

East Asia and Pacific Region: **MARINE PLASTICS SERIES**

# Technologies and Solutions to Manage Plastic Waste in Small and Remote Islands:

Using the **Technology Options for Plastic waste in Island Contexts (TOPIC)** Toolbox for Islands in Malaysia





*Technologies and Solutions to Manage Plastic Waste in Small and Remote Islands:  
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Malaysia*

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**PROBLUE**



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*Technologies and Solutions to Manage Plastic Waste in Small and Remote Islands* presents the Technology Options for Plastic waste in Island Contexts (TOPIC) Toolbox to support island decision-makers in identifying a potential mix of technologies and other solutions for their island. The study assessed the viability of technologies to manage plastic waste in different island contexts, informing the development and piloting of the TOPIC Toolbox in Malaysia, and identifying key takeaways that can be applied in other small and remote island contexts.

The study was conducted by a team from cyclos and Lasaju – Dr. Stephan Löhle, Tobias Mangelmann, Thilo Vogeler, Jana Brinkmann, Wassim Chaabane, Jason Anom, and Qurrata Ain. The work was managed by a World Bank team comprised of Kate Philp, Anjali Acharya, and Nainika Singh, under the leadership and guidance of Firas Raad and Mona Sur. Milagros Aime and Klaus Sattler provided peer review. This summary report was prepared by Kate Philp and designed by Sarah Hollis.

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# ABBREVIATIONS & DEFINITIONS

<b>Act 672</b>	Solid Waste and Public Cleansing Management Act 2007. This Act was created to provide for and regulate the management of solid waste and public cleansing, but only applies to the Peninsular states of Perlis, Kedah, Pahang, Negeri Sembilan, Malacca and Johor, and the Federal Territories of Kuala Lumpur and Putrajaya (referred to as “Act States”).
<b>ALDFG</b>	Abandoned, Lost, or Discarded Fishing Gear
<b>EPR</b>	Extended Producer Responsibility
<b>FAO</b>	Food and Agriculture Organization of the United Nations
<b>GOF</b>	General Operations Force
<b>HDPE</b>	High Density Polyethylene
<b>LDPE</b>	Low Density Polyethylene
<b>MRF</b>	Materials Recovery Facility
<b>OCC</b>	Old Corrugated Cardboard
<b>PAHs</b>	Polyaromatic Hydrocarbons
<b>PBTs</b>	Abbreviation for Pihak Berkuasa Tempatan (i.e., the Local level government being it a City Council, Municipal Council or District Council)
<b>PE</b>	Polyethylene
<b>PET</b>	Polyethylene terephthalate
<b>PMRS</b>	Perhentian Marine Research Station
<b>PP</b>	Polypropylene
<b>PS</b>	Polystyrene
<b>PVC</b>	Polyvinyl Chloride
<b>SW Corp</b>	Solid Waste Management Corporation i.e. Federal agency set up under Act 673 (Solid Waste and Public Cleansing Management Corporation Act 2007) to enforce Act 672 and national policies on solid waste management and public cleanliness
<b>TOPIC</b>	Technology Options for Plastic waste in Island Contexts (Toolbox)
<b>TRACC</b>	Tropical Research and Conservation Center
<b>WEEE</b>	Waste Electrical and Electronic Equipment

# EXECUTIVE SUMMARY

**A**round the world, the rising threat of mismanaged plastic waste and marine plastic pollution has reached a breaking point. According to a study by Pew (2020), an estimated 11 million tons of plastic waste enters the ocean every year—an amount that is expected nearly triple to 29 million tons by 2040.

All communities and ecosystems are susceptible to the harmful impacts of plastic pollution, but small and remote islands are especially vulnerable given their high coastline-to-area ratios and their reliance on the fishery and tourism sectors. Compounding the issue, solid and plastic waste management is complicated in the context of small and remote islands due to the limited scale of plastic waste, inadequate collection and treatment facilities, and high transport costs.

While there is no single solution to turn the tide on plastic pollution for small and remote islands, a combination of technologies and other upstream and downstream solutions can help these communities effectively manage plastic waste, safeguarding their valuable ecosystems and livelihoods. New innovative technologies to treat plastic waste only work effectively in specific island contexts with viability impacted by many different aspects including the volumes and type of plastic waste, existing solid waste management systems (organization, legal, finance), infrastructure, and community awareness. In addition to treatment technologies, other solutions need to be considered such as reducing the plastic input to islands upstream, before it becomes plastic waste, as well as sorting and then transporting plastic waste to a viable recycling market.

This study combines a global assessment of plastic waste management on islands with a review of existing technologies and their viability in island contexts to develop the Technology Options for Plastic waste for Island Contexts (TOPIC) Toolbox which was then piloted on five islands in Malaysia. The TOPIC Toolbox supports island decision-makers in identifying technologies and a potential mix of technologies and other solutions to treat plastic waste for their island.



## GLOBAL EXAMPLES

This study analyzed a set of global experiences and practices of solid (and plastic) waste management on small and remote islands to assess potential solutions for plastic waste management. A selection of five case studies from the analyzed islands are presented in detail in the report: Pitcairn (UK dependency), Kosrae (Federated States of Micronesia), Koror and Babeldaop (Palau), Kerkennah (Tunisia) and the East Frisian Islands (Germany). Each case study assessed the islands' size, remoteness, embeddedness within a larger system, waste volume, tourism sector and waste treatment infrastructure.

### Key Findings:

- Small and remote islands do not implement technical solutions for treatment of a large fraction of plastic waste beyond incineration and landfills.
- No material recycling technology uptake has been realized on islands categorized as "small."
- Island microsystems often cause a bottleneck in the transport of valuable waste to the established value chain of the mainland or a larger nearby island.
- Technical and organizational solutions can help:
  - > In the Pacific, deposit refund systems incentivize distributors and consumers to properly dispose of waste or recycle items of marginal economic value.
  - > Several islands are successfully operating material recovery facilities.
  - > Micro-recycling applications (e.g., pilot pyrolysis plants or artisanal recycling) can help to treat certain fractions of waste.



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## THE TOPIC TOOLBOX AND APPLICATION IN MALAYSIA

Based on these findings and a systematic review of the available technologies, this study introduces the TOPIC Toolbox—a mechanism for island policy- and decision-makers to identify appropriate technologies and solutions to address plastic waste. TOPIC Toolbox recommendations are tailored to the unique context of each island by evaluating characteristics such as population, solid waste volume, waste collection rates, portion of plastic in waste, seasonal changes (e.g., tourism), the offtake prices of recyclables and waste transport costs. These inputs are then translated into three different recommendation clusters for plastic waste management:

1. Suggestions to advance general waste management practices
2. Information on the potential market access available on the mainland

3. A matrix displaying a set of potentially viable technologies and solutions, as well as further detail on each of these in a synthesis sheet and individual factsheets.

Beyond the user-entered criteria of the TOPIC Toolbox, there are other qualitative aspects of islands that need to be considered such as any existing solid waste management infrastructure, stakeholder awareness of solid waste management practices, and financing aspects. The TOPIC Toolbox does not cover these aspects, so the report also outlines a broader framework that should be considered in tandem.

To demonstrate the practical applications, this study used the framework and the TOPIC Toolbox to identify potential solutions and technologies for managing plastic waste on five islands in Malaysia: Tioman, Perhentian, Mabul, Pom Pom and Matakang/Timba Timba.

### Key Findings:

- Given the small scale of plastic waste on the islands, available solutions are limited to transport of recyclables/waste to the mainland, artisanal recycling and controlled landfilling—and, in some cases, controlled incineration.
- The Peninsular islands (Tioman and Perhentian) have reasonable access to recycling markets and can improve market access by separating and compacting recyclables to improve handling and logistics.
- The absence of market access is a key challenge for islands in the Semporna District (Mabul, Pom Pom and Matakang/Timba Timba). These islands should focus instead on disposal options such as controlled incineration or landfilling.
- All of the islands are relatively close to mainland Malaysia. In addition to finding/enhancing disposal solutions on the islands, they should also better utilize disposal options readily available on the mainland.
- Each of the islands could implement artisanal recycling solutions and/or Ecobricks to process a portion of the plastic waste, but these solutions cannot treat all of the plastic waste volume.
- The Act 672 status of an island, as well as the presence of active NGOs, positively affects the funding and effectiveness of the waste management system and, in particular, the collection and separation of plastic.
- Marine litter poses a challenge for the Semporna District islands further impacting the ability of existing informal waste collection on the islands to manage and finance the waste management system.

## FIVE KEY TAKEAWAYS FROM THE STUDY

While the design of the TOPIC Toolbox was informed by the situation on small and remote islands—and specifically applied in Malaysia—its applicability extends beyond. The following key takeaways and recommendations for plastic waste management are relevant to all microsystems, including small and remote islands as well as remote mainland areas.

1. A comprehensive waste collection and separation system is required to cover a majority of the available plastic waste volumes.
  - > Valuables should be extracted from the waste streams, and this can be improved through separation at source, as well as easing logistics and reducing transport costs (such as with a baling machine and related material handling equipment).
2. The absolute scale of the plastic waste and the overall waste volume have a significant impact on the solutions that can be implemented.
  - > Most recycling technologies (i.e., non-artisanal material recycling and chemical recycling) require an industrial scale and a level of waste volume that cannot be generated on small islands.
3. Market access is one of the most important factors determining how plastic and other recyclable waste is treated on or off an island.
  - > Micro-recycling processes (i.e. artisanal material recycling) may be viable, but are insufficient to cover for all plastic waste volumes and composition regularly occurring in municipal waste
  - > Market price at the mainland collection point is often not high enough to cover the entire cost of collection, segregation and transport from the island. High value recycling materials may be able to offset the cost to some degree and baling and material handling equipment can reduce costs for transport.
4. There is no single technological solution to manage plastic waste on small and remote islands.
  - > Recycling technologies only provide partial solutions for processing plastic waste and need to be combined with other solutions such as controlled landfills and controlled incineration technologies.
5. Sustainably managing plastic on islands requires upstream solutions to reduce the amount of plastic consumed and plastic wasted.

## CHAPTER 1:

# PLASTIC WASTE IN SMALL AND REMOTE ISLANDS

## 1.1 INTRODUCTION

**T**he rising production and consumption of plastic combined with mismanagement of plastic waste is leading to significant pollution of marine and coastal areas.

Global plastics production has grown rapidly in recent decades, primarily due to increased demand for plastics packaging. Recent analysis suggests that the annual global average per capita plastic consumption will continue to grow from 29 kg in 2016 to 46 kg by 2040 (Pew 2020). Mismanagement of the post-consumption plastic waste, due to either a lack of collection or collection and subsequent mismanagement, results in significant quantities of plastic waste in the terrestrial, riverine, coastal and marine environments. One study estimated 11 million tons of plastic waste enter the ocean every year. Without sustained action, this amount is estimated to nearly triple by 2040 to 29 million tons per year, equivalent to dumping 50 kg of plastic waste on every meter of coastline in the world (Pew 2020).

**Addressing plastic waste on islands is crucial because of their roles as both receptors and contributors.** With a high coastline to area ratio, islands are important receptors of marine plastic debris. Their economies commonly rely on blue economy sectors such as tourism and fisheries, which depend on functional marine ecosystems. These ecosystems are threatened by increasing volumes of plastic waste. Islands also contribute to marine plastic pollution. Their specific characteristics as microsystems result in many imported products in plastic packaging and make effective solid waste management expensive and challenging. Tourism and fisheries sectors also contribute to plastic pollution via littering or mismanagement of single-use plastic packaging and abandoned, lost, or discarded fishing gear (ALDFG).

**There is no single technological solution to manage plastic waste in small and remote islands. A mix of different technologies and other upstream and downstream solutions is required, with varied options depending on the island context.** Despite the recent development of technological innovations to treat plastic waste in islands, such technologies only work effectively in specific island contexts with actual viability in diverse island contexts yet to be proven. Aspects such as the volumes and type of plastic waste, existing solid waste management systems (organization, legal, finance), and infrastructure and community awareness will all impact the viability of specific solutions to treat plastic waste in islands. Often, the most straightforward solution is to export plastic waste to the mainland or another macrosystem such as a group of islands. The viability of this solution will depend on market access for plastic and other recyclables.

**This study developed a framework and the Technology Options for Plastic waste in Island Contexts (TOPIC) Toolbox to assess and identify appropriate technologies and other solutions to treat plastic waste.** Although upstream

measures to address the use of single use plastics and the subsequent production of plastic waste are also important, this study focused specifically on existing technologies for the treatment of plastic waste. The study reviewed existing technologies and their viability in different island contexts. A framework was developed to identify key considerations when planning for solutions to plastic waste on small and remote islands. The technology review and framework informed the development of the TOPIC Toolbox to support island decision-makers in identifying viable technologies and a potential mix of technologies and other solutions for their island.

This report accompanies the TOPIC Toolbox, providing context on the issue of plastic waste in small and remote islands in Chapter 1, an assessment of global case study islands in Chapter 2, and a summary of the technologies reviewed and incorporated into the TOPIC Toolbox in Chapter 3. Chapter 4 outlines the framework and provides an overview of the TOPIC Toolbox, Chapter 5 summarizes the application of the framework and Toolbox to case study islands in Malaysia, and Chapter 6 concludes with key takeaways from the study that can be applied in other small and remote island contexts.

## 1.2 ISLAND ECONOMIES AND PLASTIC

**Many islands rely on the blue economy, but key sectors such as fisheries and tourism are increasingly threatened by plastic pollution.** Many traditional livelihoods primarily depend on fisheries. In a more globalized and industrialized world, this

reliance is sometimes replaced or supplemented by tourism revenue. Both sectors require functional marine ecosystems. These ecosystems, however, are increasingly threatened by growing solid waste pollution, particularly littered plastic waste volumes (Lebreton et al., 2020). The accumulation of plastic waste that does not originate from the island itself poses a further challenge (Eunomia, 2016).

### **Conversely, fisheries and tourism are also significant contributors of mismanaged plastic waste.**

Worldwide, estimates for ALDFG in the sea account for a significant portion of marine litter. More information on ALDFG is available in Box 1 (FAO/UNEP, 2009) and Appendix A elaborates on the treatment of retrieved ALDFG. Growing dependency on tourism results in fluctuations in population size and, consequently, fluctuations in the amount of plastic waste (Bouvett & Farrugia, 2019). For example, the solid waste output of Menorca, Spain in August is twice the average of that in winter months (Lebreton et al., 2020). Tourism can also generate additional plastic waste as tourists may use extensive single-use plastics for takeaway food and beverages, including bottled water.

### **Despite the relevance of plastic to island economies, studies on effective solid waste and plastic waste management on islands have often been overlooked**

(Monteiro, Ivar do Sul & Costa, 2018). The scarcity of data on plastic pollution and plastic material flows makes research and decision-making processes more challenging.

#### **BOX 1: QUANTITIES OF ALDFG**

Some of the causes for the loss of fishing gear may include tearing of materials due to entanglements, storms or accidents, as well as littering of end-of-life gear. Beyond fishing nets, ALDFG refers to additional catching equipment including lines, ropes, floating buoys and sink weights, among others (MacFadyne et al.).

The actual quantities of ALDFG are difficult to determine as there is little data available. According to the Food and Agriculture Organization of the United Nations (FAO) estimates, the amount of waste from the fisheries sector amounts to around 10 percent of the total annual influx

of plastic waste discharged into the seas and oceans (FAO, 2020). Larger plastic items can often be traced back to ALDFG (The Ocean Cleanup, 2018; Kühn, et al., 2015). Based on figures from Ellen Mac Arthur Foundation (2016) and AWI (2022), accounting for the accumulation of ALDFG over recent decades would result in more than 13 million tons of plastic present in the seas worldwide that can be directly attributed to ALDFG. Further details on ALDFG, including potential treatment solutions, are provided in Appendix A.

### 1.3 PLASTIC WASTE MANAGEMENT ON SMALL AND REMOTE ISLANDS

**Plastic waste management, and solid waste management more broadly, is often complicated in the context of small and remote islands.**

Small and remote islands form microsystems characterized by their isolation from larger macrosystems such as the mainland. Microsystems can also be found on the mainland, for example remote or mountainous areas. Their degree of self-dependency is higher and their degree of connectedness is lower than in macrosystems. These characteristics lead to several key challenges related to external sources of plastic, limited scale, inadequate collection and treatment facilities, and high transport costs. A simplified schematic representing plastic waste management in an island context is shown in Figure 1.

**Plastic waste generation on islands is driven by two main sources, both external—packaged goods imported for consumption and plastic debris washed ashore as marine litter—with different implications for waste management.**

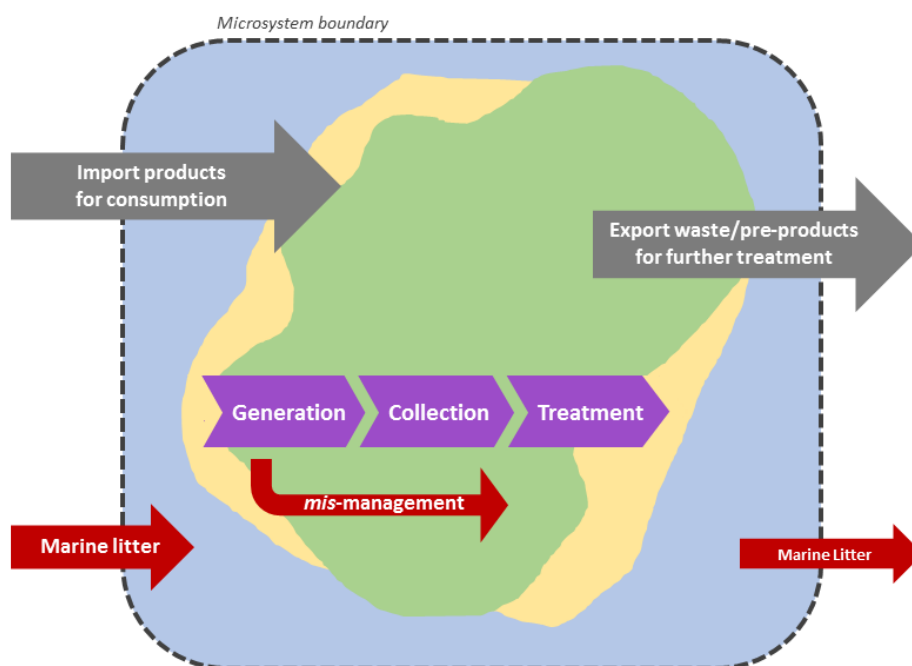
The remote nature of many islands can result in higher proportions of goods for consumption packaged in plastic, including many fresh goods. All, or the majority, of the packaged goods consumed on small islands are imported, so transporting the used packaging waste back to the

mainland source could be an option. Compared to the mainland, islands have a higher shoreline-to-area ratio resulting in high volumes of accumulated marine plastic pollution. Within the island microsystem, actions can only focus on the removal and treatment of marine plastic from the environment; its occurrence and composition can barely be influenced, aside from any local mismanaged plastic waste that may end up as marine litter. Plastic that is already in the marine and terrestrial environments can be costly and resource-intensive to collect, separate and treat as it may be partially degraded or tangled with different types or waste or other materials, such as seaweed (Chaabane, W., 2019).

**Limited scale is a fundamental challenge for (plastic) waste management solutions within any microsystem.**

In a macrosystem, a waste management practice or technology that requires a certain scale can simply expand its area of coverage. This is not possible within a microsystem such as a small or remote island, as the island sets natural boundaries. The interface with the mainland, usually via a boat connection, results in a bottleneck for integrating the microsystem into the macrosystem. Certain waste management solutions may be unviable on an island due to the limited scale, while others may be available only at a higher cost (Eunomia Research & Consulting Ltd., 2016).

Figure 1.  
**ELEMENTS OF AN ISLAND'S WASTE MANAGEMENT SYSTEM**



Source: cyclos/Lasaju

**Limited scale can be addressed by integrating the microsystem into a larger macrosystem, such as with the mainland or other nearby islands, but this will depend on the costs involved.**

The additional costs and effort to address the bottleneck will depend on several factors including regularity and type of transport, cost and physical distance, among others. These factors will determine the degree to which the island's waste management can be integrated into the mainland's regular waste management system. Island stakeholders may also set up shared inter-island waste management systems to achieve a certain scale. In doing so they will still need to address the bottleneck by expanding the scope beyond one island (Burt, A. J. et al. 2020). The costs of developing waste management solutions at the small scale of microsystems will need to be evaluated against the costs of integrating the waste management, or certain components or steps of it, into the macrosystem.

**Although essential for further treatment and transport of plastic waste, solid waste collection is often limited on islands.**

Collection is an essential part of the plastic waste management process as any waste that is not collected cannot be considered for further treatment. Collection generally accounts for a relatively high proportion of the total cost of a solid waste management system. Insufficient collection will affect the viability of any subsequent treatment and transport of plastic waste. Due to the lack of solid waste collection infrastructure on many islands, waste, including plastic, is often randomly dumped or incinerated near the generation source, negatively affecting the environment, the economy (e.g., due to impacts on tourism or fisheries) and residents' health.

**Solid waste collection on islands is further limited due to the informal sector being less prevalent than on the mainland.**

The waste management sector, particularly the collection of recyclables including plastic, is characterized by a high level of labor intensity with low initial cost for market entry. Perceived as easy to set up, it attracts a lot of informal engagement to generate income (Alam, 2014). Informal stakeholders operate on almost all steps along the plastic waste management chain, albeit dominantly at the level

of collection. Informal activities only exist in places where revenues exceeding the costs are generated. The business model depends on the accessibility of recycling facilities or other places to sell the collected waste to. Specifically, in an island context, recycling facilities are usually absent on site. Additional costs to overcome the bottleneck of the island microsystem and cover transport to recycling hubs on the mainland consume the (low) margin from informal recycling business, making the informal sector's business model within an isolated microsystem less viable and less prevalent than on the mainland. However, if there is good market access, there may still be a small informal sector.

**The most common (plastic) waste treatment after collection on small and remote islands is either landfilling or incineration.**

This treatment is typically in the form of open dumping or open burning at one or several specific locations on the island, without adequate treatment of the resulting emissions to air, land or water. These practices play a major role due to their simple method and perceived low cost, likely based on excluding long-term environmental, social and economic costs from the equation (Shamshiry, E. et al. 2011).

**Transport to the mainland or a nearby island is commonly part of the solid waste management system for small and remote islands, but it can be an expensive option.**

As well as transport of overall solid waste, some islands transport pre-treated waste fractions, for example baled plastic waste, to the mainland for further treatment. Transport of waste is particularly relevant if the treatment of specific waste fractions can be undertaken more efficiently or more in line with the environmental and health standards of the mainland. Transport from islands tends to be expensive as it relies on boat or plane transport and can be easily disrupted by the weather. Like collection, transport generally accounts for a relatively high proportion of the total costs of a solid waste management system. However, in some cases, specific waste fractions can be sold to cover some of the cost or there may be cost savings due to reverse logistics, taking advantage of returning empty cargo boats.

## CHAPTER 2:

# GLOBAL EXAMPLES FOR WASTE MANAGEMENT ON SMALL AND REMOTE ISLANDS

This study analyzed a set of global experiences and practices of solid (and plastic) waste management on small and remote islands to assess potential solutions for plastic waste management. This chapter presents a selection of the analyzed islands in detail and a summary of key findings.

## 2.1 OVERVIEW

**Based on a global assessment, small and remote islands face significant challenges in implementing effective plastic waste management.** A broad assessment of global practices was undertaken, with the waste management systems of close to 30 islands analyzed in detail. Many of these islands face significant challenges in adequately managing their (plastic) waste, resulting in high rates of plastic mismanagement. All in all, after carefully researching islands from different socioeconomic contexts, embedded in different administrative systems, with different geographic features concerning distance and remoteness from the mainland, the study was not able to identify any significant plastic recycling technology uptake realized on islands defined as “small” (i.e., based on island population and geographic size).

The assessed islands were chosen based on the availability of detailed information in English, the islands’ small size and remote locations, and their practices to address:

- Limited availability of suitable land/landforms for solid waste disposal.
- Remoteness, resulting in high costs for assets and consumables typically applied for waste management operations.
- Small and sometimes sparse populations, which limit economies of scale (i.e., represent the particularities of a microsystem).

**A selection of five case studies from the analyzed islands are presented in detail in the following sections.** The selection of a limited number of case studies presented within this chapter is based on identified effective and/ or innovative solutions to manage plastic waste on small and remote islands, with a particular focus on lessons that can be applied beyond the specific context. These particular aspects are highlighted as bullet points concluding each case study.

Table 1.

## SYNTHESIS OF PRESENTED GLOBAL CASE STUDY EXAMPLES

	Pitcairn	Kosrae	Koror & Babeldaob	Kerkennah	East Frisian Islands
<b>Size<sup>1</sup></b>	Very small	Small	Medium	Medium	Small (each one)
<b>Remoteness</b>	Maximal	High	High	Low	Low
<b>Embedded in larger system</b>	No, but some UK standards	No, but part of Micronesia	No	Yes, forms part of Tunisia	Yes, forms part of Germany
<b>Waste volume kg/head/day<sup>2</sup></b>	0.4	1.1—of which 0.14 is plastics	2.0—of which 0.16 is plastics	0.6	0.9-1.8—of which 22-46% is packaging <sup>3</sup>
<b>Tourism impact on waste volume</b>	Insignificant	Insignificant	Significant	Dominant	Dominant
<b>Waste treatment infrastructure</b>	Controlled landfill, no export	Controlled landfill, export of valuables	Sanitary landfill, pyrolysis pilot	Sanitary landfill, pyrolysis pilot	Export of all waste except compostables
<b>Notable findings</b>	Minimal scale and maximal remoteness, yet effective (plastic) waste management	Island-specific deposit refund system for specific plastic items	Island-specific deposit refund system cross-subsidizes overall waste management	Very high seasonality, tourist arrival levy dedicated to plastic waste management	Notably low plastic waste management costs through embeddedness in Extended Producer Responsibility (EPR) system

## 2.2 CASE STUDIES

### 2.2.1 Pitcairn Island—UK Dependency

Pitcairn Island is located in the southern Pacific Ocean with a population of around 50. Thousands of kilometers away from the mainland with infrequent and scarce boat connections, Pitcairn forms the archetype of a small and remote island. Pitcairn is obliged to manage all occurring waste internally—the only alternative being to allow mismanagement of the waste. Plastic pollution from other parts of the world is quite apparent. The neighboring island Henderson, administered by Pitcairn, is rated as one of the spots on earth most affected by inflowing external marine litter [The New York Times, 2017]. At the same time, according to Pitcairn Island Strategic Development Plan [2013], due to the low level of uncollected waste, the main island's waste management system has been largely seen as a success story given the remoteness of the islands. See Figure 2 for details on waste management on Pitcairn.

Pitcairn has an uncontrolled landfill (open pit) in proximity to the only settlement on the island. With some separation at source for composting, all other residual waste is transferred to this landfill. Some uncontrolled burning of waste fractions may reduce volume, with remainders deposited into the landfill or littered. There are existing plans to upgrade the landfill, including compaction equipment to use existing space more effectively. Transport is primarily via quad motorbikes that are suitable for the existing road infrastructure and the purchase of a slightly bigger collection vehicle is being considered. Better preparation of certain waste fractions for export is also being considered. No treatment on site of plastic waste beyond landfilling is currently planned to be undertaken.

The example of Pitcairn Island as an extreme example of a small and remote microsystem showcases several aspects of an island's waste management system.

- **A formal waste management system is necessary no matter the scale.** Although the landfill is

1 According to island context

2 Excludes differing levels of home composting

3 In Germany, "packaging" is accounted for—dominantly but not exclusively consisting of plastics

Figure 2.  
SOLID WASTE MANAGEMENT ON PITCAIRN

## Waste Management on Pitcairn

<b>size</b>	
<b>inhabitants</b>	~50
<i>negligible tourism</i>	
<b>Annual waste volume</b>	
Aluminiums cans	~200 kg
PET bottles	~80-100 kg
Organic Waste	<i>unknown</i>
All other landfilled fractions	~7 tons
<b>Landfill – uncontrolled (currently)</b>	
<ul style="list-style-type: none"> <li>open pit outside settlement</li> <li>currently 140 kg waste / m<sup>3</sup> (no compaction)</li> <li>surface area 35 m<sup>2</sup>/ ~1 m<sup>2</sup>/pp</li> </ul>	
<b>Landfill – controlled (planned)</b>	
<ul style="list-style-type: none"> <li>compaction to 500-600 kg waste/ m<sup>3</sup></li> <li>surface area ~225 sqm/ ~5 m<sup>2</sup>/pp (mainly for turning of compaction vehicles)</li> <li>lifetime ~30 years</li> <li>protection against excessive effluent discharge</li> </ul>	

**Handling of waste**

- green waste composted on site
- all other waste landfilled
- growing consciousness for e waste including batteries
- upgrade from collection quad to lorry considered

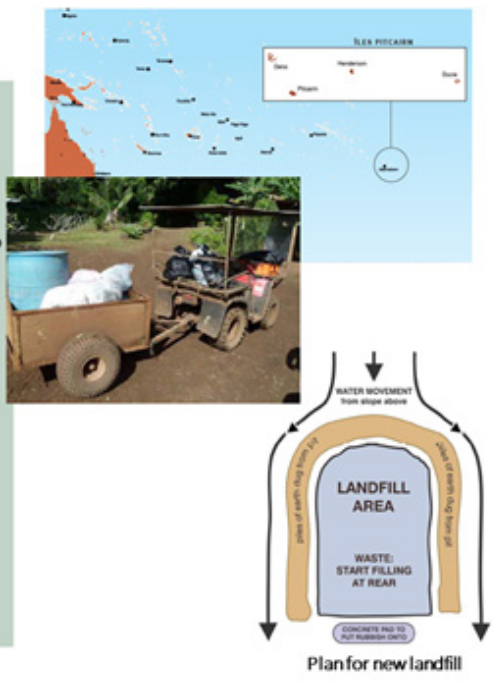
**Export of waste**

- currently no export of waste
- accumulation of waste volume for export of ~1 container per year considered
- investment in small scale baling machine considered (for PET, Aluminium)

annual revenue potential

- from PET waste US\$ ~20
- from AL cans US\$ ~150

*before transport/handling cost!*



Sources: Pitcairn Island Strategic Development Plan 2014-2018, Solid Waste Management Guideline for Pitcairn 2016, Integre

Source: cyclos/ Lasaju

less than one kilometer from most households, inhabitants only transport half their waste to the waste management facility, with the remainder of the daily volumes transported to the landfill by public collection vehicles.

- **The demand for adequate waste management infrastructure poses a challenge on small islands.** The space requirements for a landfill that can be considered environmentally sound are significant. Whereas in the case of Pitcairn, the required space does seem to be available, this may not be the case on islands that are smaller or more densely inhabited.
- **Waste management comes at a cost.** Within Pitcairn’s waste management strategy, the operational costs of the collection vehicle as well as the landfill are considered a bottleneck. The valorization potential of recyclable materials on the other hand is negligible. Only Polyethylene terephthalate (PET) and scrap metal (mainly cans) are considered valuable with limited income potential, particularly after transport costs.

### 2.2.2 Kosrae—Federated States of Micronesia

Kosrae Island forms part of the Federated States of Micronesia, a nation exclusively consisting of islands with Kosrae being the second most populous with around 6,000 inhabitants. All islands within the Federated States of Micronesia face similar challenges as isolated island microsystems and small-scale solutions are unlikely to be cross-subsidized. Unlike Pitcairn Island, Kosrae’s waste management system is less complete, with collection only undertaken to a limited extent. Kosrae is split into four municipalities and only two have operated public waste collection schemes in recent years. This demonstrates how waste management responsibilities are split among different jurisdictions, resulting in different levels of service, particularly for collection. The collection that is undertaken—at around US\$ 1 per household per month—must be cross-subsidized through other budgetary allocations. See Figure 3 for details on Kosrae’s waste management practices.

Figure 3.

**WASTE MANAGEMENT ON KOSRAE / FEDERATED STATES OF MICRONESIA**

**Waste Management on Kosrae/ Federated States of Micronesia**

<b>Size</b>	111,9 km <sup>2</sup>
<b>Inhabitants (2017)</b> <i>negligible tourist arrivals</i>	6,610
<b>Municipal Waste</b>	
per person daily	1.1 kg
per person annually	~400 kg
total daily	7.34 tons
of which 13% plastics	~1 ton
total annually	~2,700 tons
of which 13% plastics	~350 tons
<b>Waste treatment</b>	
home composting	23.6%
containers (exported)	1.9%
recycled from landfill	1.5%
final disposal on landfill	55.4%
littering	8.9%
<b>Investments for upgrade of waste management system 2018-2022</b>	US\$ 400,000*
annually in total	US\$ ~80,000
annually per person	US\$ ~12

\*excluding US\$ ~150,000 for waste oil treatment

Source: Kosrae State: Solid Waste Management Strategy 2018-2027

**Container Deposit Legislation (CDL)**

- Surcharge of US\$ 0.06 per obliged bottle
- Deposit refund US\$ 0.05
- Public waste management fee US\$ 0.01
- Glass recycled/ crushed onsite, plastic baled and exported for recycling (Taiwan, Korea)
- ~1.4 million items per year, ~0.5 items pp/ day
- return rate ~86%
- Proposal to raise surcharge to US\$ 0.07
- Replacement/ upgrade of PET baling press and new glass crushing machine proposed

**Waste management targets 2027**

- Increase collection rate from 25% to 84%
- Reduce littering from 8.9% to 1.0%
- Maintain/improve container deposit refund
- Upgrade of landfill site
- (adequate treatment of waste oil)



Source: cyclos/ Lasaju

More notable on Kosrae is the deposit refund scheme that is levered upon metal, glass and certain plastic containers. The fee includes a non-refundable component of currently US\$ 0.01 out of US\$ 0.06 in total. This is lower than the required fee to effectively run this deposit refund system, hence there is a proposal to raise the non-refundable fee to US\$ 0.02 out of a planned total of US\$ 0.07. The waste fractions that are collected through the deposit refund system are transported to the material recovery and sorting facility (co-located with the landfill), compacted and then shipped abroad. Plastic waste treatment beyond disposal to the landfill is not undertaken within the Federated States of Micronesia, with export destinations chosen according to the best offtake price.

Kosrae’s waste management experiences result in several key findings:

- **The operation of a deposit refund scheme keeps items it is imposed on from being littered**—specifically plastics, where the marginal economic value has not created a pull-effect on collection and recycling.
- It also showcases that **highly specific waste management solutions can be implemented**

**successfully on a small scale**, if the regulatory framework allows—the deposit refund scheme is a distinct to Kosrae and is not available for the whole of the Federated States of Micronesia.

- **Sustainable finance mechanisms are required to run a specific waste management system.** In this case, the deposit refund scheme requires non-refundable components to fund the operation.
- Even with higher population numbers (in comparison to very small islands like Pitcairn), the uptake of plastic waste treatment solutions is limited. In the case of Kosrae, **landfilling is considered to be the most environmentally-sound treatment option for many waste fractions.**
- As a prerequisite for any further treatment, **collection of waste poses a financial burden** that has not yet been prioritized.

**2.2.3 Koror and Babeldaop—Palau**

Similar to the Federated States of Micronesia, the United States of Palau form a nation in the Pacific Ocean. Palau’s territory is primarily two islands, Koror and Babeldaop, connected by a bridge. Koror houses

around 70 percent of the total population in an urban setting, whereas roughly 30 percent of the population live in a more rural setting within Babeldaop. The waste collection system significantly differs between the two connected islands. Whereas curbside collection is implemented in the densely populated urban areas, the more rural population takes their garbage to one of 42 segregation points spread around the island. Businesses must transport waste to the landfill themselves. See Figure 4 for details on Koror and Babeldaop's waste management practices.

The waste management system is financed largely through a cross-subsidy of Palau's deposit refund scheme. Out of US\$ 0.10 surcharge per obliged item, US\$ 0.05 is refundable and US\$ 0.025 is used for handling the deposit refund system itself. The remaining US\$ 0.025 goes to a fund that finances other waste management activities in Palau. Since 2018, the income from this deposit refund system has been sufficient to cover operational expenses (salaries, consumables, etc.) of the waste management facility, despite the total waste amount being barely related to the quantity of items subject to the deposit refund system.

The operationalization of the system is undertaken at a higher level than on Kosrae, perhaps due to the more complex finance streams. For example, all fees are channeled through the National Treasury. Furthermore, unlike Kosrae, additional packaging items are subject to this fee, (e.g., liquid beverage cartons like "Tetra Pak"), causing more complexity and versatility in treatment options. Unlike PET bottles and metal cans, which are exported for recycling, and glass bottles, which are crushed/ recycled on the island, this fraction is being landfilled. The complexity of the system is visualized in Figure 5.

Palau's waste management experiences result in several key findings:

- Similar to Kosrae, **the operation of a highly individualized waste management system is possible on a small scale**—in this case a deposit refund scheme. Unconventional ways for managing and financing waste management can yield success in smaller island contexts.
- Due to the strong involvement of national government institutions and the generally complex setup, Palau highlights potential **limits in applying holistic waste management concepts for islands**

Figure 4.  
**WASTE MANAGEMENT ON KOROR AND BABELDAOB/ PALAU**

### Waste Management on Koror and Babeldaob/ Palau

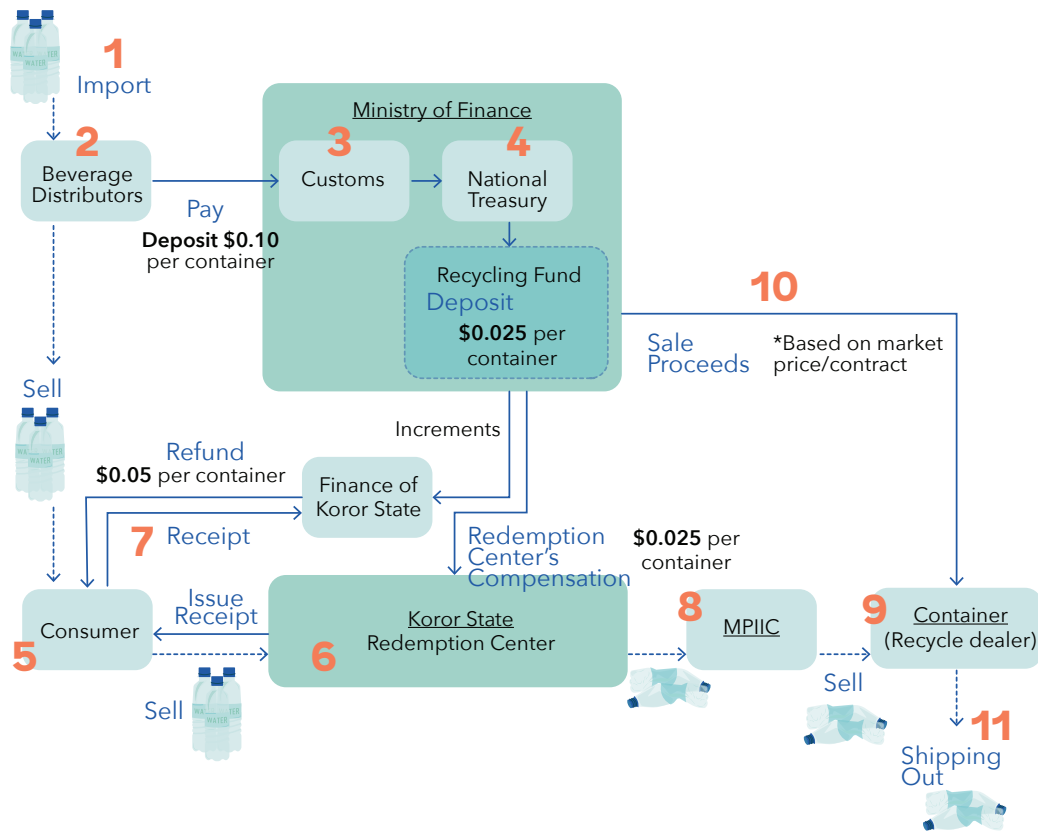
<b>Size</b>	384 m <sup>2</sup>	<b>Waste collection</b>	<ul style="list-style-type: none"> <li>▪ 42 segregation stations for collection in less densely populated areas/ 1 per ~120 inhabitants - ~30% of population</li> <li>▪ initially six fractions, reduced to two</li> <li>▪ weekly collection for urbanised <i>residents</i> ~70% of population</li> <li>▪ all other facilities (businesses, hotels, offices) transport their waste to facility</li> </ul>
<b>Inhabitants</b>	16,953		
<b>Municipal Waste quantity</b>		<b>Recycling facility</b>	<ul style="list-style-type: none"> <li>▪ Landfill size 60,000 m<sup>2</sup>/ 3 m<sup>2</sup> pp</li> <li>▪ final disposal rate ~82%</li> <li>▪ estimated annual cost of sanitary landfill operation US\$ 350,000/ US\$ 20 pp</li> <li>▪ since 2017, waste management OPEX covered by Environmental Fund</li> <li>▪ plastic, metal, aluminium fractions compacted and exported for recycling</li> <li>▪ Pyrolysis plant in operation; ~3 tons throughput monthly</li> </ul>
per person daily	2 kg		
per person annually	730 kg		
total daily	34 tons		
of which 8% plastics	2.7 tons		
total annually	12,400 tons		
of which 8% plastics	990 tons		
<b>Container Deposit Refund Scheme</b>			
Surcharge of US\$ 0.10 per obliged container; 50% refundable			
- Deposit refund US\$ 0.05			
- Handling fee US\$ 0.025			
- Waste management fund US\$ 0.025			
- ~15 million containers per year/ 2.4 pp per day; return rate ~87%			



Sources: Ministry of Public Infrastructure Republic of Palau, 2018; Asian Development Bank 2013; Palau National Solid Waste Management Strategy 2017.

Source: cyclos/ Lasaju

Figure 5.  
DEPOSIT REFUND SYSTEM SETUP IN PALAU



Source: Bureau of Public Works, Republic of Palau, 2018

that form smaller parts of mainland-dominated countries, unlike in Palau.

- Palau’s deposit refund system for common plastic items showcases how **growing coverage of different waste management aspects results in a more sophisticated system set up**. This is due to several factors including the involvement of public and private sectors, certain fluctuating cost factors (transport, prices for resources, etc.) and the decoupling of the resource value of the waste item against its value within the system.
- **Unconventional waste management solutions still require coverage of significant costs**. The waste management fees per inhabitant are levered in an unconventional way, but are substantial at around US\$ 20 per inhabitant per year. This fee calculation is based on the non-refundable part of the deposit refund system whose revenue is allegedly insufficient to cover all waste management related expenses (i.e., additional financial contributions are required to cover the cost of the current waste management system beyond operation of the waste management facility).

### 2.2.4 Kerkennah Island—Tunisia

Kerkennah Island is a Tunisian archipelago that is characterized by a large seasonal change in population. Due to its popularity as a holiday destination, the population rises from 14,000 people during low season to around 250,000 during July and August, a nearly twentyfold increase. Kerkennah has had many solid waste management issues due to its geography and the absence of a sanitary landfill. The landfill was closed in 2010 due to a lack of acceptance by residents. Subsequently, many dumpsites were established across the island, resulting in environmental and social issues. In addition, collection was limited due to constraints in logistical and financial capacities to transport the collected materials to the mainland. The sanitary landfill was reopened in late 2021.

Due to the mounting waste management challenges, several measures have been taken within a short timeframe to reset the waste management system. In collaboration with the national authorities, the island’s municipal government provided a recycling center to two local collectors for the storage of recyclable materials. In addition, citizens were involved by bringing recyclable

materials to some collection points in different zones of the island. Logistics were improved considerably to ensure collection of the waste and the reopening of the landfill. During the high season, the government supports the municipality to significantly scale up collection operations. The installation of a pyrolysis plant is planned with a focus on the treatment of non-recyclable materials, including some fishing gear.

In order to attribute costs to the high seasonality, the island's government raised a fee as part of the boat ticket price for all visitors of the island. This fee is dedicated to exclusively fund solid waste management operations, particularly the removal of littered waste. See Figure 6 for details on Kerkennah Island's waste management practices.

Kerkennah's waste management experiences result in several key findings:

- Kerkennah has extreme fluctuations in population numbers. A waste management fee is levied for every arrival, roughly reflecting the increased number of people on the island. This represents an approach to **match waste management costs with the number of visitors**.

- Accelerated environmental and social problems have led to a reconsideration of past deficiencies in the waste management system. **The consequences of waste mismanagement directly affect the local population, with the potential to create political pressure and accelerate change of practices.**
- Unlike the previous case studies, Kerkennah is part of a much bigger country. With its status as a prime tourist location, **mobilizing national resources that exceed the island's own (financial) capacity can prove effective** to initiate a shift of waste management practices.

### 2.2.5 East Frisian Islands—Germany

Germany has a highly complex and formalized solid waste management system with significant benefits from scale. However, there are still certain microsystems—usually on islands—that require particular solutions. The East Frisian Islands comprise six permanently inhabited islands, each with a few thousand inhabitants and each heavily reliant on tourism with all its associated characteristics and challenges. The East Frisian Islands'

Figure 6. WASTE MANAGEMENT ON KERKENNAH ISLAND IN TUNISIA, NORTH AFRICA

### Waste Management on Kerkennah island / Tunisia

<b>Size</b>	160 m <sup>2</sup>
<b>Inhabitants (2017)</b>	14,000
<i>Visitors during July and August</i>	200,000 to 250,000
<b>Municipal Waste</b>	
per person daily	0.6 kg
per person annually	~219 kg
<i>Total waste estimated in the Island</i>	12000 to 15000 tons/year
<b>Waste treatment</b>	
Organic used for animals	25%
Collected / exported materials	5%
Disposal/ dumping till 2020	61%
Littering	9%
<b>Investments for upgrade of waste management system</b>	US\$ 1.5 Million Material Recovery and Sorting Facility incl. landfill

Source: Chaabane, 2019

**Collection scheme**

- Mixture of take (municipal waste)
- Organic waste to animals /
- Collection of recyclable materials by 2 small local collection companies. Quantities are transported to the main land to be recycled in the country of exported abroad.
- Sorting points are installed in the island
- Involvement of the citizens to bring recyclable materials to the collection points.

**Infrastructure and equipment**

- Collection trucks
- Recycling centre provided by the government (ECOLEF system)
- Sanitary landfill is open to receive all mixed waste.
- Composting plan is planned to be built by the private sector
- Pyrolyse of fishing plastic tools and other non-recyclable plastic waste. Fuel will be provided for free to plastic collectors, including Fishermen.



Source: cyclos/ Lasaju

level of isolation is quite low. A daily ferry to the mainland runs regularly to each of the islands. While there are similarities among the six islands, there are also significant differences in how they manage waste. See Figure 7 for details on the islands' waste management practices.

The collection infrastructure varies significantly between the islands: Borkum is accessible for cars and uses collection vehicles that resemble those on the mainland. In Norderney, the lower waste volumes result in smaller, yet similar cars. Two other islands—Langeoog and Spiekeroog—do not allow regular motorized traffic and rely on basic electric carts for waste collection. The remaining two islands – Juist and Baltrum - only operate non-motorized collection vehicles in the form of horse carts.

Most collected waste fractions are transported with the regular ferry to the mainland, which is then fed into the further treatment infrastructure. All islands have a waste hub/waste center. The collected waste is accumulated and kept separately in at least two fractions across the islands—household waste and packaging including plastic waste. These waste management hubs also serve as bring stations for different types

of waste not collected through the regular system (e.g., bulky items like furniture or dangerous fractions), which also keeps this waste apart. Composting to treat organic waste is undertaken at different levels.

The management of municipal waste in Germany builds on two main pillars: 1) the extended producer responsibility (EPR) system for packaging (and also for electric and electronic waste) and 2) the collection and treatment of all other municipal waste fractions. In Germany, EPR costs are borne by the producers and are paid for every obliged item that is purchased by a consumer. Cost estimates are available as a national average, at around US\$ 17 per person per year. As there are no geographical EPR fee modulations, this average slightly favors those regions with higher costs for associated waste management, such as small and remote islands. Apart from the EPR system, the municipality charges a fee for other fractions to cover all operational expenses. This fee is charged per residential plot. In Langeoog, for example, this comes to around US\$ 19 per inhabitant per year (including a tourism factor). See Figure 8 for details on Langeoog's waste management practices.

Figure 7.

### WASTE MANAGEMENT ON EAST FRISIAN ISLANDS, GERMANY

#### Waste Management on East Frisian Islands/Germany



	Borkum	Juist	Norderney	Baltrum	Langeoog	Spiekeroog
Size	31 km <sup>2</sup>	16 km <sup>2</sup>	26 km <sup>2</sup>	6,5 km <sup>2</sup>	20 km <sup>2</sup>	18 km <sup>2</sup>
Permanent settlers + tourism factor = equivalent inhabitants	5,118 + 7,100 = 12,200	1,522 + 2,798 = 4,300	6,051 + 10,825 = 16,900	617 + 1,522 = 2,100	1,779 + 4,897 = 6,700	805 + 1,884 = 2,700
Type of collection vehicles	lorry < 12 t	horse carts	lorry < 13 t	horse carts	e- vehicles	e- vehicles
<b>Municipal waste</b>						
total/ year	3,200 tons	1,400 tons	2,900 tons	400 tons	800 tons	400 tons
total/ equiv. inhabitant/ year	262 kg	326 kg	172 kg	180 kg	119 kg	148 kg
<b>Biowaste</b>						
total/ year	100 tons	500 tons	1,600 tons	200 tons	30 tons	10 tons
total/ equiv. inhabitant/ year	8 kg	116 kg	95 kg	95 kg	4 kg	4 kg
<b>Paper</b>						
total/ year	500 tons	300 tons	1,000 tons	100 tons	300 tons	200 tons
total/ equiv. inhabitant/ year	41 kg	70 kg	59 kg	48 kg	45 kg	74 kg
<b>Packaging (national data only)</b>						
total/ year	1,781 tons	628 tons	2,467 tons	307 tons	978 tons	394 tons
total/ equiv. inhabitant/ year	146 kg	146 kg	146 kg	146 kg	146 kg	146 kg

Source: cyclos/ Lasaju

Several findings applicable to other islands' contexts can be derived from the East Frisian Islands.

- **Waste management solutions in microsystems are highly specific to the respective characteristics** and a one size-fits-all solution is usually inadequate. Even though the five islands' size and economies are similar, each has found a distinct way of running its waste management system.
- **Costs for waste management are in a similar range with other islands worldwide, despite significant socioeconomic differences.** For any island worldwide, detailed research is required to understand the entirety of direct and indirect cost contributions for the waste management system. Nevertheless, for the example of Langeoog, annual waste management costs per person are in a similar range, if not lower, than in Palau or the Federated States of Micronesia.
- **Cross-subsidies within the system represent a feasible way to finance waste management on islands**—particularly for plastic packaging with a marginal economic value. The German EPR system does not have geographically differentiated fee structures. Therefore, areas with higher costs,

like islands, are cross subsidized by the current EPR system setup. If islands form a negligible part of the entire country, these subsidies can be sustained.

### 2.2.6 Conclusion

**Based on the analysis of these islands, small islands do not implement technical solutions for treatment of a large fraction of plastic waste beyond (proper) incineration and (sanitary) landfills.** Based on the analysis of islands from different socioeconomic contexts, embedded in different administrative systems, with different geographic features concerning distance and remoteness from the mainland, no material recycling technology uptake has been realized on islands that this study considers as "small." Nevertheless, technical and organizational solutions can help in overcoming the microsystem's bottleneck to feed certain fractions of valuable waste into a mainland or larger island's established value chain. For example, the deposit refund systems in island states in the Pacific and the operation of material recovery facilities on several of the other islands help to advance the respective waste

Figure 8.  
WASTE MANAGEMENT ON LANGEOOG, GERMANY

### Waste Management on Langeoog/Germany

<b>Size</b>	20 km <sup>2</sup>
Settlers + tourism factor = equivalent inhabitants	1,779 + 4,897 = 6,700
<b>take-points/ plots</b>	~1,800
<b>Visits</b>	
No. of nights spent by tourists	1.614.917
No. of day tourists	182.157
Type of collection vehicles	e- vehicles
<b>Municipal waste</b>	
total/ year	800 tons
total/ equiv. inhabitant/ year	119 kg
<b>Biowaste</b>	
total/ year	30 tons
total/ equiv. inhabitant/ year	4 kg
<b>Paper</b>	
total/ year	300 tons
total/ equiv. inhabitant/ year	45 kg
<b>Packaging (national data only)</b>	
total/ year	978 tons
total/ equiv. inhabitant/ year	146 kg

Source: Landkreis Wittmund, 2020

- Collection scheme**
- Mixture of *take* (municipal waste, bulky waste) and *bring* system (WEEE, paper, others)
  - Composting on islands, all other fractions transported to mainland by ferry operator
- Infrastructure and equipment**
- Electric collection cars
  - Composting Plant (former landfill site)
  - Planned overhaul of logistical sorting site for processing up to three differentiated waste fractions for separate export
- Municipal fees**
- US\$ ~70/ plot/ year  
= US\$ ~19 per equivalent habitant/ year
  - 32% collection and transport costs
  - 50% treatment and overhead costs
- EPR fees for packaging (national data only)**
- US\$ ~17 per habitant/ year



Source: cyclos/ Lasaju

management systems. Micro-recycling applications (e.g., pilot pyrolysis plants or artisanal recycling) can also help to treat certain fractions of the waste but are currently only operated on a trial or experimental basis, or at a very small scale to produce souvenirs

for tourists. In general, the different islands' waste management practices showcase the necessity of a holistic understanding of the management of plastic waste as an integrated part of a wider general waste management setup.



Photo: Shutterstock / imrankadir.

## CHAPTER 3:

# TECHNOLOGIES TO MANAGE PLASTIC WASTE

The technologies available to manage plastic waste vary depending on many factors associated with both the broader waste management system and the characteristics of the plastic waste. This chapter outlines categories of technologies to manage plastic waste, classified according to the waste hierarchy. Although prevention and reuse of plastic waste are the preferred options, this report focuses on technologies downstream of these two areas to manage plastic waste that is already being produced and cannot be efficiently reused. The first step is pre-treatment of waste through separation, handling and logistics, followed by recycling (material recycling and feedstock recycling), and lastly, disposal (including both incineration and landfilling).

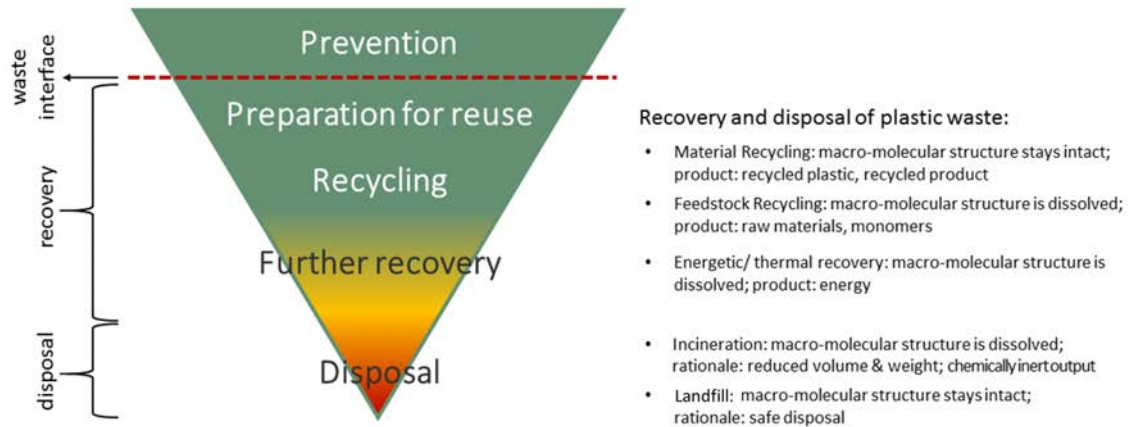
### 3.1 OVERVIEW

**Technologies to manage plastic waste can be classified according to their level in the waste hierarchy** (Figure 9). The higher in the waste hierarchy, the lower the resource use and related polluting emissions to air (including greenhouse gas emissions), land and water, and the lower the risk of mismanaged waste. Higher ranking processes, technologies or practices within the waste hierarchy are preferred from a perspective of resource efficiency and climate change, environmental and social impacts of mismanaged waste. The prevention of plastic waste is the most preferred option and can occur by either reducing the consumption of a plastic product (“reduce” under the 3Rs) or by reapplying it for the same or a different purpose after its first use (“reuse” under the 3Rs). Prevention of plastic waste reduces the pressure on a waste management system and should always be considered as a first option. However, ongoing consumption of plastic, particularly for packaging, means that although prevention is a crucial supplement to any waste management system, it cannot replace waste management entirely.

**Plastic packaging has limited reusability so preparation for reuse is primarily applied to more complex products.** Preparation for reuse includes cleaning from contamination, dismantling and detaching reusable parts from larger waste items, as well as exchanging faulty or dysfunctional parts with technologies used throughout these stages. Although reuse itself is not considered part of waste management, preparation for reuse is. This concept is usually applied to complex items like electric or electronic appliances as well as vehicles (bicycles, cars, etc.). In the case of common plastic items, certain bottles (e.g., jerrycans) or containers (e.g., takeaway food boxes) are prepared for reuse mainly through cleaning. For plastic packaging, reusability tends to be limited by the nature of its design. Every packaging item is designed to protect the product against external influences to ease logistics and so on—with minimal packaging costs being a determining factor. Once the product has been consumed, the purpose of the packaging has been fulfilled. Designing packaging beyond this primary purpose is generally out of scope for the packaging producer or user. Plastic packaging will therefore

Figure 9.

**PLASTIC WASTE HIERARCHY AND CLASSIFICATION OF THE TERM RECOVERY AND DISPOSAL**



Source: cyclos/ Lasaju

have limited secondary purposes and any preparation for reuse will likely involve simple cleaning alone. Both for products and packaging, reusability as a waste prevention strategy is embedded in the design phase with very limited interaction with the waste management system.

This report focuses on technologies to manage plastic waste downstream of prevention and preparation for reuse in the waste hierarchy, with technical solutions classified across four key areas and associated pre-treatment requirements classified across separation, handling and logistics (see Figure 10).

**After products or packaging become waste, the next level for plastic waste management is recovery of the resources from the waste—either the material itself or its chemical constituents.**

These recovery processes include all kinds of recycling (“recycle” under the 3Rs) as well as some other treatment processes like incineration applications with energy recovery. With resources being recovered and fed back into the production process, associated costs have the potential to be financially offset to a certain extent, recovering a *part* of the value within the waste. Generally, all plastics consist of polymer chains, which vary in their composition and structure. For manufacturing any plastic material, so-called monomers, have to be produced by separating hydrocarbon structures. Most commonly the fossil resource crude oil—a hydrocarbon—is used as a basic input material to start this process. The monomers form the building blocks for the polymers. In a recovery process, the material or its chemical constituents are recovered

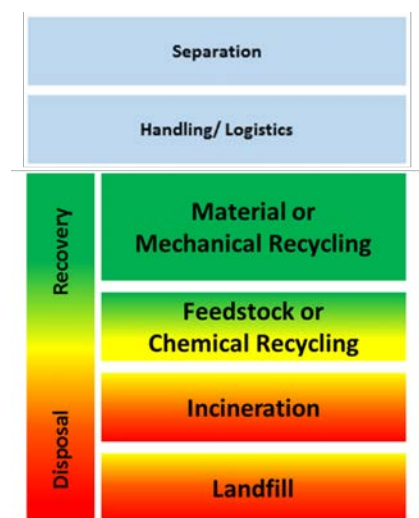
from waste to produce new materials and reduce the usage of virgin/primary materials.

**The final level in the waste hierarchy is plastic waste disposal, most commonly through (controlled) incineration or (sanitary) landfilling.**

These processes do not extract value from the waste, so the expenditure needs to be considered against the cost of alternative forms of managing (or mismanaging) the waste. Adhering to environmental and health standards is necessary to enable safe and sanitary disposal and reduce impacts on the environment and communities, but also increases the cost.

Figure 10.

**TECHNOLOGY TYPES FOR TREATMENT OF PLASTIC WASTE**



Source: Fraunhofer IVV, 2019, modified by cyclos)

The following sections outline brief descriptions of the different technology types categorized in Figure 10. Further details and technology examples can be found in the TOPIC Toolbox.

## 3.2 TECHNOLOGY TYPES

### 3.2.1 Separation, Handling and Logistics

**Pre-treatment of waste is required to enable effective recovery of resources** (e.g., through material or feedstock recycling). Key solutions in this stage include bins and containers to encourage separation, a materials recovery facility (MRF) to store and sort waste and a baler to ease logistics and handling.

- **Bins and containers** are the core component of any collection infrastructure and are usually placed in the vicinity of the waste generators/waste occurrence to allow for easy use and access. Ideally, these bins and containers encourage separation at source by households or by the informal sector (as an intermediary), allowing

for differentiated collection. Common waste fractions targeted for separation could include aluminum cans and other metals, old corrugated cardboard (OCC), PET bottles and/or other (rigid) plastics (see Figure 11). A simpler solution of just “recyclables” and “non-recyclables,” or even simply of dry waste (packaging and others) and wet waste (organic/food), could also still improve waste management outcomes. Such solutions should always be determined by the uptake potential of the further waste management infrastructure.

- An **MRF** is usually the destination for collected waste before further management is undertaken. Waste is stored, sorted and forwarded to different treatment facilities (see Figure 12). It may include a baler, a compactor, a shredder and vehicles for ease of logistics, as well as conveyor belts to help sort incoming waste. Usually, separate areas within an MRF are dedicated to specific waste fractions that are stored before being

Figure 11.  
**BINS ON TIOMAN ISLAND, MALAYSIA**



Source: Lasaju

Figure 12.  
**MRF IN KOSRAE, FEDERATED STATES OF MICRONESIA**



Source: Kosrae State Government, *Solid Waste Management Strategy 2018-2027*

Figure 13.  
**EXAMPLE OF A BALER**



Source: Bramidan

transported to the mainland or treatment site. It should provide adequate space, an adequate level of environmental and health protection, as well as the right machinery for different steps within a functional waste management system. In order to minimize transport costs and efforts, the MRF may be located in close vicinity of the treatment facilities (e.g., a landfill).

- A **baler** is used for pressing specific, homogenous waste fractions into bales to allow for more efficient handling and transport (see Figure 13). Available baler technologies cover different scales, with the smallest ones designed for manually lifting and moving the bales, ultimately limiting the need

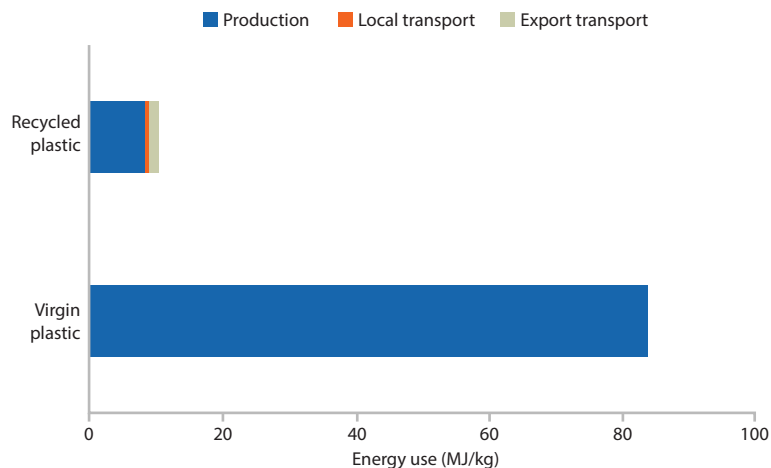
for further machines and equipment. Automated treatment machinery (e.g., for recycling) is often designed to take up full bales.

### 3.2.2 Material Recycling/Mechanical Recycling

**Material recycling (or mechanical recycling) applies to processes that leave the plastic polymers intact, requiring the least additional energy compared to other types of recycling.** The recycled material is transformed—melted by heat or shaped by pressure—into new products with similar attributes. The main advantage for this kind of recycling is a low energy input, significantly lower than the energy input required for producing plastic from virgin materials, as shown in Figure 14. This safeguards the energy that has already been used to crack the virgin material into monomers and form it into the plastic product.

**Generally, the most relevant plastic fraction in municipal waste streams associated with plastic pollution derives from packaging waste, of which several key plastic resins are suitable for material recycling.** Commonly used materials for plastic packaging are called **thermoplastics**, which will melt when heated and harden when cooled in a reversible manner. Due to these attributes, they are generally well suited for material recycling processes. The thermoplastics most widely used for packaging are polyethylene terephthalate (PET), polyethylene (PE; widely used in the form of either “high density” = HDPE or “low density” = LDPE), polyvinyl chloride (PVC), polypropylene (PP), polystyrene (PS), (for more

Figure 14.  
**COMPARISON OF REQUIRED ENERGY FOR PRODUCTION OF PLASTIC FROM RECYCLED AND VIRGIN PLASTIC**



Source: Wong, C., 2009

characteristics see Appendix B). Relevant for islands is an additional thermoplastic material nylon or, more specifically, 'Nylon 6' (polycaprolactam). Nylon is commonly used for textiles as well as fishing gear. A more detailed description on ALDFG is given in Appendix A.

**The level of similarity between recycled plastic and virgin plastic depends on the material composition and purity fed into the recycling process.**

Generally, homogenous plastic waste fractions with little contamination are transformed into recyclates with similar attributes. However, if a mixture of different plastic fractions or items is combined in one process, the output lacks a single fraction's specific characteristics. Most material recycling processes are also highly specific to one material (sub)fraction. Rigid packaging can be separated from other waste streams and fed into material recycling processes relatively easily whereas flexible packaging is more difficult to extract and often contains multilayers of different plastic types, and thus is rarely used for material recycling. Plastic extracted from post-consumer waste usually consists of a mixture of fractions and is contaminated with other materials like organic waste. The resulting recyclates' versatility is therefore limited when compared to virgin material. To achieve quality levels required by a specific application, the recyclates are often blended with virgin materials or other additives.

The most common processes covered under material recycling include:

- **Extrusion:** Plastic waste items are shredded, washed and processed via melting and filtering into granules that can be used to produce new plastic items, theoretically closing the recycling

loop. The input material is identical to the output material (i.e., PE waste can be recycled into PE granules, PP waste into PP granules, and so on), as shown in Figure 15. As it is impossible to achieve virgin material's purity from post-consumer waste, the granules are usually of lower quality, limiting their application for food grade material.

- **Injection molding/pressing:** Plastic granules are used as an input material and can be derived from an initial extrusion recycling process as a substitution to virgin materials. The particles are inserted into a cylinder where the material is fully melted, homogenized and filtered for impurities. The plastic is then either molded or pressed under pressure into a form which hardens as it cools. Depending on the quality of the input material and the applied pressure, a range of applications can be served with products from injection molding/pressing. These include pallets, pots for planting, barriers for agriculture or car bumpers (see Figure 16).
- **Intrusion:** The melted plastic material is inserted in forms and cools until it becomes hard. The resulting products include poles, boards, pillars for street signs, park benches, etc. (see Figure 17). Intrusion requires lower purity levels, enabling the processing of mixed or contaminated plastics commonly found in post-consumer waste streams. The products are usually of lower specific value and their characteristics are less versatile than injection molding. Therefore, extracting a relatively lower part of the input material value is a form of "downcycling."

Figure 15.

**PLASTIC RECYCLER IN JORDAN; RE-GRANULES FROM POLYOLEFIN RECYCLING IN MALAYSIA**



Source: cyclos

Figure 16.

**PRODUCTS MADE BY INJECTION MOLDING PROCESS USING RECYCLATES TO A CERTAIN CONTENT**



Source: Kenpoly Ltd. 2021; Hornbach/Flora Self 2021

Figure 17.

**PRODUCTS MADE WITH INTRUSION PROCESS USING RECYCLATES TO A CERTAIN CONTENT**



Source: cyclos)

- **Sintering:** A wide array of mixed and contaminated plastic waste can be used (e.g., melted and poured into square molds). It then goes through a heating process of several steps, pre-heating, melting and cooling. During the process, the pressure is continuously increased. The end product is a board with a thickness of up to 60 mm, which can be used as construction material or for furniture (see Figure 18)

**Certain material recycling processes may be applied at a micro-scale as “artisanal recycling.”**

Extrusion processes can generally be replicated on a small scale. Any subsequent injection molding would usually require high pressures that need industrial-grade equipment. Small scale injection molding processes are possible but apply lower pressure, which limits the output material quality. The market for artisanal recycling is generally limited to souvenirs and would likely require a certain level of tourism as

well as specific input fractions of plastic, demanding adequate collection and separation of the relevant plastic types.

**From a perspective of resource efficiency, material recycling is by far the preferred option to treat plastic waste if the required scale, level of separation and purity can be achieved.**

Waste management systems are ideally designed to prioritize material recycling against all other treatment options. Certain low-value processes (namely intrusion and sintering) can be operated relatively agnostic concerning the contained plastic fraction, but still require a certain maximum level of contamination with other materials. The more specific the expected attributes, the more specific the required input material. Pure material fractions from PE and PP allow a relatively high level of recycling (e.g., extrusion—either fed into an existing material market or supplemented by injection molding). The same goes for specific PET from PET bottles. Other common fractions like PET

Figure 18.

### EXAMPLE BOARDS MADE FROM SINTERING



Source: cyclos/ AHK E.A., 2021

blends (commonly used in applications other than PET bottles), PVC and Nylon generally are recyclable but need to be strictly separated from all other fractions. In the case of PVC, the contained chlorine can lead to significant pollutants that require a sophisticated technical setup. Non-thermoplastic materials like rubber are unsuitable for material recycling.

#### 3.2.3 Feedstock Recycling/Chemical Recycling

**Feedstock recycling/chemical recycling reverses the original process of producing plastics, breaking up the chemical polymer structure of the plastic waste into simpler structures and, ultimately, into monomers.** To induce this process of *de*-polymerization, energy is required. The chemically simpler output materials can then be used for a process of *re*-polymerization, starting over in the process of forming plastics. This follows the same principle as plastics production from primary/virgin hydrocarbons like crude oil. More common than the *re*-polymerization is the use of the output product for other derivatives of crude oil, mainly as fuel. In line with material recycling processes, feedstock recycling depends on the homogeneity of the input material. The more mixed the input fractions, the more variation of the output product characteristics. While feedstock recycling may, in some instances, be able to process a wider range of plastic materials than material recycling processes, this requires an additional process step like refining in order to achieve a standardized product quality.

The complexity of a petrochemical production facility requires a highly controlled environment, with a number of the plastic feedstock recycling processes only *theoretically* able to operate outside such a controlled, large-scale facility. Common feedstock recycling processes include:

- **Pyrolysis:** Input material is anaerobically heated to 400 °C to 800 °C resulting in the materials thermo-chemically dissolving to their simpler material fractions. End products consist of gas that can be used as a fuel—if captured during the process—as well as the pyrolysis oil. For example, out of a mixture of PE, PP and PS in the ratio 3:1:1, a portion of 40 to 60 percent gas is produced (Methane, Ethane, Ethylene, Propane) and up to 50 percent pyrolysis oil—a mixture of light petrol and hard coal tar. These materials are commonly used as base or intermediate materials within petrochemical processes and can, in theory, be converted for a range of applications including the production of new plastics. Nevertheless, the energy footprint of the newly produced plastics is significantly higher than for virgin plastics, negatively affecting the economics of a pyrolysis process (Lechleitner et al., 2019). Globally, pyrolysis used on either an industrial scale or a small scale, such as on islands, is only being *piloted* as a solution to manage specific plastic waste fractions (see Figure 19). Small-scale solutions in particular are more limited in the fractions that can be included.

Figure 19.

## EXAMPLE OF A SMALL-SCALE PYROLYSIS PROCESSING LINE



Source: Microengineer Ltd.

- **Hydration/Steam Reforming:** This involves a reduction of a chemical element with hydrogen. The processes use temperatures of around 500 °C and pressure of around 300 bars. With the combined application of pressure, heat and the admixture of hydrogen, it is generally possible to convert any hydrocarbon—including plastic from waste—into smaller elements and, ultimately, monomers that can be used for a variety of chemical processes. Due to its heat and pressure requirements, this process requires operations at an industrial scale rather than a small-scale for islands.
- **Solvolysis:** This process resembles the hydration process, but with negligible direct heat input. Solvolysis involves admixing a solvent media into the plastic waste. A *pilot* project designated as “Creasolv” was set up by Fraunhofer and Unilever in Indonesia in 2019 (Kunststoffe International, 05/2020; Fraunhofer IVV 2021). Viability of the process and the economics are currently limited through the heavy degradation of the solvent, which, under operational conditions, proves to be unsuitable for being fed back into the process. Solvolysis for plastic recycling can therefore be deemed *experimental*.

**Although feedstock recycling has a higher versatility for input materials, it also requires a higher level of process control and generally a larger scale than material recycling.** Feedstock (chemical) recycling allows for some additional resource recovery from those plastic fractions that are unsuitable for material (mechanical) recycling (e.g., rubber as a non-thermoforming plastic fraction). The output

material represents a generic product that can be used for a wide range of applications as a substitute to other fuels, building on existing infrastructure (Lechleitner et al., 2019). However, the high level of process control necessary (coupled with levels of contamination equivalently low, as required by material recycling) requires a relatively high level of capital expenditure. Most feedstock recycling processes only work if integrated into larger petrochemical facilities, and cannot be applied in an isolated context. Feedstock recycling processes are highly scale-dependent with their operationalization being challenging on smaller scales.

**Feedstock recycling uses resources less efficiently than material recycling, requiring significant energy input and, in some cases, being used simply as a fuel to be burned.** By nature, feedstock or chemical recycling processes reduce the complexity of the input material’s molecular structure so that the energy resources that have been used to create complex chemical structures during the process of polymerization will be lost entirely. Feedstock recycling processes rely on high external energy input. Feedstock recycling is most commonly used to produce a fuel rather than new plastics, meaning that the process remains quite linear rather than moving towards circularity.

**Feedstock recycling processes are at the focus of many research and trial activities worldwide, but this study has not identified any that are a functioning part of a waste management system.** Applications are currently limited to pilots or experiments at any stage. Their proof of suitability to recycle plastics derived from post-consumer waste has not yet been achieved, particularly on a small scale.

### 3.2.4 Incineration

**Incineration can range from basic “open burning” disposal processes to sophisticated recovery technologies that are operated at scale with complex emissions management, producing large quantities of energy.** The combustion or incineration of waste generally serves the purpose of reducing the waste’s quantity and volume. In its simplest and still widely applied form, incineration is undertaken by lighting mixed waste fractions on the street or within a courtyard. By comparison, most sophisticated incineration technologies are operated at scale with thousands of tons of hourly throughput and usage of the excess heat to produce energy. If the calorific value of the waste is exploited in this way and used for other processes—like electricity production, process heat or room heat—the term “energy recovery” is applied. In this case, treatment through incineration is considered as a *recovery* process, but not as a *recycling* process. The usage of primary resources can be reduced. Any incineration process that either requires external energy input or lacks energy recovery is considered a *disposal* process. Key incineration technology categories include:

- **Mobile incineration:** Basic small-scale technical equipment provides a more continuous and slightly more controlled process than open burning, with a fan that slightly increases the temperature. Beyond

the fan, there is no additional technical installation for exhaust cleaning, temperature control, etc. Due to this simple process with a very limited level of control, the majority of the input material should consist of bio waste, paper or wastes with low impurities (e.g., plastics). As there is no external fuel expected, the input material should also be suitable to be ignited easily (i.e., low moisture content). A mobile incineration unit without a technical setup **does not meet any emission standards.**

- **Technical incineration:** A technical incinerator provides a degree of process control including on a smaller scale, particularly in terms of operating temperature and continuous combustion. The plant resembles a furnace supplemented by equipment that may include a monitoring and control panel, a blower or similar means of introducing oxygen into the process, and some waste gas treatment steps. Due to the small capacity and small-scale design, **sophisticated exhaust gas treatment is not technically feasible.**
- **Controlled incineration:** Controlled incineration describes a process that tends to work without the addition of external fuels and where a suitably high temperature can be achieved. Controlled incineration units tend to include an exhaust gas treatment system.



Photo: Shutterstock / Lano Lan.

**The incineration process results in both air emissions and solid remnants (usually in the form of ash), which can include carcinogens, heavy metals and other pollutants.** The air emissions released are likely to include carcinogens such as polyaromatic hydrocarbons (PAHs), dioxins and furans, among others. If plastics containing chlorine, such as PVC, are involved, acidic hydrogen chloride will also be discharged. A basic incineration setup breaks down volatile compounds, resulting in the emission of dense black smoke as well as an unpleasant odor and harmful air emissions. It also results in aesthetic degradation—particularly relevant for places that rely on tourism. Some plastics (e.g., from electronics) may contain additional fractions like flame retardants that could further distort the process or result in other non-tolerable exhaust emissions. Related emissions are particularly harmful for the operating personnel of the incinerator and the people in close proximity. The incineration process not only generates gaseous emissions but also other solid remnants, usually in the form of ash, which can contain high levels of heavy metals and other pollutants.

**Safe operation of incinerators means minimum requirements related to temperature, cleaning of exhaust gas and disposal of solid remnants.** Temperatures for a process considered adequately safe range from 600° to 650° C as an absolute minimum. In addition to the incinerator's design, maintaining these temperature ranges requires the right input material. A mixture of plastic fractions most common for packaging—PET, PP, HDPE and/or LDPE—generally meets the requirements of a technically simple setup. On the contrary, if the input consists of a mixture of organic fractions or liquids, the energetic value may be lowered excessively, distorting the process. To maintain at least basic environmental and health standards, simple incinerators require some sort of pre-treatment (i.e., sorting) to achieve a relatively homogenous input stream. In addition to high temperatures aiming for around 800°, exhaust gas treatment holding back pollutants that cannot be dissolved (e.g., volatilized heavy metals) are required. Adequate exhaust cleaning is the basic pre-requirement for any form of controlled plastic incineration. Any incineration process setup also needs to consider the subsequent disposal of ashes, dust and slags, commonly on a suitably designed sanitary landfill.

**Safe small-scale solutions with energy recovery from plastic incineration have not been identified.**

The minimum scale for any process usage of energy is estimated in the range of around 200 kW<sub>th</sub> energy output. Such an operation would require the input of around 15 kg plastic waste per hour and a continuous operation over several hours, given the plastic is moderately contaminated. This number can be understood as the absolute minimum based on market-available biomass incineration technology (Interview with SEEGER Engineering, 2021). This is likely due to the technical complexity involved, the relatively high level of energy loss for low waste volumes, the complex technical requirements to bring exhaust gas emissions to an acceptable level and the need for safe disposal of any solid remnants.

### 3.2.5 Landfilling

**A sanitary landfill represents a simple, cheap and final version of waste disposal without aiming at recovering deposited materials.** The main objective of sanitary landfilling is the safe disposal of waste. This is done by ensuring that negative effects on the environment (e.g., from leachates, effluents of contaminated wastewater, discharge of air pollutants and excessive emission of greenhouse gases) are minimized. Supportive technologies aim at minimizing the required space and related emissions. From a perspective of resource efficiency, landfilling is a less preferred option to any recovery process. Yet, the related direct operating costs are low as are the requirements on the waste management system.

**Landfilling is still the preferred option for waste fractions that cannot be treated otherwise.** This may apply to certain substances that are considered dangerous and for which any alternative way of treatment (e.g., incineration) is not technically feasible. This also included remnants from incineration processes like ashes, dust and slag. Depending on the level of sanitary operations of the landfill, and the social and environmental context, landfilling is generally considered as the environmentally preferred option against other disposal practices such as open burning or unsafe technical incineration.



Photo: Shutterstock / ImagineStock.

### 3.3 CONSIDERATIONS FOR TECHNOLOGY UPTAKE

**From a perspective of resource efficiency—extracting the highest value out of the plastic waste— material recycling is the most favorable option, followed by feedstock recycling and energy recovery.** The most relevant portion of plastic waste’s value is derived from the energy that has been invested to transform it from a raw material, commonly crude oil, into plastic. Following the waste hierarchy, preventing (plastic) waste from being caused results in the least pressure on any waste management system. Once an item has become waste and cannot be fed back into a useful state (preparation for reuse), material (mechanical) recycling safeguards the biggest portion of this energy input. Feedstock (chemical) recycling reverses this process and makes no use of this portion of a material’s value. Energy recovery processes are more agnostic concerning the input material, but the resource yield is also the lowest among all recovery processes. All options for recycling, recovery or safe disposal of plastic waste may play a role in a well-designed waste management system.

**Any technological option for recovering value from plastic waste can only operate if synchronized with the collection system.**

In general, the higher the value of the recyclate as output material, the higher the requirements on the input material. To enable economically viable recycling processes, a narrow range of input parameters is required, necessitating waste management practices that feed certain waste fractions into the recycling process. The assessment on a suitable treatment technology must consider the characteristics of the potential input material. Even considering the limitations of technology applications outlined in the sections above, including the requirement of a certain scale, recovering some value from plastic waste remains a possibility. In order to maximize this, steps previous to waste treatment like pre-treatment, efficient collection and separation need to be taken into consideration. These processes form part of an integrated solid waste management system that should be designed individually as per the microsystem’s characteristics and requirement.

Based on the above considerations, certain key findings need to be taken into consideration when assessing

the suitability for any technology to manage plastic waste on small and remote islands:

- **Dependence on available input material:** Whichever technology is applied should depend on the nature of the input material (i.e., the waste composition). The better the segregation, the more possibilities for subsequent treatment steps. Therefore, technologies directly rely on adequate practices of collection and separation.
- **Pre-treatment requirements:** Both for material and feedstock recycling, the input material requirements can only be fulfilled through pre-treatment processes. Due to the usual variety of waste composition, including a variety of different plastic fractions, certain treatment and pre-treatment steps need to be combined to realize an operationally and economically feasible model. Other than controlled incineration—which, due to the high required temperatures, comes with a specific level of process control—there is no one-size-fits-all treatment solution for plastic waste.

- **Minimum critical scale:** All recycling processes are highly scale dependent (i.e., they need to be operated with a minimum input in order to have potential income exceeding the operational costs). This, again, refers to the access of the correct input material and a more sophisticated mode of recycling.
- **Island limitations:** Any technology solution on an island will be more difficult and more expensive to install, operate and maintain afar from mainland infrastructure. As an additional factors, technical expertise might not always be available on a small and remote island. Thus, islands are not necessarily the best test locations for non-proven technologies that might require frequent repairs or adjustments, particularly those with safety concerns, such as small-scale incineration.

Given the above outlined challenges concerning technology uptake for plastic waste in island contexts, **any action to mitigate the adverse effects of plastic waste requires concerted action across the waste value chain, beyond just technologies alone.**

## CHAPTER 4:

# TOPIC TOOLBOX TO IDENTIFY OPTIONS FOR MANAGING PLASTIC WASTE

The Technology Options for Plastic waste in Island Contexts (TOPIC) Toolbox has been developed to inform users about available solutions and technologies for plastic waste management in small and remote islands. Based on a defined set of user-entered criteria on the island's plastic waste metrics and market access for recyclables, the TOPIC Toolbox identifies potential solutions and technologies, and outlines key considerations for feasibility assessment and implementation. Beyond these user-entered criteria, there are qualitative factors relating to the wider solid waste management system that should be considered when identifying solutions and technologies for plastic waste. These factors include any existing solid waste management infrastructure, stakeholder awareness of solid waste management practices and financing aspects, including potential additional funding sources. A limitation of the TOPIC Toolbox is that it cannot incorporate these qualitative factors. To address this limitation, this chapter of the report outlines a broader framework that should be considered in tandem with the TOPIC Toolbox when determining relevant solutions and technologies for plastic waste management in small and remote islands. The final part of the chapter introduces the TOPIC Toolbox to assist users in applying it to their island context.

### 4.1 UNDERSTANDING A FRAMEWORK FOR THE STATUS OF PLASTIC WASTE MANAGEMENT ON AN ISLAND

**There are various factors that need to be considered when identifying options, including technologies, for managing plastic waste.** There are no standard criteria for the selection of any technological component of a plastic waste management system specific to an island's microsystem—these should be adapted based on conditions of each location. Given the remoteness and limited infrastructure, a sustainable technology should be low cost (investment and operation costs) and technically and legally feasible, ensuring pollution treatment efficiency and community acceptability (Eunomia, 2016). The decision related to a potential option for managing plastic waste should consider, amongst others, the local context, particularly the broader waste management system, waste volume and composition, available logistics, available technology, infrastructure, skills and financial resources, as well as main economic activity, intensity of tourism, stakeholder involvement, institutional framework and policy/ regulations.

A framework can be applied to understand the status of a (plastic) waste management system on an island and help to inform potential options for managing plastic waste. This framework covers five key areas with particular relevance to *plastic* waste management.

- Assess and evaluate relevant (plastic) waste metrics—*answering the question, “What is the general understanding of the situation and scale of the issue?”*

- Assess existing solid waste management infrastructure—*answering the question, “Which activities have already been undertaken in order to mitigate adverse effects from waste management?”*
- Assess potential market access for recyclables—*answering the question, “Is there already a system in place for export of recyclables to other markets? Or is there potential for such a system?”*
- Evaluate awareness of solid waste management practices, especially plastic waste—*answering the question, “Are stakeholders aware of their (potential) role in waste management practices and willing to partake in it?”*
- Explore financing aspects, including current expenditure for waste management practices and potential additional financing sources—*answering the question, “Which expenditure is required for a functional waste management system and how can associated funds be made available/ accessed?”*

The institutional framework and policies/regulations have not been explicitly addressed in the framework as these will vary significant depending on the island and national context. However, these aspects and how they relate to the five key areas should be considered.

#### 4.1.1 Relevant (Plastic) Waste Metrics

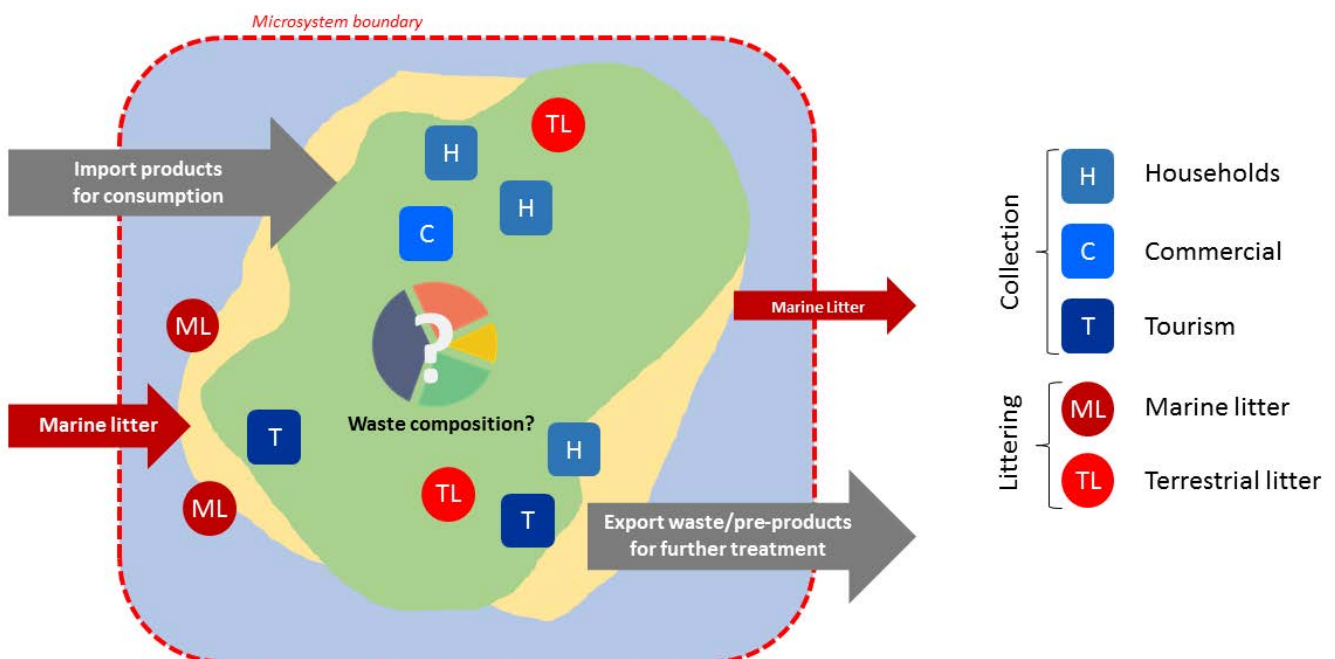
An understanding of the plastic waste potential is needed to identify relevant options for managing plastic waste. This needs to be built on reliable data including the quantity of collected or collectable plastic waste and its composition. In general, a small island is a limited space where the waste balance can be measured relatively well (see Figure 20).

**Allocation.** *Where does waste occur/who generates waste (e.g., household, commercial, tourism, river/ beach cleaning)?*

**Usually, sources of waste generation on islands can be easily identified.** Figure 20 shows that plastic waste occurrence on small and remote islands derives from anthropogenic use of consumption goods from households and commercial/tourist establishments. These waste generators on small islands can be easily allocated (e.g., through assessing consumption patterns as well as analyzing waste volumes). Islands whose economic activities are highly seasonal may experience fluctuating waste generation (e.g., through tourism related activities). Certain import bottlenecks like a port, jetty or an airport are typical for small islands. These interfaces may allow easier monitoring of incoming goods that, after consumption, become waste.

Figure 20.

#### WASTE BALANCE ON ISLANDS



Source: cyclos/ Lasaju

**A second source for plastic waste is derived from marine litter, by and large originating outside the island's zone of influence.** Fishing gear that is recovered from the surrounding sea can be counted as part of this marine litter, even though the accumulation point differs from waste washed ashore.

**Potential/ Quantity:** *How much (plastic) waste is generated?*

**The quantity of (plastic) waste is essential to informing potential options for managing plastic waste.** By evaluating basic data on an island concerning inhabitants, tourism intensity and nature of commercial and tourism activities, specific data concerning the plastic waste potential (e.g., kg per inhabitant) can be accessed. As many recycling or disposal processes are adapted according to a critical (minimum) quantity, this data informs on the *potentially accessible* quantity, allowing the maximum scale of a range for suitable solutions at the given point in time to be set. More thorough evaluations take into consideration changing consumption patterns and foresee socioeconomic and demographic developments. Over time, these will lead to different waste quantities and a different assessment base.

**Composition:** *What is the waste composition (at the two interfaces of waste generated and waste collected)?*

**In addition to the quantification of waste, the composition—, specifically in regard to the plastic content and different plastic types—is essential to determining the uptake of potential options.** Information on material composition beyond plastics is particularly relevant for all fractions that bear an economic value, commonly from metals and paper, in addition to certain plastic items. Understanding this composition allows assessment of the maximum value that can be extracted from the waste stream. This value can either be extracted by feeding it into existing (recycling) value chains or calculating a case for onsite treatment for recovery including recycling. This value quantifies the potential to offset some waste management costs. A deeper analysis beyond umbrella material fractions (like “plastics”) is required to allow for assessment of treatment solutions. For example, the treatment paths for different plastic fractions are generally different. The maximum value extraction from one plastic fraction requires a specific solution that may not allow extraction of the maximum value out of a different plastic fraction or may even be incompatible.

As an additional aspect within the waste hierarchy, hints for waste prevention can be generated from the analysis of the waste composition.

Waste composition can be measured at several interfaces, including at the point of generation, at the waste management facility or at the point of input or output at the treatment stage.

**Collection rates and leakages:** *Which waste fractions are collected at which rate (waste collected)?*

**Given the importance of scale for viable options to manage plastic waste, the coverage by waste collection services (and therefore the potential for aggregation of plastic quantities) is important.** Organic waste may be treated on site through composting or feeding to animals (fish, chicken) even on a small scale, whereas some larger commercial establishments like resorts may also be able to apply other treatment processes like incineration. Nevertheless, for common plastic fractions, these treatment processes are impossible (composting) or environmentally not acceptable (incineration). Therefore, a prerequisite for plastic waste to be counted as managed is the coverage by collection services. Collection modes include the aggregation of waste in buckets, bins, bags either on site of the generator (connected households, commercial and tourism establishments) or in public spaces, and the subsequent transport to a waste management site. Also, the result from (beach) cleaning activities—forwarded to a waste management site accordingly—can be considered as collected waste.

Leakages are quantified based on the gap in between occurring waste—generated by consumption practices on the island and accumulated marine litter from outside the island—and collected waste. These leakages are considered mismanaged waste, usually in the form of open burning, burying or ultimately littering into the marine and terrestrial environment.

For the assessment of options for managing plastic waste, the current collection rate sets the minimum scale. Waste must be collected for potential options be applied. This covers recovery including recycling options or environmentally and socially sound disposal options like sanitary landfill or controlled incineration. Assessing the current collection rate allows for assessing suitable solutions given the status quo, whereas an adaptation of the waste management system may result in different collection rates over time.

## 4.1.2 Existing Solid Waste Management Infrastructure

**Crucial for the assessment of the status quo of waste management practices is the existing solid waste management infrastructure and associated skills/capacities to maintain and operate the infrastructure.** In every waste management system, the infrastructure needs to be synchronized with the generated waste, characterized by the above outlined aspects (allocation, potential/quantity, composition and leakages/collection rate). A functional waste management infrastructure is designed to collect and treat (or pre-treat for export) all waste adequately—the same applies for any microsystem like an island.

### *Collection*

Collection determines all subsequent steps of the waste management system. Generally, the more that homogenous waste streams are made accessible from the collection system (through separation) to all following steps, the broader the possibilities to extract maximal value out of (plastic) waste streams. Even for treatment on site, namely composting, plastic is a contaminant that alters the decomposition process and needs to be separated accordingly.

Separate collection of all possible waste fractions is practically not possible. Not only would the complexity of such a system discourage participation, but the waste generator may also not be able to distinguish between different types of plastics. Simple mechanisms like the separation of waste into dry and wet fractions may significantly contribute to less contamination of different fractions and allow for better value extraction. The aggregation and collection of mixed waste is logistically easier to implement and may come with minimal collection costs. However, these advantages are offset by lower value extraction potential, either through more sorting requirements or through the exclusion of certain recycling applications in case of excessive levels of contamination, limiting treatment options to disposal only.

### *Pre-treatment*

Pre-treatment designates all activities that separate mixed waste fractions from each other to divert potentially valuable waste fractions into processes with the potential to recover some of the material's value. Any pre-treatment activity depends on established value creation potential at the treatment stage,

either through marketing valuable items and feeding them into existing value chains, or by setting up new recovery facilities. Common pre-treatment processes are sorting, realized within a wide range of manual up to automated processes, washing, and shredding, as well as the preparation for transport (e.g., through compaction or baling machines).

### *Final treatment*

Depending on the accessible input material stream after any pre-treatment processes, final treatment could include disposal methods (for mixed waste)—incineration or landfill—or target value extraction through recovery and recycling processes (for waste that has been separated to some extent). Disposal activities always have to be considered as a full recovery rate is technically not feasible. For example, any waste to energy incineration process also requires an associated landfill available for remnants. Therefore, based on the waste composition, suitable processes for recovery including recycling need to be taken into consideration jointly with disposal options. Chapter 3 elaborates further on technology options for recovery and disposal.

## 4.1.3 Market Access for (Plastic) Recyclables

**One of the most important questions determining the most suitable solutions for small and very small islands is the question of market access.**

In other words, whether recyclables, including plastic, can be transported cost effectively to a larger island, cluster of islands or the mainland to be processed in larger facilities. The market access is largely dependent on both the revenue that can be generated in those markets (e.g., through mainland recycling companies) as well as the cost of bringing the recyclable material from the island to the market.

To assess the possibility of transport to a potential market, several factors need to be taken into consideration. For example, does the regular boat/ferry connection allow for safe waste transport? As outlined above, islands usually import more material and goods than they export, allowing for vacant space on the connecting boats and associated cost advantages. Nevertheless, the available space may be unsuitable for waste, due to strong odor or limited space. For certain items, specifically relatively high value items like metal or certain plastics, both volume and odor can be minimized through correct separation at source.

#### 4.1.4 Stakeholder Awareness of Solid Waste Management

**The willingness and ability of key stakeholders to undertake adequate (plastic) waste management practices is essential to improving waste management.** Any waste management system is comprised of legal, institutional, financial and organizational provisions, as well as different entities with their activities and responsibilities including local citizens, tourists, visitors and so on. The adequate technologies (e.g., collection infrastructure, sorting and treatment—including recycling and incineration plants) play a crucial role in operating a functionally designed waste management system capable of adequately managing the plastic waste fraction. Importantly, a functional waste management system goes beyond any technological uptake and relies on its stakeholders to play an active role. Inadequate waste treatment processes like open burning, open dumping, burying or littering into the marine and terrestrial environment can be associated with a lack of infrastructure and alternative options as well as a lack of awareness about the potential adverse health and environmental effects. All functional waste management practices rely, at least partly, on the participation of every waste generator. Certain practices like littering render most subsequent steps practically impossible. Further, to enable options that are higher up the waste hierarchy, such as recycling, waste management systems also benefit from increasing participation levels through an increased level of separation at source or a larger scale of available input material.

Key stakeholder groups in a small or remote island context could include local government and national government, citizens, fisherfolk, tourists (international and national), the hospitality industry (mainly hotels and other accommodation providers), commerce and NGOs (active in environment topics).

These stakeholder groups can be analyzed according to how they contribute to the observed plastic waste management deficiencies, their potential to improve observed plastic waste management practices, how they are adversely affected by current plastic waste management deficiencies and how they could benefit from improvements from the plastic waste management system.

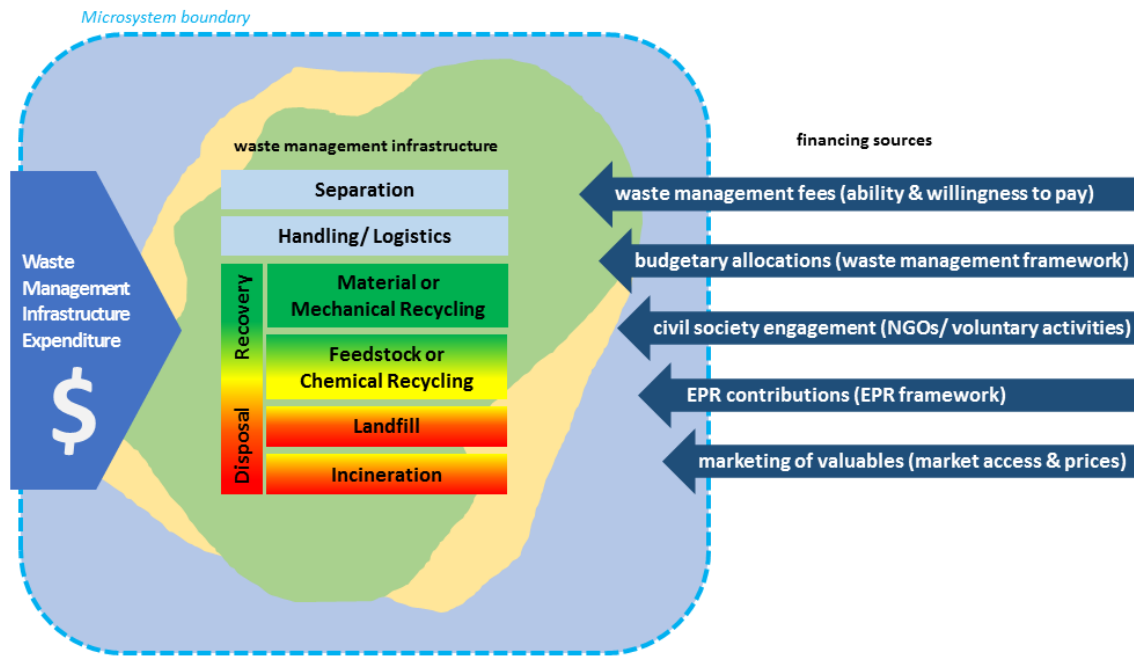
#### 4.1.5 Sustainable Financing for (Plastic) Waste Management

**Adequate (plastic) waste management, including the selection of suitable technological solutions, requires the implementation of a sustainable financing system.** A market-based approach only concentrates on waste fractions that bear sufficient value to cover all associated waste management costs. To prevent littering, waste streams with insufficient value must also be covered by the market. The gap in the value of the waste and the costs to collect it or remove it from the environment needs to be bridged through an appropriate waste management system. Understanding the financing of a waste management system as covering this balance in between occurring costs and potential income opens additional opportunities to include existing informal sector structures as well as enabling new business models. See Figure 21 for a summary of potential waste financing sources.

**Every functional waste management system comes at a net cost.** The coverage of these costs can derive from a number of sources, including:

- **Costs directly imposed on the waste generators** (e.g. households and commercial establishments) through regularly paid waste management fees, commonly in the form of a “collection fee.” Using a waste management service can be made obligatory and fees can be paid either to the municipality or to a private service provider.
- **Direct budgetary allocations** derived from different levels of government (e.g., environmental budget from national, regional/state or local governments).
- **Voluntary civil society engagement** both financially (e.g., donations) or non-financially (e.g., beach clean-ups or retrieval activities for ALDFG).
- **Systems following the “polluter pays” principle**, commonly operationalized through EPR. In this case, producers of goods (collectively) cover the costs of the adequate management of the waste caused by these goods. Other funds from tourists and visitors can also be utilized to help finance a waste management system, depending on the individual island context.
- **Extraction and marketing of valuable items** found within the waste streams, recovering a part of their original value (refer to Chapter 1.1.3).

Figure 21.  
**POTENTIAL SOURCES FOR FINANCING WASTE MANAGEMENT**



Source: cyclos/ Lasaju

- **Deposit refund systems** that financially incentivize the collection and recovery of recyclables.

Commonly, a mixture of several or all the above-mentioned sources are required and suitable. Therefore, the possibility, accessibility and the actual potential of a set of different finance mechanisms, including their interdependencies, need to be considered for an analysis on functionality of a waste management system.

**Improving financing for waste management can involve blending the higher costs of management on islands into an overarching cost structure.**

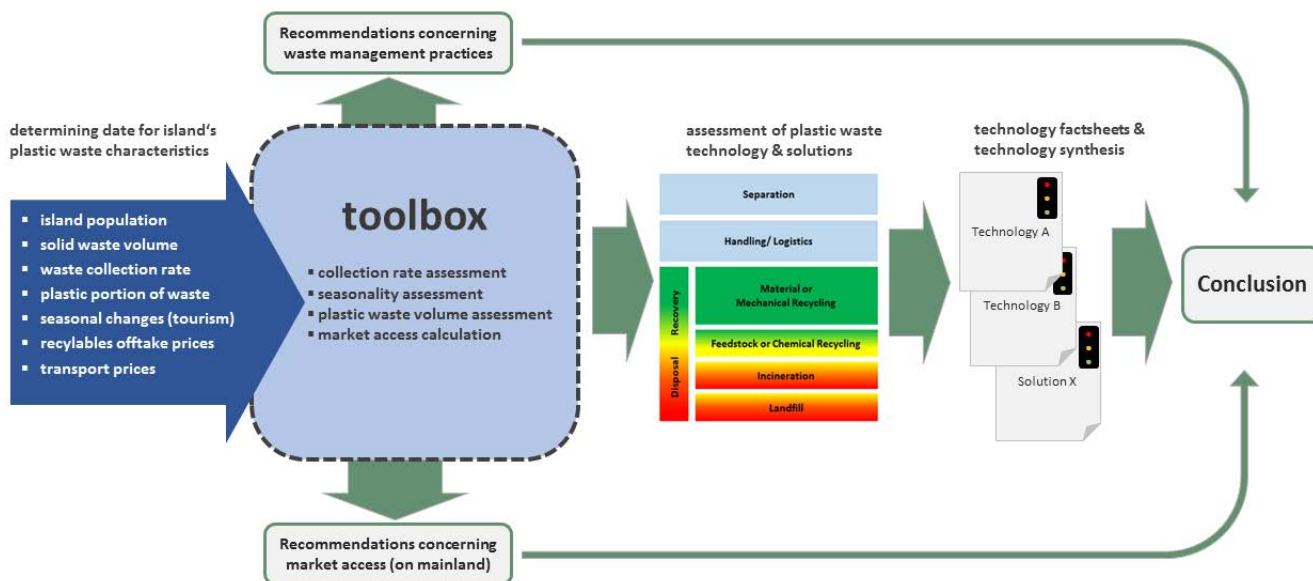
In many cases, the population residing on island microsystems forms a negligible part of the national total. This often remains the case even if considered at sub-national level (e.g., states). These higher waste management costs specific to islands may not be substantial if blended into a wider national or state budget. However, for countries with a high number of islands—like Greece or Indonesia, as well as entire countries exclusively consisting of islands such as in the Pacific—this option of blending the costs may not be available. This may also be the case in some jurisdictions within countries where much of the population resides on islands.

**4.2 USING THE TOPIC TOOLBOX**

**Based on the available technologies and considering the framework for (plastic) waste management on islands, the TOPIC Toolbox was developed to inform users about available solutions and technologies for plastic waste management in microsystems like small and remote islands.**

The TOPIC Toolbox is an Excel file that takes the user through a number of steps, requesting certain data to guide a decision on suitable solutions and technologies for plastic waste management (see Figure 22). The more quantitative determinants of an island’s plastic waste characteristics—such as waste volumes, seasonality, collection rates and market access—can be captured by the TOPIC Toolbox. While the more qualitative characteristics are equally important, they cannot be easily generalized and cannot be entered as data in the TOPIC Toolbox, though they must still inform the specific judgment of any proposed technology or solution. Solutions and technologies are discussed in detail to allow for a more informed decision. The TOPIC Toolbox should be used in conjunction with an overall assessment of island (plastic) waste management, as outlined in the framework.

Figure 22.  
**TOOLBOX APPLICATION**



Source: cyclos/ Lasaju

The TOPIC Toolbox translates input data into three different recommendation clusters for plastic waste management:

- Suggestions to advance general waste management practice based on key **island data inputs**.
- Information on the potential **market access** on the mainland.
- A matrix displaying a set of **technologies and solutions** that may be suitable for the specific island case. These technologies and solutions are discussed in a condensed format within the synthesis sheet and in detail in individual factsheets.

All three recommendation clusters are merged into the conclusion sheet and outlined in more detail throughout this chapter.

#### 4.2.1 Island Data Inputs/Waste Characteristics

The quantity of collected or collectable plastic waste and its composition needs to be assessed to identify any solutions. These numbers need to be as precise as possible to identify potential solutions. Within the TOPIC Toolbox, the sheet "Island Inputs" provides an interface for data entry (see Figure 23).

The required data entries include the population of the island, estimated daily per capita waste generation and estimated share of plastic to further assess the scale of the solution or technology. Only waste that is collected can be managed, so the collection rate informs on the quantities available for treatment. Finally, the effect from tourist arrivals is reflected through an optional seasonal factor from tourism.

Depending on the island characteristics ascertained from the entered data, two boxes with findings and recommendations are displayed. Two different outcomes are visualized in Figure 23 and Figure 24. Within the TOPIC Toolbox, the orange buttons provide links to other sheets containing additional information (as discussed in the following sub-sections).

#### 4.2.2 Market Access

Within the TOPIC Toolbox, the sheet "Market Access" (shown in Figure 25) allows for a simple calculation on the viability of transporting recyclable waste off the island. Data entry includes market price for various recyclables as well as the composition of recyclables and estimated cost and capacity for transport. Based on the data entry, a summary box displays relevant findings (identified by a yellow box in Figure 25).

Figure 23.  
**TOOLBOX SHEET 'ISLAND INPUTS' (EXAMPLE A)**

**Assessment of relevant waste characteristics**

Before an assessment of potential solutions can be undertaken, an understanding of the extent of plastic waste needs to be established through reliable data. The quantity of collected or collectable plastic waste and its composition needs to be first measured or estimated. This data needs to be as precise as possible in order to develop tailored strategies for managing the waste. The following data points are needed allow users to identify solutions that may be suitable for your islands.

Island population	3000	in persons
Average waste volume (mixed)	0.87	in kg/capita/day
Waste collection rate	90%	% of total waste volume
Estimated share of plastic	12%	% of total waste volume

Approximate total waste volume from island population	2,610	kg of mixed waste per day
	313	kg of plastic waste per day
Collected waste volume from island population available for treatment	2,349	kg of mixed waste per day
	282	kg of plastic waste per day

---

Increase of waste volume throughout the year from seasonal tourism	90%	<i>if no data available, put 0%</i>
Maximum waste volume from island population	4,959	kg of mixed waste per day
Maximum waste volume from tourists	595	kg of plastic waste per day

Using the values entered above allows for potential solutions for adequate plastic waste management to be presented, in a matrix format.

Overview treatment technologies & solutions

Certain waste fractions may be exported from your island at a positive net cost. This tool calculates if the mix of valuable materials is able to compensate the related transport costs.

Market Access Analysis

Taking into consideration all data entries, suitable measures to advance your island's plastic waste management system are recommended.

Conclusion

to Introduction

The collection rate on your island is already notably high. The vast majority of plastic waste is prevented from being dumped or littered and most plastic waste can be accessed for further treatment. Beyond selective measures to optimise collection, focus should be on implementing adequate treatment solutions and technologies to enable the maximum value extraction from plastic waste.

Waste generation from incoming tourists is a significant burden for your island. The waste management system needs to be designed to seasonally take up these increased volumes. Instruments that levy waste management contributions from tourism should be discussed.

Source: cyclos/ Lasaju

Figure 24.  
**TOOLBOX SHEET "ASSESSMENT OF RELEVANT WASTE CHARACTERISTICS" (EXAMPLE B)**

**Assessment of relevant waste characteristics**

Before an assessment of potential solutions can be undertaken, an understanding of the extent of plastic waste needs to be established through reliable data. The quantity of collected or collectable plastic waste and its composition needs to be first measured or estimated. This data needs to be as precise as possible in order to develop tailored strategies for managing the waste. The following data points are needed allow users to identify solutions that may be suitable for your islands.

Island population	500	in persons
Average waste volume (mixed)	0.87	in kg/capita/day
Waste collection rate	60%	% of total waste volume
Estimated share of plastic	12%	% of total waste volume

Approximate total waste volume from island population	435	kg of mixed waste per day
	52	kg of plastic waste per day
Collected waste volume from island population available for treatment	261	kg of mixed waste per day
	31	kg of plastic waste per day

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Increase of waste volume throughout the year from seasonal tourism	10%	<i>if no data available, put 0%</i>
Maximum waste volume from island population	479	kg of mixed waste per day
Maximum waste volume from tourists	57	kg of plastic waste per day

Using the values entered above allows for potential solutions for adequate plastic waste management to be presented, in a matrix format.

Overview treatment technologies & solutions

Certain waste fractions may be exported from your island at a positive net cost. This tool calculates if the mix of valuable materials is able to compensate the related transport costs.

Market Access Analysis

Taking into consideration all data entries, suitable measures to advance your island's plastic waste management system are recommended.

Conclusion

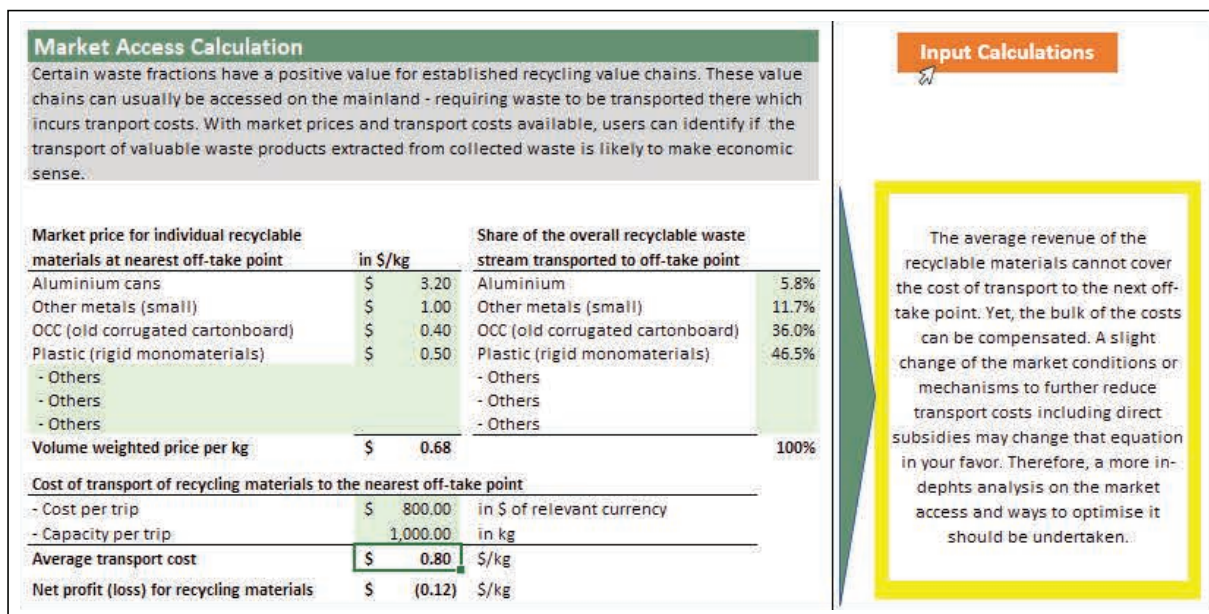
to Introduction

The collection rate on your island covers a good portion of the occurring waste, yet there is still significant need for optimization to further reduce alternatively and likely inadequately managed plastic waste. With relevant portions of plastic waste already collected, efforts should go into both increasing collection rates as well as establishing adequate treatment infrastructure.

On your island, seasonal increase of waste volumes caused by incoming tourists is at a low level. The waste management infrastructure mainly designed for serving the island's population could and should be able to absorb the additional volumes.

Source: cyclos/ Lasaju

Figure 25.  
**TOOLBOX SHEET “MARKET ACCESS”**



Source: cyclos/ Lasaju

### 4.2.3 Suggested Technologies and Solutions

#### Matrix

The “Matrix” sheet (shown in Figure 26) visualizes technologies and solutions for managing plastic waste on islands based on the maximum available plastic waste volume per day. **The TOPIC Toolbox only identifies the maximum available plastic waste volume requiring treatment. The actual volume of plastic waste available for different solutions is highly context-specific depending on the level of sorting, the level of contamination, the different plastic types available and the extent to which these plastic types can be treated by any particular solution. A detailed study should be completed to determine the feasibility of implementing any particular solution based on the specific island context.** The potential solutions in range of the island’s waste characteristics are marked by a blue bar. All displayed technologies and solutions are ranked according to their potential to contribute to a functional waste management system. A green box indicates that this technology/solution can cause a significantly positive impact on plastic waste management. A yellow box indicates that this technology/solution can cause a marginally positive impact on plastic waste management. A red

box indicates that this technology/solution fails to contribute to effective plastic waste management.

All displayed solutions are further analyzed and described in individual sheets that can be accessed from the matrix. Using the details in the individual sheets, decision-makers—as experts for their islands—can determine whether or not a specific type of technology is appropriate. Examples of technologies and solutions are provided. The objective is that decision-makers are empowered to know what type of technology is appropriate for their islands and which specific criteria they want to prioritize.

#### Synthesis

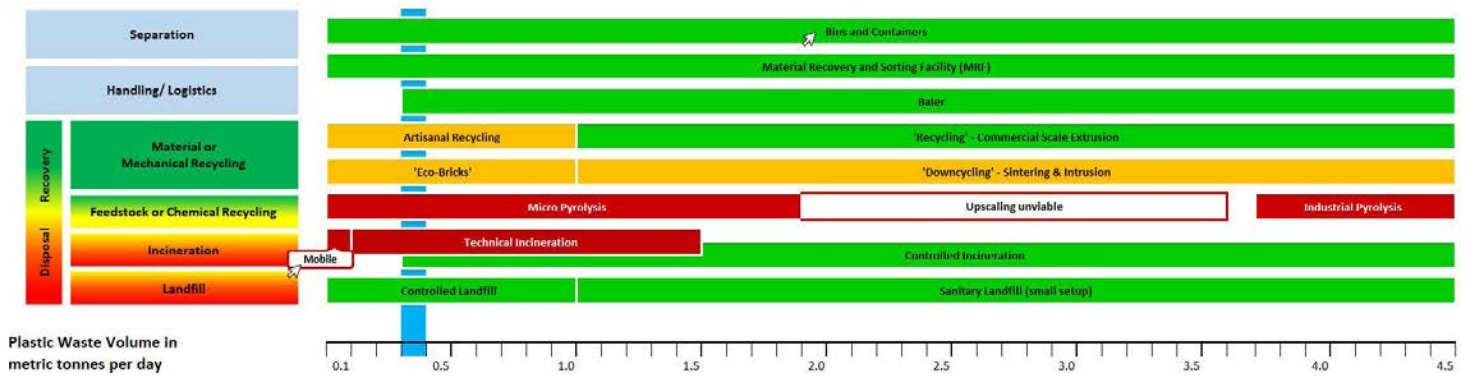
The “Synthesis” sheet provides an overview of the available options to manage plastic waste. Here, the key features of the technologies and solutions applicable for the island are outlined, allowing for a quick overview and comparison of key elements. Figure 27 provides a simplified version of the “Synthesis” sheet to show how different technologies and solutions are categorized according to five key criteria: operational complexity, economic viability, environmental effects, social effects and its potential to contribute to better plastic waste management. The results are color coded: green signals a positive assessment for the

specific criteria; yellow signals a marginally positive assessment; and red signals a negative assessment. A conclusion is given to outline the support needed for uptake of the respective technology or solution. Based on the island waste characteristics, a blue frame identifies potential solutions or technologies on the "Synthesis" sheet of the TOPIC Toolbox (not shown on the simplified version in Figure 27).

#### 4.2.4 Conclusion

The "Conclusion" sheet summarizes the results of the previous sheets (see Figure 28). Findings and recommendations are displayed here for an easily accessible overview. The given format is also optimized for printing.

Figure 26. TOOLBOX SHEET "MATRIX"



Source: cyclos/ Lasaju

Figure 27. SIMPLIFIED VISUALIZATION OF THE 'SYNTHESIS' WORKSHEET AS USED IN THE ISLAND CASE STUDIES

Solution / Technologies	Bins & Containers	Material Recovery Facility	Baler	Artisanal Recycling	Eco-brick	"Downcycling" Sintering & Intrusion	"Recycling" Extrusion	Micro Pyrolysis	Industrial Pyrolysis	Mobile Incineration	Technical Incineration	Controlled Incineration	Controlled Landfill	Sanitary Landfill
Operational complexity	Green	Yellow	Yellow	Green	Red	Red	Red	Red	Green	Yellow	Yellow	Green	Red	Green
Economic viability	Green	Yellow	Green	Green	Yellow	Red	Yellow	Green	Green	Yellow	Yellow	Yellow	Red	Green
Environmental effects	Green	Green	Green	Green	Green	Yellow	Yellow	Red	Red	Yellow	Yellow	Yellow	Green	Green
Social effects	Green	Yellow	Green	Green	Green	Yellow	Green	Red	Red	Yellow	Yellow	Yellow	Green	Green
Contribution to waste mgmt	Green	Green	Yellow	Yellow	Yellow	Yellow	Red	Red	Red	Red	Green	Green	Green	Green

Source: cyclos/ Lasaju





## CHAPTER 5:

# APPLICATION OF THE TOPIC TOOLBOX TO MALAYSIA

The TOPIC Toolbox was applied to five case study islands in Malaysia to identify potential suitable solutions and technologies for management of plastic waste. This chapter outlines the island context in Malaysia and summarizes the results from the five case study islands, including key conclusions. Further detail on the solid waste management system on each case study island is provided in Appendix C.

### 5.1 ISLAND CONTEXT IN MALAYSIA

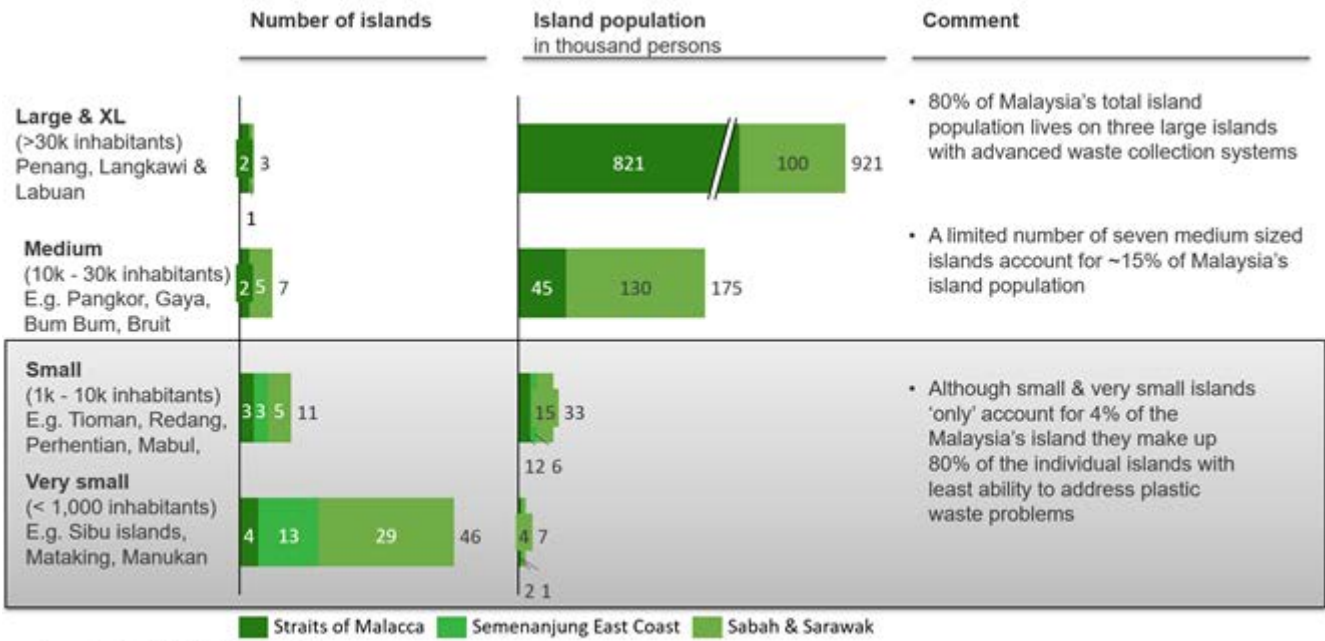
**Malaysia has around 130 inhabited islands, with the small and very small islands least able to effectively manage their (plastic) waste.** The larger islands often have a more advanced waste management infrastructure—to which about 80 percent of the total Malaysian island's population has access—that allows them to deal with plastic waste more effectively and at scale. While these islands naturally face a range of waste management challenges, the focus of this study is largely on small and very small islands (see Figure 29), that are often remote with the least ability to address plastic waste problems.

**In defining the terms “small” and “remote” for islands in this study it is necessary to take the specific context into consideration, as it varies in between countries and regions.** Within the Malaysian context, the definition of “small” considered island population and geographic size. A four-part categorization of islands, namely Large and Extra Large, Medium, Small and Very Small, was developed (Figure 29). When defining “remote,” the importance of context for different islands made a fully quantifiable definition difficult. Instead, a combination of factors was used in addition to the factor “distance to mainland,” which does not sufficiently incorporate other elements. A qualitative, case-by-case approach was taken, including distance from the nearest major population center with a high degree of connectivity (including an airport with regular scheduled flights), effort needed to reach the island (including availability and frequency of passenger and non-passenger connections from the mainland) and time needed to reach the island.

**These small and remote islands in Malaysia face significant challenges in dealing with the solid waste generated by the local population, visitors and tourists.** Due to a frequent lack of adequate waste management practices, plastic waste is dumped in unsanitary landfills/dumpsites or remains uncollected and is consequently littered into the marine and terrestrial environment. This adversely affects the viability of businesses and livelihoods relying on the functionality of these ecosystems. Financing waste management systems can also be a significant challenge and the Malaysian Government is exploring options to address this (see Box 2).

Figure 29.

**OVERVIEW OF MALAYSIAN ISLANDS BY GEOGRAPHIC SIZE AND NUMBER OF INHABITANTS**



Source: DOSM; Wikipedia; Google Earth

Source: Lasaju

**BOX 2:  
EPR FOR PACKAGING IN MALAYSIA**

Support for the waste management system can come from producers and importers putting packed goods on the Malaysian market through, for example, an EPR scheme. In this case, EPR could represent a solution to cover most of the plastic packaging management costs within islands. A 2020 WWF study outlines a possible EPR scheme for packaging waste in Malaysia (WWF 2020) and includes detailed proposals on functional waste management systems in Malaysia. The Malaysian Government in its Twelfth

Malaysia Plan has mentioned EPR as a policy approach to support the recovery of post-consumer packaging waste. Moving towards a mandatory EPR scheme by 2026, the Malaysian Government will be formulating an EPR framework that complements the Malaysian economy, aiming to ensure integrated and sustainable management of plastic waste. In general, EPR represents an important factor to sustainably finance plastic waste management alongside other income sources.

**5.2 CASE STUDY ISLANDS IN MALAYSIA**

Five case study islands off the east coast of Peninsular Malaysia and in Semporna District, Sabah were analyzed using the framework and the TOPIC Toolbox. These islands were chosen: (1) based on their classification as small or very small islands; (2) to cover both Act

672 States<sup>4</sup> and non-Act States<sup>5</sup>; and (3) because they cover regions with very different market access. This section summarizes the results for each island and Appendix C outlines the waste management system for each case study island in more detail. Conclusions from applying the framework and Toolbox to case study islands in Malaysia are outlined in section 5.3.

4 The Federal Government maintains responsibility for waste management, contributes financially to well-functioning waste collection and disposal infrastructure, and appoints a waste management concessionaire.

5 The waste management responsibility remains with the local level governments who often have limited funding, so the waste management systems are often underdeveloped.

## 5.2.1 Peninsular Islands

### TIOMAN ISLAND

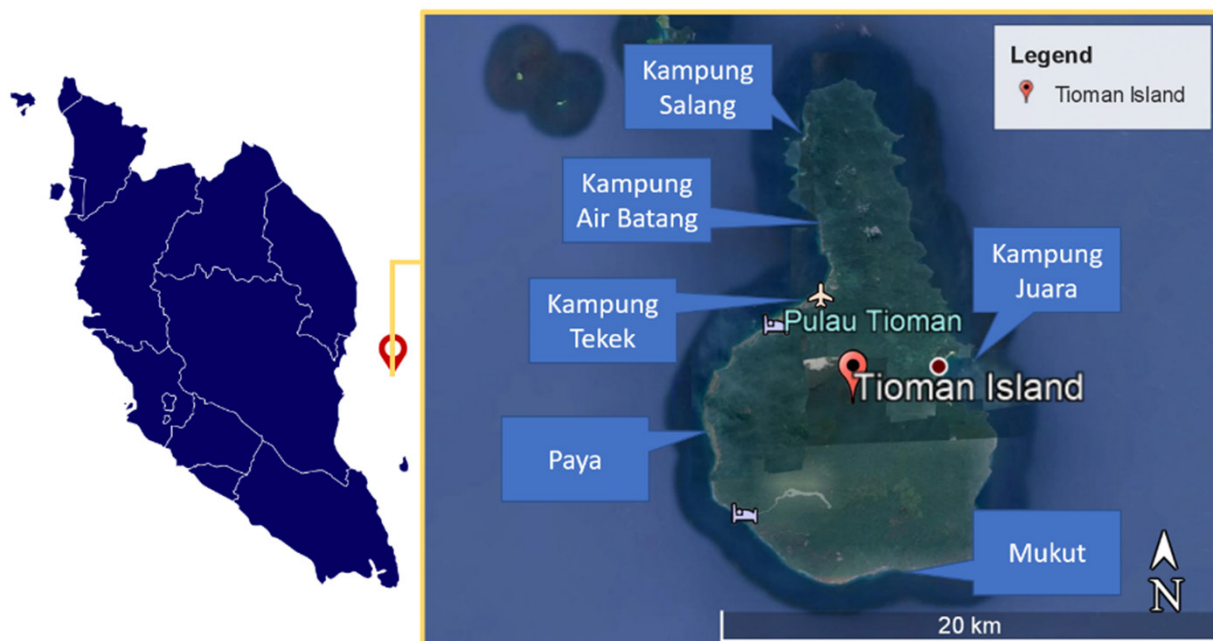
Rompin District, State of Pahang; Act 672 State

Population: 3,000

Tioman Island is one of the three largest tourism islands at the East coast of Peninsular Malaysia, located within the Rompin District, Pahang and is accessible by ferry from both Rompin (Pahang) and Mersing (Johor).

Figure 30.

MAP OF TIOMAN ISLAND



Source: Google Maps, Lasaju

Table 2.

SUMMARY OF TOOLBOX ASSESSMENT OF TIOMAN ISLAND

#### Waste Characteristics

**Solid waste:** 2,610 kg per day

**Plastic waste:** 313 kg per day

**Collected plastic waste:** 282 kg per day—well segregated

#### Market Access

- Local recycler/mixed junkyard in Mersing (mainland city servicing Tioman).
- Regular cargo boat with empty back haul available.
- Compaction of recyclables is required to make this a cost-effective solution.
- Dry storage area for cardboard is also required.

#### Technologies/Solutions

- Plastic waste volumes only support artisanal recycling or eco-bricks.
- Micro-pyrolysis is possible but not economically viable. Improved storage and compaction needed for export of recyclables.
- Controlled incineration could be used for residuals.
- The existing incinerator should be assessed to ensure it meets health and environmental standards.

#### Conclusion

- Artisanal and eco-brick recycling for a small fraction of the waste. Improved handling and logistics would allow more recyclable materials to be sent to the mainland recycling market to be mechanically recycled in commercial-scale facilities.

Figure 31.  
**COLLECTION EXAMPLES IN TIOMAN FOR MIXED WASTE AND RECYCLING COLLECTION**



Source: Lasaju

Figure 32.  
**GLASS RECYCLING**



Source: Rumah Hijau, Lasaju

Figure 33.  
**OCC COLLECTED AND STORED IN DEPOT**



Source: Lasaju

## PERHENTIAN ISLAND

Besut District, State of Terengganu; non-Act State

Population: 2,000

Perhentian Island is also one of the three largest tourism islands at the East coast of Peninsular Malaysia and attracts local and international tourists. The island is located at Kuala Besut, Besut District, Terengganu, which is near to the Terengganu State and Kelantan State border.

Figure 34.

### MAP OF PERHENTIAN ISLANDS



Source: Google Maps, Lasaju

Table 3.

### SUMMARY OF TOOLBOX ASSESSMENT OF PERHENTIAN ISLAND

#### Waste Characteristics

**Solid waste:** 1,740 kg per day

**Plastic waste:** 244 kg per day

**Collected plastic waste:** unknown—minimal segregation

#### Market Access

- Recycling can be sold in Besut.
- Transport cost needs to be lowered to achieve market access—compaction into bales and regular use of the empty backhaul to lower the cost.

#### Technologies/ Solutions

- Plastic waste volumes only support artisanal recycling or eco-bricks.
- Micro-pyrolysis is possible but not economically viable.
- Improved storage and compaction needed for export of recyclables.
- Sanitary landfill could be considered in place of exporting all waste.

#### Conclusion

- Artisanal and eco-brick recycling for a small fraction of the waste.
- Improved handling and logistics would allow more recyclable materials to be sent to the mainland recycling market to be mechanically recycled in commercial-scale facilities.

Figure 35.  
**COLLECTION EXAMPLES IN PERHENTIAN FOR MIXED WASTE AT COLLECTION POINT AND PUBLIC CLEANSING**

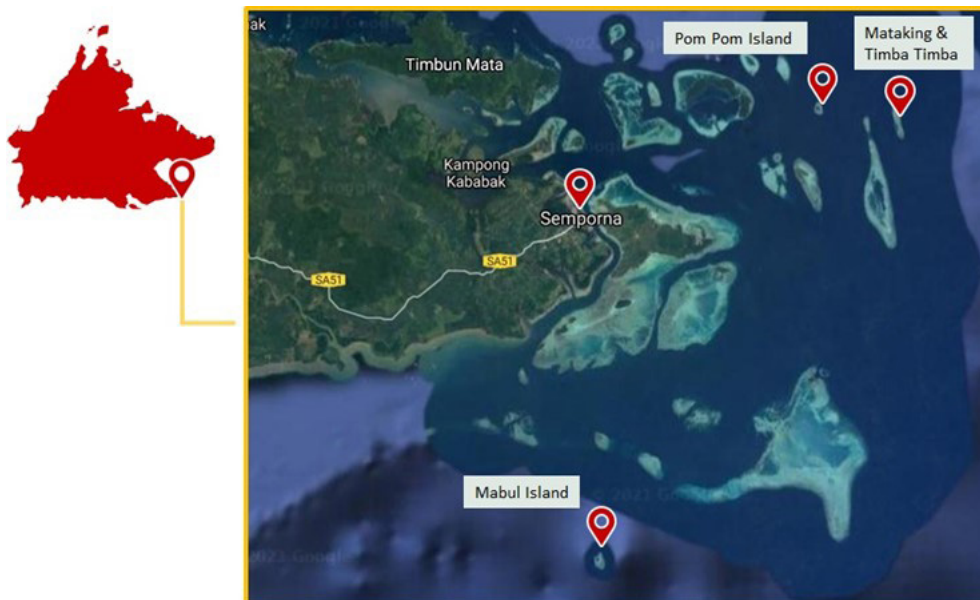


Source: Lasaju

### 5.2.2 Semporna Islands

The following four islands are within the Semporna Islands cluster, owing to their relative proximity to Semporna on the south-eastern coast of Sabah, the administrative district where the islands are located, and the islands' economic and geographical relationship to the town of Semporna.

Figure 36.  
**MAP OF THE SEMPORNA ISLANDS STUDIED**



**Comment:**

- Almost all island waste that is collected sent for onward disposal to Semporna
- The island residents vary, from village communities, resort staff or groundskeepers to the General Operations Force Battalions, resulting in varied collection methods.

Source: Google Maps, Lasaju

## MABUL ISLAND

Semporna District, State of Sabah; non-Act State

Population: 3,900

Table 4.

### SUMMARY OF TOOLBOX ASSESSMENT OF MABUL ISLAND

#### Waste Characteristics

**Solid waste:** 2,340 kg per day

**Plastic waste:** 281 kg per day

**Collected plastic waste:** 197 kg per day—poorly segregated

#### Market Access

- Recycling offtake market in Semporna is absent.
- Possible market in Tawau 1.5 hours away by road but transport would be costly.

#### Technologies/ Solutions

- Plastic waste volumes only support artisanal recycling or eco-bricks.
- Micro-pyrolysis is possible but not economically viable.
- Controlled incineration or controlled landfill could be considered, although space is limited and these options are available on the mainland.

#### Conclusion

- Artisanal and eco-brick recycling for a small fraction of the waste.
- Bulk of the waste disposed by controlled landfill or controlled incineration on the mainland.

Figure 37.  
**LOCAL CARGO BOAT (JUNGKONG) AND WASTE WASHED ON SHORE IN BETWEEN TIDES**



Source: Lasaju

Figure 38.  
**COMMUNITY BURN PILE NEAR ONE OF THE VILLAGES**



Source: Lasaju

Figure 39.  
**GUNNY SACK WITH COMMUNITY WASTE, MABUL ISLAND**



Source: Lasaju; Image: Mabul Island Community

Figure 40.  
**AD-HOC WASTE COLLECTION BINS, MABUL ISLAND**



Source: Lasaju; Image: Mabul Island Community

Figure 41.  
**WHEELIE WASTE BIN DONATED BY BORNEO DIVERS**



Source: Lasaju

Figure 42.  
**PACKAGING WASTE FOUND ON PANGLIMA REEF**



Source: Lasaju

**POM POM ISLAND**

Semporna District, State of Sabah; non-Act State  
 Population: 140

Table 5.  
**SUMMARY OF TOOLBOX ASSESSMENT OF POM POM ISLAND**

**Waste Characteristics**

**Solid waste:** 85 kg per day  
**Plastic waste:** 10 kg per day  
**Collected plastic waste:** 9 kg per day—poorly segregated

**Market Access**

- Recycling offtake market in Semporna is absent.
- Possible market in Tawau 1.5 hours away by road but transport would be costly.

**Technologies/ Solutions**

- Plastic waste volumes only support artisanal recycling or eco-bricks.
- Improvements in the collection process with bins and containers would help with the overall disposal of the mixed waste to the mainland.

**Conclusion**

- Artisanal and eco-brick recycling for a small fraction of the waste.
- Bulk of the waste disposed by controlled landfill or controlled incineration on the mainland.

Figure 43.  
**WASTE WASHED OVER A 12-HOUR PERIOD AT POM POM ISLAND RESORT BEACH FRONT**



Source: Lasaju

Figure 44.  
**UNCOLLECTED WASTE WASHED IN CLOSED PROPERTIES ON POM POM ISLAND**



Source: Lasaju

Figure 45.  
**SHED MADE FROM PET AND FLEXIBLE PLASTICS  
 CONVERTED TO ECOBRICKS AT TRACC**



Source: Lasaju

Figure 46.  
**SEGREGATION AT TRACC**



Source: Lasaju

### MATAKING/TIMBA TIMBA

Semporna District, State of Sabah; non-Act State  
 Population: 163 (just 3 on Timba Timba)

Table 6.  
**SUMMARY OF TOOLBOX ASSESSMENT OF MATAKING/TIMBA TIMBA ISLANDS**

#### Waste Characteristics

**Solid waste: 98 kg per day**  
**Plastic waste: 12 kg per day**  
**Collected plastic waste: 11 kg per day—poorly segregated**

#### Market Access

- Recycling offtake market in Semporna is absent.
- Possible market in Tawau 1.5 hours away but transport would be costly.

#### Technologies/ Solutions

- Plastic waste volumes only support artisanal recycling or eco-bricks.
- Existing technical incineration on island and collection of other waste for export to mainland.

#### Conclusion

- Artisanal and eco-brick recycling for a small fraction of the waste.
- Current waste management system of technical incineration on island and controlled landfill on mainland is effective but the environmental and health impacts of the technical incineration should be evaluated.

Figure 47.  
**SMOKELESS INCINERATOR INSTALLED  
 PRIVATELY AT THE REEF DIVE RESORT**



Source: Lasaju

Figure 48.  
**WASTE READY FOR INCINERATION AT THE REEF  
 DIVE RESORT**



Source: Lasaju

Figure 49.  
COLLECTED WASTE AT  
TIMBA TIMBA ISLAND



Source: Lasaju

Figure 50.  
PET BOTTLE CONVERTED TO CORAL PLANTER AT  
MATAKING ISLAND



Source: Lasaju

### 5.3 ANALYSIS AND CONCLUSIONS FROM THE CASE STUDY ISLANDS IN MALAYSIA

**The five islands studied each present challenges in terms of overall scale of the plastic waste volumes, level of market access and transportation costs, as well as the quality and extent of the existing waste management infrastructure and funding sources.**

- Given the small scale of plastic waste on the islands, available solutions were limited to transport of recyclables/waste to the mainland, artisanal recycling and controlled landfilling, with controlled incineration available in some cases.
- The Peninsular Malaysia islands of Tioman and Perhentian have reasonable access to recycling markets. The focus for these islands is to enable and improve the recycling market access through separation of the materials and compacting, as well as improved logistics and handling
- The absence of market access is a key challenge for the islands in the Semporna District. The focus is on disposal options such as controlled incineration or landfilling.
- In all case studies, the distance to the mainland is relatively short, so in addition to finding disposal solutions on the island itself, the option to utilize

disposal options already available on the mainland should always be considered.

- In all island situations, artisanal recycling solutions and/or Ecobricks would be able to process a portion of the plastic waste, but these solutions cannot treat all of the plastic waste volume.
- If there is a need to dispose of the waste locally on the island, both private sector (e.g., hotels/resorts) as well as local governments often opt for technical or controlled incineration options. Controlled incineration should be prioritized over technical incineration to ensure the exhaust gas treatment is sufficient. The resulting incineration ash must be disposed to a suitable controlled landfill.
- The Act 672 status of an island, as well as the presence of active NGOs, positively affected the funding and effectiveness of the waste management system and, in particular, the collection and separation of plastic.
- Marine litter poses a challenge for the Semporna district islands, particularly seasonal tides and winds that increase the amount of collected island waste. This further impacts the ability of existing informal waste collection on the islands to manage and finance the waste management system.

## CHAPTER 6:

# KEY TAKEAWAYS FOR PLASTIC WASTE MANAGEMENT IN SMALL AND REMOTE ISLANDS

This chapter outlines the key takeaways from the study for island administrators for small and remote islands globally.

## 6.1 APPLICABILITY OF THE FRAMEWORK AND THE TOPIC TOOLBOX

**Only by building an individualized, context-specific understanding of an individual island's waste management system is it possible to design effective solutions to plastic waste.** Each island—in and beyond Malaysia—has specific characteristics determining the most suitable waste management solutions and technologies. This includes elements related to the organizational and financial aspects of the waste management system. Therefore, a qualitative case study is essential to accompany use of the TOPIC Toolbox.

**The TOPIC Toolbox allows for identification of potential technologies and solutions specific to those characteristics that can be quantitatively captured.**

Applying the TOPIC Toolbox to the different types of islands based on quantitative datapoints provides a very simple and intuitive list of technology solutions. For the islands that have been subject to the case studies for this assignment, the application of the TOPIC Toolbox provided a good starting point of options for the island specific case study. As expected, several solutions are already implemented to a certain extent on the case study islands. Importantly, the TOPIC Toolbox helps to rule out technologies and solutions that are not feasible. The TOPIC Toolbox provides a general recommendation as well as notes on key factors that enable and disable application of the respective option in an island context. These findings—synthesized in the respective sheet and laid out in detail in the technology factsheets—have generally proven to provide reliable guidance for the right solutions and technologies.

**The design of the TOPIC Toolbox was informed by the situation on small and remote islands—specifically applied in Malaysia—but its applicability extends beyond.**

As the TOPIC Toolbox has largely been informed by general guidelines to evaluate waste management practices (refer to Section 4.1) and an evaluation of successful practices conducted in islands throughout the world (refer to Chapter 2), its applicability to other microsystems, including remote mainland areas in and beyond Malaysia can be assumed. The main factors narrowing the geographic scope of applicability are the selected technology examples, described in detail in the factsheets on technologies and solutions (refer to the TOPIC Toolbox). These examples have largely been taken from those available on the Malaysian market, but the guiding principles of each technology and solution are applicable beyond Malaysia. Applying the TOPIC Toolbox on other islands

and microsystems in other Southeast Asian countries, for example, and complemented by the qualitative aspects of the framework, will allow the user to identify relevant solutions.

The case studies conducted within Malaysia have generally proven the applicability of the TOPIC Toolbox. Based on these findings, three topics have been identified as of particular relevance: collection, scale and market access. These are determining factors for establishment of a (plastic) waste management system on a small and remote island (or other microsystems)—in Malaysia and beyond.

## 6.2 COMPREHENSIVE PLASTIC WASTE COLLECTION AND SEPARATION

**A comprehensive waste collection and separation system is required to cover a maximum of the available (plastic) waste volumes.** In some cases, mixed waste is collected, in other cases, no clear formal waste management can be identified (i.e., the predominant practice is burying waste or dumping/littering into the terrestrial and marine environment). As a first step towards improved waste management, a system that collects waste needs to be in place. In some regions, this is happening already, particularly in Act 672 states. Depending on the island's context, collection can be largely land-based and then transported off the island from a central waste management center (e.g., in proximity to a jetty). In some cases, the population may be better accessible through waterways, making a centralized waste management center more challenging. As a second step, this system needs to be adapted to allow for better separation of different fractions—as a fundamental prerequisite to distinguish plastic fractions from all other waste. Currently, waste management practices on Malaysian islands barely include waste separation.

**Valuables should be extracted from the waste streams.** The extent market mechanisms can extract these valuables depends on the level of access to places with functioning recyclables markets. Islands can improve extraction of valuables by: (1) separating at source; and (2) by easing logistics and reducing transport costs, such as through a baling machine and related material handling equipment. A small baler operated by trained personnel that commissions material fractions according to their market value can significantly reduce handling and transport costs, allowing for greater cost recovery.

## 6.3 SCALE OF PLASTIC/SOLID WASTE IS CRITICAL FOR TECHNOLOGY DECISIONS

**The absolute scale of the plastic waste and the overall waste volume have a significant impact on the solutions that can be implemented on islands.**

As outlined in Chapter 3 and analyzed in-depth within the TOPIC Toolbox, even incineration (i.e., the last disposal option in the waste management hierarchy) has certain scale requirements to ensure safe disposal by achieving a minimum temperature with adequate exhaust cleaning as well as a disposal concept for solid remnants (ash). The same applies to a controlled landfill where a minimum scale is required to make it viable. In addition, to implement, operate and maintain any responsible disposal solution on an island, a minimum waste quantity and a minimum infrastructure need to be present. Most recycling technologies (i.e., non-artisanal material recycling and chemical recycling) that have been identified in this study require a critical scale that can be characterized as “industrial scale,” which small islands' waste volumes cannot generate. On the other hand, micro-recycling processes may be viable, but are insufficient to cover for all plastic waste volumes and composition regularly occurring in municipal waste.

## 6.4 MARKET ACCESS IS KEY

**Market access is one of the most important factors determining how plastic (and other recyclable) waste is treated on (or off) an island.** If the recyclable material can be transported to the mainland at a reasonable cost, then high value materials such as rigid mono-material plastic should be mobilized and fed into an existing (material) recycling infrastructure, where the materials can be effectively and responsibly processed. Even though an opportunity to create local island-based value chains may not be realized in this case, a full isolation of local value chains from more integrated ones on the mainland is neither feasible from a technical nor economic point of view. Malaysia's waste management system consists of a functional, market-based recycling value chain for common plastic fractions, which should be utilized wherever possible.

**Market price at the mainland collection point is often not high enough to cover the entire cost of collection, segregation and transport.** Currently, communities and NGOs on the islands, along with the waste management operators, directly or indirectly support and subsidize this mobilization through awareness campaigns, volunteering, donations and

transport services. As a result, the high value materials are being mobilized for recycling, partly offsetting some costs associated with waste management on the islands. As mentioned in Section 6.2, baling and material handling technologies may also be able to reduce the costs for segregation and transport.

## 6.5 NO SINGLE TECHNOLOGICAL SOLUTION

**Recycling technologies only provide partial solutions for processing plastic waste and need to be combined with other solutions.** Every technology application that has been analyzed as part of this study requires a narrow or at least defined set of input parameters. Therefore, these solutions must be integrated into a broader waste management framework that incentivizes or requires pre-treatment of waste. Recycling technologies cannot be used to treat all plastic waste and must therefore be combined with other solutions. If the plastic waste cannot be recycled within the island's microsystem or transported to the mainland at an acceptable net cost, but the island has significant enough waste volumes for a local disposal solution, then a controlled landfill or controlled incineration are likely the best disposal options.

- Basic **controlled landfills** can be constructed on islands with adequate space to dispose of waste on site. The technologies applied usually use locally available resources like soil or dust to cover the landfill. For mechanized solutions, a material handling machine can also be used to compact the waste to minimize space requirements and extend the landfill's lifetime.
- Any **controlled incineration** technology solution needs to fit the local context and be robust enough and/or equipped with the relevant pre-treatment to deal with the incoming waste composition. The incinerator should also be equipped with an acceptable level of flue gas treatment and flexible enough to deal with seasonally higher waste volumes. It is also crucial that incineration technology is combined with an effective treatment solution for the solid remnants (ash).

## 6.6 UPSTREAM SOLUTIONS ARE ESSENTIAL

**Sustainably managing plastic on islands requires upstream solutions to reduce the amount of plastic consumed and plastic wasted.** This study has focused on the downstream management of plastic waste and identified that there is not one technological solution available to fix the challenge of plastic waste on islands. It is necessary to develop an integrated waste management system that ensures effective collection and segregation, as well as capitalizes on market access for recyclables, where applicable. However, as identified in the case studies, it is often necessary to use solutions at the bottom of the waste hierarchy, such as landfilling or incineration, to deal with all plastic waste on islands. These solutions can have environmental and social risks associated with them and require significant investment to be developed and operated safely. It is essential that attention is also given to the first step of the waste hierarchy to reduce plastic waste in the first place. Upstream measures can include policies to reduce the import and use of specific problematic plastic items, such as the plastic bag ban introduced in Samoa in 2019<sup>6</sup> or the plastic bag levy in Tonga<sup>7</sup>. It is also possible to implement policies to reduce plastic waste from tourism, for example, all day tourists in Mabalua are required to bring their plastic waste back to the mainland. Any upstream policies must be developed with consideration for the local context and an assessment of the institutional arrangements and political economy.

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6 <https://www.sprep.org/news/samoa-joins-the-fight-against-plastic-pollution>

7 <https://www.sprep.org/sites/default/files/documents/publications/waste-legislation-tonga.pdf>

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## APPENDIX A:

# TREATMENT OF ABANDONED, LOST OR OTHERWISE DISCARDED FISHING GEAR (ALDFG)

## MATERIAL COMPOSITION OF ALDFG

Fishing nets themselves are mainly made of plastic, most commonly Nylon (PA) but they can also be made of polyester (PES), polyethylene (PE) and polypropylene (PP), or a mixture thereof. Additionally, a variety of plastics is also used in the production of other types of fishing gear or components of fishing equipment (e.g., PP or PET for ropes, PE for floating buoys). Non-plastics are also used in the form of wooden trawl boards, cork for buoys, as well as (ferrous) metal chains and sink weights commonly made from non-ferrous lead. In addition to the material mix of the net equipment, other substances usually contribute to heavy contamination of recovered ALDFG—increasingly so with longer duration in the sea. ALDFG may have been located in seawater for decades and might therefore be overgrown, polluted, silted up, possibly contaminated with harmful substances, as well as organic and inorganic material. These impurities not directly connected to the ALDFG's original material composition can account for more than 20 percent of the total weight of recovered ALDFG. The mix of materials and the salinity make it difficult to treat fishing gear, particularly if accumulated over time. The treatment is technically demanding and resource and labor-intensive. Separating the different material fractions is only possible manually—any technological application comes with the additional challenge of the corrosion potential resulting from the salinity [(Stolte, Schneider, 2018, Fraunhofer Institute for Environmental, Safety and Energy Technology UMSICHT (Fraunhofer UMSICHT), 2019)].

## ALDFG RECYCLING

The EU project MARELITT Baltic focuses on the retrieval and collection of ALDFG as well as its processing and utilization. One core objective of the project is to identify and assess feasible methods for proper treatment, including economic and environmental considerations, as one component of the broader aim to minimize harm from ALDFG. Other areas of interest include methods for preventing, tracing and retrieving ALDFG (MARELITT Baltic, 2019). Specifically, the results concerning the recycling methods can be considered generic and applied beyond the area of scope within the Baltic Sea. (WWF 2016)

A recent study (Altvater, Michel 2018) on fishing gear material recycling finds that existing processes almost exclusively recycle end-of-life nets (i.e., nets that have been disposed of), but only very limitedly retrieved ALDFG. Even for the end-of-life gear that has not been recovered from the ocean directly, specifically defined disposal and recycling routes have not been identified. Market available material either consists of negligible fractions from retrieved ALDFG, like PE or PP, or recycled nylon retrieved from the ocean that is used at a rate of 1-10 percent of the end product. Recycled volumes are inflated by measuring the weight of the retrieved ALDFG including moisture contents of up to 40 percent as well as high portions of impurities. Further research within this study has shown that—despite dedicated marketing—the statements concerning actual ALDFG content of recycled materials are not disclosed, which may confirm the findings of Altvater/ Michel (2018) (e.g., for the material “Econyl” (Econyl 2021)).<sup>8</sup> It is assumed that recyclates like “Econyl” are marketed at a premium over virgin material in order to reflect the higher production costs.

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8 The authors clarify that this statement is concerning the content of ‘ALDFG’ within the respective material, not concerning the general content of recycled material. The high share of *recycled material from sources other than retrieved ALDFG* does still support the goals of a circular economy and is ranked accordingly high in the waste hierarchy.

The possibility of using recycled ALDFG depends primarily on the quality of the material. Significant parameters are the degree of contamination and plastic purity. Thus, the viability of any material recycling is directly dependent on the applied pre-treatment steps.

## MATERIAL OR MECHANICAL RECYCLING

Figure A1 shows the five-stage treatment process for ALDFG developed in the MARELITT Baltic project (Fraunhofer UMSICHT 2019). At the beginning, the impurities are removed manually in order to facilitate subsequent processing steps and, in particular, to protect further machinery (shredding units) from excessive wear or clogging. Large metal parts, rocks and other bulky items are removed by hand in the pre-sorting process. In addition to removing organic and mineral impurities, the lead lines are cut out of the nets and the material is cut into smaller pieces. After shredding, a magnetic separator extracts small residual magnetic metal parts that have not been removed by pre-sorting. Note that lead is a non-ferrous material that cannot be removed magnetically.

In the case of thermal disposal or landfill, the net material can be transported directly to the respective site. In order to reduce the corrosion potential for incineration machinery, a reduction of the salt content may be carried out through pre-washing. On the other hand, required pre-treatment to feed in material from ALDFG into the material recycling chain requires a much more complex process setup.

Figure A1.

### PRE-TREATMENT PROCESS FOR ALDFG WITH A VIEW TO MATERIAL RECYCLING



Source: Fraunhofer UMSICHT 2019)

In the case of material recycling, a density separation salt solution for the separation of heavy impurities such as stones, sand, metals and glass follows. A rewash is necessary to reduce the salt load. After density separation, the material is suitable for material recycling processes with less strict input parameters—like sintering and intrusion. A separation of PE and PP from PET and PA is not required, whereas extrusion as a prerequisite for every higher value recycling requires a more homogenous input stream and further treatment steps have to be added.

This starts with swim-sink tanks that are used for density separation. In the first stage, light and heavy materials are separated from each other. Sand, stones and metals, heavy plastics (e.g., PET) all sink, while light(er) plastics such as PE, PP and Nylon float. In the second stage of density separation, the light PE and PP are separated from the heavier Nylon for further separate treatment. As the subsequent step, the shredded material is washed. The fibrous material has to be freed from remaining impurities like sand, salt and organic matter and further broken down, applying friction washers or centrifugal washers. If the aim is re-granulation through extrusion for feeding the recyclates back into the (virgin) plastic value chain, a further grinding step is applied. The processed ALDFG is used to produce a fibrous, fluffy target product at the end of the entire process, which can be fed into an extrusion process.

Nylon is, in small quantities compatible with PS and PET for the extrusion process. Yet it is completely incompatible with PE and PP due to their much lower melting temperatures. PS and PET contaminations can reach up to 5 percent by weight, whereas PE and PP must only be present at marginal rates. This demonstrates that a high degree of pre-treatment does not necessarily lead to success in the targeted recycling of materials. Even after the further processing techniques such as friction or centrifugal separation are carried out, the material still contains impurities (sand) and contaminations (lead). The process trials conducted by the researchers resulted

in knotted, felted and entangled material still containing different polymer types. All these material properties hinder or even prevent recycling by plastic recyclers. Feeding pre-treated ALDFG into other recycling streams (i.e., operational facilities with established input material streams) comes with a high risk of distorting the process.

In conclusion, the following problems have emerged for material recycling of ALDFG:

- High degree of contamination with sediments and organic matter
- High level of contamination with salt, adsorbed pollutants, lead
- The different plastics are difficult to separate from each other after shredding due to strong felting of the fiber material
- Manual sorting of coarse contaminants is time-consuming and cost-intensive, but also needs to be carried out prior to incineration and energy recovery
- The processing of ALDFG is technically cost-intensive, yet successful material recycling is by and large uncertain

ALDFG recycling requires a multi-stage, cost-intensive treatment process which only makes sense if the proceeds from the recycling are very high or if economic aspects are fully taken out of the picture. According to the current state of knowledge, Fraunhofer UMSICHT (2019) does not recommend any high-value material recycling, as the technical and financial expenditure appears to be far too high and thus also ineffective in terms of energy, resources and emissions. Therefore, even applying sophisticated pre-treatment steps, material recycling possibilities for ALDFG are by and large limited to lower-value material recycling processes, including sintering and intrusion.

## FEEDSTOCK OR CHEMICAL RECYCLING

The MARELITT Baltic researchers looked at two different feedstock recycling processes that may be used for the recycling of fishing nets, namely pyrolysis and hydration/ steam reforming. Pyrolysis is by and large ruled out due to the relatively high moisture content of the retrieved ALDFG. A respective moisture content of around 30 percent even after prolonged storage has proven to be incompatible with the process that would tolerate only about 5 percent.

Additional restrictions for productive use within a pyrolysis process are related to salt loads and the contamination level, particularly with lead. Ensuring that these pollutants are separated within the process is required for the usability of the process' products (i.e., pyrolysis oil and flue gas). The flue gas cleaning must be designed accordingly for chlorine and heavy metal loads. Toxic emissions are possible without complex post-washing or post-combustion.

Hydration as a second process option has been considered, as well. Even though certain process parameters allow for a wider input range, particularly concerning the moisture content, other hindrances concerning contamination persist. Even more pronounced than the pyrolysis process, hydration is considered experimental with no setup that closely resembles ALDFG as input material being operational nor successfully trialed.

## INCINERATION

According to internationally common standards (e.g., as stipulated in EU regulations) the unconditional prerequisite for thermal processing is the environmentally compatible disposal of pollutants. In the case of ALDFG in general, this mainly refers to the lead content. A further obstacle to incineration and cause for machine corrosion can be salt load due to ALDFG's prolonged residence in the ocean. Even though disposal concepts like incineration rank lowest in the waste hierarchy, the MARELITT Baltic project found it a more suitable treatment solution than recycling, due to the experienced challenges and the generally unsatisfying outcome from pre-treatment processes (Fraunhofer UMSICHT 2019).

## SUMMARY AND FURTHER RECOMMENDATIONS

The analyses undertaken by Fraunhofer UMSICHT (2019) within the MARELITT Baltic are thorough and the methodology and its results are cohesive. Several key points are noted from Fraunhofer UMSICHT's analysis:

- Feeding recyclates back into the plastic value chain (through extrusion) is barely possible due to contamination, material mixture; intensive pre-treatment is required in any case.
- Pyrolysis is an unproven technology for recycling ALDFG or relevant constituents of ALDFG. Furthermore, the moisture content commonly found in ALDFG is incompatible.
- Hydrolysis (designated here as "steam reformation") is a theoretically suitable but experimental technology for recycling ALDFG or relevant constituents of ALDFG. Furthermore, due to extremely high energy input requirements, the recycling would yield in a high net loss.
- Incineration as a disposal process may be feasible but comes with challenges concerning the corrosion of the machinery as well as the high pollution potential from lead content.
- The only feasible recovery path for relevant quantities of ALDFG consists of sintering or intrusion (designated as "downcycling").
- Landfilling as a disposal process is not mentioned. This study considers it feasible in a sanitary landfill context due to controllable pollution levels with limited potential for harmful emissions into the environment.

This study has assumed findings from the Baltic Sea as representative for ALDFG and generally applicable to other parts of the world, including Malaysia.

## OPTIONS TO INCENTIVIZE RETRIEVAL OF ALDFG

### Financial Incentives for Retrieval

Since ALDFG is, as outlined, only recyclable to a very limited extent, there is no incentive to create added value. Even a free delivery and transfer of ALDFG to the recycling facilities on the mainland may be insufficient for uptake of the material within the recycling value chain.

A remuneration to fisherfolk to recover their gear may cause motivation for minimizing the loss of fishing gear. Different modalities like a deposit refund system, a specifically designed extended producer responsibility scheme or net contributions from available waste management budgets may be applied, likely a combination of them. If this recovery fee is further based on purity and material quality, additional revenue can be increased by removing any impurities from the net and cleaning it beforehand.

The deposit and return system could work as follows: When a fishing net is purchased, a registration number is assigned so that the net can be attributed to its owner. The buyer pays the deposit when buying the net, which is refunded when returning the net at the end of its useable lifetime or credited to the purchase of a new net. The amount of the deposit should depend on the price and size of the net material and be within the range of 10 to 20 percent of the grid price. A deposit and return system could be implemented, similar to systems for returnable bottles, operational in many European countries as well as the Pacific states of Tuvalu, Kiribati and parts of Micronesia. When fishing equipment is purchased, an additional, tangible amount is added to the purchase price. In order to make this system viable, a lot of details like registration, regional or nationwide take-back points, fraud avoidance mechanisms and so forth need to be taken into consideration.

The motivation of the existing recycling (or disposal) value chain to accept heavily polluted retrieved ALDFG may therefore have to be guaranteed by a compensation payment covering the associated (extra) costs of processing. The general mechanisms are common and viable in waste management frameworks that include extended producer responsibility (EPR) elements. Yet, EPR for fishing gear is a novel approach and requires detailed feasibility analyses and a robust conceptualization. The European Commission is currently working on a new EU directive<sup>55</sup> to reduce marine waste. At the heart of the proposed legislation is EPR, which means that manufacturers of fishing equipment bear the costs for management of associated waste, costs

for cleaning, recycling and disposal. As a farther-reaching approach, also the costs for the retrieval of ALDFG can be covered within this system.

### Design-for-Recycling





Fishing gear equipment consists of a mixture of different plastic and non-plastic material fractions. While the net material is usually nylon (polyamide PA), lines and ropes are made from PET or PP, with adjoining equipment like floats and buoys commonly made of PE. Nevertheless, certain components may even consist of a composition of different plastic materials that cannot be separated applying mechanical or manual processes. Yet, detangling and separating these components is a prerequisite for value extraction through recycling. Additionally, specifically lead weights distort any recycling process, even reducing the viability for disposal processes if they cannot be separated from the nets themselves.

In order to allow for better recycling processes, different product design may play a significant role for better waste management of ALDFG. As far as technically possible, single-plastic solutions are preferred options. Different plastics should only be used as separated and separable components of fishing equipment. Lead may be replaced by other metals or stone.

## APPENDIX B:

# COMPARISON OF COMMON THERMOFORM PROPERTIES

See Table on the following page.

Type of plastic	Polyethylene Terephthalate (PET)	Polyethylene (PE)	Polypropylene (PP)	Polystyrene (PS)
Recycling code				
Formula	C <sub>10</sub> H <sub>8</sub> O <sub>4</sub>	C <sub>2</sub> H <sub>4</sub>	C <sub>3</sub> H <sub>6</sub>	C <sub>8</sub> H <sub>8</sub>
Density	1.3 g/cm <sup>3</sup>	0.91 – 0.93 g/cm <sup>3</sup> LD 0.94 – 0.97 g/cm <sup>3</sup> HD	0.9 – 0.91 g/cm <sup>3</sup>	1.05 – 1.06 g/cm <sup>3</sup>
Melting point	260 °C	105 – 135 °C	160 – 170 °C	240 – 270 °C
Characteristics	<p><i>Positive:</i></p> <ul style="list-style-type: none"> <li>high service temperatures</li> <li>good electrical properties</li> <li>good weathering resistance (UV light)</li> </ul> <p><i>Negative:</i></p> <ul style="list-style-type: none"> <li>hot water degradation (&gt; 80 °C)</li> <li>low resistance to strong acids, alkalis, oxidizing agents, alcohols (without blending/ coating)</li> </ul>	<p>Similar to PP</p> <p><i>Positive:</i></p> <ul style="list-style-type: none"> <li>high chemical resistance</li> <li>high elasticity</li> <li>easy to dye</li> </ul> <p><i>Negative:</i></p> <ul style="list-style-type: none"> <li>Unsuitable for temperatures &gt; 80 °C</li> <li>stiffness</li> <li>brittle/ low tensile strength</li> </ul>	<p>Similar to PE</p> <p><i>Positive:</i></p> <ul style="list-style-type: none"> <li>high chemical resistance</li> <li>fatigue strength</li> </ul> <p><i>Negative:</i></p> <ul style="list-style-type: none"> <li>brittle at low temperatures</li> <li>low UV-resistance</li> <li>low scratch resistance</li> </ul>	<p><i>Positive:</i></p> <ul style="list-style-type: none"> <li>high transparency</li> <li>high hardness</li> <li>surface gloss</li> </ul> <p><i>Negative:</i></p> <ul style="list-style-type: none"> <li>brittle</li> <li>outdoor yellowing</li> <li>low chemical resistance</li> </ul>
Common application for SUPs	<p><i>Mono-material:</i></p> <p>Beverage bottles, non-beverage bottles, films</p> <p><i>Compound (e.g., PET coated with PE):</i> trays for fruits/vegetables/ meat; bottles with acidic content, films/ foils</p>	<p><i>HDPE:</i></p> <p>Bottles, jars, tubes, caps, carrier bags</p> <p><i>LDPE:</i></p> <p>Films/ foils, carrier bags, waste bin bags, coating of other plastics</p>	Bottles, jars, tubes, trays, caps, films/ foils, cutlery	<p><i>Non-expanded:</i></p> <p>Egg trays, cups (e.g., for yoghurt), cutlery</p> <p><i>Expanded (EPS):</i></p> <p>Shock-absorbing packaging, meat dishes, to-go-cups/plates/ trays</p>
Potential recycling options	<p>Incompatible with PE, PP for material recycling</p> <p>Material/mechanical recycling path for mono material PET fraction is well-established</p> <p>Feedstock/chemical recycling only experimental</p> <p>Additional difficulties for PET pyrolysis due to chemical degradation of output product through terephthalic acid</p>	<p>Incompatible with PET, PS for material recycling</p> <p>Material/mechanical recycling path for mono material HDPE fraction is established</p> <p>Material/mechanical recycling path for mono material LDPE fraction is established</p> <p>Material/mechanical recycling path for mixed PE/ PP fraction is established</p> <p>Feedstock/chemical recycling only experimental</p>	<p>Incompatible with PET, PS for material/ mechanical recycling</p> <p>Material/mechanical recycling path for mono material PP fraction is established</p> <p>Material/mechanical recycling path for mixed PE/ PP is established</p> <p>Feedstock/chemical recycling only experimental</p>	<p>Incompatible with PE, PP for material / mechanical recycling</p> <p>EPS recycling path only experimental</p> <p>Material/mechanical recycling path for mono material PS (i.e., not expanded) fraction is established</p> <p>Feedstock/chemical recycling only experimental</p>
Common recycling applications	<p>Recyclates for similar applications as virgin material</p> <p>Food-contact possible in case of high-purity input, e.g., bottles, trays</p> <p>Recyclates often recycled into yarn/ textiles</p>	<p>Recyclates for similar applications as virgin material</p> <p>No food-contact, e.g., officeware, buckets, flower pots, etc.</p> <p>Downcycling into products like park benches, barks, fences, etc.</p>	<p>Recyclates for similar applications as virgin material</p> <p>No food-contact, e.g., officeware, buckets, flower pots, etc.</p> <p>Downcycling into products like park benches, barks, fences, etc.</p>	<p>Recyclates for similar applications as virgin material</p> <p>No food-contact, e.g., officeware</p> <p>Usage of waste EPS, e.g., for insulation</p> <p>Reuse of shock absorbing elements is common</p>

Source: cyclos

# APPENDIX C:

## MALAYSIA ISLAND CASE STUDIES

### PENINSULAR ISLANDS

#### Tioman

##### Detailed description of existing waste management system

The Tioman island population consists of six villages, the largest and most populated in Kampung Tekek on the Western coast. Juara on the east coast is connected with Tekek through road and Kampong Air Batang (ABC) is connected through a small path accessible by tricycle. Other villages like Salang, Mukut and Paya and individual resorts can only be reached by boat.

Since the State of Pahang has adopted Act 672, solid waste management in the State is governed by SW Corp, and solid waste management (and public cleansing) is carried out by the regional concessionaire Alam Flora Sdn Bhd, who has also been appointed to manage the solid waste on Tioman. As a result, the waste collection rate in Tioman is very high.

For villages with road connection, the collection of the mixed waste is done by a small compactor truck (Tekek) or pick-up truck (Juara) in a combination of door-to-door collection and collection from communal drop-off points. For villages without road connection, the waste is transported by boat (e.g., from Kampung Salang, Paya, Mukut) and by tricycle from Kampung ABC.

Being an Act 672 State, the waste management concessionaire and the residents are obliged to practice separation at source. Similar to other areas in Malaysia, separation at source is not comprehensively practiced. However, a combination of local and international NGOs have worked on different initiatives to reduce the overall use of single-use plastic, foster separation at source and maximize the recycling rate.

Thus, a dual collection system has developed with the waste management concessionaire focusing on mixed waste and OCC, while the NGO and community led recycling collection focuses on mixed plastic, aluminum and glass. These collection systems demonstrate a stark difference.

On the one hand, the mixed waste management is very well organized and focused on increasing the overall collection coverage. The approach is very capital intensive (i.e., being equipped with all the relevant transport options ranging from small compactor trucks, RORO-trucks, pick-up truck and tricycles as well as a well-sized depot). On the other hand, the recycling initiatives have been implemented on a shoe-string budget with creative and low-cost collection solutions combined with intensive engagement of the local communities.

Simple “technologies” such as separated bins, information boards and communal collection sites help to increase the separation at source. Once the materials are separated, these initiatives try to maximize the processing of the recyclable materials on the island and for local use across all the waste streams.

- **Organic waste:** Some composting initiatives try to reduce the amount of organic waste. In addition, multiple households still have their own chickens who are being fed some of the organic waste.
- **Plastic:** Small artisanal injection molding is already being used on the island for suitable polyethylene feedstock (e.g., colored HDPE bottle caps) to create artisanal plastic items such as turtle shaped pendants for necklaces. These are sold to tourists and are used to create awareness for turtle and other marine live conservation. However, only a minimal amount of the island-based plastic waste can be processed locally this way.
- **OCC:** Paper grades, especially OCC, are collected mainly in Tekek for recycling. The waste management concessionaire and local shops have developed a bi-weekly collection routine. Most of the OCC is generated on the days when the transport boat arrives and delivers new packaged goods. At the end of these days, the shops, restaurants and residents in Tekek are encouraged to place OCC next to the normal collection bin and the waste management company will operate a separate collection round with

a RORO-truck to collect these materials. However, in other parts of the island, OCC is commonly burned with garden and other waste.

- **Glass:** Glass bottles collected by NGOs and local communities are ground into sand that can be used as a construction material especially for reef rehabilitation.
- **ALDFG** retrieved from the ocean is partly processed into artisanal items. However, the remaining share cannot be recycled mechanically and has to be disposed of.

An informal sector does not exist because the value of the recycling materials does not cover the cost of collection and transport back to the mainland. Only in the case of aluminum cans is the inherent value high enough to cover the cost of collection, aggregation and transport.

The disposal of the residual mixed household and commercial waste is managed by a separate contractor who operates the local incinerator on a three-year contract. However, the operation of the incinerator has caused significant problems over the past years, most likely due to the waste composition of the residual waste. The exact root cause of the problems is not well understood, but it was not possible to schedule an interview with the operator of the incinerator.

Large scrap metal items and most of the waste from public cleansing is stored at the local Alam Flora depot to be transported off the island with a large cargo barge and to be disposed of at the mainland.

### **Summary of results for Tioman**

Applying the TOPIC Toolbox, solutions and technologies that are within range for application in Tioman island include bins and containers, MRF, baler, artisanal recycling, 'Eco-Bricks', micro pyrolysis, controlled incineration and sanitary landfill.

Tioman already has an incinerator for the disposal of the plastic waste on the island. However, based on the above analysis, improved handling and logistics would allow the island to send more recyclable materials to the mainland recycling market where it would be mechanically recycled in commercial scale facilities. This processing option ranks much higher in the waste management hierarchy and would be the recommended option based on the application of the TOPIC Toolbox for Tioman.

## **Perhentian**

### **Detailed description of existing waste management system**

The Perhentian Islands are part of the Terengganu State and the islands do not fall under the regulation of Act 672. As a result, the solid waste management activities are managed by the Local Authority (i.e., the Besut District Council is responsible for waste collection and public cleansing). The Besut District Council outsources the waste management via tender to local contractors for a two-year period. The contractor has the responsibility for public cleansing at the Besut Jetty and to collect the waste from the Perhentian Islands, and is reimbursed for these services by the Besut District Council. There is no door-to-door collection on the island.

In addition, the same contractor also collects solid waste from commercial entities (e.g., hotels, resorts, restaurants) on the island, who have to pay the contractor directly for these services. However, commercial customers are not obliged to use the waste management contractor and—at least in one case—a larger resort manages the waste collection and transport themselves. An informal sector does not exist. However, there are several regular volunteer programs that try to tackle plastic waste pollution such as regular beach clean-ups, communal work and educational programs at school for recycling practices.

The actual collection process is done by a larger collection boat with a capacity of around 5 tonnes. This collection boat does a milk run along the island, stopping at the relevant collection points such as Coral Bay, Long Beach, Kampung Nelayan (three collection points) and various resorts. Smaller boats (sampans) transport the waste in bags to the collection boat. In addition, there are six local women employed by the contractor for public cleansing and to clean garden waste around the village. They also help to compile the household waste at the collection point before it is put onto the waste collection boat. As door-to-door collection is not practiced on the island, all locals need to send their waste to the collection points. The "Rumah Sampah"

planned to be utilized as a collection center for the mixed waste is mainly used as storage facility for tools, while both the mixed waste and metal scraps pile up around the Rumah Sampah. Households that do not send their waste to these collection points tend to burn the waste in their backyards.

The current collection method is a significant improvement compared to the previous practice of depositing the waste in a floating pontoon off the coast of the island where it would be picked up by the collection board because the pontoon had a higher risk of waste leaking into the ocean.

So far, the recycling activities on the island are very limited. Most of the recycling initiatives are fostered by NGOs (e.g., Perhentian Marine Research Station (PMRS) jointly with other NGOs has carried out multiple initiatives to tackle the plastic waste pollution on the island). In 2019, PMRS started to introduce recycling activities among the local community encouraging locals to do separation at source by and providing colored plastic bags to segregate recyclables materials. The recyclable materials were collected and sent to Besut (mainland) to the local recycling company with a local transport boat. All the recyclable materials such as mixed waste, aluminum cans and papers were packed in jumbo bags provided by the recycling center at a one-off fee of RM20 per jumbo bag.

The transportation cost ranged between RM400 to RM800 per trip without weight limit. However, the space on the boat is limited to approximately eight jumbo bags. Part of the transport cost was covered by the revenue from the recycling materials and the balance was subsidized by PMRS. However, this practice stopped due to COVID-19 and due to the need to subsidize the transport.

In addition, educational recycling activities have been carried out at the school by Fuze-Ecoteers and PMRS to encourage young generations to start recycling materials at home.

Lastly, some hotels also separate plastic bottles and pack them in separate and labelled plastic bags for the waste management contractor to aggregate them further. In the past, the collection boat operator used to separate and aggregate these bags. Alternatively, some of the non-sorted materials might be recovered by the informal sector and waste pickers at the landfill.

The overall boat collection caters mainly for mixed household waste, which is collected at the collection point and sent via small boats to the large waste collection boats waiting at each collection points. Not all waste types are accepted, especially garden waste which is sometimes rejected as the capacity of the barge boat is limited. However, garden waste is often also burnt by the locals either at the collection points or every house.

Bulky scrap metal items, construction waste and e-waste accumulate at the Rumah Sampah. The collection of these materials happens once a year depending on the volumes of the waste. The waste will pile up at the collection point over the course of the year.

Some of the plastics waste on the islands, such as HDPE, PET bottle and plastic straws, were used by Fuze-Ecoteers and PMRS for their artisanal projects that turns waste into souvenirs. However, the plastic volume collected for that purpose is relatively low.

On the mainland, the waste is sent to the Paya Rawa landfill in Kampung Raja (i.e., a non-sanitary landfill).

### **Summary of results for Perhentian**

Applying the TOPIC Toolbox, solutions and technologies that are within range for application in Perhentian island include bins and containers, MRF, baler, artisanal recycling, 'Eco-Bricks', micro-pyrolysis and sanitary landfill.

The plastic waste volume on Perhentian Island is too small to support any commercial scale mechanical processing solutions. Based on the TOPIC Toolbox results and the island analysis the best option seems to be the improvement of the handling and logistics to enhance market access and feed the recycling materials into the mainland recycling market.

Based on the qualitative island analysis, a few prerequisites are necessary. Firstly, this approach would require a better separation at source and collection mechanism on Perhentian Island itself. Secondly, the recycling materials would need to be compacted and stored on the island until sufficient material is available for one

boat load. Based on these two steps, the cost of transport and logistics could be reduced significantly to ensure long-term market access for the recycling materials. However, as in the Tioman case, such a solution would require upfront capital expenditures into local collection, storage and compacting solutions.

## SEMPORNA ISLANDS

### Context within Semporna District Council

Semporna District Council/ *Majlis Daerah Semporna* has jurisdiction over the case study islands of Mabul, Pom Pom, Matakang and Timba Timba. As Sabah is a Non-Act State and Act 672 does not apply in Sabah, the district council has responsibility over the collection of municipal solid waste. This includes collection of waste that is transported from the surrounding islands to the three jetties in Semporna.

In contrast to Tioman and Perhentian, which both have market access to a mainland recycling market, these islands face a different situation with very limited access to recycling markets and also limited support from the local government authority for island-based waste collection. This reduces the options available for recyclable plastic waste from the islands.

According to Semporna District Council, most plastics collected as marine litter (usually from beach clean-ups as well as directly retrieved from the sea) are rigid bottles, with little ALDFG retrieved. The district council estimates a collection between 10 to 20 kg of plastics from marine litter a day.

The district council currently operates an "Asher" unit of Pamarai Corp as a controlled incineration solution in managing part of the local waste. However, not all municipal waste is handled by the Asher, with a portion being sent to the municipal landfill. Waste sent to the Asher is segregated prior to disposal. There is limited off-take for recyclables, with a limited market for recyclables in the immediate Semporna area. Tawau, a town 1.5 hours to the west, is the next largest town with potential market for recyclables off-take.

Figure C1.

### ASHER FACILITY IN SEMPORNA



Source: Lasaju)

While the district council charges a fee of RM70 per room per month to licensed hotel and tourism operations on the islands, the provision for municipal services related to waste management is only done from the mainland collection points onwards, and not directly on the islands. It is unclear if island waste collected by the district council is sent to the Asher or directly to the landfill.

## Mabul

### Detailed description of existing waste management system

There is no waste collection concessionaire and municipal solid waste collection is the responsibility Semporna District Council, a Local Government Authority under the Ministry of Local Government and Housing, Sabah.

Households on the island of Mabul do not have an effective formalized waste collection structure. The village committee requires all households to manage and dispose of their waste properly and responsibly to maintain the island's general cleanliness. Household waste is collected communally and transported by the villages to the mainland in boats for disposal by Semporna District Council. However, it was observed that a degree of waste, including plastic waste, is disposed of into the surrounding sea or burned in communal piles.

A basic collection and separation infrastructure has been put in place in a collaboration between the community and two tour operators—Scuba Junkies and Borneo Divers. Collection is done through communal collection, with bins and collection points provided in designated areas to help with segregation. Weekly village and beach cleanings are done, with more cleanings done subject to the availability of volunteers from the two tour operators. Waste collected by the two tour operators is sent to the mainland at their own cost, utilizing their tour boats on return trips or with their supply ships.

Marine litter is a major source of waste collected on the island, with little being upcycled. A majority of the plastics from marine litter are PET bottles, flexibles or food packaging waste. Few fishing nets or lines have been observed.

Resorts and tour operators on the island collect their waste for disposal on the mainland. Waste from resorts and operators are transported from the island using their own boats and are collected in waste bags. Waste from tourism-related activities is reported to double the amount of waste generated by households, especially during holiday seasons or travel periods.

The collected waste from the island is transported to the mainland at an approximate cost of RM600 per return trip on a local cargo boat or 'jungkong.' Collected waste is then handled and disposed of by Semporna District Council.

The islanders do not pay any form of assessment tax. However, as they deposit their waste in designated waste collection spots on the island or are assisted by the two tour operators in transporting their waste out, the Semporna District Council indirectly collects and dispose household waste together with commercial waste.

### Summary of results for Mabul

Applying the TOPIC Toolbox, solutions and technologies that are within range for application in Mabul island include bins and containers, MRF, baler, artisanal recycling, 'Eco-Bricks', micro-pyrolysis, controlled incineration and sanitary landfill.

The plastic waste volumes on Mabul are small compared to the requirements of commercial scale mechanical processing solutions. The current waste management system is ad-hoc in nature, with handling and logistics of waste from the island to the mainland limited.

Combining the suggestions from the TOPIC Toolbox with the island observations the main solutions for the plastic waste would be artisanal and eco-brick recycling for a small fraction of the waste. The bulk of the waste would need to be disposed either by technical incineration on the island, controlled landfill on the island or the mainland, or controlled incineration on the mainland itself.

Given the limited space on the island and the concerns highlighted in the TOPIC Toolbox about technical incineration, the transport of the waste to the mainland seems to be the most suitable option. On the mainland, both the existing landfill and a controlled incineration facility are available as disposal options.

In the long-term it would be preferable to have a more advanced recycling industry in Sabah that can create a viable off-take market for recyclable materials. However, such a solution would require a more comprehensive analysis and policy interventions for the whole of Sabah, which is not part of the project scope.

## Pom Pom

### Detailed description of existing waste management system

There is no waste collection concessionaire and municipal solid waste collection is the responsibility Semporna District Council, a Local Government Authority under the Ministry of Local Government and Housing, Sabah.

A basic collection and separation infrastructure has been put in place in by the individual resorts and General Operations Force (GOF) battalion. Weekly beach cleanings are done by the Pom Pom Island Resort, which has the largest beach front property on the island, or by the Tropical Research and Conservation Center (TRACC), with more cleanings done subject to the availability of staff from Pom Pom Island Resort landscaping department during peak season and volunteers from TRACC. Waste collected by the resorts and TRACC is sent to the mainland at their own cost, utilizing their tour boats on return trips or with their supply ships in the case of TRACC, or by the regular supply boats returning to the mainland in the case of the resorts and GOF.

Like Mabul, marine litter is a major source of waste collected on the island, with little being upcycled. A majority of the marine litter is PET bottles, flexibles or food packaging waste. Few fishing nets or lines have been observed. TRACC upcycles collected PET bottles and flexibles into ecobricks and glass bottles as “windows” in some of their facilities.

Waste from tourism-related activities is reported to double during holiday seasons or travel periods. Waste from day-trip tourism activities is handled privately by tour operators, with a “nothing left behind” policy, with all waste returning to the mainland. During periods of high tides, strong winds and prevailing currents, the volume of marine litter on the beach can double, especially between September and November.

The collected waste from the island is transported to the mainland at an approximate cost of RM200 per return trip for TRACC. Collected waste from the resorts, TRACC and GOF battalion is then handled and disposed of by Semporna District Council. As there is no village community on or close to the island, there is no informal sector conducting material waste picking.

### Summary of results for Pom Pom

Applying the TOPIC Toolbox, the solutions and technologies that are within range for application in Pom Pom Island include bins and containers, artisanal recycling, “Eco-Bricks” and controlled landfill.

As with Mabul, the plastic waste volumes on Pom Pom are very small compared to the requirements of commercial scale mechanical processing solutions. The current waste management system as conducted by the private properties on the island are effective at managing waste generated on the island and in collecting marine litter.

Combining the output of the TOPIC Toolbox with the island analysis, the main technology options are the same as for Mabul (i.e., artisanal and eco-brick recycling could process a small fraction of the waste for awareness purposes). The bulk of the waste would need to be disposed either by technical incineration on the island, controlled landfill or controlled incineration on the mainland itself.

Given the limited space on the island and the concerns highlighted in the TOPIC Toolbox about technical incineration, the transport of the waste to the mainland seems to be the most suitable option. On the mainland, both the existing landfill and a controlled incineration facility are available as disposal options.

In the long-term it would be preferable to have a more advanced recycling industry in Sabah that can create a viable off-take market for recyclable materials. However, such a solution would require a more comprehensive analysis and policy interventions for the whole of Sabah, which is not part of the project scope.

## Mataking & Timba-Timba

### Detailed description of existing waste management system

There is no waste collection concessionaire and municipal solid waste collection is the responsibility Semporna District Council, a Local Government Authority under the Ministry of Local Government and Housing, Sabah.

A basic collection and separation infrastructure has been put in place in by the resort, facility operator and GOF battalion. Weekly beach cleansings are done by the landscaping team of The Reef Dive Resort, which is the only property on the Mataking Island, or twice daily by the groundskeepers of Timba Timba Island. Collected waste is either sent to the mainland on scheduled cargo supply trips, sent to the on-site technical incinerator in Mataking or sent to the mainland on monthly supply rounds in the case of the Timba Timba.

Like Mabul and Pom Pom, marine litter is a major source of waste collected on both islands, with little being upcycled. A majority of the marine litter is PET bottles, flexibles or food packaging waste. The Reef Dive Resort either disposes of collected waste, excluding food and organics, into their smokeless incinerator or transforms the collected PET bottles into coral planters.

Waste from tourism-related activities is reported to double during holiday seasons or travel periods. Waste from day-trip tourism activities is handled privately by tour operators, with a “nothing left behind” policy, and all waste returning to the mainland. During periods of high tides, strong winds and prevailing currents, the volume of marine litter on the beach can double, especially between September and November. A portion of the marine litter collected was noted to be transboundary waste from the Philippines or Indonesia, based on the packaging details.

Collected waste from Mataking and Timba Timba is handled and disposed of by Semporna District Council. As there is no village community on or close to the island, there is no informal sector conducting material waste picking.

### Summary of results for Mataking and Timba Timba

Applying the TOPIC Toolbox, the solutions and technologies that are within range for application in Mataking and Timba Timba islands include bins and containers, artisanal recycling, “Eco-Bricks” and controlled landfill.

The plastic waste volumes on both Mataking and Timba Timba are very small compared to the requirements of commercial scale mechanical processing solutions. The current waste management system as conducted by the private properties on the island are effective at managing waste generated on the island, and in collecting marine litter.

The TOPIC Toolbox suggestions combined with the analysis of the island and limited market access leaves mainly controlled incineration (as opposed to technical incineration currently done on the island) or controlled landfilling (on the mainland) as the main available options. Small scale artisanal and eco-brick recycling practices could always process a fraction of the plastic materials for awareness purposes.



**PROBLUE**



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