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PLASTIC MANAGEMENT AND DEVELOPMENT ON ISLANDS

Research Project

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Abstract

The plastic soup is caused by large consumption and improper waste management of plastics worldwide. A global change in plastic management is needed to counter further growth of this problem. Many studies have been done on improving plastic management in large countries and regions, but islands have often been overlooked. Additionally, plastic pollution often ends up on the shorelines of islands, making sustainable plastic management a necessity on islands. This study investigates plastic management measures that contribute most effectively to sustainable plastic management and development on Texel and Sint Maarten. Firstly, the West Frisian Islands and the Dutch Caribbean Islands are analysed according to the island characteristics that influence the local plastic management system. Secondly, Material Flow Analyses of plastics are conducted for the West Frisian Islands and the Dutch Caribbean Islands to get an overview of the plastic product, waste, and pollution flows and discover specific trends surrounding plastics on the islands. Thirdly, Scenario Analyses are presented for the two case studies Texel and Sint Maarten, which show potential pathways towards sustainable plastic management on these islands. The results show that reducing plastic consumption is a slightly more effective strategy to improve sustainable plastic management and development than managing plastic waste and pollution. Furthermore, the methods utilized in this study have shown to be innovative and effective in improving plastic management systems on islands. Still, additional research is needed on macro- and microplastic flows, measures, and their impacts on islands worldwide to significantly contribute in reducing the plastic soup.

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1. Introduction

Plastic is one of the most essential materials in our society today. It has improved our daily lives, but not without costs. The main problem with our large need for plastics is the vast amount of plastic pollution that is created on a daily basis. This pollution results in something called the 'plastic soup'. The plastic soup is a phenomenon that has been created in the last few decades. This phenomenon can be characterized as large amounts of accumulated plastics in the earth's oceans, with an estimated size of about 1.6 million km^2 in 2018 (Lebreton et al., 2018). The plastic soup consists of several types of plastics, namely macroplastics (plastics larger than 5 mm) and microplastics (plastics smaller than 5 mm). The latter are created via degradation of the former. Microplastics are estimated to double in 2050, even under the most ambitious scenario (Lebreton, Egger & Slat, 2019).

To understand the severity of the growing plastic soup problem, an overview is required of the causes and consequences of the plastic soup. First of all, the main consequence of the large amount of plastic debris in the earth's water bodies is the accumulation of this waste in offshore, coastal and shoreline regions (Lebreton, Egger & Slat, 2019), of which the largest concentration of plastic pollution is found on shorelines (Eunomia Research & Consulting Ltd., 2016). This is concerning, because the damage the plastic soup causes is catastrophic to all marine ecosystems worldwide. Several issues caused by the plastic soup include the entanglement of marine animals by plastic fishing nets, the ingestion of microplastics by marine animals, and the subsequent human health risks related to consumption of microplastics in seafood (Smith, Love & Rochman, 2018). There is an urgent need to mitigate plastic pollution to counter the continuing growth of these issues. The sole causes for these issues can be traced back to high plastic consumption and plastic waste disposal and processing without proper plastic waste management strategies (Ritchie & Roser, 2018). There is a lack of incentive for proper plastic consumption and waste management, because neither the producer nor the consumer of plastics is responsible for the destination of this material. Especially lower-income countries, such as Indonesia and the Philippines, contribute greatly to plastic pollution, because they do not have the financial resources to afford proper plastic waste management (Jambeck et al. 2015). This results in an annual addition of 3 to 15 million tonnes of plastic waste to the plastic soup (Jambeck et al., 2015).

It can be assumed that all populated parts of the world contribute to plastic pollution (Ritchie & Roser, 2018). Therefore, proper plastic management is necessary everywhere to maximize the mitigation of plastic pollution. Studies on plastic management in large countries and regions have been done extensively (Horodytska, Cabanes & Fullana, 2019; Organisation for Economic Co-operation and Development, 2018), but studies on this topic in smaller communities, such as islands, have often been overlooked (Monteiro, Ivar do Sul & Costa, 2018). One possible reason for this is that islands often have a relatively small economy (Briguglio, 1995). Therefore, individual islands have a relatively small impact on the total global plastic waste generation. Additionally, the lack of studies on islands is caused by the scarcity of data on plastic pollution and plastic material flows of islands, making research on this topic more difficult than for larger countries, which often have enough data.

Still, it is very important to analyse plastic pollution and plastic management systems of islands. One reason is that islands are often not able to afford the most expensive and effective systems that are recommended to larger countries. This is due to limited financial and spatial capacity. Innovative solutions will have to be presented, in order to allow the islands to properly manage their plastic, in turn allowing them to contribute more effectively to sustainable plastic management and development. Another reason is that islands often have unique marine ecosystems that are damaged by plastic pollution. A relatively large part of islands is shorelines compared to the mainland and shorelines contain the highest concentration of plastic pollution (Eunomia Research & Consulting Ltd., 2016). Therefore, sustainable plastic management and development is essential for islands to help decrease plastic pollution and restore these ecosystems. This study focuses on providing innovative solutions for plastic management in two island regions, The West Frisian Islands and the Dutch Caribbean Islands, with detailed case studies on Texel and Sint Maarten.

This study first introduces the research question and the sub-questions in chapter 2. Next, chapter 3 introduces the theories and concepts related to sustainable plastic management and development on islands, after which chapter 4 presents the methods used in this study, which include island characterization, a Material Flow Analysis (MFA) and a Scenario Analysis. Chapter 5 shows the results of this study, which start with the characterization of the island groups: The West Frisian Islands and the Dutch Caribbean Islands. Following the characterization, the MFAs of the plastic material flows of these islands groups is shown. After, an in-depth analysis of the most effective measures in terms of sustainable plastic management and development is done in the form of a Scenario Analysis for Texel and Sint Maarten. After the results, chapter 6 presents the discussion in which the results are analysed and compared to other studies. Lastly, the conclusion is presented in chapter 7, where the research and its implications are summarized.

Analysing Texel and Sint Maarten gives insight into the possibilities of sustainable plastic management and development for islands worldwide. The West Frisian Islands, and more specifically Texel, are chosen as a case study because they are part of the Netherlands, which is considered wealthy, but also has one of the highest rates of plastic waste generation per person worldwide (Jambeck et al., 2015). Therefore, it serves as an appropriate case study to investigate the improvements that can be made in the plastic management system of an island in a developed country with a high plastic waste generation rate. The Dutch Caribbean Islands, and more specifically Sint Maarten, are chosen as the other case study, because these islands differ from the West Frisian Islands in many aspects, such as size, location, distance from the mainland, wealth, and tourism. Thus, they serves as an appropriate comparison to the West Frisian Islands to see what the similarities and differences are between the islands and their proposed plastic management measures, which can provide broader conclusions and recommendations on sustainable plastic management and development of islands globally. Increasing sustainable plastic management and development on islands adds new insight into maximizing the mitigation of plastic pollution worldwide.

2. Research question

This study aims towards answering the following research question:

Which plastic management measures contribute most effectively to sustainable plastic management and development on Texel and Sint Maarten?

The sub-questions that need to be addressed to answer the main research question are as follows:

- What are the main differences between the West Frisian Islands and the Dutch Caribbean Islands that can influence plastic management and development?
- Where in the plastic material flows of these island groups is the most plastic leakage?
- Which plastic management measures can be implemented to counter plastic consumption and pollution in the identified weak spots in the plastic material flows of Texel and Sint Maarten?
- What are the main similarities and differences between the plastic management measures that contribute most effectively to sustainable plastic management and development on each island?

3. Conceptual and Theoretical Framework

3.1 Concepts

To answer the research question and sub-questions, a better understanding is needed of the concepts that are important in this study. These concepts and theories are plastic material flows, plastic pollution, plastic waste management, sustainable development and island characteristics. A conceptual framework is presented linking these concepts.

3.1.1 Plastic Material Flows

Understanding the life cycle of plastics tells a lot about the material flow of plastics. The different steps in the life cycle of plastics are as follows: production of plastic materials, production of plastic products, transportation, usage, disposal, and finally the management of plastic waste (UNEP, 2016). Figure 1 shows a simplified version of this life cycle. Plastic material flow is defined as the flow of plastic through these stages. In all of the stages shown in Figure 1, plastic waste and leakage can occur. This leads us to the concept of plastic pollution.

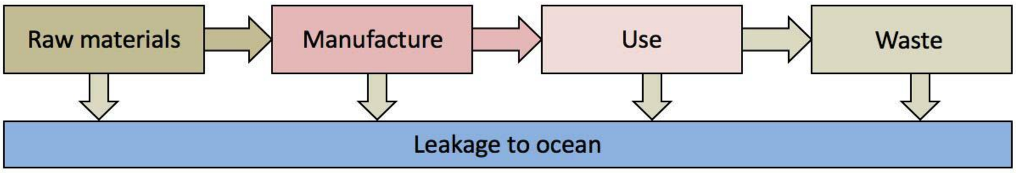

Figure 1: A simplified version of the material flow of plastics. Source: UNEP (2016), p.36

3.1.2 Plastic Pollution

Plastic waste is a result of ineffective plastic management systems, which consequently can end up as plastic pollution in the surrounding ecosystem. As mentioned in the introduction, plastic pollution can be categorized in two types: macroplastics (>5mm) and microplastics (<5mm). The main types of macroplastic pollution that originate from land-based sources are packaging, household goods, consumer goods and single-use plastics, which mainly originate from retail, food and drink, households, tourism, and plastic recycling sectors (UNEP, 2016). Packaging as a main type of macroplastic pollution can be traced back to plastic production, which is mostly focused on packaging for food and drinks. For example, in Europe, about 40% of the plastic production is aimed towards packaging (PlasticsEurope, 2018). Besides land-based sources of macroplastic pollution, there are also sea-based sources. These sources are mainly in the fisheries, aquaculture, shipping and ship-based tourism sectors (UNEP, 2016). Most macroplastic pollution generated from these sources are fishing and aquaculture gear, such as nets, lines, floats and storage boxes; strapping bands; packaging; and personal goods (UNEP, 2016). In terms of microplastics, the mainland-based pollution is from a broad range of sources. The most important sources are the tourism industry, the food and drink sector, plastic producers, the retail sector, households, terrestrial transportation, and ship cleaning, from which microplastics are generated in the form of fragmented packaging, households goods, consumer goods and single-use packaging; plastic resin pellets; personal care and cosmetic products; tyre dust; and abrasive powders (UNEP, 2016). Most of the microplastics from sea-based sources are generated by the fisheries, aquaculture and shipping sectors, which consist of fragmented fishing gear, ropes, nets, buoys and plastic resin pellets (UNEP, 2016). Which of the macro- and microplastics types or sources are dominant in plastic pollution is very dependent on the geographical location. The amount of plastic pollution that eventually ends up in the marine environment is dependent on the level of plastic waste management that is utilized in that region.

3.1.3 Plastic Waste Management

The life cycle stage which often generates the largest amount of plastic pollution is the plastic waste management stage (Ritchie & Roser, 2018). Defining the main functions of plastic waste management helps defining the main leakages points of plastic waste. Plastic waste management systems have multiple functions that often include plastics disposal, collecting, sorting and finally recycling, incinerating or landfilling (Geyer, Jambeck & Law, 2017). Plastic pollution can be generated in all of these functions.

Firstly, plastic waste disposal can be done in multiple ways. If the plastic waste management system allows it, plastics can be separated from the residual waste by consumers with the purpose of recycling, which is called source separation. If this is not done, plastics are either added to the residual waste or littered in the natural environment. The latter is the first source of plastic pollution in the plastic waste management system. After disposal, the waste is collected. Different types of waste collection exist, but the most common one used is kerbside collection, especially in developing countries (Horodytska, Cabanes & Fullana, 2019). Because of improper waste collection and transportation, such as open garbage trucks, this method often results in plastic pollution (Horodytska, Cabanes & Fullana, 2019). Improper waste collection is the second source of plastic pollution in the plastic waste management system. After collection and transportation, the plastics in the residual waste can undergo post-separation if the waste management system allows it. In most developed countries that utilize post-separation, this method is often automated in mixed-waste processing facilities. Contrarily, developing countries that utilize post-separation often do this manually via a conveyor belt, which is often less efficient. The last stage in the plastic waste management system is the processing of plastic waste. In developed countries, separated plastics are recycled on a large scale. Often, only a certain amount of plastics can be recycled. The rest is discarded as residual waste. In developing countries, the informal recycling sector is often the most dominant in recycling plastics (Horodytska, Cabanes & Fullana, 2019). Individuals collect plastic waste and pollution from households, streets, landfills or the natural environment and give or sell them to small scale recyclers. These plastic-collecting individuals help reduce plastic pollution while simultaneously incentivize a circular economy. Incineration is considered as the second-best option for sustainable plastic waste management, because energy can be recovered via this method. The main drawback for this method is the amount of pollutants that are generated that are harmful for the environment. Finally, landfilling is considered as the least sustainable option. This type of plastic waste management causes the largest amount of plastic pollution, because during the landfilling of plastic waste, the wind or water can carry the waste into the natural environment (Ritchie & Roser, 2018). Figure 3 shows a simple visualisation of the relations between the concepts discussed above. It portrays the effect of proper plastic waste management on the material flow of plastics. Plastic waste management prevents leakages (red crosses in Figure 3) from the material flow of plastics to turn into plastic pollution.

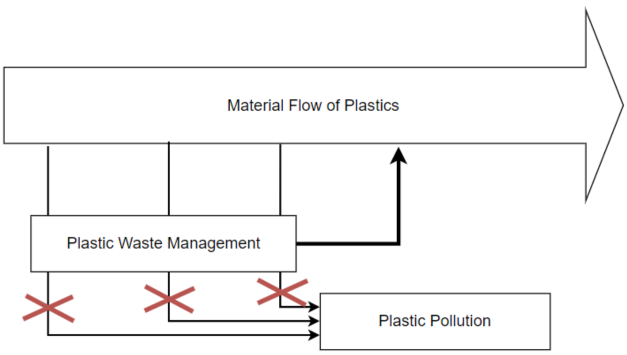

Figure 3: Visualization of the relations between the concepts: material flow of plastics, plastic waste management and plastic pollution.

3.1.4 Sustainable Development

Improving plastic management can be done via sustainable development. Sustainable development can be described as “development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (Brundtland, 1987, p.54) and is often described to consist out of three pillars: the environment, the economy, and society. A framework that takes into account sustainable development and its three pillars is the Triple Bottom Line. When looking at plastic management in this framework, this would imply that management measures could include legislation, education, and innovations that minimize plastic pollution and its damages, but simultaneously benefit the environment, the economy, and society.

It could be assumed that including the Triple Bottom Line framework into plastic management business models would be a widely used practice, because of its all-inclusive characteristics, but in reality, this does not seem the case for many businesses. The study by Dijkstra, van Beukering, and Brouwer (2020) shows that social benefits are often left out in plastic management business models. Causes for the lack of utilization of the Triple Bottom Line framework are assigned to higher costs and industry lock-in (Dijkstra, van Beukering & Brouwer, 2020).

The aim of this study is to find measures that support sustainable development, which benefit the environment, the economy, and society. The Triple Bottom Line framework is considered during selection of these measures, but the downsides of the framework, such as higher costs and industry lock-in, are taken into account as well to avoid potential sustainable plastic management barriers.

3.1.5 Island Characteristics

Plastic management on an island is influenced by the characteristics of this island. Defining these characteristics allows for a potential explanation of the current plastic management system and the recommended plastic management measures. Firstly, geographical characteristics are important to consider. These characteristics include the size of the island and population; the financial, natural, human and knowledge resources; the distance from the mainland; the political view and legislation; and the climate. Secondly, a group of characteristics to consider is tourism. These characteristics include fluctuations in population size and consequently fluctuations in the amount of plastic waste (Bouvett & Farrugia, 2019). Table 1 shows an overview of the characteristics.

Table 1: Island characteristics influencing the plastic management system

Geographical characteristics		**Tourism characteristics**
Island size	Distance from mainland	Population fluctuations
Population size	Political view & Legislation	Waste amount fluctuations
Financial resources	Climate	
Knowledge resources		

3.1.6 Conceptual Framework

The conceptual framework of this study is presented in Figure 4 that shows all the variables and concepts defined previously in this section. The island characteristics influence the current plastic management systems on the islands. From these plastic management systems, the material flows of plastics can be determined. By combining the knowledge about the weak spots and the current management systems, plastic management measures can be selected that fit the current systems. The implementation of these measures will create a new plastic management system, which minimizes plastic pollution and creates sustainable plastic management and development.

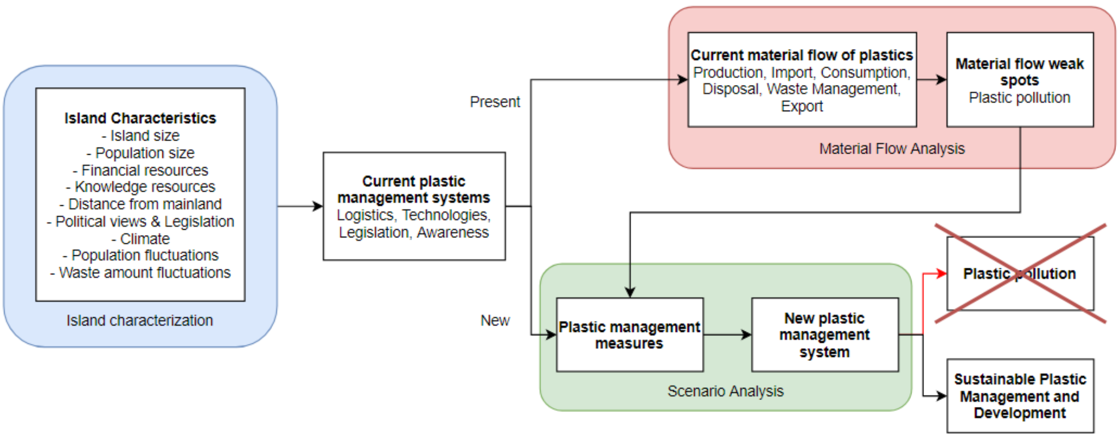

Figure 4: Conceptual Framework of the research

3.2 Literature Review

A literature review is conducted to find information on other MFAs on plastics, island-specific issues surrounding plastic management and policymaking, potential plastic management measures, and plastic management scenarios.

Several MFAs on plastics have been performed for large countries, such as India (Mutha, Patel & Premnath, 2006), Thailand (Bureecam, Chaisomphob & Sungsomboon, 2017), and Serbia (Vujić et al., 2010). These MFAs show that countries have similar structures of plastic flows, but the quantities of each flow differ greatly. For example, recycling rates range from 1% to 47%. Still, the MFAs are similar in that the largest share of plastic waste goes to landfills, which range from 53% to 99%. In terms of plastic pollution, the most common sources are littering and landfills. Other sources are improper waste collection and transportation and improper management of residue waste from incinerators. Single-use plastics are identified as the most common type of plastic pollution. To the author's knowledge, no MFAs of plastics on small islands were found, showing a lack of research on this topic. However, additional research is required, as plastic pollution poses a problem on islands as well. Plastic pollution is a problem on both the West Frisian Islands and the Dutch Caribbean Islands (de Scisciolo, Mijts, Becker & Eppinga, 2016; Debrot, van Rijn, Bron & de León, 2013; Debrot, Tiel & Bradshaw, 1999; Bravo Rebollendo & de Gier, 2019), showing the relevance of these island groups to the plastic pollution problem on islands.

To deal with the plastic leakages resulting in pollution identifiable in MFAs, plastic management measures must be implemented. There are three main ambitions to improve plastic management globally (The Ellen MacArthur Foundation, 2017; Organisation for Economic Co-operation and Development, 2018). Firstly, the plastic waste economy should improve to enhance the reuse, recycling and biodegradation of plastics. Secondly, plastic pollution into the natural environment should be reduced. Thirdly, alternatives for plastics and its feedstocks must be found, which will increase the use of non-plastic alternatives and renewable material sources. Islands, especially Small Island Developing States (SIDS), can have difficulties in meeting these goals (UNEP, 2019; Georges, 2006; Starkey, 2017). Therefore, the UNEP has addressed the main actions that islands can take to increase sustainable plastic management and development: "Ways to reduce the impact of plastics and better manage them can include: Improving waste management systems; Promoting eco-friendly alternatives to phase out single-use plastics; Educating consumers to make environmentally friendly choices; Enabling voluntary reduction strategies; and Banning or introducing levies on the use and sale of single-use plastic items" (UNEP, 2019, p.53). The selection of plastic management measures in this study focus on these proposed actions.

Part of improving plastic management systems is integrating measures and legislation that promote improving sustainability in these systems. Generally, islands have unique disadvantages when it comes to sustainable development (Douglas, 2006; Ghina, 2003; Lucas et al., 2017) and policymaking (Moncada, Camilleri, Formosa & Galea, 2010; Scobie, 2016; Sharpley & Ussi, 2014; Yu, Taplin & Akura, 1997). Island-specific issues related to these disadvantages include the following: firstly, the restricted size of the economy causing economic vulnerability, financial restrictions, and a low potential for economic diversification and poverty reduction (Briguglio, 1995; Guillaumont, 2010; Moncada et al., 2010); secondly, tourism pressures (Ghina, 2003; Moncada et al. 2010); thirdly, geographical limitations, such as small size and remoteness (Douglas, 2006; Georges, 2006; Ghina, 2003; Sharpley & Ussi, 2014; Strakey, 2017; Yu, Taplin & Akura, 1997); fourthly, a lack of resources (Ghina, 2003; Lucas et al., 2017; Scobie, 2016; Starkey, 2017); fifthly, a lack of proper waste management (Douglas, 2006; Georges, 2006; Moncada et al., 2010; Starkey, 2017); and lastly, a lack of measuring and monitoring data on sustainability and policy related topics (Lucas et al., 2017; Scobie, 2016). It is important to include these and other issues that islands face when implementing measures related to sustainability, such as plastic management policies. The paper by Yu, Taplin & Akura (1997) proposed a framework for energy policymaking in the Pacific Islands. They propose that "[t]he framework consists of six main components: (i) energy demand projection; (ii) analysis of energy resources and technologies; (iii) analysis of policies and legislation; (iv) financial analysis; (v) evaluation of socio-economic and cultural effects; and (vi) assessment of environmental issues" (Yu, Taplin & Akura, 1997, p.973). A framework for plastic management policymaking on islands should be similar in that a plastic management demand projection and an analysis of plastic management resources, technologies, and legislation need to be made, after which the same steps need to be taken. This study contributes to the second and third component of the framework, in that it analyses the plastic management resources, technologies, and legislation of the islands from which the most effective measures can be derived.

Islands can have several approaches to implementing plastic management measures and policies. These approaches can be divided into two trends, namely prevention of plastic consumption and improvement of plastic waste and pollution management. Multiple frameworks have been proposed in which these trends are imbedded (Lebreton & Andrady, 2019; Morseletto, 2020). Their results show that improving plastic waste management decreases plastic pollution, but will not stop the growth of plastic waste generation. By additionally reducing plastic consumption, plastic waste generation will decrease and plastic pollution generation will decrease even more. Besides a decrease in pollution, improving plastic waste management also contributes to countering global warming (Rigamonti et al., 2014). To the author's knowledge, no studies have been done on scenarios for plastic management on islands. This provides inadequate knowledge for governments and municipalities on islands on the effects of sustainable plastic management on an island-scale, decreasing incentive to improve their plastic management system. Therefore, it is crucial to investigate the two previously described plastic management trends on islands to provide pathways and incentives towards sustainable plastic management development for islands worldwide.

In conclusion, islands are often inadequately represented in papers dealing with current plastic management and future scenarios on plastic waste and pollution, creating a gap. Because of the lack of understanding of these plastic management systems and their futures, it is important to investigate these by creating a structural overview of the current plastic management systems of several islands. Afterwards, potential pathways towards sustainable plastic management and development can be drafted. Therefore, the combination of Material Flow Analyses and Scenario Analyses in the context of plastic management systems on islands can be considered innovative.

4. Methodology

In summary, this study first presents a characterization of the West Frisian Islands and the Dutch Caribbean Islands. Secondly, this study performs MFAs to identify the trends and places where the most plastic pollution is generated in the plastics material flows of the West Frisian and the Dutch Caribbean Islands. Thirdly, scenarios are discussed for two of the investigated islands. These scenarios include a range of plastic waste management measures that counteract the weak spots on the islands to improve sustainable plastic management and development. The measures are selected according to the most relevant criteria per island. Lastly, the differences between the islands, their material flows, and their measures are discussed, which leads to relevant recommendations for sustainable plastic management and development for islands worldwide. Figure 5 shows a summarized overview of the structure of this report.

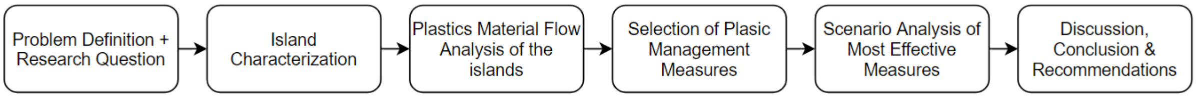

Figure 5: Flow chart of the structure of this study

4.1 Island Characterization

To properly discuss the differences in sustainable plastic management measures between the islands and the reason behind these differences, it is necessary to characterize the investigated islands. The islands are characterized according to the characteristics in Table 1. Data for this characterization is from secondary sources, which are mainly literature and websites.

4.2 Material Flow Analysis

To answer the second sub-question, points in the plastic material flow on the investigated islands have to be identified where most of the plastic pollution is generated. To identify these weak points, one MFA per island is conducted. An MFA is a quantitative method that portrays the flows of specific materials, which in this study are plastics, within a given spatial area. It makes use of a balanced equation that is based on the law of mass conservation, meaning that the input mass has to equal the output mass within the specified borders. Equation 1 shows the principle of mass-balance, where $\dot{m}$ is the material flux and k is the number of flows in a system. $\dot{m}_{storage}$ denotes the accumulation of materials in the system and is often calculated by subtracting the output flows from the input flows of the system.

$$\sum_{k_I} \dot{m}_{input} = \sum_{k_O} \dot{m}_{output} + \dot{m}_{storage}$$

Equation 1: the principle of mass balance (Brunner & Rechberger, 2005, p.59)

The MFAs in this study consists of several steps, where the mass-balance principle is checked along the way. Firstly, the system and its components are defined. The relevant plastics, dominating processes and system boundaries are defined for all islands individually. Secondly, relevant stakeholders are identified that can help with providing data for the MFAs. These stakeholders are selected according to their relevance to the plastic flows on the islands and their availability for this research. Stakeholders include governments, municipalities, waste management companies, beach combing initiatives, nature foundations, and organisations focusing on sustainable plastic management. Thirdly, data is collected on the flows of the relevant plastics within the system boundaries. Plastic material flow data is collected via primary and secondary sources. Primary sources mainly consist of interviews with the relevant stakeholders identified in the previous step and information that is provided by the stakeholders. Secondary sources consist of information presented in literature by relevant organisations, such as governments, waste management companies, and local initiatives. As mentioned before, data and literature on this topic are scarce, meaning assumptions have to be made based on existing literature and information to generate proper results. The MFAs portray the points in the plastics material flows where most of the plastic waste and pollution is generated. Figure 6 shows an example of how the structure of an MFA looks like. The product of this analysis gives a structural overview of the plastic management systems and the leakage points of the islands, simplifying the selection of potential plastic management measures.

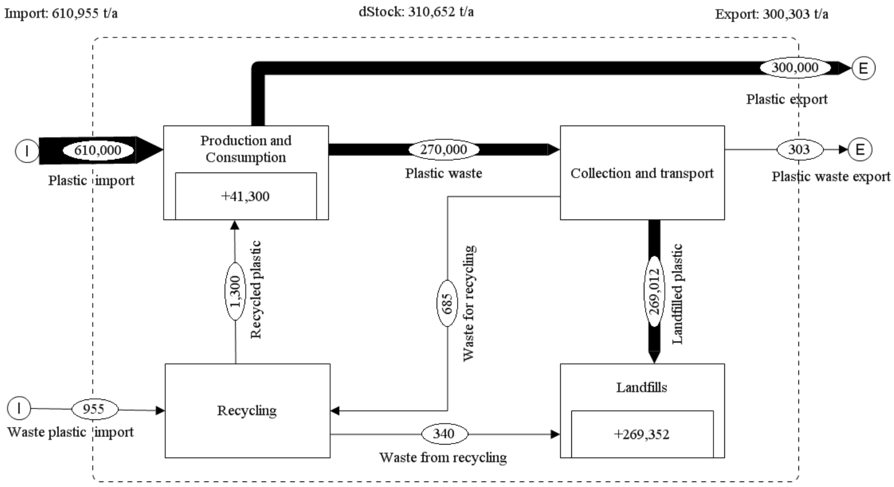

Figure 6: Example of an MFA. Source: Bureecam, Chaisomphob and Sungsomboon, 2017, p.93

4.3 Selecting and Rating Plastic Management Measures

After the MFAs, a selection is made of the potentially most effective plastic management measures, which are related to the identified weak spots in the MFAs. The selected measures are divided into the following categories: legislation, awareness, or technologies. Also, they are divided into measures addressing prevention of plastic consumption or management of plastic waste and pollution. After categorization, the measures are rated according to nine criteria, presented in Table 2, to give a general impression of their strengths and weaknesses. These criteria are based on the papers by Larash (2015) and Miller (2012) that consider environmental, economic, social, and legal impacts and are altered to fit this study. Legislative measures are dependent on political feasibility, costs and public acceptability. Important parts of political feasibility are public acceptability and costs, but also available resources and motives of the island. Because islands often have limited resources, it is important to consider political feasibility as a criteria separately. Awareness measures are largely dependent on costs and public acceptability. Technological measures are largely dependent on costs, public acceptability and technical feasibility. Because the infrastructure of most islands is relatively small, it is important that the measures fit the system. Therefore, technical feasibility is included as a criterium. As shown above, costs and public acceptability are important in all measures. They represent sustainability in terms of the economy and society, making them essential criteria to include. Lastly, effectiveness in improving sustainable plastic management is important to include to represent the environment and show the impact of a measure on the plastic management system. The measures are rated by the level of impact, positive or negative, and assigned a colour coding. Table 2 shows the impact ratings and associated colour codes.

Table 2: The rating per colour for the criteria to rate the plastic management measures individually

Criteria	Sub-criteria			
Costs	Initial	Low	Medium	High
	Maintenance	Low	Medium	High
Effectiveness in improving sustainable plastic management	Plastic consumption and pollution reduction	Very positive	Mildly positive	No effect
	Externalities	Positive effect	No effect	Negative effect
Public Acceptability	Inhabitants	High	Medium	Low
	Businesses	High	Medium	Low
	Tourists	High	Medium	Low
Political feasibility		High	Medium	Low
Technical feasibility		High	Medium	Low

Table 3: Weighting of an island's most important criteria for the plastic management measures

Criteria	Sub-criteria	Percentage
Costs	Initial	
	Maintenance	
Effectiveness in improving sustainable plastic management	Plastic consumption and pollution reduction	
	Externalities	
Public Acceptability	Inhabitants	
	Businesses	
	Tourists	
Political feasibility		
Technical feasibility		
		Total: 100%

4.4 Scenario Analysis

To select the most effective measures in terms of sustainable plastic management and development, scenarios are developed for the two cases of Texel and Sint Maarten. A scenario analysis is a qualitative decision-making tool which provides several pathways to assess how different actions can determine the outcome. This study analyses strategic scenarios (Börjeson, Höjer, Dreborg, Ekvall & Finnveden, 2006), where the scenarios investigate what happens when islands act in a certain way in terms of sustainable plastic management. This approach is chosen, because it can portray the strengths and weaknesses of the two main strategies towards sustainable plastic management and development.

Firstly, two stakeholders from each case study rank the criteria in Table 3 by importance by assigning percentages to them. These stakeholders represent the government of Sint Maarten, experts on the ecosystems of Sint Maarten, the municipality of Texel, and the beachcombing organisation of Texel. These stakeholder groups are important in decision-making on plastic management on the islands, which makes them appropriate representatives in this analysis. Table 3 was presented to the stakeholders as a weighting exercise. The assigned percentages have to add up to 100% and the criteria with the highest percentages are then taken into account in the scenarios of the case study. Secondly, each case study is divided into four scenarios, which is shown in Figure 7. The scenarios are based on two trends of sustainable plastic management and development identified in the literature review, which are prevention of plastic consumption and management of plastic waste and pollution. Therefore, the axes are plastic consumption and the local recycling rate. Each scenario discusses measures that support the goal of the scenario. Lastly, after each scenario, the feasibility of the scenario and the effects of the measures on the case study's MFA are discussed, which act as a sensitivity analysis of the measures.

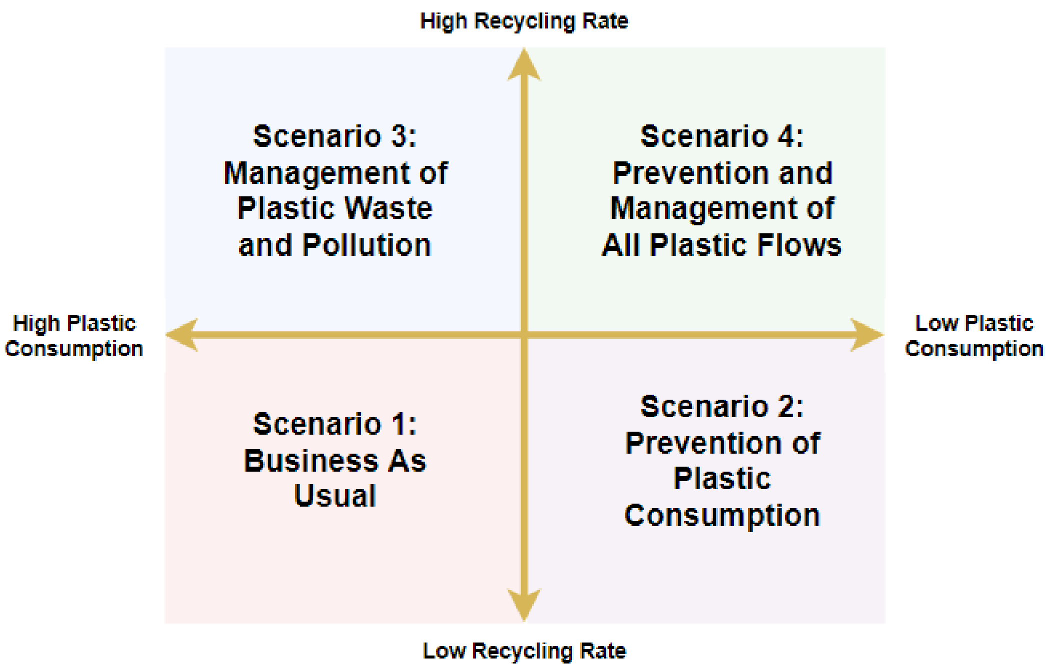

Figure 7: Scenario matrix of the Scenario Analysis

5. Results

The following chapter presents the results of the island characterization of the West Frisian and the Dutch Caribbean Islands, followed by MFAs and Scenario Analyses of Texel and Sint Maarten. The nine MFAs of the remaining West Frisian and Dutch Caribbean Islands are presented in Appendices 1 to 9.

5.1 Island Characterization

This section gives an overview of the general island characteristics of the West Frisian Islands and the Dutch Caribbean Islands. The characteristics include the island size, population size, financial resources, knowledge resources, distance from mainland, political view and legislation, climate, population fluctuations, and waste amount fluctuations. The characteristics are selected according to their possible influence on the plastic consumption, waste management systems, and pollution on the islands.

5.1.1 West Frisian Islands

The West Frisian Islands are a cluster of islands along the north coast of the Netherlands. Starting from west to east, the inhabited islands are called Texel, Vlieland, Terschelling, Ameland and Schiermonnikoog, see Figure 8.

Figure 8: Topographical map of the West Frisian Islands (Waddeneilanden Vakantie, 2020)

For all the islands, the distance to the mainland is relatively close, ranging between 2.5 and 25 km. Because all of the islands are part of the Netherlands, which is considered to be a wealthy developed country with a GDP of about 53.000 USD (World Bank, 2018), it can be assumed that all the islands have access to sufficient financial and knowledge resources to organize their infrastructure. Several budget reports from these islands confirm this assumption (Gemeente Terschelling, 2019; Gemeente Texel 2018). In terms of political views and legislation on all the islands, the local councils and national election results show a mix of political parties from 'left' to 'right', resulting in relatively politically neutral policies and regulations on the islands. The islands share the same maritime climate, and combined they attract almost 2.5 million tourists each year (Ecomare, n.d.). This is also the reason that the largest part of the businesses can be assigned to the catering and tourism industry, such as restaurants, cafes, snack bars, hotels, etc. (Sijtsma, Werner & Broersma, 2008). The large number of tourists compared to their population size (see Table 4) can potentially result in significant fluctuations in the population, which consequently results in waste generation fluctuations. No data was found on the distribution of tourist numbers throughout the year for the islands, but those living on the islands report that tourists mainly visit in the warmer spring and summer months. Therefore, fluctuations in population and waste generation during the year are in fact possible.

Table 4: Statistics of the West Frisian Islands, including island size, population size and tourists (Ecomare, n.d.)

	Texel	Vlieland	Terschelling	Ameland	Schiermonnikoog
Island Size (in km²)	162	39	85	59	40
Population size (in total inhabitants)	13.500	1.150	4900	3.700	950
Tourists (in number/year)	~1.000.000	~150.000	~500.000	~550.000	~300.000

5.1.2 Dutch Caribbean Islands

The Dutch Caribbean Islands are six islands in the Caribbean Sea, which consist of three autonomous countries within the kingdom of the Netherlands, namely Aruba, Curacao, and Sint Maarten, and three special municipalities of the Netherlands, namely Bonaire, Saba, and Sint Eustatius. The islands are divided into two clusters, see Figure 9. The first cluster are the ABC-islands, namely Aruba, Bonaire, and Curacao, and they are part of the Leeward Antilles at the southeast of the Caribbean Sea at the north coast of Venezuela. The second cluster are the SSS-islands, namely Saba, Sint Eustatius, and Sint Maarten, and they are part of the Lesser Antilles at the east of the Caribbean Sea.

Figure 9: Topographical map of the West Frisian Islands (Dutch Caribbean Nature Allialance, n.d.)

Table 5 shows that the GDP per capita of all the islands are lower than that of the Netherlands, but the income is relatively average compared to the world. From this, it is assumed that their financial and knowledge resources are lower than that of the West Frisian Islands. In terms of political views and legislation on all the islands, the local councils and national election results show a mix of political parties from 'left' to 'right', resulting in relatively politically neutral policies and regulations on the islands. The climate on the islands is characterized as tropical, with an average annual temperature above 20°C. Table 5 also shows that the number of tourists visiting annually is often more than ten times as large as their actual population. CBS (2020) states that the distribution of these tourists is equally spread throughout the year for Bonaire, Saba, and Sint Eustatius. Therefore, it is assumed that, although the islands have to deal with a large number of tourists, the population size, including the tourists, fluctuates only minimally throughout the year. It is therefore also assumed that the waste generation throughout the year is equally spread.

Table 5: Statistics of the Dutch Caribbean Islands, including island size, distance to mainland (Simal et al., 2015), population size, stayover tourists (CBS, 2020; van Buiren & Ernst, 2019), cruise tourists (CBS, 2020; van Buiren & Ernst, 2019), and GDP per capita (World Bank, 2018; CBS, 2018)

	Aruba	Bonaire	Curacao	Saba	Sint Eustatius	Sint Maarten
Island Size (in km^2)	180	288	444	13	21	34
Distance to mainland (in km)	28	89	67	~750	~750	~800
Population Size (in total inhabitants)	105.000	20.100	160.000	1.800	3200	42.000
Stayover Tourists (in number/year)	1.070.000	158.000	400.000	15.400	10.400	350.000
Cruise Tourists (in number/year)	790.000	458.000	635.000	1.600	-	1.670.000
GDP per capita (in USD)	25.600	22.500	19.500	24.200	26.100	31.800

5.2 Material Flow Analysis

The following section provides MFAs for Texel and Sint Maarten. The nine MFAs of the remaining West Frisian and Dutch Caribbean Islands are discussed in Appendices 1 to 9. Firstly, each MFA starts with a visualization and explanation of the MFA of a specific island, including the flows of the plastic products, waste, and pollution. Secondly, a more detailed overview of the types of plastic pollution on the island is given. Thirdly, the legislation and active community initiatives surrounding plastics on the island are presented. After all the MFAs are presented, a short summary is provided and implications are discussed to round off this section.

First of all, the general plastic flows on each island will be discussed. For islands without plastic production facilities, which are all islands investigated in this research, import is the sole input of plastic products and packaging. After import, plastic consumption can happen in multiple material flows. Islands, especially small ones, have shown to have three main plastic material consumption flows and one plastic pollution flow. The first consumption flow consists of the plastic material and waste flows in households. A large part of this flow consists of packaging for food and drinks, often single-use plastics. The second flow is made up of plastic materials and waste from businesses. This flow can be divided into three sub-flows. The first sub-flow is called 'in front of the counter', which includes facilities that are in the forefront of the plastic-using businesses on the islands. Worded differently, this sub-flow includes plastics that are directly related to serving the customers. Examples of this are cafes, restaurants, cafeteria and hotel rooms. Plastic products that are used here include packaging, straws, trays and cups. The second sub-flow is called 'behind the counter', which includes facilities that are in the background of plastic-using businesses on the islands. Examples of this are plastics that are used for kitchen activities, cleaning, and transport. A large part of the plastic products used here are packaging and detergent bottles. The third business sub-flow is called 'retail', which includes the plastics that are used by supermarkets and retail stores. Here, almost all plastic products used are related to packaging. The complete business flow mainly makes use of single-use plastics. Longer-lasting plastic products are used as well but are a smaller part of the plastic flows in businesses on the islands. The third flow is attributed to tourists. Tourists can play an important role in the plastic products consumption, generating waste and pollution. The number of tourists visiting annually on the West Frisian Islands and the Dutch Caribbean Islands have shown to be high (see Tables 4 and 5), meaning they play an important role in the generation of plastic waste and pollution. The plastics in this flow consists of plastics they bring to the island, plastics they consume on the island from businesses, plastics they add to the waste flow of mostly businesses, and plastics they litter resulting in pollution. The last plastic material flow is categorized as plastic pollution. This flow's main sources are littering from households, businesses, and tourists, and plastic pollution washing ashore.

5.2.1 West Frisian Islands

Plastic Waste Management

The three flows as described above are observed in all of the West Frisian Islands. Assumptions on the quantities of these flows are made, because there is a lack of data. Firstly, the assumption is made that businesses import 80% of plastic products and packaging and that the plastics are moved to the household and tourists flows via pathways such as retail on the island. Tourists can bring plastics as well, which are also part of the import, but these are most likely not a very large share. Therefore, it is assumed to be 10%. The remaining imported plastics are assigned to households, which are 10%. Secondly, a municipality of Vlieland representative stated that on average 75% of their total waste comes from households and 25% from businesses. Therefore, the assumption is made that for all West Frisian Islands 75% of the consumed plastics that is not polluted is eventually thrown away by households and 25% is thrown away by businesses. This is under the condition that the holiday parks are part of the household waste and hotels are part of the business waste. Thirdly, the assumption is made that if plastics are separated by households and businesses, about two thirds of the total plastic waste is separated and one third ends up in the residual waste. This assumption is confirmed by stakeholders of several islands, who did sample studies on this topic. Fourthly, all the West Frisian Islands have a deposit-refund system. Most large plastic bottles are included in this system. 5% to 10% of all plastic household waste is plastic bottles (de Afval Spiegel, 2020), but not all of these are included in the deposit-refund system. Therefore, it is assumed that 2% of the total imported plastic becomes part of the deposit-refund system. Lastly, about 9 kilotons of plastic end up as pollution in the Netherlands annually, of which 8.3 kilotons is categorized as packaging (Zwaveling, 2017). Also, the amount of plastic on the market in the Netherlands in 2017 was 1867 kilotons, of which 530 kilotons was classified as packaging (Snijder & Nusselder, 2019). That means that about 2% of packaging and about 0.5% of the total amount of plastics on the market end up as plastic pollution. To round off this number, it is assumed that 1% of the plastics imported on the island end up as plastic pollution. Summed up, the assumptions made are as follows:

1. 80% of the plastic import is assigned to businesses, 10% to households, and 10% to tourists
2. 75% of the consumed plastics are thrown away by households and 25% by businesses
3. If islands separate plastic waste, they separate 67% of their plastic waste. 33% remains in the residual waste
4. 2% of the imported plastics are collected via the deposit-refund system
5. 1% of the imported plastics end up as plastic pollution

These assumptions are used for each of the West Frisian Islands, except for the islands without plastic separation, for which the third assumption is irrelevant. Important in the plastic material flows of the West Frisian Islands is the plastic flow generated by the fishing industry. This industry is relatively active in the Wadden Sea surrounding the West Frisian Islands and consequently is a large consumer of plastics. When used, this plastic can be assigned to the 'behind the counter' sub-flow, but when improperly managed, it can easily become part of the plastic pollution flow. The report by Boonstra, Hest and Hougee (2016) confirm this assumption, as they state that more than half of the pollution found on the beaches of the North Sea and Wadden Sea is related to the maritime sector.

Plastic Pollution

There is a lack of quantitative data on the sources of plastic pollution on the West Frisian Islands and the Wadden Sea, such as the fraction of plastic materials that are polluted and how much results from littering or improper waste management. Still, studies have been done on the type of plastic pollution found in the Wadden Sea (Fleet et al., 2017; Boonstra, Hest & Hougee, 2016), which have shown that fishing gear is the number one type of plastic pollution in the Wadden Sea. These results show that especially plastic nets and ropes are frequently improperly disposed of and make up over 40% of the plastic pollution in the Wadden Sea. Almost 50% of the plastic pollution in the Wadden Sea comes from the maritime industry, including shipping and fishing. The runner-up is packaging, which makes up about 22% of the plastic pollution. It can be concluded that plastic pollution is mainly caused by improper plastic management by the fishing industry. Littering has a smaller effect, but still causes a significant fraction of the plastic pollution.

An important event contributing to plastic pollution was the shipping disaster of the MSC Zoe on January 1st in 2019. This has caused large amounts of pollution being washed ashore on Vlieland, Terschelling, Ameland, and Schiermonnikoog. It is unclear what amount of the plastic pollution found today is caused by this disaster, but sources have stated that the pollution from this disaster is still largely present in the Wadden Sea (Plastic Soup Foundation, 2020; WWF, 2019).

Legislation and Community Initiatives

A problem with the plastic pollution happening in the Wadden Sea is that it is not clear who the responsible party is for the waterbody. To cope with this problem, a community was started called Community Plasticvrije Waddenzee. This community includes various stakeholders, ranging from local municipalities and beach combing organisations, to governments and the Department of Waterways and Public Works. The aim of this community is to have a plastic free Wadden region in 2025 by reducing single-use plastics, reusing plastics locally, and cleaning plastic pollution. They support several initiatives, such as Fishing for Litter. Fishing for Litter is an initiative in which fishermen have the option to collect pollution that ends up in their nets and dispose of it on shore. They also support beach combing activities, which contribute to reducing plastic pollution on the West Frisian Islands.

Besides this regional support, the West Frisian Islands also have national regulations and policies which support the reduction and recycling of plastics. First of all, the Netherlands executes a deposit-refund policy in which people can get a deposit for handing in their plastic bottles. Secondly, according to the Directive 2008/98/EC from the European Union, at least 50% of the plastic waste from households and 22.5% of plastic packaging brought onto the market have to be recycled in 2020. In terms of prevention, the European Union is proposing a ban on the most commonly found single-use plastics, but it is unclear when this ban will be executed. A ban on providing customers with free plastic bags is already in place since 2016. Lastly, there are policies in place surrounding plastics in cars, electronic devices, clothing and textiles, and building materials, but these will not be discussed due to their small share in the plastic flows on the islands and their smaller relevance to the plastic soup.

The following section describes the plastic management system, pollution, legislation and community initiatives of Texel more in detail. The MFAs of the other West Frisian Islands are discussed in Appendices 1 to 4.

5.2.2 Texel

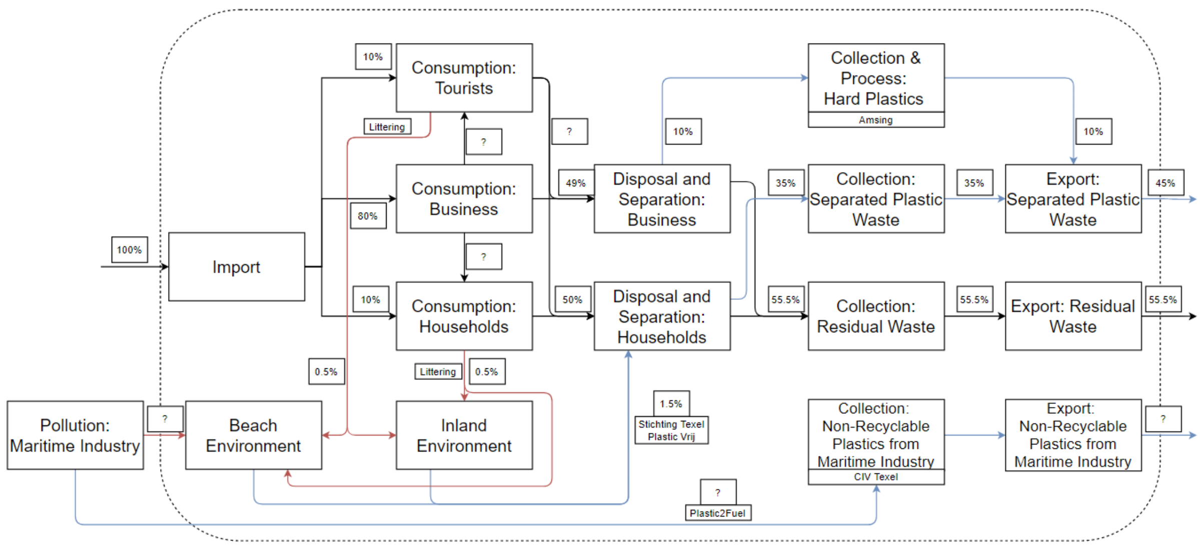

Figure 10: Material Flow Analysis of plastics on Texel

Figure 10 shows the MFA of the plastic material, waste, and pollution flows on Texel. Plastic products and packaging are imported and used by households, businesses, or tourists. After consumption, most plastics from households and hard plastics from businesses are separated. Household plastic waste is put into a plastic-waste container and is collected every three weeks. Additionally, plastic bottles are separated for the deposit-refund system, but these are included in the separated plastic waste in this MFA. A representative of the municipality of Texel stated that almost all holiday parks on Texel are not part of the household waste, but of the business waste. This representative also stated that households generate about twice as much waste as tourists. Therefore, it is assumed that on Texel half of the total plastic waste is from households and the other half from businesses, instead of the earlier assumed ratio for all West Frisian Islands. Hard plastic waste from businesses, such as buckets, jerrycans, plastic agricultural waste and garden chairs, are brought to or collected by the recycling facility Amsing Recycling, which is assumed to be about a fifth of the business waste. This is based on the earlier assumed separation rate of 67% and the fact that hard plastics, which are mainly polypropylene and high density polyethylene, make up about 30% of the plastics in Europe (PlasticsEurope, 2018). Amsing Recycling shreds the hard plastics, so that they are easier to transport. Afterwards, these processed plastics are added to the other separated plastics from households and are exported to a recycling facility in Rotterdam. Representatives of Amsing Recycling and the municipality of Texel stated that there is minimal to no plastic pollution happening from the disposal up to the export of the plastic waste and granulate. The remaining plastics from the households and businesses still end up in the residual waste. The residual waste is collected and exported to a sorting facility. There are only two types of causes for plastic pollution: littering and pollution washing ashore. Littering is caused by tourists and households and generates pollution both inland and on the beaches. Pollution washing ashore on the beaches is mainly caused by the maritime industry, more specifically the fishing industry. Lastly, pollution onshore is collected by a foundation called Stichting Texel Plastic Vrij. Stakeholders calculated that clean-ups collect about 3% of the household plastic waste, which is assumed to be 1.5% of the total plastic waste. Additionally, Plastic2Fuel is a collaboration between the companies Integrated Green Energy Solutions (IGES), FinCo Fuel Nederland B.V. (FinCo) and the fishingcooperation of Texel (CIV Texel) that deals with non-recyclable plastic waste caught by fishermen by collecting it and exporting it for the generation of diesel for the same fishing boats that collected the plastic.

Plastic Pollution

Most of the plastic pollution found on the beaches is (parts of) fishing gear washed ashore, such as ropes, nets, and lines. Additionally, an assumption is made that littering also causes plastic pollution. Stakeholders have not specifically mentioned this to be an important cause, but stakeholders from other West Frisian Islands did. Also, without regulations against littering or an island-wide consensus to prevent littering, it can be assumed it is a significant source of plastic pollution. Most land-based plastic pollution results from plastic packaging for drinks and foods.

Legislation and Community Initiatives

No specific policies preventing plastic pollution or promoting plastic recycling are present on the island. However, plastic reduction initiatives are present that affect the plastic flows of Texel. Most importantly, Stichting Texel Plastic Vrij is prominent in reducing plastic pollution and consumption on the island. This foundation organizes workshops and monthly clean-up activities to create a clean and aware Texel. They are also cooperating with some small businesses and supermarkets on the island to investigate possibilities of local recycling. Additionally, the Plastic2Fuel project reduces non-recyclable plastic waste in the waters surrounding Texel.

5.2.3 Dutch Caribbean Islands

Plastic Waste Management System

The four plastic flows described for islands are applied for the Dutch Caribbean Islands as well, which are households, businesses, tourists, and pollution. The tourism industry plays an important role on the Dutch Caribbean Islands. Next to tourists that reside on the island, the islands also have a large cruise industry (see Table 5) that put additional pressure on the plastic management system. Therefore, it is important to include this waste flow in the MFAs. Additionally, there is a theoretical chance that cruise ships dump their generated plastics waste into the water, but most countries haves imposed a ban for cruise ships to dump their plastic waste into the water (Sweeting & Wayne, 2003), diminishing the chance of plastic pollution via that route.

Because of the lack of data and information on the quantity of the flows, assumptions are made to quantize some of the flows. Firstly, similar to the West Frisian Islands, it is assumed that the largest part of the imported plastics enters the business flow, which is set at 85%. Although cruise tourists bring additional plastics onto the islands, the share of total annual tourists compared to island inhabitants is lower on the Dutch Caribbean Islands than on the West Frisian Islands. Therefore, it is assumed that 5% of the imported plastics is due to tourists. The remaining 10% of imported plastics is assigned to households. Secondly, because of the large flow of plastics from businesses to households via catering and retail, it is assumed that 75% of the plastic waste is assigned to households and 25% to businesses, which is similar to the West Frisian Islands. Thirdly, it is assumed that the littering rate is 3% to 4% and the pollution rate of landfills is 1% to 2%. This is further elaborated below. Fourthly, in terms of plastic separation, almost each Dutch Caribbean island has a different approach, making general assumptions on this topic irrelevant. Summed up, the assumptions made are as follows:

1. 85% of the plastic import is assigned to businesses, 10% to households, and 5% to tourists
2. 75% of the consumed plastics are thrown away by households and 25% by businesses
3. 3 to 4% of the imported plastics end up as plastic pollution via littering
4. If landfills are present, 1% to 2% of the imported plastics are polluted

Plastic Pollution

The types of plastic pollution on the Dutch Caribbean Islands are different than that of the West Frisian islands. Stakeholders have stated that the fishing industry is less active here, except on Curacao. This is confirmed by the data from the World Bank (2016). Therefore, plastic pollution caused by fisheries is less likely to be found. Still, plastic pollution forms a much greater threat on the Dutch Caribbean Islands than on the West Frisian Islands, which is stated by stakeholders and the report by Clear Coast Bonaire (2018). This pollution has several sources according to stakeholders. Firstly, the waterbodies surrounding the islands are largely polluted; secondly, plastics are frequently littered; and thirdly, the plastic waste management on the islands is improper. From these causes, it can be assumed that land-based plastic pollution plays a much larger role on the Dutch Caribbean Islands than on the West Frisian Islands. Since the littering rate of the West Frisian Islands was estimated at 1% of the imported plastics, the littering rate of the Dutch Caribbean Islands is estimated at 3 to 4%, depending on the existing legislation and bans surrounding plastics. Half of the littering originates from households and the other half from tourists. If there is a sign of improper plastic waste management, such as poorly managed landfills, the percentage of pollution is assumed to be 1% to 2%, depending on the ineffectiveness.

Legislation and Community Initiatives

A number of institutional frameworks exist that target at reducing plastic pollution on and surrounding islands, as mentioned in the report by Lachmann et al. (2017). For example, a Sustainable

Development Goal (SDG) set up by the United Nations, more specifically SDG 14, pleads for people to "conserve and sustainably use the oceans, seas and maritime resources for sustainable development" (United Nations, 2019). Additionally, Aruba, Curacao, and Sint Maarten are part of the Small Island Developing States, which support these islands in facing the sustainable development challenges, including waste management and plastic pollution. The rest of the legislation and community initiatives present are island specific.

The following section describes the plastic management systems, pollution, legislation and community initiatives of Sint Maarten more in detail. The MFAs of the other Dutch Caribbean Islands are discussed in Appendices 5 to 9.

5.2.4 Sint Maarten

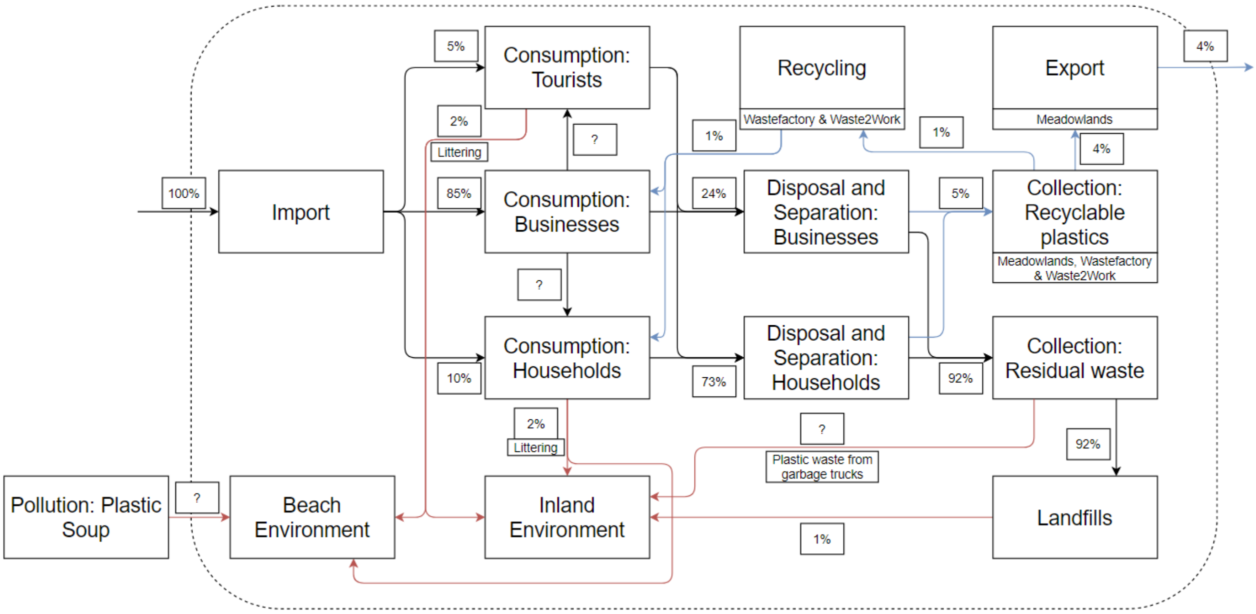

Figure 11: Material Flow Analysis of plastics on Sint Maarten

Figure 11 shows the MFA of the plastic material-, waste-, and pollution flows on Sint Maarten. After plastic products and packaging are imported, they enter the consumption phase of households, businesses, and tourists. After consumption, most of the plastic waste is added to the residual waste from both households and businesses. Multiple private hauling companies on Sint Maarten transport the waste to one of the two landfills present in the capital Phillipsburg. Here, all the waste is compacted and covered daily. A government representative of Sint Maarten stated that plastic pollution from these landfills forms a problem, even though it is covered daily. This is due to the fact that the landfills are getting overloaded (de Bettencourt & Imminga-Berends, 2015). Other sources of plastic pollution are plastic blowing off the waste collection trucks during collection of residual waste, plastic washing ashore, and, most importantly, littering from inhabitants and tourists. In terms of recycling, there is no initiative from the government, but Sint Maarten has multiple private initiatives that collects plastic waste with the purpose of recycling. Small businesses have confirmed they recycle the plastic on the island, but the largest recycling company, namely Meadowlands BV, was unresponsive. Still, a stakeholder has stated that their plastic waste is exported for recycling. The plastic collecting/recycling companies on Sint Maarten do not collect the plastics themselves, meaning that inhabitants not only have to separate the plastics voluntarily, but also take the effort of dropping the plastic off at the specific recycling locations. Because of this reason, it is apparent that most of the plastics end up with the residual waste on the landfill instead of being recycled.

Plastic Pollution

A government representative has stated that the most common types of plastic pollution present in the cities and roads on the island are bottles, Styrofoam containers and bags. On the beaches, the types of plastic pollution found most frequently are bottles, food containers, plastic bags, plastic straws, cigarette butts and bottle caps.The main cause of these types of pollution are most likely due to littering by inhabitants and tourists, but improper covering of the landfills, plastic washing ashore and waste collection trucks are also viewed as causes. Because no legislation measures are present reducing consumption and littering of plastics, the littering rate is assumed to be 4%.

Legislation and Community Initiatives

Multiple attempts have been made to ban plastic bags. The attempt that is still in progress also includes the ban of plastic straws and Styrofoam (Daily Herald, 2020). Due to the coronavirus, the approval of this law has been postponed. A petition has been made to show that the population is in favour of this law (Change.org, 2020). Additionally, an inter-ministerial working group has been created to work on the ban of all single-use plastics. Also, plans are made for building an incinerator, but this plan has been postponed multiple times due to a lack of political feasibility. Next to legislative proposals supporting sustainable plastic management, multiple community initiatives have been set up as well. The companies Meadowlands, Waste2Work, and Wastefactory focus on collecting and recycling plastic waste and pollution. Green SXM and Nature Foundation Sint Maarten promote sustainable plastic management and organize annual clean-up activities.

5.2.5 Implications Material Flow Analyses

The MFAs of the West Frisian Islands and the Dutch Caribbean Islands have a variety of plastic material, waste and pollution management systems. Tables 6 and 7 summarize the main findings from the MFAs per island region. First of all, there is a difference in plastic pollution found on the beaches of the West Frisian Islands and the Dutch Caribbean Islands. The West Frisian Islands have mainly sea-based pollution, which is largely related to the active fishing industry and lack of legislation on sea-based pollution. The Dutch Caribbean Islands have mainly land-based pollution, because the main leakage flows result from littering, garbage trucks, landfills, and the plastic soup. Additionally, the cruise ship industry puts additional pressure on the plastic management systems. All of these pollution sources largely consist of land-based plastics. Secondly, the main leakage points on all investigated islands suggest that the West Frisian Islands have less accumulation of waste and pollution than the Dutch Caribbean Islands. This can be explained by the more optimized plastic waste management systems of West Frisian Islands that either have island-wide source separation or post separation. Most Dutch Caribbean Islands have landfills and low plastic separation rates, resulting in more improperly managed plastic waste and pollution. Thirdly, most islands lack proper legislation focusing on reducing plastic consumption and pollution. Some Dutch Caribbean Islands have a ban on plastic bags and the West Frisian Islands follow Directive 2008/98/EC and have container-deposit legislation, but these measures do not solve the plastic consumption and pollution issues. The next section shows a Scenario Analysis for Texel and Sint Maarten that tackles the above-mentioned shortcomings in the current plastic management systems of the West Frisian Islands and the Dutch Caribbean Islands.

Table 6: Summary MFA of the West Frisian Islands

	Texel	Vlieland	Terschelling	Ameland	Schiermonnikoog
Local Plastic Separation	Source collection from households and source collection of hard plastics from businesses	None, post separation outside of the island	None, post separation outside of the island	None, post separation outside of the island	None, post separation outside of the island
Plastic Waste Management System	Export of separated plastic waste and plastics in residual waste	Export of all plastics in residual waste	Export of most plastics in residual waste, but some small recycling initiatives are present	Export of all plastics in residual waste	Export of all plastics in residual waste
Types of Plastic Pollution	Beach pollution: Sea-based, mostly fishing gear Inland pollution: Land-based, mostly packaging	Beach pollution: Sea-based, mostly fishing gear Inland pollution: Land-based, mostly packaging	Beach pollution: Sea-based, mostly fishing gear Inland pollution: Land-based, mostly packaging	Beach pollution: Sea-based, mostly fishing gear Inland pollution: Land-based, mostly packaging	Beach pollution: Sea-based, mostly fishing gear Inland pollution: Land-based, mostly packaging
Sources of Plastic Pollution	Beach pollution: maritime industry, mostly fisheries Inland pollution: littering	Beach pollution: maritime industry, mostly fisheries Inland pollution: littering	Beach pollution: maritime industry, mostly fisheries Inland pollution: littering	Beach pollution: maritime industry, mostly fisheries Inland pollution: littering	Beach pollution: maritime industry, mostly fisheries Inland pollution: littering
Legislation	Deposit-refund and Directive 2008/98/EC	Deposit-refund and Directive 2008/98/EC	Deposit-refund and Directive 2008/98/EC	Deposit-refund and Directive 2008/98/EC	Deposit-refund and Directive 2008/98/EC
Community Initiatives	Awareness and clean-ups: Stichting Texel Plastic Vrij and Plastic2Fuel	None	Consultancy: NHL Stenden Clean-ups: Milieujutters Terschelling Recycling: Jutfabriek	Clean-ups: Juttersvereniging Ameland	Clean-ups: Municipality

Table 7: Summary MFA of the Dutch Caribbean Islands

	Sint Maarten	**Aruba**	**Bonaire**	**Curacao**	**Saba**	**Sint Eustatius**
Local Plastic Separation	Voluntary source separation by households and businesses	Voluntary source separation for recycling and post-separation of HDPE plastics for export. Most plastic is not separated	Source separation by businesses and voluntary source separation by households	Voluntary source separation by households and businesses	Post-separation at the conveyor belt	Source separation by households and businesses and further post-separation at conveyor belt
Plastic Waste Management System	Most plastic waste ends up in landfills, but a small part is collected for export or recycling	Most plastic waste ends up in landfills and incinerators, but a small part is collected for export or recycling	Most plastic waste ends up in landfills, but a small part of plastic waste is stored separately	Most plastic waste ends up in landfills, but a small part is collected for export or recycling	Most plastics are exported for recycling, but a small part is incinerated	Half of the plastic waste is export and the other half is most likely landfilled or incinerated
Types of Plastic Pollution	Inland pollution: Land-based, mostly food containers, bottles & bags Beach pollution: bottles, packaging, cigarette buts	Beach & inland pollution: Land-based, mostly packaging, bottles & bags	Beach & inland pollution: Land-based, mostly bottles, bags and cigarette buts	Beach & inland pollution: Land-based, mostly packaging, bottles & bags	Beach & inland pollution: Land-based, bags and bottles	Beach & inland pollution: Most likely land-based, bags, packaging and bottles
Sources of Plastic Pollution	Beach pollution: Littering and washing ashore from the plastic soup Inland pollution: Littering, waste from landfills, and waste falling of garbage trucks	Beach pollution: Littering and washing ashore from the plastic soup Inland pollution: Littering, waste from landfills, and waste falling of garbage trucks	Beach pollution: Littering and washing ashore from the plastic soup Inland pollution: Littering and waste from landfills	Beach pollution: Littering and washing ashore from the plastic soup Inland pollution: Littering, waste from landfills, and waste falling of garbage trucks	Beach pollution: Littering and washing ashore from the plastic soup Inland pollution: Littering	Beach pollution: Most likely littering and washing ashore from the plastic soup Inland pollution: Littering and possibly waste from landfills
Legislation	Active: None Pending: Ban on plastic bags, straws and Styrofoam	Active: Ban on single-use plastic bags Pending: Ban on all single-use plastics	Active: None Pending: Ban on all single-use plastics	Active: Ban on single-use plastic bags, but lack of enforcement Pending: Ban on all single-use plastics	Active: None Pending: Ban on all single-use plastics	Active: None Pending: Ban on all single-use plastics
Community Initiatives	Recycling: Meadowlands, Waste2Work and Wastefactory Awareness and clean-ups: Green SXM and Nature Foundation Sint Maarten	Campaigns: Choose Zero & Ban Serio Recycling and clean-ups: Plastic Beach Party	Awareness and clean-ups: Boneiru Duradero, Clean Coast Bonaire, A Plastic Free Bonaire, Debris Free Bonaire, and Sea Turtle Conservation Bonaire	Research: CARMABI Awareness: Curacao Nature Conservation, Stichting Uniek, and Seat Turtle Conservation Curacao Recycling: Green Force, Green Phenix and Limpi	Awareness: Saba Conservation Foundation	Awareness: Statia Conservation Project

5.3 Scenario Analysis

In the previous chapter, the MFAs have shown that most islands have not reached an optimal stage yet in terms of sustainable plastic management. Significant improvements can still be made. These improvements can be made in several areas. The three areas that are discussed in this study are legislation, awareness, and technologies. All the potential measures that can be used in these scenarios are ranked in Appendix 11 according to the criteria. To analyse which measures are the most effective in the plastic management systems of islands globally, two case studies are chosen from the previously investigated islands: Texel and Sint Maarten. These case studies are chosen because of their diversity in plastic management systems and island characteristics. Texel has a plastic management system which is relatively optimal, with a high plastic source separation rate and a low pollution rate. Contrarily, Sint Maarten suffers from major plastic pollution and a lack of island-wide separation and recycling.

Four scenarios per island are presented, which are business as usual, prevention of consumption, management of waste and pollution, and prevention and management of all flows. Each scenario first shows the most effective measures in terms of legislation, awareness, and technologies, after which the expected impacts of the measures and the MFA depicting the scenario are presented.

5.3.1 Texel

The MFA of Texel shows that this island is relatively far ahead in terms of sustainable plastic management, because of its high separation rate and low pollution rate. Still improvements can be made when considering the sea-based pollution and lack of legislation and community initiatives.

Appendix 10 shows the weighting of the criteria by the stakeholder of Texel. They have stated that the measures contributing to the sustainable plastic management and development should meet certain requirements. They should:

1. Have high effectiveness in reducing plastic consumption and pollution
2. Be politically feasible
3. Be technically feasible

Scenario 1: Business as Usual

In this scenario, no changes are made in legislation, awareness and technologies. Therefore, the current material flows will continue to exist in their current forms and quantities, as shown in Figure 12.

Effects

Because no measures are taken, this scenario is highly politically and technically feasible, but there is no reduction in plastic consumption and pollution.

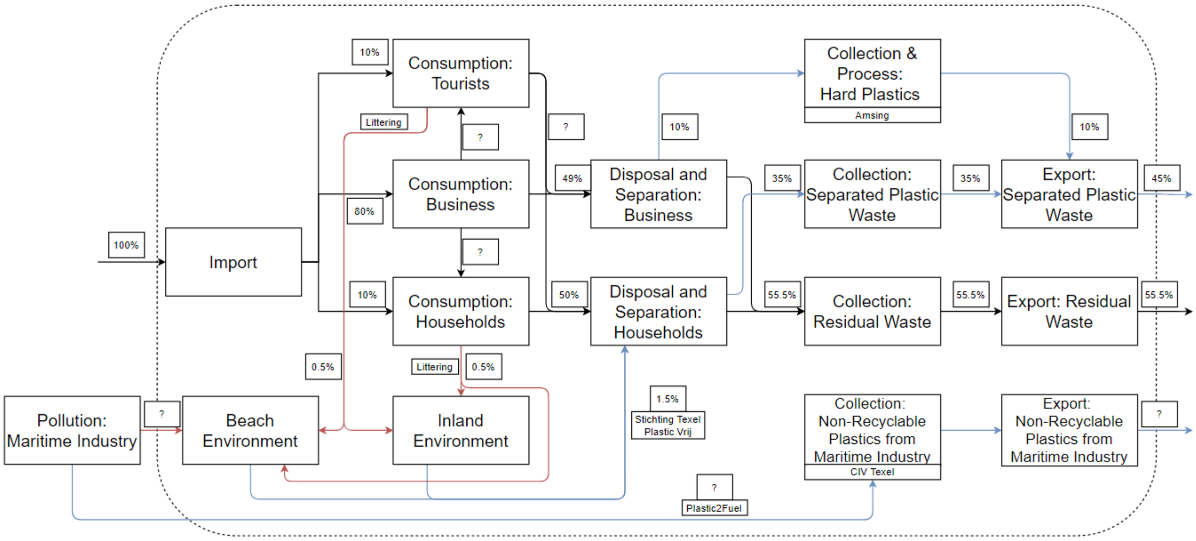

Figure 12: Material Flow Analysis of plastics on Texel in scenario 1

Scenario 2: Prevention of Plastic Consumption

Legislation

The first measure that should be introduced is a ban on single-use plastics. By introducing this ban, plastic consumption will decrease significantly. This ban should gradually move from the 'in front of the counter' business sub-flow to the 'behind the counter' business sub-flow and lastly to the 'retail' business sub-flow, because this order goes from easiest to hardest in terms of reducing plastic consumption. Important in this ban is to consider plastic packaging. Packaging for non-food products are relatively easy to find alternatives for, but food products expire quicker without plastic packaging, making it almost technically unfeasible, especially for the 'retail' sub-flow. Therefore, the ban will have to exclude plastic packaging for food products on the short term. Drafting and introducing this ban should be done with stakeholder participation, to limit public resistance.

Awareness

A combination of a top-down and a bottom-up approach is the most efficient way to reduce plastic consumption (Larash, 2015). Therefore, measures focusing on awareness of plastic consumption should support the ban of single-use plastics. The local initiatives, such as Stichting Texel Plastic Vrij, should spread information and organize workshops on reducing plastic consumption for inhabitants, businesses, and the maritime industry. For example, alternatives to single-use plastics and plastic fishing gear should be promoted. Additionally, campaigns should lobby the maritime industry and the government for introducing measures that reduce plastic consumption. All of the above mentioned campaigns should be financially supported by the municipality of Texel to increase feasibility of the goals of the campaigns.

Technologies

The technologies that should be implemented are the ones that are promoted by the campaigns. For many single-use plastics, there are wooden, paper, or cardboard alternatives. Other alternatives are biodegradable or returnable and reusable plastics. An alternative for regular plastic fishing gear is biodegradable fishing nets.

Effects

Figure 13 shows the effects of the measures on the MFA. Because of the ban on single-use plastics in several business flows, the import of plastics is estimated to reduce to 60%. The littering rate is estimated to become less than 0.5%, because most of the littering that takes place on the island currently consists of single-use plastics. Additionally, the pollution rate of the maritime industry decreases, if the anti-plastic fishing gear campaigns are effective. These reductions in plastic flows lead to a slightly higher ratio of separated plastics than scenario 1.

This scenario is highly effective in reducing plastic consumption and pollution and has a moderate technical feasibility, due to the new technologies and innovations that have to be implemented. The downside of this scenario is in the political feasibility. Introducing this ban requires financial and knowledge resources and cooperation of stakeholders, which can pose a barrier.

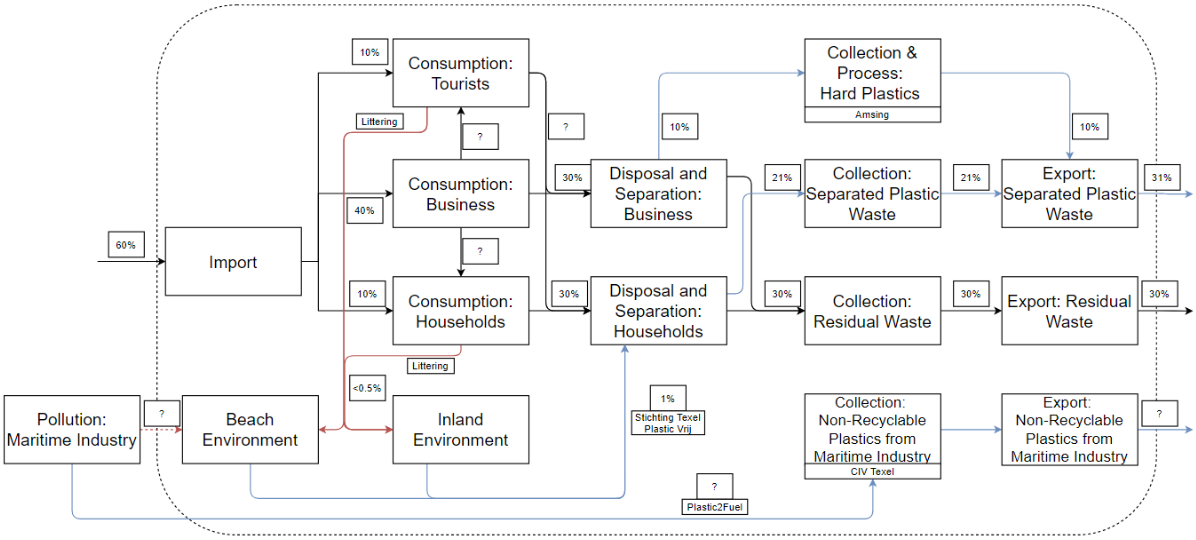

Figure 13: Material Flow Analysis of plastics on Texel in scenario 2

Scenario 3: Management of Plastic Waste and Pollution

Legislation

Legislation in terms of management of plastic waste is already present on Texel, in the forms of the European Directive 2008/98/EC and the deposit-refund policy. Theoretically, businesses could be obligated to separate their plastic waste as well, but this would be politically and technically challenging, because this would create a large change in the current plastic management infrastructure. Therefore, no additional legislation is introduced in this scenario.

Awareness

Measures focusing on awareness of plastic waste and pollution are mostly in the form of campaigns and workshops about the dangers of plastic pollution, the importance of separating and recycling plastics, and the necessity of reducing pollution via clean-ups. For example, businesses should be provided an opportunity to collaborate with local recycling initiatives. The municipality should financially support these initiatives to increase their effectiveness.

Technologies

Several technologies and initiatives should be introduced in this scenario. First of all, local recycling initiatives should collaborate with businesses to create small scale recycling facilities. This can be done independently from the municipality. To cope with the pollution from the maritime industry, improvements should be made in terms of the fishing gear. Plastic2Fuel and Fishing for Litter already collect plastics from the waters surrounding Texel, but plastic pollution can be further reduced by enabling the tracking of fishing gear. For example, by adding tags with chips to the nets, they can be tracked when they are lost. This way, the maritime industry can collect their own plastic pollution.

Effects

Figure 14 shows the effects of the measures on the MFA. Because of the introduction of local recycling, the import rate is estimated to decrease to 85%. The increased awareness of the dangers of plastic waste and pollution increases the separation rate of households to an estimated 45%. The pollution rate decreases to 0.5%. Also, an extra 15% of plastic business waste is recycled besides the already existing 10% of hard plastics that is separated and exported for recycling. The rate of plastics collected from clean-ups will only increase slightly to 2%, due to an increase in participation of clean-ups, but a decrease in pollution to be beachcombed.

This scenario is moderately effective in reducing plastic consumption and pollution and is also highly politically feasible. The downside here is technical feasibility, because businesses, inhabitants and local initiatives have to cooperate and make a big change in the current infrastructure. Creating proper recycling businesses can form a technical challenge.

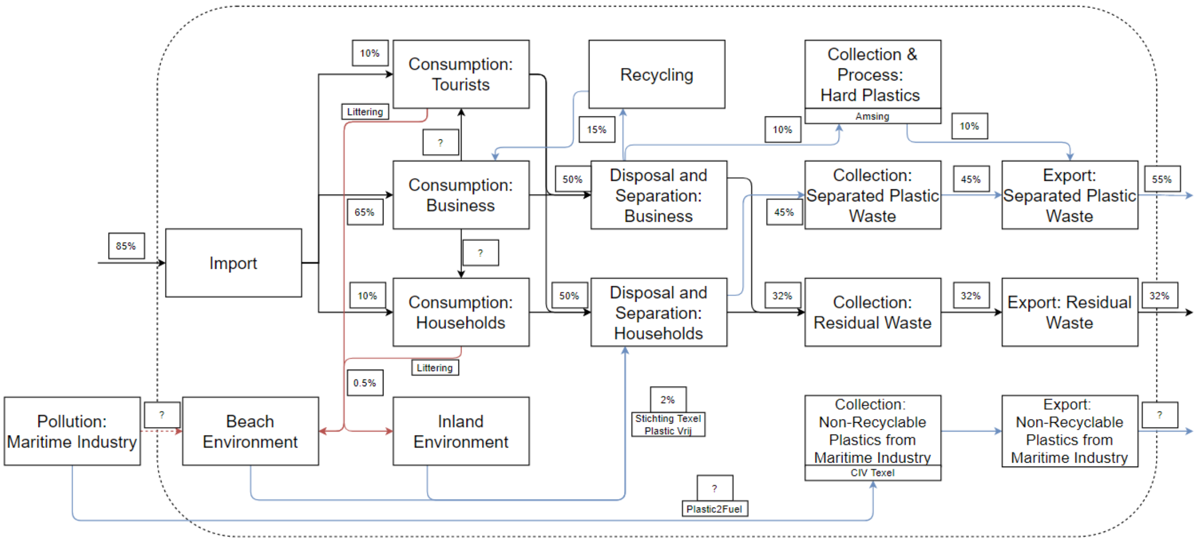

Figure 14: Material Flow Analysis of plastics on Texel in scenario 3

Scenario 4: Prevention and Management of All Plastic Flows

Legislation

This scenario requires a gradual implementation of a ban on single-use plastics. Similar to scenario 2, this order of implementation is as follows: 'in front of the counter', 'behind the counter', and finally 'retail'. Again, plastic packaging for food products will be excluded on the short term, because of the difficulty of replacing these plastics. Stakeholder participation is essential in drafting and introducing this ban, to limit public resistance.

Awareness

Awareness focuses on campaigns, workshops, education, and clean-up activities. The goal of these measures is to portray the importance of sustainable plastic consumption and the dangers of large plastic consumption, improper plastic management, and plastic pollution. Besides these measures, inhabitants and local businesses and organisations have to lobby the maritime industry to consume plastics sustainably by for example making use of alternatives to plastic fishing gear.

Technologies

Technologies that have to be implemented in this scenario are focused on recycling and alternatives to plastics. Firstly, alternatives to single-use plastics have to be implemented in the catering, hotel, tourism, and retail industry. For example, wooden, paper or cardboard single-use products and packaging can be used. Alternatively, returnable and reusable products and packaging can be utilized. Secondly, alternatives to fishing gear need to be promoted. For example, using biodegradable fishing nets or enabling pollution tracking via tags with chips. Lastly, recycling technologies are needed so that local businesses, organisations and initiatives can start recycling plastics locally.

Effects

Figure 15 shows the effects of the measures on the MFA. The reduction in plastics consumption and increase in local plastic recycling decreases the import rate of plastics to 50%. Due to awareness of plastic separation, the separation ratio is higher. Awareness of plastic pollution decreases the littering rate to less than 0.5%. The local recycling rate is estimated at 10%. This is less than in scenario 3, because plastic consumption is reduced drastically, creating less plastic waste to recycle.

The effectiveness in reducing plastic consumption and pollution is very high in this scenario. On the other hand, the political feasibility is low. Implementing the measures is time consuming, due to the drastic change in the current plastic management system and the necessary stakeholder participation. Also, the municipality has to spend many financial resources to realize this system. The technical feasibility is also low. The large change in plastic management is technically challenging, because the current plastic management system is firmly rooted in the infrastructure.

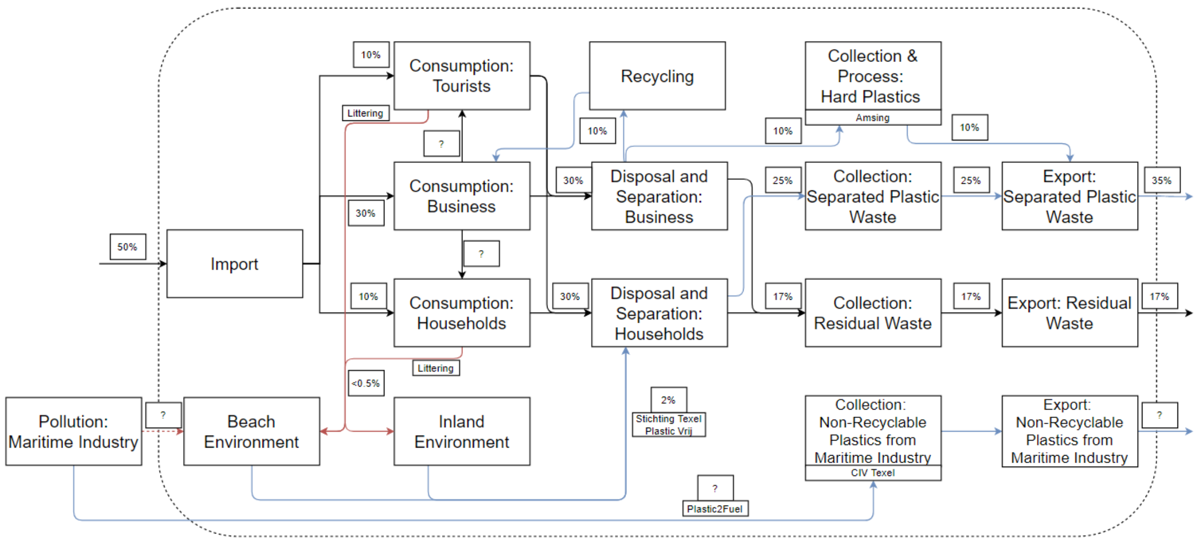

Figure 15: Material Flow Analysis of plastics on Texel in scenario 4

5.3.2 Sint Maarten

The MFA of Sint Maarten shows that this island is still in the early stages of a sustainable plastic management system. The island has a relatively low recycling rate, high pollution rate of single-use plastics, and a lack of legislation and community initiatives. These issues provide opportunities for improvements in the plastic management system on the island.

Appendix 10 shows the weighting of the criteria by the stakeholder of Sint Maarten. They have stated that the measures contributing to the sustainable plastic management and development should meet certain requirements. They should:

1. Have low initial costs
2. Have high effectiveness in reducing plastic consumption and pollution
3. Be politically feasible
4. Be publicly accepted by inhabitants

Scenario 1: Business As Usual

In this scenario, no changes are made in legislation, awareness and technologies. Therefore, the material flows will continue to exist in their current forms and quantities, as shown in Figure 16.

Effects

This scenario requires no initial costs and is highly politically feasible, but has no effectiveness in reducing plastic consumption and pollution. Also, inhabitants will not accept this lack of action against plastic pollution.

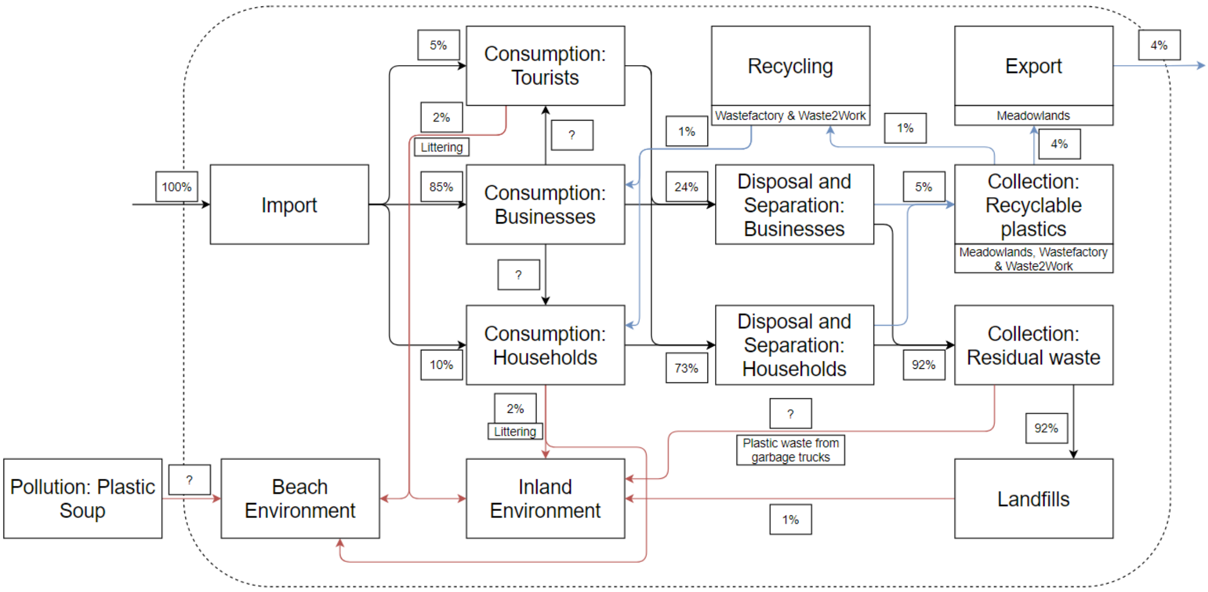

Figure 16: Material Flow Analysis of plastics on Sint Maarten in scenario 1

Scenario 2: Prevention of Plastic Consumption

Legislation

A ban on single-use plastics should be introduced. To cope with political feasibility and public acceptability of inhabitants, the most effective procedure is to first implement a tax before gradually introducing the ban (Larash, 2015). This procedure should be done with constant stakeholder participation and island-wide communication under supervision of the inter-ministerial working-group mentioned in the MFA of Sint Maarten. A gradual movement from the businesses flows 'in front of the counter' to 'behind the counter' and finally to 'retail' will result in the highest public acceptability and will increase the political feasibility. This gives businesses time to move to single-use plastic alternatives. The government should support businesses in finding alternatives, to decrease resistance towards the ban.

Awareness

Campaigns, workshops and education should be organized that focus on reducing plastic consumption and promoting single-use plastic alternatives. This requires effort from the local residents and initiatives, such as Green SXM and Nature Foundation Sint Maarten, but also from the government. The government should support the community initiatives and provide resources for them. A combination of a top-down and a bottom-up approach is the most efficient way to reduce plastic consumption (Larash, 2015), where community initiatives support the ban on single-use plastics.

Technologies

Technology measures that are implemented in this scenario act as a support to the ban on single-use plastics. Alternatives to single-use plastics should be found that function properly, but also have low initial costs. For many single-use plastics, there are wooden, paper, or cardboard alternatives. More expensive examples are biodegradable or returnable and reusable plastics.

Effects

Figure 17 shows the total effect on of this scenario on the MFA of Sint Maarten. It is expected that total plastic import decreases to 60%. Consequently, this will half the littering rate. Also, it is expected that plastic waste falling from the garbage trucks will become an insignificant pollution source, because single-use plastics were the largest part of this source. No difference in the pollution rate from landfills is expected. Other flows remain the same as well, besides a decrease in quantity of some flows.

Firstly, the initial costs of this scenario are relatively low. Financial resources will mostly be spend on supporting community initiatives and researching alternatives for single-use plastics. Secondly, the effectiveness in reducing plastic consumption is relatively high, because single-use plastics normally take up about 40% of all the imported plastics. Consequently, this will reduce plastic pollution significantly. Thirdly, public acceptability of inhabitants is moderate to high with the gradual implementation of the ban, including stakeholder participation and community communication. Lastly, political feasibility is the drawback of this scenario. First introducing a tax and then a ban will require time and proper research. Doing this together with stakeholders will take even longer.

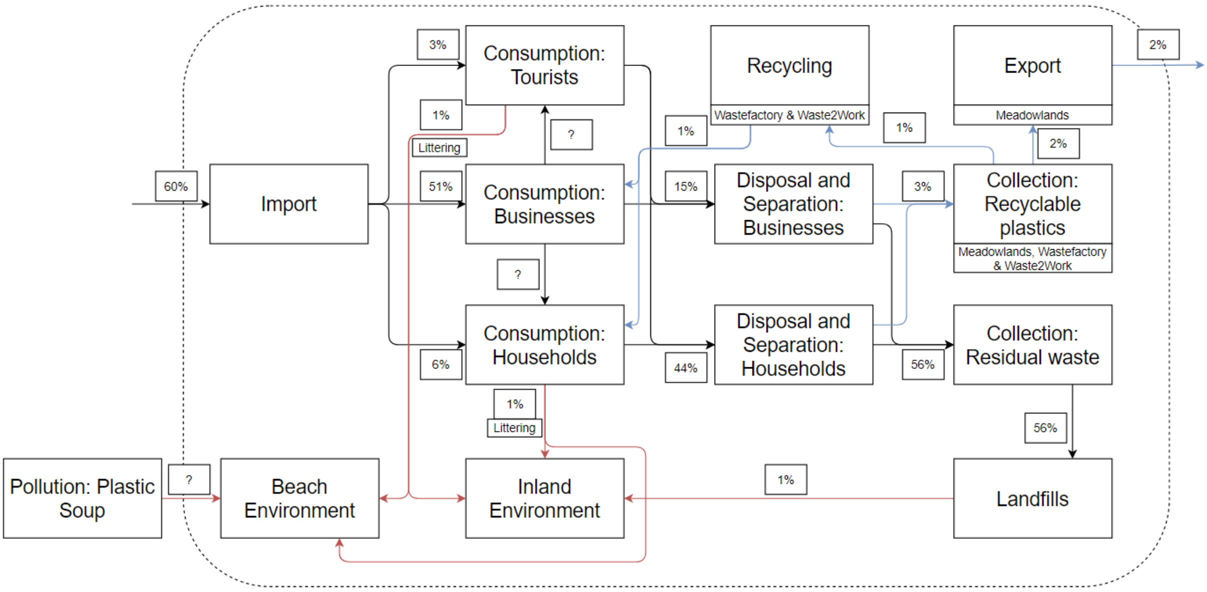

Figure 17: Material Flow Analysis of plastics on Sint Maarten in scenario 2

Scenario 3: Management of Plastic Waste and Pollution

Legislation

To promote the reuse of plastic waste, container-deposit legislation should be introduced, enabling a deposit-refund system. Local supermarkets add a small tax to plastic containers, which is paid back to the customer after they return the containers. Supermarkets can cooperate with recycling initiatives, where supermarkets are given a small fee in exchange for their plastic containers. This way, no profit is lost.

Awareness

Raising awareness on plastic pollution is essential in this scenario. Campaigns, workshops, and clean-up activities should focus on educating the community on the dangers of plastic pollution and the importance of reusing and recycling plastics. For example, the government and businesses should teach inhabitants about business models for making profit of recycling plastics, to incentivize the formation of local recycling initiatives. The government should provide human and financial resources to these measures.

Technologies

To support the already present and new recycling initiatives, affordable and effective technologies that recycle single-use plastics should be promoted. Also, recycling initiatives should invest in collecting services. Lastly, investments should be made in better management of garbage trucks, such as proper coverage. No investments in technologies for landfills will be made, because these are too expensive.

Effects

Figure 18 shows the total effect on of this scenario on the MFA of Sint Maarten. The recycling rate is estimated to grow to 21%, where about half is turned into recycled products and the other half into raw materials. Because of the increased recycling rate, there is an estimated decrease in import of 10%. Because of an increased awareness on plastic pollution, it is estimated that the littering rate will be halved and clean-ups will become a significant flow. Pollution from garbage trucks becomes insignificant, due to proper coverage. Plastic pollution from landfills is expected to remain the same.

Firstly, the initial costs of this scenario are relatively low for the government, but high for the inhabitants and businesses that set up a recycling initiative. Setting up a company and buying the proper technology can be expensive. On the other hand, long-term capital gain can be made with a proper business plan. Secondly, the effectiveness in reducing plastic pollution is moderate. The recycling rate increases, causing a slightly lower import of plastics. Also, a decrease in littering, decrease in pollution from garbage trucks and increase in clean-ups results in less pollution, but it is still present. Thirdly, political feasibility is high, because only container-deposit legislation has to be introduced. Lastly, the public acceptability of inhabitants is moderate to high. Inhabitants have to carry an extra responsibility of properly managing their waste and participating in clean-ups, but this will be moderately accepted with sufficient education and awareness on plastic waste and pollution.

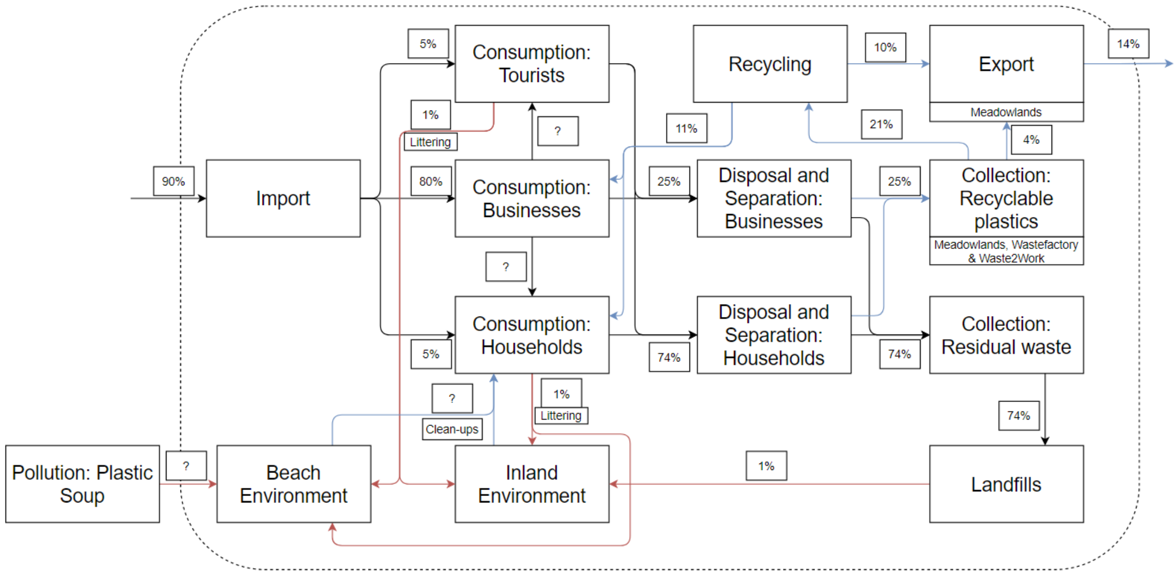

Figure 18: Material Flow Analysis of plastics on Sint Maarten in scenario 3

Scenario 4: Prevention and Management of All Plastic Flows

Legislation

Similar to scenario 2, the government should impose a ban on most single-use plastics. The same procedure should be followed, starting with a tax before the ban. Again, stakeholder consultation and island-wide communication are essential in this procedure. Additionally, a container-deposit legislation should be introduced.

Awareness

Campaigns, workshops, education and clean-up activities should be introduced that focus on sustainable plastic consumption, plastic separation, the dangers of plastic pollution, and business models for profitable recycling initiatives. Also, alternatives for plastics should be investigated and promoted. The government should support these measures by providing financial, human, and knowledge resources.

Technologies

Alternatives will have to be found for single-use plastics that are banned, mainly for the retail and catering industry. Examples of alternatives are wooden, paper, or cardboard products and packaging, biodegradable plastics or returnable and reusable products and packaging. Additionally, recycling initiatives will have to make use of technologies that are able to recycle plastics that are not included in the ban. Also, these initiatives will have to set up a system for their collection and fee services.

Effects

Figure 19 shows the total effect on of this scenario on the MFA of Sint Maarten. The import rate is estimated to be halved. The recycling rate is estimated to increase to 11%, where the recycled products are put back in the consumption flow and the raw materials are exported. The pollution rates decrease as well. It is estimated that the littering rate decreases to 1%, the landfill pollution rate is halved and the garbage truck pollution rate becomes insignificant.

Although this scenario has a very high effectiveness in reducing plastic consumption and pollution, it has downsides as well. The costs are high for businesses and inhabitants that participate in sustainable plastic management. Also, the government has high costs, because they have to financially support the recycling initiatives and the spread of sustainable plastic management awareness. Political feasibility is also relatively low, because of the many legislative steps. Lastly, public acceptability of inhabitants is relatively low to moderate. A large change in behaviour is required, but government support eases the transition to sustainable plastic management.

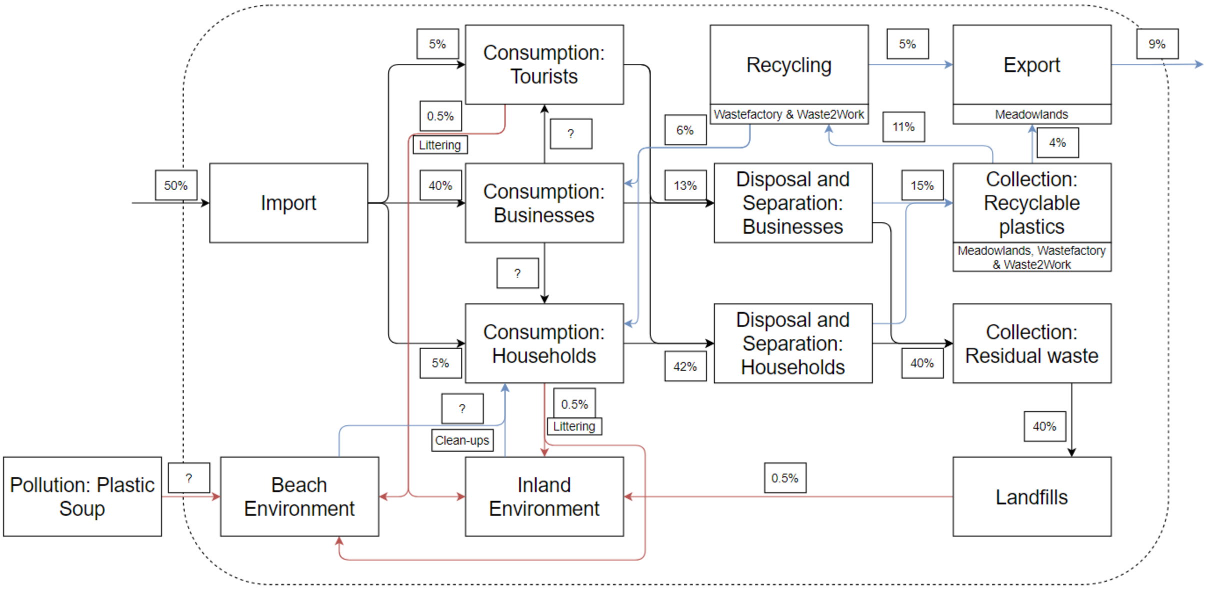

Figure 19: Material Flow Analysis of plastics on Sint Maarten in scenario 4

5.3.3 Summary Scenario Analysis

Table 8: Summary of the Scenario Analysis of Texel

			Criteria			Effects			
			Effectiveness in reducing plastic	**Political feasibility**	**Technical feasibility**	**Import**	**Export/Recycling of separated plastic waste**	**Plastics in residual waste**	**Pollution**
Scenario 1: Business as usual	No additional measures		Low	High	High	100%	45%	55.5%	1%
Scenario 2: Prevention of plastic consumption	Legislation	Ban on single-use plastics	High	Low/Moderate	Moderate	60%	31%	30%	<0.5%
	Awareness	Creating awareness on sustainable plastic consumption: campaigns, workshops, education, lobbying							
	Technologies	Alternatives to single-use plastics and fishing gear: Biodegradable plastics or alternative materials							
Scenario 3: Management of plastic waste and pollution	Legislation	-	Moderate	High	Low	85%	70%	32%	0.5%
	Awareness	Creating awareness on sustainable plastic waste and pollution management: campaigns, workshops, education, clean-up activities							
	Technologies	Single-use plastic recycling technologies and tracking pollution from maritime industry							
Scenario 4: Management of all plastic flows	Legislation	Ban on single-use plastics	Very High	Low/Moderate	Low	50%	45%	17%	<0.5%
	Awareness	Creating awareness on sustainable plastic management: campaigns, workshops, education, clean-up activities, lobbying							
	Technologies	Alternatives to single-use plastics and fishing gear + recycling technologies for plastics that are not banned							

Table 9: Summary of the Scenario Analysis of Sint Maarten

			Criteria				**Effects**			
			Initial costs	**Effectiveness in reducing plastic**	**Political feasibility**	**Public acceptability: inhabitants**	**Import**	**Export/Recycling of separated plastic waste**	**Plastics in residual waste**	**Pollution**
Scenario 1: Business as usual	No additional measures		Low	Low	High	Low	100%	5%	92%	>5%
Scenario 2: Prevention of plastic consumption	Legislation	Ban on single-use plastics	Low	High	Low/Moderate	Moderate	60%	3%	56%	3%
	Awareness	Creating awareness on sustainable plastic consumption: campaigns, workshops, education								
	Technologies	Alternatives to single-use plastics: Biodegradable plastics and/or returnable and reusable containers								
Scenario 3: Management of plastic waste and pollution	Legislation	Container-deposit legislation	Moderate/High	Moderate	High	Moderate/High	90%	25%	74%	3%
	Awareness	Creating awareness on sustainable plastic waste and pollution management: campaigns, workshops, education, clean-up activities								
	Technologies	Single-use plastic recycling technologies and proper coverage of garbage trucks								
Scenario 4: Management of all plastic flows	Legislation	Ban on single-use plastics and container-deposit legislation	High	Very high	Low	Moderate	50%	15%	40%	1.5%
	Awareness	Creating awareness on sustainable plastic management: campaigns, workshops, education, clean-up activities								
	Technologies	Alternatives to single-use plastics and recycling technologies for plastics that are not banned								

6. Discussion

The MFA results show that the West Frisian Islands have a relatively more optimized plastic management system compared to the Dutch Caribbean Islands. The West Frisian Islands have a higher plastic separation rate, because all islands have source- or post separation. Also, they have less sources of pollution than the Dutch Caribbean Islands, such as landfills or garbage trucks. Compared to the literature, the plastic waste management systems of Thailand (Chaisomphob & Sungsomboon, 2017) and Serbia (Vujić et al., 2010) seem to be more in line with those on the Dutch Caribbean Islands, with high landfilling rates and low to moderate recycling rates. The high recycling rates and absence of landfills confirm that the West Frisian Islands have a relatively sustainable plastic management system. This is most likely caused by their differences in island characteristics. The West Frisian Islands have relatively more financial resources than the Dutch Caribbean Islands allowing for more optimized plastic management systems. Additionally, the distance to the mainland is shorter for the West Frisian Islands than for the Dutch Caribbean Islands. This allows for an integrated plastic waste management system with the mainland for the West Frisian Islands. The Dutch Caribbean Islands have to manage their plastic waste per island individually. In a broader context, this study shows that island characteristics, especially financial resources and distance to mainland, can have a major effect on the local plastic management system. Briguglio (1995) and Crossley and Sprague (2014) also mentioned these island characteristics as vulnerabilities, confirming the influence of these characteristics.

From the differences in plastic management system between the investigated island groups, it could be assumed that Texel would need less measures to improve its plastic management system than Sint Maarten, but the Scenario Analysis disproves this. Tables 8 and 9 show that the most effective measures are similar for both islands. These measures include a ban on single-use plastics, campaigns and workshops on sustainable plastic consumption and/or waste management, incentives to increase participation in clean-ups, and local recycling initiatives. The differences in the measures can be largely assigned to the differences in pollution. Sint Maarten focuses its measures on single-use plastics, but Texel also focuses on sea-based pollution. When looking at the strategies, namely prevention of consumption and management of waste and pollution, the results show that each strategy has its advantages and disadvantages. In both case studies, prevention of plastic consumption is effective in reducing plastic consumption and pollution, but often difficult to realize politically. On the other hand, management of plastic waste and pollution is often politically feasible and has high public acceptance, but only decreases plastic consumption moderately and is often costly. Implementing both strategies simultaneously has the most potential in improving sustainable plastic management and development, but can be considered unfeasible when taking the criteria into account. Overall, one strategy is not clearly superior to the other, but in the cases of Texel and Sint Maarten, it can be concluded that prevention of plastic consumption is the recommended strategy, because of its effectiveness in reducing plastic consumption and pollution. Comparing the strategies to existing literature shows that the proposed measures in this study are in line with other studies on this topic. Prata et al. (2019) and UNEP (2019) show similar measures and strategies, such as introducing a ban, increasing awareness, improving recycling rates, and using alternatives for plastic products and packaging. In other studies, the strategy of reducing plastic consumption is often underrated. For example, Lebreton and Andrady (2019) focus their scenarios mainly on improving waste management; reducing plastic consumption is only an additional strategy. This study shows that reducing plastic consumption as a strategy on its own can be more effective in improving sustainable plastic consumption and waste management. The Scenario Analysis proves that it is necessary to consider prevention of plastic consumption as a main strategy in improving sustainable plastic management and development.

The most effective strategies and measures for islands found in this study are relatively similar to the ones presented in other papers not focusing specifically on island contexts. Still, islands have specific characteristics that need to be considered when implementing measures. This study shows that strategies and measures for sustainable plastic management presented by e.g. Prata et al. (2019) and UNEP (2019) can be implemented by islands while simultaneously considering the island specific issues, such as a lack of financial resources, remoteness, tourism pressures and a lack of data. For example, an increase in the local recycling rate is encouraged by Prata et al. (2019). Taking into consideration the lack of financial resources, a large recycling facility is infeasible. Instead, multiple small recycling initiatives can form a potential solution to this problem. Another example is the advice by UNEP (2019) to introduce a ban on single-use plastics. Because islands often have a lack of data and information, it can be difficult to predict the effects of this ban. This can be overcome by implementing such a measure gradually, allowing stakeholder participation and island-wide communication throughout the whole process. To summarize, global strategies and measures can be implemented on islands, if the unique island context is taken into account.

This study has also shown the effectiveness of the methods for selecting measures to improve sustainable plastic management and development. By firstly executing a Material Flow Analysis, including the types of plastic pollution and existing legislation and community initiatives, the plastic management system and main leakages points can be easily identified. By subsequently performing a Scenario Analysis, the best strategy and measures can be identified that fit the plastic management system, while also taking into account the vulnerabilities of the specific island. These vulnerabilities often include, among others: financial restrictions, tourism pressures, geographical limitations, and a lack of resources. These vulnerabilities are also identified to affect policymaking on islands (Moncada et al., 2010; Scobie, 2016; Sharpley & Ussi, 2014). By using the MFA and Scenario Analysis during policymaking, the vulnerabilities are considered, leading to more feasible legislation that can be introduced. Consequently, legislation contributes more effectively to sustainable plastic management and development. This shows that the mixed-methodology utilized in this study can be used for other islands as well and contribute to effective policymaking on these islands.

Still, improvements can be made to this study. Firstly, this study mainly focuses on macroplastics, while microplastics have been left out. Many studies, such as the ones by Bosker, Guaita, and Behrens (2018) and the UNEP (2016) have shown the importance of properly dealing with microplastics. They also state that the source of microplastics are macroplastics. Therefore, this study focuses on macroplastics to consequently reduce generation of microplastics. Still, research on reducing microplastic pollution is necessary to cope with the microplastics already present or generated from other sources such as wastewater. Secondly, this study focuses on macroplastics as a whole, but plastics can be made up of different materials that each need a slightly different waste treatment. Plastics were not categorized per material, as this would complicate the research due to the lack of data on this topic for islands. Thirdly, the reliability of the MFAs and Scenario Analysis can be improved. There is a lack of data and information on islands and their plastic management systems. Executing 11 MFAs increased reliability of the management and pollution trends found on islands, but due to a lack of monitoring and transparency of data, this study did not allow for a detailed assessment of the quantity of the flows of each island. This resulted in the need for assumptions. Although most assumptions were based on relevant literature, they can still influence the reliability of the Scenario Analysis. A change in quantities of the flows could potentially result in a different outcome in the results of the Scenario Analysis. Fourthly, due to a lack of data, the ratings of the measures for each criteria in Appendix 11 were performed to the best knowledge of the author. This resulted in ratings based on qualitative impacts which were simplified to three options and colour coded as green (positive/high), yellow (neutral/ medium) or red (negative/low). Although this gives a good indication of the strengths and weaknesses of the measures, a more detailed explanation of the characteristics is required before these measures can be implemented.

Fortunately, these drawbacks provide opportunities for future research. Firstly, a more specific MFA for each island can be presented if research focuses on measuring and monitoring the local macro- and microplastic flows and impacts of the measures. This creates more accurate MFAs, because the plastic flows can be quantized in more detail with higher reliability. Consequently, this will result in more accurate measures that can be implemented to counter the plastic leakages. Secondly, additional research on the characteristics and effects of the measures on islands is necessary. By investigating characteristics of each measure in more detail, such as costs, effectiveness, political feasibility, and public acceptability, a more accurate representation of the most effective measures can be portrayed. This incentivizes other islands to implement these as well. Thirdly, more island groups need to be investigated with the methods used in this study to confirm the current plastic management trends and possibilities or find alternative trends in plastic flows and management measures. This will result in a larger and more various group of plastic management measures, stimulating innovation and participation in sustainable plastic management and development.

7. Conclusion

This research aimed at identifying the plastic management measures that contribute most effectively to sustainable plastic management and development on Texel and Sint Maarten. Conclusions can be drawn based on the MFAs executed for all the West Frisian Islands and Dutch Caribbean Islands and the subsequent Scenario Analysis for Texel and Sint Maarten. It can be concluded that, although Texel has a more optimized plastic management system, reducing plastic consumption can be considered the most effective strategy in contributing to sustainable plastic management and development on both Texel and Sint Maarten. The 'management of plastic waste and pollution' strategy is a close second. Implementing all measures of both strategies can be considered unfeasible for Texel and Sint Maarten in the near future. Specific effective measures from both strategies are introducing a ban on single-use plastics; increasing the amount of campaigns, workshops, lobbying, and clean-ups focused on sustainable plastic management; using alternatives to plastic products and packaging; and increasing recycling initiatives.

When assessing the methods used in this research, it shows that they are very effective in answering the research question. Creating a structural overview of the plastic management system of an island is useful in identifying the most effective measures for improving sustainable plastic management and development. Weak points and leakages in the plastic management system of an island are identified quickly with the MFA, which narrows down the measures in the Scenario Analysis that are most likely to be effective. Therefore, conducting MFAs before the Scenario Analysis can be considered very effective and recommendable.

In a broader island context, the MFA results show that almost no island has the same plastic management system. However, similar trends can be found in plastic flows and management representative for islands worldwide, such as the problem of littering and the lack of focus and legislation on reducing plastic consumption. Consequently, trends can be found within the presented measures that portray a pathway towards sustainable plastic management and development for islands worldwide. Still, specific measures for improving sustainable plastic management and development are island-dependent and need to be in line with the main type of pollution and plastic management system present.

Ultimately, more research needs to be done on plastic management systems on islands worldwide. By improving the measuring and monitoring of macro- and microplastic flows on islands, more detailed and accurate MFAs can be presented in future research. If continuous research is done, including measuring and monitoring of the implemented measures and its impacts, a dynamic sustainable plastic management system can be formed on islands that adapts its measures to its current system. These improvements are necessary for islands to contribute to sustainable plastic management and development and cope with the global plastic pollution problem.

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9. Appendices

Appendix 1: Material Flow Analysis on plastics of Vlieland

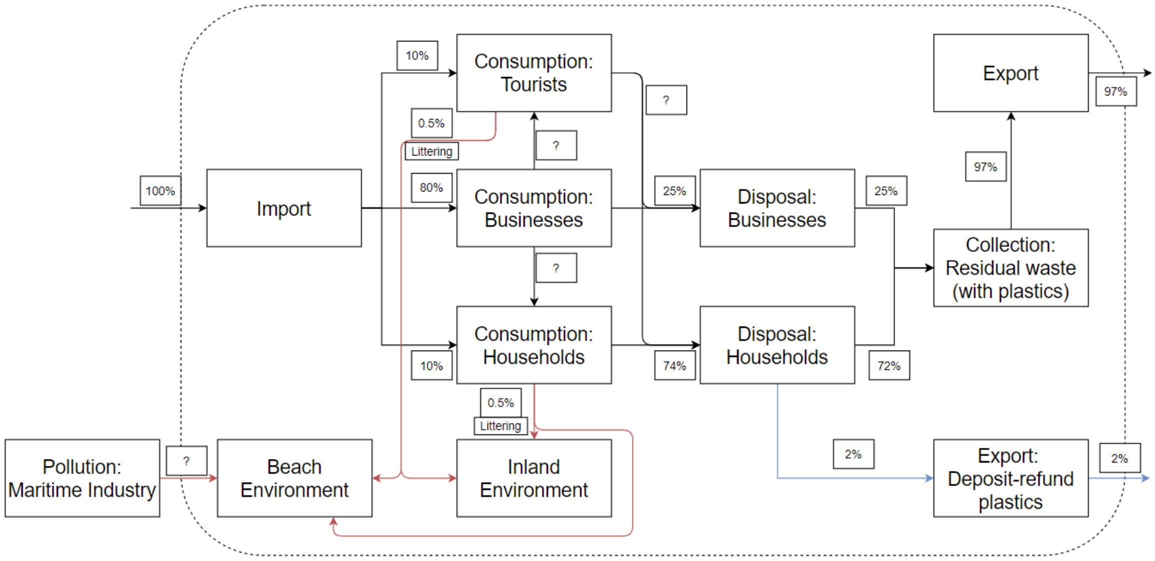

Figure 20: Material Flow Analysis of plastics on Vlieland

Figure 20 shows the MFA of Vlieland. Plastic products and packaging are imported and used by households, businesses, or tourists. During disposal of all the waste, plastic waste is not separated, except for plastic bottles in the deposit-refund system. These are collected and exported for recycling. Residual household and business waste are collected in mini-containers on a weekly basis. All the collected residual waste, including plastic waste, from businesses and households are compressed and exported to a waste sorting and processing facility called Omrin. Lastly, the plastic pollution flows are caused by littering and pollution washing ashore.

Plastic Pollution

A stakeholder from the municipality of Vlieland stated that most of the plastic pollution found on the island is on the beaches, which originates from the fishing industry. The plastic pollution mainly consists of fishing nets, ropes, and lines. Only minor plastic pollution is caused via littering, which mainly consists of land-based plastics, such as packaging. Because littering is not completely negated, it is still assumed to be a relevant part of the plastic material flows.

Legislation and Community Initiatives

There are no specific policies present on Vlieland surrounding plastics. Additionally, there are no local organizations or initiatives present that tackle plastic consumption or pollution. The organisation with the most influence on plastic on the island is the Community Plasticvrije Waddenzee, which has plans to ban plastic consumption on terraces.

Appendix 2: Material Flow Analysis on plastics of Terschelling

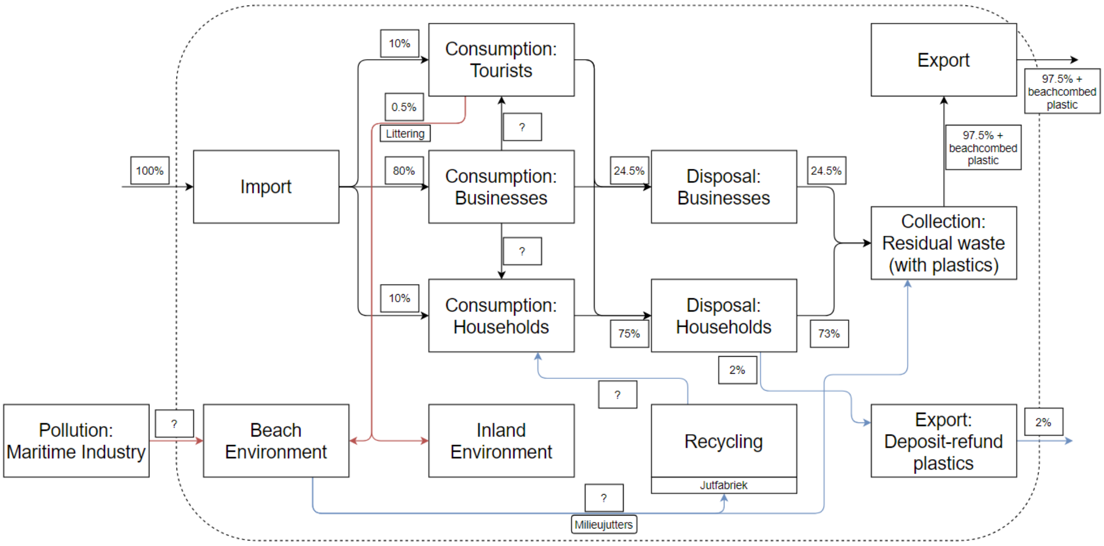

Figure 21: Material Flow Analysis of plastics on Terschelling

Figure 21 shows the MFA of Terschelling. The plastic products and packaging are imported and used by households, businesses, and tourists. Most of the plastic waste by households, businesses, and tourists ends up with the residual waste. The residual waste with the plastic is collected every two weeks and exported to the waste sorting and processing facility Omrin. A small fraction of the plastic waste is plastic bottles in the deposit-refund system that are collected and exported for recycling. In terms of pollution, a small part of the plastic that is consumed by households and businesses is littered. Also, plastic pollution washes ashore. Terschelling has an active beach combing organisation, called Milieujutters Terschelling, which cause a large part of the pollution on the beaches to be cleaned up. The collected plastic pollution is either send to local recycling initiatives, such as the Jutfabriek, or for the largest part added to the residual waste. Recycled plastics are put back into the consumption phase of the plastic flows.

Plastic Pollution

The stakeholders from the Milieujutters and the Jutfabriek have stated that the main type of plastic pollution found on the beaches is fishing gear, such as nets and lines. This is caused by improper plastic management by fisheries. Littering of plastic by inhabitants has been stated to form an insignificant fraction of the plastic pollution. This is due to the motivation to keep the island clean after the MSC Zoe shipping disaster. Therefore, it is assumed that households do not contribute to plastic pollution, but tourists still do.

Legislation and Community Initiatives

Terschelling has no specific policies surrounding plastic, but multiple initiatives are actively promoting the reduction of plastic consumption and pollution. First of all, there is an ongoing project working on a plastic-free Terschelling. The company NHL Stenden is working on banning plastic from businesses, starting with the flow 'before the counter', then 'behind the counter', and lastly 'retail'. By doing so, they hope to significantly contribute to a reduction of plastic consumption and pollution by tackling the problem at the source. Additionally, the beachcombing initiative called Milieujutters Terschelling organizes weekly beachcombing activities, which contribute to the reduction of plastic pollution in the environment of Terschelling. Beach visitors also have the option to grab a garbage bag, beachcomb themselves, and place the bag at one of the collection points. The Milieujutters Terschelling will collect the bags weekly, incentivizing the inhabitants and tourists to reduce plastic pollution.

Appendix 3: Material Flow Analysis on plastics of Ameland

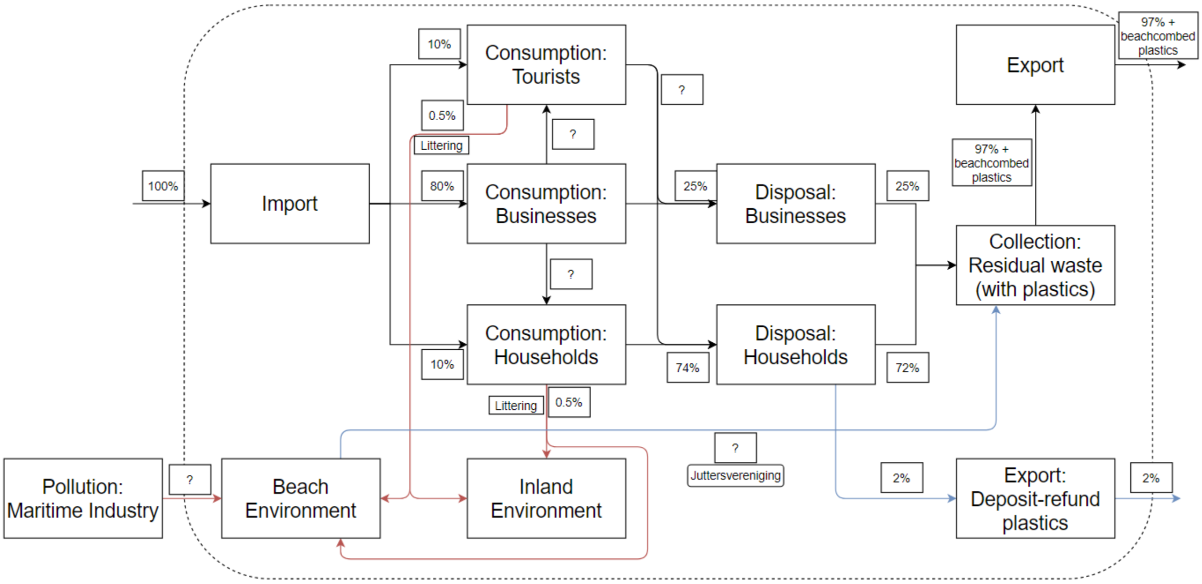

Figure 22: Material Flow Analysis of plastics on Ameland

Figure 22 shows the MFA of Ameland. Plastic products and packaging are imported and used by households, businesses, and tourists. No plastic separation is done except for plastic bottles in the deposit-refund system. These are collected and exported for recycling. All the other plastics end up either with the residual waste in mini-containers or as plastic pollution via littering. The residual waste is collected from businesses and households every two weeks and is exported to the waste sorting and processing facility Omrin. Besides littering, plastic pollution can also wash ashore. Ameland has an active beach combing organisation, namely Juttersvereniging Ameland, who reduce the plastic pollution on the beaches significantly.

Plastic Pollution

Juttersvereniging Ameland has stated that they find a variety of plastics during beachcombing. The types of plastics include packaging for drinks and good, fishing nets and ropes, balloons, bottle caps, and cigarette buts. This pollution is assigned to sea-based activities, such as fishing, but also to littering by inhabitants and tourists on the island itself.

Legislation and Community Initiatives

Juttersvereniging Ameland has stated that Ameland is somewhat inactive in preventing plastic consumption and pollution. The only organisation who is busy with these topics is themselves. They clean the beaches and add the collected garbage to the residual waste, which is exported. No other legislative measures or actions are taken, except for the legislation and actions that apply for all the West Frisian Islands.

Appendix 4: Material Flow Analysis on plastics of Schiermonnikoog

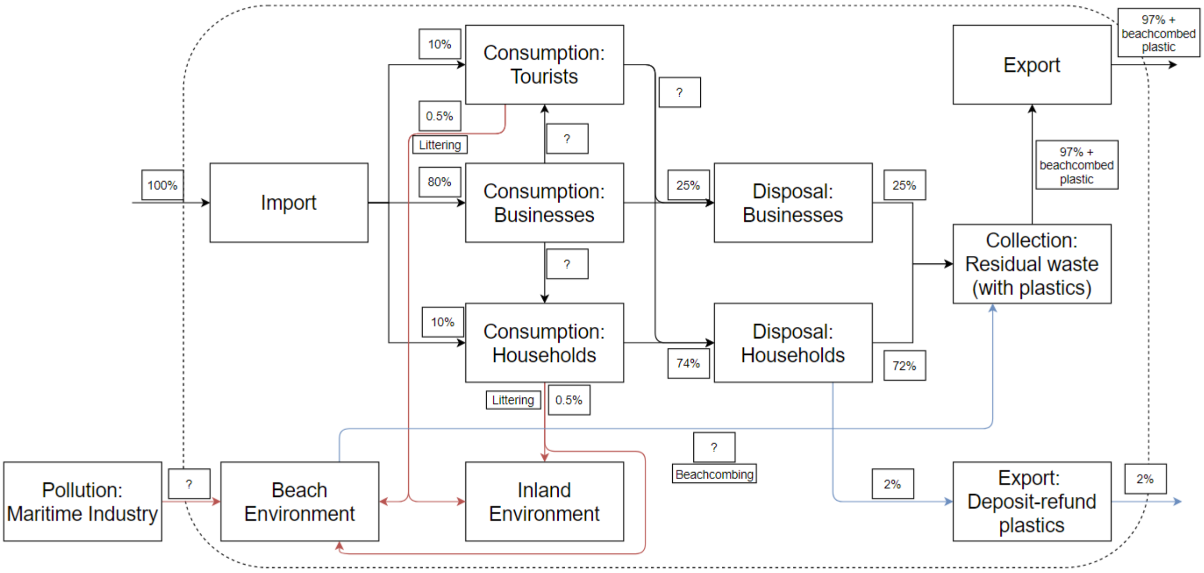

Figure 23: Material Flow Analysis of plastics on Schiermonnikoog

Figure 23 shows the MFA of Schiermonnikoog, containing the plastic material, waste, and pollution flows. Because no contact person was found to confirm this MFA, it consists mostly of assumptions. At first, after the plastic products and packaging are imported, they are used by households, businesses, and tourists. After consumption, the plastics are thrown away together with the residual waste (Gemeente Schiermonnikoog, n.d.a), except for the deposit-refund plastics, which are exported for recycling. All the collected residual waste is exported to the waste sorting and processing company Omrin. Plastic pollution sources are littering in the consumption phase and plastic pollution washing ashore. No beachcombing or plastic recycling initiatives were found on the island, but the municipality states that beachcombing activities occur frequently. The beach of Schiermonnikoog is in the top 3 of cleanest beaches in the Netherlands, affirming this statement (Gemeente Schiermonnikoog, n.d.b).

Plastic Pollution

Because the stakeholders on the other West Frisian Islands have stated that fishing gear is the number one plastic pollution found on their beaches, it is assumed that Schiermonnikoog also has this as its largest type of plastic pollution on the beaches. Some other West Frisian Islands have also stated that plastic packaging occurs more often inland, so this is assumed for Schiermonnikoog as well.

Legislation and Community Initiatives

No specific legislation or initiatives were found related to plastics on Schiermonnikoog, except for the frequent clean-up activities. Because of the lack of information on these activities, it is assumed that these have a small but relevant effect on the reduction of plastic waste and pollution on the beaches.

Appendix 5: Material Flow Analysis on plastics of Aruba

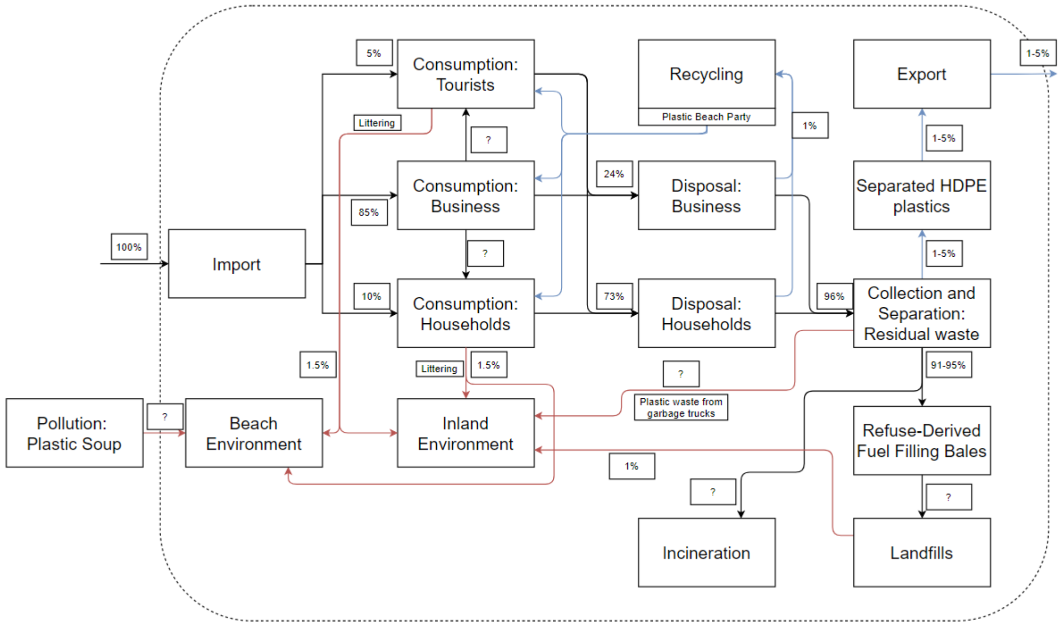

Figure 24: Material Flow Analysis of plastics on Aruba

Figure 24 shows the MFA of Aruba. Plastic products and packaging are imported and used by households, businesses, or tourists. After the consumption flow, the plastics are disposed of together with the residual waste or separated for recycling. Households and businesses have the opportunity to separate their plastics and have them collected by the Plastic Beach Party. This is a company that recycles all types of plastic waste into plastic products, which can be put back into the consumption flows. It is estimated that only a fraction of the plastic waste follows this route, because separating the plastics is voluntary. The remaining plastic waste in the residual waste is handled by two main waste companies on Aruba, which are the private waste company EcoTech Aruba N.V. and the government waste company Serlimar. These waste companies provide households and businesses containers for their waste. All the collected waste ends up at the sister company of EcoTech Aruba, called EcoGas. Here, a fraction of the plastics is separated and exported for recycling purposes, which is estimated at 1% to 5%, but the largest part of all the plastics remain in the residual waste. The residual waste including the remaining plastic waste are either processed into Refuse-Derived Fuel (RDF) filling bales, after which they are landfilled, or incinerated. There is no data available on the share of landfilled or incinerated plastics. The RDF process, which was introduced in 2019, prevents plastic pollution from happening, because the waste is wrapped into filling bales. Before the implementation of the RDF process, a regular landfill was used, which was covered up daily. This landfill still exists and creates plastic pollution due to improper management. It is estimated that about 1% of the imported plastics are polluted from this landfill. Other sources of plastic pollution are waste falling off the garbage trucks, littering by inhabitants and tourists, and pollution washing ashore. The shares of plastics washing ashore and falling of the garbage trucks are unknown.

Plastic Pollution

As shown in Figure 24, the pollution flows consist of pollution washing ashore, littering, waste from landfills, and waste falling off the garbage trucks. Improper waste management plays a large part in these sources of pollution. Stakeholders have named plastic bags, wrapping, packaging, and bottles to be the main types of pollution found on the island.

Legislation and Community Initiatives

Until 2017, plastic bags were considered the largest share of plastic pollution, but at the start of that year a single-use plastic bag ban was introduced, significantly decreasing the consumption of this type of plastic. Since the ban, the largest part of the retail and catering industries stopped using single-use plastic bags, but a small share of these industries ignores the ban and still uses them. Supporter of the plastic bag ban is the Impact Blue Foundation. A stakeholder stated that they did a research on the effectiveness of the plastic bag ban, and came to the conclusion that the annual plastic bag consumption decreased from 30 million to 275 thousand. Therefore, the littering rate is estimated at 3%. Besides this research, the Impact Blue Foundation focuses on promoting sustainable plastic management on Aruba. Next to the plastic bag ban, another law was approved late 2019 banning all single-use plastics (Aruba Gobierno, 2019). When this ban will become effective is unknown due to the corona crisis. Additional to these bans, the government initiated the campaign "Choose Zero", which pleads for a ban on the import and sale of plastic products. Besides initiatives focusing on the prevention of plastic consumption, there are initiatives focusing on cleaning and recycling plastic pollution. The most important recycling initiative is the Plastic Beach Party. This organisation is able to recycle all types of plastic waste that they collect into new products. Lastly, the Aruba Hotel and Tourism Association has a campaign named "Ban Serio" which focuses on awareness of the inhabitants on several topics, including plastic consumption and pollution. They organize annual clean-up activities both inland on along the coast to reduce plastic pollution.

Appendix 6: Material Flow Analysis on plastics of Bonaire

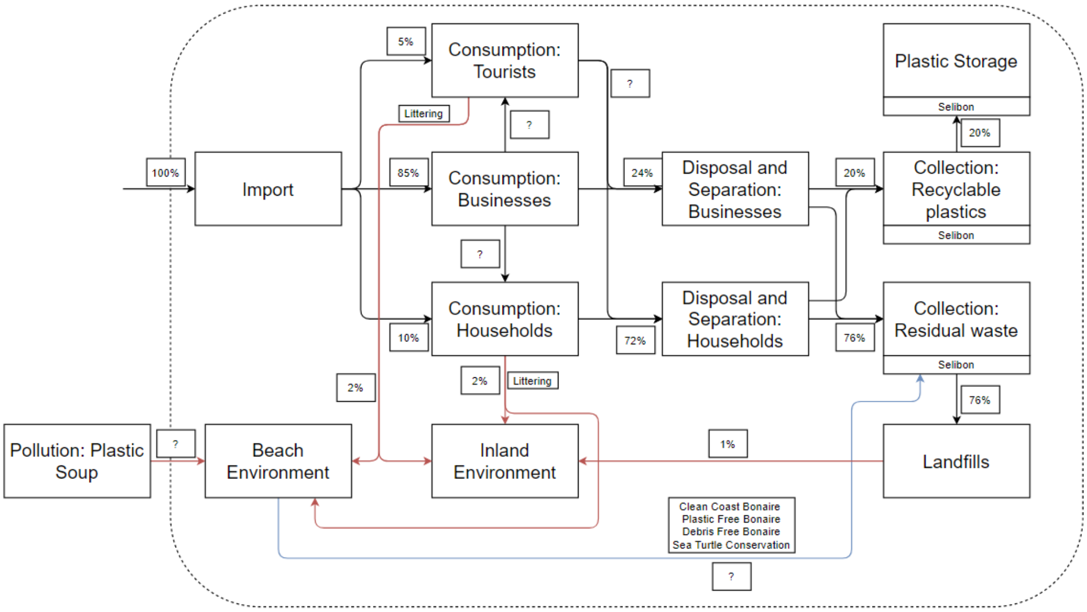

Figure 25: Material Flow Analysis of plastics on Bonaire

Figure 25 shows the MFA of Bonaire. The plastic products and packaging are imported and used by households, businesses, and tourists. After the consumption flow, the plastics are disposed of together with the residual waste or separated for recycling. Inhabitants have the possibility to separate plastics and drop it off at a waste street, but the majority of the plastics end up in the residual waste. Contrarily, many businesses on Bonaire do separate waste, because the waste company Selibon provides a collecting service for businesses. It is estimated that 2/3 of the plastic waste from businesses is separated and only about 5% of the household waste, because households have to put in more effort to separate their waste. Selibon collects the separated plastic waste from the businesses and waste streets. Plastic waste that is collected is compressed and stored in the waste facility. A Selibon representative stated that in 2018 and 2019, the total plastic waste collected by Selibon amounted to 67 and 78 tonnes respectively, which comes from businesses, waste streets and clean-up activities. Afterwards, the plastic waste is not exported or processed, but it is stored in the facility. Selibon is working on solutions to process or export the waste. After the residual waste is collected from the households and businesses, including non-separated plastics, it is landfilled and covered to reduce pollution. Still, plastic pollution results from these landfills, because the landfills are starting to get overloaded (de Bettencourt & Imminga-Berends, 2015). Additionally, plastic pollution is caused from pollution and plastic washing ashore. To combat this, clean-up activities are frequently organized by multiple initiatives, such as Clean Coast Bonaire, A Plastic Free Bonaire, Debris Free Bonaire, and Sea Turtle Conservation Bonaire.

Plastic Pollution

As mentioned before, plastic pollution on Bonaire results from littering, mismanaging of landfills, and pollution washing ashore. A research on plastic pollution on three beaches on Bonaire was conducted by Clean Coast Bonaire (2018) showing the following results. The largest part of the pollution on the beaches is due to offshore activities and littering by beach goers. On the east coast, the mostly commonly found type of pollution is plastics particles smaller than 2.5 cm, followed up by plastic pollution with a size between 2.5 and 50 cm, which mostly consists of bottles, bottle caps, and plastic bags. On the west coast, the most commonly found type of pollution is cigarette buts with plastic filters, followed up by the same type of plastic particles found on the east coast.

A Selibon representative stated that the most commonly found plastic pollution inland is plastic bags and bottles, resulting from littering by inhabitants and tourists. Because there is no ban on plastics yet, the littering rate is assumed to be 4%.

Legislation and Community Initiatives

Since 2019, plans are being made for creating a ban for single-use plastics to counter the plastic pollution happening on the island. This ban is targeted towards all single-use plastics such as plastic bags, straws, stirrers, cutlery, plates, cotton swabs, balloon sticks and polystyrene packaging and cups (Staatscourant, 2019). Beyond Plastics is an initiative of the WWF which supports the realization of this ban. This ban is still in development and was scheduled to come into force in 2021, but due to the current corona crisis, it is most likely to be delayed. Additionally, Bonaire has multiple initiatives promoting sustainable plastic management and organizing workshops, events, and clean-up activities, such as Boneiru Duradero, Clean Coast Bonaire, A Plastic Free Bonaire, Debris Free Bonaire, and Sea Turtle Conservation Bonaire.

Appendix 7: Material Flow Analysis on plastics of Curaçao

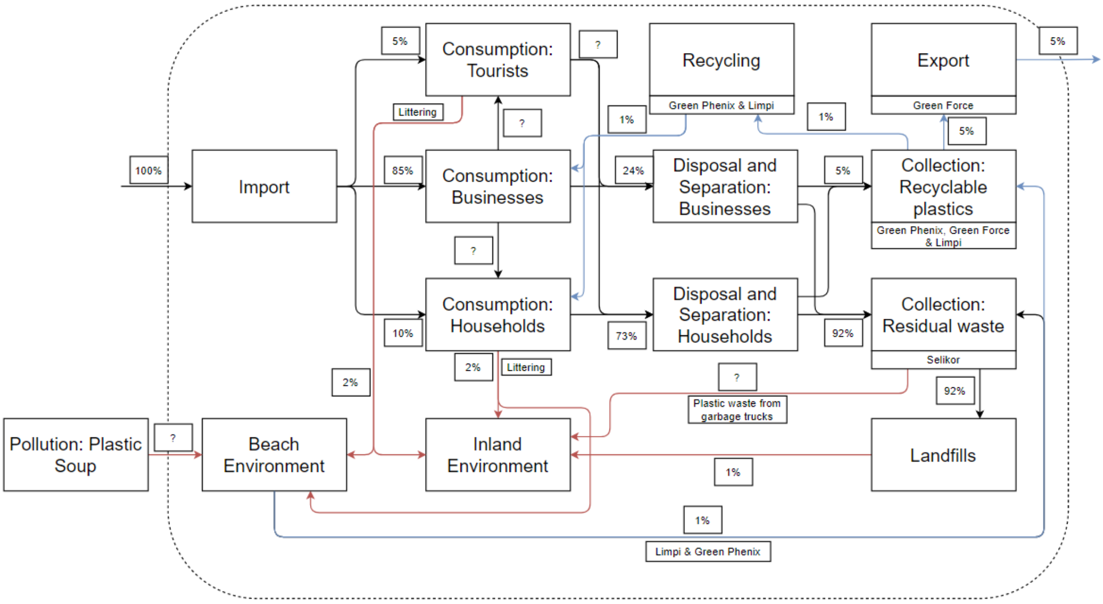

Figure 26: Material Flow Analysis of plastics on Curacao

Figure 26 shows the MFA of Curacao. he plastic products and packaging are imported and used by households, businesses, and tourists. During disposal, only a small part of the initially imported plastics ends up as separated collected plastic, which is assumed to be about 5%. This assumption is based on information from stakeholders and a waste prognosis from Selikor. Plastic is also collected via clean-up activities, which is assumed to be 1%. The collected plastic waste from households, businesses and clean-up activities can be dropped off at six locations on Curacao, of which three of them are run by the main waste processing company Selikor. From the collected plastics, the largest part, estimated at 5%, is exported for recycling by the company Green Force and the rest, estimated at 1%, is recycled on the island by the companies Green Phenix and Limpi. The plastics that end up in the residual waste are collected once a week and head straight to the landfills. Most of the time, the residual waste from businesses and households are collected separately, but they end up in the same landfill. Here the plastics accumulate, but occasionally end up as plastic pollution in the environment via wind or water. Besides landfills, there are three other sources of plastic pollution, namely pollution washing ashore, waste falling off the garbage trucks, and littering. The last source is often viewed as the main cause of plastic pollution on the island.

Plastic Pollution

The four main sources of plastic pollution on Curacao are littering, landfills, improper coverage of garbage trucks and pollution washing ashore. Stakeholders from Selikor, Green Phenix and the Sea Turtle Foundation have stated that this pollution consists of several types of plastics, such as cups, straws, and utensils, but the most commonly found type is packaging for food and drinks, such as PET bottles, plastic bags and food containers. Additionally, it is mentioned that there is a difference between the plastic pollution found on the north and south coast. Waste found on the south coast mainly consists of pollution from land based sources caused by littering or landfills, but waste found on the north coast mainly consists of pollution washed ashore, making the waste much more varied and in a more advanced state of decomposition.

Legislation and Community Initiatives

Currently, there is only one legislative measure in place regarding plastics on Curacao, which is a ban on plastic bags. Its effectiveness is questionable, because over the years plastic bags have slowly been reintroduced. Therefore, the littering rate is estimated at 4%. Nevertheless, there is a proposed draft regulation which enforces the banning several types of single-use plastics on the island. This regulation is waiting for approval by the government. Until then, actions are present reducing the consumption of plastic bags on the island. Almost no supermarkets hand out plastic bags anymore and consumers are incentivised to bring their own reusable shopping bag. Also, Green Phenix stated that inhabitants agree that the plastic ban should not only focus on bags, but on all plastics that cannot be recycled. In terms of community initiatives, Curacao has multiple organizations focusing on plastic management and pollution. CARMABI is a non-profit organization focusing on research and education surrounding maritime ecosystems, including plastic pollution. Curacao Nature Conservation, Stichting Uniek, and Seat Turtle Conservation Curacao focus on raising awareness on plastic pollution and organizing clean-up activities. Lastly, the organizations Green Force, Green Phenix, and Limpi focus on recycling plastics to increase sustainable plastic waste management.

Appendix 8: Material Flow Analysis on plastics of Saba

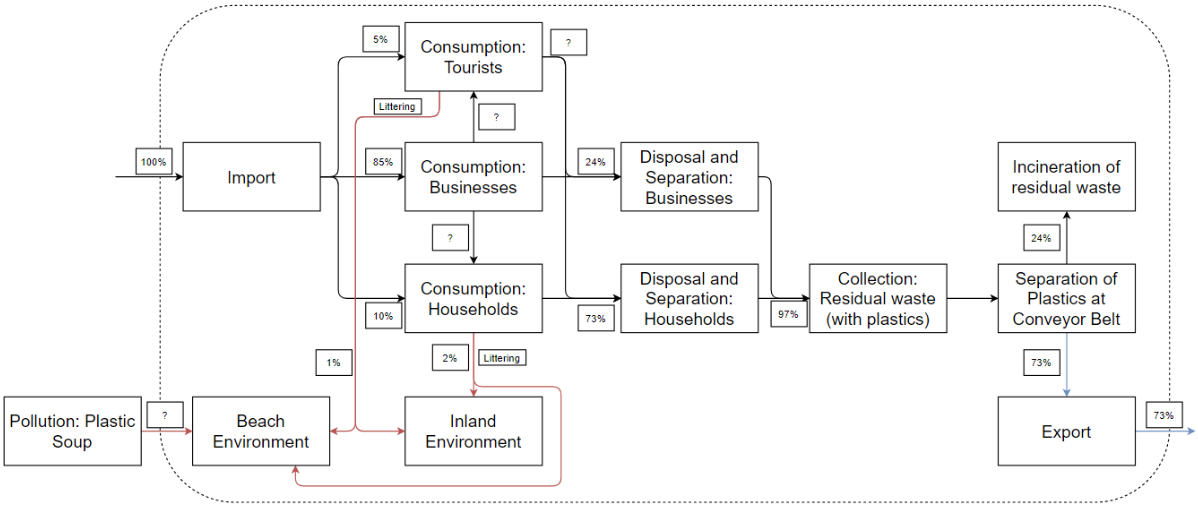

Figure 27: Material Flow Analysis of plastics on Saba

Figure 27 shows MFA of Saba. After plastic products and packaging are imported, they are used by households, businesses, or tourists. After the consumption phase, all plastics are added to the residual waste. Residual waste from households and businesses are collected together via a government-run collection service. No distinction is made between household and business waste after collection. All of the residual waste goes through a conveyor belt, where, according to an a municipality of Saba representative, about 75% of the plastics are separated. The separated plastics are exported for recycling. The remaining plastics in the residual waste are incinerated. There is only little plastic pollution present on the island, which is mainly caused via littering of the inhabitants and tourists. On the other hand, the report by de Bettencourt and Imminga-Berends (2015) classifies the problem of improper waste disposal as severe on Saba. Therefore, littering is accounted for in the material flow analysis with an assumed rate of 3%. A large part of the plastic pollution on the beaches can be accounted to plastic pollution washing ashore.

Plastic Pollution

No research has been done on the exact types and shares of plastic pollution on the island. A municipality of Saba representative has stated that from his observation, plastic bags and bottles are the most common plastic pollution present on the islands. Inland, it is mainly caused by littering, but on the beaches, pollution washing ashore plays a large role as well.

Legislation and Community Initiatives

Since 2019, plans are being made to ban single-use plastics. This plan is part of the same agreement made with Bonaire and Sint Eustatius, which is mainly focused on plastic bags, straws, stirrers, cutlery, plates, cotton swabs, balloon sticks and polystyrene packaging and cups (Staatscourant, 2019). This ban is still in development and was scheduled to come into force in 2021, but due to the current corona crisis, it is most likely to be delayed. In terms of local actions or initiatives, there is the Saba Conservation Foundation, which focuses on the preservation of the natural environment of Saba. No further initiatives are present to prevent the use or promote recycling of plastics.

Appendix 9: Material Flow Analysis on plastics of Sint Eustatius

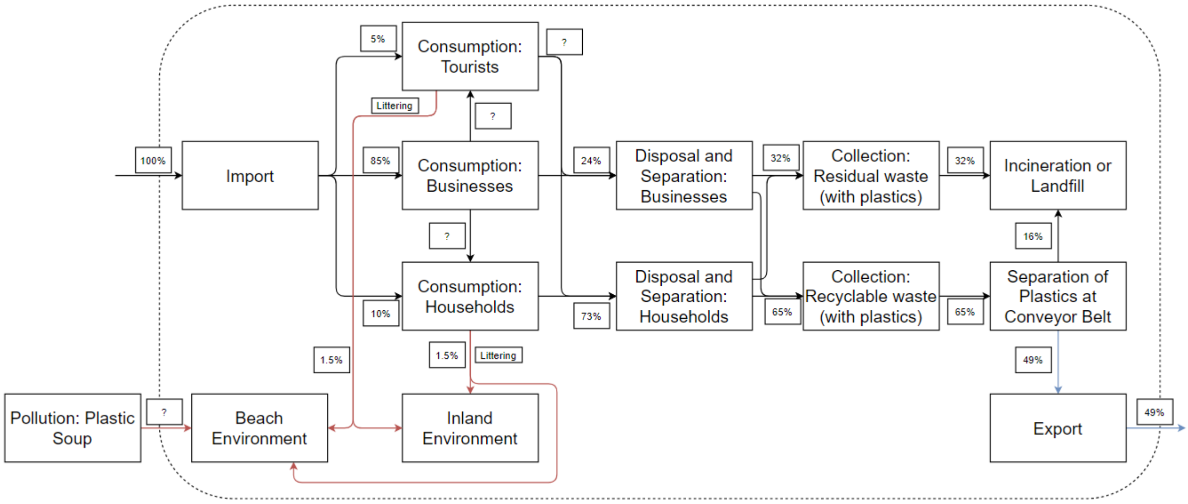

Figure 28: Material Flow Analysis of plastics on Sint Eustatius

Figure 28 shows the MFA of Sint Eustatius. Because no stakeholder responded, the MFA is based on assumptions and online information, including information published by the island's waste company Statia Waste Solutions. After plastics are imported, they are used by households, businesses and tourists. After consumption, waste is separated into two mini-containers. The orange container should contain all recyclable waste, including plastics, glass, paper, cans, batteries and cardboard boxes. The black container should include the remaining non-recyclable waste (Sint Eustatius Waste Solution, n.d.). The recyclable waste is collected by Statia Waste Solutions and is transported to a conveyor belt, where the plastics are manually separated from the rest of the waste (Sint Eustatius Waste Solution, 2018). It is assumed that about 75% of the plastics on the conveyor belt or separated, based on separation rate of Saba. After separation, the plastic waste is compacted, baled, and exported for recycling (Sint Eustatius Waste Solution, 2018). About half of the imported plastics is eventually exported for recycling. The plastics that end up in the non-recyclable container or that are not separated at the conveyor belt end up with the residual waste. Both a landfill and incinerator are present on the island, but no information was found on which share of this waste goes where. In terms of plastic pollution, littering and plastic washing ashore are the most important sources of plastic pollution. The littering rate is assumed to be 3% which is mostly caused by households. Less tourists are able to contribute to littering, because cruise ships are not able to dock on Sint Eustatius (van Buiren & Ernst, 2019)

Plastic Pollution

It is assumed that the same types of plastic pollution are present as on the other Dutch Caribbean Islands. Inland, most of the plastic pollution is caused by littering, and on the beaches most of the plastic pollution is due to plastic washing ashore. Mostly plastic packaging, bags, and bottles are found inland and on the beaches.

Legislation and Community Initiatives

Equal to Bonaire and Saba, the proposal for the single-use plastics ban is approved and is going to take effect in the nearby future. Due to the coronavirus, this is delayed until further notice. No other legislative measures are present surrounding plastics. In terms of community initiatives, the Statia Conservation Project is present, which focuses on the preservation of the natural environment, but no further initiatives are present that focus on sustainable plastic management.

Appendix 10: Weighting Innovation Criteria

Texel

Table 10: Weighting of most important criteria to consider for measures on Texel according to the stakeholders

Criteria	Sub-criteria	Stakeholder 1*	Stakeholder 2**	Average
Costs	Initial	5%	10%	7.5%
	Maintenance	5%	10%	7.5%
Effectiveness in improving sustainable plastic management	Plastic consumption and pollution reduction	15%	20%	17.5%
	Externalities	5%	3.3%	4%
Public Acceptability	Inhabitants	3.5%	3.3%	3.5%
	Businesses	3%	10%	6.5%
	Tourists	3.5%	3.3%	3.5%
Political feasibility		30%	20%	25%
Technical feasibility		30%	20%	25%
		Total: 100%	Total: 100%	Total: 100%

**Municipality of Texel representative*

***Local beachcombing organisation representative. Stakeholder 2 stated his opinion on the criteria, but did not fill in the matrix. Green is important, yellow is moderate, and red is unimportant. It is assumed that green is 20%, yellow is 10%, and red is 3.3%*

Sint Maarten

Table 11: Weighting of most important criteria to consider for measures on Sint Maarten according to the stakeholders

Criteria	Sub-criteria	Stakeholder 1*	Stakeholder 2**	Average
Costs	Initial	20%	25%	22.5%
	Maintenance	10%	10%	10%
Effectiveness in improving sustainable plastic management	Plastic consumption and pollution reduction	10%	20%	15%
	Externalities	10%	5%	7.5%
Public Acceptability	Inhabitants	20%	5%	12.5%
	Businesses	5%	5%	5%
	Tourists	2%	10%	6%
Political feasibility		18%	10%	14%
Technical feasibility		5%	10%	7.5%
		Total: 100%	Total: 100%	Total: 100%

**Government representative*

***Experts on ecosystems of Sint Maarten representative*

Appendix 11: Potential measures for sustainable plastic management

Management of Plastic Waste and Pollution

Table 12: Measures dealing with management of plastic waste and pollution ranked according to the criteria

Category	Sub-category	Measure	Costs: initial	Costs: Maintenance	Effectiveness: plastic reduction	Effectiveness: externalities	Public Acceptability: Inhabitants	Public Acceptability: Businesses	Public Acceptability: Tourists	Political feasibility	Technical Feasibility
Legislation		Set minimum on recycling plastic waste									
		Container-deposit legislation									
Awareness		Workshops									
		Campaigns									
		Clean-up activities									
Technologies	Disposal & Collection	Source-separation									
		Post-separation installation									
		Garbage trucks coverage									
		Tags with chips on fishing nets									
	Recycling	Large recycling facility									
		Small recycling initiatives for fishing gear									
		Small recycling initiatives for single-use plastics									
	Waste to energy	Incinerator									
	Landfills	Bioreactor									

Prevention of Consumption

Table 13: Measures dealing with prevention of consumption ranked according to the criteria

Category	Sub-category	Measure	Costs: initial	Costs: Maintenance	Effectiveness: plastic reduction	Effectiveness: externalities	Public Acceptability: Inhabitants	Public Acceptability: Businesses	Public Acceptability: Tourists	Political feasibility	Technical Feasibility
Legislation	Ban	Ban on single-use plastics	Yellow	Green	Green	Green	Yellow	Red	Yellow	Red	Yellow
	Tax	Tax on plastic waste	Green	Green	Yellow	Yellow	Red	Red	Yellow	Yellow	Yellow
		Tax on virgin plastics	Green	Green	Yellow	Yellow	Red	Red	Red	Yellow	Yellow
Awareness		Workshops	Green	Green	Red	Yellow	Green	Green	Green	Green	Green
		Campaigns	Yellow	Yellow	Yellow	Yellow	Green	Green	Green	Green	Green
Technologies	Disposal & Collection	Digitalized waste management: Waste4think (pay for waste)	Red	Green	Yellow	Green	Red	Red	Red	Yellow	Red
	Product design	Biodegradable plastics	Yellow	Yellow	Yellow	Green	Green	Yellow	Green	Green	Green
		Plastic packaging solutions	Red	Yellow	Green	Green	Yellow	Yellow	Yellow	Green	Yellow
		Alternatives for plastic fishing gear	Red	Green	Green	Yellow	Green	Red	Green	Green	Yellow

Table 14: Legend of the colour coding in Tables 12 and 13

Colour	Costs: initial	Costs: Maintenance	Effectiveness: plastic reduction	Effectiveness: externalities	Public Acceptability: Inhabitants	Public Acceptability: Businesses	Public Acceptability: Tourists	Political feasibility	Technical Feasibility
Green	Low	Low	Very positive	Positive effect	High	High	High	High	High
Yellow	Medium	Medium	Mildly positive	No effect	Medium	Medium	Medium	Medium	Medium
Red	High	High	No effect	Negative effect	Low	Low	Low	Low	Low