A Pathway Towards the Implementation of an Electronic Waste Management System in Seychelles

Status Quo Analysis and Assessment of Future Strategies

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Summary

Electronic waste, or e-waste, is currently the fastest growing waste stream worldwide. Due to e-waste containing a variety of valuable and toxic materials, recycling has proven to be the most appropriate strategy to manage this waste stream. Seychelles is the African country with the highest e-waste generation per inhabitant; however, e-waste is currently not being properly managed in Seychelles and mainly ends up in landfills.

Motivated by the current lack of appropriate management options for e-waste in Seychelles, this thesis has the objective to understand relevant aspects around the design of an e-waste management system in Seychelles and to assess different strategies how such a system could be implemented in the local context. The obtained results are intended to act as guidance to policy makers in the development of an effective and economically viable e-waste management system in Seychelles.

Drawing on an extensive literature review and information obtained by stakeholder consultations, existing knowledge about managing e-waste from the international community was combined with information about the status quo of waste management in Seychelles. Additionally, a business plan calculation for an e-waste dismantling facility in Seychelles was carried out to enhance understanding of financial aspects around managing e-waste. A consumer survey was conducted to gain insights into consumer's behavior and attitudes towards e-waste recycling that are relevant for assessing design options for an e-waste management system.

The results of this research allowed for a comprehensive understanding of relevant aspects to the strategic implementation of an e-waste management system in Seychelles. It was found that adopting a concise definition of e-waste and a classification scheme for different e-waste types in national legislation can effectively support e-waste management since it establishes a common understanding of what such a management system entails. This understanding will also be useful for determining an initial product scope to be covered by an e-waste system in Seychelles. Focusing on a limited but broad product scope appears to be the preferred policy option since it is expected to achieve a balance between collected e-waste volumes and experienced system complexity. With regards to allocating responsibilities to manage the overall e-waste management system, it was found that it is probable that the producers (i.e., the importers) of e-waste will lack the capacity and capabilities to properly organize the e-waste system and enforce its rules. Therefore, it appears that a government entity is likely most capable to manage the e-waste system. In regard to the applicability of different financing mechanism to cover the costs of the e-waste system, it was found that it is generally possible to make the whole society, consumers, or producers financially responsible. The conducted analysis showed that the latter two options express substantially higher complexity stating notable challenges with regards to establishing a fair and financially sustainable e-waste system. Consequentially, making the whole society responsible for financing the e-waste system appears to be the simplest and lowest-cost solution. A variety of different options have also been discussed with concerning the collection of e-waste in Seychelles. Permanent drop-off facilities, special drop-off and collection events, and formal and informal door-to-door collection are collection channels that can be utilized. On which ones to focus initially will depend on the product scope included under the e-waste management system, the amount

of resources available, and how existing collection infrastructure can best be leveraged. Additional policy measures such as the implementation of disposal bans, tipping fees, and deposit-refund schemes can further support high collection rates. The findings related to the conducted business plan calculation for a dismantling facility in Seychelles to process and export e-waste showed that the costs for the environmentally responsible treatment of valuable and non-valuable e-waste fractions are too high to enable such a facility to operate at a profit. This reveals a strong need for external support to enable the establishment of a dismantling facility, ensure its long-term financial sustainability, and eliminate business risks for the facilities' operator.

A lack of complete and reliable data limits the findings of this thesis. Therefore, a need for further research to obtain more concise data, especially in regard to e-waste amounts generated in Seychelles and international market prices for e-waste output fractions, can be identified. Further points of action such as the organization of selected pilot projects are proposed to enhance understanding of the practical implications of implementing an e-waste management system.

In general, it was found that costs and efforts attached to the implementation of an e-waste system are expected to be manageable. This is especially true if the e-waste system is developed step-by-step and resources can be built up along the way. Further, a sequential implementation of the e-waste system will enable each system element to be designed in a functional manner, supporting the transition of Seychelles towards a sustainable society.

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Abbreviations

ABS	Acrylonitrile butadiene styrene
ARF	Advanced Recycling Fee
CMA CGM	Compagnie Maritime d'Affrètement Compagnie Générale Maritime
CMR	Cleaning, Maintenance, and Repair
CRT	Cathode-ray tube
DoE	Department of Environment
DRZ	Dismantling- and Recycling-Center
EEE	Electrical and Electronic Equipment
Empa	Swiss Federal Laboratories for Materials Science and Technology
EoL	End-of-Life
EPR	Extended Producer Responsibility
EU	European Union
FPD	Flat-panel display
GDP	Gross Domestic Product
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
HARS	National Old-for-New Home Appliance Scheme
HFC	Hydrofluorocarbon
HP	Hewlett-Packard
HS	Harmonized System
HSE	Health and Safety Equipment
HW	Hazardous Waste
IT	Information Technology
ICT	Information and Communications Technology
LWMA	Landscape and Waste Management Agency
MEECC	Ministry of Environment, Energy and Climate Change
MoF	Ministry of Finance, Trade Investment and Economic Planning
MSW	Municipal Solid Waste
OECD	Organisation for Economic Co-operation and Development
POP	Persistent Organic Pollutant
PPP	Polluter-Pays-Principle
PRO	Producer Responsibility Organization
PUC	Public Utilities Corporation
SCR	Seychelles Rupee

SIDS	Small Island Developing State
SIT	Seychelles Institute of Technology
STAR	Société de Traitement et d'Assainissement Régionale
StEP Initiative	Solving the E-waste Problem Initiative
TF	Treatment Facility
UAFL	United Africa Feeder Line
UN	United Nations
UNEP	United Nations Environment Programme
UNIDO	United Nations Industrial Development Organization
UNU	United Nations University
VAT	Value-Added Tax
WEEE	Waste Electrical and Electronic Equipment
WEPD	Waste Enforcement and Permit Division

1 Introduction

Electronic waste, or e-waste, refers to all items of electrical and electronic equipment (EEE) and its parts that have been discarded by its owner as waste without the intent of re-use (UNU/StEP Initiative 2014). With an annual growth rate of 3–5%, e-waste is currently the fastest growing waste stream worldwide (Cucchiella, D'Adamo, Lenny, & Rosa, 2015; Singh & Zeng, 2016). Managing this waste stream is of increasing interest to policy makers worldwide due to its hazard potential and its content of valuable materials. A variety of different e-waste management systems have emerged to move towards the recycling of e-waste and the minimization of the amounts going to the landfill or being incinerated (Baldé et al., 2017). However, developing such a system is a challenging task because specialized segregation, collection, transportation, treatment, and disposal mechanisms are required (UNEP, 2007a). Despite the revenues from recovering valuable materials, the costs of environmentally responsible recycling of the e-waste and its toxic components can exceed those revenues (UNU/StEP Initiative, 2009; UNU/StEP Initiative, 2015), thereby disincentivizing the proper management of e-waste (Lundgren, 2012).

Managing e-waste also states a challenge for the island state of Seychelles. Therefore, this thesis is intended to provide a basis to initiate the implementation of an e-waste management system in Seychelles. The introductory chapter is intended to provide necessary background information in section 1.1, namely about the general importance of recycling e-waste, about Seychelles as a country, and about the challenges in regard to waste and e-waste management faced by Seychelles. Section 1.2 will then highlight the detailed objectives of this thesis and outline the research question.

1.1 Background

1.1.1 The importance of recycling e-waste

Recycling (i.e., the "processing of waste back to the material cycle"; Tanskanen, 2012) has proven most appropriate regarding strategies for managing e-waste as compared to landfilling or incineration from an economic, environmental, public health, and safety perspective (Apisitpuvakul, Piumsomboon, Watts, & Koetsinchai, 2008; Choi, Shin, Lee, & Hur, 2006; Hischier, Wäger, & Gauglhofer, 2005; Kim, Hwang, Matthews, & Park, 2004; Kumar, Holuszko, & Espinosa, 2017; Scharnhorst, Althaus, Classen, Jolliet, & Hilty, 2005; UNU/StEP Initiative, 2015).

From an economic point of view the recycling of e-waste can be beneficial because e-waste contains considerable quantities of valuable materials (copper-containing motors, iron parts, gold-, silver-, and copper-bearing printed circuit boards, etc.) which can make them worth being recycled (Lee, Chang, Fan, & Chang, 2004; Spitzbart et al., 2014; Tanskanen, 2012). For some metals it has even been shown that their concentration in e-waste is higher than in the earth crust which can make their recycling a lucrative business (Kumar et al., 2017; Zhang, Wu, & Simonnot, 2012). Forecasted scarcity coupled with increased demand from manufacturers and consumers has led to the price of those commodities rising (Tanskanen, 2012; UNU/StEP Initiative, 2012; UNU/StEP Initiative, 2015). Next to this, it has also been found that increasing the amount of e-waste going to recycling can create jobs in collection services as well as in the recycling industry (Electronics TakeBack Coalition, 2014; Heacock et al., 2015; Zeng, Gong, Chen, & Li, 2016).

Environmental, public health, and safety benefits may be incurred from recycling as follows: The recycling of e-waste can reduce the total global demand for primary production of metals from mining which helps to limit greenhouse gas emissions (Kumar et al., 2017; Zhang et al., 2012). Additionally, e-waste can contain a variety of toxic substances such as lead, mercury, arsenic, cadmium, selenium, hexavalent chromium, flame retardants that create dioxin emissions when burned, and ozone depleting chemicals such as chlorofluorocarbons. Landfilling and incineration, therefore, pose a significant contamination risk and the recycling of this waste stream can prevent negative impacts on the environment and human health (Czuczwa & Hites, 1984; Lee et al., 2004; Puckett et al., 2002; Robinson, 2009; Spitzbart et al., 2014; UNU/StEP Initiative, 2015; Williams et al., 2008). Studies have shown that landfills accepting electronic devices can cause groundwater contamination due to migratory potential of pollutants through soils and groundwater within and around landfill sites, in some cases even despite special prevention layers (Kasassi et al., 2008; Schmidt, 2002; Yang, 1993). Vaporization of mercury from broken lamps or other components and uncontrolled landfill fires can also contribute to the spread of toxins into the environment through the air (ACRR, 2012, UNU/StEP Initiative, 2015). Furthermore, it has been discovered that combustion in an incinerator can emit toxic gases into the atmosphere (Kiddee, Naidu, & Wong, 2013).

It is important to note that the above-mentioned advantages of e-waste recycling are only applicable if the e-waste is recycled according to treatment standards. Substandard treatment practices such as open burning to extract metals, acid leaching for precious metal recovery, unprotected melting of plastics, or direct dumping of hazardous residuals have a high potential to generate negative impacts on the environment and human health (Baldé et al., 2017; Ha et al., 2009; Lim & Schoenung, 2010; Pradhan & Kumar, 2014; Puckett et al., 2002; Robinson, 2009; Sepúlveda et al., 2010; Zhang et al., 2012).

1.1.2 General information about Seychelles

The Republic of Seychelles is an archipelago nation consisting of 116 islands with a total land area of 455 km^2 (Worldatlas, 2019) scattered over a total geographical area of over 1 million km^2 in the Western Indian Ocean, lying 1,500 km off the eastern coast of Africa (NBS, 2018). The country has a current population of 95,843 people which has been steadily growing in the past years (The World Bank Group, 2019a) and is expected to grow further in the future (NBS, 2014). The majority of the population lives on the three main islands Mahé (86%), Praslin (9%), and La Digue (4%; state of 2017; NBS, 2018) which are all no further apart from each other than 48 km (NBS, 2018). Seychelles has the highest nominal Gross Domestic Product (GDP) per capita in Africa of USD 15,630 (The World Bank Group, 2019b) and a total GDP of USD 1.498 billion in 2017 (The World Bank Group, 2019a). However, inequality is apparent (The World Bank Group, 2019b) which is also visible in Seychelles' comparably high estimated Gini index of 46.8 (state of 2013; The World Bank Group, 2019c). Seychelles' economy is mainly based on fishery and tourism (Ministry of Foreign Affairs, 2013).

Due to its geographical, economic, and social characteristics and vulnerabilities, Seychelles is characterized as a Small Island Developing State (SIDS; United Nations, 2019a; United Nations, 2019b). SIDS are countries characterized by their small size, remoteness and insularity, disaster proneness and environmental fragility (Briguglio, 1995) with the tourism industry playing a "catalytic role" in these islands (Hampton & Jeyacheya, 2014).

1.1.3 The problematic nature of waste and e-waste in Seychelles

Appropriate waste management poses a serious challenge for Seychelles; however, it is of crucial importance because the country's most important industries, tourism and fishery, depend on a pristine environment (UNEP, 1999). Combining the findings of Agamuthu and Herat (2014), Eckelman, Ashton, Arakaki, Nagashima, and Malone-Lee (2014) and UNEP (1999) about barriers to waste management in SIDS with local information obtained from stakeholder consultations and reviewed literature (Krütli et al., 2018; Lai, Hensley, Krütli, & Stauffacher, 2016) the following challenges to general waste management can be identified for Seychelles:

- High and rising waste volumes due to relatively high population density and fast economic growth
- Limited availability of land for waste management activities
- Small market sizes and limited potential for economies of scale
- Vulnerability to supply and demand shocks
- Lack of capital and financing options
- Limited institutional and human resources capacity
- High operational costs
- High costs of products that must be imported or exported

As a result of these factors, landfilling remains the primary option for waste disposal in Seychelles since it is a comparably simple and low-cost solution and the development of other types of waste management such as incineration or recycling has been hindered by the aforementioned challenges. This is problematic given Seychelles' limited physical land space and the previously mentioned adverse effects of landfilling on the environment. Waste management in Seychelles also appears to be characterized by shortfalls in implementing plans and strategies due to a lack of clearly defined responsibilities, financial flexibility, and incentives (Dine et al., 2016).

Referring to the findings of section 1.1.1, overcoming these challenges and weaknesses becomes especially important in the case of e-waste. E-waste makes up roughly 1% of the total generated waste amounts in Seychelles (Kannengiesser, Brandt, & Tu, 2017) which has been estimated to amount to around 1.1 kilotons in total in 2016 (Baldé et al., 2017). This makes Seychelles the African country with the highest e-waste generation per inhabitant (11.5 kg/inh; Baldé et al., 2017) which can mainly be explained by a linear relationship between a country's GDP and its e-waste generation (Kumar et al., 2017). Short functional lifespans of devices due to the humid and oceanic climate in Seychelles, the generally low quality of imported EEE, and societal behavior patterns that lead to the replacement of devices rather than their reparation further contribute to these high numbers (Lai et al., 2016). The amount of e-waste generated in Seychelles is expected to grow further in the future due to growing wealth and an increasing population (NBS, 2014; The World Bank Group, 2019a). Despite this high generation of e-waste, this waste stream is currently not being properly managed or recycled in Seychelles and mainly ends up in landfills except for selected scrap metal parts from certain devices such as refrigerators and washing machines that are being exported. Therefore, a clear need can be identified to establish alternative options to manage e-waste to avoid it being landfilled, move towards its recycling, and profit from economic, environmental, public health, and safety benefits.

1.2 Research Objectives and Research Question

Motivated by the current lack of appropriate management options for e-waste in Seychelles, this thesis has the objective to understand relevant aspects around the design of an e-waste management system in Seychelles and to assess different strategies how such a system could be implemented in the local context. The system shall be designed in a way that optimally uses resources while maximizing e-waste recycling rates. Therefore, the different available design options will be analyzed with regards to their suitability for Seychelles based on these criteria. This also makes it necessary to analyze the current framework conditions related to e-waste in Seychelles to understand how an e-waste management system could optimally be integrated. The obtained results are intended to act as guidance to policy makers in the development of an effective and economically viable e-waste management system in Seychelles.

While there were two studies conducted concerning general waste management in Seychelles (Kannengiesser et al., 2017; Krütli et al., 2018; Lai et al., 2016) and one characterizing e-waste flows in Seychelles (Rajković, 2018), so far, no work has been conducted about how e-waste could best be managed in Seychelles. Yet, knowledge can be drawn from experiences related to e-waste management systems that are operated in other countries as well as work that has been conducted by international organizations and other stakeholders related to the development and management of such systems. Therefore, this thesis aims at answering the following research question:

What aspects around the development of an e-waste management system exist and how can internationally available knowledge be leveraged to identify an optimal design of such a system in Seychelles?

The remainder of this thesis is structured as follows: The methodology chapter introduces the research design and scope of this thesis (2.1), the sources of data collected (2.2), and the methods used to analyze the obtained data (2.3). The results chapter outlines the newly gained information, namely in regard to an assessment of the current framework conditions relevant for an e-waste management system in Seychelles (3.1) and an analysis of the different design elements of such a system in the context of Seychelles (3.2). The final discussion chapter then examines the practical implications of the obtained results (4.1), outlines the limitations related to those results (4.2), suggests future points of actions and accompanying research (4.3), and concludes with the major findings of this thesis (4.4).

2 Methodology

This chapter describes the methodology used to answer the research question. Section 2.1 outlines the research design and scope of this thesis, section 2.2 describes the different data types that have been collected, and section 2.3 outlines the data analysis.

2.1 Research Design and Scope of Thesis

The rationale and structure of this thesis follows three distinct parts. First, an analysis of existing institutional and applied framework conditions in Seychelles will be conducted to fully understand the local context. Second, this information will then be combined with an analysis of how the different elements of an e-waste management system can be designed. Finally, based on these two types of information, a conclusion regarding the suitability of different design options will be drawn for Seychelles.

With regards to the analysis of existing framework conditions in Seychelles in part one, the institutional framework will be assessed, including international, legal, and policy framework conditions, the most relevant stakeholders outlined, the actual waste practice for different waste types in Seychelles analyzed, and estimations of generated e-waste amounts assessed.

To move towards the analysis of the different elements of an e-waste management system, it needs to be understood that such a system consists of a complex interrelated structure with several key elements, namely the rules that govern the system, the system financing, and operational aspects including the flow of e-waste into and out of a jurisdiction (UNU/StEP Initiative, 2015). These elements have been depicted in Figure 1. Every choice about the design of one of these elements also has the potential to influence the most suitable design of other elements in the system and it is, therefore, of crucial importance to understand such interdependencies and include them in any policy considerations. Given these interdependencies, the different elements of the e-waste system should generally not be developed step-by-step as separate entities but should be seen as a comprehensive system and be developed together. This is why the different parts of this thesis shall not be understood as a chronology but are rather an attempt to follow the most logical structure in terms of the different layers of an e-waste management system.

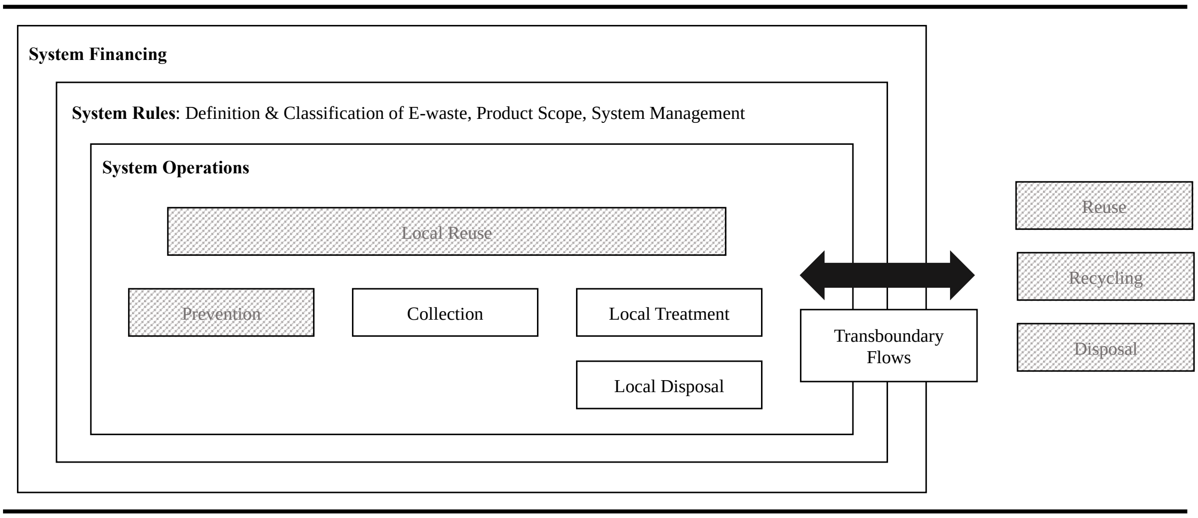

Figure 1: Elements of an e-waste management system. Elements outside the scope of this thesis are shaded in grey. Adapted from UNU/StEP Initiative (2015).

In this thesis, the system's rules will be discussed first of which the primary aspect to consider concerns the necessity to agree on and legally implement a clear definition of e-waste and a classification of different e-waste types. This will serve as a basis for all the following elements that will be discussed because it establishes a shared understanding of the term e-waste and its different types. Based on this, it will subsequently be possible to consider the potential scope of e-waste products that can be covered by an e-waste management system. Any decision in this area will have a strong influence on the system's financing needs and the requirements related to any operational aspects. The final layer that will be examined with regards to defining the system's rules is who can be made responsible for managing what aspects of the e-waste management system.

After having defined the system's rules, it is possible to move towards the system's financing where different mechanisms will be discussed to raise funds for the e-waste management system. These funds are necessary to enable the execution of the system's operations.

Operational aspects that will be considered during this thesis are how e-waste can be collected, locally treated, and subsequently be exported to international recyclers. For fractions that are not eligible for recycling, local disposal will also be considered. While recognizing the waste hierarchy and the priority of waste prevention and preparation for re-use over recycling, given time constraints these aspects have not been included in this thesis. The collection of e-waste will be discussed as a separate section, while it will be focused on the treatment and export of e-waste in a common section. This, because it will essentially be one single entity who will execute these operations via an e-waste treatment facility (TF). While the structure to discuss the other system elements will first consider available policy options, then apply them to Seychelles, and subsequently draw a conclusion with regards to the suitability of these options in the local context, the section related to the treatment and export of e-waste will also deviate from this structure. To provide a maximum of relevant insights, it was decided to treat this section by conducting a business plan calculation for a TF in Seychelles. This shall make it possible to establish if an attractive business model opportunity exists and to examine how such a TF may be best set up to achieve the most favorable economic and environmental outcome. The obtained results are then intended to provide essential background information to policy makers and in the long-term shall ensure the environmental and financial sustainability of the TF (UNU/StEP Initiative, 2016b).

The findings related to each system element will finally be discussed in regard to their practical implications, followed by an outline of the limitations of this thesis, and an outlook into the future where potential points of actions and accompanying research will be highlighted. Finally, it will be concluded on the major findings of this thesis.

2.2 Data Collection

To attain the objectives of this thesis, four main types of qualitative and quantitative data have been collected which are described below. Due to the need to obtain a large amount of local data from Seychelles, a three-month field study from 15 January 2019 until 15 April 2019 was conducted. Local data collection was organized in close collaboration with the Waste Management and Standards Section of the Ministry of Environment, Energy and Climate Change (MEECC).

2.2.1 Literature review

A comprehensive review of existing literature was conducted to assess the current knowledge related to e-waste management practices and their application in other countries and to understand existing framework conditions in Seychelles. Sources that have been reviewed include but are not limited to scientific papers, legal documents, policy plans, reports, websites, and press releases. These sources were either consulted online or obtained from stakeholders.

2.2.2 Stakeholder consultations

To better understand the current situation in Seychelles and how e-waste could best be managed accordingly, extensive consultations were held with relevant local stakeholders and experts in the field of e-waste management. This was regarded a crucial source of information given the fact that written information in Seychelles is relatively sparse and a very limited amount of literature is available specifically treating e-waste management in SIDS. The importance of seeking views from different stakeholder groups currently involved in local waste management has also been pointed out by SPREP (1999) since input from these groups will help in identifying concerns and establishing objectives which are supported by all relevant stakeholders. Consultations took place in the form of individual interviews and in two workshops.

Stakeholder interviews

Individual interviews with stakeholders were conducted either in person, via telephone, or via e-mail between 14 December 2018 and 3 April 2019. To identify interview participants, a theoretical sampling approach as described by Glaser and Strauss (2017) was used. A primary sample of participants was chosen based on information obtained from available literature and from recommendations from the Director of the Waste Management and Standards Section, Fredrick Kinloch, and the supervisor of this thesis, Dr. Pius Krütli. The obtained data from these interviews was analyzed, and the results used to identify further interview participants. A complete list of all 46 interviewed stakeholders can be found in Appendix A.1.

E-mail interviews were conducted in a structured form, asking the interview participant a set of precisely formulated research questions (Bernard, 2000). In-person and phone interviews were conducted as semi-structured interviews in open question format. Semi-structured interviews are characterized by either a series of questions or a list of topics that are to be covered in the interview and the possibility to respond to topics that are raised during the interview (Edwards & Holland, 2013). This technique allowed for diverging to interesting topics or information that emerged and at the same time, interviewees had the ability to respond in their own words (Bryman, 2012; Creswell, 2014). Information obtained during the interviews was recorded by taking notes and where possible, audiotaping.

Workshop

Two workshops with selected stakeholders were organized. The first workshop was conducted with local stakeholders in Seychelles and the second workshop included members of the "Solving the E-Waste Problem" (StEP) Initiative[1] that could provide input from the international e-waste community. Both workshops were held towards the end of writing this thesis and consisted of two parts: the presentation of the preliminary results of this thesis and the discussion of these results. A full list of participants for both workshops can be found in Appendix A.2.

The first workshop was held for a duration of two hours on 9 April 2019 at the MEECC, Botanical Garden, Victoria in Seychelles in collaboration with the MEECC. 13 stakeholders participated in the workshop, including representatives from the public and private sector as well as from civil society. Participants were selected based on their potential relevance for a future e-waste management system and their current involvement in local waste management activities. Most participants had been individually interviewed beforehand where knowledge was drawn from them and they were given the chance to describe their own views and opinions. This workshop, on the other side, also provided the participants with new knowledge and enabled them to share their views with each other. The setting of this workshop allowed for presenting the results in a form where participants could provide their input and opinions and ask for clarifications throughout the presentation. Since the presentation was split into several distinct parts, a discussion of the presented results took place after each of these parts where participants were also asked whether they generally agree with the conclusions that were drawn from these results. After the presentation, the discussion was opened to allow participants to freely share further thoughts and ask additional questions. By following this structure, it was possible to identify key concerns from stakeholders, to validate the obtained findings with them, and to receive further input. Hence, this workshop was not only intended to obtain further information from stakeholders for

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[1] The Solving the E-Waste Problem (StEP) Initiative emerged in 2004 as an independent, multi-stakeholder platform for designing strategies to tackle global e-waste challenges along the entire electronics life cycle. The initiative facilitates research and dialogues among its membership which constitutes more than 35 members from business, international organizations, governments, NGOs, and academic institutions around the world. The initiative also regularly publishes reports on its findings (UNU – StEP Initiative, 2019).

this thesis but also to increase the knowledge and awareness around e-waste management possibilities in Seychelles amongst participants, and to motivate further action.

The second workshop was held for a duration of one hour on 15 May 2019 in collaboration with the StEP Initiative in the form of an online webinar. The whole membership of the StEP Initiative was invited and the nine stakeholders that participated in the webinar included representatives from international e-waste organizations, EEE manufacturers, and research institutions. In the first half of the workshop, the preliminary results of this thesis were presented. In the second half, participants were given the chance to freely comment on the presented results and were additionally asked for input on a selected set of issues. Both workshops were audiotaped to enable subsequent analysis of the obtained data.

2.2.1 Quantitative data

Quantitative data was mainly collected related to (i) the potential e-waste amounts generated in Seychelles and (ii) expected revenues and costs for e-waste treatment and export. Again, sources were either consulted online or directly obtained from stakeholders.

While an extensive study regarding potential e-waste mass flows was already available (Rajković, 2018), it was sought to understand better how expected e-waste amounts split up between the different e-waste categories and how reliable the obtained information is. National import data for EEE from Seychelles Customs Division for the years 2013 to 2017 (CVO, 2013, 2014, 2015, 2016, 2017), census data from the National Bureau of Statistics (NBS, 2017, 2018), governmental write-off data from the Ministry of Finance, Trade Investment and Economic Planning (MoF; Š. Rajković, personal communication, February, 2019), landfill data (Kannengiesser et al., 2017), and average lifespan data for EEE (Kasper et al., 2011; Osibanjo and Nnorom, 2008; Wang, Huisman, Stevels, & Baldé, 2013) were the main types of quantitative data consulted to achieve this.

To comprehend present economic framework conditions related to an e-waste TF in Seychelles, pricing information for different goods and services was collected as well as information about space requirements, required working hours, the amount of e-waste that is expected to fill up a container, etc. A large part of the obtained information stems from the results of a dismantling campaign conducted by the Dismantling- and Recycling-Center (DRZ)[2] in 2013, spanning 13 relevant appliance groups (UNU/StEP Initiative, 2016a). This data was supplemented with estimations of local costs for labor, infrastructure, shipping, etc., and with information about international market prices for different e-waste output fractions. The information related to the value of different e-waste fractions stems from a study conducted by the StEP Initiative in 2018, where such data was collected for an e-waste program in Ghana (E. Smith, personal communication, March 26, 2019). It shall be acknowledged that market prices can vary significantly, even over short time periods. This leads to significant insecurity with regards to this data source. However, despite contacting various e-waste recyclers to obtain most recent figures, it was not possible to obtain such information. Contacted recyclers would refer to

[2] The Dismantling- and Recycling-Center (DRZ) is a socio-economic enterprise run by „Die Wiener Volkshochschulen GmbH“. The center refurbishes and recycles used and waste electrical and electronic equipment.

confidentiality issues and pointed out that such information was only provided once the exact composition and amounts of the e-waste fractions to be supplied is known. Where possible, the received data was updated with current market prices from available online sources.

Whenever data was lacking or its quality was uncertain, this shall be specified in the applicable results section and the implications of it be discussed.

2.2.2 Consumer survey

A consumer survey was conducted to increase understanding of aspects around consumer's behavior and attitudes towards e-waste recycling that are relevant to assess design options of an e-waste management system. A survey was considered the ideal research tool for this aim.

Survey design

The survey consisted of demographic data questions and two sets of factual data questions and was designed in the form of a self-administered questionnaire (i.e., it was designed to be completed by respondents without intervention of the interviewer; Bernard, 2000). The collected demographic data concerned gender, age, household size, household income, and the district where respondents lived. The first set of factual data questions asked respondents about the amount of EEE they own, where they usually purchase their EEE, how often they replace their EEE, and what they do with their EEE once they do not use it anymore. This set of questions aimed at better understanding the amount of e-waste that consumers generate and their use of available purchase and disposal channels for EEE. To account for the variability of EEE and reduce the complexity of the questionnaire, all these questions were asked specifically for mobile phones, tablets, laptops, computers, and televisions. Only the last question asking about what respondents do with their EEE once they do not use it anymore was asked generically for all types of EEE. The second set of questions asked respondents about their willingness to return EEE to retailers at the point of purchase of a new device in order to get it recycled. Further, it was also enquired whether respondents would be willing to use redeem centers that are currently collecting PET bottles and aluminum cans to bring back their e-waste and whether respondents would know about the location of at least one such a redeem center on Mahé, Seychelles. This set of questions aimed at better understanding different options to collect e-waste, especially with regards to the possible use of a deposit-refund system to incentivize consumers to bring back their EEE to collection points. All questions except one were formulated as closed questions, where respondents could either choose one of several options or simply indicate a number. The only open-ended question was asking survey participants about what they do with their EEE once they do not use it anymore. The complete survey questionnaire can be found in Appendix A.3.

The initial survey design was adapted after a pre-test with approximately 15 participants because it was found that some questions were formulated unclearly or were too complicated.

Sampling procedure and achieved sample

Data was collected in the form of a street intercept survey. While it is recognized that this sampling strategy likely leads to a nonrepresentative population sample, this method was chosen since it is, nevertheless, expected to provide a first indication with regards to the topics in question with reasonable effort. To minimize sampling bias and achieve highest possible sample accuracy, survey participants were selected in a way that closely represents the gender and age district distribution of the population in Seychelles. Samples of equal size were taken from three different geographical clusters (Anse Royale, Beau Vallon, and Victoria) to represent all districts of Mahé as equally as possible (Bernard, 2000). Based on the expected heterogeneity of the population in Seychelles, a target sample size of 150 respondents was chosen.

A sample size of 145 respondents was achieved, while roughly two thirds of the people approached would reject to complete the survey. Due to this high rejection rate, an additional selection bias cannot be excluded since it is possible that consumers with certain characteristics might have been more willing to participate in the survey and can therefore be overrepresented. However, it is not possible to characterize these deniers any further. As can be seen in Table 1, the female population of Seychelles is slightly overrepresented in this survey. Table 2 further shows that the middle-aged population is also overrepresented. This can be partially explained by the fact that children under 16 years were excluded from the survey. Further statements about the representativeness of the achieved sample cannot be made (e.g., the education level was not asked during the survey and there are no statistics about household income distribution in Seychelles available). The household income distribution of the surveyed sample can be found in Appendix A.4.

Table 1: Comparison of gender distribution of Seychelles' population and survey participants.

Gender	Seychelles' population[A] [%]	Survey participants [%]
Male	52	45.5
Female	48	54.5

[A]state of 2010; NBS (2012)

Table 2: Comparison of age distribution of Seychelles' population and survey participants.

Age (completed years)	Seychelles' population[A] [%]	Survey participants [%]
0-19[B]	30.6	10.9
20-39	33.9	51.6
40-59	25.2	31.3
60+	10.3	6.3

[A]state of 2010; NBS (2012)

[B]the youngest participant in this survey was 16 years old

It shall also be mentioned that even though a sample size of 145 was achieved, for certain survey questions the number of respondents is reduced significantly. For example, only 42 survey participants indicated to own a computer and were therefore eligible to answer questions that were asked specifically for computers. This fact further limits the validity of certain results.

Data collection

To avoid interviewer bias, the majority of the self-administered questionnaires were handed out to respondents without the interviewer providing additional comments or explanations (Bernard, 2000). However, some respondents would ask for clarifications or were not comfortable filling out the questionnaire themselves. Hence, some questionnaires were filled out via a face-to-face interview or a mix of a face-to-face interview and a self-administered survey. While it was tried to administer the questionnaire without the formulation of leading questions, the problem of reactivity shall be recognized here and it cannot be excluded that some respondents were biased by this (Bernard, 2000).

2.3 Data Analysis

2.3.1 Qualitative data analysis

The data obtained from the literature review and stakeholder consultations was qualitatively analyzed using the Grounded Theory methodology as described by Glaser and Strauss (1967). Grounded Theory is an approach to analyze, interpret, and make sense of the collected qualitative data and systematically discover theory from it (Corbin & Strauss, 2014). Data collection and data analysis are conducted simultaneously and by constantly comparing obtained data, the data can be abstracted into concepts (Bryman, 2012; Corbin & Strauss, 2014).

2.3.2 Quantitative data analysis

The collected quantitative data and the data obtained from the conducted survey were quantitatively analyzed using the statistics software R and Microsoft Excel.

The quantitative information regarding the potential e-waste amounts generated in Seychelles was analyzed with Microsoft Excel and subsequently applied to the applicable formulas to receive the final results. The results of this analysis can be found in the respective section about e-waste amounts in Seychelles (section 3.1.4).

The data that was collected to conduct a business plan calculation for a TF in Seychelles was also analyzed with Microsoft Excel. An open-source, excel-based business-plan-calculation-tool served as a basis for the final cost calculation (UNU/StEP Initiative, 2016a). A first version of the tool was developed by KERP[3], the DRZ, and Swiss Federal Laboratories for Materials Science and Technology (Empa)[4] in 2012 within a project funded by the StEP network (Task-Force 4 Recycling). This version has subsequently been further developed by DRZ and Empa within a project of the United Nations Industrial Development Organization (UNIDO) aiming to implement an e-waste TF in Kampala,

[3] KERP Competence Center is a global software and consulting partner for optimizing cross-enterprise business processes based in Vienna, Austria (UNU/StEP Initiative, 2016b).

[4] Swiss Federal Laboratories for Materials Science and Technology (Empa) is an interdisciplinary research and service institution for material sciences and technology development (UNU/StEP Initiative, 2016b).

Uganda (Spitzbart et al., 2014). This tool was expanded to provide the level of detail that was required in the context of Seychelles.

To prepare the obtained data from the consumer survey for data analysis, qualitative variables were coded and the received responses from the open-ended question were summarized into categorizes representing responding tendencies. Then, univariate analysis for all questions was conducted. To get a measure of central tendency for numerical responses, the mean, standard deviation, and median was calculated. Responses for other types of questions were summarized in table form and, where applicable, visualized to recognize frequency distributions and proportions of the obtained responses.

3 Results

The results chapter of this work can be divided into two distinct parts. The findings related to existing framework conditions with regards to an e-waste management system in Seychelles will be presented in the first section. This will then act as a basis to analyze different design elements of an e-waste system and to discuss the applicability of different policy options in the context of Seychelles in the consecutive section. Generally, straight-forward implications of those results will be discussed directly in the respective section, whereas compound, higher-level implications will follow in a separate discussion chapter.

3.1 Current Framework Conditions in Seychelles

Current framework conditions in Seychelles have already been described extensively by Kannengiesser et al. (2017), Krütli et al. (2018), Lai et al. (2016), and Rajković (2018) and shall be complemented here with additional information as applicable. Generally, the current framework conditions can be understood as a combination of international, legal, and policy conditions, which define the institutional framework for waste and e-waste management in Seychelles, and the practical aspects describing the current handling of waste and e-waste. An overview of relevant stakeholders and a section that covers estimated e-waste amounts generated in Seychelles will also be included here.

3.1.1 Institutional framework

3.1.1.1 International framework

The three main relevant international conventions with regards to managing e-waste that have been signed by Seychelles and have entered into force are the Minamata Convention on Mercury, the Stockholm Convention on Persistent Organic Pollutants, and the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal.

The **Minamata Convention on Mercury** is a global treaty to protect human health and the environment from the adverse effects of mercury (UNEP, 2017). The convention specifically mentions e-waste as a major source of mercury pollution and therefore lists a variety of mercury-added EEE such as certain types of batteries, switches, and lamps for a phase out until 2020 ("date after which the manufacture, import or export of the product shall not be allowed"; UNEP, 2017). Following this, Seychelles is currently targeting to phase out selected types of equipment and products containing mercury (Athanase & Uranie, 2016).

The **Stockholm Convention on Persistent Organic Pollutants** is a global treaty "to protect human health and the environment from chemicals that remain intact in the environment for long periods, become widely distributed geographically, accumulate in the fatty tissue of humans and wildlife, and have harmful impacts on human health or on the environment" (Stockholm Convention, 2008). Due to the presence of persistent organic pollutants (POPs) in e-waste, this convention is of relevance. Parties to the Stockholm Convention are required to take appropriate measures to eliminate the release of these pollutants from stockpiles and wastes (UN, 2017).

The **Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal** regulates movements of hazardous wastes between countries and sets up a regime of notifications and approvals that need to be attained in order for the cross-border transportation to be legal (UNU/StEP Initiative, 2013; UNU/StEP Initiative, 2015; Widmer, Oswald-Krapf, Sinha-Khetriwal, Schnellmann, & Böni, 2005). This convention is frequently relevant for the transboundary movement of e-waste since it often contains such hazardous substances (Baldé et al., 2017). However, since the convention differentiates between hazardous and non-hazardous depending on the chemical composition of the product rather than by product type it does not provide clarity as to whether a particular electronic device is to be regarded as hazardous or not (UNU/StEP Initiative, 2015). Hence, it has been recommended that e-waste should be presumed to be hazardous unless it can be shown either that it does not exhibit hazardous characteristics or that it does not contain hazardous components or substances (UN, 2017).

The Minamata Convention does not have a direct influence on the potential set-up of an e-waste management system in Seychelles. However, the convention is relevant to identify certain priority e-waste streams and gives an indication about how the e-waste composition might change over time (due to the planned phase-out of certain EEE).

The Stockholm Convention, while not providing any direct points of action, gives additional information about potentially especially harmful e-waste types and commits Seychelles to take appropriate action to mitigate negative impacts related to these e-waste types. Following this, landfilling is clearly an undesirable option (e.g., it has been found that significant amounts of brominated flame retardants released from EEE are contaminating the landfill and surrounding areas in Seychelles; UNEP, 2018) and channeling e-waste towards being recycled would significantly contribute to achieving the objectives of this convention.

The Basel Convention gives most direct guidance in terms of how to handle e-waste and is therefore highly relevant when thinking about the set-up of an e-waste management system in Seychelles. It provides clear regulations to follow when exporting e-waste types that fall under the convention and the integration of these regulations in national legislation will be utterly relevant since exportation of e-waste from Seychelles will be necessary to get it recycled.

3.1.1.2 Legal framework

Currently, Seychelles neither has any legislation in place specifically in regard to waste management (Kannengiesser et al., 2017) nor to e-waste management (Rajković, 2018). However, three acts and two regulations have been identified by Kannengiesser et al. (2017) to govern environmental concerns such as air, water, and soil protection which have close interlinkages to any possible waste and e-waste management system. In the context of this thesis, the main relevant legal document is the Environment Protection Act (EPA, 2016) of which the most important points shall be discussed below.

While there is no legal definition of the term "e-waste" in place, the **EPA** defines the term "waste" as "garbage, refuse, sludges, construction debris and other discarded substances or materials resulting from industrial and commercial operations or from domestic, individual and community activity" (EPA, 2016, section 2). The term "hazardous waste" (HW) is defined as per section 1(2) of the EPA (2016) as "waste which is poisonous, corrosive, irritant, noxious, explosive, inflammable, radioactive, toxic or harmful to the environment or as defined by an International Convention to which Seychelles is party to". As a result, e-waste is only legally differentiated from other waste classes if it falls under the definition of HW according to the Basel Convention. There is also no waste or e-waste classification present in any legal framework (Kannengiesser et al., 2017).

Next to including a definition of waste and HW, by virtue of section 34(2) of the EPA (2016) it is declared illegal to dump waste in places other than specified designated disposal sites. The EPA (2016) as per section 39(1) also states that "no person shall dispose of any hazardous waste except in accordance with an authorization from the Ministry" and forbids by virtue of section 38 to 39 the import, transport within or through, and export of HW without authorization from the Ministry respectively the Minister and requires additional "prior informed consent of the receiving country" for exportation, which is in line with the provisions set by the Basel Convention. As a mean to promote recycling, section 41 of the EPA (2016) also states that the Minister may prescribe fees to be paid by importers or manufacturers to cover costs with respect to the disposal of the imported goods.

Other legal documents relevant to the management of e-waste are the **Customs Management Act** (2016) which bans the importation of certain goods into Seychelles (e.g., of toxic chemicals under the Stockholm Convention), the **Excise Tax (Amendment) Act** (2017) which add taxes and levies on selected goods, and the **Consumer Protection Act** (2010) which sets the minimum warranty for EEE to six months and requires suppliers of EEE, if the product is returned with a proper reason, to repair it within 60 days, replace it within seven days, or refund the customer within 24 hours.

3.1.1.3 Policy framework

The main policy framework with regards to waste management in Seychelles is the **National Waste Policy 2018-2023** (MEECC, 2018) which is an update to the **National Waste Policy 2014-2018** (MEECC, 2014). The policy mentions guiding principles for waste management in Seychelles such as the waste hierarchy, the Extended Producer Responsibility (EPR) principle, and the Polluter-Pays-Principle (PPP). Further, it states the minimization of waste going to the landfill as one of its main objectives. The MEECC and the Landscape and Waste Management Agency (LWMA) are mentioned as the lead institutions for implementing the policy and the necessity to strengthen their resources to achieve the policies goals is being acknowledged. Next to this, a need to update legal frameworks and regulations, to expand infrastructure, to invest in the development of skilled labor and, to increase efforts in public education and awareness is being identified within the document. Moreover, following the PPP the policy states that waste management activities should be financed by the generators of waste as far as possible which shall mainly be achieved via the use of tipping fees and the introduction of additional levies on imported products. With regards to recycling, the policy points out the use of deposit-refund schemes to encourage waste segregation and specifically mentions the objective to establish a scheme for the separation and collection of EEE to be able to recycle and export it. The policy also acknowledges the need to facilitate waste processing activities to attract private operators.

While the policy does not recognize e-waste as a separate waste type within the recognized waste classes, it nevertheless defines e-waste as "waste electrical and electronic equipment that is dependent on electric currents or electromagnetic fields in order to function (including all components, subassemblies and consumables which are part of the original equipment at the time of discarding)"

(MEECC, 2018, p. 3). This definition appears to draw from the definition of waste electrical and electronic equipment (WEEE) as per Article 3(1) of the European Union's (EU) WEEE Directive (2012/19/EU)[5], however, appears to mix up the definitions of EEE and e-waste (it is not e-waste that is dependent on "electric currents or electromagnetic fields in order to function", but EEE, and e-waste would then be EEE that turned into waste). While the policy mentions no further classification of e-waste, the previous National Waste Policy 2014-2018 (MEECC, 2014) includes such a classification which almost coincides with the 10 e-waste classes used in Annex IA of the old EU WEEE Directive (2002/96/EC).

The National Waste Policy documents are drafted in an application-centric manner and point out specific development objectives of the waste sector. The **Seychelles Sustainable Development Strategy (SSDS) 2012-2020** remains more high-level with regards to waste management. It mentions concerns about the growing generation of waste and e-waste and names source segregation of solid waste and the promotion of recycling as strategic objectives to achieve sustainable development in Seychelles. This document specifically points out the need to develop a strategy for collection and treatment of e-waste and lists the Department of Environment (DoE) and the LWMA as responsible parties to implement this. Insufficient knowledge and awareness of stakeholders, an insufficient capacity to implement policies and regulations, a poor research and monitoring framework, outdated and incoherent legislation, and weak enforcement of legislation have been mentioned as general barriers to sustainable development within the document (Payet et al., 2012a, Payet et al., 2012b).

The **updated Solid Waste Master Plan 1995 for the period 2003-2010** includes a waste characterization study, future waste generation projections, and an implementation plan to achieve a set of objectives with regards to waste management in Seychelles. Amongst others, these objectives include the expansion of monitoring and enforcement capabilities, the development of appropriate human resources, and connected to this, a clear definition of roles and responsibilities. Further, the masterplan mentions the PPP and the introduction of a tax-based system or an annual fee for the domestic sector as possible measures to achieve a sustainable financing of the waste management system. The masterplan also recognizes WEEE as a separate waste stream that will need special attention but does not propose any specific objectives with regards to this (Scott Wilson, 2004). The development of a new masterplan to replace this outdated version is currently being undertaken (Theilmann, Wahl, Antha, Dine, & Sinon, 2018).

3.1.2 Stakeholder's assessment

A stakeholder's assessment is an important step in the development of any e-waste management system. It serves the purpose of "defining the actors involved and their role in the e-waste management system by groups of stakeholders" and "characterizing the stakeholder group with a set of indicators" (Schluep,

[5]The EU WEEE Directive was put in place to address the e-waste problem and improve the collection, treatment and recycling of electronics at the end of their life. The first EU WEEE Directive (2002/96/EC) entered into force in February 2003 and provided for the creation of collection schemes to increase the recycling of WEEE and its re-use. A revision of this directive (2012/19/EU) entered into force in August 2012 to tackle the fast-increasing waste stream (European Commission, 2019).

Müller, & Rochat, 2012, p. 17). Schluep et al. (2012) define the following stakeholder groups to be directly relevant in most e-waste management systems:

- Manufacturers and importers
- Distributors and retailers
- Consumers (individual households, businesses, and government)
- Collectors
- Refurbishers
- Dismantlers and recyclers
- Downstream vendors
- Final disposers
- Most affected communities
- Civil society

The role of these stakeholders and the role of national policy-makers and regulators in Seychelles has already been extensively described in Kannengiesser et al. (2017), Krütli et al. (2018), Lai et al. (2016), and Rajković (2018), which is why it shall not be discussed in detail here. However, the roles of the three main responsible entities for developing and implementing an e-waste management system in Seychelles shall shortly be outlined here since they will be directly mentioned throughout this thesis.

The **Ministry of Environment, Energy and Climate Change (MEECC)**, as per section 4(1) of the EPA (2016), is the main responsible entity to "develop and implement policies, programs and guidelines in pursuance of the national objectives on environment protection". Within the MEECC, the Waste Enforcement and Permit Division (WEPD), as part of the Department of Environment (DoE), has the main points of contacts with waste. The division is responsible for the development and implementation of waste policies and regulative frameworks concerning waste and for the enforcement of standards related to this (Rajković, 2018). The Director of Solid Waste Management is currently the only employee exclusively in charge of waste management policies (von Rothkirch, Chautems, & Djamil, 2018).

The **Landscape and Waste Management Agency (LWMA**) is the main governmental body in charge of implementing policies, plans, and strategies of the MEECC with regards to waste (von Rothkirch et al., 2018). As such, the agency is responsible for organizing waste collection, treatment, and disposal which also involves monitoring of the waste disposal site and the management of different contractors involved in the provision of waste-related services (Rajković, 2018).

The **Ministry of Finance, Trade Investment and Economic Planning (MoF)** is the responsible entity to manage the finances of the Government of Seychelles by planning financial and economic policies and strategies (MoF, 2019). In the case of waste management, the MoF is responsible for providing economic resources to the MEECC and the LWMA. The MoF receives its money from the general tax budget and from commercial waste collection and tipping fees (von Rothkirch et al., 2018).

3.1.3 Current waste practice

The current waste practice in Seychelles can be analyzed from different levels. Is has been decided to differentiate between the current practice related to general waste, recyclable waste, HW, and e-waste. There are different processes in place for each of these waste types that are relevant for the development of an e-waste management system in Seychelles. These processes shall be discussed in the following sections.

3.1.3.1 General waste

To understand how general waste is currently being handled in Seychelles is relevant for the development of an e-waste management system since e-waste is currently mainly being disposed over this waste channel. Two levels, waste collection and waste disposal, need to be considered.

Waste collection

When examining the current general waste collection practice in Seychelles, it is necessary to differentiate between municipal solid waste (MSW) generated from individual households and commercial waste generated by businesses.

MSW is defined in the newly produced waste classification by the LWMA as "household waste and waste originating from communal waste bins, skips, and other public collection points" (F. Joubert, personal communication, March, 2019). Collection of this waste type is a public service organized by the LWMA that is provided free of charge to households. While there is a monthly fee in place that each household pays to the Public Utilities Corporation (PUC), only parts of the so collected funds are used to pay for specific waste related projects but no households funds are collected to pay for general waste management activities (von Rothkirch et al., 2018).

Communal waste bins and litter bins have been distributed in Seychelles to collect MSW. Bulky household waste that does not fit into the provided bins is usually dumped next to these bins (Kannengiesser et al., 2017). In addition to this, bulky waste has also been collected in the previous years in the course of an annual special collection event called "Clean up the World". Households would be informed about this event in advance and could put their waste on the roadside for it to be picked up (Rajković, 2018). Until now, the private waste collection company Société de Traitement et d'Assainissement Régionale (STAR) has been solely responsible to collect MSW in Seychelles (Krütli et al., 2018). However, a request for tender for new waste collection contracts has been made and in the close future ten different companies will be responsible for MSW collection services in different regions on Mahé, Praslin, and La Digue (Joubert, 2019). The new contracts will be valid for six years and were intended to commence on 8 April 2019 (L. Payet, personal communication, April, 2019a); however, as of mid-April 2019 not all contracts have been finalized. The motivation behind contracting several waste collection companies was to enable small entrepreneurs to develop a business and to enhance enforcement power of the LWMA since MSW collection would no longer be a monopoly and collectors could be replaced by one another in case of non-fulfillment of their contract duties (Joubert, 2019; F. Kinloch, personal communication, February, 2019). For this reason, it was also included in the new contracts that in the case of "failure in the performance of obligations" the LWMA can terminate a contract after thirty days' written notice (L. Payet, personal communication, April, 2019a). Another mechanism to enforce compliance under the new contracts is the fact that contractors will be reimbursed by the LWMA based on a monthly evaluation form which assesses the "% of work completed" by the collector (L. Payet, personal communication, April, 2019a).

Under the new contracts, the collection companies shall "collect, transport, and deposit at the designated sites" all MSW on a daily basis. Green, bulky, and metal waste shall be collected on a weekly basis (L. Payet, personal communication, April, 2019a). As such, the LWMA has the authority to designate specific disposal sites for each waste type and the collection companies are obliged to follow these instructions (L. Payet, personal communication, April, 2019a). Further, waste types collected under this MSW collection contract shall not be mixed with waste collected from other sources (e.g., private or commercial collection contracts) and the collection companies are required to report "any abnormal disposal, illegal dumping, fly tipping, and any other related issues on site" to the LWMA (L. Payet, personal communication, April, 2019a).

With regards to the management of MSW, the LWMA is also currently organizing an individual waste bin trial where each household has its own waste bin. Individual waste bins are regarded as a starting point to enable and enforce waste separation and to charge households for the provided waste collection services. These are long-term goals by the LWMA concerning their MSW system (Joubert, 2019).

So far, the commercial sector had three available options to organize the transport of their waste to a disposal site. Firstly, they could bring their waste to a disposal site themselves; secondly, they could contract a private waste collection company for this; and thirdly, they could contract the LWMA which would then subcontract STAR to conduct this service (Krütli et al., 2018). Next to these official disposal channels, it appears that many shop owners, especially those that produce only small waste amounts, would illegally dump their waste into the communal waste bins designated for MSW (Kannengiesser et al., 2017; Krütli et al., 2018). Theoretically, the commercial sector is supposed to fully cover the costs for collection and disposal of their waste. However, this is currently not the case due to too low amounts charged for the services provided and significant amounts of outstanding debts to STAR from commercial businesses. For this reason, the LWMA is currently partially subsidizing commercial collection services (Joubert, 2019; Krütli et al., 2018).

Simultaneously to contracting new MSW collectors, the LWMA is currently also revising the commercial collection system. In the future, commercial entities will be obliged to have a private contract with a waste collection company licensed by and registered with the LWMA (Joubert, 2019; L. Payet, personal communication, April, 2019a). This is intended to enable market forces to determine the price of collection services and should avoid the necessity of the LWMA to subsidize the commercial waste collection system. To enforce this new obligation for businesses, the LWMA is aware that they will need to increase their monitoring resources (Joubert, 2019). Additionally, as with the MSW collection system, these new contracts forbid mixing commercial waste with other waste types in case the contracted company would perform both services (L. Payet, personal communication, April, 2019b)

Waste disposal

Once the waste has been collected, there are three officially available options to dispose of it. Landfilling, as the option used in most cases, export, and incineration, which is only used for a few selected waste types such as medical waste (Kannengiesser et al., 2017). The main landfill in Seychelles, Providence, is split up into two subsections, of which the newer section is supposed to be sanitary. However, because the installed leachate treatment plant is not operating at the moment and the leachate is discharged into the sea, this is currently not the case. Furthermore, landfill gas is not being captured (Kannengiesser et al., 2017; F. Kinloch, personal communication, February, 2019).

When waste enters the landfill, it is weighed at the weighbridge and distinguished into different waste classes. Different tipping fees apply depending on the waste class and weight of the discarded material (Joubert, 2019; Kannengiesser et al., 2017; Krütli et al., 2018; Rajković, 2018). So far, the applied waste classification has not been backed up by any legal framework (Kannengiesser et al., 2017) and tipping fees have not been applied in a consistent manner (Krütli et al., 2018). However, at the time of writing this report, a new waste classification including defined tipping fees and treatment options is being developed by the LWMA (F. Joubert, personal communication, March, 2019). Tipping fees will be based on disposal costs of the according waste type (Joubert, 2019). This new waste classification is mainly – but not exactly – consistent with the different waste classes recognized by the National Waste Management Policy 2018-2023 (MEECC, 2018) but differs significantly from the old waste classification system applied at the weighbridge (Rajković et al., 2018).

Non-availability of governmentally subsidized land and high rental costs for the areas surrounding the landfill have been mentioned as barriers to developing further waste management activities that could offer alternative ways of disposing waste. These barriers act as a deterrent for private entrepreneurs to establishing a business in waste activities. Next to this, even though governmentally subsidized land patches are clearly assigned and registered by the Providence Industrial Authority, some of the land that is supposed to be unoccupied and available for the development of further waste management activities is currently covered by waste (e.g., huge piles of scrap metal). This further increases the prevailing problem of land shortage. Recognizing the need to reorganize the current land allocation, the LWMA is currently working on a proposal about how to distribute the space at the landfill to make land use more efficient. However, these plans have not been finalized as of April 2019 (Joubert, 2019).

3.1.3.2 Recyclable waste

There are already some waste recycling practices present in Seychelles and understanding these practices is relevant in the context of e-waste management since it is likely that certain aspects can be transferred to e-waste and that learnings can be drawn from the functioning of involved processes. There is a deposit-refund system in place for aluminum cans, PET bottles, and selected beer bottles which is currently being expanded to include all types of alcoholic glass bottles, and there are some scrap dealing companies on the island that collect and export scrap metal for it to be recycled (Krütli et al., 2018; Rajković, 2018).

PET bottles, aluminum cans, and alcoholic glass bottles

The system and infrastructure in place for aluminum cans and PET bottles is effectively the same and is currently being expanded to include alcoholic glass bottles. It has been described extensively by D'offay et al. (2016) and Krütli et al. (2018) which is why only the most relevant aspects shall be pointed out here.

Generally, the government-led system follows a version of a deposit-refund system which is a market-based policy instrument that provides a financial incentive to consumers to return their waste to designated collection points. In practice "an initial payment (deposit) is made at the point of purchase and is fully or partially refunded when the product is returned to a specified location" (OECD, 2016, p. 22). In Seychelles, at the point of entry on importation, a tax is being collected for each PET bottle and aluminum can which is then used to refund consumers once they bring these items to designated collection points, called redeem centers. The refund amounts to 0.70 Seychelles Rupees (SCR) for PET bottles and 1 SCR for aluminum cans and is planned to amount to 1 SCR for alcoholic glass bottles. Parts of the collected funds are not returned to the consumers but are retained by different stakeholders to pay for further costs of the disposal system. After collection, the cans and bottles are diverted to a private recycling company who sells them on the international market. For alcoholic glass bottles, funds are already being collected since October 2018. However, it is not yet possible to return the bottles for a refund because an insufficient amount of funds has been collected so far (only one importer has paid as of February 2019; Jannie, 2019). This type of a deposit-refund scheme, where parts of the collected deposit are used to pay for the actual disposal system, can also be understood as an implementation of the EPR principle and the PPP. Producers, in the context of Seychelles defined as importers, are made responsible for covering the system's costs and would subsequently transfer these to the consumers (i.e., the polluters) via a raise in retail prices (OECD, 2016).

This collection system for PET bottles and aluminum cans appears to be working rather well for hotels and larger businesses since they stockpile these items and pick-up is then organized by the redeem centers (Lai et al., 2016). However, such a pick-up system does not exist for individual households and it appears that only a small proportion of households (14.7% for PET bottles and 12% for aluminum cans according to a household survey conducted by Rommelspacher et al., 2018; N=151) currently brings their cans and bottles to the redeem centers themselves. A significantly larger share would sell or give away their cans and bottles to the so-called informal sector (66.6% for PET bottles and 70% for aluminum cans according to a household survey conducted by Rommelspacher et al., 2018; N=151) who then brings the PET bottles and aluminum cans to the redeem centers. The informal sector refers to "the part of an economy that is not taxed or monitored by any form of legal authority" (UNU/StEP Initiative, 2015, p. 23). The remaining bottles would still be thrown away together with general waste. The informal sector then goes through bins and landfills to collect these bottles as well (Rommelspacher et al., 2018). It is interesting to note that the informal sector appears to be relatively organized. Individual collectors collect cans and bottles and subsequently sell them to a bigger collector who oftentimes owns a truck to transport the collected items. This collector then sells the cans and bottles to the redeem centers. A margin on the price of the collected items is added for every step to allow each stakeholder to make a profit (Candassamy, 2019). It is estimated that this system allows for about half of all aluminum cans and PET bottles to be collected separately (D'offay et al., 2016). However, its sustainability is in question since using the informal sector is not generally regarded to be desirable by local stakeholders (Ally, Essack, Nef, & Ziltener, 2016). The fact that households do not return their cans and bottles to the redeem centers themselves can be traced back to three main issues.

Firstly, it appears that while awareness about the collection system in place is comparably high (only approximately 18% of respondents during a survey conducted by Rommelspacher et al. in 2018 did not know about the system in place for PET bottles and aluminum cans, N=151), it is significantly lower regarding the location of the four existing redeem centers on Mahé. The survey conducted during this thesis found that only 33% of respondents (N=135) would know where at least one redeem center is located on Mahé and those respondents who knew about a redeem center would mostly only know about the one located in Providence.

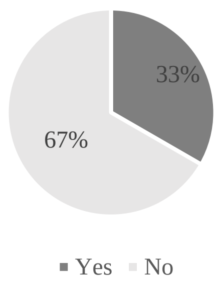

Figure 2: Do people know where at least one redeem center is located on Mahé, Seychelles? Source: Survey.

Secondly, next to the mere existence of those four redeem centers, there is no other formal system in place to separately collect PET bottles and aluminum cans at the household level. The survey conducted by Rommelspacher et al. (2018, p. 27) found that this collection system does not offer enough convenience to consumers. Survey participants stated as reasons for not bringing these items to the redeem centers themselves that the centers were "too far away" and mentioned that they would be willing to bring their cans and bottles there themselves "if the centers were closer or more conveniently situated". This perception is obviously also connected to the missing awareness about the location of all four redeem centers.

The third reason why aluminum cans and PET bottles are usually not brought to the redeem centers by the consumers directly is that the financial incentive appears to be too low. Respondents of the survey conducted by Rommelspacher et al. (2018, p. 27) stated that "they spent more money bringing in the PET bottles and cans than they would get for them". This perception can also be linked back to the too low convenience and awareness connected to the formal collection system in place. Moreover, once the informal sector developed, it was also possible for consumers to sell their cans and bottles to informal collectors, receiving less money in return but with significantly higher convenience. This appears to be more attractive to many consumers compared to using the formal system in place (Candassamy, 2019; Rommelspacher et al., 2018).

Another remaining issue connected to the PET bottle and aluminum can recycling system is that the funds collected by the deposit system are currently not sufficient to cover the system's costs. Theoretically, because all PET bottles and aluminum cans are taxed when entering the country but not all of them are returned to a redeem center, an income surplus should be accumulated. However, as can be seen in Table 3, this is not the case. For PET bottles, the amount of money collected and spent is roughly the same, while for aluminum cans, only two thirds of the money being spent in 2018 has actually been collected (Jannie, 2019). The main reason for this, according to interviewed local stakeholders, is an improper functioning of the processes at the customs division level leading to many importers being able to circumvent the applicable tax. The customs division is the responsible entity for collecting taxes on goods at the point of entry on importation (SRC, 2019). It was mentioned that the division's workforce is too small to correctly execute its tasks and that low wage levels enable bribery and corruption. Insufficient monitoring and enforcement capabilities by other government entities to control this division have furthermore been mentioned. This discrepancy between collected funds and money spent has also led to the funds cross-subsidizing each other, even though they are intended to be separate (Jannie, 2019).

Table 3: Money collected and spent for PET bottles and aluminum cans in 2018. Source: Jannie (2019).

	Money collected [Mio. SCR]	**Money spent [Mio. SCR]**
PET bottles	23.7	24.6
Aluminum cans	3	4.5

SeyBrew glass bottles

Next to the planned government-run deposit-refund system for alcoholic glass bottles mentioned above, there is an already existing deposit-refund system in place specifically for SeyBrew glass bottles[6]. This system is organized by Seychelles Breweries, the private company producing SeyBrew (Diageo, 2019). At the point of purchase, 2 SCR are collected from consumers for each bottle. Consumers can then bring back these bottles to any store selling SeyBrew and receive 2 SCR per bottle as a refund. The stores subsequently return the bottles to the distributors of SeyBrew who bring them back to Seychelles Breweries to be washed and re-used (Agricole et al., 2016; D'offay et al., 2016). This system appears to be working relatively well and over 20 million SeyBrew glass bottles are annually collected like this (Diageo, 2019). While it is unknown how many of these bottles are returned by the informal sector it is likely that this proportion is lower as compared to the PET bottle and aluminum can system. This, because the glass bottles can be returned to any store selling SeyBrew (which is practically every supermarket in Seychelles) and the offered refund is larger. Therefore, consumers are not only offered a higher level of convenience but also a stronger incentive to return their SeyBrew bottles themselves.

[6] Seybrew is the most frequently drunk beer in Seychelles and is being locally produced by Seychelles Breweries (Diageo, 2019).

Scrap metal

Compared to other recyclables, scrap metal has a relatively high monetary value (Chalmin, 2011). For this reason, various private businesses exist in Seychelles that are currently exporting scrap metal. In 2018, a total amount of 4,576 tons of scrap metal was exported which included exports of iron, steel, copper, and aluminum (F. Kinloch, personal communication, April, 2019). There is no formal collection system in place for scrap metal. The companies either receive the scrap metal at their facility or they go out and collect it with a private truck. Depending on the amount and value of the scrap metal, the companies would pay for the scrap metal or not. The collected scrap metal is subsequently exported for recycling at times when international market prices are high (Gowressoo, 2019; Lai et al., 2016; Laurence, 2019; Naidoo, 2019; Rajković, 2018). The dependency on sufficiently high market prices to pay at least for the costs of exportation has led to huge amounts of scrap metal piling up around the area of Providence landfill (Joubert, 2019).

Importantly, the scrap metal companies also export scrap metal originating from e-waste such as from refrigerators, washing machines, air conditioners, televisions, and other devices where they would extract the most valuable scrap metal parts and landfill the remaining parts (Gowressoo, 2019; Naidoo, 2019; Rajković, 2018).

3.1.3.3 Hazardous waste

Since e-waste currently falls under the definition of HW as according to the Basel Convention and appears to be generally recognized as HW in Seychelles' policy framework, it is also important to understand the current HW practice in Seychelles. As has been described in section 3.1.1.2, this practice is mainly guided by the provisions listed in the EPA. An authorization to dispose HW can be obtained from the MEECC by submitting a so-called "HW Basel Permit". An appropriate final disposal mechanism is then determined given the volume and chemical characteristics of the waste. Available disposal options for HW are landfilling, incineration, storage, and export (Frenzel et al., 2018).

Landfilling is currently the local option applied most often which states a significant risk of contamination to the environment. Therefore, a strong need for a "safe and leak-proof central stockpile" for HW can be identified, either to store it until an appropriate treatment option is available or to prepare it for export (Frenzel et al., 2018, p. 79). Other weaknesses in the system in place around HW have been identified in detail by Frenzel et al. (2018). In general, it appears that HW disposal guidelines are not clear enough and that there is an overall lack of monitoring, enforcement, and communication between different stakeholders to properly organize the HW system. For example, it has been pointed out that it is not always clear when to use the permit form and that some stakeholders would still dump their HW in a non-authorized way to avoid paying a disposal fee. One illustration of this is that battery acid would oftentimes simply be poured into the ground and not be treated according to the prescribed treatment option (Frenzel et al., 2018). Additionally, it appears that people directly dealing with HW are not sufficiently aware of the health risks involved and are not properly trained and equipped to work with this waste type (Krütli et al., 2018; Rajković, 2018).

3.1.3.4 Electrical and electronic equipment and e-waste

The existing system around e-waste has been extensively described by Rajković (2018) and will be summarized below and added with additional information as applicable.

As has already been pointed out in section 3.1.1.2, e-waste currently falls under the definition of HW as defined in the Basel Convention (hence, not all e-waste would be categorized as HW). However, there are indications, that e-waste is generally treated as HW in Seychelles. For example, in the new waste classification developed by the LWMA all e-waste will fall under the category "hazardous waste" at the landfill weighbridge (F. Joubert, personal communication, March, 2019). As a result, many of the processes involved in e-waste are guided by the current HW practice.

There is no separate collection or treatment scheme in place for e-waste in Seychelles and it is currently being disposed of within different waste classes. The only known formalized treatment stream for e-waste is for refrigerant hydrofluorocarbon (HFC) gas contained in cooling devices such as air conditioners, fridges, and refrigerators. As part of the implementation of the "Montreal Protocol on Substances that Deplete the Ozone Layer the Seychelles Ozone Unit" based within the MEECC has started a collaboration with the "Deutsche Gesellschaft für Internationale Zusammenarbeit" (GIZ) GmbH[7] and the United Nations Environment Programme (UNEP) to remove the harmful refrigerant gas from old fridges and air conditioners prior to their disposal. For air conditioners, technicians are trained to do this using a portable recovery unit to de-gas the old device before installing the new device. For fridges and refrigerators – since they are not usually replaced by a technician – consumers have the possibility to call the Seychelles Institute of Technology (SIT)[8] to get a technician to come to their house to recover the gas. An information campaign has been conducted to let the population know about this possibility; however, it is unknown how many people actually use the service (Chang-Waye, 2019). Generally, only cooling devices that are still functional are de-gassed since for broken devices the possibility is relatively high that the gas has already escaped the device. For this reason, cooling devices collected at the roadside or during the "Clean up the World" event are also not treated. After degassing, the cooling devices are then usually delivered to a scrap metal dealer who removes the scrap metal parts and landfills the remaining parts (Chang-Waye, 2019). It is important to note that cooling devices contain many other hazardous components next to the refrigerant gas (Smith, 2019b). These components still end up in the landfill. There is currently also no treatment available for the collected gas and it is stored at the SIT. Efforts to export it to a treatment plant have so far not been successful due to too high transport costs (Chang-Waye, 2019).

Next to this treatment stream for cooling devices, as has already been mentioned in section 3.1.3.2, scrap metal dealers currently also process certain e-waste devices (Rajković, 2018). Further, it was found that scavengers occasionally burn cables to extract the copper inside and sell it to the scrap metal

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7 The "Deutsche Gesellschaft für Internationale Zusammenarbeit" (GIZ) GmbH is a service provider in the field of international cooperation for sustainable development and international education work. The organization has experience in areas such as economic development and employment promotion, energy and the environment, and peace and security and collaborates with businesses, civil society actors, and research institutions (GIZ, n.d.).

8 The Seychelles Institute of Technology (SIT) is a technical and vocational education and training institution under the auspices of the Ministry of Education that is active in the fields of engineering, built environment, and information and communication technology (SIT, n.d.).

dealers (M. Azemia, personal communication, March, 2019; Naidoo, 2019). This practice can cause serious damage to human health and the environment by emitting dioxins, furans, and other toxic chemicals (Akenji, Hotta, Bengtsson, & Hayashi, 2011; Williams et al., 2013). While it is known that certain battery types coming from cars and golf carts are also exported by scrap metal companies, it is unknown if batteries from e-waste are exported as well. It is assumed that most of the batteries originating from e-waste end up in the landfill due to their significantly lower scrap metal content (Frenzel et al., 2018; Gowressoo, 2019; F. Kinloch, personal communication, February, 2019; Naidoo, 2019).

Next to the scrap metal dealers, some retailers of EEE also take back old devices if they fall under warranty. However, these devices are then not exported but are either given to repair stores or being landfilled (Ernesta, 2019; Kazibwe, 2019; Rajković, 2018; Ramani, 2019).

The telecom company Cable & Wireless Seychelles is the only known company with a take-back system in place for certain e-waste devices such as modems and landline phones since they only lend those items to their clients, which officially still makes them their property once these devices turn into e-waste. The company is also the only known exporter of e-waste next to the exports of scrap metal parts originating from e-waste (Rajković, 2019). According to Rajković (2018, p. 31) the company "stated to have shipped in five years approximately one 40ft container per month to a recycling company in the UK" loaded with different types of appliances and materials from their own company (e.g., landline phones and copper wires). However, compliance of these exports with the provisions set in the EPA and the Basel Convention is unclear and it is unknown whether exports are still being done (Rajković, 2018).

Due to missing appropriate disposal options for e-waste, it has also been indicated by various stakeholders that many households, businesses, and government entities currently store significant amounts of e-waste at home or in unused office rooms (M. Azemia, personal communication, March, 2019; Ernesta, 2019; Kazibwe, 2019; Laure, 2019).

In 2017, aware that the existing e-waste system is undesirable, the MEECC has tried to enable a private sector e-waste business by calling for expressions of interest to conduct this business on a governmentally subsidized piece of land close to Providence landfill. However, clear criteria to evaluate the tender applications were missing. For example, it was not indicated what e-waste types would need to be collected by the business operator and how they would need to be treated and exported (F. Kinloch, personal communication, March, 2019). It also appeared that many scrap metal companies submitted an expression of interest simply to be able to conduct their business on subsidized land and possibly expand their business to deal with the valuable fractions of e-waste. It remained unclear how it was planned to deal with the hazardous and non-valuable fractions of e-waste (F. Kinloch, personal communication, February, 2019; Rajković, 2018). Further, it is to date not clear whether the allocated piece of land is actually available for such a business or whether it is covered by scrap metal (Joubert, 2019; F. Kinloch, personal communication, February, 2019). In general, it appears that there is interest in entering the e-waste business in Seychelles under the assumption that the government would provide the necessary support and eliminate too high risks. This has also been confirmed by several interviewed stakeholders (Gonzalves, 2019; Gowressoo, 2019; Naidoo, 2019).

3.1.4 E-waste amounts in Seychelles

Knowing the amount of e-waste that is generated over a specific time period in a country is highly relevant to understand the amounts that can be collected and processed and to design the e-waste management system accordingly. For Seychelles specifically, two data types are most comprehensive which can be used to estimate the overall e-waste generation in the country. The first type of available data covers information about the total amount of e-waste being disposed of each year. This data consists of estimations about the amounts going to Providence landfill via waste class 1, 2, and 5 for the year 2017 as assessed by a waste sorting study conducted by Kannengiesser et al. (2017), the amounts going to the scrap dealers via waste class 6 and the amounts of e-waste collected during the "Clean up the World" event via waste class 15 (Rajković, 2018). An overview of the specific disposed amounts can be found in Appendix A.5. The second type of data is import data collected by the Seychelles Customs Division, which is available for the years 2013 to 2017 (CVO, 2013, 2014, 2015, 2016, 2017). Compared to the landfill data which is only available for e-waste as one single category, the import data is available per UNU-Key[9]. Based on the availability of this data, different mathematical models can be applied to estimate e-waste generation in Seychelles which are outlined below.

Market Supply Model (adapted)

The availability of the above described data indicates that an adapted version of the so-called Market Supply Model is the most suitable method to assess e-waste amounts in Seychelles. This model estimates overall e-waste generation from product sales in all historical years with their respective obsolescence rates in the evaluation year (Dwivedy & Mittal, 2010; Jain & Sareen, 2006; Oguchi, Kameya, Yagi, & Urano, 2008; Streicher-Porte et al., 2005). Mathematically, this can be represented by

$$W(n) = \sum_{t=t_0}^{n} POM(t) \times L^{(p)}(t, n), \quad (1)$$

where W(n) is the e-waste generation in evaluation year n; POM(t) is the product sales in the historical year t; t_0 is the initial year that product has ever been put on the market; and $L^{(p)}(t, n)$ is the discard-based lifespan profile for the batch of products sold in historical year t, which reflects its probabilistic obsolescence rate in evaluation year n (discarded equipment in percentage to total sales in year t; Melo, 1999; Murakami, Oguchi, Tasaki, Daigo, & Hashimoto, 2010; Oguchi, Murakami, Tasaki, Daigo, & Hashimoto, 2010).

A study conducted by Rajković (2018) has used this method and adapted it to the local data availability in Seychelles to get a comprehensive estimation of the e-waste amounts generated in Seychelles in 2017. The study used available import data to estimate product sales and information about the expected residence time of EEE per UNU-Key to model the lifespan profile per UNU-Key and see how much of the imported EEE turns into e-waste each year. The residence time is the period the equipment spends

[9] UNU-Keys refer to different e-waste classes according to a classification system developed by the United Nations University (UNU). The system groups e-waste products according to average weights, material compositions, End-of-Life (EoL) characteristics, and lifespan distributions. For example, it categorizes devices such as mice, keyboards, external drives, and other IT accessories under UNU-Key 0301 "Small IT" due to their similar overall characteristics (Baldé et al., 2015).

at a household, business, or the public sector before being disposed of; hence, it includes the number of years the product can effectively be used ("active life"), the years it can be refurbished or reused ("passive life"), and the storage time before disposal (Baldé et al., 2015; UNEP, 2007b). The estimated residence times were applied in the form of a Weibull distribution which has been assessed for Dutch e-waste flows (Wang et al., 2013). Since the import data was only available for the years 2013 to 2017 and most EEE has a longer lifespan than five years, the imported amounts for the years 2008 to 2012 were estimated by extrapolating available data backwards via a linear regression. To account for the fact that residence times in Seychelles likely differ from those in the Netherlands, the obtained e-waste amounts per UNU-Key were then matched with the available data regarding the total amounts of e-waste being disposed of each year by multiplying the beta-shape of the Weibull function with a correction factor. By following this procedure, it was not only possible to estimate the total amount of e-waste being generated but also how it splits up between the different e-waste categories. To account for relatively large uncertainties in the available data, a minimum, mean, and maximum value was calculated. It was found that a minimum of 790 tons, a mean of 1,030 tons, and a maximum of 1,274 tons of total e-waste were generated in 2017 in Seychelles (Š. Rajković, personal communication, February, 2019).[10] This is also in line with the findings of Baldé et al. (2017) which estimated the total annual e-waste generation in Seychelles to amount to 1,100 tons. A mass flow diagram to see how and in which quantities the EEE and e-waste circulates between different actors is depicted in Figure 3.

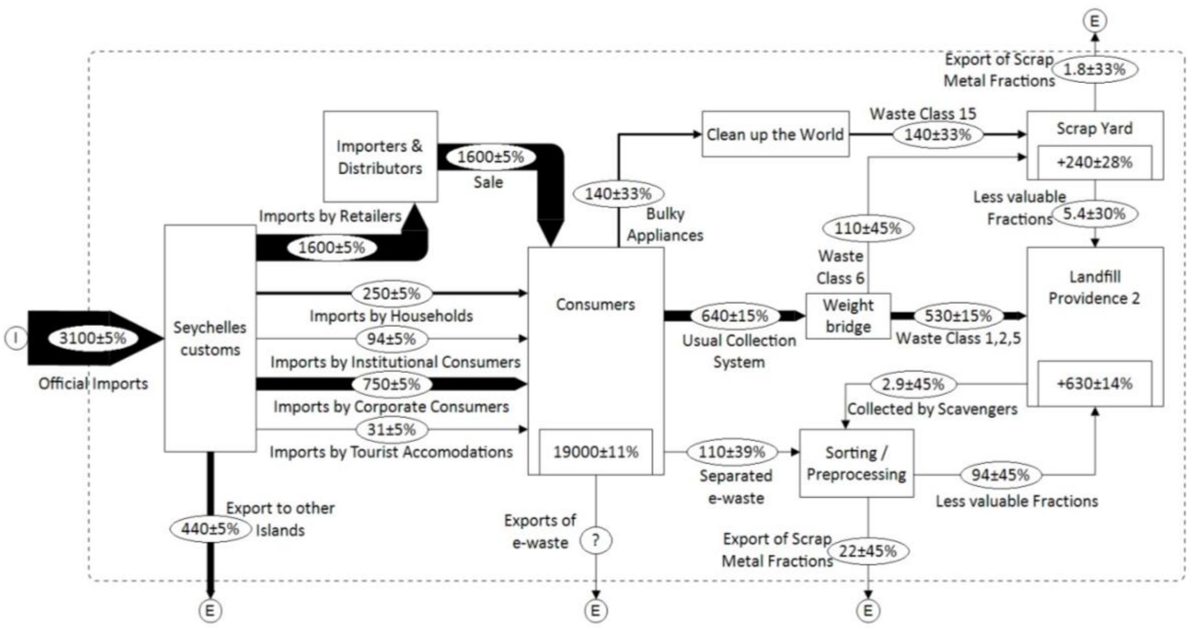

Figure 3: Mass flow diagram of EEE and e-waste on Mahé, Seychelles in 2017. Source: Rajković (2018).

[10] These numbers were taken from the Microsoft Excel data sheets created by Š. Rajković (personal communication, February, 2019). The numbers indicated in the report by Rajković (2018) refer to the e-waste amounts generated on Mahé, Seychelles. These amounts were calculated from the estimated total e-waste amounts based on the distribution of Seychelles' population on the different islands. The report indicated a minimum of 660 tons, a mean of 890 tons, and a maximum of 1,120 tons of e-waste that were generated in 2017 on Mahé.

Next to those estimations about the total annual e-waste amounts generated in Seychelles, it is also relevant to know how these amounts split up between different stakeholder groups. Rajković (2018) has estimated the total e-waste generated by the government per UNU-Key based on governmental write-off data from the MoF (Š. Rajković, personal communication, February, 2019). This amount could be subtracted from the total estimated amount of e-waste generated. To then estimate how the remaining e-waste amounts split up between households and the commercial sector, the relative amounts registered at the landfill by Kannengiesser et al. (2017) for the waste classes 1, 2, and 5 were used. Waste class 1, coming from households, accounted for 83% of the registered e-waste while waste class 2 and 5, coming from commercial businesses, accounted for 17%. An overview of how much e-waste is expected from what stakeholder group can be found in Table 4.

Table 4: Estimated generated e-waste amounts in Seychelles in 2017 per stakeholder group in tons.

	Mean	**Min**	**Max**
Government	16.7	10.8	22.6
Commercial Sector	172.1	132.3	212.7
Households	840.3	646.1	1,038.6
Total	***1,029.1***	***789.2***	***1,273.9***

Several limitations of this adapted version of the Market Supply Model must be mentioned to highlight the considerable uncertainty related to the obtained numbers. The main limitation stems from the combination of uncertain data inputs. It has been shown that an oversimplification of methods and potential data uncertainties in variables can substantially decrease the reliability of the estimated results (Jain & Sareen, 2006; Wang et al., 2013).

First of all, an uncertainty of up to 45% persists for certain data inputs related to the total amounts of e-waste being disposed of. Since it was possible to roughly quantify this uncertainty, it was possible to integrate it in the calculated minimum, mean, and maximum estimations. Further, uncertainty related to the actual amounts of EEE being imported is also notable. When looking at the import data for EEE for the years 2013 to 2017 (CVO, 2013, 2014, 2015, 2016, 2017), large irregularities concerning the total amounts of annually imported EEE can be detected for which no explanation was found (e.g., 2,700% more “cooled dispensers” have been imported in 2014 as compared to 2013). These irregularities indicate that the obtained data might not reflect the real amounts being imported, an assumption that has also been confirmed by interviewed local stakeholders. Additionally, it was not clear whether the gross or net weight for the imported appliances was registered, leading to further uncertainty about the actual amounts of imported EEE. This uncertainty is increased by extrapolating the obtained data backwards to be able to apply the Weibull distribution. Hence, the obtained quantities likely fail to reflect reality which is supported by the fact that for some appliance types, negative import amounts were obtained for certain years (even though these numbers were excluded from the calculation). While it was considered to calculate the average imported amounts for the years 2013 to 2017 per appliance type and apply these amounts to past years, it was decided that a linear regression is more suitable since this method allowed to account for a growth in imports over time. While it was possible to quantify the uncertainty related to the estimated e-waste amounts being disposed of, the uncertainty related to the import data could not be quantified. Therefore, this uncertainty has not been included in the calculation for any minimum, mean, and maximum scenario and shall only be mentioned here.

Further uncertainty stems from the circumstance that the assumed residence times for EEE have not been empirically determined in Seychelles but were taken from a study about residence times measured in the Netherlands. This variable can vary significantly between different geographical regions (UNEP, 2007b) and for Seychelles specifically, it was estimated that the active life of EEE, which constitutes part of the residence time, can be up to 50% shorter compared to European countries (Rajković, 2018). Jain and Sareen (2006) have found that while results about e-waste amounts can generally be extremely sensitive towards data quality, this is especially true in case of an assumed or non-validated lifespan profile. Even though a scaling factor has been applied by Rajković (2018) to account for this uncertainty, due to the fact that this factor was calculated based on the relatively uncertain amounts of e-waste being disposed of, it is unclear how exact the so calculated lifespan profiles for EEE in Seychelles reflect reality. Furthermore, this scaling factor was calculated over all EEE categories and, therefore, neglects the fact that it might differ between appliance types. Comparable to the uncertainty related to the import data, it was not possible to quantify the uncertainty related to actual residence times. Therefore, this uncertainty has been excluded from the calculation.

Lastly, there is also uncertainty connected to how the e-waste amounts were assumed to split up between the different stakeholder groups. While the uncertainty related to the amounts being disposed of by the government was quantified and included in the minimum, mean, and maximum calculation by Rajković (2018), it was not possible to do this quantification for the amounts estimated to come from households and commercial businesses. The approach of applying the relative percentages registered at the landfill for waste class 1 compared to waste class 2 and 5 is critical because it does not cover all e-waste being disposed of. Further, the amounts coming from the commercial sector might be underestimated because commercial businesses would sometimes dispose of their waste via the MSW collection system (which would then be registered as waste class 1) and if the waste collection company STAR would collect the waste from businesses, this would be done in conjunction with MSW and would therefore also be registered as waste class 1. Furthermore, since the sorting activity conducted by Kannengiesser et al. (2017) only looked at the overall amounts of e-waste, and not different e-waste categories, it is unclear how the e-waste composition might change between the commercial sector and households (e.g., the e-waste coming from the commercial sector might have a higher amount of IT devices).

Given the fact that there are significant uncertainties related to the above described e-waste estimation, it was decided to conduct further calculations to enhance understanding of the accuracy of the obtained results. Due to the fact that there is no further data available for all types of e-waste, these calculations were solely conducted for mobile phones for which additional data is available.

Complete Saturation Method

For saturated markets, assuming a stable population and constant e-waste stocks, it is possible to apply a simplified version of the Market Supply Model, called the Complete Saturation Method, where it is assumed that the quantity of new product sales equals the e-waste output at the same time (Walk, 2004). This method can mathematically be represented by

$$W(n) = POM(n), \tag{2}$$

where W(n) is the e-waste generation in evaluation year n; and POM(n) is the product sales in the evaluation year n. Import numbers for mobile phones over the past years show no constant market growth and led to the assumption that the mobile phone market in Seychelles is saturated. This has been corroborated by looking at the extremely high mobile phone penetration rate of 175% (mobile phones per 100 inhabitants) and the fact that the number of mobile phone subscribers has not grown significantly over the past years (state of 2017; NBS, 2018). This assumption has also been confirmed by Paulian Kazibwe (2019), the Finance Director of Airtel Africa Limited, one of the two biggest telecommunication companies present in Seychelles. Consequently, applying the Complete Saturation Method seems to be justified and leads to a mean value of 10.4 tons or a total number of 104,000 mobile phones being discarded each year when using import data to estimate POM[11]. Limitations of this method mainly originate from the uncertainty regarding the reliability of the import data which has previously been described. Further, it appears that significant amounts of mobile phones are purchased abroad (see section 3.2.4.2). These mobile phones do not appear in any import statistics which likely leads to POM being underestimated in this calculation.

Leaching Model

Apart from import data for mobile phones there is also information available about the total number of mobile phone subscribers in Seychelles. Following the assumption that this number reflects the total stock of mobile phones in Seychelles and that the mobile phone market is saturated, another applicable model is the Leaching Model. This model calculates the e-waste generation as a fixed percentage of the total EEE stock divided by the average product lifespan (Araújo et al., 2012; Chung, Lau, & Zhang, 2011; Robinson, 2009; van der Voet, Klejin, Huele, Ishikawa, & Verkujilenc, 2002). The model can be represented by

$$W(n) = S(n)/L^{(av.)}, \tag{3}$$

where W(n) is the e-waste generation in evaluation year n; S(n) are the quantities of appliances in stock for the year n; and $L^{(av.)}$ the average lifespan which represents the most possible time when the product becomes obsolete. In Seychelles, the average number of mobile phone subscribers between 2012 and

[11]An average amount of 20.8 tons of mobile phones are registered to be imported each year (based on import data from 2013 to 2017). Because it is assumed to be more likely that this weight was measured including mobile phone chargers, this amount can be split in half. Schluep et al. (2012) indicate the average weight of a mobile phone and a mobile phone charger to be 0.1 kg each.

2017 amounted to 152,146 (assumed to be S[n]; NBS, 2017, 2018), which translates into an average mobile phone penetration rate of 165%[12]. If an average residence time of 9.6 years for mobile phones based on the Weibull distribution by Wang et al. (2013) is assumed to be $L^{(av.)}$, an estimated total amount of 1.58 tons of mobile phones will be discarded each year. If we apply the corrected Weibull distribution as used in Rajković (2018), with an average residence time of 11 years, an estimated total amount of 1.38 tons of mobile phones will be discarded each year.

Since this calculation combines the stock of mobile phones in their active life (hence, still being subscribed) with the residence time that has been determined for a stock that also includes mobile phones in their passive life and their storage time, it was decided to additionally apply this method based on the expected active lifespan of a mobile phone. By this, the stock of mobile phones in their active life is combined with a mobile phone's expected average active lifetime. Assuming an average active life of 13.5 months (Kasper et al., 2011; Osibanjo & Nnorom, 2008) an estimated total amount 13.5 tons of mobile phones will break every year ("leave their active life"). For note, this estimation refers to the total number of mobile phones breaking each year, and not the number of mobile phones being disposed of (which has been previously calculated when applying residence times), which explains the higher estimate. Because it was assumed that each mobile phone subscription corresponds to one mobile phone in use that will eventually be discarded in Seychelles, the actual amount of mobile phones turning into e-waste each year is likely overestimated by this calculation method since it was not considered that some subscribers were tourists (which would not discard their mobile phone in Seychelles) and that some mobile phones have two SIM-card slots (i.e., not every subscription corresponds to one mobile phone; Rajković, 2018). What might lead to an underestimation of the actual amount of mobile phones turning into e-waste each year is the fact that mobile phones that are not actively used anymore (hence, that do not have a subscription), are not included in the assumed stock. To account for this uncertainty about the real stock of mobile phones in Seychelles, it was decided to conduct a survey and apply the obtained results to the Leaching Model. The survey asked respondents about the number of mobile phones that their total household "actively uses", that are "still working", and that they simply "have at home". The questions were therefore designed to measure the stock of devices in their active and passive life and the amount of devices being stored. The survey indicates an assumed mobile phone penetration rate in Seychelles of 122%, of which 79% would still be functional and actively used, 10% would still be functional but not used anymore, and 12% would not be functional anymore but still be stored at home (N=142; see Figure 4).[13] These percentages are significantly lower compared to the penetration rate based on mobile phone subscriptions which also reflects in the obtained results (i.e., higher estimated e-waste amounts). By combining the survey results either with residence times as estimated by Wang et al. (2013) or Rajković (2018), or with the active lifespan as estimated by Kasper et al. (2011) and Osibanjo and Nnorom (2008), an estimate of total annual e-waste generated from mobile phones between 0.9 and 8.5 tons is obtained (for more details see Table 5).

[12]This also correlates roughly with the mobile phone penetration rate of 175% in 2017 as mentioned in ITU (2018).

[13]This information is also available for tablets, laptops, computers, and televisions. A list of all results, including standard deviation and median can be found in Appendix A.6.

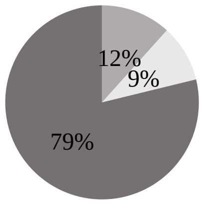

Figure 4: Usage status of mobile phones at households in Seychelles.

Compared to the Leaching Model applied to mobile phone subscriptions, its application based on the obtained survey data likely underestimates the total amount of mobile phones being discarded each year. This stems from the fact that survey participants were asked to indicate the number of mobile phones on a household level which was intended to capture all age groups so that a correct number of mobile phones per person could be estimated based on Seychelles' total population.[14] While conducting the survey, the impression arose that some survey respondents might not have understood this and have indicated the number of mobile phones they would personally own. Therefore, this might have led to an underestimation of the total mobile phone stock. Further, it is possible that some survey participants might have misunderstood the difference between the usage categories and would simply indicate the number of mobile phones they actively use. This could have led to a further underestimation of the stock. Lastly, as has already been mentioned in section 2.2.2, it is also likely that survey participants are not representative of Seychelles' population. Consequently, the obtained answers should be considered as an indication of the stock of EEE at the household level but provide a limited external validity.

An overview of all results regarding estimated annual mobile phone e-waste generation is displayed in Table 5. A significant difference between estimated e-waste amounts depending on whether the active lifetime or the residence time for mobile phones was applied is evident in the summary output. This makes sense since mobile phones are estimated to remain longer at the household (instead of being disposed) when the residence time is applied. In general, it can be concluded that there is significant uncertainty with regards to the amounts of e-waste generated from mobile phones in Seychelles due to a lack of reliable data. Estimations range from 0.9 to 13.5 tons being generated annually and while it makes sense that some data sources result in higher or lower estimates, given the limitations of each of the used methods, it is not possible to provide a statement on what estimate might be most reliable. The same uncertainties that were shown to exist for mobile phones are also relevant for the total e-waste amounts generated in Seychelles showing that it is highly insecure how reliable the estimate by Rajković (2018) is.

[14] For example, children likely own no or fewer mobile phones as compared to adults. This age group was however excluded from the survey. Therefore, if the number of mobile phones would have been asked on an individual level, the average amount of mobile phones per person would have been overestimated.

Table 5: Overview of estimated annual e-waste generation from mobile phones based on different calculation models.

Method used	Type of data used	Estimated amount [tons]
Adapted Market Supply Model[A]	Put on market + residence time by Rajković (2018)	5.7
Complete Saturation Method	Put on market	10.4
Leaching model (subscribers)	Stock (active life) + residence time by Wang et al. (2013)	1.6
Leaching model (subscribers)	Stock (active life) + residence time by Rajković (2018)	1.4
Leaching model (subscribers)	Stock (active life) + active lifetime	13.5
Leaching model (survey)	Stock (active life) + residence time by Wang et al. (2013)	1.0
Leaching model (survey)	Stock (active life + passive life + storage time) + residence time by Wang et al. (2013)	1.3
Leaching model (survey)	Stock (active life) + residence time by Rajković (2018)	0.9
Leaching model (survey)	Stock (active life + passive life + storage time) + residence time by Rajković (2018)	1.1
Leaching model (survey)	Stock (active life) + active lifetime	8.5

[A]The amount of mobile phones as estimated by Rajković (2018) was divided into half since it was assumed that this estimation included mobile phone chargers.

3.1.5 Conclusion for Seychelles

Based on the obtained findings about the current framework conditions in Seychelles around a potential e-waste management system, it can be concluded that there are already a variety of different processes and activities in place which can potentially be leveraged when thinking about how to manage e-waste. Existing waste collection processes and infrastructure present from other recycling practices can be expanded to include e-waste, the procedures in place for HWs can be further developed to include precise instructions about how to handle hazardous e-waste types, and the tender conducted in the past for an e-waste TF can provide important learnings for any future plans related to this. However, several barriers to the implementation of a functional e-waste management system in Seychelles are also identifiable. These barriers match with the general barriers that have previously been reported by Theilmann et al. (2018) concerning the implementation of general solid waste management plans in Seychelles. Generally, four different types of barriers must be considered that inhibit the proper functioning of existing waste processes and act as a deterrent to the development of new waste management activities. These are (i) operational barriers such as a lack of monitoring and enforcement, a lack of financial resources, and a lack of skilled labor; (ii) content-related barriers such as the formulation of policies and plans that are not implementation-specific; (iii) structural barriers such as a lack of transparency, the existence of corruption, and the unclear allocation of responsibilities; and (iv) contextual barriers such as a lack of political will, a lack of public awareness, and a lack of financial incentives for the private sector to establish a business in the waste sector. Moreover, these barriers are highly interlinked with each other. Consequently, improvements in one aspect foster the overcoming of several barriers but deficiencies also have the potential to worsen more than one aspect. These identified barriers will require special attention when analyzing the potential design options of an e-waste management system in Seychelles.

3.2 Design Elements of an E-Waste Management System

With a detailed explanation of framework conditions in Seychelles at hand, it is possible to analyze the different design elements of an e-waste management system and assess the applicability of available policy options in the discussed local framework. These design elements are first defining the e-waste system's rules via establishing a shared understanding of e-waste by the implementation of a clear e-waste definition and classification system, defining the scope of products covered by the system, and determining the stakeholders responsible for managing the e-waste system. Then, the design element of the e-waste financial system will be discussed, and lastly, the operational system elements of e-waste collection, treatment, and export will be outlined.

The structure of the following sections shall therefore be split up into three parts. First, generally available knowledge about the respective design element and the available policy options will be discussed. Second, this knowledge will be embedded in the local framework conditions of Seychelles and third, a final conclusion will be drawn with regards to the suitability of the discussed policy options.

3.2.1 Definition and classification of e-waste

3.2.1.1 Background and relevance

A high-quality e-waste management system requires a common understanding of e-waste via the implementation of a clear and shared definition and a suitable classification scheme in national legislation. Globally, there is currently no such common understanding and application of the term "e-waste" in legislation and everyday use (Baldé et al., 2015; StEP Initiative, 2014; UNEP, 2007b). However, some definitions are used more widely than others and it is generally recommended to countries to adopt an already common definition in their legislation by the mean of establishing a globally uniform understanding aiming to increase operational efficiency of a global e-waste management system (UNU/StEP Initiative, 2018). The most commonly used legal definition of e-waste comes from the EU, as established in their WEEE Directive (2012/19/EU). The directive defines EEE as per Article 3, 1.(a) as "equipment which is dependent on electric currents or electromagnetic fields in order to work properly and equipment for the generation, transfer, and measurement of such currents and fields and designed for use with a voltage rating not exceeding 1,000 volts for alternating current and 1,500 volts for direct current". E-waste is subsequently defined as per Article 3, 1.(e) as "electrical or electronic equipment which is waste including all components, sub-assemblies, and consumables, which are part of the product at the time of discarding" and refers to the meaning of waste as per Article 3(1) of the EU's Waste Framework Directive (2008/98/EC). The directive defines waste as "any substance or object which the holder discards or intends or is required to discard". Following this definition, the term e-waste not only refers to non-functional EEE but also to EEE that is still functioning but is regarded as waste by the consumer (e.g., if the device becomes technically obsolete). Further, this definition includes EEE that has been discarded as well as EEE that is only intended to be discarded but has not been discarded yet. This distinction is important to include because it allows e-waste to be controlled by a management system before its disposal, meaning that policies and regulations can target e-waste that still remains at the consumer to direct it towards being recycled (Secretariat of the Basel Convention, 2017). Further, Roldan (2017) highlights that one of the main advantages of the EU WEEE Directive’s definition is that it also covers EEE which can currently not be specified since the definition is not technology-specific. This is desirable given the constant emergence of new technologies.

Next to defining e-waste, it is possible to categorize e-waste within the chosen definition. Categorizing e-waste facilitates a more effective monitoring and management of e-waste because it allows to distinguish between different e-waste types. Further, it enables the comparison of national e-waste statistics with other countries (Baldé et al., 2015; Roldan, 2017). Baldé et al. (2015, p. 12) recommended that a classification system for e-waste should categorize products by “similar function, comparable material composition (in terms of hazardous substances and valuable materials), and related End-of-Life (EoL) attributes”. Moreover, products within the same category should have a homogeneous average weight and lifespan distribution. The UNU-Key classification system is currently the only system that categorizes e-waste according to these criteria (Baldé et al., 2015). The UNU-Keys can be linked to the EU’s classification system as per the 10 e-waste categories of the old EU WEEE Directive (2002/96/EC, Annex IA) and the six categories of the directive’s recast (2012/19/EU, Annex III). Further, the UNU-Keys can be matched with international trade codes – the harmonized system (HS) codes – which are used by customs organizations to document commodities and economic activities (Baldé et al., 2015).

Next to adopting a definition and classification of e-waste, it is also crucial to include a clear distinction between hazardous and non-hazardous e-waste types to further facilitate operational aspects. It is recommendable that this distinction considers the provisions of the Basel Convention to aid transboundary movements of e-waste (Böni, 2019a; UNU/StEP Initiative, 2011; UNU/StEP Initiative, 2018).

3.2.1.2 Conclusion for Seychelles

As a result of the above, and as a first step towards a legal framework around e-waste, it is suggested that the Government of Seychelles adopts an official legal definition and classification of e-waste and updates relevant documents accordingly. It is preferable that the chosen definition and classification are already widely used by other countries. The chosen e-waste definition should include e-waste that has not been discarded yet (which is opposed to the current waste definition of the EPA [2016, section 2]) and the classification system should follow a logical categorization of different e-waste types, preferably based on the criteria that have been mentioned above (i.e., similar function, comparable material composition, similar EoL attributes, and homogeneous average weight and lifespan distribution), and include a distinction between hazardous and non-hazardous e-waste.

The corresponding legal document that needs to be amended is the EPA. However, since it has been mentioned by Sharon Gerry (2019), the Senior Legal Officer of the MEECC, that amendments to the EPA are generally difficult to implement, the best way to include an e-waste definition and classification is likely to add a provision to the EPA (“notwithstanding to the EPA”).

Once a definition and classification of e-waste has been implemented, e-waste should also be recognized as a separate waste class in any operational context and should no longer generally be categorized as HW.

3.2.2 Product scope

3.2.2.1 Background and relevance

Having established a shared understanding of e-waste and different e-waste classes, it is possible to consider what product scope to cover by the e-waste management system and its policies in the short-, medium-, and long-term (UNU/StEP Initiative, 2014). Defining the product scope is a crucial decision that needs to be considered carefully because it will influence most other system elements by determining the volume of materials to be handled, the scope of involved stakeholders, the system's financing needs, and specific operational requirements (UNU/StEP Initiative, 2015).

Every e-waste management system should target to cover all e-waste in the long run (UNU/StEP Initiative, 2015); however, including more product types in the system can also increase its complexity (UNU/StEP Initiative, 2009). Therefore, it is more suitable in some cases to only cover a limited scope at the start of an e-waste management system to be able to "effectively and efficiently address the most urgent concerns and objectives". Over time, more products are includable as the system is working and resources become available (UNU/StEP Initiative, 2015, p. 16).

3.2.2.2 Available policy options

Generally, two different approaches with regards to the initially chosen product scope can be identified. It can either be started with a full scope, including all e-waste that is covered by the established definition, or with a phased scope, where only certain e-waste types are initially included in the system, and the scope is expanded over time.

Full scope

A full scope approach entails that all e-waste types included in the e-waste definition are also covered by all e-waste related policies. For example, this approach is currently implemented by Switzerland and the EU's WEEE Directive (Nnorom & Osibanyo, 2008; UNU/StEP Initiative, 2015). From an environmental point of view, this option is most desirable since all e-waste is taken care of (Smith, 2019b). However, including all types of e-waste products will require greater resources since basic system management activities that need to be carried out such as reporting, monitoring, and enforcement will be more complex. A greater volume and variety of products that will be collected and processed will also require more logistics infrastructure and processing equipment. As a result, it is often challenging and costly to start with a full product scope and it is therefore not always feasible (UNU/StEP Initiative, 2015).

Phased scope

Another approach, which is initially applied by most e-waste management systems, is to focus on a specified subset of e-waste products and expand the product scope with time. Four criteria can be identified based on which such a subset of products can be chosen, namely environmental impact, product volume, required infrastructure, and monetary value.

- **Environmental impact:** Products with a particularly problematic potential environmental impact can be prioritized. For example, China first focused on refrigerators and air conditioners to ensure that the contained potentially harmful chemicals and gases are properly captured (UNU/StEP Initiative, 2015) and Switzerland, even though it now covers a full product scope, has started its e-waste system by recycling refrigerators and freezers (Gnos, 2019; Nnorom & Osibanyo, 2008).

- **Product volume:** Products that make up a large part of the overall e-waste volume can be included in a system first. This approach usually focuses on Information Communications Technology (ICT) equipment such as computers, laptops, and mobile phones but can also include other product types such as common household electronics (UNU/StEP Initiative, 2015). For instance, such an initial product scope has been prioritized by the U.S. state of California whose system is focused on display devices, TVs, and laptops (UNU/StEP Initiative, 2009). Likely, volume was also a deciding criterion why Switzerland expanded its system to include Information Technology (IT) devices after having started with cooling devices (Gnos, 2019).
- **Required infrastructure:** The product scope can also be chosen based on the infrastructure (e.g., processing equipment, means of transportation, etc.) that is already present in a country and that is required to manage certain products. For example, if little or none of the necessary infrastructure to manage e-waste is present, it potentially makes sense to begin with a reduced scope of products that do not require a too complex infrastructure to ensure that these products can be properly collected and treated (UNU/StEP Initiative, 2015). It can also be started with products requiring a similar treatment and therefore a similar infrastructure. For example, cooling equipment, lamps, and ICT devices require very different treatment. On the other hand, different ICT devices (with the exception of equipment containing CRTs) require a similar treatment and could be included together in an initial product scope (Smith, 2019b). If there is already some infrastructure present, it can also make sense to start with a product scope for which the existing infrastructure can be leveraged (UNU/StEP Initiative, 2015).
- **Monetary value:** The last criterion that can be considered when thinking about the most suitable initial product scope is the monetary value of certain e-waste types. Generally, the higher the value of the e-waste products included in a system, the smaller the need for additional financing. This can enhance acceptance of an e-waste management system since high system costs have the potential to lead to significant opposition by stakeholders (Böni, 2019a; Deepali, 2019).

In reality, the final decision on the product scope covered by the e-waste management system will usually include aspects of all the above-mentioned criteria (UNU/StEP Initiative, 2015). An overview of positive and negative aspects of taking a full or a phased scope approach is listed in Table 6.

Table 6: Advantages and disadvantages of full scope and phased scope approach. Adapted from UNU/StEP Initiative (2015).

	Advantages	Disadvantages
Full scope	- Covers all products - Does not need further legislation when new products come on market or if new environmental problem is identified	- Adds complexity to the system - Can strain infrastructure - Can lead to a focus on recycling of non-problematic but valuable fractions and products
Phased scope	- Allows to focus on prioritized product types - Can ensure that problematic products and fractions are dealt with as a priority - Allows for iterative build-up of scope and infrastructure in parallel	- Not all e-waste is taken care of - Although many existing e-waste management systems have talked about moving to full scope most have been reticent to enlarge the scope leading to long delays - Can confuse the message to consumers that recycling of all e-waste is important

3.2.2.3 Conclusion for Seychelles

When thinking about the most appropriate product scope approach for Seychelles, two main aspects need special consideration. Firstly, Seychelles, as a developing country as well as a SIDS, has limited resources available in terms of finances, human resources, knowledge, etc. to build up an e-waste management system. Secondly, Seychelles produces relatively small overall e-waste amounts and economies of scale will be a crucial factor to limit the system's costs.

Consulted stakeholders from the international community that have vast experience in establishing e-waste management systems in developing countries all agreed that a phased approach will be more suitable given Seychelles' local context and its limited resources considering the high complexity of implementing a full scope approach. Further, the resources the government is willing to invest and what specific targets it prioritizes (e.g., environmental protection, keeping costs low, reducing overall waste volume, etc.) is a crucial factor when specifying the product scope to be covered by the e-waste management system. Different e-waste product types have been recommended to start with under a phased scope approach. Generally, ICT devices such as computers, laptops, and mobile phones as well as their peripherals (e.g., printers, mice, keyboards, etc.), and excluding cathode-ray tube (CRT) monitors and screens, are oftentimes suitable to target first. This is due to the following considerations:

- They usually make up a relatively large fraction of all e-waste. Including them in the product scope can therefore enable a significant increase in overall e-waste recycling rates and contribute to scaling up the system and exploit economies of scale (Spitzbart et al., 2014).
- They are relatively valuable which reduces the need for additional system financing (Spitzbart et al., 2014).
- They contain relatively large amounts of toxic substances. Focusing on these products first, therefore, has the potential to significantly reduce the risk of negative environmental impacts (Spitzbart et al., 2014).

- They generally require a similar treatment due to similar product characteristics. As a result, similar collection and processing mechanisms can be used which reduces system complexity and costs (Schluep, Spitzbart, & Blaser, 2015; Smith, 2019a).
- They require less sophisticated handling practices as compared to other products since they are not imminently hazardous (even though they contain hazardous parts). Therefore, transportation and dismantling of these products is relatively simple, does not state a significant risk to human health, and does not require any specialized high-cost equipment. This again, reduces system complexity and costs (Schluep et al., 2015).
- This type of e-waste is produced to a large part in the commercial and governmental sector. Collection from these sectors is usually cheaper and simpler and achieves higher collection rates (Böni, 2019b; Deepali, 2019; Gnos, 2019; Karcher, 2019; Spitzbart, 2019).

Computers excluding screens, laptops, and mobile phones are also relatively suitable to be transported as whole devices prior to any dismantling since they can be transported in a relatively high density and their hazardous components are relatively safely contained within the device (e.g., batteries). Consequently, given the fact that there is currently no dismantling facility available in Seychelles, these three devices could offer a simple and relatively low-cost starting point for an e-waste management system. Additional ICT devices and their peripherals could then be included once a basic dismantling facility becomes available (Schröder, 2019; Karcher, 2019).

When choosing an initial ICT product scope, it is practical that many other types of appliances such as coffee machines, irons, washing machines, etc. can also be processed "without relevant influence on technical and financial aspects as well given the technical setup of the facility", even though these products might not be specifically targeted by the system (Spitzbart et al., 2014, p. 10). For Seychelles, this becomes especially relevant for bulky e-waste because there is already some bulky e-waste separation and collection in place where the devices are currently brought to the scrap metal dealers. The new MSW collection contracts offer a good opportunity to oblige waste collectors to bring collected bulky e-waste to a designated location such as an e-waste TF. However, since most bulky e-waste contains comparably few toxic components (with the exception of cooling devices) and is less valuable due to high amounts of plastics, initially solely focusing on such e-waste types is less desirable. Nevertheless, in the case of Seychelles most bulky e-waste products could theoretically be included relatively easily in an e-waste system next to the devices mentioned above.

Other types of e-waste require more sophisticated collection and treatment mechanisms due to their hazardous characteristics which can state a significant risk to the environment and human health. The most relevant are cooling and lightning equipment, and equipment containing CRTs (UNEP, 2007a). These e-waste types require separate collection and the build-up of specific treatment infrastructure. This, combined with their relatively low amount of valuable materials, makes them relatively costly to treat and their treatment is expected to strain the resources of an e-waste management system notably (Spitzbart et al., 2014). Therefore, it will likely be more appropriate to focus on these appliances at a later stage.

Because it is expected that some equipment containing CRTs will also be collected when choosing a product scope as described above (e.g., when a CRT TV-set or a computer including its CRT monitor is collected), including this type of equipment could make sense once an e-waste TF has been established. The CRT is the main component of this equipment type and consists of different parts containing different hazardous substances. The CRT can either be separated from the device by manual dismantling and subsequently be transported to a specialized TF abroad, or, if a CRT cutting device is available, it can be separated into the so-called panel and funnel glass before transport (Schluep et al., 2015).

For cooling and freezing equipment, it shall be mentioned that it could make sense to already collect these appliances and store them at a dedicated place to export them at a later stage when resources become available. This, because many of these appliances are presently being collected either by the Seychelles Ozone Unit or via the bulky waste collection system. While it usually makes sense to process all e-waste fractions that are being collected, it is also possible to simply store some of the collected e-waste at the beginning, especially in case resources are limited. For example, Taiwan decided to store e-waste in the initial years of their e-waste program because the established TF fell short of having the capacity to process all the collected e-waste (UNU/StEP Initiative, 2015). Since the treatment of cooling equipment generally requires highly sophisticated treatment equipment and states a health risk to dismantling workers, it could also make sense to export these devices as a whole after degasification, which is, for example, being done in Malta (Mallia, 2019).

In conclusion, it will be necessary for Seychelles to find the right balance between limiting system complexity and expended resources as well as achieving a certain level of economies of scale to ensure feasibility of the system's operations. Therefore, it will most likely make sense to start an e-waste management system in Seychelles with a relatively broad product scope but to put special emphasis on the collection and treatment of selected products. For example, initially the collection of ICT devices and their peripherals could be specifically targeted while other devices with similar treatment requirements are collected and treated as well if they appear in the e-waste stream.

3.2.3 Overall system management

3.2.3.1 Background and relevance

The next element to consider when determining the design of an e-waste management system is the allocation of responsibilities with regards to establishing and managing the overall system. Governance tasks that need to be organized include policy formulation and evaluation, operations (collection and processing), stakeholder consultation, collection and disbursement of finances, coordination of service delivery, monitoring, and enforcement (OECD, 2016; UNU/StEP Initiative, 2015).

Generally, any decision with regards to who should be responsible to manage the e-waste system should be taken "in view of the policy goals, product characteristics, market dynamics, actors in the product chain, and the resources needed to implement the policy" (OECD, 2016, p. 40). Any choice in this area is highly interlinked with the chosen financing mechanism due to the fact that managing the system's finances is usually one of the main tasks of the system manager (OECD, 2016; UNU/StEP Initiative, 2015).

3.2.3.2 *Available policy options*

Generally, there are two organizational entities that can be made responsible for executing tasks related to the general management of an e-waste system, namely a Third-Party-Organization (TPO) or a government entity. The two available policy options are outlined in the section below.

Third-Party-Organization (TPO) approach

The first available option is to designate responsibility for managing the e-waste system to a TPO. This option would usually apply if it is decided to follow the so-called "Extended Producer Responsibility" (EPR) principle (Baldé et al., 2017).

Most e-waste legislations and policies worldwide currently refer to this principle when talking about the allocation of responsibilities in an e-waste system (Baldé et al., 2017). About 400 such schemes are in operation across the world, mostly in OECD countries and only some in emerging market economies (state of 2016; OECD, 2016). EPR is defined as an environmental policy approach in which a producer's responsibility for a product is extended to the post-consumer stage of the product's life cycle, including its final disposal (OECD, 2001). The key idea behind is that most of a product's environmental impact in the post-consumer stage is predetermined in the design phase and by making producers of EEE responsible for this product stage, they should be incentivized to improve the environmental design of their products (Baldé et al., 2017). However, the definition of a "producer" is usually expanded from manufacturers of EEE to importers and/or retailers of EEE, even if this falls short of the original design incentive, because some e-waste can incur in a country without having been produced there (OECD, 2016; UNU/StEP Initiative, 2018). For example, in the EU a large part of the member states "obligate an EEE's first importer into the national state as the 'producer' in the absence of a manufacturer within the member state" (UNEP, 2012, p. 37). The EPR principle also tries to relieve the burden on municipalities and taxpayers for managing EoL products, reduce the amount of waste destined for final disposal, and increase recycling rates (OECD, 2016). EPR policy is consistent with the PPP in so far as financial responsibility for treating EoL products is shifted from taxpayers and municipalities to producers, which would transfer the costs downstream until they reach the consumer via an increased product price (UNU/StEP Initiative, 2015; Widmer et al., 2005). Obligations under an EPR scheme can include the provision of the necessary financial resources but can also include operational and organizational aspects such as e-waste collection and treatment (OECD, 2016).

Experience shows that it can be impractical and not particularly feasible for each producer to fulfill these obligations individually (OECD, 2016; Raymond, 2002). Therefore, producers usually establish a TPO, called a Producer Responsibility Organization (PRO) in this context, that collectively fulfills the responsibilities of its members (i.e., the producers; Widmer et al., 2005). This can allow producers to exploit economies of scale, reduce overall system costs, share risks (particularly at the beginning of a system), reduce free-riding[15], simplify operations, and reduce administrative burdens (OECD, 2016). Typically, the main task of a PRO is to collect fees from its members and then contract out collection

[15] Free-riding is one of the key challenges in any EPR system and is understood as a situation "where one firm benefits from the actions and efforts of another without paying or sharing the costs". In the context of EPR this means that certain producers would try to evade their EPR obligations (OECD, 2016).

and processing services, reimbursing the contracted parties with the collected fees. Often, the policy formulation itself is still left to the government; however, certain elements may also be left open for the PRO to decide such as the structure of fees to be paid by producers and the selection of vendors of collection and processing services (OECD, 2016).

PROs have been shown to provide a higher level of system flexibility as compared to governmentally organized systems and are able to develop relationships with its members more easily. Additionally, since the PRO is acting on behalf of its members, it has a direct incentive to keep costs low which can lead to higher operational efficiency (UNU/StEP Initiative, 2015).

Generally, it can be voluntary or mandatory for producers to join a PRO to fulfill their EPR obligations. However, it has been found that voluntary approaches to EPR systems often fail to achieve ambitious policy targets since they can be hindered by poor regulatory capture and data availability, a lack of monitoring and transparency, a failure to limit free-riding, and high transaction costs (OECD, 2004; OECD, 2016; Quinn & Sinclair, 2006). It has also been noted that voluntary systems can work better when large producers (e.g., Apple, HP, Samsung, etc.) are present in a country because those are already used to fulfilling EPR obligations in other countries and are able to exert peer pressure on smaller producers to join the PRO and limit free-riding (Schluep, 2019). An example of a system where it is voluntary for producers to join a PRO (but obligatory to fulfill their legal EPR obligations) can be found in Switzerland. When the Swiss PRO was first established, it only counted 14 members who were all big producers on the market (Gnos, 2019). The membership subsequently grew because being a member made it easier for producers to fulfill their obligations. Nowadays, almost all producers on the market have joined the scheme. Free-riding is avoided to a large part due to extensive monitoring and peer pressure from other producers (Lackovic, 2019). Compared to this successful voluntary approach, an example where such an approach has failed can be found in South Africa. There, as a result of the voluntary nature of the scheme, not all producers equally contributed to the system which put an excessive amount of pressure on only a few producers (Schluep, 2019).

If a PRO approach is chosen, the e-waste system can be managed by one or more PROs. Anti-competitive behavior by monopolistic PROs in the past has led to the emergence of many systems with multiple PROs where producers have the possibility of freely deciding which one to join. This is intended to establish competition amongst the different organizations and ensure cost-effectiveness. For example, a review by the European Commission (2014) has found that all of the 36 reviewed EPR systems for e-waste in the European Union were managed by multiple PROs. On the other side, monopolistic PROs provide simplicity in terms of monitoring, reporting, and stakeholder consultation and tend to lead to increased transparency (EXPRA, 2013). In smaller jurisdictions, they may also reflect an effort to capture economies of scale (OECD, 2016). A typical structure of a single PRO system with commercial and/or municipal collection and processing services is portrayed in Figure 5.

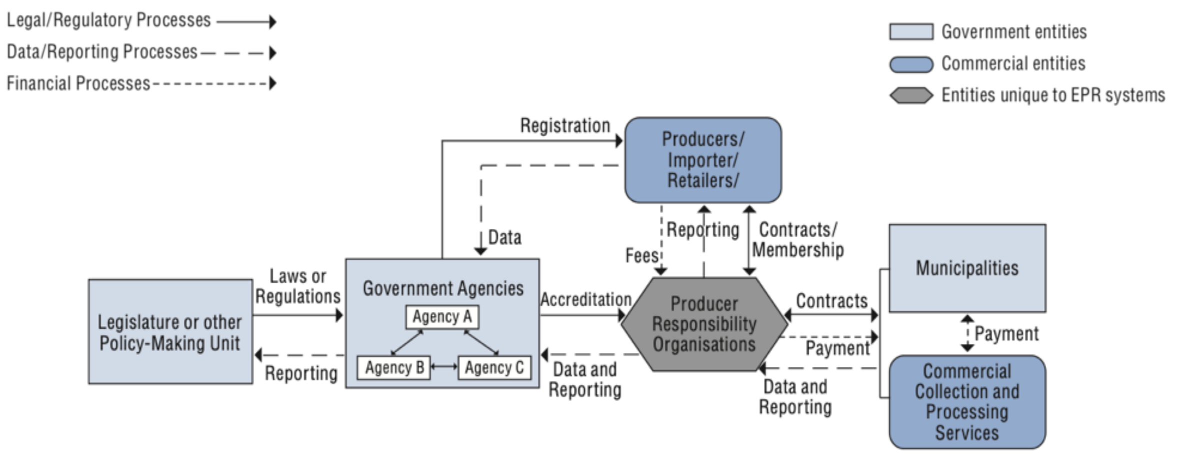

Figure 5: Structure of a single PRO system with commercial and/or municipal collection and processing services. Material flows are not included for simplicity. Municipalities may pay commercial providers for services and/or be paid for recyclables depending on the arrangements in the EPR system. Registration can be viewed as something the governments perform (i.e., they "register the producers") or something that is done by producers (i.e., the producers register with the government). The depiction of the directionality is thus somewhat arbitrary. Source: OECD (2016).

PROs can be established as for-profit organizations but are usually non-profit organizations. The main argument in favor of for-profit status is that the profit incentive will drive PROs to be efficient, but a for-profit status will also make profitable waste fractions more attractive which bears the risk of "cherry-picking", meaning that only valuable e-waste components are collected and managed. A PRO operating in a single-PRO governance structure is almost always a non-profit organization (OECD, 2016).

When thinking about whether a PRO approach might be appropriate for managing the e-waste system, three main issues need to be considered. These concern enforcement capabilities, the overall capability and capacity of the PRO(s) to manage an e-waste system, and a potential conflict of interest of the PRO(s) with the overall goal of the e-waste management system.

One of the downsides of a PRO-led system is that there is a higher risk of free-riding as compared to a government-led system due to limited **enforcement capabilities** of PROs. Free-riding in an EPR system can either happen by producers not registering, by them reporting wrong information (e.g., about the actual quantity of goods put on market), or by them reporting correct information without then taking any further action. This places an unfair burden on compliant companies not only in terms of additional recycling costs but also by making them uncompetitive on product pricing (since they will have to add the additional costs incurred by the e-waste system to the product price; Khetriwal, Widmer, Kuehr, & Huisman, 2011). When free-riding and evasion of fees is extensive, the financial viability of an EPR system can be put at risk (Kalimo et al., 2012). The challenge of reducing free-riders generally increases with the number of producers and the length of the product chain (OECD, 2016). The only way a PRO itself can counteract free-riding is by peer pressure of producers who are already part of the organization on producers that are not yet. Other means of enforcement such as levying fines or banning producers from the market are usually only within the legal authority of the government. Further, a PRO's capability to limit free-riding can be hindered by having less access to information about producers as compared to the government (e.g., import and put-on-market numbers, and a producer's profit and loss statement). This limited enforcement power can also impede a PRO's ability to ensure compliance of other stakeholders with other rules of the system such as treatment standards (OECD, 2016).

As a result, to ensure the viability of a PRO-led system the government will at least be needed as a regulatory entity ensuring enforcement of the system's rules and applying suitable sanctions. The government can further support the PRO by sharing relevant information (OECD, 2016). For example, within the PRO-led system in Malta the government's Environment & Resources Authority has been given the task to supervise free-riders and would fine them if non-compliance is detected. The authority can also order audits for any of the producers to ascertain that the information they provide is at least close to truth (Mallia, 2019). The Swiss PRO for battery recycling "INOBAT", which is mandatory to join for producers, also receives support by the government in limiting free-riding by receiving import data. This allows the organization to be informed about who has imported batteries and the corresponding amounts to verify that all producers are registered as members and report correct information (Gnos, 2019; Lackovic, 2019).

A PRO can also find itself generally unable to properly execute certain system functions if the organization exhibits a limited **overall capability and capacity to manage an e-waste system**. This can especially be an issue if the producers behind the organization have limited resources and experience in managing e-waste systems. For example, it can be quite complex to calculate a system's costs and accordingly, the fees that need to be paid by producers. This is especially true if it is not only necessary to determine the overall system costs but also how they are divided between different e-waste products respectively e-waste categories to avoid cross-subsidization (Khetriwal et al., 2011). Cross-subsidization occurs if the fee charged on one category of e-waste is higher than its recycling costs and the differential is used to pay for the recycling of another category of e-waste whose recycling costs are higher than the fee charged (e.g., the treatment of refrigerators is significantly more expensive compared to the treatment of mobile phones; UNEP, 2007a). Producers usually oppose such cross-subsidization since they are not willing to pay for additional costs related to products they are not responsible for. Moreover, system costs can change over time and need constant re-evaluation, which increases complexity further (UNU/StEP Initiative, 2015).

Other system management activities such as the organization of collection services and approving collectors and processors of e-waste will require additional resources and capabilities from the PRO's side. A relevant aspect regarding this is the availability of necessary collection infrastructure and treatment facilities. It has been found that it can be increasingly challenging for PROs to fulfill their obligations if such supporting infrastructure is not present since they would then essentially need to build up this infrastructure by themselves which would strain their resources substantially (Baldé et al., 2017).

Another aspect to consider, in case a PRO approach is chosen, is that there is a potential **conflict of interest** between the organization and its members and the overall goal of the e-waste management system. Producers have an incentive to keep costs as low as possible while the e-waste system should target to maximize its e-waste collection, including of non-valuable fractions, and to treat it according to strict environmental and health and safety standards. Given these potentially conflicting interests, the government needs to establish an adequate system to monitor the PRO and PROs should be required to report regularly on the technical and financial aspects of their operations (OECD, 2016). The OECD (2016) lists as minimum information that every PRO should report (1) the fees collected; (2) the amount of products put on the market by its members; and (3) the amount of waste collected and treated (reused, recycled, recovered and disposed of). Due to this conflict of interest, the Government of Malta's Environment & Resources Authority not only audits individual producers but also the PROs itself (Mallia, 2019) and in Switzerland the independent research institution Empa regularly audits the Swiss PRO "Swico" (Swico, 2019a).

As a result of all of the above-mentioned aspects, many different versions of PRO-led systems have emerged, where PROs would have more or less responsibility depending on the capabilities and capacities of the producers present on the market.

Government-centric approach

Another available option is to designate responsibility for managing the e-waste system solely to a specific government entity (UNU/StEP Initiative, 2015). This can be practical because such a managerial system can build upon and leverage aspects of the general waste management system that is already in place (which is usually managed by the government; Roldan, 2017). Furthermore, as has already been mentioned, governmental entities have a higher power of enforcement as compared to PROs and can therefore better ensure compliance of involved stakeholders with the system's rules. However, governments often lack a direct incentive to keep system costs low and as a result the e-waste system might be designed less economically efficient (UNU/StEP Initiative, 2015).

While a government-centric approach appears to be the obvious choice when an e-waste system is intended to be financed by a household fee or tax, whose collection clearly lies within the sphere of the government, the situation is less clear if it is decided to follow another system financing approach related to the EPR principle (for further details about financing, see section 3.2.4). In such a case, it will be necessary to carefully evaluate the aspects that have been described above and decide whether a PRO or a government entity will be more suitable to manage the e-waste system. An example of an EPR system that is run by the government can be found in China. The country first considered an approach to EPR for its e-waste that relied on PROs to collect fees and sub-contract waste services but then rejected this because of concerns that such an organization would not be effective in fulfilling its tasks without strong support from the government. Instead, the government chose to collect fees from producers directly and to disburse the funds via the Ministry of Finance (Tong & Yan, 2013). In Chinese Taipei, an EPR system, even though not specific to e-waste, initially relied on a PRO approach but as difficulties arose from false data reporting, financial scandals, lack of transparency, and poor design of PRO responsibilities the system was shifted to a government-run EPR system (Ching-Wen, 2004; Fan, Lin, & Chang, 2005). Two main points of concern towards a government-led EPR system are that it may delay or prevent producers from taking on the responsibilities implied by the concept of EPR (OECD, 2016) and that producers might object this type of system out of concerns that the funds collected from them could be diverted to uses other than the EoL management of e-waste (OECD, 2016). A depiction of a typical government-run EPR system can be found in Figure 6.

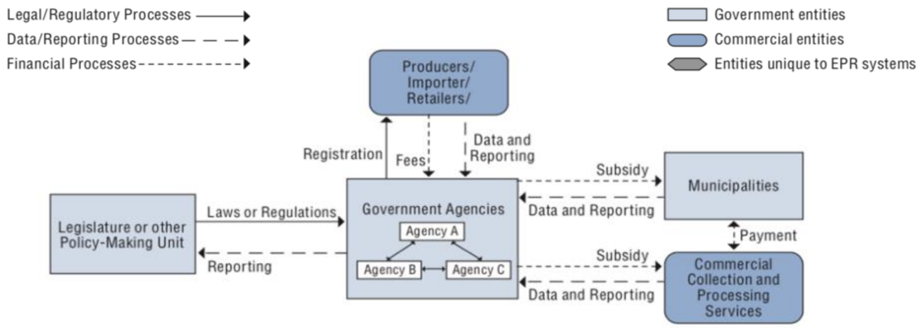

Figure 6: Structure of a government-centric EPR system with commercial and/or municipal collection and processing services. Material flows are not included for simplicity. Municipalities may pay commercial providers for services and/or be paid for recyclables depending on the arrangements in the EPR system. Registration can be viewed as something the governments perform (i.e., they "register the producers") or something that is done by producers (i.e., the producers register with the government). The depiction of the directionality is thus somewhat arbitrary. Source: OECD (2016).

An overview of advantages and disadvantages of a government- and a PRO-led system can be found in Table 7. In practice, a shared responsibility model is often adopted where the "the best of both worlds" can be harnessed (OECD, 2001). For example, a government's role can be most effective by monitoring and ensuring that the system's rules are enforced while a PRO might find itself better able to execute functions that require direct interactions with producers (OECD, 2016; UNU/StEP Initiative, 2015). What needs to be understood is that even if it is decided that a PRO has the necessary capabilities and capacity to manage an e-waste system and a maximum of responsibility is left with the organization, significant action will be required by the government concerning policy formulation and evaluation, data collection and management, accreditation, enforcement, etc. for which resources in the form of authority, staff, and funds are needed (OECD, 2016).

Table 7: Advantages and disadvantages of a TPO and a government-centric e-waste system management approach. Adapted from UNU/StEP Initiative (2015).

	Advantages	Disadvantages
TPO approach	- More flexible – can adjust rules and outcomes more easily - Easier for TPO than government to develop relationship with members - Business incentive to operate economically efficient	- Potential lack of enforcement mechanism (avoid free-riding, ensure collection and treatment standards, etc.) - Potential lack of capacity and capabilities for overall management - Potential conflict of interest; needs monitoring by government
Government-centric approach	- Can build upon and leverage existing waste management system - Have powers of enforcement (levy fines, ban noncompliant producers) - No potential conflict of interest	- Not always most efficient economically - Can stifle (quick) innovation - Money flowing into and out of government departments can be problematic

3.2.3.3 Conclusion for Seychelles

The decision on who should be responsible for the overall system management in Seychelles depends not only on the local context but also on the other policy approaches chosen. As already mentioned, for example, it can be said that if a general household fee or tax is chosen as a financing mechanism a government-led system will be the preferable option. However, for other approaches it will be necessary to analyze the situation in more detail. The final decision on how best to allocate responsibilities will depend on the following aspects:

- To what extent would a PRO in Seychelles have the necessary capacity and capabilities to fulfill its responsibilities?
- How much government support would be needed (e.g., provision of information and infrastructure, imposing sanctions against free-riding, etc.) to enable the proper functioning of the PRO?
- To what extent would the government be able to properly monitor the PRO and ensure its compliance with the system's rules?

First of all, if it is decided to follow a PRO approach, since there are no producers of EEE present in Seychelles, it would effectively be the importers of EEE that would make up the PRO membership. In most cases, these are also the retailers of EEE in Seychelles. Given Seychelles low overall e-waste volumes, it will make sense to follow a single-PRO approach to leverage possible economies of scale and limit system complexity. The PRO should then be set up as a non-profit organization because this has been found to be more suitable for single-PRO systems and it should be mandatory for all producers to join the scheme.

One of the key aspects influencing the suitability of a PRO approach in Seychelles is the fact that EEE is generally imported into Seychelles by small- to medium-sized commercial businesses and that there is no large EEE manufacturer present on the market (CVO, 2013, 2014, 2015, 2016, 2017; Rajković, 2018). A few authorized resellers of products manufactured by large companies such as Apple, Samsung, LG, and Xerox exist, however, these resellers are usually not able to access the resources of the company manufacturing the products because the only relationship between the retailer and the EEE manufacturer is a contract that allows the retailer to purchase the EEE directly from the manufacturer and subsequently sell it to consumers. Probably the biggest companies importing e-waste into Seychelles are the telecommunication companies Airtel Africa Limited[16] and Cable & Wireless Seychelles[17], which are both affiliated with internationally leading telecommunications companies. However, since these two companies only import a very selected scope of EEE such as mobile phones and routers it cannot be expected of them to solely take on a leading role in a PRO.

As a result of the above described situation, it is expected that a PRO in Seychelles would have limited capacity and capabilities to organize an e-waste system and enforce its rules. Free-riding is presumed to be significant since many importers will try to avoid the fulfillment of their responsibilities and the

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[16] Airtel Africa Limited is a subsidiary of Bharti Airtel Limited (Airtel Africa, 2019).

[17] Cable & Wireless Seychelles is part of Liberty Latin America (Cable & Wireless, 2019).

organization will most likely only count a few producers at the beginning on which all responsibilities, including the financing of the EoL treatment of all e-waste within scope, would fall (Böni, 2019a). Additionally, there is currently no sufficient infrastructure around e-waste collection and processing present in Seychelles which will additionally hinder the proper management of the e-waste system by a PRO.

With regards to the first question listed above, it can therefore be said that it is unlikely that a PRO by itself will have the necessary capacity and capabilities to manage an e-waste system by itself. Various interviewed stakeholders have also mentioned great doubts about this. Thus, considerable support from the government will be needed if a PRO approach is chosen in terms of enforcement, infrastructure build-up, provision of information, and other management tasks, as well as financial support, especially at the beginning when fee evasion will extensive. Before such support from the government cannot be ensured, the burden placed on the producers by making them responsible to manage the e-waste system will simply be too high which will endanger the viability of the e-waste system.

Next to this, in case a PRO approach is chosen, the government would still need to monitor the organization and enforce compliance. This will use further governmental resources and states another risk of system failure if not executed properly. Experience from other waste management activities in Seychelles and interviews with local stakeholders indicate that monitoring and enforcement power by the government is oftentimes insufficient which makes this risk significant.

To sum up, placing responsibility to manage the e-waste system on producers will still require significant action and resources by the government, with a higher risk as compared to a government-centric approach that the system might not function properly. A government-led system is therefore likely the preferable choice, even if it is decided to follow an EPR-based approach.

3.2.4 Financing mechanisms

3.2.4.1 Background and relevance

It has been found that the quality and coverage of services in the waste sector such as the collection, transport, dismantling, recycling, and disposal of waste are determined to a large extent by the amount of funding available (Woodruff, 2014). Even though value can be generated by the sale of certain e-waste fractions, the achieved revenues are not sufficient to cover the full costs of an e-waste management system, which include not only operational costs for collection and treatment but also administrative, reporting, monitoring, and communication costs as well as costs for a broader range of activities such as public information and awareness campaigns (OECD, 2016; UNU/StEP Initiative, 2009; Wang et al., 2012). Therefore, establishing a sustainable financing mechanism with clearly allocated responsibilities is key for enabling good systems governance (UNU/StEP Initiative, 2018; Widmer et al., 2005; Woodruff, 2014). Such a financing system should be run in a transparent manner to ensure cost-effectiveness, stimulate competition, and catalyze the mobilization of financial resources from citizens and other external sources (UNU/ StEP Initiative, 2016b; Woodruff, 2014). It is also recommended that the system is subject to external auditing (UNU/StEP Initiative, 2018).

3.2.4.2 *Available policy options*

Generally, there are three different stakeholder groups available that who could bear financial responsibility for an e-waste management system via different financial mechanisms. These are (i) the entire society via a household fee or household tax, (ii) consumers of EEE via an EoL fee or an Advanced Recycling Fee (ARF), or (iii) producers of EEE via a compliance cost scheme or a producers-pay-government-distributes approach (UNU/StEP Initiative, 2009). The functioning of each of these mechanisms shall be outlined below and be split up into two parts. First, the mechanism itself shall be described, and second, its applicability to Seychelles shall be discussed.

Household fee and household tax

Description

E-waste can be seen as a societal challenge since it not only impacts consumers, but the entire population, and it can be argued that in many countries most households will produce e-waste at some point in time. Therefore, responsibility to finance an e-waste management system can be borne by the entire society. This can either be implemented via a household fee or a household tax. For both of these systems the amount to pay is independent of the actual amount of EEE consumed or the amount of e-waste produced.[18] Usually, such a fee or tax is raised to cover the costs of the general waste management system and parts of the fund are then allocated specifically to e-waste activities (UNU/StEP Initiative, 2015; Roldan, 2017).

An advantage of such an approach is that the individual impact on people is lower as compared to other financing mechanisms since the overall system costs are spread out over a greater number of people. Next to this, even though it is generally not a simple task to match the revenues generated by any financing mechanism with the total costs of the e-waste system, the fact that with a household fee or tax it is not necessary to know how the overall system costs split up between different e-waste product categories significantly simplifies this (Roldan, 2017). However, the approach of making the whole society responsible for e-waste management activities is often criticized because it does not follow the PPP and as such does not incentivize the reduction of EEE consumption (UNU/StEP Initiative, 2015).

The main difference between a household fee and a household tax is that with a flat fee system all households are charged the same amount, while with a progressive tax, households are charged depending on their income. As a result, taxation systems usually exhibit a higher degree of variability in the amount of tax revenue brought in on a per period basis which increases the risk of over- or underfunding the system (Roldan, 2017). However, a tax can be the preferable option if it is decided to minimize the financial impact on a country's poorer population. In case the government's general tax budget is used to pay for waste management activities, as opposed to raising a fee or tax that is

[18] It is recognized that this financing mechanism does not include the commercial sector, which is potentially undesirable since this sector also produces e-waste. Due to a lack of found literature the option of expanding this mechanism to the commercial sector shall not be discussed here; however, it is generally possible to include a commercial tax or fee in this financing mechanism.

specifically dedicated to waste management, another point of concern is that resources might be re-allocated in case government priorities change (UNU/StEP Initiative, 2015).

Applicability to Seychelles

In Seychelles, it can be argued that a financing mechanism which makes the whole society responsible to pay for e-waste management is justified since more or less all households can be expected to produce e-waste at some point in time. For example, in 2010 90% of all households owned at least one mobile phone, 95% at least one television, and 87% at least one radio which shows the high amount of EEE present in many households in Seychelles (NBS, 2017, 2018).

As has already been mentioned in section 3.1.3.1, households currently do not pay a fee or tax dedicated to waste management apart from the monthly fee to the PUC which is, however, only partially used to pay for specific waste projects. The LWMA and the MEECC, on the other side, receive their money from the general tax budget (von Rothkirch et al., 2018). This makes two possible options to raise money from all citizens evident: (1) the fee collected by the PUC can be raised and the resulting additional funds can be dedicated to e-waste management or (2) the general tax imposed on households can be increased to also cover the costs of the e-waste system. Next to these two options that build on already existing financial structures, it is also possible to introduce a new fee or tax dedicated to waste management and use part of the funds for e-waste management. In fact, the last option may be preferable. Using the general tax budget states a risk that resources might be re-allocated and expanding the fee charged by the PUC is also critical. The PUC is a company that is not directly involved in any waste management activities (but rather provides services related to water, electricity and sewage; PUC, 2019). It therefore does not seem logical to raise money for an e-waste system over this channel and will likely not be understood by the public. Further, a recent report by Theilmann et al. (2018) has shown a variety of significant weaknesses related to the existing financial system in place around waste management and it has been mentioned by Flavien Joubert (2019), the CEO of the LWMA, that it is desirable to move the current waste management system into a direction where households are held more directly responsible for waste management activities. Therefore, restructuring the current waste financial system by introducing a new waste tax or fee could offer a chance to eliminate existing weaknesses and include households more directly in the financing of the waste system.

Whichever option will be chosen, the main advantage of adopting a financing mechanism where a fee or tax is collected from households is that the financial system will be relatively simple to manage because the Government of Seychelles already has experience in collecting fees and taxes and also has the necessary monitoring capabilities to ensure that every household pays. Free-riding is therefore expected to be minimal and low additional monitoring costs are expected. Due to the comparably simple cost calculation that will be necessary, administrative costs related to this will also be comparably low. While the simplicity of this system has been recognized by most interviewed stakeholders, it has also been mentioned that introducing new taxes or fees or raising existing ones is a politically extremely sensitive topic in Seychelles and will be difficult to implement. This, because an additional financial burden would be placed on the poorer population, which is something the government is stringently trying to avoid due to the country’s already high inequality. Given this context, imposing an income-dependent tax will likely lead to lower levels of opposition by stakeholders as compared to a flat fee. However, it appears that a flat fee could also be justified in Seychelles since it has been mentioned by various stakeholders that the poorer population produces a similar amount of e-waste as other income groups. This was explained by the fact that they would consume a lot of low-quality EEE with short functional lifespans.

End-of-Life fee and Advanced Recycling Fee

Description

Another approach that can be chosen to raise finances for an e-waste management system is to charge the consumers of EEE. This approach states an implementation of the PPP where the polluter, i.e. the person producing e-waste, is also recognized as the person responsible to pay for the resulting disposal costs (UNEP, 2012; UNU/StEP Initiative, 2015). Generally, there are two different fee systems available to implement such an approach.

In case an **End-of-Life (EoL) fee** is applied to pay for an e-waste management system, the generator of e-waste, meaning the last owner of a product who decides to recycle it, needs to pay a fee reflecting the product’s full EoL treatment costs at the point of disposal. By this mean, the fee is intended to create an incentive to prolong the lifetime of a product (UNU/StEP Initiative, 2015).

The main advantage of such a system is that there is a low risk for under- or overfunding the system since funds are only collected for devices that actually need to be recycled. However, making consumers pay for the disposal of e-waste creates a strong disincentive to separate it from the normal waste stream (since there, no or lower disposal fees would apply; UNU/StEP Initiative, 2015). This disincentive becomes especially strong if a country has a long history of “free” disposal services where consumers are not used to paying for the disposal of their waste (SPREP, 1999). In fact, Japan is currently the only country that has implemented an EoL fee system (UNU/StEP Initiative, 2015).

If an **Advanced Recycling Fee (ARF)** financing mechanism is applied, consumers pay for the e-waste system at the point of purchase of new EEE. The fee placed on each product is usually based on its respective disposal costs (e.g., disposal costs for a refrigerator are significantly higher than for a mobile phone) and the relative amounts that are currently being collected or expected to be collected of the product in the future. For example, if only 5% of all mobile phones are separately collected but a fee reflecting a phones full disposal costs is collected for all of them, the e-waste system is expected to be overfunded. The fee would therefore usually be adapted to these collection ratios (OECD, 2016; UNU/StEP Initiative, 2009).

Even though an ARF system makes consumers and not producers responsible for the financing of the e-waste system, it can nevertheless be in line with the EPR principle since it is common that producers transfer their costs for managing the e-waste system to consumers by putting an invisible or visible fee on their products. A visible fee appears separately on a purchase receipt while an invisible fee is included in the product price (OECD, 2016; UNU/StEP Initiative, 2009). For example, in Switzerland the two main PROs responsible for managing e-waste, “SENS eRecycling” and “Swico”, are financed by an invisible ARF (BAFU, 2018; Hischier et al., 2005; Lackovic, 2019). On the contrary, the EU WEEE Directive allows a visible fee system as a measure available to producers to collect funds from consumers (2012/19/EU). In general, both, an invisible and a visible fee system, are possible. For visible fees it has been found that they have the potential to raise consumer awareness but that they can also lead to public resistance (UNEP, 2012).

Making consumers responsible for financing the e-waste system at the point of purchase can be advantageous because it not only follows the PPP but also, in comparison to a household fee or tax, establishes a direct incentive to reduce consumption via increased product prices (UNEP, 2012; UNU/StEP Initiative, 2015). However, it is important to understand that any ARF system exhibits higher complexity due to two reasons. Firstly, the calculation of fees can be challenging because not only the total system costs need to be known but also how they distribute between different products or product classes. This can be difficult to assess and there is a trade-off between a simpler fee structure and achieving a low level of cross-subsidization between products and the product still bearing a relationship to its actual recycling costs (Khetriwal et al., 2011). Recalculating the fee structure on a regular basis will also be necessary since, for example, a sudden increase in recycling costs or a loss of market opportunities to resell e-waste fractions can change the costs incurred by the system (UNU/StEP Initiative, 2015). Additionally, changes in demand for EEE can lead to variability of the amount of money collected (Roldan, 2017). Secondly, monitoring and enforcement will also require significantly more attention in an ARF system because retailers are incentivized to disobey with the obligation to put an ARF on their products. Such non-compliance enables the retailers to offer products at a cheaper price compared to compliant retailers which provides the former with a competitive advantage. Retailers might also collect an ARF on their products but would subsequently not transfer the collected money to the entity responsible for managing the e-waste funds. To avoid this behavior and ensure a level playing field for all retailers of EEE, sufficient resources need to be allocated to the proper monitoring of the financial system and penalties need to be awarded if non-compliance is detected (UNU/StEP Initiative, 2015).

As a last point, it is also important to mention that it might not even be desirable to increase prices of certain EEE, especially in developing countries. It has been argued that EEE has the potential to "benefit society in economic, innovative, and social ways" because, for example, access to a computer can enable new business opportunities (Roldan, 2017, p. 49). Therefore, while implementing a PPP for waste management is generally desirable, this might not necessarily be true for e-waste.

Applicability to Seychelles

In the local context of Seychelles, an EoL fee can be excluded as a suitable financing mechanism because the disincentive to separate e-waste from the normal waste stream is expected to result in low e-waste collection numbers. Even if an additional ban to dispose of e-waste via the normal MSW collection system is enacted, enforcement of this ban will be difficult because MSW is currently being disposed via communal waste bins and the Government of Seychelles generally exhibits relatively low power of enforcement in regard to certain waste management activities.

With regards to an ARF, representatives from the MoF and other interviewed stakeholders have stated that consumer protection is a key point of concern when new policies are developed and that the cost of living might increase too much by putting an ARF on EEE. This has been mentioned to be especially relevant when it comes to EEE that is used by consumers in daily life (Barbe, 2019; de Comarmond, 2019; Hassan, 2019; Kazibwe, 2019). While it is generally possible to exclude these types of EEE from an ARF, this has the potential to seriously constrain the product scope of the e-waste system. Further, experience from other countries shows that ARFs are usually marginal when compared to the total product price (Deepali, 2019; Lackovic, 2019). The implementation of such a financing mechanism is therefore not expected to significantly constrain consumers' choice. Various local stakeholders have also acknowledged that it will be extremely challenging to implement an ARF system in Seychelles. This was substantiated by the fact that the local retailer system is decentralized and consists of many small- to medium-sized businesses. These will be difficult to monitor and control, and significant resources will need to be deployed to ensure compliance of all retailers (Barbe, 2019; Laure, 2019; Payet, 2019b).

Moreover, interviewed stakeholders stressed the consideration that a large part of EEE is currently bought abroad or over online sales channels due to the high price levels of EEE sold in local retail stores. It will effectively not be possible to capture these products under an ARF system which can put the viability of this financing system at risk.

To enhance understanding of the actual amounts of EEE bought over such alternative purchase channels, a designated part of the survey that has been conducted during this thesis asked respondents where they usually buy their EEE. The possible answers were "in a store in Seychelles", "online", and "abroad" and the question was asked specifically for mobile phones, tablets, laptops, computers, and televisions. This range of devices was selected because interviewed local stakeholders have indicated that these devices are bought over such alternative purchase channels most frequently and because they are highly relevant for an e-waste management system in terms of volume and financial value (see section 3.2.2.3). The results of the survey indicate that a significant share of these devices appears to not be purchased in local retail stores. While purchases over online sales channels seem to be relatively infrequent, approximately half of all survey participants indicated that they usually buy their mobile phones and tablets abroad. For televisions and computers, these shares are smaller which can be explained by the devices larger size which complicates transport. These results suggest that small-sized EEE is relatively likely to be purchased abroad while larger-sized items are still expected to be purchased to a far extent at local retail stores. An overview of all results for the different devices is displayed in Figures 7 to 11. In addition, stakeholders mentioned that cheaper types of small-sized EEE are probably still bought to a large part in local stores because consumers are expected to be less price sensitive on these items. Based on the findings of this survey, it is assumed that in case an ARF mechanism at retail stores would be implemented, a large part of fees for devices that will eventually turn into e-waste in Seychelles will not be collected. Even if it would be required for consumers to declare such purchased goods at the point of import, controlling this will essentially not be possible, and experience from other countries shows that including online stores in such a fee system is also extremely challenging (Mallia, 2019; Roldan, 2017). As a result, the fee put on devices in local retail stores will factually need to be high enough to not only pay for their own disposal costs but also for those of the devices for which no fee was collected. This could be considered unfair to consumers purchasing their EEE locally. Further, the additional increase in local product prices is expected to incentivize the purchase of EEE via alternative sales channels even more, which can lead to a competitive disadvantage of the local economy (Böni, 2019a; Roldan, 2017).

Figure 7: Where survey respondents buy their mobile phones (N=143)

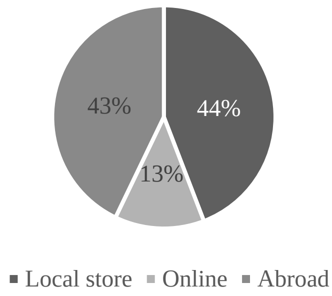

Figure 8: Where survey respondents buy their tablets (N=77)

Figure 9: Where survey respondents buy their laptops (N=109)

Figure 10: Where survey respondents buy their computers (N=41)

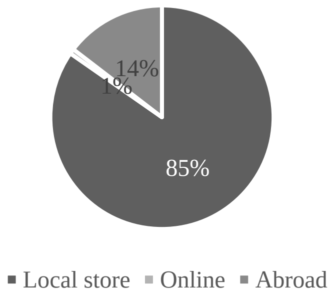

Figure 11: Where survey respondents buy their televisions (N=137)

Compliance cost scheme and producers-pay-government-distributes approach

Description

The most typical approach when following the EPR principle is to make producers of EEE directly responsible to meet the costs associated with the e-waste management system (OECD, 2016; UNEP, 2012; UNU/StEP Initiative, 2015). This approach can also be regarded as an implementation of the PPP because producers will pass on their additional costs downstream to consumers by internalizing it in the product price (UNU/StEP Initiative, 2015). As has already been discussed in section 3.2.3.2, fees can be collected from producers either by a PRO (called a compliance cost scheme) or by the government in case it is decided against a PRO approach.

If it is decided that a PRO should be responsible to collect fees from producers via a **compliance cost scheme**, the exact financing model and how costs are split up between the different producers can either be left open for the PRO to decide or it can be prescribed by the government. Generally, a fee structure that is as closely linked to the actual EoL treatment costs of the products is preferable (OECD, 2016). Most commonly, the amount to pay by each producer is either determined based on the number of products placed on the market (unit- or weight-based), the producer's market share, or the return share (how much of a producer's product appears in the waste stream) and can either be based on current or future recycling costs (UNU/StEP Initiative, 2009). For example, the Swiss PROs "Swico" and "SENS eRecycling" have embraced a unit-based system where each producer needs to pay a fixed fee per product type placed on the market (which is then passed on to consumers via an invisible fee). The fee per product type is determined based on the respective disposal costs (Borthakur & Govind, 2016; Lackovic, 2019; UNEP, 2007a). It is also possible to adapt such a fee periodically. This is for example done by Norway's PRO "El Retur" that recalculates costs based on the current market share of its members on a monthly basis (UNEP, 2007a). Malta's PROs "WEEE Malta" and "WEEE Recycle", on the other side, adopted a system where estimated future cost of the e-waste system are calculated and then split up between producers based on the number of products they placed on the market (Mallia, 2019). In general, even though some of these systems are more complex to calculate than others, similar to the ARF model, setting the correct fee is a challenging task due to the necessity to differentiate between costs of different products respectively product types (Khetriwal et al., 2005; UNU/StEP Initiative, 2015).

A major hurdle that is often mentioned in the context of a compliance cost scheme approach is the one of so-called "historical waste" and "orphan waste". Historical waste arises from appliances put on the market before an e-waste legislation was enacted (UNU/StEP Initiative, 2015) and orphan waste refers to appliances that are subject to EPR requirements but whose producers are no longer in operation (e.g., due to bankruptcy) or cannot be identified (e.g., due to a missing brand name on the product; OECD, 2016). As a result, it remains unclear for historical and orphan waste who is responsible to pay for the disposal costs. Usually, this issue is resolved by either treating them as the collective responsibility of those actively placing products on the market (UNEP, 2007a; UNEP, 2012) or by allowing producers to share financial responsibility with consumers (UNEP, 2012). Sharing responsibility with consumers (and therefore stating a mix between an ARF and a compliance cost scheme) is usually achieved either directly via a visible fee at the retail level or via a so-called "reimbursed compliance cost model". With this model, producers pay an upfront fee to the PRO when placing appliances on the market but are later reimbursed for those costs through a visible fee paid by consumers at the time of purchase. This system is for example applied in a majority of the EU's member states (UNU/StEP Initiative, 2009).

If it is decided against establishing a PRO to manage the e-waste management system's finances but to nevertheless follow the EPR principle and make producers financially responsible for the system's costs, responsibility for fee collection and disbursement can also be allocated to a government entity. This is usually called a **producers-pay-government-distributes approach**. Essentially, such a system functions the same way as a compliance cost scheme, with the same fee structures available to choose from and the same challenges related to historical and orphan waste and the calculation of correct fees (OECD, 2016). However, an advantage of this approach is that, next to the possibility to collect fees directly from producers, the government usually has additional options for fee collection available. One of these options is to collect fees directly at the point of import via an import tax or import levy. Producers would then be charged based on the number of products imported which is synonymous to the number of products placed on the market. However, instead of the producer declaring this number directly to the PRO or the responsible government entity, the country's customs division is made responsible to execute the task of fee collection and would subsequently transfer the money to the entity administering the e-waste system's finances. A functioning process at the customs level is essential to ensure the financial viability of this approach since all imported EEE needs to be declared and fees collected accordingly (Roldan, 2017).

Applicability to Seychelles

An EPR approach is nowadays one of the most recommended mechanisms by policy makers to manage e-waste (OECD, 2016). However, in Seychelles many challenges in regard to this approach exist.

Regardless of whether a compliance cost or a producer-pays-government-collects approach is applied, similar to an ARF system, a raise in local product prices by producers passing on their additional costs to consumers is a critical and politically sensitive issue in Seychelles. The apparently frequent use of alternative purchase channels for certain goods is also problematic. Local producers, and indirectly the consumers that purchase their goods, will have to cover the costs for the disposal of these goods as well. As with an ARF, the setting of the correct fee price on a per product level will state another challenge. Next to this, producers are likely unwilling to comply with their obligations and will try to evade fee payments. This will require the investment of significant resources into monitoring activities to effectively avoid free-riding. Based on the findings of section 3.2.3.3, it is expected that a PRO will face larger difficulties with regards to this as compared to the government and a producer-pays-government-collects approach is, therefore, likely preferable over a compliance cost scheme approach. However, the analysis of the current waste system in Seychelles has shown several aspects that give reason to believe that a government entity would still encounter significant difficulties.

Due to the fact that Seychelles is a country that does not produce any EEE and, hence, all consumed EEE needs to be imported and pass through the customs division, an obvious option to consider when implementing a producers-pay-government-distributes approach is the implementation of an import levy or tax. According to interviewed stakeholders, this option would likely be easiest to implement from a political standpoint (Cosgrow, 2019; de Comarmond, 2019). Not only is such an approach mentioned in the EPA (2016, section 41) as a means to promote recycling but it has also already been implemented for PET bottles, aluminum cans, and alcoholic glass bottles. However, there are a number of reasons why it is doubtful that it will be possible to implement such an import levy or tax for e-waste in a functional manner. As has already been mentioned in section 3.1.3.2, the levy system in place for PET bottles, aluminum cans, and alcoholic glass bottles still exhibits a variety of weaknesses, especially from a financial point of view, and it appears that the Seychelles Customs Division is currently not able to properly capture all these imported items. Compared to these relatively clearly defined items, there is a large variety of EEE, which appears to currently not being properly captured either (given the large irregularities with regards to the import data of EEE as discussed in section 3.1.4). Different levies or taxes would need to be defined for all types of EEE under their respective HS codes. Because there are many small retailers present in Seychelles who mainly import their EEE themselves, there is also a large number of individual importers which the system must capture (see Table 8; CVO, 2017; Rajković, 2018). An import levy or tax system for EEE would therefore exhibit larger complexity as compared to the existing levy systems which is likely to enhance already encountered difficulties.

Table 8: Overview of imported amounts of EEE by number of importers. Source: CVO (2017) and Rajković (2018).

Volume per importer	Number of importers	Cumulative amount	Share [%]
>10 tons	72	2’529	70
>6.7 tons	100	2’749	76
>1 ton	331	3’428	95
Total registered	***1’522***	***3’621***	***100***

Furthermore, interviewed stakeholders mentioned that many online retailers currently evade paying applicable import taxes or levies. This is enabled by the fact that importers only need to fill a bill of entry and declare their imported products if the product’s value exceeds 5000 SCR (~370 USD). Consequently, many online retailers import their products in small amounts to avoid declaration and fee payments (Barbe, 2019; Hassan, 2019; Ramani, 2019).

The above described aspects suggest that in case an import levy or tax is applied as a mechanism to collect fees from producers, free-riding of producers will be extensive, at least at the beginning of the system. This will further exacerbate the problem that compliant producers will need to pay for the EoL treatment costs of products for which no fee or tax was collected, which is already expected to be significant given the assumed large amounts of EEE imported over alternative purchase channels. While it is generally possible to initiate an import levy or import tax scheme with a limited product scope to reduce the financing system’s complexity (by having to control fewer importers and simplifying fee calculations), as has already been described in section 3.2.2.3, including a relatively large scope of EEE under the e-waste management system will be crucial in Seychelles to achieve a certain level of economies of scale. Grossly limiting this scope is therefore likely an undesirable option.

If it is decided to implement an import levy or tax system, despite the above described challenges, it will be of crucial importance to provide better and more effective enforcement at the customs level and expand monitoring activities. Possible measures to help this process can include the provision of more resources to the customs division to ensure that the division has the necessary capacity to control all imports and the implementation of adequate penalties for producers trying to evade fee payments which act as a meaningful deterrent (UNU/StEP Initiative, 2015).

3.2.4.3 Conclusion for Seychelles

Considering the findings of the previous sections, it appears that a household tax or fee for general waste management will be the simplest and most cost-effective financing solution for an e-waste management system in Seychelles.

Due to the assumed large amount of EEE being purchased over alternative channels, in any EPR or ARF system it is likely that a significant number of products that will eventually turn into e-waste in

Seychelles will not be captured under the financing scheme. This can put the long-term financial viability of the e-waste system at risk because consumers and/or producers of local EEE will object paying for the EoL treatment costs of these products. While it is generally possible for the government to subsidize the e-waste system to balance out the missing fee amounts, this is critical because self-funding waste systems are usually preferable over the reallocation of existing government funds. It would then at least be necessary to establish a fixed financial flow from the government's budget to the e-waste system; however, the risk that these funds are eventually redirected to other governmental activities remains. While the use of alternative purchase channels and the resulting discrepancy between money collected and money spent will be hard to avoid, free-riding by non-compliance of retailers or importers could potentially be limited by expanding monitoring and enforcement capabilities. Nevertheless, developing these capabilities will take time and will require significant resource investments. Even if a PRO could be made responsible for this task, the government would still need to expand its own capabilities to monitor the PRO and provide it with the necessary support. Until these capabilities have been expanded, evasion of fee payments is expected to be extensive regardless of whether the fees will be collected from consumers at the retail level or from producers either directly or at the point of import. This increased need for monitoring and enforcement and the fact that a higher level of detail regarding fee calculations is necessary as compared to a household tax or fee system will generally lead to higher overall system costs.

Expanding an existing household fee or tax, or implementing a new one, would mostly eliminate the possibility to evade fee payments with minimal additional monitoring and enforcement efforts and would also make the problem of alternative purchase channels redundant. The relative simplicity of such an approach would therefore limit additional expenses related to this. While it might generally be more desirable for waste management approaches to follow the PPP, the advantages of using a household fee or tax are likely to outweigh this in Seychelles and can also be justified due to the use of EEE by most households. Increasing the fee charged by the PUC or using the general tax budget to pay for the e-waste management system can be an option; however, the implementation of a household tax or fee for general waste management, and using parts of the collected funds for managing e-waste, can additionally offer a chance to reorganize the current waste financial system and eliminate existing deficiencies. The implementation of a household fee or tax is further supported by the fact that it appears to be a long-term goal of the government to make households financially responsible for waste management services. Indeed, such an approach would place an additional financial burden on the poorer population, which is critical given the already high inequality in Seychelles; however, in case an income-based tax is applied, this burden can be minimized and might even have a smaller overall impact on the poor population compared to a price raise of EEE.

3.2.5 Separation at source and collection of e-waste

3.2.5.1 Background and relevance

Implementing the operational part of any e-waste management system begins with organizing the separation and collection of e-waste, the so-called "take-back" (Tanskanen, 2012), which is a key element to enable appropriate downstream treatment (Ponce-Cueto, Gonzalez, & Carrasco-Gallego, 2011). When thinking about how best to design such a take-back system, three areas need to be considered: (1) to ensure that the largest possible proportion of the e-waste that is available to collect is safely collected; (2) that e-waste is not combined with other waste types; and (3) to deliver the e-waste to the downstream TF with minimal damage or material loss (UNU/StEP Initiative, 2015).

To be able to monitor the effectiveness of such a take-back system, collection volumes should be continuously measured (UNU/StEP Initiative, 2015). Further, experience shows that setting clear, realistic, and achievable collection targets, which should be developed in close consultation with relevant stakeholders, can be an effective tool for increasing collection rates (OECD, 2016; UNU/StEP Initiative, 2009; UNU/StEP Initiative, 2015;). Based on the effectively achieved collection volumes these targets should be continuously adjusted (UNU/StEP Initiative, 2015). An overview of different methodologies to determine suitable collection targets can be found in UNU/StEP Initiative (2015).

In general, two factors can be identified which will determine the success of any take-back system: the awareness of final users and their disposal behavior as well as the availability of collection infrastructure determining the level of convenience for consumers to dispose of e-waste (Magalini, 2007; Spitzbart et al., 2014; UNU/StEP Initiative, 2015). Hence, one of the main difficulties related to the implementation of a take-back system is to find the right balance between expending resources and generating convenience for and awareness amongst consumers (Widmer et al., 2005). For example, consumers would ideally have limitless possibilities to bring back their e-waste, but each collection point is also associated with additional costs (UNU/StEP Initiative, 2009). In fact, it has been found that collection and transportation usually incur the main costs of the e-waste management system which makes it evident that a careful design of this system element is of paramount importance (Tanskanen, 2012).

When thinking about the best way to organize e-waste collection, it needs to be differentiated between collecting e-waste from the government, commercial entities, and households as well as between small-sized e-waste (i.e., waste that can be carried and fits into a normal waste bin) and bulky e-waste. Each stakeholder group and each appliance type can be targeted differently, and responsibilities can be allocated to the different stakeholders as deemed appropriate (UNU/StEP Initiative, 2015). For example, the EU WEEE Directive, as per Article 5(2), makes it incumbent on producers to provide collection and disposal services to private households "at least free of charge" but leaves it open whether business clients shall be charged for these services or not (2012/19/EU). The scope of products that will be collected will also be relevant to consider since different types of e-waste require different handling practices. Especially relevant regarding this is the appropriate collection of potentially hazardous items as well as items containing personal data (Tanskanen, 2012).

3.2.5.2 Available policy options

There are a variety of different methods available to collect e-waste. This section will discuss the most widely used methods followed by an analysis of their potential to collect e-waste in Seychelles. In most cases, a mixture of different collection methods is used to obtain the highest possible collection rates (UNU/StEP Initiative, 2009).

Permanent drop-off facility

Description

Permanent drop-off facilities are a widely used collection method where people can drop off their e-waste all year round. Generally, such facilities are targeting private consumers (households) and, due to the circumstance that the e-waste needs to be transported to these facilities, they are mainly used to drop-off small-sized e-waste (UNU/StEP Initiative, 2015). Some storage space is always required until the e-waste is brought to a TF. The storage location should at least have at least an impermeable surface as well as weatherproof covering (UNEP, 2007a; UNEP, 2012). Further specific requirements common to all permanent drop-off facilities can be found in UNEP (2007b). The most frequently used types of drop-off facilities are described below.

Public drop-off facilities for e-waste are typically co-located with drop-off sites for other waste types and mainly address private consumers (UNU/StEP Initiative, 2015). Occasionally, commercial businesses are also allowed to drop off smaller amounts of e-waste (Swico, 2019b; WasteServ Malta Limited, 2019a). The use of such drop-off points by consumers appears to be tightly linked with the level of convenience they provide, which is determined by the frequency of drop-off points, the corresponding distance consumers will have to travel, and appropriate opening hours (UNU/StEP Initiative, 2009). To react to this, Switzerland has built up a dense network of roughly 600 such collection facilities, with one collection point serving approximately 14,000 people, where consumers can drop off their e-waste, next to other waste types, free of charge during convenient opening hours. Commercial businesses are also allowed to drop off smaller amounts of e-waste free of charge (Swico, 2019b). As a result of the so provided high convenience, circa 70% of all e-waste from households is collected over this channel (Gnos, 2019). Such public drop-off points do not necessarily require a lot of infrastructure and can initially simply consist of a container as displayed in Figure 12. Malta has chosen another approach that does not require the build-up of much infrastructure by providing six public drop-off sites (also in conjunction with drop-off for other waste types and corresponding to approximately 76,500 people per collection point) and expanding this network with so called "WEEE-Trolleys" (see Figure 13). These simple container boxes have been distributed to local councils, schools, and businesses and consumers can drop off small e-waste whenever these buildings are open (WEEE Malta, 2019). In Malta, commercial businesses are allowed to use the six larger public drop-off sites between once and eighteen times a year, depending on the size of the delivery vehicle used (WasteServ Malta Limited, 2019a).

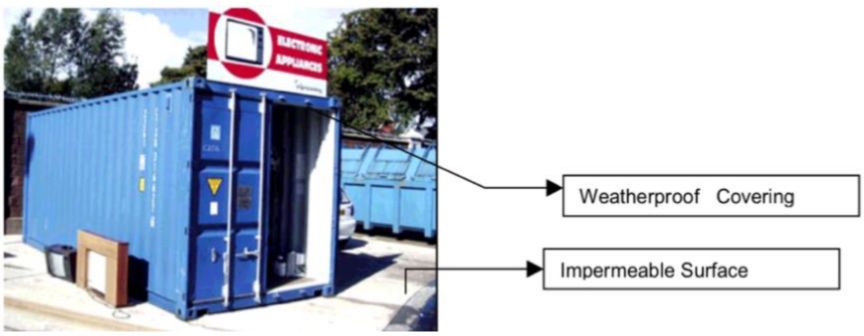

Figure 12: Shipping container as a public drop-off facility. Source: UNEP (2000b).

Figure 13: “WEEE Trolley” as a public drop-off point as used in Malta. Source: WEEE Malta Ltd (2019).

Public drop-off points are usually managed by the public sector, however, if a sufficiently high incentive is provided – such as a financial reimbursement for collected e-waste when brought to a TF – the private sector can also have an interest in setting up such collection points (UNU/StEP Initiative, 2016b). Even though some initial investments might be necessary to install such public drop-off facilities, they have generally been found to be highly cost effective since minimal upgrading is required (UNEP, 2012).

Next to typical public drop-off points, another obvious collection point is the e-waste **treatment facility** (TF), which also receives the e-waste that has been collected elsewhere. Using the TF as a collection point has the advantage that no further transport of the e-waste is required before its treatment. However, this option should more be seen as an addition to other collection points because these facilities are not present in a dense enough network to ensure sufficient convenience for consumers. Drop-off at the TF is a service that is usually available to households, commercial businesses, and the government (UNU/StEP Initiative, 2015).

Another type of e-waste collection points that is frequently used are **retail stores** of EEE. The idea behind is to oblige those actors selling EEE to contribute to the collection system (UNU/StEP Initiative, 2015). This obligation usually covers acceptance of e-waste from individual consumers without a charge (UNEP, 2007a) and has been found to be a very successful measure to collect e-waste (UNEP, 2012). The main advantage of using retailers as collection points is that a dense network of collection points can be created without the need to build up additional infrastructure. For example, in Switzerland roughly 6000 such collection points for e-waste exist, in addition to the 600 available public drop-off facilities (corresponding to roughly 1,400 people per collection point; Gnos, 2019).

Generally, two different versions of such a drop-off retailer system have emerged:

- **One-for-one/old-for-new:** With this type of system, whenever a customer purchases a new product from a retailer, an equivalent product can be returned free of charge at the location of sale. Most countries in the EU follow such a principle (UNU/StEP Initiative, 2015), including Malta (WEEE Malta, 2019), and in Japan, it is estimated that 80% of the collected e-waste is currently collected through this system (UNEP, 2007a).
- **Zero-for-one:** The second option goes further than the first one and obliges all retailers of EEE to act as a permanent collection point for e-waste, regardless of whether the consumer purchases a new product at the same time. Usually, this obligation is applied per type of equipment, meaning that when a store is selling a specific type of EEE it is also obliged to take back any EEE that is of such type (UNU/StEP Initiative, 2015). This system is for example applied in Norway (UNU/StEP Initiative, 2009) and Switzerland (Swico, 2019b). To not disproportionately impact small retail stores, this obligation can be linked to a size threshold

(UNU/StEP Initiative, 2015). For example, Réunion, an island department of France, has implemented a one-for-one system for all e-waste in combination with a one-for-all system for e-waste smaller than 25cm (TCO, n.d.).

Applicability to Seychelles

In Seychelles, one of the obvious ways to collect of e-waste is to expand the already existing redeem centers for PET bottles and aluminum cans to act as public drop-off points for e-waste. This service can be made available to households and potentially also to the commercial sector for smaller quantities. As has already been described in section 3.1.3.2, knowledge by the general public about the existence of such collection points is currently insufficient and it will therefore be of crucial importance to increase awareness raising efforts. This not only has the potential to increase collection rates for e-waste but also for PET bottles and aluminum cans. In the future, to allow for more convenience to consumers, additional redeem centers can be built (since currently one redeem center serves approximately 21,000 people, which are relatively many, especially when there are no disposal alternatives available). Drop-off containers similar to those used in Malta could be used as a less infrastructure-heavy approach in addition to the redeem centers. The containers could be distributed in public spaces such as schools, churches, and governmental buildings. Because it is likely that other types of waste will also be thrown into these receptables (which is what has happened in pilot waste sorting projects in Seychelles in the past), additional sorting will be required once the e-waste is collected. Informing the public about the purpose of these containers can potentially limit this.

Due to Seychelles' limited resources to build up additional collection infrastructure, using retailers of EEE as e-waste drop-off points available to households could also be a suitable option which can offer high convenience to consumers at minimal costs. A previous survey conducted by Rommelspacher et al. (2018) has found that five out of eight interviewed storekeepers would be willing to offer bins to the public for such activities and other retailers that have been consulted during this thesis have also indicated willingness to participate in such a collection system as long as pick-up of the e-waste will be organized and will be free of charge to them (Kazibwe, 2019; Ramani, 2019). However, it has also been mentioned by interviewed local stakeholders that small retail stores in Seychelles often face seriously constrained storage space due to high rental costs. This could limit their willingness and ability to participate in such a retailer drop-off system (Ramani, 2019; Uzice, 2019). A one-for-one approach, a size threshold for collected e-waste, or the organization of a regular pick-up of the collected items could offer a possible compromise to limit the burden placed on these retailers. Interviewed stakeholders with experience in the implementation of retailer systems in other countries have also pointed out that retailers often oppose this new obligation but once it has been decided to implement (and enforce) it, they would usually accept it, especially once they realize that generally no extremely large amounts of e-waste would be delivered to them and that this new obligation is, in fact, rather manageable.

Special drop-off & collection events

Description

Special drop-off events are one- or two-day events which are held in easily accessible areas such as parking lots, government buildings, or retail stores where generators can pass by and drop off their e-waste. With collection events, the e-waste is collected at the doorstep. To ensure the success of such events, informing the public about them is of crucial importance which is usually achieved via broad advertising campaigns (UNU/StEP Initiative, 2015). Typically, these events are organized by the government or by a commercial stakeholder and can also be a collaboration between both. Commercial stakeholders are oftentimes willing to support these events because they can leverage them as a marketing instrument to promote their own business.

Different to other collection methods, special drop-off and collection events can serve a dual purpose of increasing collection rates as well as educating the public about e-waste. Information leaflets can be distributed and during drop-off events, the booth staff can directly interact with interested passers-by (UNU/StEP Initiative, 2015). This makes them a suitable method to use when e-waste collection is first started which is further facilitated by the fact that they do not require a lot of infrastructure and resources. For example, special drop-off events have been used rather successfully in Colombia when e-waste collection was first commenced (Böni, 2019b).

Applicability to Seychelles

Hosting special drop-off and collection events can be an effective way to collect e-waste, especially when e-waste collection is first started. Given the still relatively low awareness of the Seychellois population with regards to e-waste, these events could be especially beneficial and also appear to be suitable due to their low infrastructure requirements.

A special drop-off event could for example be conducted in collaboration with a local retailer of EEE or a telecommunications company. Interviewed stakeholders from these sectors have indicated willingness to contribute to such an event. If it is decided to include bulky e-waste in the product scope of the e-waste management system, a special door-to-door collection event could also be hosted. This could be organized very similarly to the "Clean up the World" event; however, it is generally preferable that collection is solely dedicated to e-waste to ensure the safe and undamaged transportation of the collected items.

Formal door-to-door collection

Description

E-Waste can also be picked up at the doorstep or curbside outside of special collection events. This can either be organized in conjunction with other waste types or solely for e-waste and can either take place on-demand or on a regular basis. Such organized pick-ups are mainly relevant for bulky e-waste or large amounts of e-waste from a single stakeholder and can target households, commercial businesses, and the government. The pick-up itself can be conducted by the government (or a subcontracted collector), which would then usually state an expansion of existing waste collection services, by retailers upon delivery of a new appliance, or by commercial entities (including e-waste treatment facilities themselves). The so provided collection service can be offered free of charge or for a fee and, especially for pick-up on demand, it has emerged that businesses and/or individual consumers are able to use this service a few times a year for free and beyond that, are charged a fee (UNU/StEP Initiative, 2015). For example, in London (UK), individuals can get their large domestic appliances collected up to four times a year without being charged for it (UNU/StEP Initiative, 2015) while in Switzerland this service is provided on an unlimited basis to commercial entities disposing e-waste in large quantities

(>250kg) but is not available to households (Swico, 2019b). In Malta consumers can call their municipality to have their bulky waste, including e-waste, picked up free of charge on an unlimited basis whereas commercial entities need to pay for waste pick-up (WasteServ Malta Limited, 2019b; WasteServ Malta Limited, 2019c).

Generally, door-to-door or curbside pick-up is one of the costliest collection methods for e-waste. However, it also offers high convenience to consumers, notably with regards to the collection of bulky e-waste, and has the potential to collect e-waste in better condition as compared to other collection methods, especially when it is collected separately and not in conjunction with other bulky waste types. This becomes highly relevant when the sorting out of potentially reusable devices after collection is included in the take-back system and when potentially hazardous e-waste types are transported (Roldan, 2017; UNU/StEP Initiative, 2015).

Applicability to Seychelles

Door-to-door collection will be relevant in Seychelles to collect bulky e-waste from households as well as large quantities of e-waste, including bulky e-waste, from commercial entities.

With regards to collection of bulky e-waste from households, if included in the product scope of the e-waste system, the new waste collection contracts for MSW offer an opportunity to include this in the planned weekly bulky waste collection. While it is preferable to collect e-waste separately from other waste types, to limit necessary resources, it could also initially be conducted in conjunction with other bulky waste types such as bulky metal waste as proposed by interviewed stakeholders. The bulky e-waste could then be sorted out at the landfill. This sorting activity is expected to be relatively simple because bulky waste is generally easy to sort. In fact, this is already done with bulky waste collected during the “Clean up the World” event where bulky scrap metal parts are separated at the landfill to be picked up by the scrap metal dealers. Whether included in the weekly collection schedule for bulky waste or not, collection of bulky e-waste should be conducted relatively frequently because it is expected that households will oftentimes put these items on the roadside regardless of whether collection is scheduled or not, which is currently experienced for all types of bulky waste. Consulted local stakeholders agreed that households should not be directly charged for such regular door-to-door collection services but that the costs of such a collection system should rather be included in any e-waste financing scheme as described in section 3.2.4.

While pick-up on demand is expected to use too many resources if offered to households, this service could be provided to the commercial sector for large quantities of e-waste. Theoretically, it is possible to charge a fee for this service; however, this is not suggested since it would create a strong incentive to not use the service and dump the e-waste somewhere else. The commercial sector could also be included in a regular bulky e-waste collection for households. If it is decided to charge the commercial sector directly for e-waste collection services (as proposed by various interviewed local stakeholders), providing such a regular collection service might actually be the preferable option because a fee could then be charged to businesses regardless of whether they use the service or not. This would eliminate the incentive to dispose of the e-waste via other channels. Given the oftentimes small storage place of commercial businesses, collection should be scheduled relatively frequently since businesses are not expected to be willing to store e-waste over a longer time periods.

Informal door-to-door collection

Description

Especially in developing countries, it is vital to not only consider the formal sector that is available to conduct activities related to door-to-door e-waste collection but also the informal sector. This is relevant, if it is possible to gain money by the collection of e-waste (i.e., when the e-waste or e-waste parts are valuable enough to sell or when a financial value is attributed to them, e.g., by a deposit-refund system; UNU/StEP Initiative, 2015).

Experience shows, that the informal sector can be highly efficient in collecting e-waste because this sector usually has a large workforce and the necessary flexibility to carry out door-to-door collection and can even access e-waste when separation at source is absent (e.g., by scavenging waste bins and landfills; OECD, 2016; Spitzbart, 2019; UNU/StEP Initiative, 2015; Widmer et al., 2005). In countries such as Ghana, India, and China informal collectors directly buy e-waste from individual households and businesses and subsequently resell it with a margin to recyclers to make a profit (Sinha-Khetriwal, Kraeuchi, & Schwaninger, 2005; 2016; Spitzbart, 2019; UNU/StEP Initiative, 2015). Such an approach achieves high collection rates because it also provides an incentive for consumers to hand out their e-waste (Pandey & Govind, 2014; Pariatamby & Victor, 2013). For example, in Ghana collection rates of roughly 95% were achieved, mainly due to a highly efficient informal sector (Amoyaw-Osei et al., 2011).

Because the informal sector is neither registered nor licensed and is, hence, operating without any controls and standards and does not take environmental regulations into account, this sector can generally operate at a lower cost than the formal sector. This can save public authorities large sums of money due to avoided collection costs (OECD, 2016; UNU/StEP Initiative, 2015). Moreover, collection by the informal sector can lead to several social and economic benefits for the poor such as social cohesion and income for marginalized people (Pandey & Govind, 2014; Pariatamby & Victor, 2013; UNU/StEP Initiative, 2015; Zhang et al., 2012). However, due to the uncontrolled nature of the informal sector and its primary incentive to maximize economic returns, there is a high risk of cherry-picking. This is especially true when informal collectors are reimbursed based on the collected e-waste's actual market value and not, for example, on a "per kg of e-waste collected" basis where the "value" of the e-waste is determined by a deposit that is put on it (Spitzbart, 2019; UNU/StEP Initiative, 2015). If the collected e-waste is sold to substandard treatment facilities after collection (since these facilities are often able to provide higher reimbursements due to their informal nature), this could cause further negative economic and environmental impacts (OECD, 2016). From a social perspective, the informal sector is also precarious due to low incomes, poor working conditions, and long working hours. Further, informal workers are also not covered by any social insurance or health protection which is especially problematic given the potentially hazardous nature of certain e-waste types and the fact that informal collectors are typically untrained in how to handle these items (OECD, 2016; UNU/StEP Initiative, 2015).

Consequently, the potentially positive contribution of informal waste collection and sorting activities is increasingly recognized and it is oftentimes recommended by the international community to integrate the informal sector into any formalized system in case such a sector is already present at the time an e-waste management system is built up. However, if it is decided to follow an informal door-to-door collection approach, minimizing the associated negative aspects is of paramount importance (OECD, 2016). It needs to be ensured that, after collection, the e-waste is sent to licensed recyclers (UNU/StEP Initiative, 2016b). For example, this can be done by providing financial incentives to informal collectors at authorized facilities (Zhang et al., 2012). Additionally, it is recommended that the informal sector is "professionalized" and "formalized" as far as possible. This can include signing direct contracts or agreements with organized e-waste collectors or the e-waste TF or supporting the informal collectors to comply with tax laws (OECD, 2016). Providing informal collectors with access to training and safety equipment is also crucial to enable them to operate under environmental, health, and safety standards (UNU/ StEP Initiative, 2016b). An incentive for informal collectors to participate in such a system could for instance be to link any financial reimbursement for the e-waste collected to the condition that they get "organized, registered officially, and commit to adhere to the legislation" (UNU/StEP Initiative, 2015, p. 32).

Applicability to Seychelles

The situation with regards to the informal sector is special in Seychelles. In most developing countries, an informal collection sector is already present before a formal e-waste management system is built up since the financial value of selected e-waste parts is high enough to sell them to a TF and make a profit. However, in Seychelles neither a recycling facility nor an informal collection sector has developed so far because not even the high-value parts of e-waste provide sufficient revenue to operate a profitable business, mainly due to high land and shipping costs. For PET bottles and aluminum cans, on the other side, such an informal collection sector is present in Seychelles due to a refund that is offered for collected items. Therefore, it is expectable that a similar system would develop around e-waste if a financial value would be attributed to e-waste, for example via a deposit-refund scheme.

Experience from other countries as well as the achieved collection volumes for PET bottles and aluminum cans in Seychelles show that such a collection system has the potential to be relatively efficient and achieve high collection rates. However, it is also highly critical given the many downsides connected to the existence of an informal sector. Interviewed stakeholders with direct experience in dealing with an informal e-waste sector disagreed on the question as to whether such a sector for e-waste collection is desirable in Seychelles. Although, it has been pointed out that the existence of such a sector is likely less problematic in Seychelles as compared to other developing countries since there are currently no informal recyclers present and the collected e-waste would therefore still be processed by a formalized TF. The downside of poor general working conditions remains but since the collection of e-waste by itself is oftentimes not extremely problematic, the risk related to the environment and the collector's health is considered bearable. Providing collectors with safety equipment, informing them about potential health risks, and offering training about how to handle e-waste could further reduce these risks. Related to this, any financial reimbursement should be attached to certain conditions regarding the quality of the delivered items. For example, only the delivery of complete devices should be reimbursed to ensure that the most valuable parts are not taken away beforehand and hazardous e-waste parts remain contained in the device (Schluep, 2019).

A last aspect to consider regarding e-waste collection by an informal sector is the fact that some consumers might be unwilling to hand out e-waste that still contains personal data (e.g., mobile phones, computers, laptops, etc.) to informal collectors. Interviewed stakeholders mentioned that oftentimes, this sector is considered untrustworthy with regards to data security, while such concerns are smaller when disposing of a device containing personal data over a formalized disposal channel (e.g., a closed bin at a retail store or a registered redeem center). Because these types of devices are often amongst the most desirable to be collected (see section 3.2.2.2), it is important to still offer alternative channels to consumers to dispose of such items.

Further supporting policy measures

Description

The separation and collection of e-waste can not only be motivated by the provision of appropriate collection channels, but a variety of different policy measures can additionally support the achievement of high collection volumes. The three most commonly used measures with regards to this are disposal bans, disposal fees and the use of deposit-refund schemes.

Banning the disposal of e-waste together with general waste via a **disposal ban**, effectively forcing consumers by law to separate e-waste, can encourage high collection volumes (UNU/StEP Initiative, 2015). For example, such bans have been enacted in Switzerland (Bundesrat, 1998) and the EU (2012/19/EU, Article 6.1). Experience shows that the actual enforcement of this law is difficult and especially for small-sized e-waste it is almost impossible to track who commits any violations because the e-waste would simply "disappear" in waste bins. However, the main value of this measure lies in the fact that such a regulation can act as a means of communication to send a clear message about the importance of e-waste separation to the public (Gnos, 2019; UNU/StEP Initiative, 2015).

Disposal fees can be an effective market-based policy instrument to motivate the separation of e-waste. A twofold logic can be applied. Firstly, disposal of e-waste should be offered free of charge and secondly, the pay-as-you-throw principle (i.e., disposal charges based on generated waste amounts) should be applied to general waste. This enables waste generators to decrease their expenses by reducing their waste generation and separating different waste types. This system has already achieved a significant decrease in household's waste generation and an increase in waste separation in various countries (Watkins et al., 2012). For example, in Switzerland this system has led to a reduction of unsorted waste by 40% by charging consumers for the purchase of general waste bags but providing them with free disposal options for recyclables, including e-waste. This system also provides a source of income to cover the costs of a waste management system (in Switzerland, 36% of costs are covered by this system; Carattini et al., 2016). While typically such a system is applied at the household level via fees for purchasing official refuse bags or charges when waste bins are emptied, it can also target the commercial sector, for example, via gate fees at the landfill (Watkins et al., 2012).

A **deposit-refund scheme**, as has already been mentioned in section 3.1.3.2, is another market-based policy instrument that provides a financial incentive to consumers to return their e-waste to designated collection points (OECD, 2016). For example, 11% of all EPR schemes use deposit-refund schemes to increase collection volumes of various goods (Kaffine & O'Reilly, 2015) and the use of such schemes has also been specifically recommended for e-waste (Watkins et al., 2012). Most commonly, the deposit is made at the point of purchase but can also be collected at an earlier stage such as the point of import. Theoretically, it is even possible to not directly collect a deposit but to rather pay refunds from a generally available budget (OECD, 2016). A variation of this scheme is, for example, successfully implemented by the company “Closing the Loop” to collect mobile phones in several African countries. Europe-based businesses pay a fee to the company for every newly purchased mobile phone and the company then uses the so collected funds to reimburse collection partners in African countries on a “per kg of mobile phones collected” basis (de Klujiver, 2019). Another example of how a deposit-refund scheme can be applied for e-waste is the National Old-for-New Home Appliance Scheme (HARS) that has been implemented in five large cities and four provinces in China between 2009 and 2011. Consumers were given a discount on the purchase of a new device if they got their old device separately collected to channel it towards recycling (OECD, 2016; UNU/StEP Initiative, 2015).

Applicability to Seychelles

In Seychelles, due to households using communal waste bins to dispose of their MSW, it will be difficult to identify violators of a disposal ban for e-waste. However, such a regulation has the potential to influence the disposal behavior of commercial businesses because individual waste bins are attributed to them. Therefore, enforcement at this stakeholder level might be possible because waste collectors would be able to see if and by whom e-waste is dumped together with other waste types and could report this to the LWMA.

For the commercial sector, tipping fees at the landfill weighbridge could furthermore be utilized to incentivize separation of e-waste. At the household level this is currently inapplicable due to the communal waste bins. These will not allow to register the waste amounts produced by individual households or, if a system of chargeable waste bags would be applied, to enforce their use because violators are again unidentifiable. However, if individual waste bins for households would be installed in the future this measure could also support e-waste separation at the household level. Under the new waste classification developed by the LWMA e-waste will be categorized as HW and a tipping fee higher than for general waste will apply (F. Joubert, personal communication, March, 2019). This acts as a clear disincentive to separate e-waste from the normal waste stream. Experience from other waste types with high tipping fees shows that businesses in Seychelles are sensitive to such price signals. For example, a change from a general charge for the disposal of medical waste at the Victoria hospital incinerator to a charge based on “per kg of medical waste disposed” led to stakeholders disposing this waste type via other, less appropriate disposal channels. Waste collectors are also already sorting out scrap metal parts from the general waste to avoid paying the applicable tipping fee (Frenzel et al., 2018). As a result, it is expected that the elimination of tipping fees for e-waste can foster its separation from the normal waste stream.

For further promoting the separation of e-waste, direct financial incentives in the form of refunds for collected e-waste could also be provided. While such incentives are likely unnecessary for bulky e-waste (most people will be pleased if this waste type is picked-up by a waste collector and bulky waste cannot “disappear” in waste bins), it could be an effective instrument to motivate consumers to drop-off smaller-sized e-waste at designated collection points instead of throwing it into normal waste bins. Consulted local stakeholders have mentioned doubts that a significant amount of the Seychellois population will bring their e-waste to such drop-off points and have raised the possibility of financial incentives as a tool to support this, especially, because this has already led to relatively high collection numbers for PET bottles and aluminum cans. Further, during a survey conducted by Rommelspacher et al. (2018) households have indicated a lack of incentives as a reason why they currently do not sort waste. This provides indications that the provision of financial incentives could be effective.

Providing such a financial incentive for the separation and collection of e-waste leads back to the question whether an informal sector is desirable in Seychelles. If it is decided to exclude the informal sector from a system but to still provide financial incentives for e-waste separation, implementing a one-for-one collection system at retail stores appears to be the most suitable option. Like this, bringing back e-waste is linked to the purchase of a new device which essentially excludes the informal sector as a potential collector. For better understanding of this option the survey conducted for this thesis asked people about their willingness to bring back e-waste to a retailer when purchasing new EEE if they know that the retailer will subsequently recycle it. The question was introduced by explaining respondents why the recycling of e-waste is generally desirable to protect human health and the environment. Respondents could then indicate whether they require a financial incentive to bring back their e-waste to a retail store or not. If they indicated that they do require a financial incentive, they had a choice between different price discounts on the new device asking which one would "effectively motivate" them to bring back their old device when purchasing a new one. To account for the fact that different devices potentially have a different personal value and that they require a different effort to transport them, respondents were asked the same questions for mobile phones respectively tablets, laptops, computers, and televisions. Moreover, these devices are suitable to include at the beginning of an e-waste management system (see section 3.2.2.2). The proposed discounts were chosen based on consultations with local stakeholders.

The survey results indicate that depending on the device only between 21% and 27% of the respondents are willing to bring back their old device without a financial incentive while the rest requires a discount on the newly purchased device. Of these respondents, between 39% and 55% require a discount of over 400 SCR (~ 30 USD). An overview of responses for all devices can be seen in Figures 14 to 21. These results provide an indication that a large fraction of EEE consumers in Seychelles appears to be unlikely to separate small-sized e-waste and bring it to a dedicated collection point without a financial incentive. The results also suggest that a comparably high financial incentive is required to motivate consumers to do so. This poses a challenge with regards to the financing of such a mechanism. While the financial incentive required by the informal sector is expected to be much smaller and could stem from a general e-waste management fund, a financial incentive to motivate individual consumers would increase costs too much. A deposit-refund system could offer a possible solution. A deposit could be collected at the point of import, following the same mechanism of an import levy or tax, and could be refunded once consumers return the equipment to the retailer. While generally the same difficulties apply as with an import levy or tax, a deposit-refund system could nevertheless be a more feasible in this context. This, because it will make sense to only include selected devices whose collection is prioritized in the system which will significantly limit the complexity of such an approach. Also, the fact that a lot of EEE appears to be purchased abroad and, therefore, would be uncapturable by an import levy or tax becomes less relevant since not all devices are expected to be brought back to retailers, especially because it is linked to the purchase of a new product.

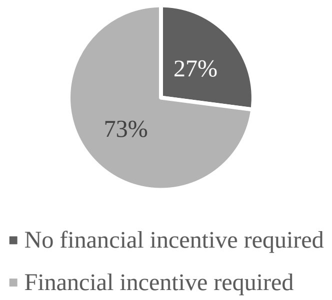

Figure 14: Mobile phone/tablet: Necessity of a financial incentive (N=133).

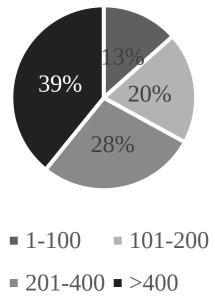

Figure 15: Mobile phone/tablet: Size of financial incentive in SCR (N=97).

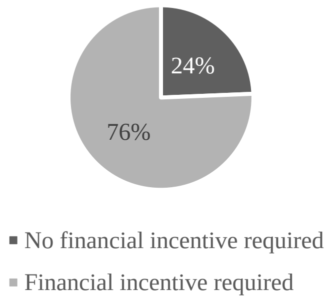

Figure 16: Laptop: Necessity of a financial incentive (N=115).

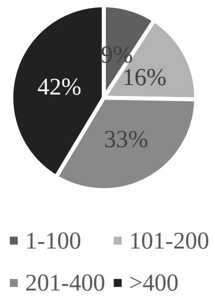

Figure 17: Laptop: Size of financial incentive in SCR (N=87).

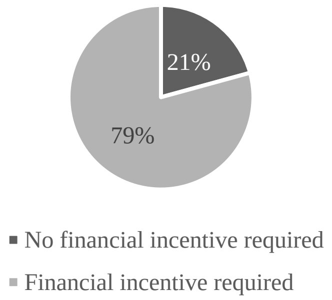

Figure 18: Computer: Necessity of a financial incentive (N=82).

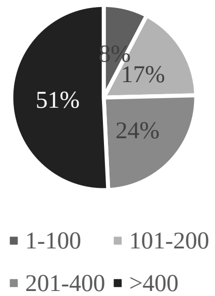

Figure 19: Computer: Size of financial incentive in SCR (N=65).

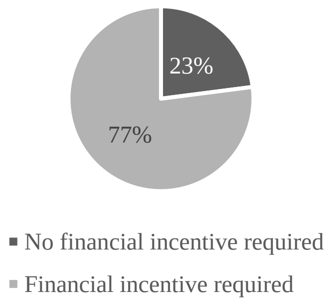

Figure 20: Television: Necessity of a financial incentive (N=135).

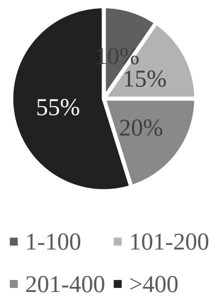

Figure 21: Television: Size of financial incentive in SCR (N=104).

3.2.5.3 Conclusion for Seychelles

Given Seychelles' limited resources, a take-back system for e-waste can be built up step-by-step. After a storage location for the collected items has been determined, which can also initially simply consist of an empty container, the actual e-waste collection can be started.

Interviewed stakeholders have pointed out that governmental entities and the commercial sector are usually most suitable to start e-waste collection, especially via individual cooperations (i.e., selected companies are individually contacted to organize e-waste collection from them). Targeting these stakeholder groups is promising in Seychelles because it has been reported that large amounts of e-waste are currently being stored in offices ("rooms full of e-waste"; M. Azemia, personal communication, March, 2019; Ernesta, 2019). Therefore, it is expected that this e-waste could be collected with relatively little effort and at low cost. It has also been mentioned that out of the different stakeholders in the commercial sector, hotels are likely to be most cooperative because they often follow relatively strict CSR policies, are already active participants in current recycling schemes in Seychelles, and have expressed interest to increase their recycling activities in the past (Deepali, 2019; Payet, 2019a). Next to these individual cooperations, a good starting point for e-waste collection that does not require the build-up of much infrastructure is expanding the already existing redeem centers for PET bottles and aluminum cans to act as public drop-off points for e-waste, which can be made available to households and businesses. The final storage facility could act as an additional drop-off point. It is recommended to supplement these collection channels with special drop-off events, which are also a simple measure to start collecting e-waste and simultaneously raise awareness among the public about the existence of the new e-waste system. Special collection events can also be hosted if it is decided to include bulky e-waste in the product scope. Small-scale pilot projects are another measure to try out other ways to collect e-waste without investing too many resources. For example, a pilot project could be conducted to try out whether drop-off containers similar to those used in Malta could act as a means to collect e-waste. As resources become available with time, the available collection channels can be expanded. Additional redeem centers could be built up, retailer drop-off systems could be implemented, and door-to-door collection services for households and businesses could be provided. In case a retailer drop-off system is implemented, enforcement will be necessary to ensure that retailers comply with this obligation.

With regards to supporting policy measures, it is suggested to enact a disposal ban for e-waste once collection channels are made available because it sends a clear message to consumers and can increase collection rates, especially from the commercial sector. Next to this, tipping fees for e-waste at the landfill should be eliminated to avoid a disincentive to separate e-waste. The provision of financial incentives via a deposit-refund system for e-waste is presumed to substantially support e-waste collection. However, connected to this it will be necessary to consider whether an informal sector should be excluded from an e-waste collection system or not. A one-for-one retailer system will probably lead to lower collection numbers and the informal sector is also expected to require a lower financial incentive as compared to individual consumers, which can make this a relatively simple, low-cost solution that could achieve high collection rates. However, many downsides are connected to the existence of such an informal sector. Hence, it will be necessary to carefully consider whether the advantages outweigh the disadvantages. To try out the effectiveness of such a proposed one-for-one retailer system, another pilot project could be conducted.

A final point to consider, is the use of individual producer take-back schemes. For example, Hewlett-Packard (HP) has implemented a take-back program for printer cartridges in a variety of countries where consumers can send their cartridges via mail to be recycled for free (HP Development Company, L.P., 2019). Another example is Apple's so-called "trade-in" scheme, where consumers can send all Apple devices and even some third-party devices for recycling, either by mail or by returning them to an Apple store. This service is also provided free of charge and depending on the returned device, a credit on the purchase of a new device can be provided additionally (Apple Inc., 2019). While it appears that there are currently no such take-back schemes available in Seychelles, such producer take-back schemes could be another mechanism worth exploring to increase e-waste collection numbers. The fact that such schemes are already present in islands such as Mauritius and Réunion gives reason to believe that they could also be applicable to Seychelles, which has also been confirmed by interviewed stakeholders.

3.2.6 Treatment and export of e-waste – a business plan for a treatment facility in Seychelles

3.2.6.1 Background and relevance

Once e-waste has been collected, it will be necessary to treat it up to a certain level and subsequently transport the resulting output fractions further downstream to international processing facilities. To execute these functions for all e-waste in scope of the system, it will be required to set up a formalized TF in Seychelles. A business plan, including a business plan calculation, for such a TF is presented here to provide a maximum amount of insight to policy makers. In more detail, the business plan pursues the following main objectives:

- To estimate the financials of a chosen baseline scenario for one year based on specific framework conditions (revenue, operational costs, investment costs, etc.)
- To provide information concerning the best set-up of the TF (space requirements, required number of employees, equipment, etc.)
- To identify special points of concern and conduct a sensitivity analysis to see how modifications in different framework conditions affect the financial outcome

To optimally apply quantitative information that has been obtained, reports about previously conducted business plan calculations for treatment facilities in other countries have been consulted. These include examples from Cambodia (Schluep & Spitzbart, 2015), Egypt (Mostafa & Dina, 2018), Tanzania (Blaser & Schluep, 2012), and Uganda (Spitzbart et al., 2014).

3.2.6.2 Set-up of treatment facility and relevant assumptions

Before going into the details of the cost calculation, the planned set-up of the TF and related assumptions will be discussed. This concerns the three questions of who will own and operate the TF; what scope of products will be treated by the TF; and to what possible level the e-waste can be dismantled by the TF.

Ownership and operator's models

The first point of concern regarding an e-waste TF in Seychelles is who will own and operate it (UNU/StEP Initiative, 2015). Since there are several environmental issues that have to be matched with economic aspects, a form of ownership that is capable to lead despite profit-reducing factors needs to be found (Spitzbart et al., 2014).

The first option is that the facility is owned and operated solely by the **private sector** which can for example be a local entrepreneur but also an international company active in the e-waste recycling business. Economic efficiency is one of the main advantages of this option because private businesses have a direct incentive to set up an economically viable solution and maximize profit. However, a challenge will be that the private operator has the necessary capabilities and capacity to manage a TF. This option is most likely also weakest regarding environmental sustainability since maximizing profit can be at odds with treating all parts of e-waste and upholding high treatment standards (Spitzbart et al., 2014). It is, therefore, important that the government sets clear standards that have to be met by the TF and monitors the TF accordingly. A private sector approach has, for example, been adopted by the EU and Japan where local entrepreneurs have set up TFs (UNU/StEP Initiative, 2015). Rwanda has also taken such an approach, however, different to the EU and Japan, the country has leased out its e-waste recycling plant to EnviroServe Rwanda, a subsidiary of EnviroServe Dubai which is a large e-waste recycler operating in 13 countries across Middle East, Africa, and Caucasus (Bizimungu, 2018; Sabiiti, 2018; Schluep, 2019). Bringing in an international e-waste recycler can especially be practical if national resources are limited. Further, transboundary shipments can be substantially simplified because the recycler would essentially send itself e-waste, which would facilitate transportation procedures under the Basel Convention (Schluep, 2019).

Alternatively, a TF can also be built and operated by the **public sector** which, for example, is done in Taiwan. There, the government created the necessary TF infrastructure and operates it under full public ownership (UNU/StEP Initiative, 2015). In the past, this business model was popular, and municipalities were usually responsible for the execution of waste recycling activities; however, these activities have more and more been outsourced to private companies. One main advantage of this business model is the fact that revenues from the commercialization of fractions can directly be used to reduce waste management fee charges. The downside of this option is that the government usually acts less economically efficient due to a lack of a direct incentive to operate at low costs. A reason why the government still sometimes owns and operates TFs by itself is that such facilities can be set up as a social enterprise. For example, the primary objective of such an enterprise can be the re-integration of long-term unemployed people into the labor market. Such social enterprises can be found in many Western European countries like Germany, France, Sweden, or Austria. (Spitzbart et al., 2014).

A hybrid between the private and the public model is a **public-private partnership** model (UNU/StEP Initiative, 2015). In that case, ownership is split between private and public shareholders and a board that manages the facility on which all shareholders are represented is established. This option was found to be an appropriate way to balance ecological responsibilities and economic sustainability and is usually chosen if government support is essential in ensuring the facilities' operational capacity. For example, infrastructure like the estate and building for the TF could be brought in by the government and in return, it would have direct influence on how treatment standards are met by the private operator

(Spitzbart et al., 2014). For example, China and the United States' state of California have followed such an approach with the former offering cheap loans and the latter offering recycling subsidies for TFs meeting the compliance requirements (UNU/StEP Initiative, 2015).

Generally, all of the above models are implementable in the context of Seychelles, but the implications of each one need to be understood and considered carefully. While it appears that the private sector in Seychelles is generally interested in operating an e-waste TF, reasons that have been mentioned why nobody has actually established such a business yet are that it is too complicated and not profitable (enough) without government support. Hence, it appears that no private sector business is possible in Seychelles without external support. Not even the most valuable fractions of e-waste are currently being exported and a TF that also treats non-valuable fractions and operates under stringent environmental standards is, therefore, even less conceivable. Even though financial support could also be provided by a TPO, it appears that governmental support, for example in the form of subsidized land or payments for a certain amount of e-waste treated, will at least be needed in the short-term until a TPO has been established in a functional manner. For this reason, the option of a public-private partnership appears to be a suitable option where the government provides support and retains a certain control over the TF's operations. Monitoring and ongoing controls of the TF will still be necessary and can be conducted either by the government or an external third-party because this approach does not eliminate the incentive to achieve cost savings via reducing quality standards and choosing cheap disposal options. A tender for proposals could be launched to identify the most suitable private sector stakeholder for a partnership. Tenders have also been mentioned by several stakeholders as a good way to ensure cost-effectiveness in Seychelles (Gonzalves, 2019; Joubert, 2019; Payet, 2019a).

A pure private sector approach can also be considered in case an international recycler would be found to operate a TF in Seychelles. This could significantly simplify aspects around the export of e-waste, which has been mentioned by several stakeholders to be extremely complicated if compliance with the Basel Convention is required. International recyclers might be more interested to enter the market in Seychelles if they are allowed to operate under full ownership. In addition, they are likely to require less governmental support because they would already have much resources available. Proper monitoring of the TF and enforcement of treatments standards is a crucial aspect if such an approach is chosen. A public sector approach appears to be less desirable in Seychelles since the government would need to organize all aspects around the TF which can require the use of substantial resources. Furthermore, letting the private sector develop a business and support entrepreneurship appears to be of interest to the local government which is enabled by the private and the public-private partnership model. However, if the government would decide to build up the TF as a social enterprise, a public sector approach could be considered as well.

Treated product scope

What could be a suitable product scope for an e-waste management system in Seychelles has already been discussed extensively in section 3.2.2. For the baseline scenario of this business plan calculation it was decided to follow the selected product scope of the StEP calculation tool (UNU/StEP Initiative, 2016b) which focuses on appliances contained in the old EU WEEE Directive's categories small household appliances (cat. 2), IT and telecommunications equipment (cat. 3), and consumer equipment (cat. 4; 2002/96/EC). More specifically, the following appliances have been selected as input to the TF:

- Small household appliances (SHA; e.g., iron or coffee machine)
- IT accessories (mix keyboard, mouse, etc.)
- PC/server
- Notebook
- Printer/scanner/copier
- Mobile phone (incl. recharger)
- CRT monitor
- Flat-panel display (FPD) monitor
- Audio appliances (CD-/radiorecorder)
- Video appliances (CD-/DVD-player)
- CRT TV
- FPD TV

These appliances correspond to selected UNU-Keys (for which a matching can be found in Appendix A.7) and they have been selected based on their quantities in the e-waste stream, their content of resource efficient substances, and their potential to reduce negative environmental impacts.

Applied dismantling depth

Once the e-waste has been delivered to the TF, it will be necessary to dismantle it up to a certain level. To determine the best dismantling depth, the logic of the "Best of 2 Worlds" (Bo2W) approach can be applied. The recycling of e-waste involves more complicated processes compared to other materials such as scrap metals due to a variety of material types being commingled with each other (Tanskanen, 2012). One way to deal with this complexity is proposed by the Bo2W approach which suggests the geographical separation of pre-processing and end-processing of e-waste. A description of these processing steps can be found in Figure 22.

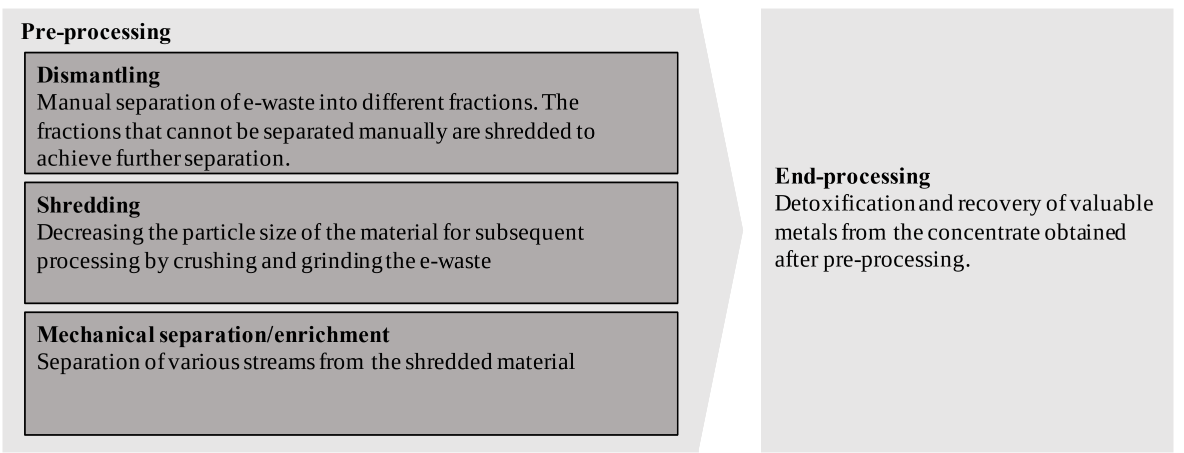

Figure 22: E-waste processing steps. Adapted from Namias (2013) and Schubert and Hoberg (1997).

Multiple studies have shown that manual dismantling is preferable over mechanical pre-processing options to reach high recycling rates (Chancerel, Meskers, Hagelüken, & Rotter, 2009; Meskers et al., 2009; Namias, 2013; Kumar et al., 2017; Wang et al., 2012). Benefits include a higher material liberation and higher grade material for end-processing (UNU/StEP Initiative, 2015; Wang et al., 2012), the removal of hazardous materials (Kumar et al., 2017), and a decreased material loss (up to 40% of materials can be lost as dust in mechanical treatment options; Namias, 2013). Other benefits of manual dismantling independent of the achieved recycling rates are increased job opportunities (Kumar et al., 2017), a lower energy consumption, and lower investment costs (UNU/StEP Initiative, 2015). However, since manual dismantling is a time-consuming approach it leads to high labor costs in countries with high wage levels and can, therefore, be economically disadvantageous (Kumar et al., 2017; Wang et al., 2012). For end-processing of e-waste it was found that specialized state-of-the-art treatment facilities can achieve the most efficient overall detoxification and recovery of valuable materials. These facilities require high capital investments and can only operate at a profit by treating large volumes to achieve economies of scale. For example, there are only a few precious metal refineries worldwide, all located in industrialized countries, that can fulfill the technical and environmental requirements to execute the involved processes at a satisfactory level (Wang et al., 2012). As a result, the Bo2W approach suggests to geographically separate e-waste processing and combine full manual dismantling in countries with low labor costs, usually developing countries, with state-of-the-art end-processing, which is mostly available in industrialized countries (Chancerel et al., 2009; Meskers et al., 2009; Wang et al., 2012). To determine from a purely economic perspective what level of manual dismantling makes sense in Seychelles, the following equation as described by Wang et al. (2012) is applicable:

$$\pi = \sum_{i=1}^{r} p_i m_i - C_{labor} \times \sum_{j=1}^{s} t_j, \tag{4}$$

where π is profit; p_i is the market price for material i; m_i is the weight of recovered material from recycling; C_{labor} is the unit labor cost per hour; and t_j is the duration for dismantling step j. Consequently, a combination of labor costs, dismantling time, materials respectively material fractions recovered, and market prices for the latter determine a products' most profitable dismantling depth. Generally, higher market prices can be achieved when selling cleaner (more dismantled) fractions, but cleaner fractions also incur higher labor costs (Gnos, 2019; Schröder, 2019; Smith, 2019a). Therefore, it needs to be examined whether the increased revenue from deeper dismantling exceeds the additional labor costs. Theoretically, this equation can be applied to each product treated by a TF for a number of different dismantling depths. This thesis differentiates between the three different dismantling depths as proposed by UNU/StEP Initiative (2016a). These are applied to all treated products, hence excluding the option that different products can be dismantled up to different levels. The three dismantling depths have been described by UNU/StEP Initiative (2016a) as following:

A. Hazardous components and high valuable components, like printed circuit boards, are removed only and the remaining parts are destined to mechanical separation/recycling.
B. Apart from removing hazardous components, manual dismantling of components into more or less pure materials and recyclable fractions is conducted where viable with reasonable effort.

C. Appliances are dismantled up to a point, at which further separation into pure materials is not possible without mechanical shredding.

It is also important to mention that even though a certain dismantling scenario might be most profitable, downstream e-waste recyclers oftentimes state specific technical requirements about how the e-waste needs to be treated before they receive it. Hence, in practice it might be necessary to negotiate with the recyclers abroad and agree on the most suitable scenario for both parties (Hakverdi, 2019; UNEP & UNU, 2009).

3.2.6.3 Business plan calculation

After the definition of the framework conditions related to the TF, it is possible to conduct the actual cost calculation. Quantitative analysis of expected input amounts, required human resources, equipment, space, and infrastructure, expected revenues from the sale of output fractions, and shipping costs will be conducted, which will finally be summarized in an overview of the total operational costs of the TF. Relevant qualitative information related to the discussed topics shall also be provided in the corresponding sub-section.

Expected input amounts

The expected input amounts to the TF were based on the mean estimation of total e-waste generated in Seychelles by Rajković (2018). It was estimated that 70% of all e-waste generated from the public sector and 15% from households and businesses can be collected. These estimates are based on information received from interviewed stakeholders, expected input amounts from existing business plan calculations of other developing countries, and practical experience from other countries about how much can be collected (Baldé et al., 2017; Eurostat, n.d.; Roldan, 2017). An overview of how much e-waste is expected to be collected from what stakeholder group is listed in Table 9, while the exact information per UNU-Key can be found in Appendix A.8. It is also important to notice that no purchase costs and no collection costs for these input amounts have been included (i.e., the e-waste is delivered for free to the TF).

Table 9: Expected annual e-waste input amounts per stakeholder group.

Stakeholder group	Input amounts [t]
Government	5.1
Commercial sector	9.0
Households	44.1
Total	***58.2***

Required human resources

Assumed basic data concerning the required human resources of the TF is listed in Table 10 and is based on recommendations from the StEP calculation tool (UNU/StEP Initiative, 2016b). Assumed basic data concerning working hours is listed in Table 11 and is based on data obtained from local stakeholders.[19] Generally, the dismantling of e-waste does not require many skills and is relatively uncomplicated. While it is noted that dismantling efficiency increases as experience is gained by the dismantling workers, generally every person can learn how to dismantle e-waste (Hakverdi, 2019; Spitzbart et al., 2014).

Table 10: Assumed basic data concerning required human resources. Source: UNU/StEP Initiative (2016a).

Employees	Quantity	Calculation bases
General manager	1	in total
Department manager	1	per 25 dismantling workers
Skilled worker	10%	of all workers
Unskilled worker	90%	of all workers
Administrative staff	10%	of total staff

Table 11: Assumed basic data concerning working hours.

Number of salaries	12
Working hours per week[A]	48
Working days per week[A]	5.5
Official holidays per year[B]	13
Holiday entitlement per year[B]	21
Working days per year	253
Annual working hours	2206

[A]Sources: Candassamy (2019), Gonzalves (2014), Gowressoo (2019), Naidoo (2019), and Uzice (2019)
[B]Source: A. Lesperance (personal communication, March 5, 2019)

This basic data was combined with the assumed dismantling time per appliance group for all three dismantling depths (see Appendix A.10) and the expected input amounts to the TF. This led to a total of 375 required working hours for dismantling depth A, 2,906 hours for dismantling depth B, and 4,479 hours for dismantling depth C. Based on these results, the staff composition as listed in Table 12 was selected. At least one general manager and one department manager were always included in the staff composition regardless of the expected input amounts since interviewed stakeholders mentioned that the administrative effort to negotiate with recyclers, organize shipments, etc. is significant and will, therefore, require at least two people with the necessary skills to take care of this.

[19] A full list of indicated working hours as indicated by all consulted stakeholders can be found in Appendix A.9.

Table 12: Selected staff composition.

Employees	Dismantling depth		
	A	B	C
General manager	1	1	1
Department manager	1	1	1
Skilled worker	1	1	1
Unskilled worker	0	1	1
Administrative staff	0	0	0
Total	***3***	***4***	***4***

Salaries as listed in Table 13 were assumed based on indicated wage levels by different stakeholders (for a full list of indicated wage levels see Appendix A.11), leading to total annual staff costs of 32,400 USD for dismantling depth A and 38,880 USD for dismantling depth B and C. A detailed overview of how the total staff costs are divided between the different employees can be found in Appendix A.12.

Table 13: Employee salaries.

Employees	Salary [USD/month]
General manager[A]	1,000
Department manager[B]	850
Skilled worker[B]	850
Unskilled worker[C]	540
Administrative staff[B]	850

[A]based on salary for “skilled worker” as indicated by Naidoo (2019)

[B]based on average salary for “skilled worker” as indicated by Candassamy (2019) and Naidoo (2019)

[C]based on average salary for “unskilled worker” as indicated by Candassamy (2019) and Naidoo (2019) and the local minimum wage as indicated by the Employment (National Minimum Wage) (Amendment) Regulations (2016, section 2)

Required equipment

Next, a closer look at the required equipment of the TF was taken. Table 14 contains basis assumptions related to the equipment needs of the TF.

Table 14: Assumed basic data concerning equipment needs

Items	Costs[A] [USD/unit]	Lifespan[B] [yrs]	Required quantity	Calculation bases[B]
Administrative working place (PC, table, chair)	800	15	1	per administrative staff member
Dismantling working station (table, chair)	200	10	1	per dismantling worker
CRT-treatment unit	10,000	25	1	total per facility if dismantling depth C applied
Truck	26,500	5	0	total per facility
Working tools	300	1	1	per dismantling worker
Health and safety equipment	150	1	1	per worker
Ventilator	50	10	1	per total staff member
Collection box	100	15	10	per 100 t/a input
Palette	5	10	5	per 100 t/a input
Scale (min. capacity 200kg)	600	20	1	per 2000 t/a input
Pallet truck (internal transport)	300	20	4	per 1000 t/a input

[A]Costs based on prices from online research (alibaba.com, amazon.com, ...), personal communication with local stakeholders, and Spitzbart et al. (2014).

[B]Lifespan and calculation bases for the required equipment quantities based on experiences by European dismantling facilities. Sources: Spitzbart et al. (2014) and UNU/StEP Initiative (2016a).

Key elements of the dismantling facility are the dismantling workstations and the equipment for the dismantling workers. Health and safety equipment (HSE) like safety boots, work gloves, dust masks, and safety glasses are essential. For the storage of collected e-waste and the output fractions, appropriate receptacles are needed and a pallet truck is necessary for internal logistics. A standard toolbox to be able to dismantle most of the equipment includes a screw driver, hammer, axe, side cutter, pliers, industrial scissors, cutter, power screw driver, and putty knife (Spitzbart et al., 2014). If it is considered to include additional treatment steps to achieve further dismantling, the following additional equipment can be considered (Spitzbart et al., 2014):

- A CRT-treatment station for the separation of leaded funnel glass from fluorescent powder and front glass contained in CRT-equipment
- A small crusher for smashing fractions like plastics for transport optimization
- A cable stripper for increasing the content of pure copper in the output
- Mobile equipment for decontamination of mercury-containing lamps

Due to too low input quantities for a TF in Seychelles, the only additional equipment included in this calculation is a CRT-treatment station if dismantling depth C is applied. Moreover, it was assumed that no truck for external transportation is required. Based on these assumptions, the expected input amounts, and the selected staff composition the equipment as listed in Table 15 will be required to run the dismantling facility.

Table 15: Required equipment.

Items	Dismantling depth		
	A	B	C
Administrative working place (PC, table, chair)	2	2	2
Dismantling working station (table, chair)	1	2	2
CRT-treatment unit	0	0	1
Truck	1	1	1
Working tools	1	2	2
Health and safety equipment	1	2	2
Ventilator	3	4	4
Collection box	6	6	6
Palette	3	3	3
Scale (min. capacity 200kg)	1	1	1
Pallet truck (internal transport)	1	1	1

The purchase of this equipment will cost 30,415 USD for dismantling depth A, 31,115 USD for dismantling depth B, and 41,115 USD for dismantling depth C. In this business plan calculation, it was decided to exclude these initial investment costs because of the assumption that the TF will receive financial support when initially purchasing necessary equipment (e.g., by the government or a project fund). However, annual depreciation costs based on the respective lifespan of the equipment have been included which amount to a total of 5,978 USD for dismantling depth A, 6,453 USD for dismantling depth B, and 6,853 USD for dismantling depth C.

Required space and infrastructure

With regards to the specific space requirements of the TF, the assumptions as listed in Table 16 were applied.

Table 16: Assumed basic data concerning space requirements. Source: UNU/StEP Initiative (2016a).

Type of infrastructure	Required space [m^2]	Calculation bases
WEEE-receiving area	20	per sorting worker; if no sorting worker allocated 20m^2
Management/administration	15	per administrative worker, department manager and general manager
Recreation and sanitary rooms	3	per total staff member
Dismantling working stations	20	per dismantling worker
Dismantling CRT	20	per unit
Storage	1	per t/y of input
Outside area	1	per t/y of input

Concerning space requirements, it is important to mention that sufficient storage space is needed to buffer fluctuating input quantities that cannot be treated immediately and to provide space for output fractions that have to be accumulated until a shipping container can be filled up. Depending on the type of output fraction, it can either be stored outside or in open shelters; hazardous fractions have to be stored in a separate area that has to comply with higher safety standards (e.g., floor sealing; Spitzbart et al., 2014). Based on the above listed assumptions, the expected input quantities, and the selected staff composition, a total area of 195m^2 for dismantling depth A, 218m^2 for dismantling depth B, and 238m^2 for dismantling depth C is required. A detailed overview of which area requires how much space can be found in Appendix A.13. Guidance regarding the specific layout of a possible TF and further infrastructure requirements is displayed in Spitzbart et al. (2014) and UNEP (2007b).

To estimate the total infrastructure costs for the TF, rental costs for a governmental lease of 2.94 USD/m^2 annually for open land at Providence as indicated by the Providence Industrial Authority (personal communication, March, 2019) were assumed.[20] Electricity costs of 0.33 USD/kWh (state of September 2018; L. Marguerite, personal communication, February 26, 2019) were included as well. Based on the specific electricity consumption of the DRZ, the electricity usage was set at 40 kWh/m^2 (Spitzbart et al., 2014). Costs for cleaning, maintenance, and repair (CMR) were estimated to amount to 10% of the total rental costs (Schluep & Spitzbart, 2015). An overview of the resulting infrastructure costs can be found in Table 17.

Table 17: Infrastructure costs.

Infrastructure	**Dismantling depth**		
	A	B	C
Rent	575	642	701
Electricity	2,580	2,884	3,148
CMR	57	64	70
Total	***3,212***	***3,590***	***3,919***

Sales revenues and costs from output fractions

To be able to estimate potential sales revenues and costs for different output fractions, the expected quantities of each output fraction based on the input amounts to the TF were calculated first. To assess this, information from the dismantling campaign conducted by the DRZ in 2013 was used (UNU/StEP Initiative, 2016b). An overview of resulting output fractions for each dismantling depth per ton of input category can be found in Appendix A.14. Combining this information with expected revenues and costs per ton of output fraction as listed in Table 18, the total revenues from the sale of the output fractions

[20] Rental costs for a 60-year governmental lease. Not included is a non-refundable deposit that needs to be paid within 14 days after the lease has been granted. Additionally, it has not been considered that after every 5 years, in the course of a review, it can be expected that rental prices increase by 25%. It was also mentioned by the Providence Industrial Authority (personal communication, March, 2019) that these prices will be reviewed in the close future and might therefore be subject to change.

was calculated. For wood, glass, and residual waste no disposal costs were included because it was assumed that these fractions will be disposed of in the local landfill. All other prices reflect the revenues and costs of the respective output fractions that can be expected on the international recycling market.

Applying these prices to the expected output quantities per fraction, total revenues of 22,711 USD for dismantling depth A, 13,638 USD for dismantling depth B, and 15,072 USD for dismantling depth C can be expected. A detailed overview of how these revenues distribute between the different output fractions is available in Appendix A.15. These results are rather unexpected because cleaner fractions, achieved by deeper dismantling, generally generate more revenue when being sold to recyclers (Gnos, 2019; Schröder, 2019; Smith, 2019a). When looking into the details of the cost calculation, it can be seen that the decreased revenue for deeper dismantling depths can mainly be attributed to relatively high costs that need to be paid for the recycling of plastic. While for dismantling depth A most of the plastic is still contained in other output fractions such as mixed scrap, for which even a revenue can be achieved, significantly more plastic as a clean fraction is generated when dismantling depth C is applied. While it is theoretically possible that this result reflects real market prices, it appears to be more likely that a possible lack of detail in the assumed prices has led to distortions regarding the final result. Especially for plastic as an output fraction, market prices can vary largely and depend on the type of plastic (e.g., for clean Acrylonitrile Butadiene Styrene [ABS] plastic a revenue can be achieved while costs are incurred for the recycling of plastics containing BFRs) and how clean the plastic fractions are (i.e., if different plastic types are commingled together).

Generally, these results give a useful indication about the expectable revenues from the sale of the output fractions of the TF; however, they should be cautiously interpreted. The exact prices offered by recyclers for different output fractions can vary significantly over time and between different recyclers. The prices depend on the detailed material composition of the delivered fractions and the respective international market prices for those materials. These market prices experience strong variations over time and it is generally hard to predict the exact material composition of certain output fractions because this can even differ within a single e-waste product category. The quality of the output fractions can also have an influence on the offered price by recyclers, for example, when some e-waste has been stored for a longer period of time which can lead to a reduced material quality. Finally, the prices offered by recyclers can also depend on the quantity in which the output fractions are delivered (Gowressoo, 2019; Lauwers, 2019; Schröder, 2019; Smith, 2019b; Solenthaler, 2019).

As a result of this uncertainty, several interviewed stakeholders mentioned that it can make sense to first collect a certain amount of e-waste, and then start negotiations with recyclers when detailed information about what output fractions can be supplied can be provided. Importantly, recyclers are sometimes willing to agree on fixed prices over a certain period of time. This guarantees the recyclers that they won’t have to pay high prices in case international market prices rise but also guarantees local dismantlers a certain revenue for their output in case market prices go down (Mallia, 2019; Solenthaler, 2019). Considering these aspects highlights the importance of negotiations with recyclers. It is recommended to compare quotes of several recyclers to identify the best sales partner and achieve a maximum amount of profit from the output fractions.

Table 18: Sales revenues and costs of e-waste output fractions.

Output fraction	Revenues/costs	Source
Aluminum	1,444[A]	ScrapMonster (2019a)
Iron/steel	293	E. Smith (personal communication, March 26, 2019)
Copper	6,000[B]	ScrapMonster (2019b)
Neodym magnet	7,000	Mostafa & Dina (2018)
Bronze/brass	3,684[C]	ScrapMonster (2019c)
Stainless steel	1,070[D]	ScrapMonster (2019d)
Plastics	-563	E. Smith (personal communication, March 26, 2019)
Wood	0	
Cable with plugs	1,126	E. Smith (personal communication, March 26, 2019)
Cable without plugs	1,351	E. Smith (personal communication, March 26, 2019)
Processors	21,387	E. Smith (personal communication, March 26, 2019)
Hard disk drive with printed wired board	1,688	E. Smith (personal communication, March 26, 2019)
Hard disk drive without printed wired board	441[E]	CashforComputerScrap (2019)
Power supply (without cable)	338	E. Smith (personal communication, March 26, 2019)
Drivers	507	E. Smith (personal communication, March 26, 2019)
Printed wired board – high quality	5,910	E. Smith (personal communication, March 26, 2019)
Printed wired board – medium quality	3,490	E. Smith (personal communication, March 26, 2019)
Printed wired board – low quality	2,139	E. Smith (personal communication, March 26, 2019)
Mobile phones without batteries	9,456	E. Smith (personal communication, March 26, 2019)
Motors/inductors/transformers	507	E. Smith (personal communication, March 26, 2019)
Deflection coil	1,632	E. Smith (personal communication, March 26, 2019)
Getterpill-electrogun	-1,000	Spitzbart et al. (2014); Mostafa & Dina (2018)
Mixed scrap	169	E. Smith (personal communication, March 26, 2019)
Glass	0	
Residual waste	0	
Batteries	1,801	E. Smith (personal communication, March 26, 2019)
Capacitors	901	E. Smith (personal communication, March 26, 2019)
LCD-displays	-675	E. Smith (personal communication, March 26, 2019)
Fluorescent tubes	0	E. Smith (personal communication, March 26, 2019)
Printer cartridges	0	E. Smith (personal communication, March 26, 2019)
CRT-tubes	-300	Mostafa & Dina (2018)
CRT-glass	428	E. Smith (personal communication, March 26, 2019)
Phosphor-powder	-1,000	Mostafa & Dina (2018)

[A]Average price for 1100 Scrap/3003 Scrap/5052 Scrap, SMI North America, state of December 2018

[B]Price for #1 Copper Bare, SMI Europe, state of December 2018

[C]Average price for brass scrap (70/30 Brass Scrap, SMI North America; 80/20 Brass Scrap, SMI North America; 85/15 Brass Scrap, SMI North America; 70/30 Brass Scrap, SMI Europe; 85/15 Brass Scrap, SMI Europe), state of December 2018

[D]Price for 305 SS Solid, SMI Europe, state of December 2018

[E]Pricing of 1/07/2019

Shipping

Regardless as to what level the e-waste will be dismantled by the TF, it will be necessary to export the resulting fractions to recycling facilities abroad. The export process comes with a certain level of complexity, especially for hazardous items that fall under the Basel Convention (UNU/StEP Initiative, 2013). There are specific regulations around how these items need to be packaged, what permits need to be obtained, and what additional fees are to be paid (Atallah, 2019; Gobine, 2019; de Klujiver, 2019; Maag, 2019; Spitzbart et al., 2014).

Four shipping companies are currently operating in Seychelles, namely Maersk, Mahe Shipping Company Ltd., Compagnie Maritime d'Affrètement Compagnie Générale Maritime (CMA CGM), and United Africa Feeder Line (UAFL). It was possible to obtain direct information about shipping costs to different destinations from Maersk and UAFL, which was combined with shipping costs that have been provided by other interviewed stakeholders. For a full list of indicated costs see Appendix A.16. Based on the obtained information, a conservative estimation of 2,000 USD per 20ft container was made (which was not differentiated for different destinations). HW surcharges were assumed to be included in this price and were estimated to amount to 400 USD per container. These surcharges are subject to change depending on the exact type of hazardous items that will be shipped. Estimated shipping costs were subsequently combined with expected output quantities (in tons) that were assumed to fill up a container, which varies depending on the output fraction (e.g., a container full of plastic weighs less than a container full of scrap metal). An overview of assumed quantities per container load can be found in Appendix A.17. Based on this information, it was possible to calculate the number of containers that will need to be shipped annually and the resulting total annual shipping costs. Total annual shipping costs of 11,510 USD for dismantling depth A, 10,425 USD for dismantling depth B, and 10,174 USD for dismantling depth C were obtained, which translates into 5.8, 5.2, and 5.1 containerloads.

In this calculation, the possibility of mixed lots (i.e., shipment of different output fractions in the same container) was considered to always be able to fill up a container. Being able to fill up containers will be crucial in Seychelles to limit shipping costs. However, downstream recyclers might state specific requirements on how to receive the different fractions and might reject receiving all fractions together that are intended to be shipped (Maag, 2019). Consequently, finding a recycler that accepts such mixed lots will be crucial. Furthermore, it needs to be mentioned that combining different output fractions will also make shipment procedures more complicated because different items need to be declared. What is generally desirable is that hazardous items are not shipped together with non-hazardous items to avoid paying a HW surcharge for the transport of non-hazardous goods (Gnos, 2019). Filling up containers is also expected to be facilitated by applying a relatively superficial dismantling depth since this results in fewer different output fractions. However, more dismantled fractions can usually be transported more densely (e.g., a full washing machine compared to single parts of a washing machine requires a larger volume) which can reduce shipping costs (Böni, 2019b; UNU/StEP Initiative, 2016b). With regards to the different scrap metal output fractions, it should be considered to sell these to the local scrap metal companies. Interviewed scrap metal dealers have indicated interest in purchasing these metals.

Overall operational costs

As can be seen in Table 19, when summarizing all the above-mentioned revenues and costs and adding estimated administrative costs of 4,800 USD[21], the total operational costs of a TF in Seychelles amount to 35,190 USD for dismantling depth A, 50,510 USD for dismantling depth B, and 49,554 USD for dismantling depth C. Consequently, regardless of the applied dismantling depth, it will not be possible to make a profit from operating the TF and additional financial support will be necessary. While the revenues from the sale of the e-waste output fractions are sufficient to cover the variable costs of the TF, they are not high enough to also cover fixed costs. Especially the costs for employing staff is substantial which can be explained to a large part by the need for two relatively expensive managers. The generally high staff costs also contribute to dismantling depth A being the most profitable dismantling scenario; however, the main difference in profitability between the different dismantling depths stems from the large difference in sales revenues that can be achieved from the different output fractions. As already mentioned, initial investment costs are not included in this overview which would amount to 30,415 USD for dismantling depth A, 31,115 USD for dismantling depth B, and 41,115 USD for dismantling depth C. These costs only include purchase costs for required equipment. Further possible investments that might be needed such as construction costs have been excluded from this calculation.

Table 19: Total operational costs [USD].

	Dismantling depth		
	A	B	A
Sales revenues/costs	22,711	13,638	15,072
Shipping costs	-11,510	-10,425	-10,174
Total variable costs	**11,201**	**3,214**	**4,898**
Human resources	-32400	-38,880	-38,880
Infrastructure	-3,212	-3,590	-3,919
Administration	-4,800	-4,800	-4,800
Depreciation	-5,978	-6,453	-6,853
Total fixed costs	**-46,390**	**-53,723**	**-54,452**
Total operational costs	***-35,190***	***-50,510***	***-49,554***

[21] Administrative costs were estimated based on indications from Spitzbart et al. (2014) and Mostafa and Dina (2018). A detailed list of assumed administrative costs can be found in Appendix A.18.

3.2.6.4 *Sensitivity analysis*

For better understanding of the obtained results and how they are influenced by changes in the input variables, a sensitivity analysis regarding input amounts and rental costs was conducted. For note, a sensitivity analysis regarding the composition of the e-waste input was excluded because the uncertainties related to the expected revenue from the sale of output fractions was regarded to be too high to lead to reliable results.

Input amounts

As has been discussed in section 3.1.4, notable uncertainty regarding the total e-waste amounts generated in Seychelles prevails and it is further highly uncertain how much of this e-waste will be possible to collect. Therefore, a sensitivity analysis regarding input amounts into the TF has been conducted. In the basic cost calculation total e-waste input amounts of 58.2 tons were assumed. This amount was varied to see how total operational costs as well as operational costs per ton of e-waste are influenced by the e-waste input amounts. As can be seen in Figure 23, operational costs per ton of e-waste decrease with increasing input amounts for all three dismantling scenarios. This indicates clear economies of scales since with every additional ton of input, the treatment of one ton of e-waste becomes cheaper. Interestingly, these economies of scale are high enough in case of dismantling scenario A to lead to a reduction in total operational costs with increasing e-waste input amounts (see Figure 24). This can be explained by that fact that the increase in revenue with each additional ton of input (because more e-waste output can be sold on the international market) appears to be larger than the increase in costs related to shipping, infrastructure, staff, etc. Especially the increase in staff costs for dismantling depth B and C lead to higher operational costs for these two scenarios for which the increased revenue is insufficient to compensate for.

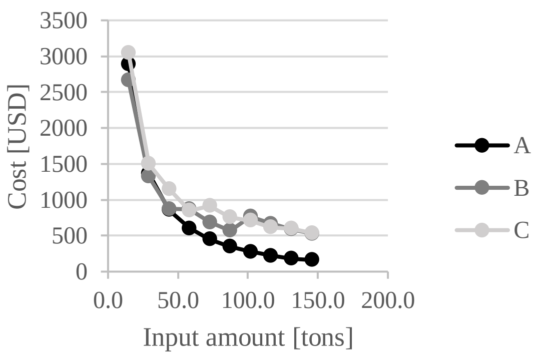

Figure 23: Operational costs per ton of e-waste treated.

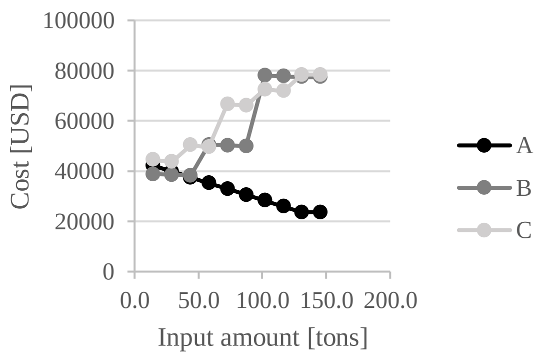

Figure 24: Total operational costs.

Rental Costs

Several interviewed stakeholders mentioned high rental costs as a reason why no e-waste business has developed yet in Seychelles. While it was assumed in the basic calculation that the land on which the TF will operate is subsidized by the government, there appears to be uncertainty with regards to whether such land is actually available. To account for the possibility that actual market prices will need to be paid for renting the land of the TF, cost data was collected from stakeholders currently operating on such unsubsidized land. For an overview of all indicated rental prices see Appendix A.19. The obtained information showed that rental prices can be up to 14 times higher (43.9 USD/m^2 annually) for open land (where no shelter or similar is constructed) and up to 85 times higher (263.5 USD/m^2 annually) for a covered warehouse. This difference in rental prices is tremendous and explains why high rental costs currently act as a deterrent to enter the e-waste business in Seychelles. An overview of how total annual rental costs and total annual operational costs change when these two rental prices are applied to the cost calculation of the TF can be found in Table 20. This substantial increase in operational costs makes the need for governmentally subsidized land apparent, and in case such land is not available, additional external financial support is required to ensure a financially sustainable e-waste business.

Table 20: Annual rental costs for unsubsidized land (open land & covered warehouse) and resulting change in operational costs of the treatment facility [USD].

	Dismantling depth		
	A	B	C
Open land			
Total rental costs	8,581	9,591	10,469
Total operational costs	***43,997***	***60,353***	***60,299***
Covered warehouse			
Total rental costs	51,506	57,566	62,836
Total operational costs	***91,214***	***113,126***	***1117,903***

3.2.6.5 Conclusion for Seychelles

The main conclusion that can be drawn from this business plan calculation is that under the current local and global market conditions, an e-waste TF in Seychelles cannot become an economically self-sufficient business if solely relying on the intrinsic value of the treated materials, even if subsidized government land would be available to operate on. Hence, it will be crucial to provide the TF with further support options, regardless of what ownership and operator's model will be chosen, to guarantee business sustainability under favorable as well as unfavorable economic conditions and reduce entrepreneurial risks.

To financially support a TF providing a payment per kg of e-waste treated, irrespective of the exact type of e-waste treated, is usually considered (Hakverdi, 2019; Lackovic. 2019; Maag, 2019; UNU/StEP Initiative, 2015). More elaborate systems are also possible. For example, the size of the payments to the TF can be continuously adapted to match current international market prices or a lower boundary for sales revenues of output fractions can be guaranteed to the TF while the operator of the TF still has the opportunity to increase these revenues by acting economically efficient (Böni, 2019a; Maag, 2019; Solenthaler, 2019). Payments to the TF would usually come from the general funds of the e-waste system (UNU/StEP Initiative, 2015). For example, if a flat household fee is chosen to finance the TF, based on the operational costs of the basic cost calculation, this would result in an annual fee per household of 19.43 SCR for dismantling depth A, 27.89 SCR for dismantling depth B, and 27.37 SCR for dismantling depth C (assuming 24,770 households; state of 2010; NBS, 2018). Even though other costs of the e-waste system such as collection costs and administrative costs are not included in this fee, these numbers indicate that the burden placed on consumers to enable the recycling of e-waste will likely be manageable.

Other means of support, apart from financial support, are also possible and can include Value Added Tax (VAT) exemptions for imported goods that are necessary to operate the TF, tax exemptions, visa facilitations for foreign workers, and the provision of financial support for initial investment needs (de Comarmond, 2019; Hassan, 2019; Payet, 2019b; Uzice, 2019).

4 Discussion

This thesis examined the different aspects which determine the development of an e-waste management system in Seychelles. By combining existing knowledge about managing e-waste from the international community with information about the status quo of waste management in Seychelles, a comprehensive understanding of relevant aspects for the strategic implementation of a local e-waste management system was gained. Given that major aspects have already extensively been addressed and discussed in the results section, this section will focus on the discussion of the most tangible outputs, i.e., concrete implications which the results may have upon implementation on the ground (4.1). Further, limitations related to those implications will be lined out (4.2) and future research and points of action will be clarified (4.3). Further, a final conclusion of the major findings of this thesis will be drawn (4.4).

4.1 Practical Implications

The analysis of the current framework conditions in Seychelles revealed that Seychelles' waste framework already exhibits a variety of processes which can be built upon. Especially the existing recycling initiatives for PET bottles, aluminum cans, and scrap metals provide a framework from which important learnings about the implementation of an e-waste management system in Seychelles can be drawn. The system for PET bottles and aluminum cans, for instance, shows that financial incentives appear to effectively support separation of different waste types. The scrap metal businesses provide an example of a functioning private sector business in the recycling sector. However, the analysis of the framework conditions in regard to waste management in Seychelles also led to insights about possible barriers related to establishing an e-waste management system such as a lack of monitoring and enforcement power by the Government of Seychelles, a lack of clearly allocated responsibilities, a lack of public awareness, and a lack of financial incentives for the private sector to establish a business in the e-waste sector.

Given those above-mentioned enablers and barriers, it seems most appropriate to start an e-waste management system in Seychelles as simple as possible and implement additional elements step-by-step as the system is working. Two concrete suggestions were worked out to foster initial simplicity: First, it appears infeasible to include all e-waste types in the initial product scope of the e-waste system due to the high managerial complexity associated with such a full product scope approach. Starting with a limited scope (e.g., by initially focusing on ICT devices and their peripherals) and slowly expanding it with time will limit initial complexity, yield benefits from a learning curve, and avoid overstraining available resources. Second, it was found that while the implementation of Extended Producer Responsibility mechanisms is generally a desirable approach to manage different waste types, such an approach might not be the most suitable option to manage e-waste in Seychelles. It is expected to be difficult to monitor all producers present in Seychelles and enforce their compliance with the rules of the e-waste system such as the payment of applicable fees. Additionally, producers in Seychelles are likely to exhibit limited capacity and capabilities to manage an e-waste system on their own. Therefore, if an Extended Producer Responsibility approach would be implemented it is probable that at least at the beginning substantial government support, especially from a financial perspective, will be required.

Establishing a simpler system structure (e.g., by financing the e-waste system via a general household tax or fee) can not only increase the likelihood of an effective and financially viable e-waste system but also has the potential to achieve this at a lower cost due to a reduced need for administrative efforts.

Following a simple approach when implementing an e-waste management system, therefore, appears to be preferable, at least until the government has expanded its expertise and skills in managing complex systems. Initially establishing a system with limited complexity can allow involved stakeholders to develop their skills simultaneously with the expansion of the system and avoids the overwhelming by a variety of tasks for whose execution the stakeholders lack the necessary knowledge and experience.

As a last point, it may be sensible to collaborate with international stakeholders having relevant experience in the field of e-waste management because certain system elements will still exhibit complex structures. For developing countries, such support options are generally available and can provide helpful guidance, especially when knowledge within the country is limited.

4.2 Limitations

While this thesis contributes to understanding implications around an e-waste management system in Seychelles, there are several limitations that delimitate the results presented previously.

First of all, the obtained results with regards to the total e-waste amounts generated in Seychelles carry a high degree of uncertainty and therefore only have limited informative value. While the consumer survey conducted as part of this thesis provides a good indication about the amounts of selected electrical and electronic equipment at the household level, it does not allow for an estimation of total e-waste amounts generated in Seychelles. Other data that could provide insights on this (e.g., import data or residence time data) appears to be linked to notable insecurities in regard to its reliability or has not been assessed specifically for Seychelles.

Second, the sparse availability of quantitative data limited the validity of the obtained results with regards to the business plan calculation. While the results of this calculation provide an indication about operational costs of a treatment facility in Seychelles, notable uncertainty persists in regard to the result's reliability. This uncertainty mainly originates from a lack of reliable data concerning the expected e-waste input amounts to the treatment facility and the expected revenues and costs that can be obtained from the sale of e-waste output fractions.

Lastly, another limitation of this thesis is that a single researcher conducted the research process. Consequently, an objective interpretation of the obtained information cannot be guaranteed. Several steps were performed to limit the chance of subjective judgements such as cross-validating the obtained results with multiple data sources and discussing them with several stakeholders; however, especially the analysis and interpretation of qualitative data obtained through direct stakeholder consultations could still be subject to unintentional subjective judgements.

4.3 Proposed Points of Action and Accompanying Research

Based on the findings of this thesis and the limitations outlined in the previous section, several opportunities for potential points of action and accompanying research can be identified.

Firstly, a general need for increased monitoring and data collection efforts by the government becomes evident. Not only can this increase the government's capability to enforce regulations, but it can also contribute to a better understanding of an existing system and allows for the appropriate design of new system elements. For example, understanding the quantities of e-waste that are available to collect at the different stakeholder levels is highly relevant to decide on an initial product scope, suitable collection channels, required infrastructure, and the system's financing needs. Therefore, the obtainment of additional data related to this will provide valuable insights. Data could, for example, be collected by conducting an extensive survey to assess the stock of electrical and electronic equipment (in its active and passive life and the amounts being stored) at the household level, at commercial businesses, and at governmental entities, including an assessment of the lifespan profile of this equipment (active and passive lifespan and storage time).

To gain further understanding in regard to estimating the amounts of e-waste that will be possible to collect and act as input to an e-waste treatment facility in Seychelles as well as assessing the effectiveness of different e-waste collection channels, the initiation of pilot projects can also be beneficial. For instance, e-waste collection from selected commercial stakeholders could be organized and potentially be supplemented with an e-waste drop-off event for households. This could already provide a good indication about what e-waste types will be possible to collect in what quantities and from which stakeholders. Further collection measures can also be trialed. E-waste collection bins could be placed at selected retailers or public places; drop-off events for households might be conducted where consumers are provided a financial incentive to bring their e-waste; and a one-for-one retailer system limited to a single device type including a financial incentive could be organized. Such collection pilot projects have the potential to provide insights into what collection mechanisms are most effective in the local context and can promote an enhanced understanding of whether financial incentives can indeed support separate e-waste collection. Broad advertising of such pilots will be crucial to lead to a successful outcome.

To obtain further information related to operating a treatment facility in Seychelles, after a certain amount of e-waste has been collected, negotiations with international e-waste recyclers should be started, providing additional insights into the requirements international recyclers put on the condition of e-waste to be delivered to their facility and the revenue that can be expected from the sale of the collected e-waste. Information with regards to the regulations in place for transboundary shipments can additionally be obtained and it can be measured how much of what e-waste type fits into a shipping container. While it is likely that an initial pilot exercise will solely include the direct shipping of the collected e-waste, a dismantling exercise could also be included to better understand the needs connected to the dismantling of different appliances. For such an exercise, it will make sense to conduct this in collaboration with an international stakeholder with experience in the dismantling of e-waste.

These suggestions for possible next steps and further research share their necessity for capital and human resources. While funding can originate from a variety of sources, international project funds appear to be an especially suitable source of capital because these types of projects, promoting the sustainable development of a developing country, are usually eligible for such funds. Due to a lack of human resources and unclearly allocated responsibilities frequently being mentioned as a main barrier to the implementation of an e-waste management system, special attention should be allocated to managing these issues properly. Establishing a technical working group within the Ministry of Environment, Energy and Climate Change for managing e-waste could be a suitable approach to achieve this. Within the working group, stakeholders with different backgrounds should be represented and responsibilities be clearly allocated. To enable that actual action will be taken by such a working group, involved stakeholders should allocate time specifically for this engagement. Expanding available staff involved in waste management activities should be considered to allow for this.

4.4 Conclusion

It is hoped that this thesis provides a helpful document to policy-makers and establishes an enhanced understanding of relevant aspects related to the implementation of an e-waste management system in Seychelles. Conserving Seychelles natural environment is of uttermost importance due to the fact that the islands economy is largely based on it. Landfilling e-waste states a risk to this which makes the development of a system to manage e-waste in an environmentally sound way desirable. Due to the valuable characteristics of e-waste the private sector in Seychelles appears to be interested in entering the e-waste recycling market. Supporting these ambitions and providing the necessary framework can enable Seychelles to take a leading role amongst SIDS in the recycling of e-waste.

Moreover, this thesis shows that costs and efforts attached to the implementation of an e-waste system are expected to be manageable, especially when such a system is developed step-by-step and resources can be built up along the way. Seychelles has already established a variety of recycling initiatives and there is growing awareness about the importance of recycling certain waste types. Therefore, expanding these recycling initiatives to e-waste is a promising step further and supports the transition of Seychelles towards a sustainable society.

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Appendix

A.1 List of Interviewed Stakeholders

Table 21: List of local and international interviewed stakeholders.

Name	Type of contact	Institution	Position
Local stakeholders			
Alain de Comarmond	Personal interview	Ministry of Environment, Energy and Climate Change (MEECC)	Principal Secretary
Andy Gobine	Personal interview	Mahe Shipping Company Ltd	Head of Freight Forwarding & Relocation
Anvish Gowressoo	Personal interview	Samlo & Sons	Employee
Ashik Hassan	Personal interview	Ministry of Finance, Trade Investment and Economic Planning	Director General - Trade Divison
Cliff Gonzalves	Personal interview	AAI Enterprise Pty Ltd	Consultant
David Uzice	Personal interview	STAR Seychelles	CEO
Elaine Ernesta	Personal interview	GOS-UNDP-GEF Programme Coordination Unit	Project Manager: Resource Efficiency
Esin Hakverdi	Personal interview	Dock Recycling	Head of Department
Flavien Joubert	Personal interview	Landscape and Waste Management Agency (LWMA)	CEO
Fredrick Kinloch	Personal interview	Ministry of Environment, Energy and Climate Change (MEECC)	Director of Waste Management
Inese Chang-Waye	Personal interview	Ministry of Environment, Energy and Climate Change (MEECC)	Senior Ozone Officer Seychelles
Kodi	Personal interview	Samlo & Sons	Worker
Lemmy Payet	Personal interview	Landscape and Waste Management Agency (LWMA)	Consultant
Maria Jannie	Personal interview	Waste Management Fund (WMF) and Environmental Trust Fund (ETF)	Coordinator
Marie-Therese Purvis	Personal interview	Sustainability for Seychelles (S4S	Chairperson
Michael Laurence	Phone interview	Cut All Pty Ltd	Director
Nanette Laure	Personal interview	Ministry of Environment, Energy and Climate Change (MEECC)	Director General - Waste, Enforcement and Permit Division
Paulian Kazibwe	Personal interview	Airtel Seychelles	Finance Director
R. Candassamy	Phone interview	Harini & Co (Pty) Ltd.	Director
Raja Ramani	Personal interview	Cellular Services Pty Ltd (agent for Samsung)	Director
Ricky Barbe	Personal interview	Ministry of Finance, Trade Investment and Economic Planning	Senior Trade Officer, Trade Division
Sanjay Naidoo	Interview	Surya Group of Industries	Operation Director
Sharon Gerry	Personal interview	Ministry of Environment, Energy and Climate Change (MEECC)	Senior Legal Officer

Name	Type of contact	Institution	Position
Wallace Cosgrow	Personal interview	Ministry of Environment, Energy and Climate Change (MEECC)	Minister
International stakeholders			
Christoph Solenthaler	Personal interview	Solenthaler Recycling	CEO
Deepali Sinha	Phone interview	Sofies India	Managing Director
Dennis Lackovic	Personal interview	Swico Recycling	CFO
Elisabeth Smith	Phone interview	StEP Initiative; Dismantling- and Recycling Center (DRZ)	Executive Officer; Director
Esin Hakverdi	Personal interview	Dock Recycling	Head of Department
Heinz Böni	Personal interview	Swiss Federal Laboratories for Materials Science and Technology (Empa)	Head Critical Materials and Resource Efficiency Group
Joost de Kluijver	Phone interview	Closing the Loop	Director
Joris Lauwers	Email communication	Umicore Precious Metals Refining	Supply Manager
Judith Maag	Personal interview	Maag Recycling AG	Managing Director
Markus Spitzbart	Phone interview	Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH (GIZ)	Head of Programme "Sustainable E-Waste Management in Ghana"
Mathias Schluep	Phone interview	World Resources Forum	Program Director
Melanie Haupt	Phone interview	Swiss Federal Institute Institute of Technology (ETH Zurich)	Postdoctoral Researcher
Michael Gasser	Phone interview	Swiss Federal Laboratories for Materials Science and Technology (Empa)	Scientist
Mohamed Atallah	Email communication	United Africa Feeder Line (UAFL)	Trade Manager
Nicolai Solenthaler	Personal interview	Solenthaler Recycling	Assistant
Patricia Schröder	Phone interview	Reclite	Director
Reinhardt Smit	Email communication	Closing the Loop	Project Director Africa
Roger Gnos	Personal interview	Swico Recycling	Technical Control, Project Manager
Rolph Payet	Personal interview	Secretariat of the Basel, Rotterdam, and Stockholm Conventions, UN Environment	Executive Secretary
Sana Rajković	Personal interview		Student
Sergio Mallia	Phone interview	WEEE Malta	Operations Manager
Susanne Karcher	Phone interview	Envirosense; Southern African E-waste Alliance (SAEWA)	Owner; Chair & Coordinator

A.2 List of Workshop Participants

Table 22: List of workshop participants of MEECC workshop (9 April 2019).

Name	Institution
Estephan Germain	Landscape and Waste Management Agency (LWMA)
Flavien Joubert	Landscape and Waste Management Agency (LWMA)
Fredrick Kinloch	Ministry of Environment, Energy and Climate Change (MEECC)
Jimmy Lenclume	Seychelles Energy Commission (SEC)
Lisa Bastienne	SIDS Youth AIMS Hub - SEYCHELLES (SYAH)
Mia Dunford	Sustainability for Seychelles (S4S)
Michelle Azemia	Ministry of Environment, Energy and Climate Change (MEECC)
Myron Meme	Landscape and Waste Management Agency (LWMA)
Nanette Laure	Ministry of Environment, Energy and Climate Change (MEECC)
Rahul Mangroo	Landscape and Waste Management Agency (LWMA)
Sandra Lawrence	Seychelles Revenue Commission (SRC), Customs Division
Tony Imaduwa	Seychelles Energy Commission (SEC)
Wallace Cosgrow	Ministry of Environment, Energy and Climate Change (MEECC)

Table 23: List of workshop participants of StEP workshop (15 May 2019).

Name	Institution
Abhishek Kumar Awasthi	Tsinghua University
Alfredo Cueva	United Nations Industrial Development Organization (UNIDO)
Arthur Haarman	Swiss Federal Laboratories for Materials Science and Technology (Empa)
Chris Slijkhuis	Individual person working for Müller Guttenbrunn and representing EERA
Corey Dehmey	Sustainable Electronics Recycling International (SERI)
Eelco Smit	Philips
Elisabeth Smith	StEP Initiative and Dismantling- and Recycling Center (DRZ)
Nikhil Sayi Amdyala	International Telecommunication Union (ITU)
Sidney Chiu	E-Titanium Taiwan

A.3 Survey Questionnaire

Date:
Location:

Dear Sir/Madam,
My name is Nina Rapold and I am a Swiss student from ETH Zurich currently writing my Master's thesis with the Ministry of Environment and Climate Change (MEECC). We are trying to develop a system in Seychelles to manage electronic waste (your mobile phone, laptop, television, refrigerator, washing machine, etc.) and would therefore like to ask you some questions. Your data will be treated confidentially and will only be used for this work. Thank you for your help!

General Information

Gender: ☐ Male ☐ Female

Age (years): ….

How many people live in your household? ….

Average monthly household income:
☐ <5,000 SCR ☐ 5,000–10,000 SCR
☐ 10,000–20,000 SCR ☐ >20,000 SCR
☐ Prefer not to say

In which district do you live?
☐ Anse aux Pins ☐ Anse Boileau ☐ Anse Etoile
☐ Au Cap ☐ Anse Royale ☐ Baie Lazare
☐ Beau Vallon ☐ Bel Air ☐ Bel Ombre
☐ Cascade ☐ Glacis ☐ Grand'Anse
☐ English River ☐ Mont Buxton ☐ Mont Fleuri
☐ Plaisance ☐ Pointe La Rue ☐ Port Glaud
☐ Saint Louis ☐ Takamaka ☐ Les Mamelles
☐ Roche Caiman

Baseline information on electronic devices

The following questions are supposed to give us a better idea what kind of electronic devices you have at home, where you buy them, how often you buy new devices and what you do with your old devices.

1. **What electronic devices do you have at home (total per household)?**

	Mobile Phone	Tablet	Laptop	Desktop PC/ Computer	Television
How many devices do you have at home?					
How many are still working?					
How many do you actively use?					

2. **Where do you usually buy your electronic devices?**

	I bought it in a store in Seychelles	I bought it online	I bought it abroad	I don't have such a device
Mobile Phone	☐	☐	☐	☐
Tablet	☐	☐	☐	☐
Laptop	☐	☐	☐	☐
Desktop PC/ Computer	☐	☐	☐	☐
Television	☐	☐	☐	☐

If you usually buy your devices in a store in Seychelles, which store are you most likely to use? ……………

3. **How often do you usually replace your electronic devices?**

	More than once a year	Once a year	Every two years	Every 3-5 years	Less than every 5 years	I don't have such a device
Mobile Phone	☐	☐	☐	☐	☐	☐
Tablet	☐	☐	☐	☐	☐	☐
Laptop	☐	☐	☐	☐	☐	☐
Desktop PC/ Computer	☐	☐	☐	☐	☐	☐
Television	☐	☐	☐	☐	☐	☐

4. **What do you usually do with your old electronic devices once you don't use them anymore (eg. put it into normal waste bin, store it at home, etc.)?**

   ……………………………

Retailer take-back system

Electronic waste contains many valuable materials which can be recycled as well as toxic components that need to be disposed of in a special way to prevent those components from harming the environment and human health. Therefore, it is necessary to collect electronic devices separately from the normal waste.

5. **Assuming you could bring your old electronic device to the retailer when buying a new one and the retailer then disposes of it in a responsible manner. What would effectively motivate you to bring your old electronic device to the retailer instead of disposing of it in the normal waste?** *Please select only one option per device.*

a) Mobile Phone/ Tablet

☐ Knowing that my old device is recycled in an environmentally responsible manner when I bring it to the retailer motivates me enough to bring it back.

When I would get a price reduction of … rupees on my new device.

☐ 1-100 ☐ 101-200 ☐ 201-400 ☐ More than 401

b) Laptop

☐ Knowing that my old device is recycled in an environmentally responsible manner when I bring it to the retailer motivates me enough to bring it back.

When I would get a price reduction of … rupees on my device.

☐ 1-100 ☐ 101-200 ☐ 201-400 ☐ More than 401

c) **Desktop PC/ Computer**

☐ Knowing that my old device is recycled in an environmentally responsible manner when I bring it to the retailer motivates me enough to bring it back.

When I would get a price reduction of … rupees on my new device.

☐ 1-100 ☐ 101-200 ☐ 201-400 ☐ More than 401

d) **Television**

☐ Knowing that my old device is recycled in an environmentally responsible manner when I bring it to the retailer motivates me enough to bring it back.

When I would get a price reduction of … rupees on my new device.

☐ 1-100 ☐ 101-200 ☐ 201-400 ☐ More than 401

6. **Another option to collect electronic devices could be to use the 4 existing redeem centers for PET and beverage cans on Mahé as collection points where you could bring back your old device at any time without buying a new device.**

   a. **Do you know where you could find such a redeem center?**

      ☐ Yes ☐ No

   b. **Would you use the redeem centers to bring back your old devices when you would get the same amount of money that you indicated for the retail stores?**

      ☐ Yes ☐ No

Thank you for participating in this survey!

A.4 Household Income Distribution of Survey Respondents

Table 24: Household income distribution of survey respondents. Source: Survey.

Household income [SCR]	Number of respondents
< 5000	4
5,000–10,000	40
10,000–20,000	27
> 20,000	16

A.5 Disposed E-Waste Amounts

Table 25: Disposed e-waste amounts per waste class. Source: Rajković (2018).

Waste class	Mean estimate [tons]	Minimum estimate [tons]	Maximum estimate [tons]
1	441.1	375.0	507.3
2	72.3	61.4	83.1
5	17.7	15.0	20.3
6	112.1	61.7	162.5
15	135.0	74.3	195.8
Total	***778.2***	***587.3***	***969.1***

A.6 Usage Status of Selected Electrical and Electronic Equipment

Table 26: Usage status of selected EEE per person (N=142). Source: Survey.

Type of device	Usage status	Mean	Standard deviation	Median
Mobile phone	Non-functional, stored at home	1.224	0.563	1.000
	Functional, stored at home	1.081	0.507	1.000
	Functional, actively used	0.965	0.349	1.000
Tablet	Non-functional, stored at home	0.362	0.450	0.250
	Functional, stored at home	0.330	0.420	0.250
	Functional, actively used	0.310	0.385	0.200
Laptop	Non-functional, stored at home	0.479	0.400	0.400
	Functional, stored at home	0.460	0.379	0.400
	Functional, actively used	0.423	0.323	0.423
Computer	Non-functional, stored at home	0.106	0.209	0.000
	Functional, stored at home	0.091	0.192	0.000
	Functional, actively used	0.091	0.192	0.000
Television	Non-functional, stored at home	0.664	0.395	0.500
	Functional, stored at home	0.632	0.405	0.500
	Functional, actively used	0.594	0.383	0.500

A.7 Matching of UNU-Keys with Input Categories of Business Plan Calculation

Table 27: Matching of UNU-Keys with used input categories for business plan calculation.

UNU-Key	UNU-Key description	Input categories of StEP calculation tool
201	Other Small Household Equipment	Small household appliances (SHA): iron
203	Hot Water	Small household appliances (SHA): coffee machine
301	Small IT	IT accessories (mix keyboard, mouse)
302	Desktop PCs (excl. monitors, accessories)	PC/server
303	Laptops (incl. Tablets)	Notebook
304	Printers (f.i. scanners, multifunctionals, faxes)	Printer/scanner/copier
306	Mobile Phones (incl. Smartphones, pagers)	Mobile phone (incl. recharger)
308	Cathode Ray Tube Monitors	CRT monitor
309	Flat Display Panel Monitors (LCD, LED)	Flat-panel display (FPD) monitor
403	Music Instruments, Radio, HiFi (incl. Audio	Audio appliances (CD-/radiorecorder)
404	Video	Video appliances (CD-/DVD-player)
407	Cathode Ray Tube TVs	CRT TV
408	Flat Display Panel TVs (LCD, LED, Plasma)	FPD TV

A.8 Expected Collection Volumes per UNU-Key

Table 28: Expected collection volumes per UNU-Key.

Appliance group	Expected collection volume [t]
Other Small Household Equipment	17.9
Hot Water	6.3
Small IT	8.3
Desktop PCs	4.6
Laptops	5.9
Printers	3.0
Mobile Phones	1.7
Cathode Ray Tube Monitors	0.1
Flat Display Panel Monitors	0.6
Music Instruments, Radio, HiFi	3.1
Video	2.1
Cathode Ray Tube TVs	0.6
Flat Display Panel TVs	4.1
Total	***58.2***

A.9 Working Hours and Working Days of Employees in Seychelles

Table 29: Working hours per day and week and working days per week as indicated by different stakeholders.

Working hours per day	Working hours per week	Working days per week	Source
10	60	6	Harini (2019)
8	44	5.5	Naidoo (2019)
N/A	40	N/A	Gonzalves (2019)
8	N/A	N/A	Gowressoo (2019)
N/A	48	N/A	Uzice (2019)

A.10 Dismantling Time per Appliance Group

Table 30: Dismantling time per ton of UNU-Key appliance group [hrs].

Appliance group	Dismantling depth		
	A	B	C
Other Small Household Equipment	1.11	55.56	55.56
Hot Water	0.67	13.33	50.00
Small IT	1.72	51.55	51.55
Desktop PCs	17.54	21.05	78.95
Laptops	17.86	89.29	178.57
Printers	3.70	37.04	55.56
Mobile Phones	27.78	194.44	444.44
Cathode Ray Tube Monitors	6.86	14.71	29.41
Flat Display Panel Monitors	23.33	46.67	46.67
Music Instruments, Radio, HiFi	2.69	26.88	26.88
Video	3.33	53.33	80.00
Cathode Ray Tube TVs	2.99	6.41	12.82
Flat Display Panel TVs	14.71	24.51	24.51

A.11 Wage Levels

Table 31: Wage levels as indicated by different stakeholders [USD].

Labour wage [USD/month]	Type of position	Source
620 [A]	Worker	Uzice, 2019
540[A, B]	"Casual worker"	Employment (National Minimum Wage) (Amendment) Regulations. (2016, section 2([b]).
470[A, B]	(a) a worker under a contract of continuous employment; (b) a worker under a contract for a fixed term; or (c) a part-time worker	Employment (National Minimum Wage) (Amendment) Regulations. (2016, section 2([a]).
440 [A]	Worker	Gonzalves (2014)
880 [A]	Manager	Gonzalves (2014)
600	Unskilled worker	Naidoo (2019)
100	Skilled worker	Naidoo (2019)
550 [A]	Unskilled worker	Harini (2019)
700 [A]	Skilled worker	Harini (2019)

[A] Wage originally indicated in SCR; applied conversion rate: 1 USD = 13.6 SCR

[B] based on hourly wage as defined in indicated source, monthly wage calculated assuming 48hrs week, 1 month = 4 weeks, for all others a wage per month was directly indicated by stakeholders

A.12 Staff Costs

Table 32: Staff costs of the TF per employee type as indicted by different stakeholders [USD].

Employee type	Dismantling depth		
	A	B	C
General manager[A]	12,000	12,000	12,000
Department manager[B]	10,200	10,200	10,200
Skilled worker[B]	10,200	10,200	10,200
Unskilled worker[C]	0	6,480	6,480
Administrative staff[B]	0	0	0
Total	***32,400***	***38,880***	***38,880***

[A]wage based on skilled worker by Naidoo (2019)

[B]wage based on indicated average for skilled worker by Naidoo (2019) and Harini (2019)

[C]wage based on indicated average for unskilled worker by Harini (2019), Naidoo (2019) and minimum wage by the Employment (National Minimum Wage) (Amendment) Regulations. (2016, section 2([a]).

A.13 Required Space of Treatment Facility

Table 33: Required space of the treatment facility [m^2].

Type of infrastructure	Dismantling depth		
	A	B	C
WEEE-receiving area	20	20	20
Management/ administration	30	30	30
Recreation and sanitary rooms	9	12	12
Dismantling working stations	20	40	40
Dismantling CRT/Further treatment[A]	0	0	20
Storage	58	58	58
Outside area	58	58	58
Total required area	***195***	***218***	***238***

[A]one CRT treatment unit chosen for dismantling scenario C

A.14 Resulting Output Fractions from Different Input Fractions

Table 34: Resulting output fractions from different input fractions (part 1). Source: UNU/StEP Initiative (2016a).

Output fractions	ther Small Household Equipmer			Hot Water			Small IT			Desktop PCs			Laptops			Printers			Mobile Phones		
	Dismantling depth			Dismantling depth			Dismantling depth			Dismantling depth			Dismantling depth			Dismantling depth			Dismantling depth		
	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
Aluminium											3.0%	7.9%			5.4%			0.3%		3.4%	3.4%
Iron/ Steel		35.1%	35.1%			6.7%		11.9%	11.9%	46.1%	46.1%	59.1%		1.1%	4.8%		0.9%	19.0%		1.6%	1.7%
Copper												1.3%			0.1%		0.1%				0.1%
Neodym Magnet												0.1%			0.2%						
Bronze/Brass															0.3%						0.1%
Stainless Steel												0.5%			1.0%						0.2%
Plastics		39.5%	39.6%		27.0%	56.4%		73.6%	73.6%	6.2%	6.2%	8.8%		14.5%	27.6%		29.0%	51.0%		22.7%	27.5%
Wood																					
Cable with plugs		1.2%			2.5%		9.7%			3.3%			7.5%	0.4%		3.5%			31.1%		
Cable without plugs			1.0%			2.1%		8.5%	8.5%		3.0%	4.5%		5.9%	7.0%		2.2%	2.5%		4.7%	4.8%
Processors											0.4%	0.4%			0.7%						
HDD with PWB										4.3%				4.8%							
HDD without PWB											3.4%										
Power supply										9.5%	9.5%										
Drivers										15.3%	15.3%			9.0%							
Printed Wired Board Q1										9.2%	9.7%	9.8%		12.5%	14.0%					10.3%	10.3%
Printed Wired Board Q2								1.4%	1.4%			0.3%			0.2%		1.6%	1.6%			
Printed Wired Board Q3								2.7%	2.7%		0.3%	2.0%					0.9%	0.9%			6.4%
Mobile Phones without batteries																			43.8%		
Motors / Inductors / Transformers												1.1%			1.2%		0.7%	2.9%		1.0%	15.6%
Deflection coil																					
Getterpill - electrogun																					
Mixedscrap	100.0%	24.2%	24.3%	100.0%	70.5%	34.8%	90.3%	1.9%	1.9%	5.4%	2.4%	3.1%	56.5%	15.3%	15.8%	90.6%	47.2%	3.9%		28.5%	2.1%
Glass																	10.0%	10.0%			
Residual waste															0.6%		1.5%	2.0%			
Batteries										0.3%	0.3%	0.3%	15.0%	15.5%	15.5%				25.1%	25.1%	25.1%
Capacitors										0.4%	0.4%	0.8%				0.1%	0.1%	0.1%			
LCD-displays													21.0%	21.0%	5.5%	0.1%	0.1%	0.1%		2.7%	2.7%
Fluorescent Tubes															0.1%	0.2%	0.2%	0.2%			
Printer Cartirages																5.5%	5.5%	5.5%			
CRTtubes																					
CRT-glass																					
Phosphor-powder																					
Total per year	***100.0%***	***100.0%***	***100.0%***	***100.0%***	***100.0%***	***100.0%***	***100.0%***	***100.0%***	***100.0%***	***100.0%***	***100.0%***	***100.0%***	***100.0%***	***100.0%***	***100.0%***	***100.0%***	***100.0%***	***100.0%***	***100.0%***	***100.0%***	***100.0%***

Table 35: Resulting output fractions from different input fractions (part 2). Source: UNU/StEP Initiative (2016a).

Output fractions	Cathode Ray Tube Monitors			Flat Display Panel Monitors			Music Instruments, Radio, HiFi			Video			Cathode Ray Tube TVs			Flat Display Panel TVs		
	Dismantling depth			Dismantling depth			Dismantling depth			Dismantling depth			Dismantling depth			Dismantling depth		
	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
Aluminium		0.5%	1.4%	0.5%	1.6%	1.6%		1.1%	1.1%		2.7%	6.4%		0.6%	0.9%		5.5%	5.5%
Iron/ Steel	1.8%	7.4%	11.5%	10.0%	40.0%	40.0%		13.0%	13.0%		26.0%	41.3%		0.5%	4.5%		45.0%	45.0%
Copper			1.5%															
Neodym Magnet																		
Bronze/Brass																		
Stainless Steel																		
Plastics	13.8%	19.5%	19.5%	7.2%	20.6%	20.6%		47.1%	47.1%		1.5%	16.0%	6.1%	14.5%	15.0%	8.0%	24.2%	24.2%
Wood																		
Cable with plugs	1.5%			2.7%			4.5%			3.0%			1.5%			0.6%		
Cable without plugs		2.5%	2.5%		2.5%	2.5%		6.0%	6.0%		4.5%	6.8%		1.2%	1.2%		1.6%	1.6%
Processors																		
HDD with PWB																		
HDD without PWB																		
Power supply																		
Drivers																		
Printed Wired Board Q1					5.5%	5.5%											5.5%	5.5%
Printed Wired Board Q2	2.0%	2.0%	2.0%	1.0%							8.8%	9.4%	1.0%	1.0%	1.0%	1.0%		
Printed Wired Board Q3			3.0%					8.6%	8.6%						2.2%			
Mobile Phones without batteries																		
Motors / Inductors / Transformers		0.2%	5.0%		0.4%	0.4%		10.5%	10.5%		6.5%	12.8%			1.4%		1.7%	1.7%
Deflection coil	4.5%	4.5%	4.5%										2.2%	2.2%	2.2%			
Getterpill - electrogun	0.1%	0.1%	0.1%										0.1%	0.1%	0.1%			
Mixedscrap	25.4%	12.4%	0.6%	56.3%	5.8%	5.8%	92.6%	10.5%	10.5%	95.7%	48.2%	5.0%	14.4%	5.2%	0.5%	77.7%	3.4%	3.4%
Glass				11.8%	11.8%	11.8%										3.6%	3.6%	3.6%
Residual waste				1.6%	2.9%	2.9%		0.3%	0.3%		0.5%	1.0%				1.8%	2.2%	2.2%
Batteries							2.5%	2.5%	2.5%									
Capacitors	0.4%	0.4%	0.4%	0.3%	0.3%	0.3%	0.2%	0.2%	0.2%	0.7%	0.7%	0.7%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%
LCD-displays				8.3%	8.3%	8.3%	0.2%	0.2%	0.2%	0.6%	0.6%	0.6%				6.2%	6.2%	6.2%
Fluorescent Tubes				0.3%	0.3%	0.3%										0.9%	0.9%	0.9%
Printer Cartirages																		
CRTubes	50.5%	50.5%											74.5%	74.5%				
CRT-glass			47.8%												70.5%			
Phosphor-powder			0.2%												0.3%			
Total per year	***100.0%***	***100.0%***	***100.0%***	***100.0%***	***100.0%***	***100.0%***	***100.0%***	***100.0%***	***100.0%***	***100.0%***	***100.0%***	***100.0%***	***100.0%***	***100.0%***	***100.0%***	***100.0%***	***100.0%***	***100.0%***

A.15 Sales Revenues and Costs for Output Fractions of the Treatment Facility

Table 36: Sales revenues and costs for expected total amounts of e-waste output fractions of the TF [USD].

Output fractions	Applied Dismantling Depth		
	A	B	C
Aluminum	4.25	757.68	1675.59
Iron/steel	633.57	3667.33	4293.92
Copper	0	18.17	411.62
Neodym Magnet	0	0	115.14
Bronze/brass	0	0	72.04
Stainless steel	0	0	91.68
Plastics	-394.37	-11,230	-13,383
Wood	0	0	0
Cable with plugs	2,581.5	444.83	0
Cable without plugs	0	2,309.15	2,990.63
Processors	0	389.97	1280.01
HDD with PWB	330.97	481.84	0
HDD without PWB	0	68.34	0
Power supply (without cable)	146.24	146.24	0
Drivers	353.30	624.33	0
Printed Wired Board Q1	2,478.43	9,566.82	10,120.80
Printed Wired Board Q2	190.02	1,259.74	1,393.94
Printed Wired Board Q3	0	1,134.44	1,568.92
Mobile Phones without battries	7,118.86	0	0
Motors / Inductors / Transformers	0	291.33	588.97
Deflection coil	28.27	28.27	28.27
Getterpill - electrogun	-0.67	-0.6704	-0.67
Mixedscrap	7,848.29	2,265.86	1,439.57
Glass	0	0	0
Residual waste	0	0	0
Batteries	2,547.27	2,600.81	2,600.81
Capacitors	48.61	48.61	65.03
LCD-displays	-1,061.8	-1093.1	-470.73
Fluorescent Tubes	0	0	0
Printer Cartridges	0	0	0
CRT-tubes	-141.78	-141.78	0
CRT-glass	0	0	191.30
Phosphor-powder	0	0	-1.90
Total per year	***22,711***	***13,638.2***	***15,072.3***

A.16 Freight Costs

Table 37: Freight cost per 20ft container as indicated by different stakeholders.

Freight cost [USD]	Destination	Source
2,495	Ukraine	Hess et al. (2018)
1,425	India	Hess et al. (2018)
952	Durban, South Africa	M. Atallah (personal communication, March 26, 2019)
952	Port Louis, Mauritius	M. Atallah (personal communication, March 26, 2019)
1,052	Nhava Sheva, India	M. Atallah (personal communication, March 26, 2019)
1,153	Antwerp, Belgium	M. Atallah (personal communication, March 26, 2019)
950	not defined	Laurence (2019)
1,500[A]	Ukraine	Harini (2019)
600[B]	not defined	Naidoo (2019)
1,800[C]	not defined	Naidoo (2019)
1,030	Port Louis, Mauritius	V. Constance (personal communication, May 6, 2019)
1,275	Durban, South Africa	V. Constance (personal communication, May 6, 2019)
1,050	Antwerp, Belgium	V. Constance (personal communication, May 6, 2019)
1,600	Jebel Ali, Dubai	V. Constance (personal communication, May 6, 2019)

[A]3,000 SCR indicated for 40ft container; half the cost can be expected for a 20ft container

[B]minimum freight rate as mentioned by Surya, 2019

[C]maximum freight rate as mentioned by Surya, 2019

A.17 Container Space

Table 38: Number of tons of output fractions that fill up a container.

Output fractions	Tons per container	Source
Aluminum	24	F. Kinloch (personal communication, April, 2019)
Iron/steel	22	F. Kinloch (personal communication, April, 2019)
Copper	10	F. Kinloch (personal communication, April, 2019)
Neodym magnet	10	Naidoo (2019)
Bronze/brass	21	F. Kinloch (personal communication, April, 2019)
Stainless steel	10	Naidoo (2019)
Plastics	9	Bleher (2014)
Wood	N/A	
Cable with plugs	10	Naidoo (2019)
Cable without plugs	10	Naidoo (2019)
Processors	10	Naidoo (2019)
Hard disk drive with printed wired board	10	Naidoo (2019)
Hard disk drive without printed wired board	10	Naidoo (2019)
Power supply (without	10	Naidoo (2019)
Drivers	10	Naidoo (2019)
Printed wired board – high quality	12.5	Average of indications provided by de Klujiver (2019) and Lauwers (2019)
Printed wired board – medium quality	12.5	Average of indications provided by de Klujiver (2019) and Lauwers (2019)
Printed wired board – low quality	12.5	Average of indications provided by de Klujiver (2019) and Lauwers (2019)
Mobile phones without batteries	5	de Klujiver (2019)
Motors/inductors/ transformers	10	Naidoo (2019)
Deflection coil	10	Naidoo (2019)
Getterpill-electrogun	10	Naidoo (2019)
Mixed scrap	10	Naidoo (2019)
Glass	N/A	
Residual waste	N/A	
Batteries	10	Naidoo (2019)
Capacitors	10	Naidoo (2019)
LCD-displays	10	Naidoo (2019)
Fluorescent tubes	10	Naidoo (2019)
Printer cartridges	10	Naidoo (2019)
CRT-tubes	10	Naidoo (2019)

Output fractions	Tons per container	Source
CRT-glass	10	Naidoo (2019)
Phosphor-powder	10	Naidoo (2019)

A.18 Administrative Costs

Table 39: Administrative costs.

Type of administrative expenses	Expenses [USD]
Travel costs	2,500
Office supplies, postal and bank charges	500
Telecommunication/internet	300
Consulting services	500
Marketing and public relations	500
Permissions and quality management	500
Total	***4,800***

Source: Spitzbart and Schluep (2014) and Mostafa and Dina (2018)

A.19 Rental Prices

Table 40: Annual rental prices as indicated by different stakeholders.

Rental cost [USD/m^2][A]	Type of land	Source
263.52	Covered warehouse, no government support	Naidoo (2019)
43.92	Open land, no governent support	Naidoo (2019)
150.24	Covered warehouse, no government support	Harini (2019)
1.99	Covered warehouse, with goverment support	Harini (2019)
2.94[B]	Open land, with government support	Providence Industrial Authority (personal communication, March, 2019)

[A]All prices originally indicated in SCR, conversion rate 1 USD = 13.6 SCR.

[B]Price for the first 5 years; 25% price increase after every 5 years for the duration of the lease; not including one-time payment of 2.94 USD/m^2