The economic impact of plastic pollution, and the benefits of reducing mismanaged waste

in Fiji

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Acronym List

Acronym	Description
ALDFG	Abandoned, Lost, or Otherwise Discarded Fishing Gear
APEC	The Asia-Pacific Economic Cooperation
APWC	Asia Pacific Waste Consultants
BaU	Business-as-Usual
BPA	Bisphenol A
CBA	Cost-Benefit Analysis
CEO	Chief Executive Officer
CBD	Convention on Biodiversity
EU	European Union
GDP	Gross Domestic Product
GHG	Greenhouse gas
HDPE	High-Density Polyethylene
Norad	Norwegian Agency for Development Cooperation
NOAA	The National Oceanic and Atmospheric Administration
NPV	Net Present Values
OECD	Organisation for Economic Co-Operation and Development
PET	Polyethylene Terephthalate
PWFI	Plastic Waste Free Islands
PIC	Pacific Island Countries
SIDS	Small Island Developing States
UNEP	United Nations Environment Program
WTV	Willingness to Visit

1. INTRODUCTION

In 2019, with support from the Norwegian Agency for Development Cooperation (Norad), IUCN launched the Plastic Waste Free Islands (PWFI) project. The initiative's overarching goal is to drive the circular economy agenda forward and to reduce plastic waste generation and leakage from island states. The project consists in assisting several island nations in the Pacific and Caribbean regions to reduce plastic waste generation and eliminate leakage to the ocean on which they depend. The PWFI project was implemented in Fiji, Samoa, and Vanuatu in the Pacific, and in Antigua and Barbuda, Grenada, and Saint Lucia in the Caribbean Region.

As part of the PWFI project, economic assessments were conducted. This report presents the findings of a study that aimed at estimating the impacts of plastics leaked into the marine environment from Fiji, and the costs and benefits of implementing a solution, a regional recycling system to reduce mismanaged plastic waste and its leakage into the marine environment.

1.1. MARINE PLASTICS

Since the early 1950s, the use of plastics in everyday life has increased due to its durability, lightness, and low production cost (Filho et al., 2020). Plastics fulfil numerous vital functions in our society. For example, they serve as a critical component in maintaining food safety and security (Dalberg, 2021). The volume of plastics produced between 2002 and 2015 was the same as the amount produced in the previous 52 years, between 1950 and 2002 (Geyer et al., 2017). At a global level, only 9% of plastics produced are recycled, and 22% of the plastic waste generated is mismanaged[1] (Watkins et al., 2012; Geyer et al., 2017; OECD, 2022a). Mismanaged plastics leak into the oceans (Thompson et al., 2009). Most of the mismanaged plastics are single-use plastics, mainly coming from food packaging, bottles, straws, and grocery bags. The main source of plastic waste flow in the oceans is land-based, contributing to approximately 80% of all marine plastics (Jambeck et al., 2015). Land-based litter load can come directly from the shoreline caused for example by tourism or it is transported from distant areas such as inland towns and industrial sites via watersheds and wastewater pipelines, mainly due to inefficient waste management practices (Veiga et al., 2016). The remaining 20% comes from sea-based activities (Wu, 2020), mainly from the fisheries sector (Andrady, 2011). Fisheries can add to marine plastic debris through discarded, lost, and abandoned fishing gear in the oceans and waterways (Oko-Institut, 2012). In addition to this, it is also responsible for throwing litter overboard from vessels (Hinojosa, 2011; Lusher et al., 2017).

The marine plastics problem can be explained using the 'Driver, Pressures, States, Impacts and Responses' framework (Löhr et al., 2017; Miranda et al., 2020) (**Figure 1**). The drivers of plastic production originate from human needs such as food

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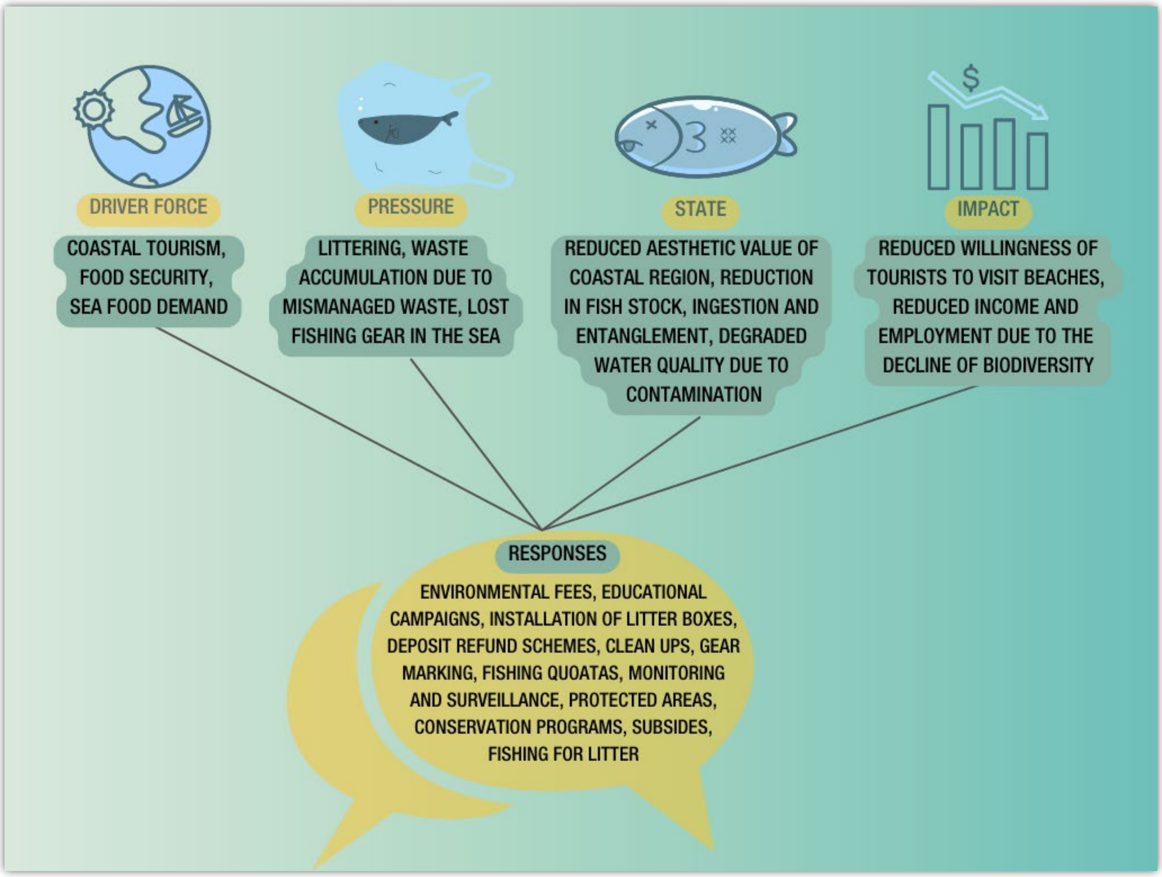
[1] Pew (2020) defines mismanaged plastic waste as "any plastic waste that is openly burned or that is directly dumped or leaked into the environment".

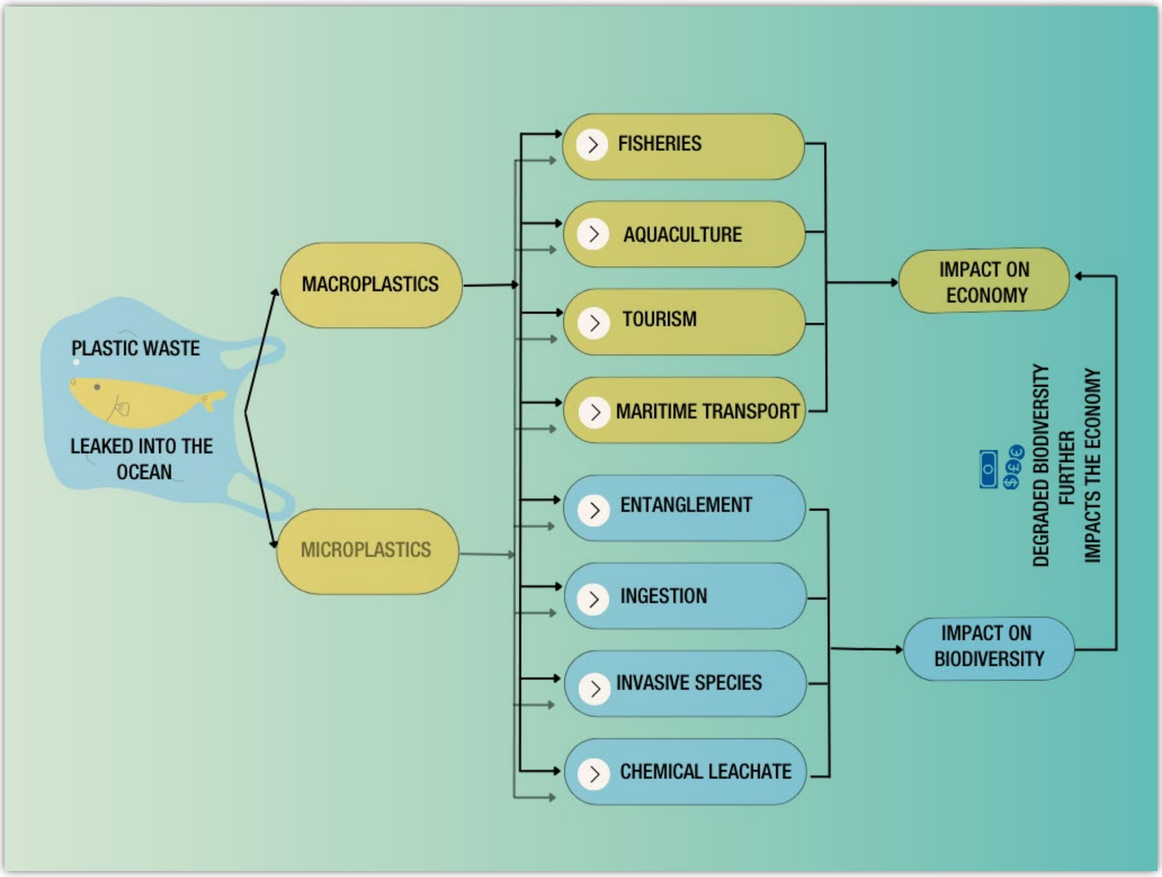
security, movement of goods and services, and shelter (Thevenon et al., 2014). These needs are fulfilled by the economic sectors where plastics are widely used (e.g., packaging of products, fishing nets for fisheries, construction, transportation, healthcare equipment, agriculture and electronics, among others) (Abalansa et al., 2020). The use of plastics generates waste.



Sources: Romagosa et al., 2014; Chassignet et al., 2021; Jahanishakib and Mohammadpour, 2021; Gebremedhin et al., 2018.

Figure 1 – Driver-Pressure-State-Impact-Responses framework for plastic pollution with examples

Once plastics become waste, a part of this waste is mismanaged and leaks into the oceans. This generates negative impacts to the economy and biodiversity (**Figure 2**). The plastic pollution leaked generates four types of consequences. First, it impacts the physical ocean system through contamination (e.g., reduced health of marine habitats and water quality due to the presence of plastics) and sunlight blockage (Gallo et al., 2018). Second, the reduced environmental quality impacts marine biodiversity and ecosystems (e.g., increased fish mortality rates due to ingestion and entanglement, and reduced aesthetic value of beaches due to plastic litter) (Werner et al., 2016). Third, the degraded marine biodiversity and ecosystems have an impact on the provision of marine ecosystem services (e.g., supply of seafood and raw materials, transportation, storm protection) (Beaumont et al., 2019; Barbier, 2017). Finally, the economy is directly impacted (e.g., through lower fisheries and tourism revenues) (Bailly et al., 2017).



Source: UNEP (2014a).

Figure 2 – Impact of plastics once ending up in the oceans[2]

Marine plastic pollution can generate significant economic costs. This is driven by the loss in revenue from tourism, fishing, aquaculture, transport, and other ocean-based activities (**Figure 2**) (McIlgorm et al., 2020). The costs associated with marine litter are divided between direct and indirect costs (Newman et al., 2015). Direct costs include the expenses for repair and replacement. For instance, fisheries revenues can be impacted due to damaged gear (Macfadyen, 2009) and expenses to the government to clean beaches where recreational activities are conducted (Mouat, et al., 2010). Additionally, the shipping industry can suffer losses due to marine debris entangling with propellers, potentially obstructing the engine (IMO, 2018). The indirect costs are related with impacts to biodiversity and habitats, including costs resulting from decreased ecosystem service provision (Rodríguez et al., 2020). For instance, the fishery sector's revenue is further reduced due to the reduction in catches in the presence of marine plastics and lost or abandoned gear (Richardson et al., 2021). Tourism industry's revenue could be impacted due to reduction in tourists' visits and spending in the presence of marine debris (McIlgorm et al., 2020).

Moreover, plastics at every stage of its life cycle (from production to consumption to waste treatment) emits a significant amount of greenhouse gases, which together with other sources, threaten the ability of the global community to keep global temperature rise below 1.5°C (Ford et al., 2022; Hamilton and Feit, 2019). It is estimated that by

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[2] The study focuses on macroplastics.

2050, the life cycle of plastics could contribute up to 15% of the global carbon budget (Zheng and Suh, 2019).

Viool et al. (2019), calculated the economic impact of mismanaged plastic waste, based on quantifiable costs or direct impacts. Their study considered loss of revenue from marine tourism, clean-up costs for governments, and loss of revenue for fisheries and aquaculture They estimated that marine plastic pollution could have resulted in an economic loss of USD 6 to USD 19 billion in 2018 for 87 coastal countries around the world whose economies depend on fisheries and tourism industries. Dalberg (2021) estimated the cost of plastics produced in 2019 over its estimated lifetime. The study included the cost of Greenhouse gas (GHG) emissions, plastic waste management costs, and the cost incurred due to a reduction in marine ecosystem services. Dalberg (2021) estimated this cost will be at least USD 3.7 trillion (+/-USD 1 trillion) over the plastics' lifetime. More than 90% of this cost is not included in the current market price of plastics.

These impacts will continue to increase if no action is taken to stop plastic production, consumption, and leakage. A report by the Organisation for Economic Co-Operation and Development (OECD) states that the global plastic use and waste will triple by 2060 in the absence of plastic management policies. By 2060, plastic leakage to the environment is projected to double to 44 million tonnes a year, increasing the negative impacts on marine biodiversity and ecosystems, and further contributing to climate change (OECD, 2022b). Dalberg (2021) estimated that without substantial intervention, the societal lifetime costs of the virgin plastics projected to be produced in 2040 (lifetime cost of plastics excluding the market cost) could exceed USD 7.1 trillion, with a margin of +/- USD 2.2 trillion.

To reduce the volume of plastics, efficient political responses and legal tools are required at the local, national, and international level (Nielsen et al, 2019; da Costa, 2020). The responses can be ex-ante (i.e., before plastic production and waste generation) or ex-post (i.e., once the plastic waste is dumped) (Lachmann et al., 2017; Schmaltz et al., 2020; Van Rensburg et al., 2020). Ex-ante measures include retention and reduction of waste at source (Wang, 2018). This can be achieved through changing producers' behaviour, e.g., extended producer responsibility (Raubenheimer et al., 2020; OECD, 2022a), or changing consumers' behaviour, (e.g., through bans and taxes) (Oosterhuis et al., 2014; BFFP, 2021). Consumer choices can also be altered through positive reinforcements such as educational campaigns (Willis et al., 2017) and incentives, such as deposit refund schemes for Polyethylene Terephthalate (PET) bottles and plastic bags (Schuyler et al., 2018). In the case of ex-post responses, waste treatment and management techniques need to be addressed (Willis, 2018; Rajmohan et al., 2019). A report by Pew (2020) estimated that the volume of mismanaged plastics will more than double in the next 20 years if nothing is done. Jambeck et al. (2015) mention that to achieve a 75% reduction in the mass of mismanaged plastic waste, the 35 top-ranked countries with poor waste management practices would need to improve their waste management system by at least 85% by 2025. However, improving waste management infrastructure requires substantial investments (and time), especially in low and middle-income countries. The focus of these countries should first be on improving solid waste collection (UNEP, 2018a) and implementing local/coastal clean-ups (Rochman et al., 2016).

Some policies also aim at reducing plastics that have already escaped into the sea. For example, incentivising the fishing industry and rewarding fishers to bring back litter has proven to be successful in some cases (OSPAR, 2017; KIMO, 2010). This said, it might be more efficient to work on economic instruments that target land-based waste to reduce a significant amount of plastics, as most of the marine litter comes from land-based activities (Sheavly and Register, 2007; Jang et al., 2014; APEC, 2019). This said, in turn there is no one straight solution to curb the problem with plastics. The choice of a set of interventions for a country depends on the source of pollution being addressed, the country's institutional characteristics and infrastructure, consumer preferences and habitual behaviour, and the economy's overall sectoral composition (Oosterhuis et al., 2014).

Moreover, the transboundary nature of plastics along their lifecycle requires a truly global response to effectively tackle the crisis (UNEP, 2018b). In response to this, in March 2022, at the fifth session of the United Nations Environment Assembly (UNEA), a resolution was adopted to develop an international legally binding instrument on plastic pollution, including in the marine environment. The negotiations for the development of this “plastics treaty” are currently ongoing.

1.2. SOUTH PACIFIC OCEAN REGION

The Pacific Ocean is the largest of five oceans of the world and a major contributor to the world’s economy (Seidel and Lal, 2010). Scattered in the Southern part of the Pacific Ocean are 30,000 islands that comprise 22 habitable islands countries, which is home to more than 12 million people (Smith et al., 2007; Charlton et al. 2016; Statistics for Development Division, 2020). The South Pacific Ocean Region is 98% ocean and 2% land, which highlights the importance of the ocean for the inhabitants (SPREP, 2015). Most of these islands share a dependence upon the ocean for food and economic development (Filho et al., 2019; Andrew et al., 2019). These islands are considered as Small Island Developing States (SIDS) due to their small, isolated, and resource-limited area that face ‘specific social, economic and environmental vulnerabilities’ (UN, 2012; UNOPS, 2020).

The Pacific SIDS unique geography and rich biodiversity plays a key role in developing the region’s economy (Jupiter et al., 2014; UN, 2020). Tourism has been a major contributor to economic development within the Pacific SIDS for many years (Everett et al., 2018). In 2019, there were more than 2.2 million short-term visitors to these islands which generated USD 4 billion or 8% to the regional gross domestic product (GDP) by directly employing over 90,000 people (SPTO, 2021). The fisheries sector is also of fundamental importance for these islands, providing social-cultural benefits and food security for the locals (FAO, 2018). An average of 89% of households in the region consume local fish or seafood, equating to 37 kilograms per person annually (FAO, 2021). Fish consumption accounts for 50 to 90% of the diet of the coastal communities, 3 to 4 times the world average (Hilmi et al., 2018). The Pacific Ocean has the largest marine diversity in the world with up to 3,000 species found on just a single reef (SPREP, 2011).

However, the rapid increase in economic activities and urban communities within the Pacific SIDS is leading to increased preferences of imported and pre-packed products, resulting in growing volumes of disposable packaging and plastic waste (Friel et al., 2013; SPREP, 2018a). Additionally, these islands are vulnerable to plastic pollution due to their expansive coastlines of 57,797 km (Andrew et al 2019), position within the trade winds and at the outer edges of oceanic gyres (Eriksen et al., 2013).

Waste disposal in Pacific SIDS countries is calculated approximately 1 kg per person per day, compared to 0.6 kg/person/day the global waste disposal rate (SPREP, 2020a; Mohee et al., 2015). According to Asari (2019), out of all of the waste generated in these islands, around 14% is composed of plastic waste. Another study by Asia Pacific Waste Consultants (APWC 2020)[3] states that around 7 to 17% of all waste is composed of plastics, out of which 73% has potential to be leaked into the marine environment because of littering and uncontained disposal sites. Most of the plastics leaked consist of single-use packaging such as PET water bottles, plastic packaging, polystyrene containers, plastic cutlery and cups (Asari, 2019; Filho et al., 2019). In addition, plastic waste is also carried from other countries through winds, ocean gyres and other offshore sources of marine plastic pollution such as abandoned, lost or otherwise discarded fishing gear (ALDFG), which can represent the most significant types of debris on the South Pacific Islands (Richardson et al., 2016). These islands contribute only 1.3% of the global total of mismanaged plastic waste and yet the region is one of the main recipients of its impacts (Tudor and Williams, 2021; Jambeck et al., 2015).

These marine plastic pollution inflows not only threaten the economic system but also the natural environment, including coral reefs, mangroves, fisheries, seabirds, and marine mammals (Lachmann et al., 2017). They place additional burdens on the already over-stretched waste management infrastructure of South Pacific Islands (Farrelly et al., 2020).

Due to their limited land space, remoteness and geographic isolation, Pacific SIDS face unique and significant challenges in providing sustainable waste management systems (Mohee et al., 2015; Rojat et al., 2006). Limited segregation of recyclable materials is undertaken, and waste collected can end up in uncontrolled dumpsites and poorly managed landfills (UNEP, 2010; Dever and Every, 2021). The lack of containment causes significant risk of leakage into the environment and harm to terrestrial and marine ecosystems and human health (OECD, 2022a).

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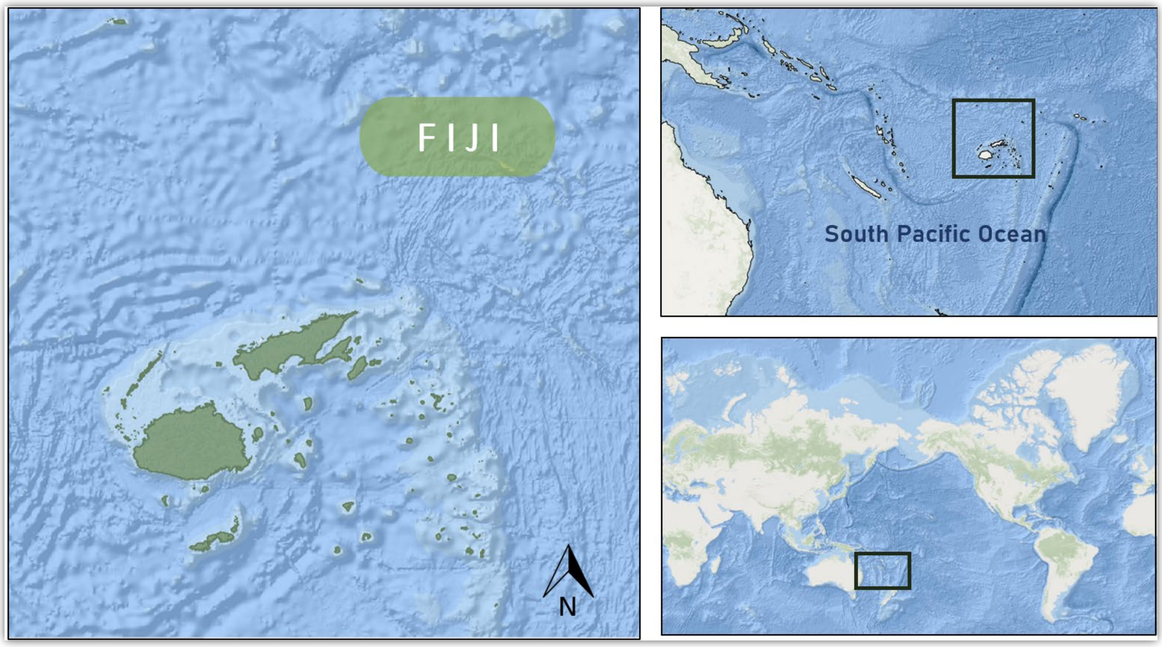
[3] This estimate is based on the estimation of single-used plastics in Fiji, Samoa and Vanuatu.

There are existing legal frameworks at multiple levels of governance for plastics (including local, national, regional and international level) waste, such as banning and levies on plastic bags, restriction of import and production of plastic packaging (Farrelly et al., 2020; Farrelly et al., 2021). However, the waste management and collection systems need significant improvement (SPREP, 2022). One of the key challenges for Pacific SIDS is the funding of a financially sustainable mechanism to support a robust waste management infrastructure (UNOPS, 2020; Farrelly et al., 2020). Given that Pacific SIDS resources are scarce and land area is limited, with an improved waste management system, raising public awareness is also essential to prevent and reduce plastic pollution and waste at source (Chowra, 2013).

Abandoned trash at the coast of Fiji (APWC).

2. CASE STUDY INTRODUCTION

Fiji is an archipelago in the southwest Pacific Ocean. It consists of 322 islands, scattered over about 3,000,000 km^2 and a third of which are permanently inhabited (**Map 1**) (Department of Foreign Affairs and Trade of Australia, 2022; FAO, 2022). **Table 1** provides an overview of some key data in Fiji.



Source: ESRI, 2018.

Map 1 – Location map of Fiji

Table 1 – General data of Fiji

Key Facts	
Official name	Republic of the Fiji Islands
Land Area	18,333 km^2
Exclusive Economic Zone	1.3 million km^2
Capital	Suva
Administration Districts	15 provinces; divisional (Central, Eastern, Northern and Western)
Climate	Tropical maritime
Terrain	Volcanic Island Archipelago
Population in 2019	889,955

Sources: Department of Foreign Affairs and Trade of Australia, 2022; Jagan, 1988; Foster, 2021; World Bank, 2020.

Fiji also has an extensive and high diversity of marine habitats, including estuaries, sea grass, macro-algal, soft shores, lagoons and coral reefs (Government of Fiji, 2020). These marine habitats support a rich biodiversity, which is a large source of revenue for the economy of the Fiji Islands (DoE, 2014).

Coral reef off the coast of Fiji (Shutterstock, John A. Anderson).

Fiji is the economic and technological hub of the South Pacific and has one of the region's most developed economies (World Bank, 2021). The Fijian economy is predominantly made up of the services sector (71%) followed by the industry sector (19%) and primary sectors (10%), including agriculture, forestry and fisheries (Fiji Bureau of Statistics, 2020a).

The main sector in the services industry is tourism. The Republic of Fiji has the most developed tourism offering in the Pacific region based on its palm-fringed white sand beaches, lush rainforests, coral reefs, lagoons, and five-star resorts (SPTO, 2021). The tourism industry contributed approximately 26% towards Fiji's GDP in 2019 (SPTO, 2021). The fisheries sector is also important to the economy of Fiji. Fisheries is the third largest natural resource sector, behind sugar and subsistence farming (Bacolod et al., 2020). Fisheries contribution to GDP in 2015 was estimated at 1.6% (FAO, 2022). In addition, fishing is valued for its cultural and recreational aspects (Kitolelei et al., 2011).

Fiji's developing economic activities are putting its rich biodiversity and ecosystems at risk (DoE, 2007). Most of the natural habitats are also degraded, and 67% of known mammal species are threatened or endangered (CBD, 2022). One of the main threats is increased plastic pollution, among others (Government of Fiji, 2020).

2.1. PLASTIC LEAKAGE ESTIMATES FIJI

According to APWC (2021a),19,764 tonnes of plastic waste was generated in Fiji in 2019. Plastic waste can either become managed waste[4] (also referred to as "properly disposed of waste") or mismanaged waste[5]. Of the total plastic waste volume,

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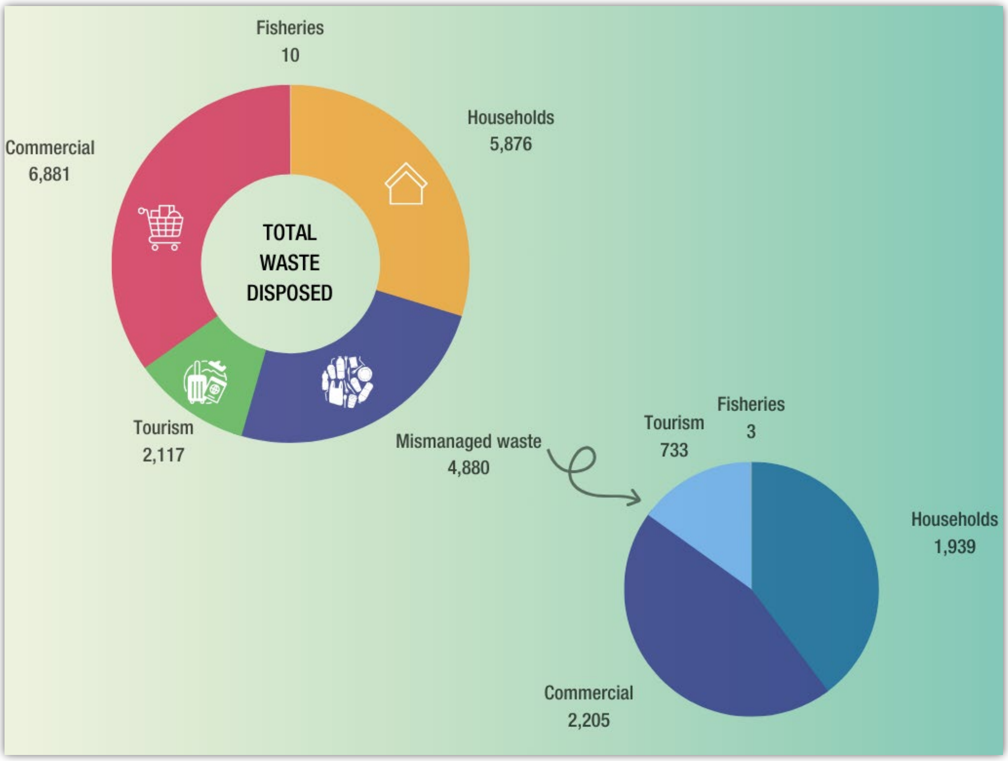
[4] According to APWC (2021a), "Managed waste is waste that when disposed is captured by formal waste management processes (landfill, dumpsite, recyclers, recyclers stockpiles). If properly managed, this waste will not have the potential to be leaked."

[5] According to APWC (2021a), "Mismanaged waste is waste that when disposed is not captured by formal waste management processes (landfill, dumpsite, recyclers, formal stockpile etc). Mismanaged waste has the potential to be leaked."

14,884 tonnes (75.6%) were managed plastic waste, while 4,880 tonnes (24.8%) were mismanaged plastic waste.

Approximately 86% of all the plastic waste (managed and mismanaged) consists of household and commercial waste[6] (**Figure 3**). While household and commercial waste are the largest overall quantities of general and plastic waste; when considering the per person disposal rate, tourists dispose seven times as much waste as a local resident per capita per day, largely contributed by land-based tourism. Land-based tourism accounts for around 94% of plastic waste from the tourism sector. Most of the plastic waste consists of single-use plastics, predominantly plastic bottles, Styrofoam containers and soft plastics made of PET and High-Density Polyethylene (HDPE) (APWC, 2021a; DoE, 2010).

Approximately 24.8% of all plastic waste generated in 2019 was mismanaged (APWC, 2021a). The main reasons for mismanaged waste in Fiji are a lack of adequate or designated areas for waste disposal and waste management plans. Therefore, dumping, burying and burning of waste is common, which exacerbates potential plastic leakage into the environment (DoE, 2010). In addition, leakage can still occur after collection, for example from landfills. Based on Jambeck et al. (2015), in this study it is assumed that 25% of all mismanaged plastics end up in the marine environment, they become marine plastics. It is important to note that this percentage is a conservative estimate of the amount of plastic waste that may be leaking into the ocean.



Source: APWC, 2021a.

Figure 3 – Plastic waste in tonnes in Fiji from different sectors (2019)

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[6] According to APWC (2021a), 'commercial' waste, besides commercial businesses, also includes institutional, medical, construction, industrial and uncategorised waste.

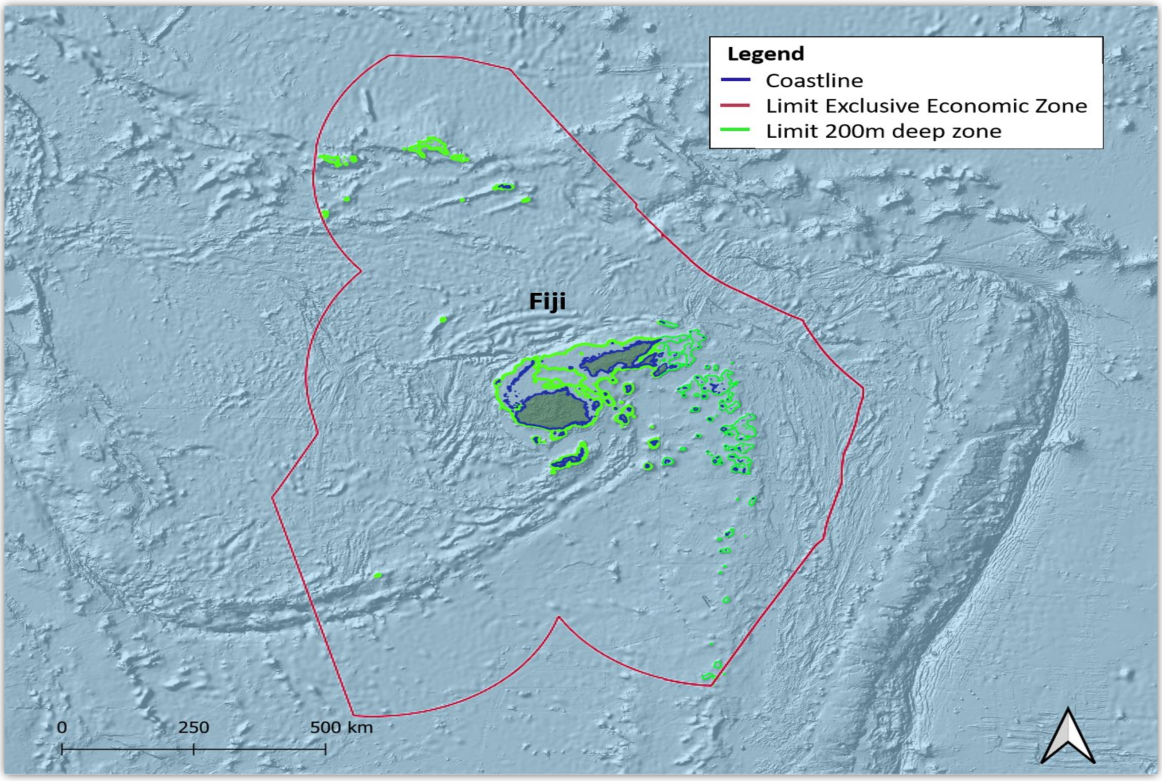
In the last several years, Fiji has taken several critical measures to address plastic pollution and has also introduced a robust legislative framework to prevent marine pollution and protect the oceans. As outlined by FAOLEX (2022), some of these relevant measures include:

- *The Environment Management Act (2005)* – sets out the framework for waste management and pollution control to protect the country's natural resources.
- *Environment Management (Waste Disposal and Recycling) regulation (2007)* – obliges the facilities that import or manufacture plastic bottles to hold a plastic bottle permit.
- *Fiji's Litter Act (2008)* – prescribes penalties for littering and makes it a criminal offence to deposit litter in public places.
- *Container deposit regulation (2011)* – this regulation defines requirements for a deposit refund scheme to ensure that used beverage containers are collected and recycled.
- *Environment and Climate Adaptation Levy Regulations (2017) (plastic bag levy)* – sets out the charges on plastic bags that must be collected by a cashier when a plastic bag is provided by the business to a consumer. This charge is then collected by the Chief Executive Officer (CEO) and Commissioner of Inland Revenue.
- *Environment Management Act (2019)* – prohibits plastic bags, stating that it is an offence to manufacture, sell, supply, or distribute them. This legislation was further supported by the Climate Change Bill (2019), which bans single-use plastic bags, polystyrene and single-use containers, straws, cups, and utensils.

Other than the above-stated legal instruments, Fiji also participates in regional initiatives such as Cleaner Pacific (2025), Pacific Regional Waste and Pollution Management Strategy (2016–2025) and Pacific Marine Litter Action Plan (2018-2025). These actions lay out regional waste management strategies both on land and at sea, aiming to minimise marine litter across the Pacific Island Countries (PICs) and Territories (SPREP, 2018b).

3. IMPACT OF MARINE PLASTICS IN FIJI (2019)

Plastic leakage can cause different economic and environmental impacts. One issue that will determine the impact of plastics is where it accumulates. For example, plastics floating on the sea surface can impact fisheries, whereas plastics that end up on a beach can negatively affect tourism numbers. Different estimates of where plastics end up in the environment exists. According to GRID-Arendal (2018)[7] 0.5% of plastics accumulate on the sea surface, 33.7% on the coastline and seafloor, 26.8% in coastal waters (less than 200 metres deep), and 39% in the open ocean (over 200 metres deep). Lebreton et al. (2019), estimated that 98.6% ends up on the shoreline, 0.18% accumulates in coastal waters, and 1.2% in the open ocean. **Map 2** presents an overview of these different regions within Fiji's territory.



Sources: Flanders Marine Institute, 2019; University of California Berkeley library geo data, GEBCO, 2012.

Map 2 – Marine regions of Fiji

The following sections provide a more in-depth overview of the different impacts caused by mismanaged plastic waste that leaks into the marine environment.

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[7] Supporting papers: Jang et al. (2015), Lebreton et al. (2012), Jambeck et al. (2015), Cózar et al. (2014), Eriksen et al. (2014), van Sebille et al. (2015).

3.1. IMPACT ON FISHERIES

Fisheries are not only a source of marine plastics, but also suffer from its impact. This impact can be directly and easily measurable through market values (McIlgrom et al., 2011), or indirectly, as related to the degradation of natural marine capital assets. Direct economic impacts can occur due to the costs to repair or replace damaged or lost gear due to encounters with marine plastics (e.g., repairing vessels with tangled propellers, clogged water intakes, etc.), as well as the loss of earnings due to lost productive time dealing with marine plastics encounters and from reduced or contaminated catches (Takehama, 1990; McIlgrom et al., 2009; Newman et al., 2015).

Mouat et al (2010) conducted a survey study of Scottish net fisheries to investigate the extent by which this sector is impacted by marine litter, concluding that marine litter negatively impacted Scottish fisheries' 2008 revenue by 5%. Globally, an average of 80% of all marine litter is composed of plastics (Dunlop et al., 2020). Therefore, it can be considered that the impact of marine plastics on Scottish fisheries' revenue was 4%, i.e., 80% of 5%. This impact is broken down into four cost categories: dumped catch, net repairs, fouling incidents, and time lost clearing nets (Mouat et al., 2010). A series of studies have used Mouat et al. (2010) as input for their calculations of the cost to fisheries of marine plastics. For example, Arcadis (2014) estimated and adjusted the impact of marine litter on European Union (EU) fisheries at 0.9% of the revenue. UNEP (2014a) and Trucost (2016) calculated that marine plastics cause an annual global revenue loss of 2% in marine fisheries.

Takehama (1990) estimated that the cost of damage on Japanese fishing vessels caused by marine debris, based on statistics from the insurance system, resulted in an estimated impact on fisheries' revenue at 0.3% of gross annual value.[8] This estimate was used by McIlgorm et al., (2011, 2009) to estimate the economic cost of marine debris damage in the Asia-Pacific region.

Artisanal fishing boat in Fijian waters (IUCN).

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[8] McIlgrom et al., 2020 did update this impact estimate to 1% in their recent study on marine plastics impact in the APEC Region.

In 2019, Fiji's fisheries reported a catch volume of 44,672 tonnes, caught by 1,276 fishing vessels and generating USD 30,623,786 in revenue (Fiji Bureau of Statistics, 2020b; FAO, 2022; Gillet, 2020). Applying the global estimate of the impact of marine plastics on fisheries revenues used by UNEP (2014a) and Trucost (2016), gives a potential loss of over USD 600,000 to the fisheries sector of Fiji in 2019[9].

Fiji's fisheries sector and others fishing in the Southeast Pacific, also contribute to marine plastics through abandoned, discarded, or lost fishing gear or ALDFG (APWC, 2021a), which in return impacts the fishing industry (Lusher et al., 2017). ALDFG can perform "ghost fishing," which means that it can continue to trap fish and crustaceans, as well as ensnaring and capturing other species, given that this gear is no longer being controlled (Edyvane and Penny, 2017; NOAA Marine Debris Program, 2015). Ghost fishing, despite not being addressed in this study (which looks only at the direct costs to the fishing sector) is an important aspect to consider when looking at fisheries and marine plastics. Fish ensnared in lost fishing gear can lead to increased fish mortality, reduced fish catch, reduced sustainability of the catch (Butler et al., 2013), and revenue losses of 5% or even higher (Mathews et al., 1987, Nakashima and Matsuoka, 2004; Tschernij and Larsson, 2003). In 2019, APWC, based on fisheries statistics and Richardson et al. (2019a), estimated leakage of fishing gear in Fiji as follows: (i) 88 nets, (ii) 116 traps and (iii) 2,454 lines. This quantity of gear corresponds to an estimated 19.9 tonnes of plastic gear leaked that year (APWC, 2021a). In a second estimate, using trade statistics, APWC (2021a) calculations suggest that an average of approximately 13.25 tonnes of fishing gear could be leaked annually in Fiji's marine environment from its fisheries, providing two estimates of the potential volume of ALDFG.

Shark caught in fishing net, Fiji (Tom Vierus, Ocean Image Bank).

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[9] The fisheries sector in PICs may be up to two to three times larger than what is reported officially (APWC, 2020). If this is the case, this would increase the impact of marine plastics on fisheries revenue, the economy, and livelihoods.

In addition to the rates at which fishing gear is lost, other factors that contribute to the likelihood of ghost fishing are the gear's degradation rate, which depends on different factors, including for example: water temperature, catch efficiency of the gear, susceptibility of species to ghost fishing, depth where the gear is lost, and/or the tidal and current conditions, which influence whether nets ball up faster or slower (Antonelis et al., 2011; Brown and Macfadyen, 2007; Erzini et al., 1997; Kaiser et al., 1996; Masompour et al., 2018). Thus, although ghost fishing is not included in this study as a direct cost to the fisheries sector, if included, ghost fishing would increase the cost estimates by increasing the estimated losses to the fisheries sector due to marine plastics.

3.2. IMPACT ON TOURISM

As with fisheries, tourism is another sector that is not only a source of mismanaged plastics but is also impacted by the presence of marine plastics. One of the main impacts on tourism from marine litter comes from the pollution of beaches and coastal areas. Mismanaged waste significantly diminishes the aesthetics of coastal areas. Beyond that, plastic debris poses potential physical harm and long-term health risks to people (Deloitte, 2019). These can have a negative impact on tourists' willingness to visit (WTV) beaches, leading to an economic loss for businesses and countries reliant on tourism (Jang et al., 2014; Kosaka and Steinback, 2018). Ballance et al., (2000) state that tourist behaviour, including WTV, can change according to the numbers of plastic items present on beaches.

Fisherman's boat docking at Lautoka Island in Fiji (Shutterstock, Worchi Zingkhai).

A study conducted by Krelling et al. (2017) used a contingent valuation to assess the WTV of a beach under different littering scenarios on two beaches in Brazil. Ballance et al. (2000) used a travel cost method to assess the impact of plastics on tourism in Cape Town, South Africa. **Table 2** provides an overview of the results of both studies.

Table 2 – Willingness to visit a beach under different littering scenarios

Plastic items present per metre	International tourists not willing to visit the beaches
Ballance et al. (2000)	
0-1.8 items	No change
1.8-8 items	85%
8 items and more	97%
Krelling et al. (2017)	
0-1.2 items	No change
1.2-9.6 items	19.9%
9.6-24 items	42.7%
More than 24 items	82.4%

On a global level, UNEP (2014a) and Trucost (2016) assumed a 3% loss of global marine tourism revenue caused by marine litter, while McIlgrom et al., (2020) used a value of 1.5% of marine tourism GDP for their study on the economic costs of marine debris to The Asia-Pacific Economic Cooperation (APEC) economies. These, however, are studies that focus on a global or regional impact, including many countries that are not as dependent on beach-going tourists as Fiji. Conversely, Jang et al., (2014) found that visitor visits to Geoje's beaches, in the Republic of Korea, decreased by 63% after litter washed up on the beaches after a storm. These values are closer to what was found by Ballance (2000) and Krelling et al. (2017). These studies highlight that marine plastics pose a significant threat to the tourism sector of Fiji, and the Fijian economy overall, given the importance of tourism. Applying the estimated global percentage loss caused by plastic pollution to the tourism sector used by UNEP (2014a) and Trucost (2016) to the revenue generated by the tourism in sector in Fiji gives an estimated loss of USD 164.5 million in 2019.

3.3. CLEANUP COSTS

To estimate the impact of marine plastics, in addition to revenue losses for the fisheries and tourism sectors UNEP (2014a) used the opportunity cost of volunteered time to estimate the global clean-up cost imposed by plastic litter on beaches. For example, according to data of the last five years from the International Coastal Clean-up, 152-person days were used to clean 536 kilograms of plastics from the coastline of Fiji (Ocean Conservancy, 2019). However, according to Deloitte (2019), local municipalities and governments are crucial in establishing waste management systems and funding waste collection and treatment processes. Consequently, in many countries, a varying yet frequently substantial portion of the budget is allocated to these tasks. Deloitte (2019) estimated the clean-up costs for coastlines, waterways, marinas, and ports. For Oceania they estimate this cost at 0.06 USD per capita, which would be USD 55,108 for Fiji in 2019[10].

In addition to the costs presented above, marine plastics can cause other social and environmental impacts.

3.4. FURTHER IMPACTS FROM MARINE PLASTICS

3.4.1. Employment

If plastic pollution accumulating on the coastline decreases the number of visitors, this will not only reduce the revenue generated by the tourism sector but can also have a significant impact on the number of people employed in this sector. The tourism sector in Fiji supports over 118,000 jobs (IFC, 2020). In addition, the multifaceted structure of the tourism sector implies that it has strong links with other sectors, and channels spending into local supply chains, including agriculture, building and construction, cultural industries, and more (IFC, 2020; APWC, 2021a). Any impact on the tourism sector will thus also affect these sectors.

Marine plastic pollution has a negative impact on fisheries revenue, and consequently, on the number of people employed in the fisheries sector. Numerous studies have attempted to estimate the proportion of the population active in various parts of the fisheries sector. Ram-Bidesi et al. (2011) reported that coastal subsistence fishers in Fiji account for 65% of coastal fishing activity. Starkhouse (2009) estimated the number of (a) subsistence fishers in the country to be about 23,000; (b) full-time artisanal fishers to be about 5,000; and (c) part-time artisanal fishers to be 12,000. Gillett (2016), using data from an earlier study by Hand et al. (2005), estimated there were 9,000 artisanal coastal fishers and 3,000 coastal subsistence fishers in Fiji. In addition, Hand et al. (2005) estimated employment in the offshore fishing to be 510 full-time equivalents[11].

Finally, Fiji also has recreational fisheries for tourists. Increased marine plastics impacting fisheries will also affect this sub-sector of the tourism industry and the people employed in it.

3.4.2. Food security

In addition to contributing to employment and household income (Andrew et al., 2019), fisheries also ensure food security (FAO, 2022). Fish makes an important contribution to the diet of residents in Fiji, with daily consumption of fresh fish in indigenous Fijian households estimated at 23.4% (NFNC 2007). In 2013, per capita fish consumption was estimated at approximately 35.6 kg (FAO, 2022). Marine plastics can impact food security both directly through reduced fish stock, and by contaminating fish with macro- and microplastics.

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[10] Based on a population of 918,465 in Fiji in 2019 (https://data.worldbank.org/indicator/SP.POP.TOTL?locations=FJ).

[11] In addition, according to the FFA (2015), 3,667 Fijians were employed in the offshore tuna industry in 2014.

3.4.3. Balance of trade

Tourism is Fiji's main revenue source, contributing approximately 38% of the country's GDP (IFC, 2020). Tourism also contributes to around 40% of foreign exchange earnings (SPTO, 2021). A reduction in tourism would strongly impact these earnings.

Fisheries' contribution to GDP in 2014 was approximately 1.6 % of national GDP. In addition, Fiji both imports and exports fish. Gillett (2016) found that for the period 2010-2014, the export of fishery products represented between 5.9% to 19.5% of the value of all Fiji's exports. The export value of fish and fishery products in 2015 was estimated at USD 110 million, including an estimated USD 58 million as re-exports, and USD 104 million worth of imports (FAO, 2022). A reduction in fish capture would also impact the balance of trade, as reduced local catches can increase fish imports and reduce foreign exchange earnings.

Furthermore, many PICs receive substantial government revenue from foreign fishing activities in their zones. In 2014, Fiji received USD 555,814 as access fees for foreign fishing, which amounts to approximately 0.04% of total government revenue for the year (FAO, 2022). Although the impact of marine plastics on foreign fishing vessels was not included in the cost-benefit analysis of this study, a reduction in their fish catch or an increase in their costs could impact the revenue received by Fiji from local fisheries.

3.4.4. Other impacts

Marine plastics are not the only problem affecting the fisheries and tourism sectors, and the economy of Fiji. Recently, some of the biggest impacts on the local economy and tourism sector in Fiji have been cyclones (BOM and CSIRO, 2014; Government of Fiji et al., 2017) and the global travel restrictions following the outbreak of Covid-19, creating seriously adverse economic impacts, including a collapse of the tourism industry (IFC, 2020; Chand Nair, 2022). Although improving, the tourism sector has not yet fully recovered. In addition, the tourism sector is also vulnerable to the impact of climate change, manifested by sea level rise, an increased frequency and intensity of storms, which can deter tourists from visiting the island, and coastal erosion, which can create a loss or degrade tourism resources such as beaches (Government of Fiji et al., 2017; Ministry of Economy, 2018).

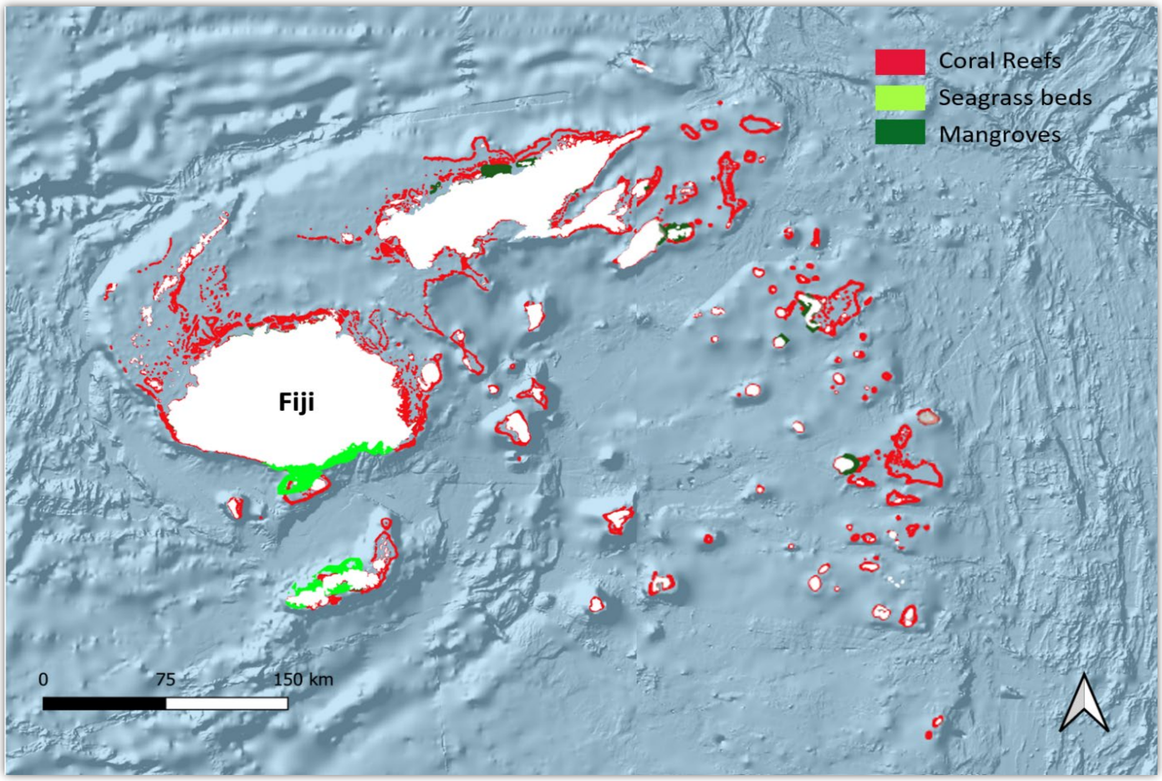
While this study includes a climate change impact scenario in the future fisheries revenue scenarios, the full extent of the impact of climate change – including for example: changing migration and distribution patterns or fish reproduction of certain fish species, altered habitats of fish species, and impacts of more frequent extreme weather events on fishing efforts (Government of Fiji et al., 2017; Palacios-Abrantes et al., 2022) – has not been considered. Furthermore, in addition to the potential long-term impact of ghost fishing, overfishing has reduced the available fish resources in Fiji (Breckwoldt and Seidel, 2012; Fache and Pauwels, 2020).

3.4.5. Impact on marine and coastal ecosystems

Beyond the direct impact of marine plastics on fish stocks, there are several challenges that could seriously impact the future of marine natural assets. Fiji's coastal zone and marine ecosystems are not only characterised by beaches, but also by mangroves (488.4 km^2), seagrass beds (1,740.4 km^2) and coral reefs (3,369.7 km^2) (UNEP-WCMC, 2022) (**Map 3**). These ecosystems not only play an increasingly key role in tourism but are also an integral component in natural coastal defence and the ecology of the island.

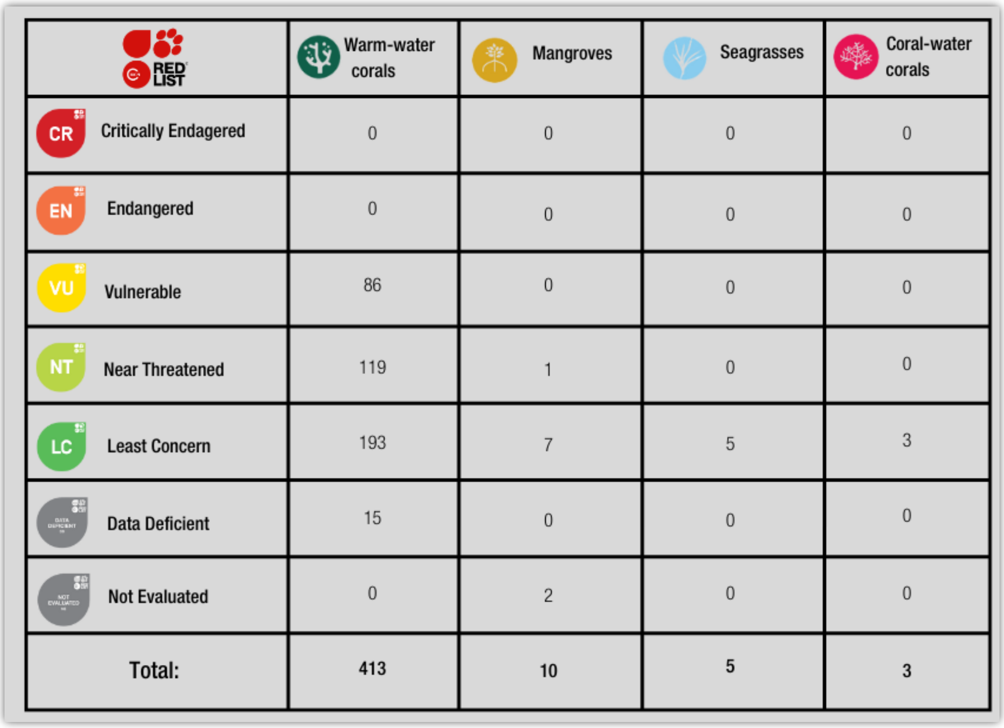
Coral reefs, mangroves and seagrass beds provide a range of key ecosystem services, such as protection of the shoreline from erosion and storm damage, breeding grounds for many species of fish and other marine species, water purification, disease control, carbon sequestration, nutrient cycling, sediment reduction, and recreation (Dudley et al., 2010, 2015; Gonzalez et al., 2015; Barbier et al., 2017; Himes-Cornell et al., 2018; Luisetti et al., 2013; Mtwana Nordlund et al., 2016; Ondiviela et al., 2014; Ruiz-Frau et al., 2017). According to the “Fiji National Marine Ecosystem Service Valuation” report, the national value of the marine environmental services assessed, including those provided by corals and mangroves, was in the range of FJD 2,281.81–2,487.41 million per year in December 2014 dollars (Gonzalez et al., 2015). These essential ecosystem services underline the importance of conserving and restoring these ecosystems. In addition, some species – specifically certain coral species – have a critical or vulnerable conservation status (**Figure 4**).

In addition, these ecosystems provide resources that support traditional practices of local communities (Gilman, et al, 2006). For instance, coastal and marine resources provide livelihoods for several rural communities in the fisheries sector, as well as recreation, sports, and enjoyment, and are an overall source of employment for many people (Gonzalez et al., 2015; Ruttenberg et al., 2018).



Sources: Giri et al., 2011; UNEP-WCMC, 2021; UNEP-WCMC et al., 2021.

Map 3 – Areas of coral reefs, seagrass beds, and mangroves in Fiji



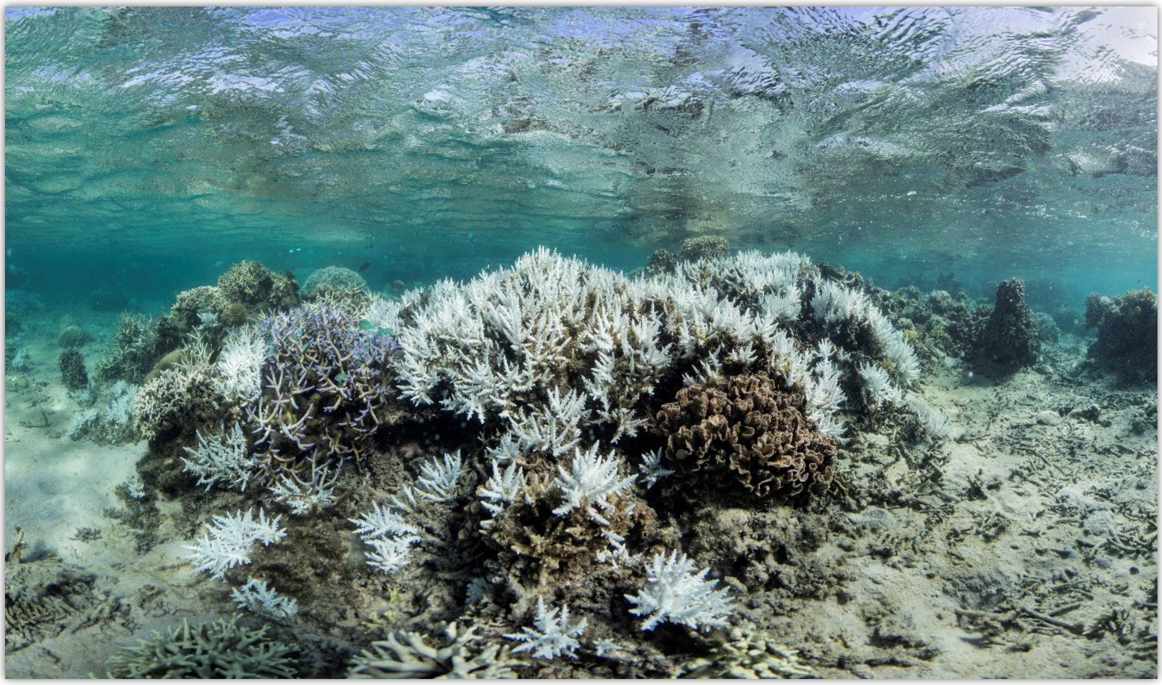
	Warm-water corals	Mangroves	Seagrasses	Coral-water corals
CR Critically Endagered	0	0	0	0
EN Endangered	0	0	0	0
VU Vulnerable	86	0	0	0
NT Near Threatened	119	1	0	0
LC Least Concern	193	7	5	3
Data Deficient	15	0	0	0
Not Evaluated	0	2	0	0
Total:	**413**	**10**	**5**	**3**

Source: UNEP-WCMC, 2022.

Figure 4 – IUCN Red List status of coral, mangrove and seagrass species in Fiji (2022)

Coral reefs, seagrasses and mangroves are affected by marine plastics (NOAA Marine Debris Program, 2016; Tekman et al., 2022). For example, plastic debris interferes directly with the ecological role of mangrove forests (Ivar do Sul et al., 2014), they obstruct water flows in mangrove areas (Kantharajan et al., 2018) and can also interfere with establishment of mangrove forests (Smith, 2012). Coral populations can decrease significantly as the amount of litter increases (Richards and Beger, 2011; Yoshikawa and Asoh, 2004). Richards and Beger (2011) found in their research in the Majuro lagoon, Republic of the Marshall Islands, a significant negative correlation between the level of hard coral cover and coverage of marine debris. Plastics can also increase the degree of disease contracted by corals (Lamb et al., 2018). Marine litter can also negatively affect seagrass ecosystems (Ganesapandian et al., 2011). Abandoned fishing gear damages seagrass beds by re-suspending sediments, disturbing rhizomes, and impacting the root structure of seagrasses (Barnette, 2001). In addition, mangrove forests and seagrass beds function as both traps and filters for marine plastics, including microplastics (Debrot et al., 2013; Sanchez-Vidal et al., 2021).

The impact of plastics should not be seen as an isolated effect. Plastic pollution is an additional stressor on marine ecosystems that are already dealing with multiple stressors (Lartaud et al., 2020; Tekman, 2022). Climate change causes coral bleaching (Petit and Prudent 2010), ocean acidification (Godbold and Calosi, 2013), and rising sea levels, accompanied by more frequent and severe storms (Sippo et al., 2018; Hughes et al., 2017). Further impacts occur through pollution from leakage of sediments, fertilisers and pesticides, and chemicals (Orth et al., 2006; Lovell et al., 2004; Silbiger et al., 2018; van Dam et al., 2011), as well as due to overfishing (Government of Fiji et al., 2017; Burke et al., 2011; Zaneveld et al., 2016), unsustainable tourism (Burke et al., 2011; Lamb et al., 2014), algal blooms (Franks et al., 2016), and invasive species (Biswas et al., 2018; Unsworth et al., 2018).



Coral bleaching in Fiji (The Ocean Agency-Ocean Image Bank).

An ecosystem's degradation caused by plastics pollution in marine and coastal habitats impacts tourism, the fish stocks that depend on these habitats, as well as marine wildlife in general. Marine biodiversity that is not directly targeted by fisheries – such as seabirds and marine mammals – are not only impacted through habitat degradation, but also suffer directly from marine plastic pollution.

3.4.6. Impact on marine wildlife

Fiji has a great diversity of marine mammal species, including ten confirmed species (Government of Fiji, 2020). As many as 15 other species are also likely to be resident or transient species in Fiji, but there is a lack of evidence to confirm this (Miller et al., 2016; UN, 2017). The waters of Fiji are a nesting ground for five of the seven species of sea turtles: green, hawksbill, leatherback, loggerhead, and Olive Ridley (WCS, 2019). Marine turtles are important to Fiji as they are considered 'cultural icons' and bring prestige to the traditional ceremonies of the country (WWF, 2018). Local communities have joined efforts to preserve these species through different educational and data collection campaigns (WWF, 2017; UNEP, 2018b). There are approximately 30 different seabird species (BirdLife International, 2022). Many of these species are threatened (**Table 3**).

Table 3 – IUCN Red List status of threatened marine species in Fiji (2022)

Marine mammals		
Sperm Whale	*Physeter macrocephalus*	Vulnerable
Fin Whale	*Balaenoptera physalus*	Vulnerable
Blue Whale	*Trichechus manatus*	Endangered
Sea turtles		
Loggerhead Turtle	*Caretta caretta*	Vulnerable
Leatherback	*Dermochelys coriacea*	Vulnerable
Olive Ridley	*Lepidochelys olivacea*	Vulnerable
Green Turtle	*Chelonia mydas*	Endangered
Hawksbill Turtle	*Eretmochelys imbricata*	Critically endangered
Seabirds		
Wandering Albatross	*Diomedea exulans*	Vulnerable
Buller's Shearwater	*Ardenna bulleri*	Vulnerable
Providence Petrel	*Pterodroma solandri*	Vulnerable
Pycroft's Petrel	*Pterodroma pycrofti*	Vulnerable
Black Petrel	*Procellaria parkinsoni*	Vulnerable
White-winged Petrel	*Pterodroma leucoptera*	Vulnerable
White-necked Petrel	*Pterodroma cervicalis*	Vulnerable
Campbell Albatross	*Thalassarche impavida*	Vulnerable
Collared Petrel	*Pterodroma brevipes*	Vulnerable
Polynesian Storm-petrel	*Nesofregetta fuliginosa*	Endangered
Phoenix Petrel	*Pterodroma alba*	Endangered
Far Eastern Curlew	*Numenius madagascariensis*	Endangered
Fiji Petrel	*Pseudobulweria macgillivrayi*	Critically endangered
Beck's Petrel	*Pseudobulweria becki*	Critically endangered

Sources: Taylor et al., 2019; Cooke et al., 2018; Seminoff, 2004; Casale et al., 2017; Abreu-Grobois et al., 2008; Wallace et al., 2013; Mortimer et al., 2008; BirdLife International, 2017; BirdLife International, 2018a; BirdLife International, 2018b; BirdLife International, 2018c; BirdLife International, 2018d; BirdLife International, 2018e; BirdLife International, 2018f; BirdLife International, 2018g; BirdLife International, 2018h; BirdLife International, 2018i; BirdLife International, 2018j; BirdLife International, 2018k; BirdLife International, 2018l; BirdLife International, 2019.

Marine plastics can also endanger marine fauna. Kanhai et al. (2022) classify the impact of marine plastics on biodiversity as follows: (1) Biological effects (e.g., ingestion of plastics); (2) Physical effects (e.g., entanglement); (3) Ecological effects (e.g., introduction of invasive alien species); and (4) Chemical effects (e.g., transporter of pollutants). Tekman et al., (2022), in their extensive literature review on the effects of plastic debris and hazardous substances on marine species, classify these impacts on marine fauna as:(i) Physical interactions, specifically: entanglement, ingestion, colonisation, and contact or coverage; and (ii) Chemical interactions: additives and absorbed substances.

The interactions have impacts on marine species such as seabirds, sea turtles, marine mammals, sharks, rays, and sponges (Tekman et al., 2022). According to the Convention on Biodiversity (CBD) Report, ‘Marine Debris: Understanding, Preventing and Mitigating the Significant Adverse Impacts on Marine and Coastal Biodiversity’ (2016), the total number of species known to be affected globally by marine debris (mainly plastics) is around 800; of those, the proportion of cetacean and seabird species affected by marine debris ingestion is 40% and 44%, respectively (CBD, 2016). Whereas, according to Fossie et al. (2018) it has been documented that plastic debris has negatively impacted over 1,400 species of marine fauna.

Ingestion: A wide range of animals ingest plastics. Certain marine animal populations – especially those that feed exclusively at sea, such as seabirds and sea turtles – present plastic debris in their stomachs (Hammer et al., 2012; Wilcox et al., 2015). Sea turtles can, while feeding, ingest plastic debris at all stages of their lifecycle (Mascarenhas et al., 2004), which can potentially have lethal consequences (Schuyler et al., 2014). For example, Wilcox et al., (2018) found a 50% probability of mortality once the sea turtles they analysed had 14 pieces of plastics in their digestive system. Discarded and semi-inflated floating bags are particularly hazardous as they are often mistaken for jellyfish and can block the oesophagus once ingested (Gregory, 2009). Tekman et al. (2022), analysing the studies collected in the LITTERBASE database[12], found a total of 272 seabird species had encountered plastic debris by ingestion. Reinert et al. (2017), found that 11% of 6,561 examined manatees had ingested marine debris or had become entangled, 50 of which died as a direct result.

Entanglement: happens if a plastic item wraps itself around the body, for example abandoned or lost fishing gear (Macfadyen et al., 2009; Richardson et al., 2019b). Marine mammals are among the species most affected by entanglement (Hammer et al., 2012). Fishing gear poses special risks for large, air-breathing marine animals, such as whales, dolphins, seals, sea lions, manatees, and dugongs, drowning after they become entangled in the nets (Laist, 1997; Lusher et al., 2018). Other species that are affected through entanglements are sharks, rays, and chimaeras (Parton et al., 2019).

Colonisation by alien species can be facilitated by plastic debris, which can be a threat to marine biodiversity and ecosystems. Aggressive invasive species can be dispersed by free-floating marine plastics. Their introduction can endanger sensitive, or at-risk coastal environments (García-Gómez et al., 2021). Plastic debris can function as vectors, transporting viral and bacterial pathogens (harmful to both humans and animals), potentially spreading them to new areas (Bowley et al., 2021).

Contact or **coverage** with plastics, also called smothering, is another type of interaction. For example, coverage of sponges with plastics can impair prey capture and growth rates (Mouchi et al., 2019).

Chemical impacts occur: (1) because of harmful substances associated with plastics, such as Bisphenol A (BPA) or flame retardants; and (2) through sorption and desorption of chemical pollutants (Hermabessiere et al., 2017, Tekman et al., 2022).

According to Tekman et al. (2022), plastic pollution should always be considered in the context of the many other stressors affecting the marine environment. At present, plastic pollution alone may, by itself, not drive critical decreases in populations; it may just push an individual, population or ecosystem into decline and possibly over a critical threshold. For example, habitat destruction impacts all marine wildlife in Fiji (Government of Fiji et al., 2017; Government of Fiji, 2020). Globally, seabirds are

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[12] https://litterbase.awi.de/.

threatened by bycatch and overfishing, climate change, and invasive species (Croxall et al., 2012; Dias et al., 2019). Turtles are also threatened by climate change (Laloë et al. 2016), as well as by harvest (Rupeni et al., 2002) and bycatch (OFP, 2001); while birds are at risk due to predation by cats, rats, pigs, and by harvesting Banh (Watling, 2013; Tekman et al., 2022). Other impacts on marine wildlife come from collisions with boats (Jägerbrand et al., 2019), chemical pollution (Arzaghi et al., 2020), noise pollution (Badino et al., 2016) and ocean deoxygenation (Laffoley and Baxter, 2019).

Tour around Fiji (APWC).

In this study, the impact analyses for the fisheries and tourism sectors, as well as the presentation of the effects on marine ecosystems and wildlife, as discussed above, focus mainly on interactions with macroplastics. However, **microplastics** are also of concern. Marine plastics, specifically those with a lifetime of hundreds of years, tend to degrade into micro- and nano-plastics over time. The size of these plastic pieces facilitates their uptake, can block the digestive tract, and contribute to the chemical body burden eliciting toxicological effects (Carbery et al., 2018; Tekman et al., 2022). These plastics may contain chemical additives and contaminants, some of them with suspected endocrine disrupting effects that when ingested, may be harmful for marine animals (Gallo et al., 2018; Prokić et al., 2019). In addition to the direct ingestion of plastic debris, plastics are also ingested by larger animals higher in the food chain. Microplastics are easily ingested by small organisms, such as plankton; contaminants leach from plastics tend to bioaccumulate in those organisms that ingest them – the higher the trophic level, the higher the chemical concentrations (Hammer et al., 2012). Markic et al. (2018), in their study on ingestion of plastics by fish, commonly part of the diets of the inhabitants of PICs, found plastics in 33 of the 34 species examined. They found the highest concentration in fish in Rapa Nui, located within the South Pacific subtropical gyre, where the concentration of marine plastics is high. Furthermore, the evidence that humans are exposed to microplastics is mounting, but the understanding of the health risks is still incomplete (Dalberg, 2021).

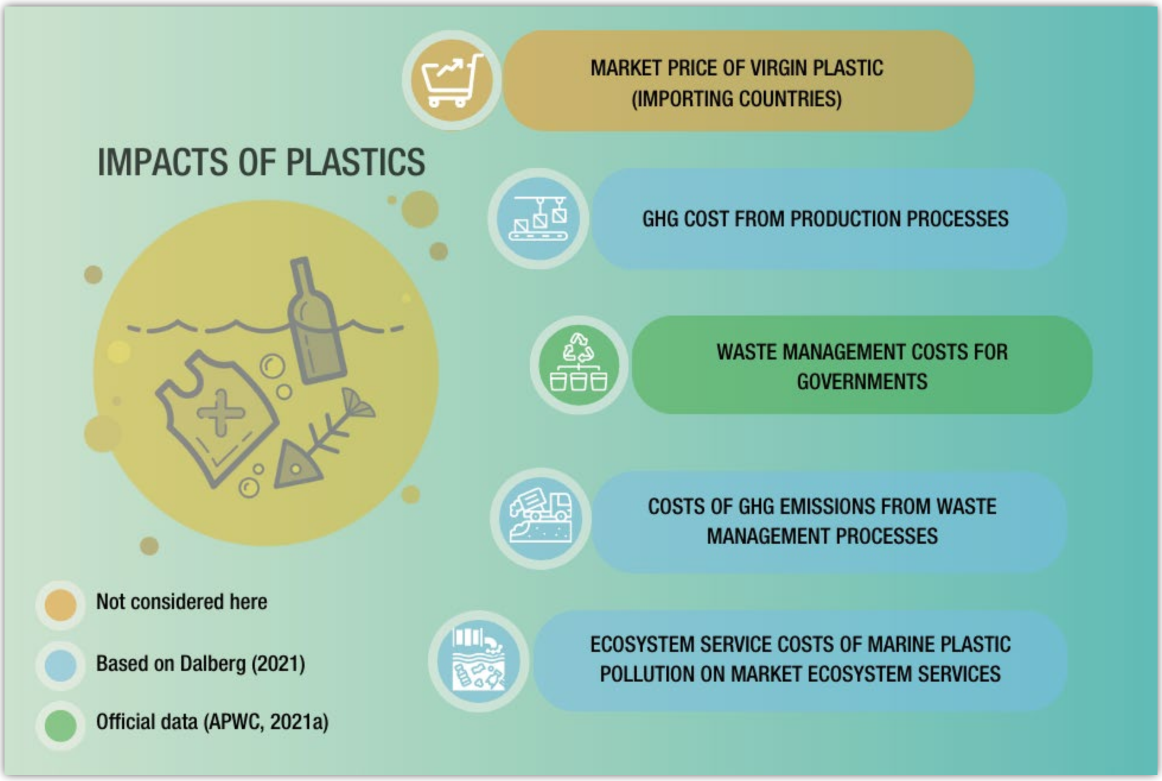
Although some estimates of the potential economic costs of marine plastics were presented in the previous parts, they do not fully capture the impact on ecosystems, while also not taking into consideration the volume of plastics leaked into Fijian waters. No data are available on plastics that enter the marine environment from Fiji from non-national sources, but in the following sections, this report will aim to connect plastic waste generation and marine plastic leakage from Fiji with an estimate of the economic impact of this mismanaged waste.

4. THE COSTS OF PLASTIC WASTE IN FIJI (2019)

4.1. METHODOLOGY

In this report, the results generated by Dalberg (2021) will be used to estimate the economic cost of plastics in Fiji. Benn et al. (2022), also used these estimates in their report "Economic case for a circular plastics economy in Africa" to estimate the economic costs of plastics in Côte d'Ivoire, Kenya and South Africa. The first estimates presented here, provide an approximation of the minimum cost to society of plastic waste generated in Fiji and plastics leaked into the marine environment (considering only plastic leakage from Fiji). The next part of this report provides projections for how these costs could grow under a Business-as-Usual (BaU) scenario and compares this with the costs under a recycling scenario.

Figure 5 provides an overview of the quantifiable costs considered here to estimate the societal costs of plastic waste in Fiji in 2019, based on Dalberg (2021). As the focus is only on plastic waste and not annual plastic production and consumption in Fiji, the market price of virgin plastics is not considered. The waste management costs are based on official data (APWC, 2021a).



Source: Dalberg, 2021.

Figure 5 – Overview of dimensions that make up the quantifiable minimum lifetime cost of plastics

APWC (2021a) provided the following inputs that were used to estimate the waste management cost of plastics generated in 2019:

- **Input 1:** Public solid plastic waste management costs amounted to FJD 3,187,920 (USD 1,479,930).
- **Input 2:** 19,674 tonnes of plastic waste generated in 2019 (either managed or mismanaged).
- **Input 3:** Annual estimated amount of waste disposed of through formal waste management processes in 2019[13], amounted to 139,558 tonnes, out of which 14,884 tonnes were plastics (around 11% of total).
- **Input 4:** 4,880 tonnes of mismanaged plastic waste.
- **Input 5:** 1,220 tonnes of plastics leak into the marine environment (based on Jambeck et al., 2015).

The cost of (plastic) waste in 2019 is thus estimated at **FJD 22.8** (USD 10.6) per tonne, and the total plastic waste management costs amount to **FJD 339,332** (USD 157,759).

Dalberg (2021) based the costs of losing marine ecosystem services due to marine plastic pollution on the value of marine ecosystem services from Costanza et al. (2014), and on the impact on marine ecosystem service provision from Beaumont et al. (2019). Dalberg (2021) estimated the minimum cost of plastic pollution to be USD 4,085-8,170 per tonne of plastics in the ocean per year. To estimate the impact only for 2019 in this study, the impact on ecosystem services per tonne of plastics is multiplied by the volume of plastics estimated to have entered the ocean from Fiji in 2019 (APWC, 2021a).

To estimate the cost of lifecycle greenhouse gas (GHG) emissions, Dalberg (2021) based their calculations on data from Zheng and Su (2019). In addition, they used the cost of carbon provided by IPCC (2018). Dalberg (2021) used an estimated 4.3 tonnes of CO_2e per tonne of plastics produced and 0.53 tonnes of CO_2e per tonne of waste generated, while the cost of carbon per tonne was set at USD 100. In this study, it is considered that plastic waste includes both the GHG emissions from its production processes, as well as those generated once it becomes waste (managed or mismanaged). In this study, the estimated amount of plastic waste generated in Fiji in 2019 is thus used. This amount is multiplied by the GHG emissions and the cost per tonne of carbon, providing an estimate of USD 483 per tonne of plastic waste generated.

4.2. QUANTIFIABLE SOCIETAL COST OF PLASTIC WASTE IN FIJI IN 2019

In 2019, it is estimated that 14,884 tonnes of plastic waste were properly disposed of in Fiji. In addition, there were 4,880 tonnes of mismanaged plastic waste, of which 1,220 tonnes leaked into the marine environment (Jambeck et al., 2015; APWC, 2021a). This waste generation and plastic leakage has impacts in terms of plastic

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[13] Plastic waste disposed of through formal waste management processes is considered well-managed and does not lead to leakages.

waste management costs, and costs due to ecosystem services loss and GHG emissions (**Table 4**).

Table 4 – Quantifiable societal costs of plastic waste in Fiji in 2019

Category	Costs in FJD and USD	
Plastic waste management costs	FJD 339,994	
	USD 157,843	
Annual marine ecosystem service costs of plastic pollution	Lower estimate (USD 4,085 per tonne)	Higher estimate (USD 8,171 per tonne)
	FJD 11,673,899	FJD 23,350,656
	USD 5,419,638	USD 10,840,602
GHG emission costs	FJD 20,562,110	
	USD 9,545,012	
Total	FJD 32,576,003	FJD 44,252,760
	USD 15,123,493	USD 20,544,457

Sources: APWC, 2021a; Dalberg, 2021.

Even though not all costs of plastic production, plastic waste and plastic leakage have been considered, e.g., potential health costs of plastic pollution, the results highlight the significant societal costs of plastic use and waste generation in Fiji. The results add to the increased understanding that, in addition to reducing waste generation, improvements in Fiji's waste management system are necessary.

5. PROPOSED SOLUTION

A broad range of instruments and policies have the potential to decrease the use of plastics and especially reduce plastic leakage into the marine environment, including bans of certain types of plastics (some of which have already been implemented in Fiji, APWC, 2021a), substitutions, or deposit-refund schemes, among others.

Among the recommendations for Fiji to improve its waste management system, APWC (2021a) states that "it is important to promote plastic reduction…it is equally important to recycle plastic waste that has already been produced". They add that source separation is needed, while there is also a need to invest in infrastructure such as waste transfer stations and material recovery facilities to support the recycling sector and source separation. This goes in line with the new Fiji waste strategy, which promotes waste prevention and minimisation through reduction, reuse, and recycling (APWC, 2021a). In addition, for the Caribbean Region, APWC (2021b) proposes establishing a regional recycling hub. In the Pacific, such a hub has been proposed by APWC (2021a) to be established in Fiji (SPREP, 2020b). Thus, in the next steps, the solution that is analysed is the establishment of a system in Fiji that would collect recyclable plastics, and separate and recycle them, while also having the capacity to receive materials from other places[14], such as Samoa (Raes et al., 2023).

Recycling bins on an international fishing boat in Fiji (APWC).

This report focuses on the costs and benefits of implementing a broader national recycling system in Fiji. Evaluating a broader implementation of recycling in Fiji will also support existing efforts, as recycling[15] has already increased in some parts of Fiji in recent years (e.g., in Lautoka and Nadi) (APWC, 2021a). Currently, there are six active private companies that offer recycling services across a broad range of products. These companies participate in the collection and export of waste materials. In addition, waste picking is present at some disposal sites in Fiji as a means of collecting recyclables.

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[14] Under the Basel Convention and amendments, the trade of plastic waste is only permitted when it is clean, sorted, and easy to recycle – unless the importing country has been granted an exemption (Ugorji and van der Ven 2021).

[15] APWC (2021a) estimated that in 2019, 28 tonnes of plastics were recycled. This volume is not considered in this study.

This report focuses specifically on the costs of implementing mechanical recycling. In this recycling system, the recovered material can either be remanufactured or repurposed into a new product with a different function, as it generates similar or slightly downgraded recycled material (Pales and Levi, 2018; Nikiema and Asiedu, 2022). The mechanical recycling process includes the following steps: collection and sorting, grinding, washing, and drying. Some of the most commonly processed plastic waste materials include polypropylene, low-density polyethylene, HDPE, and PET (Nikiema and Asiedu, 2022).

6. COSTS OF PLASTIC WASTE IN FIJI UNDER BUSINESS-AS-USUAL (BAU) AND PROPOSED SOLUTION (2023-2040)

6.1. METHODOLOGY (BAU AND RECYCLING SCENARIOS)

6.1.1. Forecasting of plastic waste generation and leakage under BaU and recycling

Future plastic waste generation, under the BaU scenario, has been estimated using the growth rate of plastic waste used by Lebreton and Andrady (2019) for the period 2020-2040. In the case of Fiji, this annual growth rate is equal to around 2.6%, and includes both plastics properly disposed of through the waste management system (around 75%), and mismanaged plastic waste (around 25%).

In 2019 4,880 tonnes of plastic waste was mismanaged (APWC, 2021a). Based on Jambeck et al. (2015), a conservative conversion rate of mismanaged plastic waste to marine plastics of 25% was applied (an estimated 1,220 tonnes of plastics entered the marine environment in 2019). This average leakage into the marine environment was applied to the future estimates of mismanaged plastic waste.

For the recycling scenario, the potential volume of recycled plastics in Fiji has been obtained from APWC (2021a) data. It is estimated that 31% of the total amount of plastic waste properly disposed of can be recycled. In addition, it is assumed that a recycling rate of 100% of recyclable plastics that are currently properly disposed of through the conventional waste management system, will generate an estimated average reduction of mismanaged recyclable plastics of approximately 60% (U.S. GAO, 1990; Iowa the Policy Project, 2008; Waste et al., 2013; DEC, 2020; COEX, 2020). Thus, if 31% of plastics can be recycled, the amount of mismanaged plastic waste will be reduced by 19.1%. This implies that the volume of plastics leaked into the marine environment (25% of mismanaged plastic waste) will also be reduced by 19.1%.

In this report it is assumed that Fiji would gradually implement the recycling system (25% implementation rate in 2023, which means that 7.2% of the total plastic waste generated would be recycled (out of which 6% is from plastics previously disposed of properly, and 1.2% is previously mismanaged plastic waste) – up to 100% implementation or 28.7% of the total amount of plastics waste generated in 2026 and thereafter (out of which, 24% is from plastics previously disposed of properly, and 4.7% is previously mismanaged plastic waste).

6.1.2. Impact estimates (2023-2040)

Once the volumes of future plastic waste, mismanaged waste and leakage into the marine environment have been projected under the two scenarios (BaU and recycling), the future impacts can be estimated. First the different costs are calculated for the BaU scenario, then the expected costs and benefits of the recycling scenario, and finally the net benefit of recycling[16] (**Figure 6**).

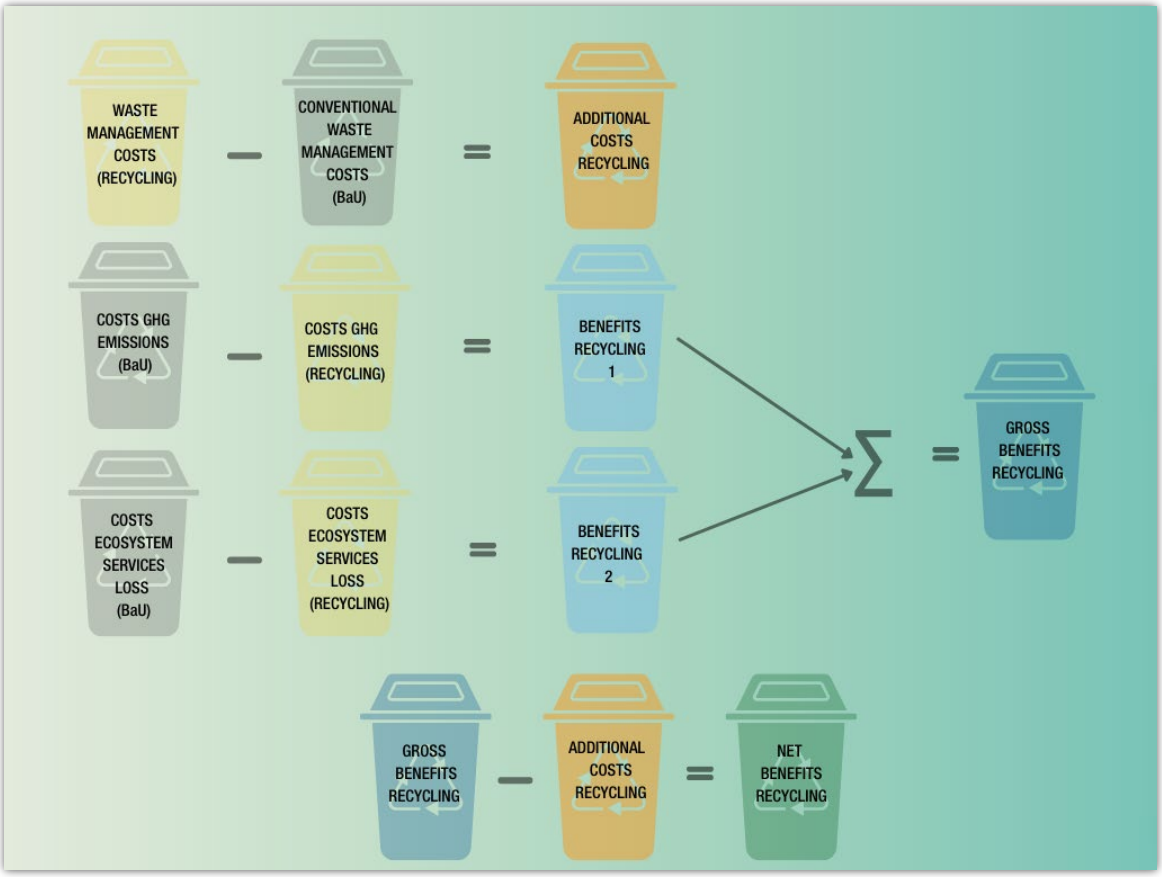

Figure 6 – Step taken to calculate net benefit of recycling in Fiji

To calculate the net benefit of recycling, the following steps are taken:

1. Based on future plastic waste generation (under BaU and recycling scenarios):
    - Estimate future plastic waste management costs (excluding mismanaged plastic waste).
    - Estimate GHG emission costs.
2. Based on future plastic leakage into the marine environment (under BaU and recycling scenarios):
    - Estimate future impact on ecosystem service provision.
3. Based on differences in management costs and impacts due to GHG emissions and losses of ecosystem services, the costs and benefits of implementing the recycling system as compared to the BaU can be calculated.

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[16] Although it is referred to as a benefit, the net benefit could be negative if the estimated cost of GHG and ecosystem service loss is larger under the recycling scenario, than under the BaU.

6.1.3. Methodology to estimate future waste management costs

Plastic waste management costs – BaU

Under the BaU scenario, costs were estimated using the average plastic waste management costs per tonne of plastic waste properly disposed of in 2019. These costs were derived from APWC (2021a) and used in the previous chapter. Thus, the waste management cost of FJD 23 per tonne is used. This cost is then multiplied by the annual – and increasing – amount of plastic waste properly disposed of during the period 2023-2040, considering constant prices. The plastic waste management costs that are estimated based on 2019 costs, and that exclude costs related to implementation and management of the recycling system, are hereinafter referred to as **conventional plastic waste management costs**.

Plastic waste management costs recycling scenario

Under the recycling scenario, the final cost of recycling plastics was estimated as follows in **Equation 1**:

$$Additional\ Cost_{recycling} = (Cost_{recycling}^{CWMC} + Cost_{recycling}) - Cost_{BaU}^{CWMC} \quad (\textit{Equation 1})$$

Where,

$Cost_{recycling}$ was estimated by including the costs of collection, sorting of plastics, and recycling costs. For collection costs, data from Searious Business (2021a) on labour, investment, and fixed costs were used. Sorting and recycling costs, including both operating and capital expenditure, were estimated using Pew (2020). **Annex A1**, **Table A1** through **Table A8** provide more detail on the data used. Finally, as a simplification, no impacts of scale (neither economy nor diseconomy) were considered for the cost of recycling plastics. This means that for any volume of plastics that need to be recycled, the costs remain constant.

$Cost_{BaU}^{CWMC}$ = conventional plastic waste management costs under BaU scenario

$Cost_{recycling}^{CWMC}$ = conventional plastic waste management costs under the recycling scenario. This was estimated considering a simplified assumption of a linear relationship between cost and amount of plastic waste collected (i.e., x tonnes of plastics recycled induce a decrease by y% of waste $(\frac{plastics\ recycled}{plastics\ collected})$ leading to a savings of y% of the conventional plastic waste management costs).

6.1.4. Methodology to estimate future impacts (GHG costs and ecosystem service loss)

To estimate future impacts of plastics (2023-2040) two different types were used.

GHG costs of plastic waste:

- In the case of the BaU scenario, annual waste generation is multiplied by the amount of GHG emissions per tonne of plastics, and by the social cost of GHG per tonne (see impact estimates plastics in 2019).
- In the case of the recycling scenario, the approach is similar. However, the production of secondary plastics via mechanical recycling is considered to reduce GHG emissions (Enkvist and Klevnäs, 2018; Tullo 2019; Jeswani et al., 2021). Nikiema and Asiedu (2022) present an estimate that mechanical recycling typically reduces CO_2 emissions by 2.3 to 0.27 tonnes. Thus, in this study a reduction of 1.3 tonnes is considered when recycling plastics versus using virgin plastics. This reduction is then considered for the part of plastic waste that is recycled (3.6 tonnes of CO_2 emissions), whereas for the non-recycled part, estimates remain the same (4.8 tonnes of CO_2 emissions).

Loss in ecosystem services due to plastic leakage:

- The estimate of the cost due to the loss in marine ecosystem service provision builds on the methodology presented previously. Dalberg (2021) estimated the annual cost of one tonne of plastic leakage into the marine environment to be between USD 4,085 – 8,170. In this second part, an average value of USD 6,128 will be used to present the results, instead of providing two estimates as presented in the first part.

In addition, Dalberg (2021) included in their estimates the fact that plastic waste, given the duration before it is completely degraded, can generate costs for at least several hundreds and potentially even thousands of years. Hence, they did not consider the annual costs of plastics produced in a single year only once, but developed a model considering that these costs will be incurred for longer durations. Following Dalberg (2021), the annual costs of plastics leaked into the ocean in for example 2023 is considered every year for the duration of the period of analysis (2023-2040 in this study). Similarly, for each additional year, additional costs will be considered and repeated the following years:

Total cost loss ecosystem services for period of analysis = $(\text{Cost}_{2023}) + (\text{Cost}_{2023} + \text{Cost}_{2024}) + (\text{Cost}_{2023} + \text{Cost}_{2024} + \text{Cost}_{2025}) + \ldots + (\text{Cost}_{2023} + \ldots + \text{Cost}_{2040})$.

6.1.5. Gross benefits of recycling

The previous parts explained the different costs considered. However, as was shown in **Figure 6** above, the aim is to estimate the specific costs and benefits of the recycling scenario as compared to the BaU, with as a final estimate the net benefit of the recycling system. The benefits of implementing the recycling scenario are based on the expected reduction of negative impacts by implementing recycling on a national level as compared to a BaU scenario. Thus, the benefits are calculated based on the difference between the impacts under BaU versus recycling.

6.2. COST-BENEFIT ANALYSIS OF BAU VERSUS RECYCLING

To estimate the impact of recycling, and compare this to a BaU scenario, a cost-benefit analysis (CBA) is applied. CBA is an analytical tool used to judge the advantages and disadvantages of an investment or decision by assessing its costs and benefits to put the welfare change attributable to it in perspective. Therefore, it is often used to guide policy alternatives (European Commission, 2015). To conduct a CBA, key considerations are the period of analysis, the discount rate, the different alternatives to be considered and the estimated costs and benefits related to these alternatives (presented in the previous section). In the study here, only one scenario is considered to potentially generate benefits (recycling scenario), versus only costs considered for the BaU scenario. However, comparison of the two alternative scenarios still occurs (see different steps shown in **Figure 6** above), whereas the final result will also be used to evaluate whether the recycling scenario is a more profitable option than a BaU, based on the assumptions and data used in this study.

6.2.1. Period of analysis

The period of analysis for all the CBA models was set to 18 years, from 2023 to 2040. The final year of the analysis was based on Raes et al. (2022a, 2022b).

6.2.2. Discount rate

The discount rate is used in the CBA analysis to transform future monetary values to net present values (NPV). By doing this, the cash flows of the system can be compared. There are two key reasons for applying a discount rate. First, individuals normally prefer benefits in the present compared to obtaining them in the future (Boardmand et al., 2011). This assumption is based on the uncertainty of obtaining future benefits compared to the certainty of obtaining the benefits in the present (Staehr, 2006). Second, there is an opportunity cost of forgoing the present benefits for future benefits. In this case, the discount rate represents the opportunity cost of forgoing the benefits of any other investments (Boardmand et al., 2011). Based on this, it is important to decide which discount rate is adequate to use; a higher discount rate represents a higher decrease of future values.

The process in which future values are converted and expressed in terms of present values is called discounting (Boardmand et al., 2011). The discounting process uses a discount rate to convert future values to present values. In this study, the discount rate was calculated as the average of multiple discount rates and is equal to 5.66% (see **Annex A2**, **Table A9** for details on its calculation).

6.2.3. Net present value (NPV)

CBA methodology allows the use of financial indicators to assess the performance of any investment and compare it with others. In this case, the recycling scenarios and the related BaU scenario are compared. To assess the performance of each scenario, the indicator used is the NPV of the BaU and of the two recycling scenarios.

The NPV is the difference between the benefits and cost using the discounting process to get the present net benefits. The result is the NPV of an investment. **Equation 2** shows how to calculate the NPV:

$$NPV = \sum_{t=0}^{T} \frac{(Benefit_t - Cost_t)}{(1+r)^t} \qquad (\boldsymbol{Equation\ 2})$$

Where:

NPV = Net Present Value of an investment
Benefit = Gross benefits of the investment in year t (here gross benefit of recycling)
Cost = Costs of the investment in year t (here additional cost of recycling)
T = period of analysis
t = year; and
r = discount rate

The reference year of 2023 is used to present the value of the costs and benefits, and the resulting NPV of the analysis of the impact of recycling.

6.2.4. Benefit-cost ratio

This ratio helps to summarise the overall value for money of the implementation of recycling scenario. **Equation 3** below shows how to calculate this ratio.

$$Benefit\ cost\ ratio = \frac{\sum_{t=0}^{T} \frac{(Benefit_t)}{(1+r)^t}}{\sum_{t=0}^{T} \frac{(Cost_t)}{(1+r)^t}} \qquad (\boldsymbol{Equation\ 3})$$

Where:

Benefit = gross benefits of the investment in year t (here gross benefit of recycling)
Cost = Costs in year t (here additional cost of recycling)
T = period of analysis
t = year; and
r = discount rate

6.3. RESULTS

6.3.1. Plastic waste generation

BaU scenario (2023-2040)

Figure 7 shows the estimated annual plastic waste generation (managed and mismanaged waste) and leakage into the marine environment under the BaU scenario. Plastic waste generated in 2023 is 21,897 tonnes (16,490 tonnes managed waste, and 5,407 tonnes mismanaged), with 1,352 tonnes leaked into the marine environment. It is estimated that this increases to 33,847 tonnes of plastic waste generated in 2040 (25,489 tonnes managed waste, and 8,357 tonnes mismanaged), with 2,089 tonnes of plastics leaked into the ocean without any changes to the current waste management practices (or usage of plastics).

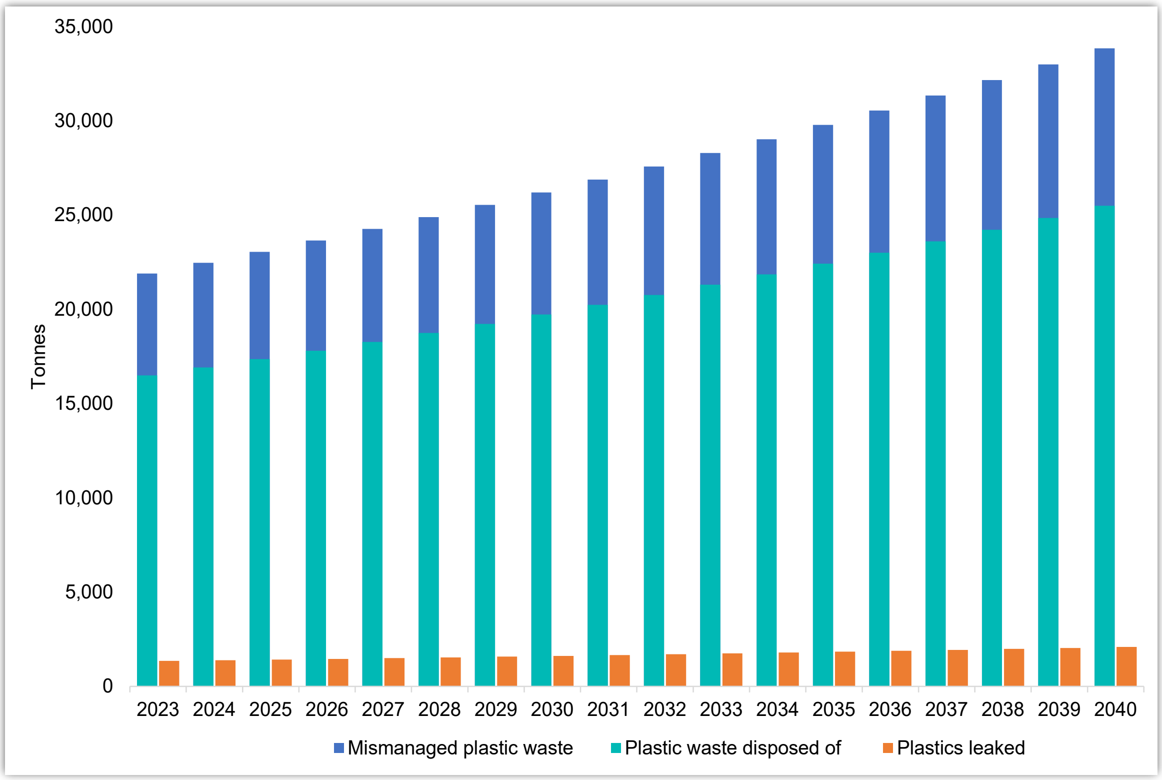

Figure 7 – Plastic waste generated and leaked each year under BaU (2023-2040)

Recycling scenario (2023-2040)

As mentioned previously, it is estimated that Fiji should be able to recycle up to 31% of its managed plastic waste, and 19.1% of its mismanaged plastic waste, which in turn could reduce leakage by 19.1%. It is important to note that it is assumed that recycling will not decrease overall plastic usage and waste generation, but only reduce mismanaged plastic waste and leakage into the marine environment. Hence, the total amount of plastic waste remains the same under the BaU scenario and the recycling scenario.

Figure 8 shows that plastic waste generated in 2023 is 21,897 tonnes (with 15,177 tonnes of managed waste, 1,571 tonnes recycled, and 5,148 tonnes mismanaged plastic waste), and 1,287 tonnes leaked into the marine environment. It is estimated that this increases to 33,847 tonnes of plastic waste generated by 2040 (as under the BaU), with 9,715 tonnes being recycled and 1,690 tonnes leaked during that year.

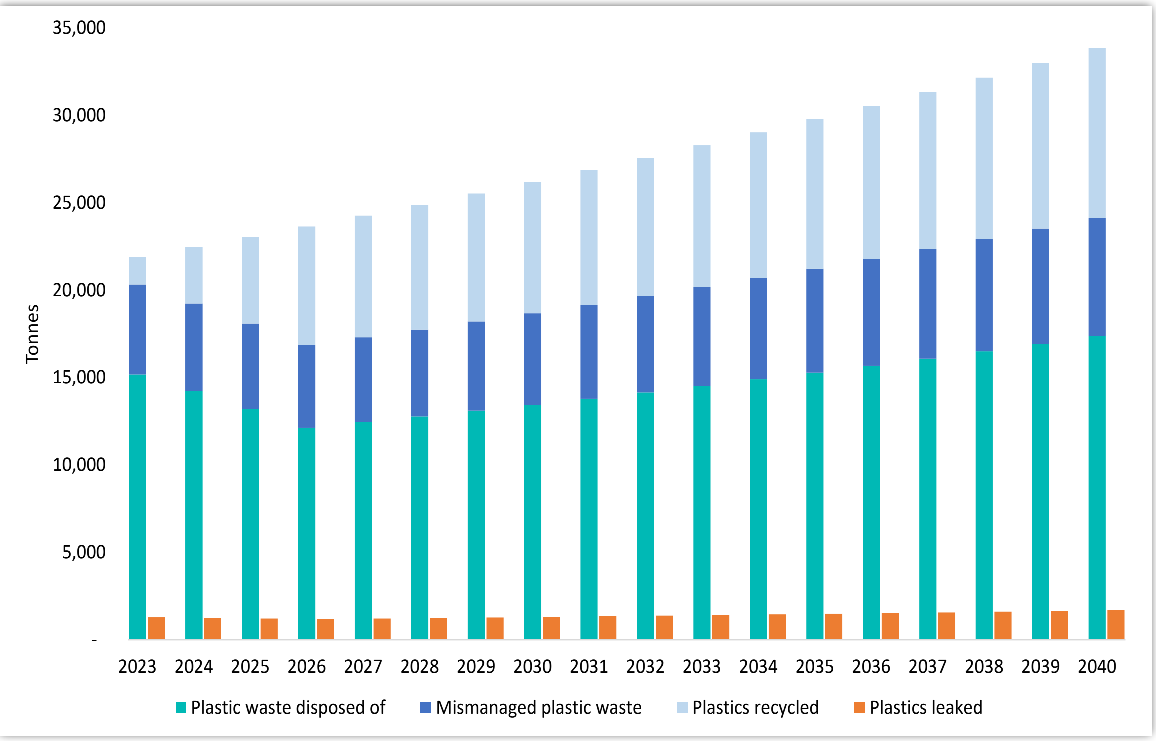

Figure 8 – Plastic waste generated, recycled, and leaked each year under recycling scenario (2023-2040)

Figure 9 displays plastics leaked into the ocean under both scenarios, as well as the avoided leakages as a result of implementing the proposed recycling system. The avoided plastic leakage due to recycling is estimated at 65 tonnes in 2023 and increases to 389 tonnes in 2040.

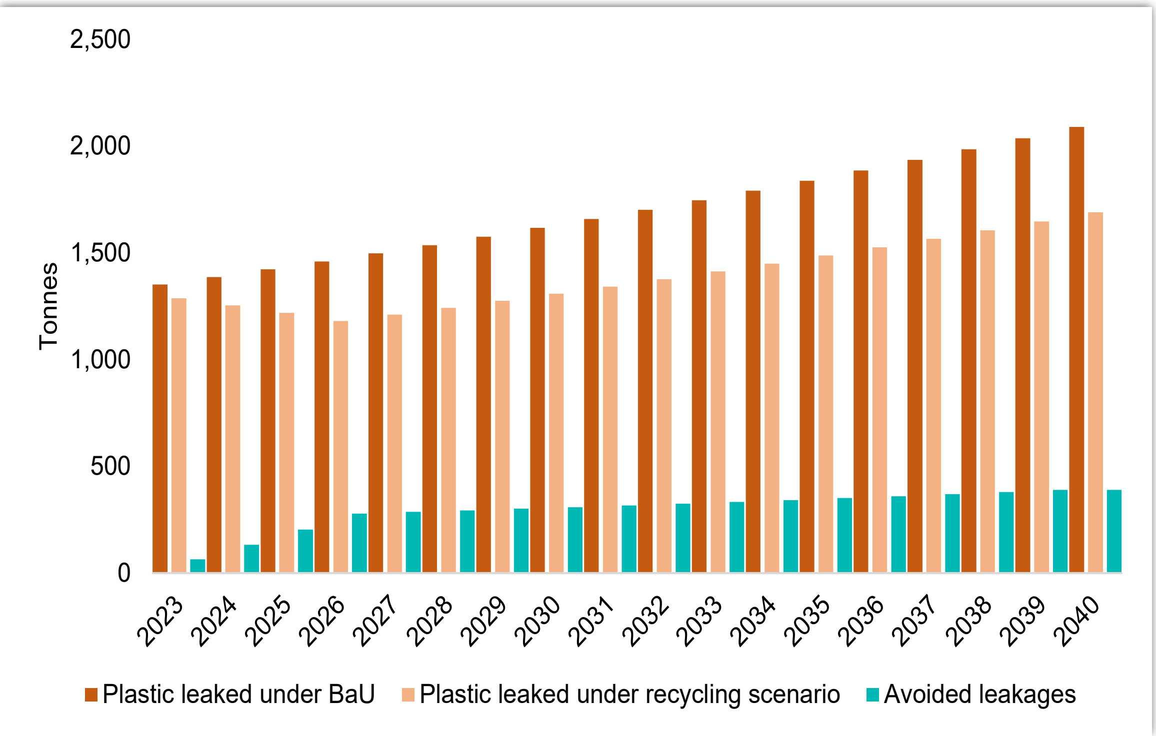

Figure 9 – Plastics leaked under BaU and recycling scenario, and annual avoided plastic leakage as a result of the implementation of the recycling system

6.3.2. Plastic waste management, GHG emission and ecosystem service loss costs under BaU (2023-2040)

The conventional plastic waste management costs are estimated at **FJD 376,682** (USD 174,876) in 2023 and **FJD 582,252** (USD 270,312) in 2040 under the BaU scenario. In total, over the period of analysis they are estimated at **FJD 8,504,420** (USD 3,948,199) (non-discounted value).

The costs induced by GHG emission from plastics are only considered for one specific year. For example, it is estimated that waste generated in Fiji in 2025 generates GHG emission costs of **FJD 23,978,481** (USD 11,132,071) and of **FJD 31,783,666** (USD 14,755,648) in 2036. In total, over the period of analysis costs due to GHG emissions are equal to **FJD 514,327,842** (USD 238,778,014) (non-discounted value).

The ecosystem services costs caused by plastic leakage into the marine environment for a given year, will have a longer-term impact (in this study only considered until 2040). For example, in 2025 new marine plastic leakage estimated to occur during that year will have an impact of **FJD 18,779,252** (USD 8,718,316) but this will have increased to a total impact of **FJD 300,468,026** (USD 139,493,048) by 2040, as the leaked plastics continue to persist in the ocean. Therefore, the costs related to the loss of ecosystem services grow more every year, and thus, by the year 2040 the ecosystem services costs will greatly outweigh the annual GHG emission costs and the plastic waste management cost (**Figure 10**).

In total, over the period of analysis, the costs generated by plastic waste are estimated to be equal to **FJD 4,072,724,399** (USD 1,890,772,701) (future or non-discounted value) (0.2% conventional plastic waste management costs, 12.6% GHG emission costs, and 87.2% loss of ecosystem services costs).

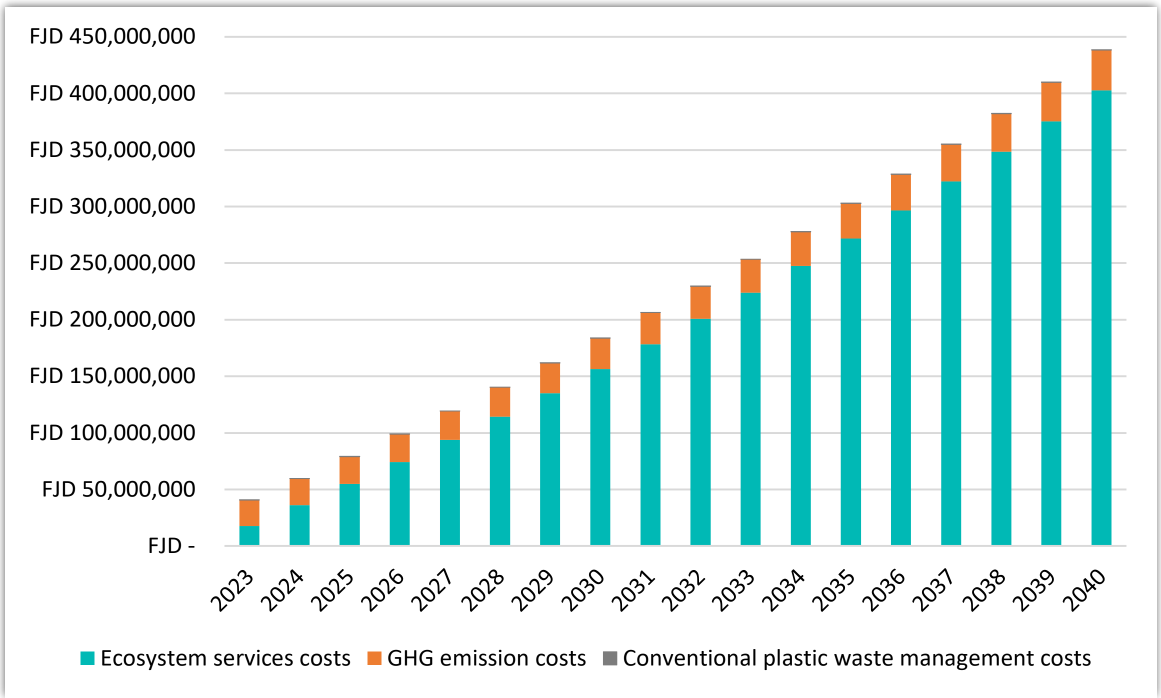

Figure 10 – Costs through loss of ecosystem services, conventional plastic waste management and GHG emissions, BaU (2023-2040)

6.3.3. Costs of implementing the recycling scenario

As was presented previously, the operating cost of the conventional plastic waste management system was estimated to amount to around FJD 23 per tonne of plastic waste (details in **Section 3.4**).

Establishing improved infrastructure to collect and store separated plastic waste will create costs. This estimated cost per tonne of plastics is presented in **Table 5** (details in **Annex A1**).

Table 5 – Estimated costs of recycling plastics per tonne (2019)

Types of costs	FJD per tonne	USD per tonne
Collecting costs	234	109
Sorting costs	225	104
Recycling costs	852	395
Total	**1,311**	**608**

Sources : Searious Business, 2021a; Pew, 2020.

For instance, the total cost of recycling 1,571 tonnes of plastic in 2023 is estimated to amount to **FJD 2,059,570** (USD 956,161) and gradually increase up to **FJD 12,734,234** (USD 5,911,900) for 9,715 tonnes of recycled plastics in 2040. Adding up all the annual costs of recycling plastics (2023-2040) amounts to a total cost of recycling plastics equal to **FJD 173,424,528** (USD 65,965,967) (non-discounted value).

Recycling plastics through a new recycling scheme is expected to decrease the costs of the conventional waste management system compared to the BaU scenario. Based on the previously established conventional management cost of FJD 23 per tonne of plastic waste properly disposed of in 2023, recycling 1,313 tonnes of plastics that were previously disposed of through the conventional waste management system, reduces the conventional waste management costs by **FJD 29,993** (USD 13,924). This leads to conventional plastic waste management costs amounting to **FJD 346,689** (USD 160,951) and a conventional waste management costs of **FJD 3,501,920** (USD 1,625,775). In 2040, 9,686 tonnes of plastics are estimated to be recycled, out of which, 8,118 were previously disposed of through the conventional waste management system, reducing these costs by **FJD 185,447** (USD 86,094) which leads to conventional plastic waste management costs of **FJD 396,805** (USD 184,218) and a conventional waste management costs of **FJD 5,273,972** (USD 2,448,455). The total cost of conventional plastic waste management for the period 2023-2040 under the recycling scenario gives a future value of **FJD 5,978,855** (USD 2,775,699).

Figure 11 compares the conventional plastic waste management budget under the BaU scenario with the conventional plastic waste management budget under the recycling scenario, which is added to the cost of recycling. For instance, in 2025, the costs of the conventional plastic waste management system are equal to **FJD 396,485** (USD 184,069) under BaU, and **FJD 301,774** (USD 140,100) under the recycling scenario, with the cost of recycling plastics amounting to **FJD 6,503,529** (USD 3,019,280).

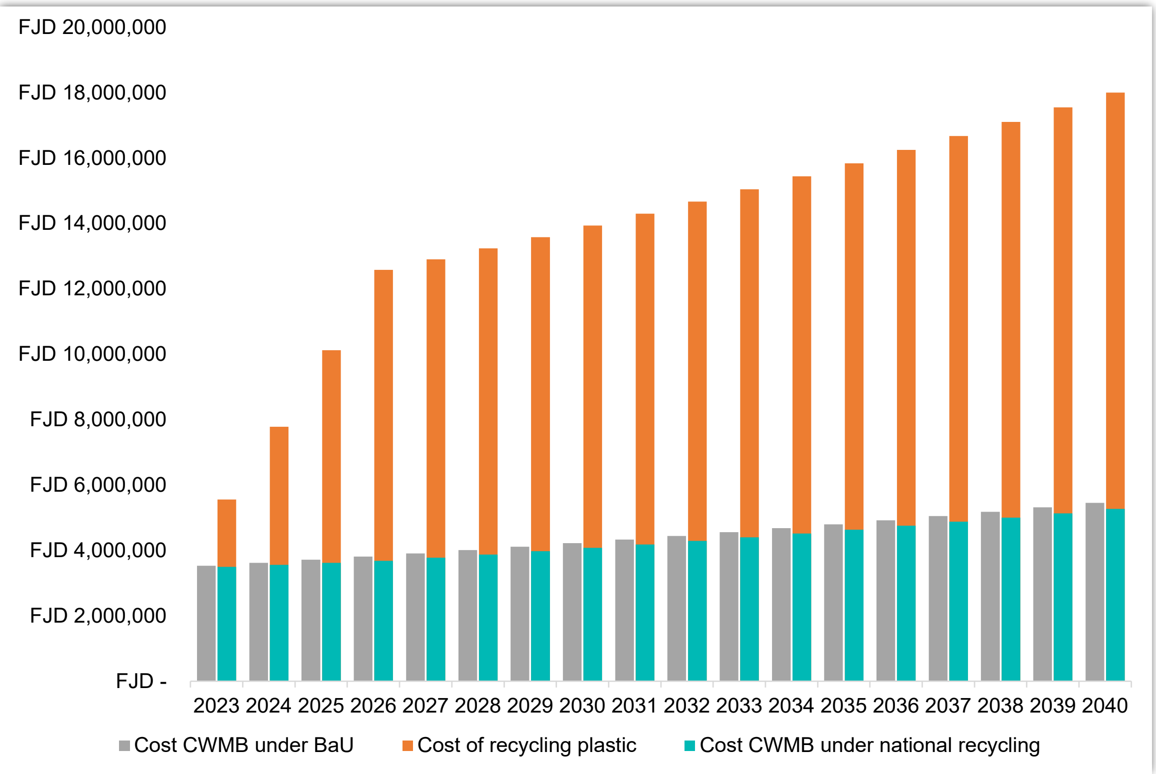

Figure 11 – Estimated cost of recycling, and the plastic waste management costs under BaU and recycling scenario (FJD/year)

The difference between the costs of the two waste management scenarios is presented in **Figure 12** and represents the estimated additional costs of implementing the recycling system. The additional costs of recycling plastics in 2023 are equal to

FJD 2,029,576 (USD 942,236) and increase to **FJD 12,548,787** (USD 5,825,806) by 2040 (in future value).

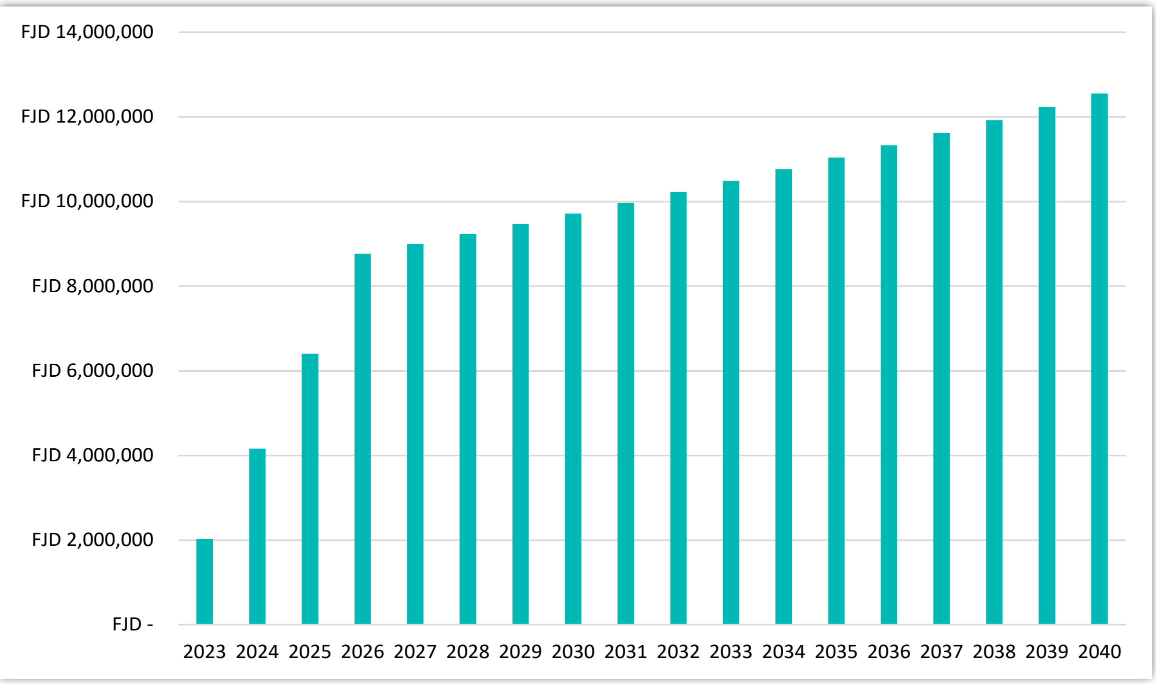

Figure 12 – Additional cost of recycling (FJD/year)

6.3.4. GHG emissions and ecosystem service loss costs under the recycling scenario (2023-2040)

GHG emission costs

Under the recycling scenario, it is considered that each tonne of plastics recycled replaces one tonne of imported virgin plastics. This leads to fewer GHG emissions, 3.5 tonnes of CO_2 emissions per tonne of recycled plastics, compared to 4.8 tonnes of CO_2 emissions per tonne of virgin plastics. The GHG costs of recycled plastics are thus estimated at USD 354.5 per tonne versus USD 483 per tonne for virgin plastics. Therefore, recycling plastics reduces the cost from GHG emission by USD 128.5 per tonne of recycled plastics compared to the BaU scenario. It is also assumed that plastics recycled during a given year replace virgin plastics that should have been produced (and imported) during that same year. In 2023, it is estimated there will be 1,571 tonnes of recycled plastics and 20,325 tonnes of virgin plastics that will be either disposed of through the conventional waste management system or mismanaged, creating a total cost of **FJD 22,345,947** (USD 10,374,163). This cost can be broken down into **FJD 1,169,388** (USD 542,891) from recycled plastics, and **FJD 21,176,560** (USD 9,831,272) from new plastics. In 2040, it is estimated that 9,715 tonnes of plastics could be recycled (see **Figure 8** above), while there will also be 24,131 tonnes of new plastics, with total GHG emission costs of **FJD 32,524,176** (USD 15,099,432) in future value, with **FJD 7,230,276** (USD 3,356,674) coming from recycled plastics and **FJD 25,293,900** (USD 11,742,758) from newly produced plastics.

The total cost of GHG emissions of plastic waste under the recycling scenario has a future value of **FJD 477,705,371** (USD 221,775,938), with **FJD 101,032,420**

(USD 46,904,559) from recycled plastics and **FJD 376,672,951** (USD 174,871,380) from newly produced plastics.

Costs of loss ecosystem services

It is expected that recycling plastics will reduce leakage into the marine environment through an improved collection system for recyclable plastics. This reduction of leakage will decrease the impact of plastics on the provision of marine ecosystem services. In 2023, it is estimated that recycling 1,567 tonnes of plastics, out of which 254 were previously mismanaged, could reduce leakages by 63 tonnes, with still 1,263 tonnes of plastics leaked into the marine environment. For 2023 alone, this leakage could generate costs of **FJD 16,988,950** (USD 7,887,163) in losses of ecosystem services. The total impact of 2023 leakage is estimated to be equal to **FJD 305,801,094** (USD 141,968,938) by 2040 under the recycling scenario.

Under the recycling scenario, 25,079 tonnes of plastics will be leaked into the marine environment between 2023 and 2040 (compared to 30,516 tonnes under the BaU scenario). The total cost of ecosystem services loss due to plastic leakage under the recycling scenario is estimated to have a future value of **FJD 2,961,623,090** (USD 1,374,941,082).

Total impact (ecosystem services loss and GHG emission costs)

Figure 13 displays the results for the period 2023-2040. In 2040, the total costs due to losses in marine ecosystem service provision and GHG emissions is estimated at **FJD 363,557,746** (USD 168,782,612) in future value or a 48% average annual growth rate.

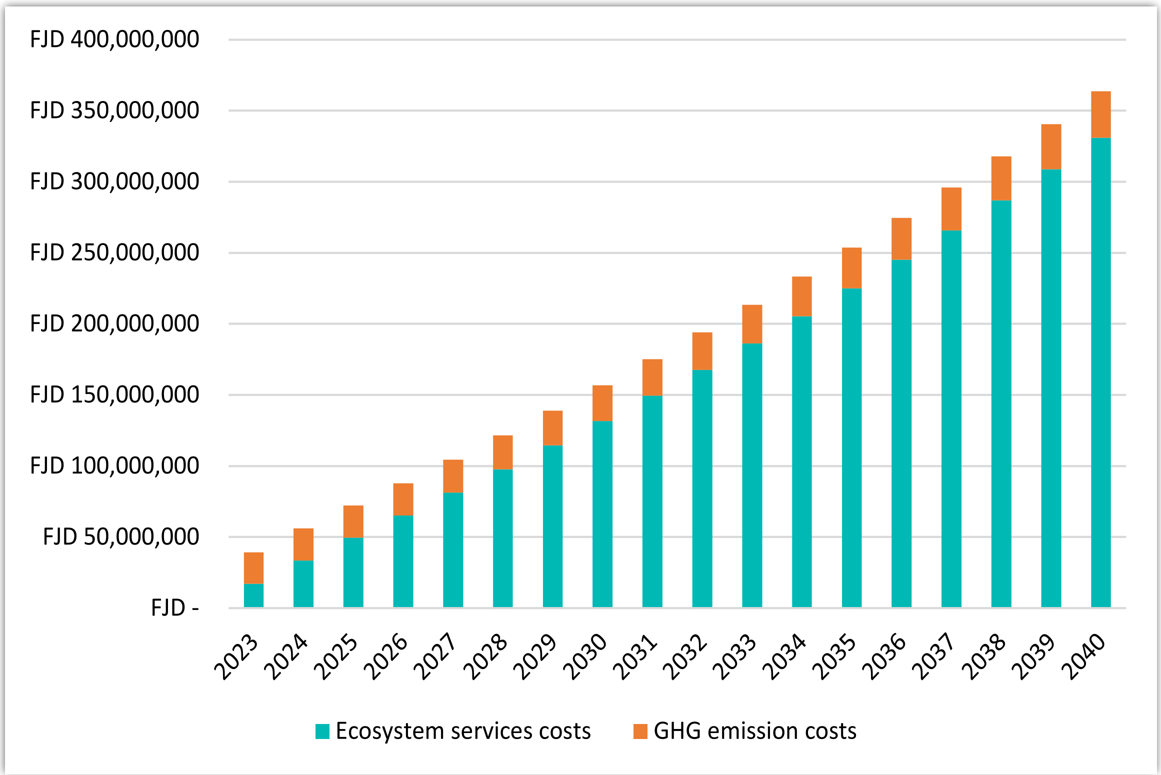

Figure 13 – Cost induced by loss of ecosystem services and GHG emissions, recycling scenario (2023-2040)

6.3.5. Total gross benefits of the recycling scenario compared to BaU

As described previously, recycling plastics and the subsequent avoided leakage results, when compared to the BaU scenario, in a reduction in the loss of ecosystem services due to plastic leakage. In addition, recycling plastics generates a reduction in GHG emissions. These reductions lead to a decrease in the impact of plastics, in this study illustrated through a decrease of the total societal costs of plastic pollution. Comparing the costs of ecosystem services loss and GHG emissions under the national recycling scenario and the BaU scenario gives an estimate of the gross benefit of recycling plastics (see **Figure 14**).

The total cost reductions (or gross benefits) of each component are:

- The total reduction in costs from GHG emissions through recycling of plastics gives a future value of **FJD 36,622,471** (USD 17,002,076).
- The total future value of the reduction in losses of marine ecosystem services is estimated at **FJD 588,269,047** (USD 273,105,407) over the period.

The sum of these two components gives the total future value of the gross benefit of implementing the recycling scenario for the period 2023-2040. This value is equal to **FJD 624,891,518** (USD 290,107,483).

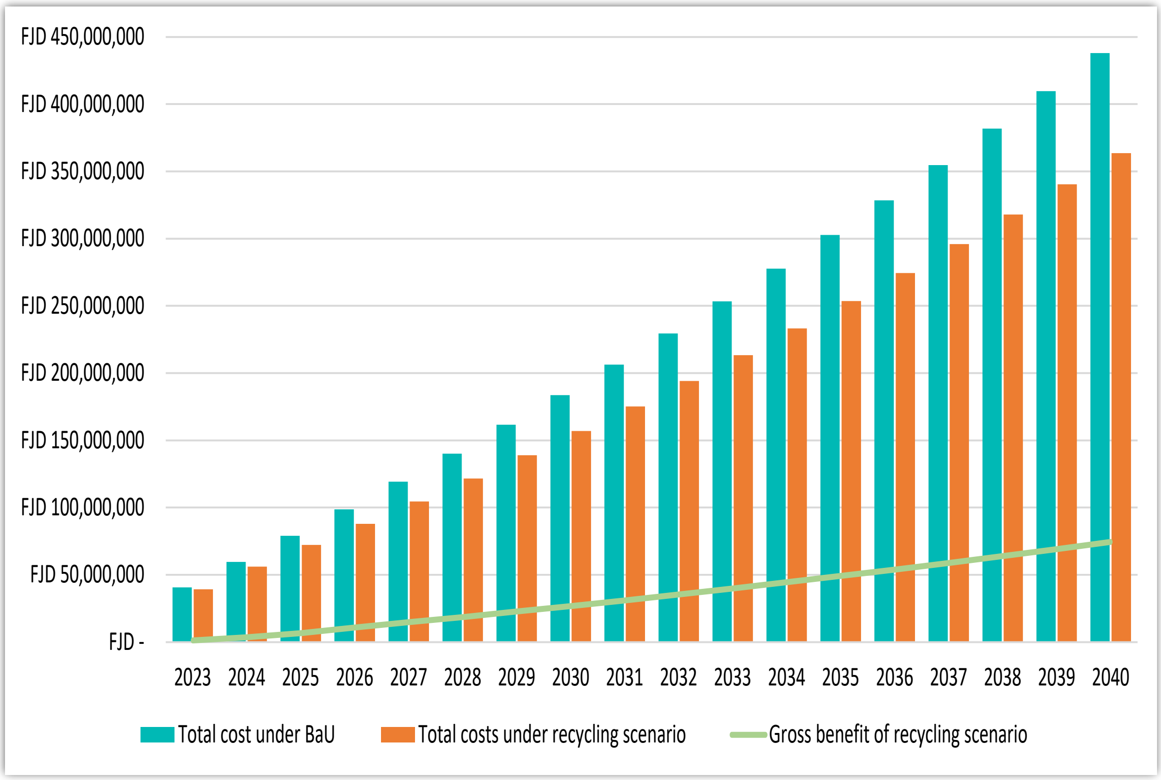

Figure 14 – Gross benefits from a reduction of costs resulting from the implementation of the recycling scenario compared to the BaU scenario

6.3.6. Results CBA: Net benefits of implementing the recycling system

To get the net benefit of implementing the recycling system, the additional recycling costs need to be rested from the gross benefits from recycling. For instance, in 2023, the recycling scenario is estimated to cost **FJD 2,032,588** (USD 943,634) while generating **FJD 1,287,293** (USD 597,629) in gross benefits. This would give a net benefit for the year 2023 of - **FJD 742,283** (- USD 344,607). Repeating the process for every year of the period of analysis (2023-2040) gives the annual future values of the net benefits of the recycling scenario (**Figure 15**). The total net benefits, in future value, of the recycling system are estimated at **FJD 453,992,548** (USD 210,767,200).

By applying the discount rate, the benefits and costs in present (2023) values are estimated. **Figure 15** shows the present values of the total benefits and costs generated by the recycling scenario. The sum of the annual net benefits in present value becomes positive in 2026. The NPV of the recycling system is equal to **FJD 221,714,926** (USD 102,931,720), with a **benefit-cost ratio of 3.2**. Thus, according to the results of the CBA, and considering the costs and benefits considered, the implementation of the recycling system will generate a positive net present value for the period considered.

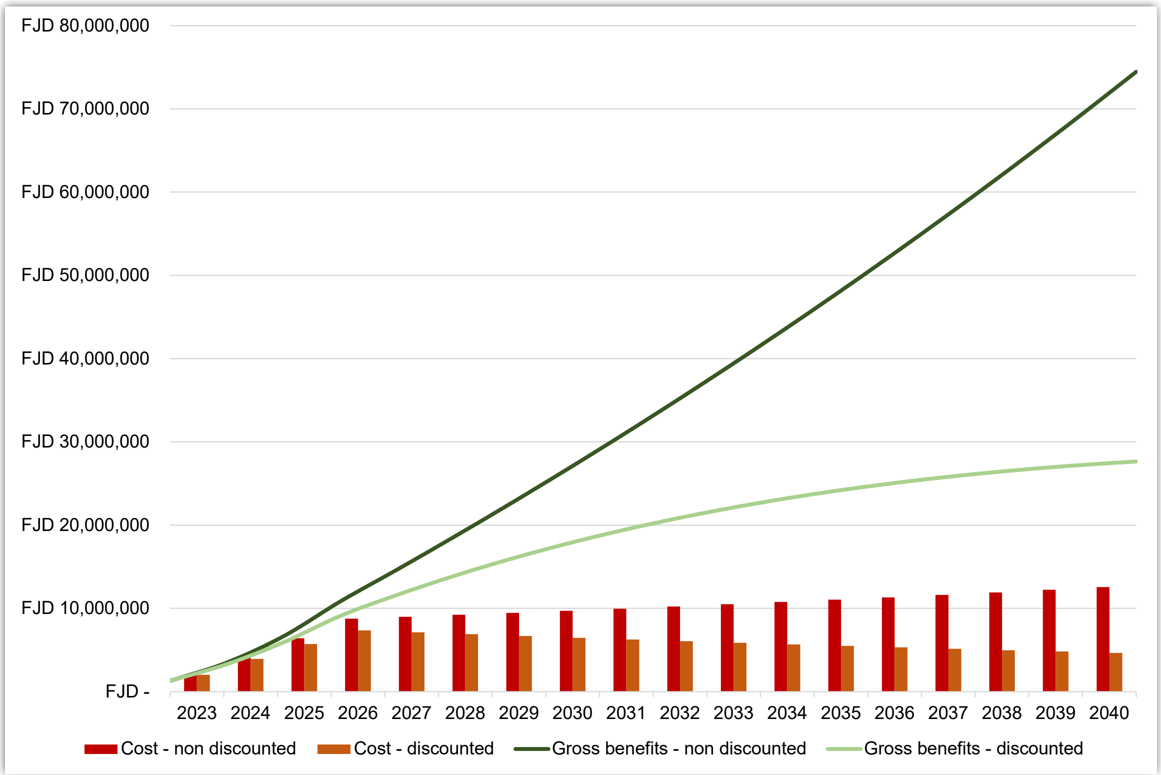

Figure 15 – Estimated cost of recycling plastics for Fiji (future and present values); benefits of the national recycling (future and present values) (discount rate 5.66%).

However, not all benefits from recycling and reducing plastic leakage have been considered in the results presented above. For instance, plastic scraps can be sold on the appropriate market, the price depending on several factors such as the country, the type of polymer, and/or the quality. Fiji could potentially resell some or all its recycled plastics or create a new market for this material. For example, if the average price of USD 245.5[17] per tonne, found in the EU (Eurostat, 2021), is applied, then, considering constant prices, the present value of the recycled plastics for Fiji (132,312 tonnes) would amount to **FJD 38,770,126** (USD 17,999,130) for the period considered (2023-2040). However, this price is potentially higher than what could be obtained in a market accessible for Fiji's plastic scrap material. Market creation for recycled plastics does remain a challenge. This is due to several reasons, including the fact that recycled plastics are often seen as lower or inconsistent in quality, and thus can sell for prices up to 50% less than certain types of primary plastics (Enkvist and Klevnäs, 2018). The variety of plastics available, each with unique chemical and physical characteristics, impedes the smooth operation of plastic recycling. Furthermore, recycled plastics are always economically competing with the market for new plastics. The latter typically displays higher material efficiency relative to secondary plastic production, owing to the constant supply of more affordable feedstock (OECD, 2018). This stifles the potential for a robust secondary market for plastic packaging (OECD, 2021).

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[17] Exchange rate of 1.0031 USD per EUR used to convert Eurostat (2021) data (exchange rate retrieved on July 15, 2022).

Prototype of bench made of recycled plastics (Serious Business).

Additional benefits could also be generated not only through the sale of plastics as raw materials for recycling, but by directly using collected plastics for the development of new value chains. For example, within the PWFI project, Searious Business (2021b) developed a product concept to develop beams, planks, tiles, and parts (as semi-finished products), and outdoor public and private furniture (as end products) from recycled plastics as an alternative value chain for Fiji. This could increase the revenue from recycled plastics and make the proposed recycling system more profitable. An improved recycling system and especially the development of value chains can also generate employment opportunities.

Finally, PICs are limited in land size. Only two per cent of the Pacific region is land mass; therefore, landfill capacity and site suitability are limited (Mohee et al 2015). The predominant method of waste disposal in Fiji involves the delivery of municipal solid waste to sanitary landfills, controlled dumps, and open dumps, primarily in urban areas. There are nine disposal sites of this type in Fiji. The only sanitary landfill in Fiji is the Naboro Sanitary Landfill (APWC, 2021a). By reducing the amount of waste that ends up at this landfill and other dump sites, the lifespan of these sites can be moderately extended. This is another financial benefit for the waste management system, especially in the case of the Naboro site (Graham et al., 2022).

Landfill in Fiji (Serious Business).

7. SUMMARY AND CONCLUSIONS

The results of this study show the estimated societal costs of plastic waste and leakage in 2019 to be the followings in Fiji: (1) plastic waste management costs of **FJD 339,994** (USD 157,843); (2) GHG emission costs of **FJD 20,562,110** (USD 9,546,012); and costs due to losses in ecosystem services between **FJD 11,673,899** (USD 5,419,638) and **FJD 23,350,656** (USD 10,840,602). The total costs of plastic waste in Fiji in 2019 are estimated at between **FJD 32,576,003** (USD 15,123,493) and **FJD 44,252,760** (USD 20,544,457).

Under the BaU scenario, the quantifiable societal costs, in future values, for 2023-2040 are estimated at: (i) conventional plastic waste management costs of **FJD 8,504,420** (USD 3,948,199); (ii) GHG emission costs **FJD 514,327,842** (USD 238,778,014); and costs of ecosystem services loss of **FJD 3,549,892,136** (USD 1,648,046,489). The total costs due to plastic waste under the BaU scenario for 2023-2040 are estimated **FJD 4,072,724,399** (USD 1,890,772,701) in future value.

Under the recycling scenario, the quantifiable societal costs, in future values, for 2023-2040 are estimated at: (I) plastic waste management costs of **FJD 179,403,371** (USD 83,288,473), of which **FJD 173,424,528** (USD 80,512,780) correspond to the recycling system and **FJD 5,978,843** (USD 2,775,693) to the conventional plastic waste management system; (II) GHG emission costs of **FJD 477,705,371** (USD 221,775,938) and (III) costs of marine ecosystem service losses of **FJD 2,961,623,090** (USD 1,374,941,082).

The present value of the additional costs of implementing and managing the recycling system is estimated at **FJD 100,381,077** (USD 46,602,171), whereas the present value of the gross benefits of the national recycling scenario is estimated to be **FJD 322,096,003** (USD 149,533,892) for the period of 2023-2040. Thus, according to the results, the implementation of the recycling system results in positive net benefits of **FJD 221,714,926** (USD 102,931,720) for the period considered, even though the overall costs of the plastic waste management system under the recycling scenario are higher than under the BaU.

This study mainly focuses on estimating quantifiable societal costs, looking at waste management costs and the impact of GHG emissions and loss of ecosystem services provision, including for the fisheries and tourism sector. Some costs, such as the impact of ghost fishing, and benefits, such as the potential for selling plastics on the market for recyclables, were not included. There are also impacts of plastic pollution that cannot be quantified, such as the cultural importance of the marine environment for the people of Fiji. In addition, mismanaged plastics also have broader impacts on marine biodiversity and ecosystems, which can generate additional impacts to the economy. This said, it is difficult to quantify the impact on marine ecosystems and biodiversity (Tekman et al., 2022). Finally, the impact of marine plastics must be seen in light of the multiple stressors, which impact the marine environment, and the blue economy that depends on it.

This study, together with the one on Samoa (Raes et al., 2023) strengthens the importance of considering the establishment of Fiji as a recycling hub in the Southern Pacific. This is in line with what APWC (2021a) mentions, such a hub could be facilitated through the Moana Taka Partnership, as this partnership facilitates shipping and provides potential adjustment of freight cost, which in the past has been a barrier to recycling initiatives in the Southern Pacific. The results also show the importance of the development of alternative value chains or a functioning market for plastic scraps to assure financial profitability of recycling. Although the system is considered profitable by a reduction of societal costs, not all these benefits are tangible and will not generate direct financial revenue for the recycling system.

The results demonstrate that the implementation of a recycling system can generate a positive social and environmental impact through a reduction of plastic waste and marine plastic pollution as compared to the BaU. Notwithstanding, additional social, economic and environmental benefits can be derived from the simultaneous implementation of a range of policy solutions and tools to address the problem and generate a larger reduction in mismanaged plastics, and potentially also in the consumption of plastics. These include, for example: reducing and substituting plastic use to systems such as extended producer responsibility, market-based instruments such as deposit refund schemes or landfill taxes, and the improvement of waste collection systems and infrastructure, including for fishing systems and gear (Newman et al., 2015). APWC (2021a) highlights the following actions that should be taken to reduce mismanaged waste in Fiji: 1) increase the financial support and incentives for waste pickers and private recyclers; 2) implement the Environment Management (Container Deposit) Regulations 2011; and 3) promote innovation and the production of alternatives to single-use plastics and plastic packaging. Further cost-effectiveness and cost-benefit analyses will be needed to continue supporting the decision-making process, understand trade-offs among different alternatives, and should include further work around the cost-and benefits of establishing a regional recycling hub in the South-east Pacific Region. In adopting a circular economy approach, it is crucial to ensure that beyond its environmental benefits, the plastic economy also bolsters national economies and livelihoods. This can be achieved through job creation, economic expansion, investment, and promoting social equity, as highlighted by Ugorji and van der Ven (2021).

Although this report focuses on recycling as one solution, it is important to highlight that recycling alone will not be enough to solve the plastic pollution crisis. In addition to recycling, a range of instruments and initiatives have been proposed globally to reduce mismanaged plastic waste, but go beyond the scope of this study, such as, product taxes, to include the externalities caused by plastic leakage into the environment and to generate revenue. This, however, comes with additional challenges, including, for example, where to tax the products (during production, export, import, usage). If plastics are taxed at the production source, it may not be collected where the main impact is caused. For example, according to APWC (2021a), the costs of plastic pollution on SIDS are hugely disproportionate to their contributions. These global and distributional issues highlight the importance of not only developing national legislation and regional collaboration, but also a global treaty on plastics, which is currently being negotiated.

There is also a need for further data on mismanaged plastics and leakage along the value chain, and where it accumulates in the terrestrial and marine environment. Additional work is also needed to understand the actual cost of plastics, including microplastics. Although efforts have been undertaken, such as the studies conducted by Trucost (2016) and Dalberg (2021) used in this report, more empirical evidence is needed.

Finally, to provide a better picture of how marine plastics, together with multiple stressors, impact the national economy and what the benefits of reducing plastic pollution are, a broader framework is needed. Ocean Accounting[18] seems particularly suited for this. Future national assessments should aim to include this accounting system as part of economic impact estimates and scenario analysis.

Remarks

The volume of plastic waste generated, as well as the percentage of managed and mismanaged waste was based on import data, as well as surveys. There is a level of uncertainty around the actual volume of plastic waste generated in Fiji every year, how much is mismanaged and how much actually leaks into the marine environment. This uncertainty has an impact on the different cost and benefit estimates.

Within the limitations of this study, it was not possible to estimate the volume of plastics that enter the case study area and can also create an impact on Fiji's economy. Instead, only plastic leakage from Fiji was considered. Thus, this study did not consider the potential impact of plastics leaking into Fiji's national waters and directly impacting the Fijian economy beyond the potential societal cost of plastics leaked from Fiji itself. Remote islands are often exposed to marine plastic pollution to a degree that is disproportionate to their size and domestic contributions, with the source and responsibility often originating thousands of kilometres away (EIA, 2020; Richardson et al., 2017). However, the most plastic accumulations in the South Pacific take place in the South Pacific gyre, in an area located between Chile and the Pitcairn Islands, outside of the research area (Eriksen, et al, 2013). The eastern centre area of the South Pacific is where the highest densities of marine plastics should be found (Martinez, et al, 2009).

Global estimates on marine ecosystem provision were used. However, for countries such as Fiji, the marine environment and the ecosystem services it provides can be proportionally more important than the global average. Thus, the average societal costs through the loss of marine ecosystem services, may not adequately reflect the financial value of these services for Fiji. In addition, not all costs created by plastic pollution were considered, as not all are easily quantifiable.

Although the aim of the cost benefit analysis of the recycling scenarios was to be as comprehensive as possible, some assumptions were made that influence costs. First, scale effects on the costs of collection and separation were not considered, as costs were expressed per tonne. Actual costs may thus be higher or lower depending on the effects of scale. For example: to reduce costs of services, a minimum specific number of trucks/boats may be required, or if containers are not completely full, it makes their

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[18] https://www.oceanaccounts.org/.

shipping cost more expensive per tonne of plastics transported. In addition, the costs of collecting and transporting plastics within Fiji do not include an additional cost for marine transportation between different islands. Finally, mechanical recycling is only applicable for selected types of plastics collected in large enough volumes (Nikiema and Asiedu, 2022).

According to EIA (2020), recycling is also restricted in PICs due to several factors, including for example: intra- and inter-island logistical and transport challenges, lack of collection and sorting facilities, limited port capacity in some countries, lack of backloading/reverse logistics agreements, and difficulty in securing and retaining markets for post-consumer materials. Further assessments are needed to determine full cost (and benefit) estimates of a fully operational regional recycling system, including marine transport costs within Fiji.

This study used global data on the costs of recycling, as published by Pew (2020). However, according to Nikiema and Asiedu (2022) the lifespan of the plant depends on the type of plant, with low-cost systems tending to last for a shorter time (5–15 years) than expensive systems (30 years and more). Accordingly, costs per ton per day of capacity vary notably, depending on the technology considered.

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Annexes

ANNEX A1. COST OF IMPLEMENTING THE RECYCLING SYSTEM

APWC provided data on tonnes of waste collected and its attached cost.[19] The annual estimated amount of waste collected in 2019 amounts to 139,558 tonnes for an annual cost of FJD 3,187,920. This leads to an average cost of FJD 22.8 per tonne. The average cost of managing waste is considered constant up until 2040. **Table A1** shows the base data needed to estimate the cost of the recycling of plastics in 2019. That cost has been considered constant and used for the future scenarios (2023-2040).

Table A1 – Additional data used to estimate plastic waste management costs

Maximum recyclable amount	31.85%
Plastic waste generated (tonnes, 2019)	19,764
Plastics properly disposed of (tonnes, 2019)	14,884
Mismanaged plastics (tonnes, 2019)	4,880
Growth rate from 2020-2040	2.59%
Discount rate	5.66%
Hourly wage used (minimum wage times two)	FJD 4.64
Waste management budget	FJD 3,187,920

Source: APWC (2021), Lebreton and Andrady (2019)[20], Ministry of Communication (2015)[21], and Moore et al. (2020).

Collecting cost

Given the cost/number of hours needed to collect 99.99 tonnes of plastics provided by Searious Business (2021), the following are the estimated costs corresponding to 5,673 tonnes of plastics, which is the potential amount of plastics that could be recycled (31.85% of 14,884 plus 60% times 31.85% of 4,880) (**Table A2, Table A3,** and **Table A4**).

Table A2 – Estimated labour costs for 5,673 tonnes of plastics

Activity	Hours per week	Cost per week	
Managing collection points and drop off sites	1418	FJD 6,581	USD 3,055
Administration	397	FJD 1,843	USD 855

Source: Own elaboration based on Searious Business (2021).

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Table A3 – Estimated investment costs for 5,673 tonnes of plastics

Items	Cost	
Van	FJD 25,000	USD 11,606
Workspace Renovation	FJD 13,000	USD 6,035

Source: Own elaboration based on Searious Business (2021).

Table A4 – Estimated fixed costs for 5,673 tonnes of plastics

Fixed cost	Cost per month	
Gas	FJD 8,510	USD 3,951
Rent	FJD 28,367	USD 13,169
Water	FJD 11,347	USD 5,268
Electricity	FJD 17,020	USD 7,902
Car insurance / maintenance	FJD 5,673	USD 2,634

Source: Own elaboration based on Searious Business (2021).

Table A5 shows the total annual costs of collecting plastics and the cost per tonne of plastics that could be recycled in 2019. This cost is considered constant and used for estimates in future scenarios (2023-2040).

Table A5 – Total cost and cost per tonne of 5,673 collecting plastics

	Total annual cost		Cost per tonne	
Labour cost	FJD 438,035	USD 203,359	FJD 77	USD 36
Investment cost	FJD 38,000	USD 17,642	FJD 7	USD 3
Fixed cost	FJD 850,999	USD 395,078	FJD 150	USD 70
Total	**FJD 1,327,034**	**USD 616,079**	**FJD 234**	**USD 109**

Source: Own elaboration based on Searious Business (2021).

Cost of sorting.

Costs of sorting include both operating and capital expenditure. The costs of sorting are based on data by Pew (2020)[22] and presented in **Table A6**. Costs have been adapted to Fiji by adjusting for Purchasing Power Parity (PPP), considering the average PPP of Upper middle-income countries[23] and the PPP of Fiji. Even with this adjustment, it is important to note that costs are country- and location-specific; therefore, cost values proposed in this study are indicative.

Table A6 – Estimated costs of sorting

Selected Countries and Economies	Year	GDP (PPP)	Operating expenditure per tonne (USD)	Capital expenditure per tonne (USD)	Total per tonne (FJD)	Total per tonne (USD)
Average Upper middle-income	2020	18073.10	117	39	336	156
Fiji	2020	12078.80	78	26	**225**	**104**

Source: Own elaboration, based on Pew (2020) and World Bank (2022)[24].

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[22] Pew (2020). Breaking the Plastic Wave. The Pew Charitable Trusts, Philadelphia, PA, USA. Available at: https://www.systemiq.earth/wp-content/uploads/2020/07/BreakingThePlasticWave_MainReport.pdf.

[23] Fiji is considered an upper middle-income country.

[24] World Bank. 2022. GDP, PPP (current international $) – Upper middle income. Available at: https://data.worldbank.org/indicator/NY.GDP.MKTP.PP.CD?locations=XT. Accessed 22 April, 2023.

Costs of recycling

The costs of recycling are also based on data published by Pew (2020)[15] and have been adjusted similarly to the sorting costs. The recycling costs considered are presented in **Table A7.**

Table A7 – Estimated costs of recycling

Selected Countries and Economies	Year	GDP (PPP)	Operating expenditure per tonne (USD)	Capital expenditure per tonne (USD)	Total per tonne (FJD)	Total per tonne (USD)
Average Upper middle-income	2020	18,073.10	452	140	1,275	592
Fiji	2020	12,078.80	302	94	**852**	**396**

Source: Own elaboration, based on Pew (2020) and World Bank (2022).

The total cost of implementing and maintaining the recycling system in Fiji is displayed in **Table A8**. The table also shows the stepwise implementation of the system, considered to reach full capacity in 2026.

Table A8 – Costs of implementing recycling for Fiji per year

Year	Implementation rate of the policy	Amount recycled	Plastic waste (tonnes) (BaU)	Plastics properly disposed of (tonnes) (BaU)	Mismanaged plastic waste (tonnes) (BaU)	Amount recycled (tonnes)	Cost (FJD) (non-discounted)	Cost (FJD) (r= 5.66%)
2023	25%	8%	21,797	16,490	5,307	1,567	2,053,326	2,053,326
2024	50%	16%	22,363	16,918	5,445	3,214	4,213,214	3,974,681
2025	75%	24%	22,943	17,357	5,586	4,947	6,483,813	5,770,428
2026	100%	32%	23,538	17,807	5,731	6,767	8,869,413	7,446,655
2027	100%	32%	24,149	18,269	5,880	6,942	9,099,563	7,207,351
2028	100%	32%	24,776	18,743	6,032	7,123	9,335,685	6,975,738
2029	100%	32%	25,418	19,230	6,189	7,307	9,577,934	6,751,567
2030	100%	32%	26,078	19,729	6,349	7,497	9,826,470	6,534,601
2031	100%	32%	26,755	20,241	6,514	7,692	10,081,454	6,324,606
2032	100%	32%	27,449	20,766	6,683	7,891	10,343,055	6,121,360
2033	100%	32%	28,161	21,305	6,856	8,096	10,611,445	5,924,646
2034	100%	32%	28,892	21,858	7,034	8,306	10,886,798	5,734,253
2035	100%	32%	29,642	22,425	7,217	8,521	11,169,297	5,549,979
2036	100%	32%	30,411	23,007	7,404	8,743	11,459,126	5,371,626
2037	100%	32%	31,200	23,604	7,596	8,969	11,756,476	5,199,005
2038	100%	32%	32,010	24,216	7,793	9,202	12,061,542	5,031,931
2039	100%	32%	32,840	24,845	7,996	9,441	12,374,524	4,870,226
2040	100%	32%	33,692	25,489	8,203	9,686	12,695,628	4,713,718

ANNEX A2. DISCOUNT RATE FOR NPV

To obtain a discount rate for this study, an average of different discount rates is used. **Table A9** presents the discount rates used to estimate the average discount rate.

Table A9 – Series of discount rates used to estimate Fiji's discount rate

Country	Discount Rate
European Union	4
Norway	4
France	4.5
USA (CBO)	2
USA (OMB)	5
USA (EPA)	5
USA (GAO)	0.1
ADB infrastructure	9
ADB social projects	6
World Bank	11
Philippines	10
Australia OPB	7
New Zealand	6
European Union	4

Source: Moore et al. (2020)[25].

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