COCOS (KEELING) ISLANDS PLASTIC RECYCLING ASSESSMENT 2021

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Executive Summary
This report, commissioned by the Indian Ocean Territories (IOTs) Regional Development Organisation (RDO) and the Shire of the Cocos Keeling Islands (CKIs), outlines the challenges inherent to managing plastic debris (≥5mm) washed ashore within the IOTs from offshore sources. The problem of plastic pollution is complex, plastic being a term encompassing a range of materials with diverse properties and waste treatment needs. This report will present a tool the Shire can use to appraise the viability of competing plastic management options proposed by the private sector and enable the Shire to design their own plastic management strategy.

A study in 2019 estimated that (at that time) 238 tonnes of plastic existed on the beaches of the CKIs. Current protocol for managing any debris that is collected is to incinerate, however, it has been acknowledged that this practice is not economically or environmentally sustainable. Based on the specific logistical challenges for remote islands, this report has identified mechanical recycling (sorting, shredding, cleaning, remoulding), export of valuable ocean plastics ($1-$10/kg), and catalytic pyrolysis as potential pathways for the management of offshore plastics arriving in the CKIs. Steps that need to be considered for a plastic management plan include:

1. Refusing and reducing domestic plastic use in line with Western Australia's Plan for Plastics (WA DWER, 2020), which is among the most progressive in the country, and CKIs potential long term plastic free goal.
2. Collecting and sorting both ocean plastics and domestic plastics.
3. Cleaning sorted plastic materials.
4. Recycling and creating new products
5. Utilising recycled products on island or exporting valuable plastic materials.

The IOTs are eligible to become a part of a new internationally recognised plastic credit system through The 3R Initiative, which could offset some of this cost. This system allows companies to mitigate the impact of plastic waste that remains beyond their control by paying for the collection and recycling of plastics in communities like the IOTs, which are inundated by offshore marine plastics (Guidelines for Corporate Plastic Stewardship, 2021). By incorporating recycling methods, plastic credits, community education programs, and sustainability practices, the Shire of the Cocos (Keeling) Islands can leverage the value of ocean plastics to create a once again pristine island system.

The University of Western Australia, where this Report was written, acknowledges that its campus is situated on Noongar land, and that Noongar people remain the spiritual and cultural custodians of their land, and continue to practice their values, languages, beliefs and knowledge.

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GLOSSARY & ABBREVIATIONS

CDI scheme	Container deposit incentive scheme
Chemical Recycling	The process of turning plastic polymers into monomers through the application heat, pressure, depleted oxygen, catalysts, and/or solvents
Consumption	Total plastic use by a specified industrial and domestic users
CKIs	Cocos (Keeling) Islands
CRC	Community resource centre
Domestic Plastics	Plastic items consumed by residents and visitors of the Indian Ocean Territories (municipal waste)
WA DWER	Western Australia Department of Water and Environmental Regulations
Energy recovery	Combustion of plastic waste to create heat used for steam production, then applied in energy generation (turbines) or for industrial processes
HDPE	High density polyethylene (RIC #2)
Incineration	Burning of waste materials. Not considered 'energy 'recovery' because most potential energy is lost in this process.
Incoming Plastics	Plastic debris arriving on IOT beaches from offshore sources
IOTs	Indian Ocean Territories
LDPE	Low density polyethylene (RIC #4)
Macroplastics	Plastic items >5mm
Mechanical Recycling	Sorting plastic polymers then washing, shredding, and melting to create new plastic products
Microplastics	Plastic particles <5mm
OI	Ocean's Institute, University of Western Australia
PET	Polyethylene terephthalate (RIC #1)
Post-consumer domestic	Used plastic materials generated within a household
PP	Polypropylene (RIC #5)
PS	Polystyrene (RIC #6)
PVC	Poly-vinyl chloride (RIC #3)
Recycling	The process of turning waste into a re-usable material
RIC	Resin Identification Code. Identifies the plastic polymer by a number stamped into the plastic product to facilitate sorting
SOCKI	The Shire of the Cocos (Keeling) Islands
UWA	The University of Western Australia
WA	Western Australia
WARRRL	Western Australia Reduce Reuse Recycle Ltd. The corporation overseeing the WA container deposit incentive scheme

(1) MARINE PLASTIC POLLUTION
WITHIN THE INDIAN OCEAN TERRITORIES

(1) MARINE PLASTIC POLLUTION WITHIN THE INDIAN OCEAN TERRITORIES

1.1 LOCATION

The Indian Ocean Territories consist of two territories: the Cocos (Keeling) Islands (CKIs) and Christmas Island (CI) with populations of 550 and 2,072 respectively (2016 Census). Both territories are situated in the Indian Ocean northwest of the Australian north-west shelf (CKIs: >2,200 km; CI: >1,500 km) and south of Indonesia.

Remote island groups, like the IOTs, face immediate pressures of climate change and increased anthropogenic pollution due to global population growth. Specifically, as plastics become more frequently consumed by populations in Southeast Asia and Australia, marine plastic pollution has become a major concern for the Indian Ocean Territories. This report will focus on plastic debris in the CKIs with the intention of using its approach and content to address plastic management strategies for Christmas Island. The CKIs are low lying with the highest point on South Island at 9 m above sea level. The islands have a total land area of ~14 km^2 and 26 km of coastline, which mostly consists of gently sloping beaches composed of sand, shell and coral rubble with more exposed locations having steeper beach faces composed of large coral fragments and small to medium boulders.

1.2 PLASTICS FROM OFFSHORE SOURCES

The location of the CKIs is in the path of the Indonesian Throughflow (ITF) current where oceanic waters are transported from the Pacific to the Indian Ocean. The ITF current collects plastic debris from the rivers and seas of Indonesia and transports them to the IOTs (Schott et al., 2009). The most recent comprehensive assessment of plastic accumulation on the Cocos (Keeling) Islands estimated a minimum of 238 tonnes of plastic debris washing ashore in the island group and accumulating over time (Lavers *et al.,* 2019). A 2020 particle tracking model shows that 100% of beached plastics arriving in the IOTs come from river sources in the Southern Hemisphere Indian Ocean (SIO), specifically from Indonesia (Fig.1) (van der Mheen *et al.,* 2020). A small fraction of the 238 tonne estimate of beach debris is generated within the IOTs.

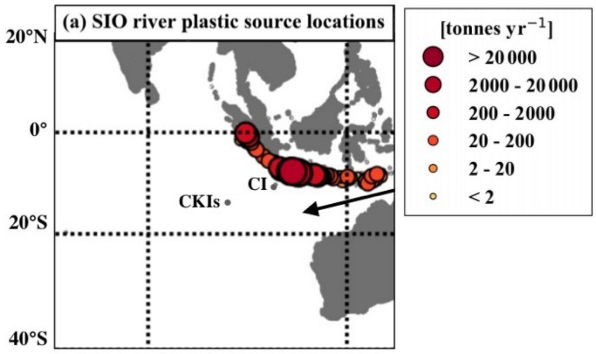


Figure 1 (van der Mheen et al., 2020) Tonnes of plastics entering oceans annually from Southern Hemisphere Indian Ocean (SIO) rivers. Individual rivers that feed into currents like the Indonesian Throughflow (ITF shown with black arrow) directed to the IOTs have individual contributions of up to 20,000 tonnes per year.

1.3 ENVIRONMENTAL AND HEALTH RISKS OF PLASTIC POLLUTION IN THE IOTs

Environmental Risks

Plastic debris in the IOTs has been recorded in marine, intertidal, and terrestrial environments, which threaten organisms associated with these habitats. Iconic species of the IOTs that are vulnerable to entanglement and or plastic ingestion include: seabirds, marine mammals, sea turtles, fish, and invertebrate species (Kühn & van Franeker, 2020).

Human health implications
Biphenol-A and phthalates in plastics have been linked to human health concerns, specifically in children and pregnant women. Although waste incineration is an effective waste removal method, it is known to produce carcinogenic chemicals which can affect reproduction, the endocrine system, behaviour, and neural function in humans and animals (Halden, 2010; Kodavanti & Loganathan, 2017). Further research is needed to explore specific environmental and human health effects of plastic use, exposure, and incineration specific to the Cocos (Keeling) Islands and Christmas Island.

1.4 IOT SPECIFIC MARINE PLASTIC DEBRIS ACCUMULATION & COMPOSITION

A rapid assessment of beached marine debris was conducted in February 2021 at Home and Direction Islands, with parts of West and South Islands also surveyed (Figure 2). The rapid survey involved walking along the beach, stopping every 50-100 m, taking a GPS fix, then counting and identifying any debris within a 1 m transect through the low, mid and upper regions of the beach zone. Plastic abundance was classified into density categories (Very low < 5, Low 5-15, Medium 15-35, High 30-50, Very High >50). Exposed east facing shorelines on the outer edge of the atoll had the highest plastic densities with hotspots seen on South Island and at Northpoint on West Island (Figure 2). While we were unable to survey more of South Island, CKI locals clearly indicated that all of the southeast beaches are heavily impacted by beached marine debris, with a particular area at the northern part of the island being considerably worse in terms of plastic accumulation (Figure 2).

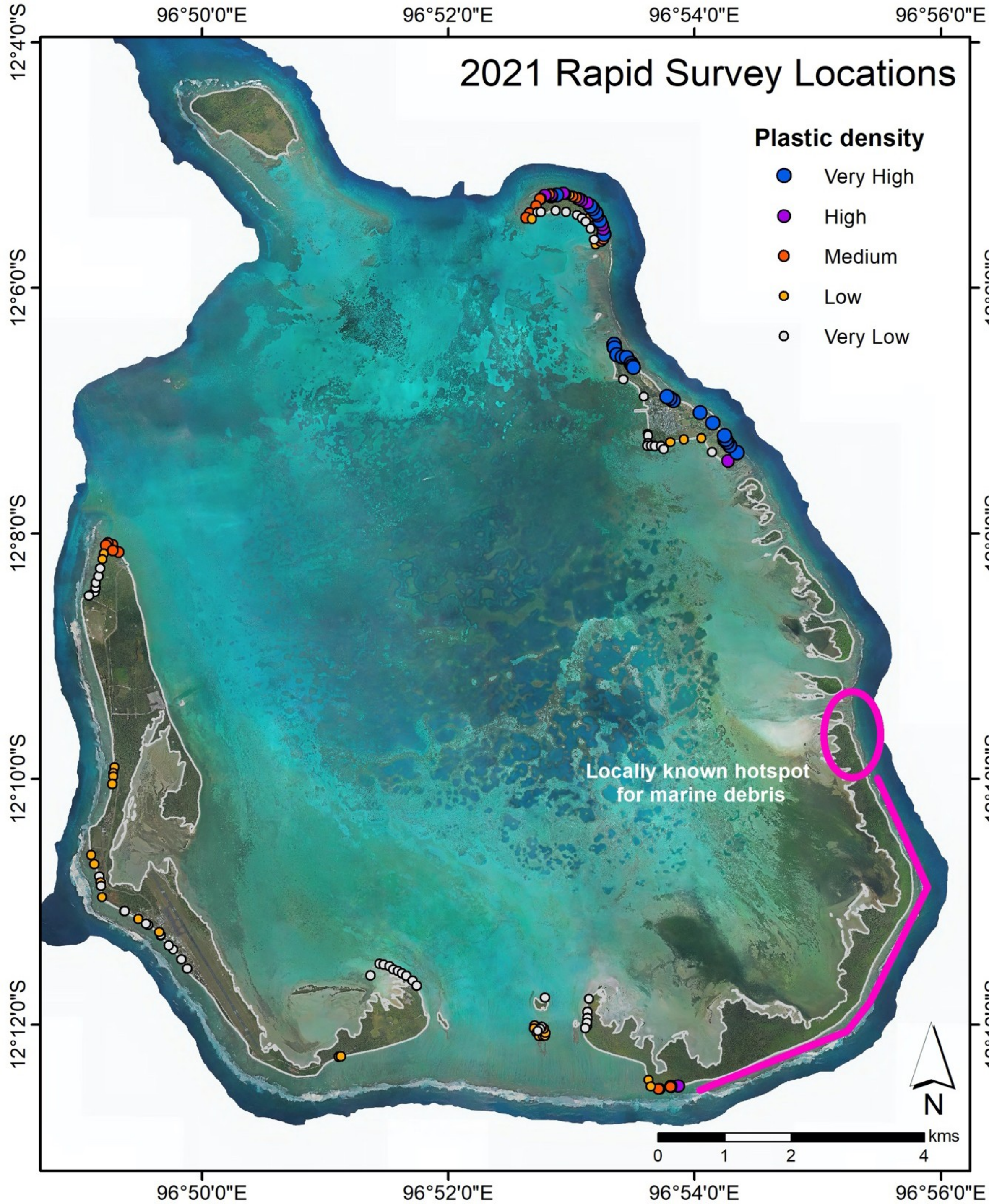


Figure 2 Plastic debris rapid surveys identifying accumulation points within the CKIs. Pink denotes areas where surveys were not conducted but are locally known hotspots for marine debris. Surveys conducted between February 19 - 27, 2021.

Figure 3 Common marine plastic debris in the CKIs. (a) PET bottles with PP or HDPE caps Home Island. (b) flip-flops Home Island (c) expanded polystyrene fishing float Direction Island (d) rope mass Home Island. (e) Coca-Cola PP bottle cap West Island. (f) mixed plastics (soft plastics and lighters)

The major macro-plastic types washing ashore in the CKIs are shoes (particularly polyurethane 'flip-flops') and single-use plastic items (PET plastic drink bottles, expanded polystyrene containers, and food packaging, straws and lighters) (Figure 3). PET items have particularly high value in the recycling market and have high recycling potential in the IOTs. Plastics must not have biofouling or extensive UV degradation to be eligible for recycling. PET bottles on beaches within the CKIs are relatively clean and would require only low energy washing methods to prepare for recycling.

Table 1 (Lavers et al., 2019) Macro-plastic densities and masses per m2 (± standard deviation) per island in the Cocos (Keeling)

Island/Site	Density (items m^{-2})	Mass (g m^{-2})
Home Island	**16.03** ± 13.65	40.15 ± 48.91
Hornsburgh Island	**13.37** ± 12.24	91.20 ± 47.95
South Island	**12.23** ± 13.35	155.33 ± 127.72
West Island	**9.76** ± 8.17	22.79 ± 16.19
North Keeling	**8.07** ± 4.27	-
Direction Island	**5.69** ± 0.05	273.24 ± 377.26

According to Lavers *et al.,* 2019, **Home Island** has the highest density of plastic items per m^2 (Table 1). Sea Shepherd (Australia Marine Debris Campaign) data contributed by Liza Dicks (2020) confirms these data. **South Island and Hornsburgh Island** have the second and third highest density of beach plastics by item. The variability of plastic abundance on the islands is high, suggesting patchiness in the number of items in any given section of the beach.

The mean mass (g/m^2) within sampling areas on **South Island and Direction Island** are the highest in comparison to other islands within the CKIs, likely due to heavy masses of plastic rope washed ashore (Table 1) (Lavers *et al*., 2019) coupled with the likelihood that this type of debris does not readily wash back into the ocean. In 2020, Sea Shepherd recorded 4,500 kg of rope on South Island within a 400m stretch of beach. Special logistical considerations should be made to accommodate higher volumes of debris removed from these two islands than other islands within the atoll.

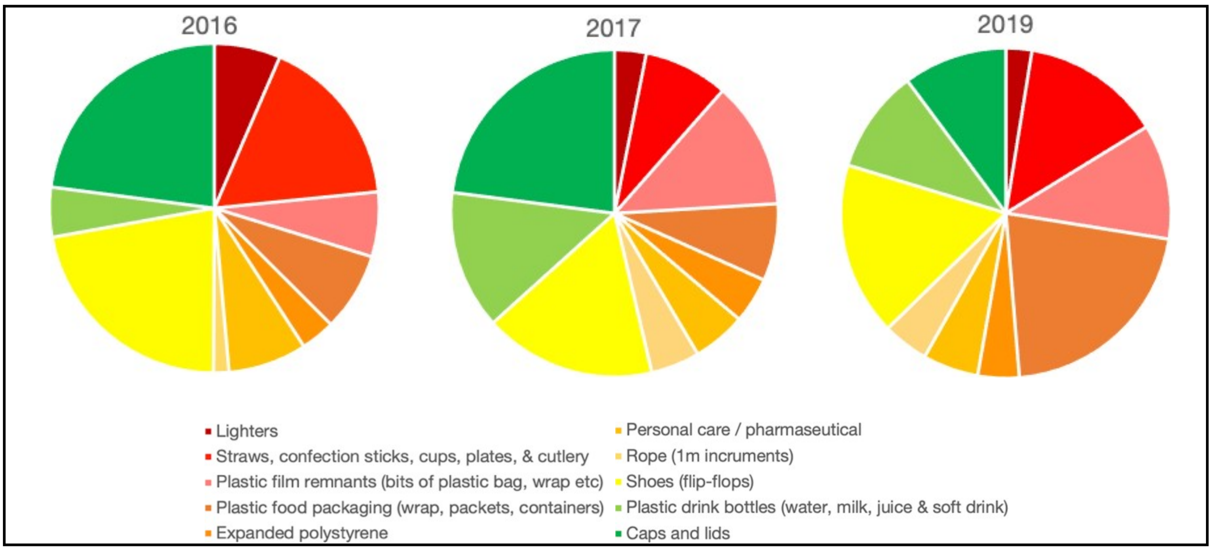
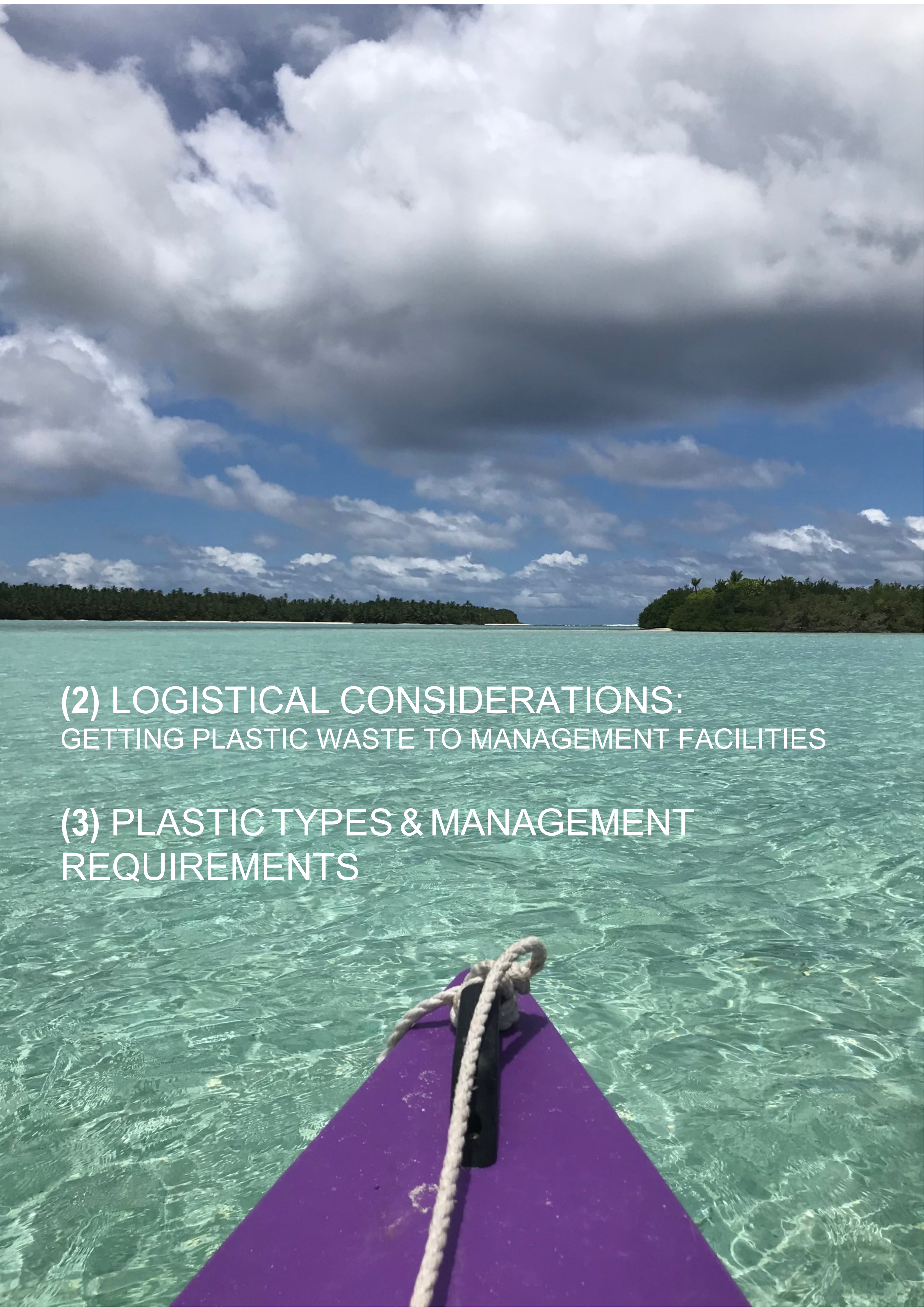


Figure 4 Data contributed by Liza Dicks (Remote Campain Coordinator Sea Shepherd Australia). Top 10 macro-plastics by type on Cocos (Keeling) Island beaches from 2016, 2017, and 2019. The above percentages are number of items per category / total number of items (collected annually). Sampling locations include Direction Island and West Island (Yoga Beach, Jetty, Memorial, and Rumah Baru).

1.5 EXISTING WASTE MANAGEMENT SCHEME – PLASTICS

The Shire of the Cocos (Keeling) Islands manages the Home Island Transfer Station, the location of a landfill site, green-waste burn site, and incinerator. The WR1T Incinerator was installed in 2015 to compensate obstacles to waste management caused by the remoteness of the location. Due to the high cost of shipping to mainland Australia, and the inability to bury waste due to the risk of penetrating the freshwater lenses (the main drinking supply for the island), controlled incineration was historically the best option for plastic waste processing. The Shire is now looking for an alternate approach to incineration of plastic waste, which we will propose in this review. Currently, a conservative estimate of 16,000kg of high-density polyethylene (HDPE) and 12,000kg of polyethylene terephthalate (PET) are municipally collected from Home Island and West Island and incinerated.



(2) LOGISTICAL CONSIDERATIONS:
GETTING PLASTIC WASTE TO MANAGEMENT FACILITIES

(3) PLASTIC TYPES & MANAGEMENT REQUIREMENTS

(2) LOGISTICAL CONSIDERATIONS FOR GETTING PLASTIC WASTE TO MANAGEMENT FACILITIES

Collection and sorting of plastics is a labour-intensive and potentially high cost step (Burt et al., 2020). Considerations for the feasibility of plastic collection from beaches include: (1) access to beaches, (2) substrate type, and (3) distance from the potential recycling facility on Home Island.

Access to beaches with high plastic accumulation is variable. The windward side of eastern and south-eastern islands within the atoll typically have the most plastic debris due to a predominant SE wind direction. High surf over the outer reef crest makes access by boat from the windward side of islands too dangerous for collection operations. Majority of South Island beaches need to be accessed during the highest tides via the lagoon and still requires a significant walk in shallow water.

2.1 ISLAND SPECIFIC CONSIDERATIONS

HOME ISLAND

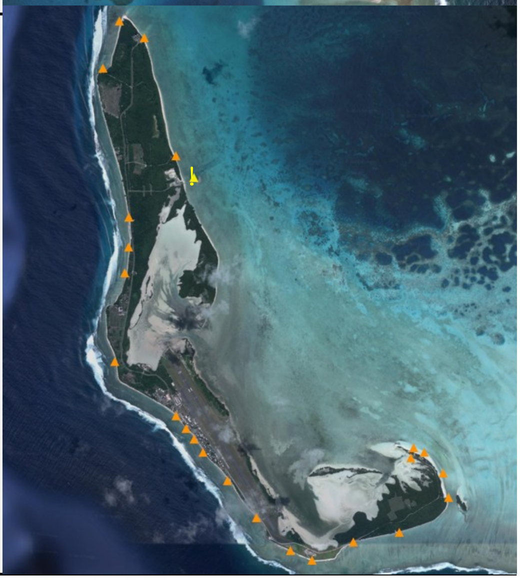
- Plastic accumulation focused on northeast facing beaches
- Most accumulation on the upper beach along the border of the vegetation (average = 5.8 plastic items m-^{2}; 15 survey locations)
- Plastic hotspots are easily accessible (5-20m from a road). 28 vehicle access points [▲]
- Walking short distances on coral rubble required
- No vessel necessary for the transport of collected plastics

DIRECTION ISLAND

- Plastic accumulation focused on northeast facing beaches
- Only 6 walking access [▲] points to northeast facing beaches (heritage trails)
- Walking long distances on coral rubble required
- Plastics need to be transported from the Direction Island ferry dock [▲] to Home Island ferry dock (appx 3.5 km)

WEST ISLAND

- Plastic accumulation concentrated on the north tip of the island, some debris on west facing beaches and Pulu Maria (accessible by small vessel). Least amount of plastic debris on lagoonal beaches
- 23 vehicle access points to beaches [▲] (12 west facing; 5 south facing; 6 lagoons)
- Mostly easy to transverse beaches: sandy with coral rubble patches
- Plastics can be transported to Home Island via ferry from Rumah Baru ferry jetty [▲] (8.7 km)



SOUTH ISLAND

- Plastic accumulation: east and southeast facing beaches
- No vehicle access, all plastic collection and removal carried out by foot [▲] and small vessel access [▲]
- No existing ferry access points
- Smaller islands like Pulu Baln Madar and Pulu Blan can be accessed via small vessels
- Little existing infrastructure for plastic collection: currently, small vessels can transport marine debris from the north and southwest ends of South Island to West Island. Marine debris must be packed into vehicles, and transported via ferry from Rumah Baru ferry jetty to Home Island (8.7 km) Pulu Baln Madar
- *Considerations for creating access paths from the lagoon to windward

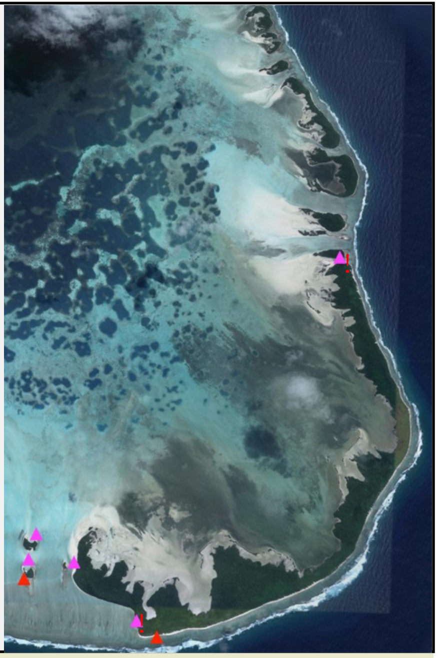


Table 2. Cocos (Keeling) Islands logistical considerations to collecting marine debris (plastics). Access points to beaches specified as follows: ▲ = vehicle; ▲ = ferry; ▲ = walking path; ▲ = small vessel

Existing infrastructure (roads, ferry jetties, and beach access) will allow for the collection of plastics from all beach aspects of **Home Island** and **West Island** without new infrastructure developments. Collection strategies should first focus efforts on **Home Island** windward facing beaches (2.8 km), as these beaches have the highest density of plastic accumulation (items/m^2) of all islands in the atoll and will be closer to the C(K)I Shire Works Facilities that will process marine plastic debris (Lavers *et al.*, 2019, & 2021 UWA Assessment).

Direction Island (DI) marine plastic collection will be physically demanding with only six footpaths to the 1.9 km stretch of beach on the windward coast. Beach access points that can be used to carry collection bags to the ferry terminal are, on average 250m apart (190m-467m), and 0.54km (332-700m) from the ferry jetty. There is no vehicle transport to the ferry terminal, and no drinking water on DI. Collectively, these factors will make beach plastic removal logistically and physically challenging, but not unachievable.

West Island beaches have lower volumes of marine plastics than South Island, Home Island, and Direction Island. There are a few hotspots (observed Feb 2021): one on the north tip and on the southeast in the vegetation. Both locations could be cleared and packed into vehicles easily. Consideration for the capacity of marine debris that can be transported via ferry to Home Island must be further investigated.

South Island collection will present the most significant logistical challenges, as it has no roads, walking paths, or ferry jetties. South Island can be accessed by launching from Canoe Beach and anchoring in the lagoon of the southernmost tip of the island. Access to the north end of South Island is tide dependent and beach clean-ups from the north end could only be conducted a few times a year due to shallow water over large sand flats in the lagoon. Carrying debris from the southeast aspect to the north and south tip is not possible. The Shire should consider clearing access paths from lagoonal beaches to the windward side of the southeast aspect of South Island. Debris collection points on the lagoon side of these paths would allow waste to be collected by visitors over time, ready for removal during an appropriate tidal cycle.

(3) TYPES OF PLASTICS AND THEIR MANAGEMENT REQUIREMENTS

3.1 RESIN IDENTIFICATION CODING SYSTEM (RIC)

In 1988, a plastic polymer identification method was created by the Society of the Plastic Industry (rebranded in 2010 to the Plastic Industry Trade Association, and more recently to the Plastic Industry Association). By assigning numbers, called resin identification codes (RIC), to common polymer groups the industry created an easy pathway for sorting plastics for disposal and recycling. There are 7 RICs in total, which have been summarised in Table 1. Frequently arriving debris items within the C(K)I group include thongs (polyurethane; #7), plastic drink bottles (polyethylene terephthalate (PET or PETE); #1), bottle caps (polypropylene; #5 & #2), expanded polystyrene (#6), and lighters (#7) (Figure 3). Table 3 is adapted from the American Chemistry Council Plastic Packaging Resins Document to highlight polymers frequently occurring in the marine debris of the IOT beaches.

RESIN IDENTIFICATION CODE	NAME	PRODUCT APPLICATIONS	PRODUCTS MADE WITH RECYCLED CONTENTS
1	Polyethylene terephthalate (PET or PETE)	**Packaging** • Plastic soft drink bottles • Food jars • Microwave trays **Other** Textiles, carpet, films, engineering moulding	Tourist products: vases, bowls; filament chord, plastic bricks
2	High density polyethylene (HDPE)	**Packaging** • Plastic bottles: milk, juice, large water containers, household cleaners • Shampoo bottles • Retail grocery bags • Cereal box liners **Other** Injection moulding, extruded pipes, plastic wood composites, wire insulation	Plastic lumber for outdoor decking, fencing, and picnic tables; pipe, bricks, floor tiles, buckets, bins
3	Polyvinyl chloride (PVC or vinyl) *Rigid & flexible*	**Packaging** • Rigid: blister packs • Flexible: Shrink wrap, deli wrap **Other** Rigid: pipe, permanent framework, window frames, fencing Flexible: waterproof coated fabrics, medical products (tubing), insulation, carpet backing	Windows, pipes, decking, fencing, panelling, gutters, floor tiles and mats, resilient flooring

RESIN IDENTIFICATION CODE	NAME	PRODUCT APPLICATIONS	PRODUCTS MADE WITH RECYCLED CONTENTS
4	Low density polyethylene (LDPE)	**Packaging** • Bread bags • Frozen food bags • Coating for paper milk cartons • Container lids **Others** Toys, injection moulding, adhesives, sealants	Floor tiles, panelling, furniture, outdoor lumber
5	Polypropylene (PP)	**Packaging** • Yoghurt containers • Bottle caps and closures • Prescription medication bottles **Others** Plastic fibres, appliances, and automotive applications	Brooms, brushes, garden rakes, shipping pellets, funnels
6	Polystyrene (PS)	**Packaging** • Take away food items (cups, plates, bowls, cutlery, meat and poultry trays) – *expanded or non-expanded polystyrene* • Protective foam for packaging • Compact disk cases **Others** Building insulation, coat hangers, medical products, toys, cable spools	Thermal insulation, eggshell cartons, plastic moulding (wood replacement products), Expanded polystyrene (EPS) foam protective packaging
7	Other: resin other than those listed above OR made of a mixture of resins	• Large reusable water bottles • Lighters • Thongs • Polyurethane matting	*Not easily recyclable* Polyurethane can be recycled into soft-fall and carpet underlay

Table 3. Resin identification codes, polymer product applications and recycling potential adapted from the American Chemistry Council Plastic Packaging Resins Document.

Cocos (Keeling) Islands surveys from beaches with plastic accumulation reveal that most plastic items arriving from offshore sources have intact RIC labels (Figure 5). RIC labelling is the most time-efficient and low-cost method of polymer identification (required for selecting plastics eligible for recycling), although other, more technical methods do exist. RIC label identification could easily be conducted by volunteer plastic collectors if separate bins are provided for different polymer types. Volunteer driven beach clean-up and sorting would save the IOT shires from having to redirect resources and personnel from existing public works related jobs.

Figure 5 Intact Resin Identification Code (RIC) labels on beached plastics on Direction Island, Cocos (Keeling) Islands.

Where there are no labels, sorting becomes more difficult. Polymer identification by visual inspection (no RIC) is not reliable with the exception of expanded polystyrene (EPS) (#6), which is easy to identify visually and by its exceptionally low density, and lighters (#7), which are usually intact and mainly from the same manufacturer. In addition, some plastics may be separated depending on how they sink or float in water (density separation test). For example, in freshwater, PVC will sink while HDPE and LDPE will float. Flame can be used to sort other plastics, in combination with other methods of categorisation: e.g. Polyolefins and nylon burn both with a blue flame with a yellow tip, but nylon will sink in water.

3.2 NEW VS. AGED PLASTICS

Photo-thermal degradation and biofouling are the two major factors that separate aged marine plastics, from new plastics. At sea, plastics can become brittle due to UV and heat exposure; a process called photo-thermal oxidation, and generally known as ***photo-thermal degradation***. This process often causes fragmentation of the original product into many smaller pieces, making identification of the polymer type difficult. Identifying the type of polymer is a crucial step in the recycling process, and one reason why new, unfragmented, plastics can be easier to recycle.

Biofouling is the process of marine organisms attaching themselves to a hard substrate, in this case plastic. If a plastic item is to be recycled it needs to be cleaned of any algae or bivalves (shelled organisms like mussels) before being shredded. Biofouling is likely to be observed on large items that wash ashore in Cocos, but unlikely on small PE and PP items like straws, bags, and lids because they will often sink under the weight of the accumulated organisms.

(4) WASTE MANAGEMENT POLICY

The Indian Ocean Territories are external territories of Australia, administered from the federal Department of Infrastructure, Transport, Regional Development and Communications, Canberra, but with Western Australian Government departments largely providing State-type services. Australian federal and WA state legislation have developed plans for phasing out single use plastics but have yet to fully consider challenges to carrying out this legislation in the remote Indian Ocean Territories. The Shire of the Cocos (Keeling) Islands has taken the initiative to oversee an improved recycling plan for plastics and phasing-out of single use plastics at the local level.

TABLE TIMELINE (PLASTIC LEGESLATION AND TARGETS)

Year	Australia *National Plastic Plan 2021*	Western Australia *WA Plan for Plastics 2020*	Cocos (Keeling) Islands *SOCKI Corporate Business Plan 2020-2023*
2018		WA **lightweight plastic bag ban** (July 1, 2018).	
2019	National Waste Policy Action Plan (NWPAP) agreed to Australia's environment ministers.		
2020	First National Plastics Summit Passing of the *Recycling and Waste Reduction Act 2020*. Microbeads phased out.	Containers for Change (**container deposit scheme**) implemented on October 1, 2020 (WA Plan for Plastics 2020). *See section 4.5 for CKI eligibility.*	Promote alternatives to plastic water bottles- **water bubblers installed on Home Island** (SOCKI -Corporate Business Plan 2020/21-2023/24 E3.1.2.5).
2021	Regulate unsorted mixed plastic waste exports (July 2021).		**Promote alternatives to plastic crockery and cutlery** (e.g. install commercial dishwasher in Cyclone Shelter) with a view to banning the importation of single-use plastic ware and straws (SOCKI -Corporate Business Plan 2020/21-2023/24 E3.1.2.6).
2022	Regulate unprocessed single polymer or resin waste plastic exports (July 2022) **Phase out expanded polystyrene (EPS)** in consumer packaging (July 2022), and food/beverage containers (December 2022).		Plans to host an **International recycling convention** to showcase CKI practices and encourage dialogue on best practice (SOCKI - Corporate Business Plan 2020/21-2023/24 E3.1.2.7).

Year	Australia *National Plastic Plan 2021*	Western Australia *WA Plan for Plastics 2020*	Cocos (Keeling) Islands *IOTs RDO CKI 2030 Strategic Plan*
2023	Over 80% of supermarket products to display the Australasian Recycling Label (December 2023).	Implementation of WA legislation for state-wide **phase-out of plastic plates, cutlery, stirrers, straws**, thick plastic bags, polystyrene food containers, and helium balloon releases (WA Plan for Plastics 2020).	
2024 - 2026	National Industry Packaging Targets: • 100% re-usable, recyclable, or compostable packaging. • **70% of plastic packaging to be recycled.** • Problematic and unnecessary single use plastic packaging phased out.	Implementation of WA legislation for state-**wide phase-out of barrier/produce bags, polystyrene packaging**, cotton buds with plastic shafts, microbeads, and oxo-degradable plastics.	
2030	Microfibre filters to be incorporated in design of all new residential and commercial washing machines (July 2030).		**Plastic-free goal** (*in discussion*). (IOTs RDO *Our Cocos (Keeling) Islands 2030 Strategic Plan* 2019).

Table 4. Plastic waste legislation and targets (Australian national, state, and local level for the Cocos (Keeling) Islands).

(5) TURNING PLASTICS INTO AN OPPORTUNITY

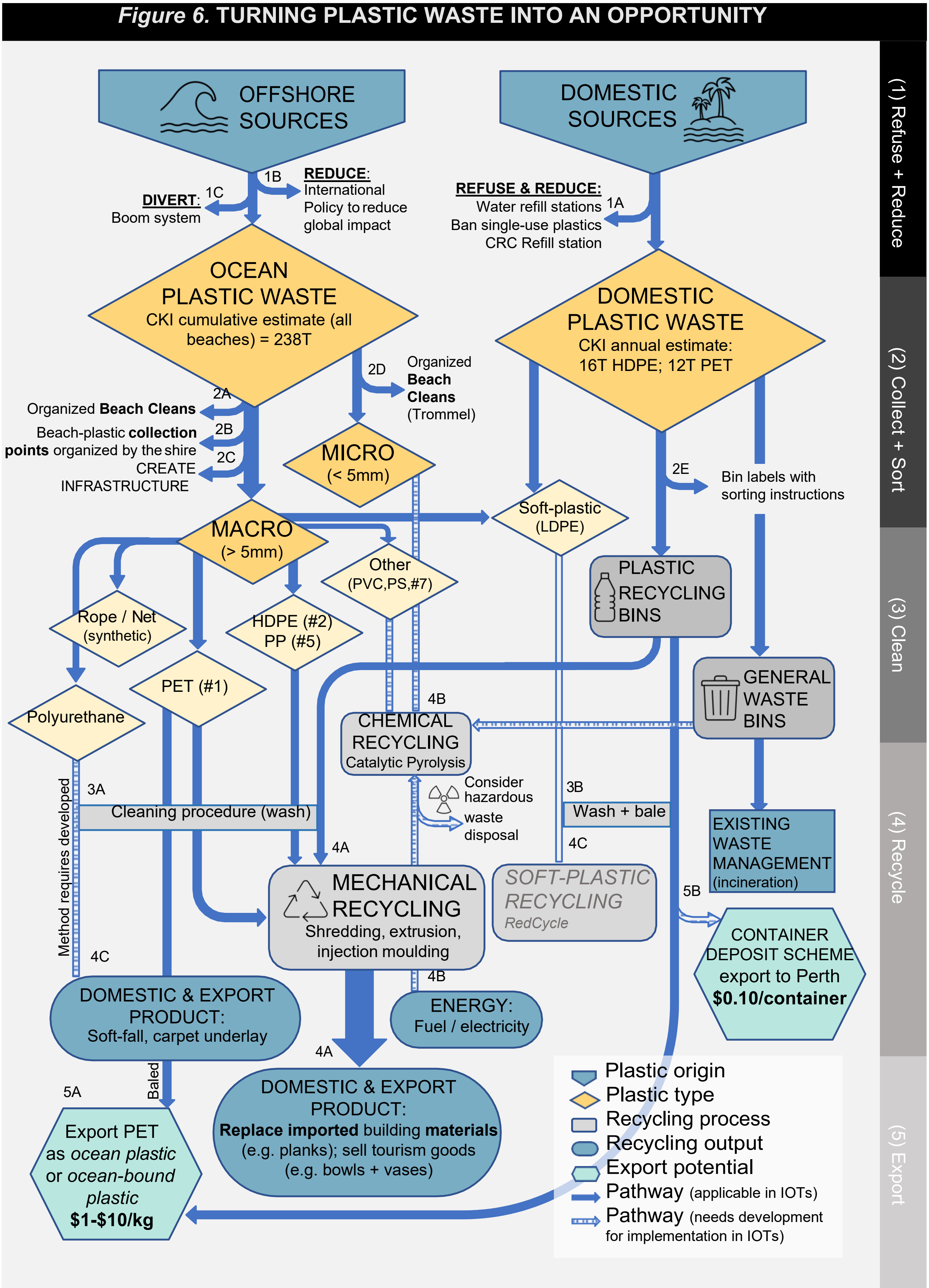


Figure 6 Flow chart for marine and domestic plastic recycling scheme in the Cocos (Keeling) Islands. Starting with the raw plastic material, this figure takes plastics through of the five phases (on right side of diagram) required to recycle plastic waste into new products. Numbers/letter labels above pathways are further explained in Section 4 ('Turning Plastics into and Opportunity')

(5) <u>TURNING PLASTICS INTO AN OPPORTUNITY</u>

Pathways for plastic recycling for the remote Cocos (Keeling) Islands is represented in Figure 6. The three main channels for plastic recycling include: mechanical recycling, the export of cleaned plastic products to be recycled on the mainland, and chemical recycling.

> (4A) **Mechanical recycling** involves sorting plastic polymers then washing, shredding, and melting to create new plastic products that can be used within the IOTs as an alternative to importing these materials. The technology exists for this process to be carried out in the short term.
>
> (5A) If the supply of ocean and domestic plastic waste exceeds the demand for products domestically, these products or raw materials can be **sold and exported**. The market for 'ocean plastics' continues to grow, and washed, baled PET containers can be sold for up to $10/kg (container deposit scheme or commercial brand partnerships), which has the ***potential of offsetting shipping and biosecurity costs*** *of export*.
>
> (4B) **Chemical recycling** is the process of turning plastic polymers into monomers through the application of heat, pressure, depleted oxygen, catalysts, and/or solvents. These processes can refine plastics into crude oil/fuel: an end-of-life option for plastics that cannot be used in mechanical recycling and have low export value. Chemical recycling could further develop as a pathway that is a long-term solution for plastic waste in the IOTs. This section of the report investigates the feasibility of refusing, reducing, collecting and recycling, and exporting plastic waste in the IOTs and funding opportunities to subsidise these pathways, turning plastic waste into an opportunity.

5.1 REFUSE & REDUCE: SUSTAINABILITY PRACTICES

Recycling is just one component of managing single use plastics. Although this report focuses on recycling, identifying and rethinking plastic applications on a domestic and commercial scale will relieve stress to the plastic waste management of marine debris.

(***5.1A***) The Shire of the CKIs has incorporated sustainability practices surrounding plastics into their 2020/21 – 2023/24 Business Plan (Table 4). CKIs supports a small and caring community that has an opportunity to set the standard for similar remote islands. Purchasers have an opportunity to import products from sustainable businesses that limit plastic use. The CKIs Shire 2021 goal of banning the importation of single-use plastics can be achieved by promoting organic alternatives to single-use plastic. For example, alternatives to plastic straws are bamboo or paper straws or personal metal straws. Disposable cutlery can be made from bamboo or another compostable plant-based alternative. An area that is often overlooked is the material used in packing fruit and vegetables and can holders. Suppliers who use plant-based box liners rather than plastic should be prioritised. For drinks, the six-pack rings can be replaced with plant-based alternatives or products like the "6 Pak Can Clip" from PakTech®, which are less risky to turtles than rings and can be added to the HDPE waste stream.

Reducing the use of PET bottles for drinking water should be made a high priority. To address this issue, the CKI Shire has installed water bubblers on Home Island to encourage refilling water bottles. This program can be developed further through Corporate sponsorship supplying non-plastic, re-usable insulated drink bottles to each of the 550

CKIs residents. This would result in a reduction in the importation of PET bottles that required disposal.

Figure 7 Hopetoun CRC refill station

The movement away from single-use plastic has produced new businesses opportunities on the mainland. These businesses buy everyday domestic and personal products in bulk for resale as a refill service. The Australian Community Resource Centres (CRC), in Hopetoun, Western Australia, has added a refill station to service its small community. The products that sell well include dish soap, laundry detergent, cleaning solvents, and shampoo products (Figure 7). The Hopetoun CRC has shared their experience with the CRC community and would be a valuable source of information. The CKIs CRC could implement a refill station for community members and tourists on Home and West Islands that is affordable and reduces plastic importation and use on Cocos.

Promotion of alternatives to plastic can be undertaken through schools and education of expecting mothers. Examples include the promotion of metal lunch boxes over plastic ones through the school. High quality metal boxes are durable and capable of lasting for many years. New mothers should know about the environmental costs and benefits of reusable nappies and have the option of using them. The benefit of metal lunch boxes and re-usable nappies is the reduction of plastics being imported and the diversion of plastic away from the waste stream with little cost to the Shire of CKI.

(***5.1B***) Ultimately, the flow of offshore plastics to the IOTs needs to be addressed at the source. By identifying brands of plastic items (e.g. AQUA Danone®, Coca Cola, and Red Bull) that are washing up on once pristine beaches these corporations can be held accountable for the fate of their products overseas. Mobile applications like *Marine Debris Tracker* and *Litterati* (litterati.org) can be used to record such data. The UWA Oceans Institute is seeking pathways to reduce plastic pollution in Indonesia, which will in turn reduce plastic waste arriving in the Indian Ocean Territories.

(***5.1C***) Logistically, some islands of the CKIs are difficult to access. Passages like that between Pulo Siput and the north end of South Island could be eligible for the implementation of a 'boom system' to divert plastics to more accessible beaches like the north end of West Island. There are many examples where booms have been used to redirect the flow of plastic, generally into a device to extract the floating debris. Further hydrodynamics research needs to be conducted to realistically assess the implementation of a boom system, and an environmental assessment needs to be conducted prior to such an implementation.

5.2 PLASTIC WASTE COLLECTION

Ocean plastic waste accumulation in the coastal environment of CKIs must be collected and transported to Home Island for further processing. The collection phase will be time-intensive due to logistics (Section 2, Figure 5) and will require an approach that considers eco-tourism driven collection, organised beach clean-ups, installing collection and sorting bins at beaches, applying to be a certified plastic credit project, and the creation of new infrastructure.

(***5.2A***) **Coordinated beach clean-ups** have been successful in removing plastic debris from 'hotspot' beaches around the Cocos (Keeling) Island Group. The most recent clean-up campaign led by Liza Dicks (Remote Campaign Coordinator Sea Shepherd Australia) consisted of 7 volunteers who removed over **11 tonnes** of beach plastics over a two week period in November/December of 2020. This equates to approximately 5% of the total plastic estimate for the CKI group.

Compared with other clean-up programs, the clean-up events in Cocos have been extremely efficient. A study from the Aldabra Atoll (Seychelles) estimated a cost of $10,000 per day to clean beaches of a remote island, where the cost of the Sea Shepherd Australia Marine Debris Campain clean-up was volunteer based and operational costs were covered by the Sea Shepherd NGO. Volunteer operations will likely not be able to keep up with the rate of incoming plastics. The Shire of the CKIs may need to be involved in the recovery of ocean plastics outside of the volunteer led programs.

Figure 8 Novel and conventional plastic collection bins: 'Goby the fish' in Bali (left) and recycling bins at tourist beach in the CKIs (right).

(***5.2B***) **On-site beach plastic collection bins** for individual driven beach clean activities will provide an opportunity for constant cleaning of affected beaches. A similar program has been successful on Lord Howe Island, NSW. In addition to secure collection bins for ocean plastics, installation of an artistic plastic collection container could be started by schools for the collection of PET bottles. The image above is of a collection bin in Bali called 'Goby loves plastic, please feed him!' (Figure 8). He's the only fish that should eat plastic and was designed to reduce the amount of plastic waste in the region. Studies have shown that children have a significant positive effect on changing the environmental concern levels of their parents (Lawson et al., 2019). By incorporating plastic recycling into the school curriculum, and having children build a sculpture like 'Goby the fish', the challenges of plastic pollution in the CKIs can stay at the forefront of community action.

(***5.2D***) **Microplastics** are part of the plastic problem on the beaches of Cocos. Although difficult to remove or recycle, particles are dangerous to organisms in the environment and removal should be considered. Methods like a portable trommel system to sieve microplastics from the sediment could be implemented to address the issue of microplastics on a small scale, but this is a time intensive model and capture of natural debris, and organisms within the substrate needs to be addressed and avoided.

(***5.2E***) Domestic plastic collection bins need to be developed to collect and sort targeted plastic polymers. Stickers detailing eligible containers can promote correct sorting and cleaning of recyclable plastic waste.

5.3 PLASTIC CLEANING PROCEDURES

Once polymers are sorted by type (e.g. PET bottles, HDPE bottles, PP lids), they can be cleaned in preparation for mechanical recycling. Cleaning procedures will be provided by The Plastic Collective organisation.

5.4 PLASTIC RECYCLING

(***5.4A***) **Mechanical recycling** involves sorting plastic polymers then washing, shredding, and melting them to create new plastic products that can be used or sold locally, or exported as a recycled product. The CKIs Shire members and Manager of Works and Services interest in producing building materials (e.g. composite planks) and tourist keepsakes (e.g. vases and bowls) from ocean plastics is possible through the mechanical recycling process. Mechanical recycling is time intensive (sorting collected plastics and cleaning procedures) but has a lower capital cost than chemical recycling methods like catalytic pyrolysis, with lower maintenance and training costs. A mechanical recycling facility would provide an opportunity to be eligible for corporate funding of operation through the plastic credit system.

The Plastic Collective is an Australian company that provides end-to-end plastic recycling solutions for commercial, community, and educational applications. Their resource recovery program allows corporate sponsors to fund (through plastic credits) the collection of plastics building of recycling facilities and plastic recycling training in specific communities. This program has successfully developed recycling facilities in Les Village, North Bali (funding: TK Maxx), Mantanani Island, Borneo (funding: Coca-Cola Malaysia), and the Whitsunday Islands, QLD (sponsorship: Coca-Cola South Pacific). The Plastic Collective

Figure 9 The Plastic Collective mechanical recycling facility for shires or small commercial aplications.

has a mechanical recycling solution for small industrial applications with an annual processing capacity of 500 tonnes per year. This facility contains equipment for shredding, extruding, and injection moulding to create new products. The recycled products include (1) shredded or pelletised recycled material to be sold to brands for profit and/or (2) new products like the desired composite planks and tourist goods the Shire of the CKIs is looking to produce. The unit also complies with Australian standards for OH&S and include digital CO_2 emission monitoring.

COSTS: The current annual operational cost for the CKIs' incinerator used to burn plastic waste is estimated to be $330,000. The capital cost of building a mechanical recycling facility is estimated to be **$100,000 - $350,000** with operations requiring 2-5 trained staff. Set-up, training, and educational tools are included in this initial cost. If planks are produced, they would replace imported materials costing around $100/m^2 (excluding shipping).

Plastic credits may be a funding option for the collection, sorting, and recycling of beach plastics. The plastic credit is a transferable unit representing a specific quantity of plastic pollution collected from the environment and recycled. The plastic credit system has been developed by The 3R® Initiative for companies to make their value chain circular by mitigating the impact of plastic waste that remains beyond their control (Guidelines for Corporate Plastic Stewardship, 2021).

(***5.4B***) **Chemical recycling** is a general term that includes gasification, pyrolysis, catalytic pyrolysis. The chemical recycling of plastics is often referred to as 'waste to energy' pathway. It is the transformation of a polymer back into its original constituents (monomers).

It should be noted that due to the high cost of production and production of toxic gasses, gasification is not ideal for the IOTs. Gasification turns fossil-fuel based materials like plastic into syngas (‘synthetic gas’), a mixture of primarily hydrogen and carbon monoxide. The combustion of syngas produces energy due to the reactive nature of the H_2 and CO in the mixture.

Pyrolysis, specifically catalytic pyrolysis, is the thermal degradation of plastic waste (in the absence of oxygen and the presence of catalysts) at different temperatures (300C-900C). Dr. Thomas Maschmeyer at the University of Sydney has developed this technology into a method called the Cat-HTR™. Cat-HTR™ is a catalytic hydrothermal reactor that transforms end-of-life plastic into clean fuel. Small scale equipment utilising this method is currently being developed and within the next ten years could be an innovative and resourceful solution for traditionally non-recyclable plastics on CKI.

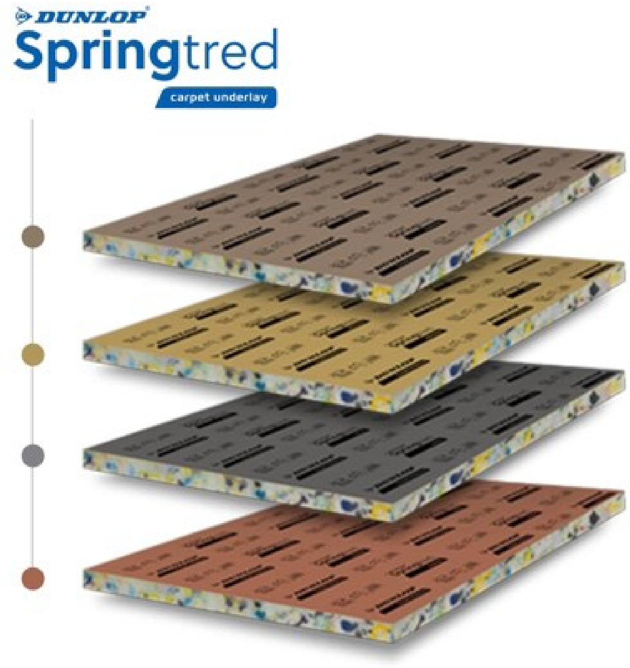


Figure 10 Dunlop-flooring recycled polyurethane carpet underlay, and raw polyurethane flip-flop accumulation on Home Island, Cocos (Keeling) Islands (February, 2021).

(***5.4C***) **Polyurethane** is not conventionally recycled (RIC #7) (Table 3) but has potential for downcycling in areas like the CKIs where marine debris is composed of a high percentage of polyurethane flip-flops (Figure 4). The CKIs currently import rubber soft-fall, which could be replaced by recycled flip-flop soft-fall made on Home Island. No companies currently specialise in producing soft-fall from recycled polyurethane, but this product can be produced through a process of cleaning, shredding, adding adhesive, and applying heat in a press. Dunlop Flooring Australia uses a similar process to commercially produce recycled polyurethane carpet underlay (left). A shredder that is operated as part of the greater mechanical recycling plant could be utilized to facilitate the recycling of flip-flops into soft-fall tiles.

5.5 PLASTIC EXPORT

The Indian Ocean Territories present a unique case study in the significant distance from the islands to mainland Australia. Due to the high cost of shipping (estimated by the CKIs Shire to cost $15,000/container) plus biosecurity regulations for items arriving at Fremantle port (WA), if plastics are exported, the value of exported products must outweigh the extreme shipping costs.

(***5.5A***) The Plastic Collective (mentioned in section 4.4A) has partner brands that purchase cleaned and shredded recycled polymers. Ocean plastics (incoming) and ocean-bound plastics (domestic) can fetch between $1/kg - $10/kg via such schemes. If mechanical processing is initiated, then a benefit-cost analysis is recommended to investigate the viability of engaging in a plastic crediting scheme.

(***5.5B***) **Container Deposit Incentives** (CDIs) or Container Deposit Schemes (CDS) have been shown to significantly reduce the amount of beach debris in coastal communities. If the volume of plastic waste exceeds the volume required for the production of recycled goods, there's potential for selling material to **WA Return Recycle Renew Ltd.** (WARRRL) for $0.10 per container. Western Australia adopted their CDS in 2020, but the CKIs are not yet included in the Containers for Change WA scheme as they have not adopted the CDS regulations. If PET bottles sold on Cocos are from WA suppliers, they will be eligible for the scheme. Baled containers are not currently accepted, but WARRRL is currently amending these regulations. A 20 metre shipping container can fit approximately 300,000 - 500,000 baled PET bottles (collectively worth $30,000 - $50,000). Further considerations for biosecurity needs to be accounted for if a CDI scheme moves forward.

(6) WASTE MANAGEMENT TECHNOLOGY PROS & CONS

Recycling Type	PROs	CONs	Companies
Mechanical	• Lower capital and operational/maintenance costs than chemical recycling. • Lower emission methods than chemical recycling. • Reduces need for importing goods that can be produced with recycled material arriving to the IOTs. • Strong educational tool. • No hazardous waste produced in operation.	• Only select polymers can be recycled recycling. • Time intensive sorting process.	The Plastic Collective https://www.plasticcollective.co/ Precious Plastics https://preciousplastic.com/ EcoCrab https://www.ecocrab.com/
Gasification	• Utilises all polymer types • Potential for energy production.	• High capital costs • High greenhouse gas emissions. • High cost of production. • Toxic gasses produced.	Perpetual-Bio
Pyrolysis	• Creates renewable biocrude oil • Decrease the import of fuels to the IOTs	• High capital costs • High greenhouse gas emissions. • Less efficient than catalytic pyrolysis. • Requires higher temperature and more	Circular Energy https://circularenergy.eu/mobile-plastic-waste-pyrolysis-system/ ReNewELP https://renewelp.co.uk/ PlasticEnergy https://plasticenergy.com/ Pyrowave https://www.pyrowave.com/en/

		energy than catalytic pyrolysis.	
Catalytic Pyrolysis Cat-HTR™	• Creates renewable biocrude oil • Decrease the import of fuels to the IOTs • More efficient than traditional pyrolysis • Can convert plastic into biocrude oil in as little as 20-30 minutes	• High capital costs • High greenhouse gas emissions. • Small scale facility applicable to IOT use is still in design phase	Licella https://www.licella.com.au/

(7) QUICK WINS, IMMEDIATE ACTION, & LONG TERM OUTLOOK

Quick Wins *2021*	Immediate Action *2021-2022*	Future Action *2023-2030*
• **Beachside plastic collection containers** for locals and tourists • **Refill station** for dish detergent, laundry liquid, shampoo, conditioner, body-wash to reduce single use plastic containers • Incorporate ocean plastic pollution and **plastic recycling into school curriculum** (PET 'fish' collector) • Seek eligibility for **WARRRL container deposit scheme**.	• Implement **mechanical recycling facility** (Capital costs: $100K-350K) • Apply for funding of plastic waste collection and sorting through the 3R Initiative **plastic credits program** • Collaborated beach cleans (focus on Home Island and West Island first, then Direction Island, Hornsburgh, and South Island)	• Collect data on annual domestic plastic waste and beached marine debris volumes to assess financial viability of **catalytic pyrolysis** • Collection strategy for **plastics on remote beaches** implemented. • Ocean microplastic management strategy

(8) KNOWLEDGE GAPS

The Indian Ocean Territories include both the CKIs and CI. While an understanding of the problem of plastics management on CKI is developing, the scope of the incoming plastics problem on Christmas Island is not fully understood and needs attention and considered alongside domestic plastics management. Undertaking a similar project to this one on CI would benefit the community, the environment and align with Australian national and WA state sustainability goals.

During the process of developing a recycling strategy for the CKI, the Shire should consider the following knowledge gaps:

1. MECHANICAL RECYCLING BUSINESS CASE: Plastic credits and operations

A formal business case can be further developed by an organisation like The Plastic Collective. The Plastic Collective can facilitate the development of a robust **financial model for mechanical recycling on Home Island**. The Plastic Collective can also provide figures on how much of the collection and recycling process would be subsidised by **plastic credits** purchased by their corporate partners. The cost of a formal business case appraised by the plastic collective is approximately $5,000 and can be completed within 6-8 weeks' time. Steve Hardman (steve@plasticcollective.co), the director of The Plastic Collective, has been briefed on this project and can carry out the aforementioned recommendations.

2. LOCAL OCEAN CURRENTS WITHIN THE CKIs

To identify seasonal changes in locations of plastic hotspots so that plastics can be more easily collected in large amounts. To achieve this, it is important to understand localised surface water currents within the CKIs. A partnership between local people in the CKIs to collect and send information to UWA researchers has been initiated to start understanding these local surface currents. In February 2021, the UWA team built a drifter and trained Kylie James from Cocos Adventure Tours in its operation. This drifter will track current speed and direction around accessible beaches to be used in models that can predict the locations of remote plastic hotpots. The development of these models by specialists at UWA can minimise resource expenditure on locating hotspots by foot in remote hard to access areas and allow for the most efficient collection of ocean plastics.

3. ACCUMULATION RATE OF PLASTICS ON THE CKIs' BEACHES FROM OFFSHORE SOURCES

Facilitating continued research access to the CKIs will improve the current understanding of ocean plastic dynamics around the islands. The rate of plastic accumulation within the CKIs is currently unknown. Estimating the arrival rate of incoming ocean plastics is vital for cost-effective management. A PhD student (Lillian Stewart), at the University of Tasmania will be further investigating arrival rates of plastic to the CKIs, which will be instrumental in planning the frequency and location of future beach clean activities. Building on this work will lead to better and more accurate modelling and subsequent management of the area.

4. RECORDS FOR THE ANNUAL VOLUME OF DOMESTIC PLASTIC WASTE: Assessing the viability of catalytic pyrolysis

The final gap that requires immediate attention is quantifying the long term volumes of domestic plastic waste production and beached marine debris. This is required to fully assess the option of catalytic pyrolysis. Small scale operations have been developed, but the capital costs are expensive. If ocean plastic arrival rates and annual municipal plastic volumes are known, a business case can be made for converting plastics into oil within the scope of the CKI Public Works Department. The Cat-HTR™ unit, if developed for small scale implementation, would allow the recycling of plastics that would not be utilised for mechanical recycling.

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