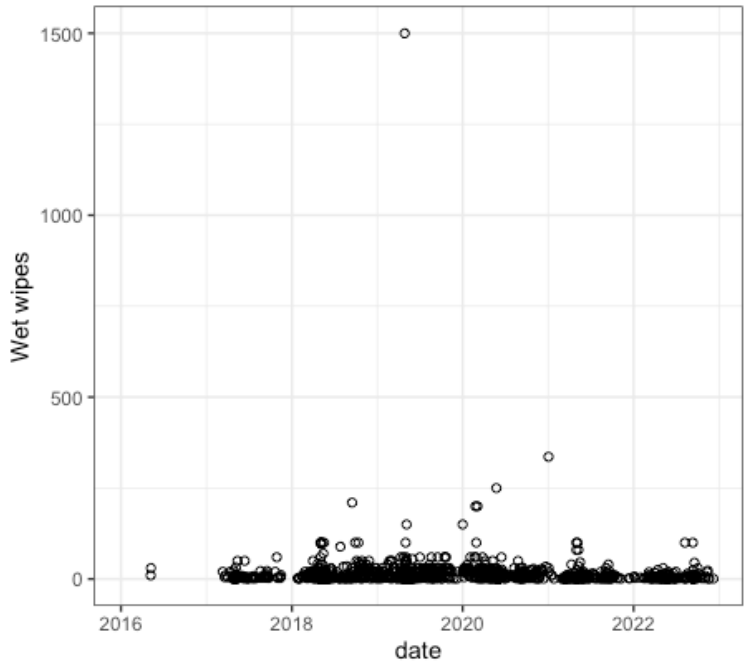

Figure F7 Plot of Wet wipes.

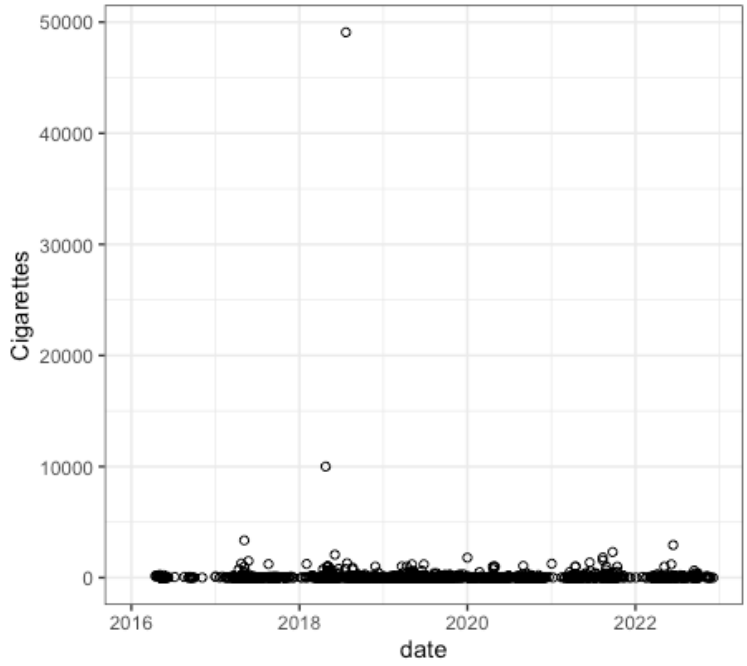

Figure F8 Plot of Cigarettes.

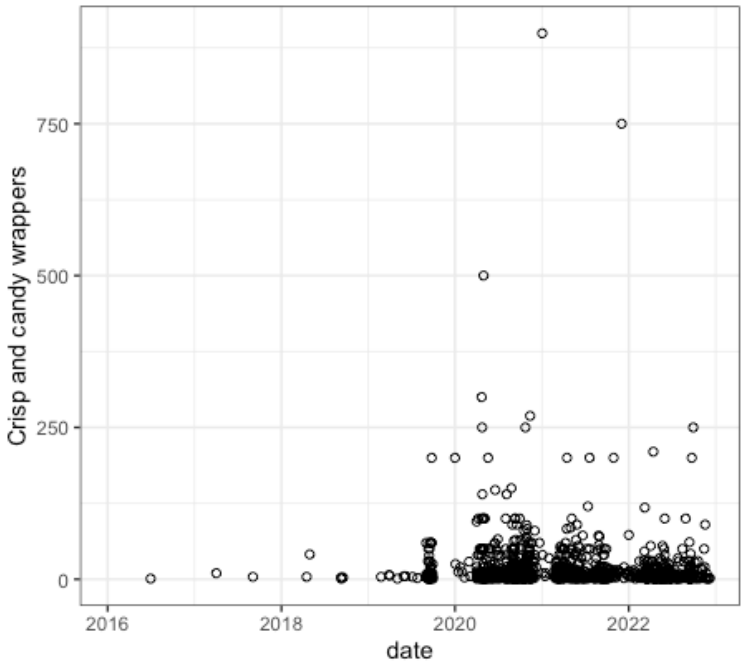

Figure F9 Plot of Crisp and candy wrappers.

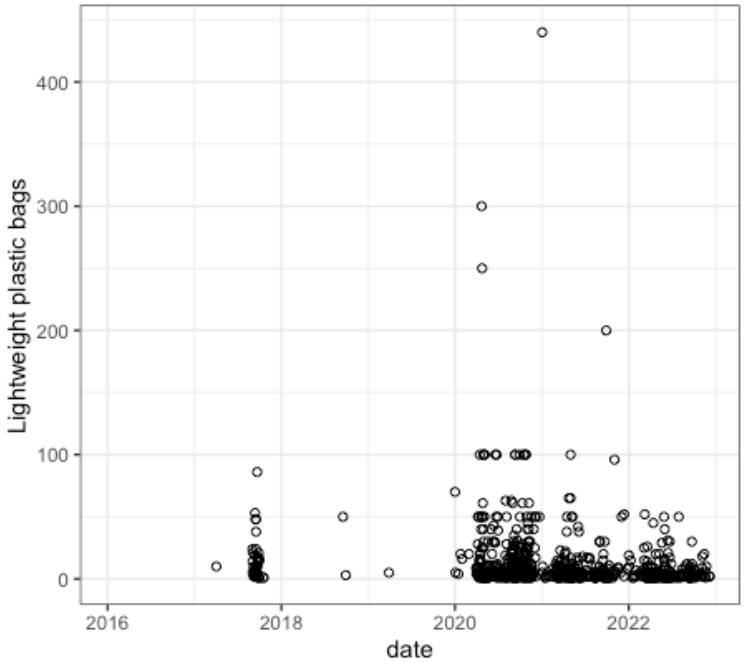

Figure F10 Plot of Lightweight plastic bags.

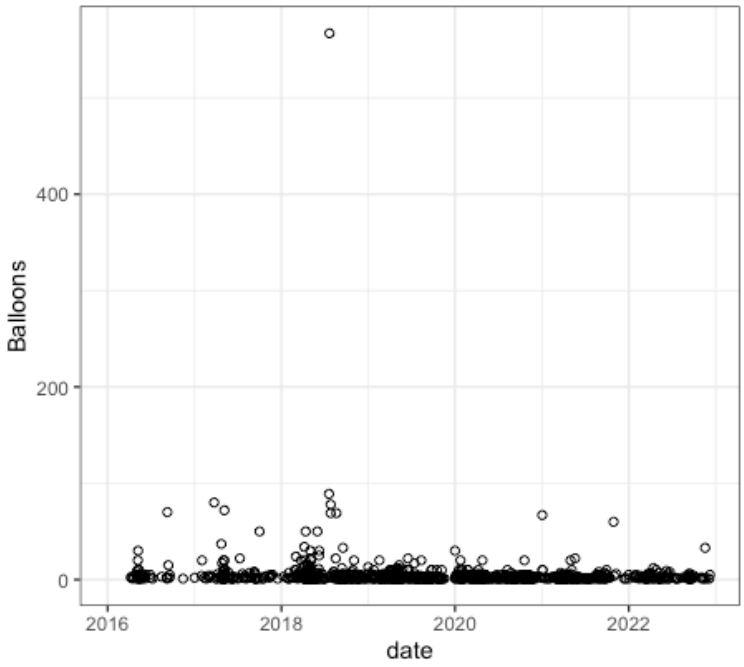

Figure F11 Plot of Balloons.

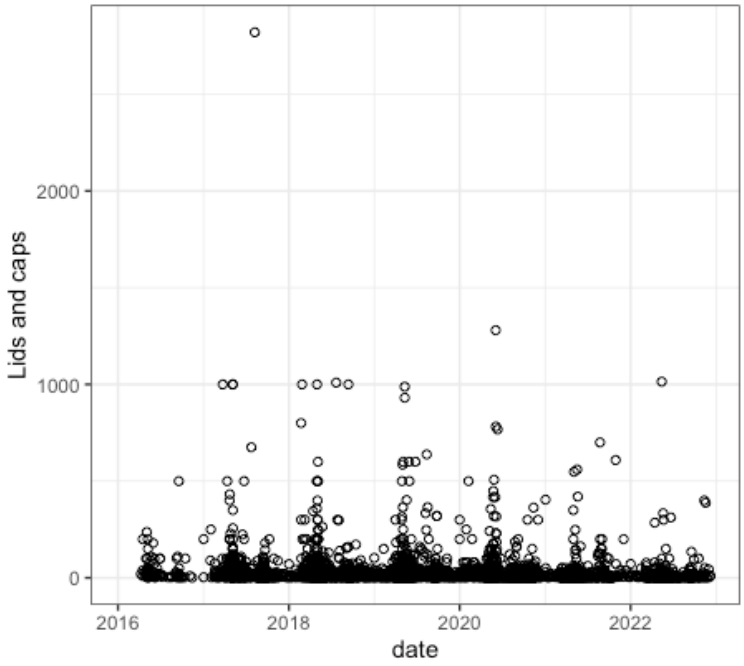

Figure F12 Plot of Lids and caps.

Appendix E. Ranks of surveyed single-use plastics

2016

1	Plastic beverage bottles and containers	16 842	38%
2	Plastic and EPS take away food containers	11 142	25%
3	Plastic cotton bud sticks	7 948	18%
4	Lids and caps	3 855	9%
5	Cigarettes	2 183	5%
6	Plastic and EPS cups, plates and cutlery	1 159	3%
7	Plastic straw and stirrers	751	2%
8	Balloons	264	1%
9	Pads, tampons and tampon applicators	60	0%
10	Wet wipes	40	0%
11	Crisp and candy wrappers	1	0%
12	Lightweight plastic bags	0	0%

2017

1	Plastic cotton bud sticks	138 452	55%
2	Plastic beverage bottles and containers	57 584	23%
3	Lids and caps	22 258	9%
4	Cigarettes	17 337	7%
5	Plastic and EPS take away food containers	10 261	4%
6	Plastic straw and stirrers	2 668	1%
7	Plastic and EPS cups, plates and cutlery	1 612	1%
8	Wet wipes	719	0%
9	Balloons	608	0%
10	Lightweight plastic bags	595	0%
11	Pads, tampons and tampon applicators	342	0%
12	Crisp and candy wrappers	14	0%

2018

1	Cigarettes	110 080	35%
2	Plastic beverage bottles and containers	61 271	19%
3	Plastic cotton bud sticks	39 262	12%
4	Lids and caps	38 504	12%
5	Plastic and EPS take away food containers	34 936	11%
6	Plastic straw and stirrers	14 767	5%
7	Plastic and EPS cups, plates and cutlery	10 560	3%
8	Wet wipes	4 484	1%
9	Balloons	2 246	1%
10	Pads, tampons and tampon applicators	857	0%
11	Lightweight plastic bags	53	0%
12	Crisp and candy wrappers	52	0%

2019

1	Plastic beverage bottles and containers	81 107	38%
2	Cigarettes	33 135	16%
3	Lids and caps	32 143	15%
4	Plastic cotton bud sticks	28 695	14%
5	Plastic and EPS take away food containers	16 729	8%
6	Wet wipes	5 922	3%
7	Plastic straw and stirrers	5 883	3%
8	Plastic and EPS cups, plates and cutlery	4 271	2%
9	Pads, tampons and tampon applicators	1 262	1%
10	Crisp and candy wrappers	1 025	0%
11	Balloons	759	0%
12	Lightweight plastic bags	5	0%

2020

1	Plastic beverage bottles and containers	26 197	20%
2	Lids and caps	22 246	17%
3	Plastic and EPS take away food containers	21 369	17%
4	Cigarettes	14 578	11%
5	Plastic cotton bud sticks	13 299	10%
6	Crisp and candy wrappers	9 961	8%
7	Lightweight plastic bags	5 666	4%
8	Plastic and EPS cups, plates and cutlery	5 099	4%
9	Wet wipes	4 422	3%
10	Plastic straw and stirrers	3 885	3%
11	Balloons	720	1%
12	Pads, tampons and tampon applicators	463	0%

2021

1	Cigarettes	25 107	32%
2	Lids and caps	11 180	14%
3	Plastic and EPS take away food containers	11 077	14%
4	Plastic beverage bottles and containers	8 218	11%
5	Plastic cotton bud sticks	6 954	9%
6	Crisp and candy wrappers	6 584	8%
7	Plastic and EPS cups, plates and cutlery	2 488	3%
8	Lightweight plastic bags	2 475	3%
9	Wet wipes	1 655	2%
10	Plastic straw and stirrers	1 600	2%
11	Balloons	452	1%
12	Pads, tampons and tampon applicators	213	0%

2022

1	Cigarettes	12 738	29%
2	Lids and caps	6 942	16%
3	Plastic and EPS take away food containers	5 517	13%
4	Plastic beverage bottles and containers	5 178	12%
5	Plastic cotton bud sticks	4 221	10%
6	Crisp and candy wrappers	3 697	8%
7	Plastic and EPS cups, plates and cutlery	1 544	4%
8	Lightweight plastic bags	1 256	3%
9	Plastic straw and stirrers	1 022	2%
10	Wet wipes	954	2%
11	Balloons	283	1%
12	Pads, tampons and tampon applicators	248	1%