Solid Waste Management in the Seychelles

USYS TdLab Transdisciplinary Case Study 2016

Report

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Contents

Acronyms and Abbreviations

AD	Anaerobic Digestion
BAU	Business As Usual
BOD	Biological Oxygen Demand
BW	Biodegradable Waste
CEO	Chief Executive Officer
CEPS	Citizens Engagement Platform Society
DE	Department of Environment
DECC	Department of Energy and Climate Change
DO	Dissolved Oxygen
EDF	European Development Fund
EED	Environmental Education Division
EPA	Environment Protection Act
ETF	Environment Trust Fund
GDP per capita PPP	Gross Domestic Product per Capita Purchasing Power Parity
IOT	Indian Ocean Tuna Ltd.
IPCC	Intergovernmental Panel on Climate Change
IRD	Institut de recherche pour le développement
LPTP	Leachate Preliminary Treatment Plant
LWMA	Landscape and Waste Management Agency
MCQ	Multiple Choice Questionnaire
MEECC	Ministry of Environment, Energy and Climate Change
MF	Ministry of Finance
MFA	Material Flow Analysis
MSW	Municipal Solid Waste (a waste class)
NBS	National Bureau of Statistics
NGO	Non-governmental Organisation
OECD	Organisation for Economic Co-operation and Development
OW	Original weight
PET	Polyethylene Terephthalate

POPs	Persistent Organic Pollutants
PS	Principal Secretary
PUC	Public Utilities Corporation
RC	Redeem Centre
RCFA	Roche Caiman Fishermen Association
S4S	Sustainability for Seychelles
SAS	Story and Simulation Approach
SBS	Seychelles Bureau of Standards
SCR	Seychelles Rupee
SEC	Seychelles Energy Commission
Seybrew	Seychelles Breweries Ltd.
SFA	Seychelles Fishing Authority
SFBOA	Seychelles Fishing and Boat Owners Association
SIDS	Small island developing states
SSDS	Seychelles Sustainable Development Strategy 2012–2020
STAR	Société de Traitement et d'Assainissement Régionale (the primary waste management contractor in the Seychelles)
SWAC	Solid Waste and Cleaning Agency
SWM	Solid waste management
SWM Plan	Solid Waste Management Plan
SWM Policy	Solid Waste Management Policy
TdLab	Transdisciplinary Laboratory
TS	Total solids
UN	United Nations
UNCOP	United Nations Conference of the Parties
UniSey	University of Seychelles
VS	Volatile solids
WEPD	Waste, Enforcement and Permits Division
WMS	Waste Management System
WMTF	Waste Management Trust Fund

Preface and Acknowledgments

Preface

The cooperation between ETH Zürich and the Seychelles, in particular with the Ministry of Environment, Energy and Climate Change has a long tradition, especially with the Environment Department in the field of invasive species and nature conservation. We – the TdLab – want to continue to cultivate this tradition, to broaden the scope of our research activities to other areas of concern, and to extend it to other partners in the long term. To this end, we signed an Agreement of Cooperation with the University of Seychelles (UniSey) at the beginning of this year to jointly conduct teaching and research projects. In this context, we have implemented a first project. This report provides evidence of this. Our observations have shown that waste is a major challenge for the Seychelles, and that this topic is an excellent target for a transdisciplinary case study (tdCS). The tdCS of the TdLab is a problem-oriented and research-based course for master's students at ETH Zürich. The aim is to understand a real problem in its various facets, to scientifically analyse it, and to find possible solutions. A special concern and an equally great challenge is to reach the learning goals for the students and at the same time achieve a practical result for our praxis partner, the Ministry of Environment. We think we have succeeded.

The 18 ETH Master students with a diversity of scientific backgrounds and the 18 undergraduate students of the UniSey, who joined during the field phase in the Seychelles, did an excellent job. They provided new insights into a complex problem. They conducted about 200 interviews, and during the three weeks of fieldwork students were engaged in over 3,000 work hours. The event was also a success from a teaching perspective: students learned how to proceed from a vague idea to a concrete research question; they acquired and created new knowledge on waste management in general, and in particular in the Seychelles; they have applied a variety of new methods; they have learned to work in groups, especially in intercultural groups; they have engaged intensively with stakeholders; and they have learned to organise and execute a project independently and to take responsibility. In short, students experienced working practice: they had to achieve results under the pressure of producing practically relevant results and within a limited period of time. But we should also note that students had fun; many new friendships and networks have emerged. One does not go without the other, emotions are key for any such endeavour.

We think such new teaching-research events in this North-South context with two participating universities and different partners are not easy, but they yield considerable opportunities for all parties involved. It promotes scientific and cultural exchange, and methodical and social competence of the students as well as the teachers. The TdLab and the Ministry have jointly defined and framed the issue and conducted the project together with the UniSey for mutual long term benefit. The project would not have been possible without the personal and strong support from various individuals both from the Ministry and UniSey, including Denis Matatiken, Lemmy Payet, Dr. Michelle Martin, Rachel Onezime and Dr. Karl Fleischmann. Students have interacted intensively with stakeholders, thus, in addition to academic knowledge; practical knowledge must

be included in such a project. This collaboration promotes joint learning and strengthens the capacity on all sides. It is our intention to be transparent and open, making the results of our study available to all stakeholders. We aim to share our findings with the population of the Seychelles by preparing the results of our work as a newspaper supplement for the local media. Likewise, we ensure that awareness in the Seychelles for the important waste problem is raised and that a broad engagement to take action and generate solutions will become possible. Finally, in terms of sustainability it is our ambition to continue to support the Seychelles by providing further input to solve a difficult problem.

We would like to thank the large number of involved people for their kind and considerable commitment!

We are looking forward to further activities – and to the next tdCS in 2018.

Dr. Pius Krütli & Prof. Dr. Michael Stauffacher
Responsible heads of the Transdisciplinary Case Study of the TdLab of ETH Zürich

Acknowledgments

Special thanks are in order to Dr. Michelle Martin and Mr. Lemmy Payet for their great commitment to the case study, help in guiding our research during their visit to Zurich, and warm welcome upon arrival to the Seychelles. We are also extremely grateful for the hospitality granted and the expertise provided to us by the University of Seychelles – particularly from Dr. Karl Fleischmann and Terence Vel – who provided us ample working space and expert support throughout the field phase. Additionally, we would like to thank all the members of the advisory board – Mr. Denis Matatiken, Mr. Lemmy Payet, Dr. Marie-Therese Purvis, Dr. Michelle Martin, Mrs. Nanette Laure, Ms. Marie-May Jeremie, Mr. Alain de Comarmond, Mr. Tony Imaduwa, Mrs. Rachel Onezime, and Dr. Karl Fleischmann – for their constructive inputs to our work.

We received valuable information from our interview partners in and outside of the Seychelles, and they also deserve our sincerest gratitude. We would like to thank Judith Maag for showing us Maag Recycling's operations in Winterthur. The experts we consulted from EAWAG, Christian Riuji Lohri and Imanol Zabaleta, and from ETH Zurich, Prof. Dr. Gerhard Furrer Prof. Dr. Ruben Kretzschmar, Dr. Grégoire Meylan, Dr. Bin Bin Pearce, and Dr. Michael Plötze, provided several research groups early guidance, and we are very thankful that they shared their expertise with us. Finally, we would like to recognise the members of the Seychelles community whom we interviewed – government officials, community members, store owners, recycling managers, farm owners, business owners, and many more – for their time and valuable answers.

Executive Summary

The Seychelles is classified as a small island developing state (SIDS) with unique economic and ecologic challenges, characterised by particular vulnerability to sea level rise, land scarcity, and fluctuations in global markets. Sustainable development – at the intersection of economy, society, and ecology – is therefore crucial to the Seychelles, and is the focal purpose of the teaching and research collaboration between the University of Seychelles (UniSey) and ETH Zürich. This case study was developed as a joint teaching activity of the Transdisciplinarity Lab (TdLab) at ETH and the Environmental Sciences programme at UniSey. Stakeholders chose the topic to be solid waste management (SWM) because it was identified as an especially pressing issue in the Seychelles which requires a long-term solution.

SWM is a significant challenge for the Seychelles because landfilling, the currently employed waste management strategy, poses direct threats to the island nation's specific weaknesses: landfilling produces greenhouse gases, consumes scarce land, and releases leachate that creates potential environmental concerns. However, due to the small scale of the Seychelles economy, there is little capital available to stimulate innovations in SWM. The focus of this case study was to understand SWM in the Seychelles and to provide insights into waste reduction. To guide the study, the following overarching research questions were proposed:

1. How does the current system operate? What are ecological risks and waste management challenges?
2. What are potential waste reduction strategies for stakeholders such as the government, consumers, and waste managers? What are obstacles preventing their implementation?
3. How could the future of waste management look like?

The case study was split into seven topics to gain comprehensive and in-depth knowledge about the SWM system. We formed groups to investigate the following topics: Legal & Institutional Framework, Recycling Markets, Material Flow Analysis, Environmental Impacts of the Providence Landfills, Consumer's Perspective, Potential for Biogas Production, and Landfill Scenario Modelling. We conducted research over six months, including a three-week field phase, to address the specific sub themes within the general scope of our research questions proposed above.

The methods employed varied across groups. Groups typically began with a literature review of official government documents, waste management reports in developing countries, Seychelles waste and economic data, and other research in related topics. In the field phase, we conducted semi-structured interviews with stakeholders, surveys with the public, material flow analyses, scenario modelling, water sample analyses, and further literature review to address knowledge gaps identified in the first literature review. Our

ultimate goal was to capture and synthesise stakeholder knowledge and opinion on waste management and reduction strategies to determine the potential of various waste treatment implementations.

Existing data show that landfilling rates are increasing every year, and interviews with NGOs, recyclers, and government officials indicate that little initiative has been taken to combat waste generation; some previous projects, involving in glass and paper recycling, have been abandoned. The general consensus is that the levy placed on PET, aluminium cans, and Seychelles Brewing Company glass bottles is popular and successful, and largely depends on the role of informal collectors of PET and cans. Our material flow and other data analyses give quantitative data to support that PET and aluminium cans are primarily diverted from the landfill, while other waste fractions, notably glass, paper, and organic waste, have high landfilling rates despite a high recycling potential. To analyse the impact of these and other waste fractions on environmental quality, we measured water quality near the landfill. While sampling done on the landfill leachate demonstrated the presence of nitrate and heavy metals, we could not conclude that the neighbouring water bodies were affected. It is therefore recommended that further water quality testing be conducted near the landfill in future studies. However, given the potential leaching of toxic material and the scarcity of land, we still believe that action in waste management is urgent.

We found that many stakeholders believe the government should be responsible for incentivizing waste reduction in the Seychelles. While the government has outlined waste management goals in its policies and plans, our analysis of the legal framework demonstrates that governmental organisations face three significant obstacles preventing their implementation: unclear allocation of responsibilities, lack of financial flexibility, and unspecific policy. We argue that removing ambiguities in documents, policies, and agreements would facilitate government implementation of waste management actions, especially if organisations are provided control over their own finances. The government has several legal, administrative, and financial mechanisms available, and in interviews, stakeholders claim that existing recycling systems can be expanded or modified to include glass, paper, organic waste, and other plastics. But it is important to note, however, that any implementations must be complemented by education and structured, efficient waste collection. Based on the results from a questionnaire, if provided an adequate collection system, consumers demonstrate a willingness to recycle; in surveys, they appear to prefer quality over price when making certain purchase decisions. This contradicts the elevated influx of cheap, disposable goods entering the Seychelles, and indicates that action should be taken to control imported products, through levies, bans, or other mechanisms.

The Seychelles has promise to decrease its waste generation effectively. Stakeholders indicate a particular interest in reducing organic waste deposition, the largest fraction landfilled, using an anaerobic digester. Our analysis of a prospective biowaste system demonstrates that there are available feedstock suppliers and produced biogas and compost customers. We modelled a scenario to include organic waste reduction, which could lead to a dramatic decrease in landfilling. In another scenario, we show that inaction could cause 7–10 landfills to be filled by 2040, which may not be feasible given the scarcity of land in the Seychelles.

In conclusion, we found that the government is the most capable stakeholder to drive waste reduction in the Seychelles. While consumers, recyclers, NGOs, and other stakeholders are willing to contribute to waste management, they lack the capital, infrastructure, and legal means to implement waste reduction strategies. There are successful models, including the levy scheme, which can be adapted to include more waste streams. Incentives, in the form of bans, taxes, tax-exemptions, education, and collection, are implementable and should be combined together to tackle waste management from different angles. Restructuring legal documents and allocating responsibilities will help elicit government action in developing these incentives.

Further research based on this case study would facilitate a further in-depth understanding of the elements of SWM in the Seychelles. Improved data management, more consumer surveys, and financial information would provide additional insight into prospective waste management systems that would be suitable to implement in the Seychelles context and ultimately lead to waste reduction.

Section I

John Hensley, Adelene Lai, Pius Krütli, & Michael Stauffacher

General Introduction

The Seychelles is an archipelago nation with an estimated population of 92,000. Its 115 islands are located 1,500 kilometres off the eastern coast of Africa in the Indian Ocean, spread over an area of 1.4 million square kilometres (Figure I.1). Due to its geographical, economic, and social characteristics, the Seychelles is characterised as part of the 51 small island developing states (SIDS).

SIDS are economically and ecologically fragile (Ghina, 2003). Generally comprising archipelagos or island nations with small and dispersed land areas, they are particularly vulnerable to sea level rise induced by anthropogenic climate change. Land is scarce, and therefore poses a significant challenge for many SIDS. Additionally, they usually tend to possess diverse and highly endemic flora and fauna, which tend to be affected by exposure to foreign species brought by human interaction. Typically geographically isolated and limited by population and economic scale, SIDS are highly dependent on the international market and vulnerable to economic shocks, and they lack capital to mobilise projects (Eckelman et al., 2014). This effect is magnified due to their dependence on tourism, specialised niche markets, and on their limited resources, such as fishing.

Figure I.1
Location of the Seychelles' inner islands.

The Seychelles faces challenges in each of the criteria demonstrated above. Therefore, sustainable development – which is economic, social, and ecological – is crucial to the Seychelles and similar SIDS, and is heavily emphasised in many significant official documents written in the Seychelles.

To understand and promote sustainable development in the Seychelles, the University of Seychelles (UniSey) and ETH Zürich developed a research collaboration. In early 2016, a long-term partnership agreement called for collaboration in teaching and research, specifically to undertake a bi-annually recurring transdisciplinary case study between ETH Zürich and UniSey. This case study (Box 1) was developed as a joint teaching activity of the Transdisciplinarity Lab (TdLab) at ETH and the Environmental Sciences programme at UniSey. The joint teaching activity was conducted by Dr. Krütli, Prof. Stauffacher, Dr. Fleischmann, and Mrs. Rachel Onezime in 2016. For UniSey, the case study was a placement provision, giving students the opportunity to conduct field research. For ETH, it is an elective 7-credit point master course, exposing the students to a complex real-world problem addressed from multiple perspectives. Several stakeholders engaged in discussions to determine the topic of the case study. Members of ETH, the Ministry of Environment, UniSey, local non-governmental organisations (NGOs), and other significant organisations agreed that the case study in 2016 should focus on solid waste management (SWM) in the Seychelles, a recently growing issue for the country.

SWM is a major issue affecting both developed and developing economies due to the increasing amount of waste generated annually (Figure I.2). Economic growth, higher industrialisation, population rise, and elevated standards of living are often correlated to increases in waste generation (Kothari et al., 2014). For economies dependent on tourism, solid waste management is considered as one of the most important environmental aspects in long-term development (Muñoz, et al., 2015).

Box 1 – Transdisciplinary Case Study Definition

Transdisciplinary case studies (tdCS) are problem-oriented, research-based seminars held in real-life situations, to facilitate the production of scientific and praxis-related joint knowledge. In a tdCS, students from a diverse set of academic backgrounds approach a real-world sustainability problem (e.g., SWM). They collaborate with stakeholders and experts in and outside academia to bridge an intensive exchange between academia and practise. Throughout the tdCS, interdisciplinary methods are conducted, such as scenario analysis, sustainability assessment, and multi-criteria assessment, which are coupled with interdisciplinary methods like material flow analysis, cost benefit analysis, in-depth interviews, and surveys.

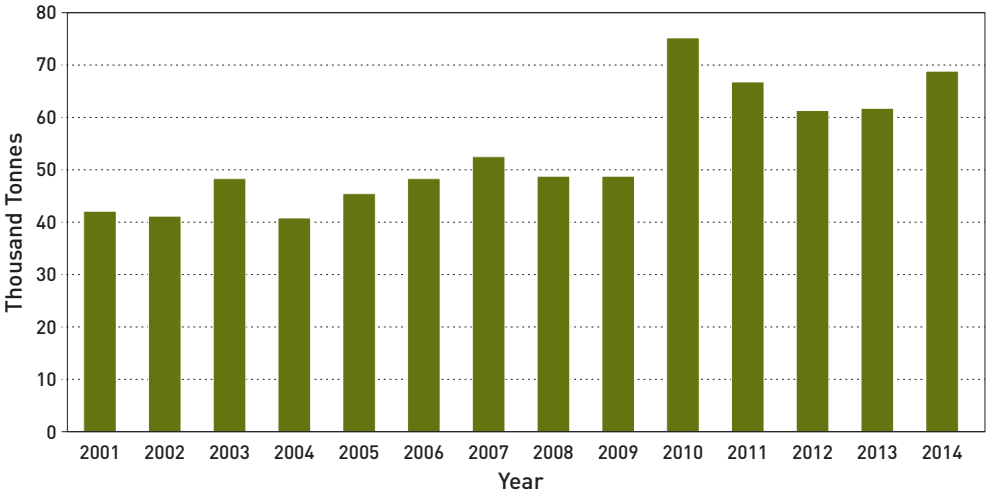

Figure I.2
Annual tonnage of waste delivered to the Providence Landfill from 2001–2014. Source: LWMA, 2016.

SWM has become a significant challenge for the Seychelles. SWM has been handled by STAR, a government-contracted company, since 1996. Presently, STAR only landfills all major fractions of waste, with the exception of PET, aluminium cans, and large scrap metal. Landfilling poses environmental concerns including leaching of pollutants, methane emissions, and resource depletion. Additionally, because land is scarce and expensive in the Seychelles, landfilling will incur significant costs to the government in the future. Seychellois waste generation has increased recently due to economic development and tourism, and estimates suggest that consumption will continue to rise in the near future. Landfill construction has not kept up with waste generation: the Providence II Landfill on Mahé, the largest in the archipelago, is estimated to reach capacity in less than 6 years instead of the planned 10. Despite the costs, the government has not established clear targets for waste management or reduction (Talma, et al., 2013).

A particular challenge for SWM development in the Seychelles is scale. Due to the small population of the country, there is little capital available to support SWM projects, particularly to stimulate recycling initiatives or advanced waste treatment. Additionally, the low volume of total waste generated provides insufficient quantities to have technically feasible treatment systems. The small economies of scale prevent waste businesses from generating revenues to overcome operation and investment costs. Consequently, landfilling presents a seemingly cheaper option for waste treatment, but this poses long term sustainability issues.

The focus of the case study is to understand SWM in the Seychelles and to provide insights into waste reduction. To guide the study, the following overarching research questions have been proposed:

1. How does the current system operate? What are ecological risks and waste management challenges?
2. What are potential waste reduction strategies for stakeholders such as the government, consumers, and waste managers? What are obstacles preventing their implementation?
3. How could the future of waste management look like?

The research team involved in the study consists of the three aforementioned research partners, 18 Environmental Science bachelor's students from UniSey, and 18 master's students from ETH with a mix of environmental, agricultural science and engineering backgrounds. Additionally, an advisory board of nine stakeholders from the MEECC and administration, business, and civil society were included (Table I.1).

Table I.1
List of advisory board members and their backgrounds.

Board Member	Institution	Function
Mr. Denis Matatiken	Ministry of Environment, Energy & Climate Change	Special adviser to the Minister
Mr. Lemmy Payet	Landscape and Waste Management Agency	Deputy of CEO and waste expert
Dr. Marie-Theres Purvis	CEPS	Private consultant and education sector expert
Dr. Michelle Martin	S4S	Executive Director and waste expert
Mrs. Nanette Laure	Ministry of Environment, Energy & Climate Change	Director, General Waste, Enforcement and Permits Division
Ms. Marie-May Jeremie	Ministry of Environment, Energy & Climate Change	Director, Standards and Enforcement Section
Mr. Alain de Comarmond	Ministry of Environment, Energy & Climate Change	Principal Secretary, Environment
Mr. Tony Imaduwa	Energy Commission	CEO
Mrs. Rachel Onezime	UniSey	Head of Curriculum for Environmental Science
Dr. Karl Fleischmann	UniSey	Senior Lecturer

The team conducted the case study in two phases. During the semester from February through June, ETH students engaged in literature reading, background research, research plan development, and field phase preparation. About halfway in this period, members engaged in a two-day workshop involving stakeholders from Sustainability for Seychelles (S4S) and Landscape and Waste Management Agency (LWMA). This preparatory phase was followed by three weeks of intensive field research in the Seychelles, a collaborative effort by both UniSey and ETH students.

To achieve a balance between a comprehensive, systemic overview and in-depth work, the case study was split into smaller groups as depicted in the system picture below (Figure I.3). The key features used in this system picture were determined through a literature study of waste systems in SIDS as well as respective key documents of the Seychelles. It has previously been identified that integrated waste management can be separated into influencing factors – legal institutions, the economy, and societal behaviour – and the phases of the waste cycle: waste production, waste

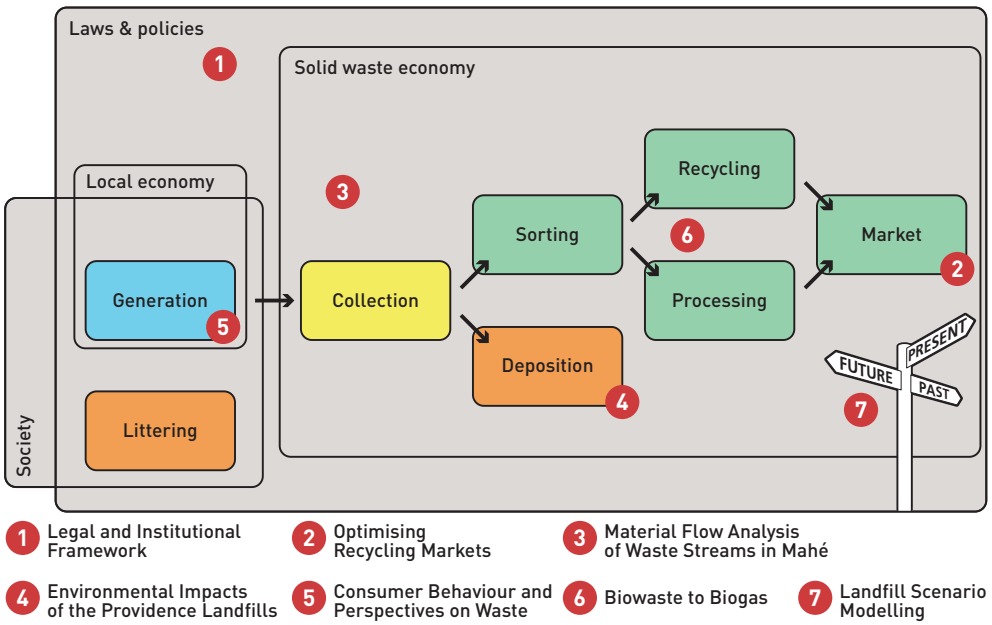

Figure I.3
Case study system picture and group breakdown.

minimisation, collection and handling, and disposal (South Pacific Regional Environment Programme). To model these factors in a system picture, we first established a waste flow diagram from generation to deposition, where an off-stream from collection allowed for recycling and processing to secondary markets. Then, the system picture was divided into two economic spheres, local economy and solid waste economy, which govern their respective components of the waste flow diagram. Society and law and policy were demonstrated as overarching spheres in the system picture: the local economy is influenced by the society sphere and all

Table I.2
Description of research groups and their methods.

Group	Description	Methods
1 Legal and Institutional Framework	Analysis of the function of legal and institutional frameworks in the waste system, including legal framework, governmental structure, and financial mechanisms	Interviews with government officials; analysis of institutional framework of the waste system (document analysis)
2 Optimising Recycling Markets	Analysis of recycling markets; investigation of optimisations for recycling of PET and aluminium cans, glass, and paper; provision of insights into failures developments of previous and current recycling projects and businesses	Interviews with waste stakeholders; surveys with consumers; cost analysis of waste recycling systems and products; feasibility studies of waste options
3 Material Flow Analysis of Waste Streams in Mahé	Generation of quantitative system pictures of waste and commodity flows; identification of main drivers of waste production and potential optimisation points	Data collection for material flows; interviews with waste stakeholders; modelling of waste streams with open source program STAN; interpretation of data and calculations
4 Environmental Impacts of the Providence Landfills	Determination of environmental impacts of the current landfill system, including landfill leaching into the ocean and leachate quality; provision of current landfill-environment interactions and evidence for potential adverse impacts	Water sampling and analysis of landfills; interviews with fishermen/workers at the landfill and in waste related environments
5 Consumer Behaviour and Perspectives on Waste	Analysis of the consumer and social aspects of waste generation and mitigation; investigation of consumer behaviour	Interviews with consumers, stores, and other stakeholders; analysis of data and identification of reduction hotspots
6 Biowaste to Biogas	Analysis of the potential of biogas production; investigation of available feedstocks for biogas; determination of possible collection system(s) for high potential feedstocks	Interviews with waste stakeholders; modelling of biowaste system; analysis of potential feedstocks and biogas potentials
7 Landfill Scenario Modelling	Provision of a scenario analysis to consider possible future scenarios through possible events; investigation of the future amount of waste deposited at Mahé's landfills	Interviews with key stakeholders and experts; visualisation of outcomes and scenario generation; scenario analysis and modelling of potential future states of waste deposition on Mahé's landfills

spheres are governed by law and policy. The final component added to the system picture was a scenario analysis, which investigates possible future outcomes of the waste system.

The groups are divided into seven subtopics that each represent a different element of the overall waste management system. Table I.2 provides a brief description and list of methods employed by each research group, in the order of the following chapters in the report, to analyse their specific sphere or step of the system picture. The final objective was to capture all elements of SWM to investigate the research questions listed above.

The following report presents the case study on solid waste management in the Seychelles. Section II of the report has been divided into seven chapters which each include the methods, results, and conclusions of each individual research group. The seven chapters are ordered according to Table I.2 demonstrated above. A combined conclusion (Section III) follows these chapters, and an outlook was drawn based on the results of the study. The Appendix concludes this document after Section III.

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Section II

Editors' note on confidentiality

We have chosen to keep all references to information provided by our interview partners anonymous throughout the report for reasons of confidentiality. We also respect any wishes from our partners to keep interview transcriptions confidential.

We recognise that bias may exist in the interviews conducted with our partners. Potential causes include errors in transcription and translation, familiarity between researchers and interview partners, and evasion of controversial responses. To the best of our ability, we tried to mitigate bias by conducting interviews in Creole only when necessary; asking objective, neutral questions; and ensuring comfortable settings for interviews.

Mégan Dine, Irma Dubois, Elisabeth Güttinger, Lisa Hämmerli, Aisha Rachel, & Olivia Pfister

1 Legal and Institutional Framework

1.1 Introduction

Waste management is an archetypal public good because it promotes overall public welfare and environmental health (Massoud & Fadel, 2002). In nearly all countries, regardless of the stage of economic development and level of population welfare, the public sector is primarily responsible for the collection and management of waste, though other models of WM involving the private sector through public-private partnerships (PPP) also exist (ibid). Nevertheless, government plays a crucial and necessary role in establishing clear regulatory and legal bases for a well-functioning waste management system (WMS).

The WMS of the Seychelles has followed a relatively dynamic trajectory in terms of its development and currently consists of different policy layers, mechanisms, and legal instruments. More detail can be found in the Solid Waste Management Policy 2014-2018, but we provide a brief summary of the history here: until 1995, the Public Utilities Corporation (PUC) was in charge of sanitation and waste. After government restructuring, the Solid Waste & Cleaning Agency (SWAC) overtook most sanitation and waste responsibilities. Because SWAC experienced periods of separation from and inclusion in the Department of Environment, it had varying levels of independence in decision-making and internal management throughout its lifetime. According to the 1995 Environment Protection Regulation, SWAC's functions were to monitor, regulate, and authorise the deposition of waste at waste disposal sites (A Situation Report).

A significant development which still has a strong impact today took place in 1997, when a private operator, STAR Seychelles (STAR), was contracted by SWAC in an agreement lasting 20 years to provide municipal waste collection, waste treatment, and disposal services in accordance with the policies in the 2003-2010 Solid Waste Master Plan. Following another government restructuring in 2009, the Landscape and Waste Management Agency (LWMA) was established under the Ministry of Environment and Energy (MEE) as a result of an amalgamation between SWAC and the Landscape Management Division (Mwebaza et al., 2009). Officially, the LWMA has since become the main governmental institution overseeing waste management at the national level.

Inevitably, a clear legal basis must support the successful functioning of such a public-private system. However, despite the numerous documents, publications, and Acts of government, to the best of our knowledge, there exists no clear delineation of the legal and institutional frameworks which govern the waste management system of the Seychelles. Such circumstances can jeopardise the WMS's functionality not only on a day-to-day basis, but also in terms of long-term innovation and development.

The goal of this study is to provide a comprehensive analysis of the current WMS to clarify stakeholders' roles, particularly as they relate to jurisdiction and implementation, WMS challenges, and other existing knowledge gaps. Through a

thorough investigation of strategic plans, involved governmental bodies and other stakeholders, available financial mechanisms, and institutional challenges, our research aims to address the following research questions:

1. What are the legal and institutional frameworks of the WMS and how do they function?
2. How does collaboration between the WMS actors take place, as well as internally within these institutions themselves?
3. What financial mechanisms currently exist/are available and how can they be applied to the WMS?

Ultimately, we aim to highlight the institutional challenges in WMS operation and obscurities in responsibility among relevant bodies through the information gathered in our analyses.

1.2 Methods

We employed two methods sequentially–document analysis and stakeholder interviews–to address our research questions. Accordingly, we first undertook a thorough analysis of the various Master Plans, Acts, and Strategies to develop a preliminary understanding of the system. After acquiring initial knowledge of governmental structure, legal frameworks, and financial mechanisms from the documents, we iteratively validated our findings with stakeholders.

Through the synthesis of information gained from stakeholder interviews, we were able to identify significant individuals, departments, and organisations with legal authority within the waste management system and developed an understanding of how they operate in conjunction with each other. We also discussed financing mechanisms in these interviews to gain insight into the most effective instruments.

1.2.1 Document Analysis

The following documents were selected based on their availability/accessibility and relevance to the WMS:

- The International treaties (Basel Convention, Stockholm Convention)
- 2012–2020 Seychelles Sustainable Development Strategy (SSDS)
- Updating of the Solid Waste Master Plan for the Seychelles: 2003–2010 (SWM Plan)
- 1995 Environment Protection Act (EPA)
- 2014–2018 Solid Waste Management Policy (SWM Policy)
- 2016–2020 LWMA Strategic Plan
- Trade Tax Act
- Appropriation Act

We analysed the documents through the lens of the following aspects: legal obligation of terms, liability, position in the legal framework, enforcement control, responsibility of implementation, contracting authorities, and coherency.

We then constructed preliminary system diagrams (Figure 1.1) which conceptualise the legal framework governing waste management, incorporating elements of governmental structure and financial mechanisms based on the knowledge obtained from our analyses. We presented these system diagrams to stakeholders during our interviews to allow experts to identify ambiguities in need of clarification.

1.2.2 Expert Interviews

We selected stakeholders to ensure an optimal representation of the different sections of government/the WMS. Table 1.1 details our interview participants and their expertise in our study.

The interviews were semi-structured and based on a guide. In practice, our questions were ultimately tailored specifically to the interviewee according to their field(s) of expertise. All interviewees were shown our system diagrams (see Appendix) and asked to comment on the accuracy of the system as depicted, as well as offer any additional insights they may have.

Briefly, the main topics of discussion pertained to:

1. **Responsibility/Governmental Structure:** specifically, regarding the different duties, background and responsibilities, as well as both inter- and intra- institutional collaboration;
2. **SSDS, EPA, SWM Policy, SWM Plan:** how the documents are used by the stakeholders in their respective roles, who is responsible for the implementation and enforcement of the policies in the documents, and who commissions the documents;
3. **Financing:** amounts of funding received and from whom, revenues generated, and expenditures; and
4. **Instruments:** These are used as a mechanism of control and a regulating tool. Here we wanted to find out which instruments they use and their opinion about the effectiveness of these instruments.

Table 1.1
List of interview partners.

Organisation	Function/Position	Name	Expertise
LWMA	Consultant and Deputy Chief Executive Officer	Lemmy Payet	General waste system, landfill operations, waste classifications
LWMA	Chief Executive Officer	Lena Desaubin	LWMA operations, collaboration with other bodies
Department of Environment (DE)	Senior Legal Officer	Sharon Gerry	EPA
DE	Director of Enforcement and Permits Section	Marie May Jeremie	DE internal operations
Secondary School, formerly the DE	Teacher and former DE employee	Brenda Andimignon	Waste management education
DE	Principal secretary for Environment (PS)	Alain Decomarmond	DE internal operations
DE	Responsible for Environmental Education	Jeanette Larue	DE internal operations, waste education
DE	Director General/Head of Waste and Enforcement Permits Division	Nanette Laure	DE internal operations, financial mechanisms
Seychelles Energy Commission (SEC)	Chief Executive Officer	Tony Imaduwa	Energy systems, biogas, electricity
Sustainability for Seychelles (S4S)	Executive Director/Chief Executive Officer	Michelle Martin	NGO activities, outreach
Seychelles Parliament	Proportional member of the National Assembly	Sebastien Pillay	Waste management politics
STAR	Head of Support Services at STAR Seychelles	Regina Sinon	STAR internal operations, collaboration with other bodies
STAR	Director	Bernard Croguennec	STAR internal operations
Ministry of Finance (MF)	Assorted	Astride Tamatave, Patricia Marie, Seylina Verghese	Budgeting, financial mechanisms
UNDP/GEF coordination	Coordinator of the Waste Management Fund	Maria Jannie	Financial mechanisms
Ministry for Environment, Climate Change and Energy (MEECC)	Minister	Didier Dogley	MEECC operations
Consultancy	Independent Consultant	Cliff Gonsalves	Waste management expert

1.3 Results

In this section, we elaborate on the structures, administrative mechanisms, and financial mechanisms in the WMS. The information provided incorporates a combination of literature and stakeholder information regarding each topic.

1.3.1 Political and administrative structures

Through our literature review and revisions with stakeholders, we developed a final system diagram to demonstrate our understanding of relevant actors in the WMS. Figure 1.1 is the final version of the WMS diagram, and serves as an overview of the current interaction of involved bodies and waste management activities.

Figure 1.1 demonstrates how governmental bodies influence the actors within the Seychelles' WMS. Notably, MF is primarily responsible for the early stages of the WMS, when the waste is still technically a good. As the good transitions to waste, MEECC has central jurisdiction over the WMS, and involves the Waste, Enforcement, and Permit Division (WEPD) and LWMA in waste management and processing. The non-governmental stakeholders have assorted roles that help carry out waste management in the Seychelles. The roles of all non-consumer stakeholders will be discussed further in this section.

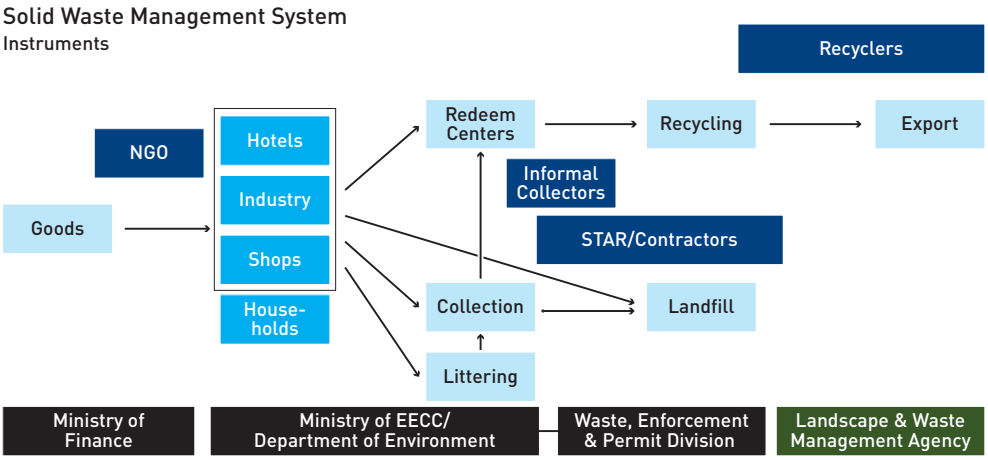

Figure 1.1
System diagram showing an overview of the WMS using PET and cans as an example (final version after multiple validation steps with stakeholders). The presumed flow of waste in the Seychelles is directed by the arrows between processes and stakeholders, from 'goods' to 'littering,' 'landfill,' and 'export.' The light blue markers represent processes, while the medium blue markers represent consumers. The dark blue markers represent other non-governmental stakeholders and are located near their relative primary spheres of influence. Finally, we provide relevant governmental bodies at the bottom, where each is placed underneath its primary obligation in the WMS.

The government is divided into ministries which are each responsible for managing tasks related to their specific function. MEECC is located below and can serve as an example of the organisational structure of a ministry (Figure 1.2). At the head of the ministry is the minister, who oversees the departments within the ministry and is responsible for enacting laws and regulations. The principal secretaries (PS) for the minister manage these departments. Underneath the departments lie divisions, agencies and units with specific responsibilities in maintaining, implementing, and providing jurisdiction for their scope of work. The divisions, agencies and units themselves are stand alone entities derived from specific pieces of legislation and with set mandates.

Ministry of Environment, Energy & Climate Change

MEECC oversees the environment, energy policy, and climate change in the Seychelles. It has two departments, the Department of Environment (DE), and Energy and Climate Change (DECC). Notably, these two branches of MEECC are separate entities only connected at the topmost level of their management structure. However, significant overlap in activities likely exists; for example, the Environmental Education Division engages in environmental education that probably is based on the activities in the Waste, Enforcement & Permits Division (WEPD). We have chosen to analyse only the organisations within MEECC that are involved in the WMS.

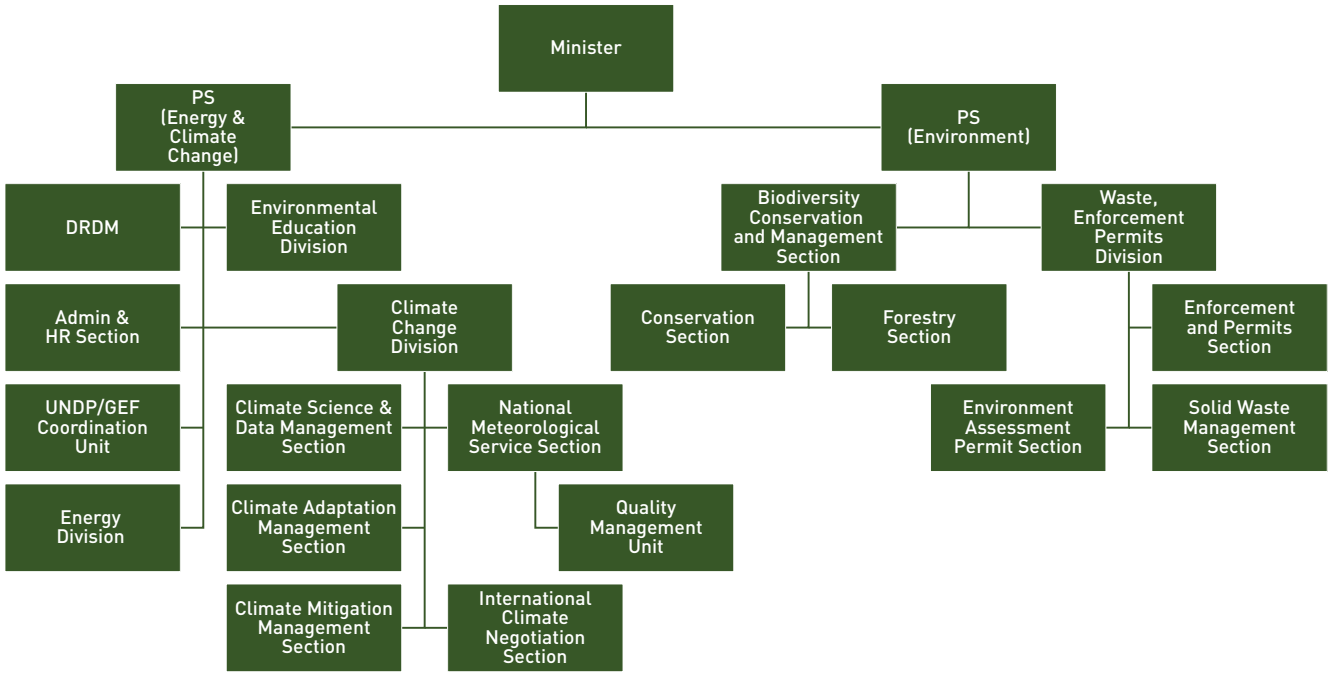

Figure 1.2
Diagram of MEECC organisational structure. Source: MEECC, represented by PS Env. A Decomarmond.

The main function of the DE is to implement "policies and programmes of the national objectives on environment protection" (Environment Protection Act, 2012). One of the DE's primary functions is to coordinate the waste management system, as well as to plan the future waste management system strategically (Roller, 2008). According to stakeholders, the DE primarily creates policies and enforces them. With special regards to waste management, the DE is responsible for contracting waste collection and for supervising the activities of the LWMA. The DE intends to open a new waste manager position, but stakeholders state that the DE is having difficulties in finding someone with sufficient training and interest in government work. Therefore, the DE has been hiring waste management experts as government consultants.

Within the DECC, the Seychelles Energy Commission (SEC) has also expressed interest and involvement in the waste management system, particularly in biogas opportunities (for more information, refer to Chapter 6). The following results focus on the roles of organisations within DE in waste management.

Waste, Enforcement & Permits Division

According to information from our interviews, the main responsibility of the Waste, Enforcement & Permits Division (WEPD) is to enforce and supervise the regulations and laws in the EPA, for example, the Plastic Bag Regulation. The WEPD also implements policies and legislation regarding waste, including issuing permits for imports and authorised discharges of waste. The WEPD was recently restructured to incorporate this aforementioned jurisdiction over waste management.

Environmental Education Division

Interviews with stakeholders indicate that the Environmental Education Division (EED) is responsible for educating the civil society through environmental campaigns, television programs and community outreach on waste issues.

LWMA

The LWMA is a public body that provides landscaping, waste management, and other services on behalf of the government (Policy and Implementation Framework, 2015). The EPA states that the LWMA "shall be responsible for the management of waste including the monitoring and control of a waste disposal site" (EPA, 2014). As indicated by stakeholders and EPA, their responsibilities include:

- providing technical instructions on the deposition at the disposal sites;
- creating contracts with collectors in order to ensure waste collection;
- monitoring contracted waste collection;
- providing statistical data on waste generated, processed and disposed; and
- advising the Minister on waste management plans and written laws influencing their performance.

The government classifies related agencies into a category system, which establishes these agencies' relationships with and dependence on the government. LWMA is classified as Category 1a, which implies a high regulatory dependency on the government (In contrast, public bodies in Category 2 have more autonomy in their management. The government provides Category 2 organisations more freedom to employ staff, to manage expenses, and from supervision by their respective ministry). Consequently, the LWMA is only able to hire new staff subject to the agreement of the Department of Public Administration. Additionally, the Ministry of Finance determines its budget. Stakeholders argue that LWMA should be given more autonomy to manage its budget and employment of staff members, because then LWMA can act more quickly to carry out its tasks without requiring the Ministry's approval.

In the EPA, it is stated that the MEECC must appoint a Chief Executive Officer (CEO) to manage the LWMA. Additionally, a board is responsible for guiding the CEO to meet the LWMA's objectives, ensuring clear output measurements, approving decisions, and reporting to the minister. The board consists of members of the private sector, consultants and at least one staff member from the DE who is currently the legal officer. Stakeholders have said that the DE position in the board enhances information exchange and initiation of regulatory measures. The LWMA is funded by the Appropriation Act as well as through revenues obtained by the Agency (Environment Protection Act, 2012). The Appropriation Act allows the parliament to determine the budget of each ministry and agencies including LWMA once per year. The LWMA's performance is overseen by the DE, and therefore the LWMA is obliged to report its performance according to specific objectives (Policy and Implementation Framework, 2015).

In some interviews, stakeholders argue that the collaboration between the MEECC and the LWMA has potential for improvement. In particular, several stakeholders indicate that the LWMA and DE should coordinate and reallocate waste management responsibilities, for example, through clearly stated responsibilities in the forthcoming revised EPA. As another example, they say that after the WEDP was restructured, it became unclear who should provide enforcement for illegal dumping. Both the WEPD and LWMA are allowed to fine illegal dumping, but for serious offenses, the LWMA cannot fine the illegal dumper and instead must report to WEPD. Interviews show that similar ambiguities and policy inefficiencies obstruct proper waste management enforcement and leave tasks unfinished.

Another stakeholder suggestion is that the LWMA should be as involved in policymaking in an advisory capacity. Since the LWMA is the primary agency involved in implementation, this stakeholder believes it can provide meaningful input to create more effective policies and laws. In contrast, another stakeholder indicated that the LWMA does not collect statistical data about waste management adequate-

ly, which hinders long-term planning. However, it should be noted that it is the MEECC's responsibility to supervise the LWMA's data collection.

Ministry of Finance

The Ministry of Finance is responsible for collecting funds and allocating them to their respective ministries, agencies, and other governmental and government-associated bodies. The Ministry of Finance is responsible for implementing taxes, levies, and other financial instruments which can be used to fund the WMS.

STAR

STAR is the private contractor hired by DE to collect waste and manage the landfills on Mahé. The LWMA is responsible for monitoring and evaluating the performance of STAR. The 20-year contract between LWMA and STAR began in 1997. The contract includes the following objectives for STAR:

- prevention of waste generation;
- recycling and reuse of waste or its use in form of energy; and the
- optimisation of disposal methods.

The contract requires STAR to undertake the following:

- separate waste as efficiently as possible;
- clean beaches and roads on Mahé; and
- guarantee the operation and maintenance of the compost and treatment plant.

According to interviews, LWMA pays STAR 6 million SCR per month for municipal solid waste collection. If STAR does not collect the waste from the bins in time, LWMA deducts a certain amount per site and sends another contractor to clear the bins and deposit the waste on the landfill. While STAR is the primary contractor, LWMA employs 300 other waste collectors.

The contract with STAR ends in 2017. The new SWM policy states that "important lessons have been learnt about operation of such long term investment contracts" and that "future procurement and contracting" will change accordingly (SWM Policy, p. 29). Stakeholders say that a new contract is being developed with international assistance. The duration of the contract will be cut significantly to about 5 years. They believe that all elements of the contract will be more specific to the goals of the SWM Policy compared to before.

NGOs

NGOs primarily aid in activism, promotion, education, civil engagement, project implementation, and policy influence in the Seychelles' waste management sector. According to stakeholders, S4S is the only NGO in the Seychelles that is involved in the waste sector. Stakeholders indicate that the main collaboration between the government and S4S is in the education of consumers on waste management. Interviews show that though the government often underestimates the potential of NGOs, collaboration between the DE and NGOs has developed in a positive direction.

Summary of Stakeholders

We present the following table (Table 1.2) to summarise the stakeholders analysed in the section *Political and administrative structures*. We also demonstrate each organisation's responsibilities, as well as their annual budget, number of staff, and influenced documents wherever possible.

1.3.2 Legal and administrative mechanisms

The following section presents interview and literature results of the legal and administrative mechanisms that have been implemented in the Seychelles waste management system. Figure 1.2 provides an overview of the international and national policies that govern the Seychelles' waste management.

Table 1.2
Summary of waste stakeholders.

Organisation	Responsibilities	Annual Budget (Millions SCR)	Staff	Relevant Documents
DE	Policy making, enforcement of laws and policies related to solid waste, tendering STAR contract	47.9	N/A	Responsible for EPA, SWM Policy, SSDS
WEPD	Enforcement, production of policies and legislations	0.5	35 total; 13 Standards & Enforcement	N/A
EED	Public awareness and environmental education	N/A	6 staff	N/A
SEC	Regulates tariff and electricity regulator	N/A	8 staff	Energy Act 2013
MF	Fiscal policy, budget administration and approval	N/A	N/A	Appropriation Act
LWMA	Control of management of landfill; Monitoring of 300 waste contractors, STAR, implement policies	151	15 staff	Strategic Plan LWMA, monitoring of STAR contract
STAR	Municipal solid waste collection, cleaning of Victoria, management of landfill	72	250 staff	STAR contract
S4S	Promote sustainable living in Seychelles	1.2	2 fulltime, 4 part time, staff, volunteers; 100 members	Promote SWM Policy

International Treaties

Relevant international treaties in the waste sector are the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal, and the Stockholm Convention on Persistent Organic Pollutants (POPs).

The overarching objective of the Basel Convention is to protect human health and the environment against the adverse effects of hazardous wastes, guaranteeing that waste is disposed "as far as is compatible with environmentally sound and efficient management," in the State where it is generated. It aims to control the export and import of hazardous waste (Basel Convention).

The Seychelles declared its inclusion in the Convention on 11 May 1993 (Roller, 2008). The mandates of the convention are only legally binding when integrated into the national law. Analysis has concluded that specific actions and targets – including proper waste collection and allocating waste liability – should be integrated into EPA to fulfill the requirements of the Basel Convention (Roller, 2008).

The objective of the Stockholm Convention is to protect human health and the environment from POPs. Analysis has drawn attention to the fact that Seychelles is obliged to develop a strategy and appropriate treatment capacities for POPs (Roller, 2008). However, land is scarce on the Seychelles, requiring this waste stream to be exported. The Seychelles has signed and ratified the Stockholm Convention.

Environmental Protection Act of 1994

The aim of the Environment Protection Act of 1994 is "to provide for the protection, improvement and preservation of the environment and for the prevention, control and abatement of environmental pollution" (EPA, 1994, Part 1, Section 3). Significantly, Section 3.12–13 provides prevention, control, and abatement of waste and waste minimisation. The EPA provides legislation, establishes enforcers and provides fines for waste and waste minimisation (Roller, 2008). Under the EPA, a regulation was enacted in 2008 to restrict the use of plastic bags (Environmental Protection Act).

Stakeholders state that the EPA is currently being revised because there is a need for updating. One major change will be that the MEECC will have the capacity to impose levies through a shift of this power from the Trade Tax Act to the EPA. Another change is to increase penalties to match inflation. One stakeholder also mentioned that the EPA must be revised before the SWM Plan can be updated. Interviews show that mechanisms such as levies and bans must be implemented in the EPA to allow the government to improve waste management.

2012–2020 Seychelles Sustainable Development Strategy

The Seychelles Sustainable Development Strategy (SSDS) integrates national priorities for sustainable development and structures the implementation of the integrated action plans (SSDS). The first strategic objective regarding waste is "to enhance the legal framework for the management of solid waste" (SSDS). The SSDS also states that a proposed 2011–2020 Solid Waste Master Plan will complement its main objectives and programmes, specifically for waste management (SSDS). This updated Solid Waste Master Plan has not yet been developed and stakeholders indicate it is unclear when it will be released.

The interviewees indicated that the SSDS and the SWM Policy guide new legislation and regulations. However, due to the improper allocation of responsibilities and enforcement ambiguities, the implementation of SSDS objectives has been delayed by two years. A midterm review of the SSDS is planned. Additionally, some stakeholders believe that the SSDS should provide more specific objectives, and that the budget allocated for SSDS implementation is too small. An example of a current SSDS objective to "enhance the legal framework for the management of solid waste," with a guiding activity of "updating main legislation" (SSDS, p.115). Unfortunately, the SSDS does not indicate responsible parties for carrying out this task, nor specific tasks to accomplish this activity.

Stakeholders state that the EPA is not being revised by the same authors of the SSDS. The only link between these two documents is the crosschecking done by WEPD, which will verify that the objectives in the EPA adhere to those in the SSDS. There are no criteria for how to provide feedback and guidance for SSDS implementation. Stakeholders say that the SSDS document states that a Secretariat should be established. According to interviews, a SSDS council with principal secretaries exists, but their specific roles in SSDS implementation are not clearly defined.

2003–2010 Solid Waste Master Plan

Effective between 2003–2010, the Solid Waste Master Plan (SWM Plan) was primarily an evaluation of the current WMS and an assessment of potential WMS options.

Stakeholders hold different opinions about the necessity and function of the SWM Plan. Some believe that the SWM Plan is a strategy that defined how and when waste management activities should be implemented. One argued that the LWMA should be responsible for implementing the objectives in the SWM Plan, and that therefore a SWM Plan is not necessary per se. Others believe that because the SWM Plan is developed by waste experts, it is crucial for the government to plan waste management strategies based on this expertise. The SWM Plan does provide significant guidance for waste management,

and that the Environment Protection Act should require that the SWM Plan be updated (Roller, 2008). One objective of the 2016–2020 LWMA Strategic Plan is to develop a National Waste Management Master Plan. However, it does not state within the former who will be responsible for drafting this plan.

2014–2018 Solid Waste Management Policy

The objective of the Solid Waste Management Policy (SWM Policy) is "to protect public health and the environment through the sustainable management of solid waste" (SWM Policy, p.11). The policy framework is based on nine guiding principles, including the Waste Hierarchy, the Precautionary Principle or the Polluter Pays principle (SWM Policy, p.10). The SWM Policy provides a list of actions, as guided by the SSDS, to improve waste management. These actions build upon the obsolete SWM Plan and the outcomes of the 9th European Development Fund (EDF) solid waste management programme and should be updated every two years (SWM Policy, p.12).

The LWMA is the organisation often responsible for implementing the actions called for in the SWM Policy, while the WEPD is responsible for their enforcement. According to interviews, WEPD can easily work with the SWM Policy. However, the LWMA does not follow the SWM Policy because it believes it has not been validated. Others confirm that policy is validated and properly endorsed.

Stakeholders agree that there is little clarity as to who is responsible for implementing the SWM Policy. This is because the MEECC, WEPD, NGOs, and other partners from the private sector are all somehow de facto involved in SWM Policy actions.

2016–2020 LWMA Strategic Plan

According to the 2015 Policy and Implementation Framework Policy, public bodies are required to develop a three- to five-year Strategic Plan with clear performance standards and targets in collaboration with their parent ministry. LWMA's 2016–2020 Strategic Plan includes situation analysis; strategic vision, priorities and goals; and objectives and implementation plans.

Summary of Legal & Administrative Implementations

Table 1.3 summarises the findings presented in the section *Legal and administrative mechanisms*. In this table, we summarise the studied documents, and analyse them based on the criteria in the left column. The inputs into the table are based on our knowledge after conducting the study.

Table 1.3
Summary of legal & administrative implementations.

Analysis Criteria	International treaties	EPA	SSDS	SWM Policy	SWM Plan	Strategic Plan
Lawfully mandatory	Yes, partly integrated in the national law	Yes	No	No	Outdated	No
Liability	No, partly integrated in the national law (EPA)	Yes, Art. 3 1. (2) "This acts binds the Republic"	Endorsed by cabinet	Validation workshop	Outdated	Not clear
Position in the legal framework	Guidance/ national law depending on ratification process	Environment law	Overarching document, strategy	Guideposts for strategy development and implementation (SMW Policy)	Guidance for LWMA and MEECC	Guidance for LWMA
Responsibility of implementation	MEECC	MEECC	SSDS Secretariat under MEECC (p. 22)	LWMA key in implementing this policy (p. 29)	Unclear	LWMA
Contracting authorities	UN COP, UNEP	MEECC	MEECC	MEECC	Unclear	MEECC
Enforcement control	MEECC	MEECC	Mentioned for each objective. For waste, mostly LWMA	Unclear	Unclear	Unclear
Coherency between documents	Partly included in the EPA	Legal framework basis for implementation of SSDS	Links at each objective mentioned, Convention	Builds further on the SWM Plan. The actions are consistent with SSDS.	Was consistent with the existing environment Management plan for the Seychelles 2000–2010. Consistent with EPA 1994, overlaps between SWAC and MEECC	Policy and Implementation Framework 2015

1.3.3 Financial and Legal Mechanisms

This section describes the mechanisms used by the government to meet waste management objectives and to fund waste management projects.

Implemented mechanisms

This section describes the financial and legal tools implemented by the government to reduce illegal dumping and waste deposited at the landfill. Figure 1.3 provides an overview of existing financial instruments implemented in the Seychelles to finance and operate the WMS.

As demonstrated in Figure 1.3, the WMS contains five significant financial mechanisms that control the flow of money to influence the processes and stakeholders in the WMS. These financial mechanisms are controlled by acts, policies, and other documents, which are ultimately produced by the government. Therefore, the gov-

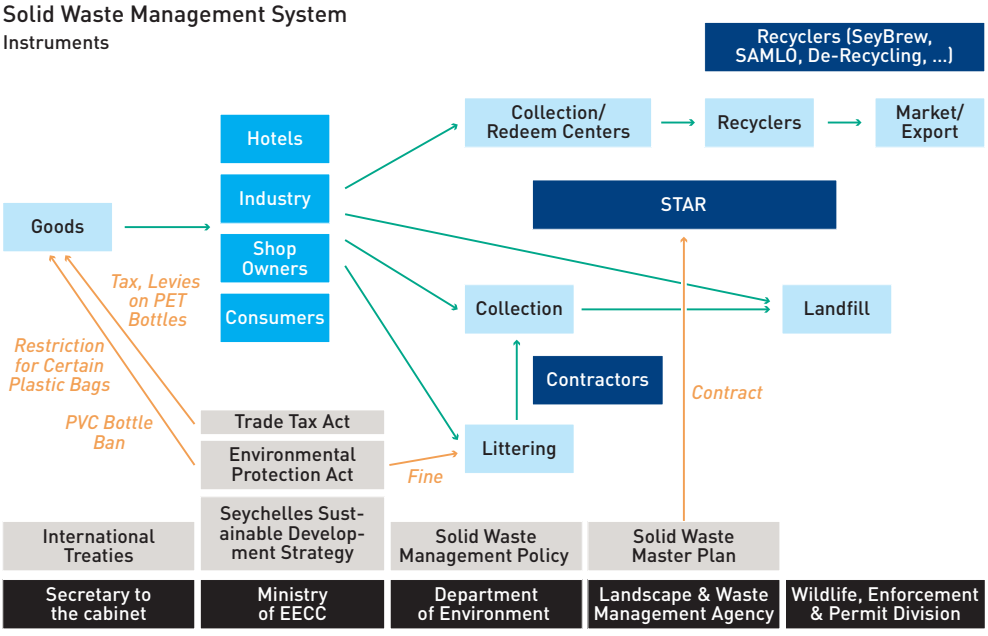

Figure 1.3
Overview of financial instruments implemented in the WMS. The sea green arrows indicate the flow of waste from goods to landfill and export, similar to Figure 2.1. The orange arrows indicate the flow of money from the governmental acts to their respective processes or stakeholder, according to their financial instrument. Again, the non-governmental stakeholders are placed near their spheres of influence, while the governmental bodies (black) that are responsible for their specific legal document (grey) are shown on the bottom below the sections of the WMS over which they have influence.

ernment has a high influence over the operations of the WMS. These five financial mechanisms are described further in this section.

Payment of contractor

In the contract between LWMA and STAR, LWMA is required to pay STAR per tonne of waste collected at the landfill. Interviewed stakeholders reveal that STAR is instead paid a flat fee of 6 million SCR per month, and believe that this does not incentivise STAR to sort waste at the landfill. Because LWMA has many other private contractors, a large portion of its budget is allocated to pay other contractors besides STAR.

Restrictions on plastic bags

Through the Environment Protection Regulations in the EPA, the manufacture, trade and commercial distribution of domestically produced and imported plastic bags with thickness under 30 micrometres are restricted. In a revision last year (2015), the restriction became more stringent: all plastic bags with thickness under 50 micrometres are now banned. One stakeholder believes that fewer thin plastic bags are deposited in the landfill. Stakeholders indicate that the government is discussing banning plastic grocery bags completely.

Levy on PET bottles and metal cans

The Trade Tax Act imposes a 1 SCR levy on PET bottles and aluminium cans. The Ministry of Finance is the only governmental body that can impose levies, but after the EPA is revised, MEECC will be able to apply levies as well. Stakeholders agree that levies have effectively diminished PET and metal can deposition on the landfill, and that the government prefers this method because it is self-sustaining financially.

Fines

The EPA declares the price of and terms for fines for littering, fly-tipping, illegal dumping and other offenses. The fine amount is generally 500 SCR for littering (EPA). Stakeholders believe that there are few fines given for littering and fly-tipping because offenders are not easily seen. Many organisations, including the environmental officers from the WEPD but also the inspectors from the LWMA, are allowed to fine offenders. Citizens can also call the Green Line, a telephone hotline, to inform the Environmental Education Division when they see illegal dumping.

Education

EED, LWMA and NGOs are primarily responsible for waste education. The EED works closely with the WEPD for waste reduction and management advertising. S4S also collaborates with the EED to promote campaigns to prevent littering. There are different opinions about the role of education. Some interviewed stakeholders believe that the public has been educated enough regarding proper waste management, while others believe that the government could increase waste education at schools and through promotion.

Sources of revenue

This section provides an overview of the revenue sources that fund waste management projects. The three primary funds are the Consolidated Fund, the Environmental Trust Fund and the Waste Management Trust Fund. Significant revenue pools are described in detail in this section.

The Consolidated Fund

The Consolidated Fund is the overall state budget. The Minister of Finance, Trade and Blue Economy appropriates the money from the Consolidated Fund in the Appropriation Act to governmental bodies. The 2016 Consolidated Fund budget was 6'564'229'000 SCR, according to an interview. Relevant cash flows and their proportion of the total budget include:

- MEECC, 47'865'000 SCR (0.7%);
- LWMA, 151'434'000 SCR (2.3%); and
- WEPD, 500'000 SCR.

Waste Management Trust Fund

The Waste Management Trust Fund (WMTF) was established in the 2007 Waste Management Trust Fund Notice under the Public Finances Act. A stakeholder said its primary objective is to finance the levy system for PET bottles and aluminium cans. Additionally, the fund can also assist in public education on waste management. The fund is administered by a board consisting of the PS of the Environmental Department, the PS of the Financial Department and other members appointed by the MEECC, such as representatives from the Ministry of Education, representatives from industry, and the Chamber of Commerce Industry. Most of the fund consists of money collected through levies and money raised by public activities and donations (Waste Management Trust Fund Notice). We were unable to determine the amount of money allocated in this fund.

The levy system falls under the WMTF. Levies are collected when PET bottles or aluminium cans are imported or purchased and fall directing into the WMTF. Then, the money is transferred to redeem centres where consumers return used bottles and cans for a 50 cent refund. Stakeholders indicate that the redeem centres receive an additional 15 cents per PET bottle and 20 cents per metal can from the WTMF to cover operations costs, or transport costs from La Digue and Praslin to the exporters on Mahé. The flow of materials and money through the levy scheme is discussed further in Chapter 3.

The EPA already provides a legal basis in Section 13 for the MEECC to introduce "a fee to be paid to the designated Agency under Section 12(2) by importers or manufacturers of specified materials, products or goods including packaging material to cover costs in respect of disposal of the materials, products or goods" (EPA, Section 13). However, the PET bottles and metal cans levy is not a fee under the EPA but a tax under the Trade Tax Act. Further analysis demonstrates that the advantage

of a fee system over a tax is that fees can feed directly into the waste management system while tax revenues fall into the overall state budget, and could therefore finance non-waste projects (Roller, 2008).

Environment Trust Fund

The Environment Trust Fund (ETF) is also defined in the Public Finance Act in the Environment Trust Fund Order. The fund is administered by the Minister and PS from the Ministry of Environment and Finance and other members nominated by the ministers. The objectives of the fund are to:

- Carry out programmes to prevent and reduce pollution;
- Promote environment education and research;
- Clean and beautify Seychelles; and
- Do such other things as may be necessary or conducive to the protection, preservation or improvement of the environment (ETF Project Manual).

The ETF has an annual budget of approximately 6 million SCR. Fees on treated water for households, fines from illegal dumping, court fines, donations and sales on niche items – including Coco de Mer and Sooty Tern eggs – generate money for the ETF. A monthly environmental charge of 15 SCR is defined in the Water Supply Regulations, 2014 in the Public Utilities Corporation Act. Stakeholders disagree on the price of the environmental charge and whether it should be required. The fund is accessible to all individuals and organisations wishing to implement projects that benefit the environment (ETF Project Manual). WEPD may request for additional money from the ETF to cover unexpected cleaning. An interviewed stakeholder says that from January–June 2016, 300'000 SCR was allocated to WEPD for unexpected cleaning.

European Development Fund

The European Development Fund (EDF) was granted to the Seychelles. The new landfill, Providence II, was paid for by the EDF.

Collection & Disposal of Waste

Another significant source of income for the waste management system is waste collection. As indicated by stakeholders, all money from waste collection is given to LWMA. Waste is classified by STAR into municipal solid waste and commercial waste, and designates fees accordingly. Households are currently not charged for municipal solid waste unless in large proportions. In this case, households must pay a fee of 50 SCR/tonne at the weighbridge to deliver waste to the landfill. Commercial waste producers are required to have either a contract with LWMA or STAR for waste disposal. In both contracts, STAR collects the waste. Stakeholders indicate that LWMA prefers to have contracts with the businesses.

Approximately 20 million SCR is generated annually from waste collection. Stakeholders indicate that this feeds into a suspension account and then largely

flows into the Consolidated Fund. Because the suspension account is managed by the Ministry of Finance, stakeholders reveal that LWMA cannot allocate money they collect as freely as they wish.

Stakeholder opinion on regulatory tools

Through a survey, stakeholders provided suggestions to improve waste management in the Seychelles. The list involves financial, legal, and technical solutions to lower waste production, illegal dumping, and deposition and includes:

- Increasing education and awareness
- Tax reduction or exemption on biodegradable goods
- Levies on waste collection at households and businesses
- Introduction of the levy system for more goods, e.g., glass bottles
- Banning more products, e.g., Styrofoam take-away boxes
- Setting standards for imported product quality
- Incentivise investments in waste management
- Introduce a bed fee for tourist that could go into the waste management system

1.4 Discussion

The results of the literature analysis and stakeholder interviews demonstrate several areas of concern regarding waste management policy. In this discussion, we provide an analysis of significant legislative obstacles: unclear responsibility allocation, financial inflexibility, and lack of incentives.

It is the opinion of many stakeholders that the government only establishes objectives in its waste management strategies and contracts without providing specific tasks to the organisations involved. When responsibilities are not allocated, then organisations are not liable for or aware of these objectives. Therefore, waste management strategies become delayed or ignored. The ambiguities lie primarily in two points in government legislation: in the contracts between government bodies and in task formation and delegation.

The contracts between the MEECC, WEPD, and LWMA often provide objectives without specific, distinct tasks to establish liability among organisations. The MEECC is primarily responsible for creating the policies which the WEPD and LWMA must enforce. However, sometimes the contracts overlap or are not specific enough to ensure that all objectives are fulfilled. An example of these ambiguities includes the dual role of WEPD and LWMA for fining

illegal dumping. While the aim of both organisations having jurisdiction over fining is to increase vigilance, responsibilities are constantly passed between organisations because they are unclear who is actually delegated the task. Ultimately, policymaking and strategic planning become forgotten or severely delayed, like in the case of the SWM Policy. Setting deadlines and responsible persons in waste management and enforcement will clarify roles and improve collaboration between the government bodies.

Some stakeholders believe that the LWMA should be given more autonomy, for example, by being classified as a Category 2 organisation. Proponents argue that since the LWMA enforces and directly handles waste management, it should be given more flexibility and responsibility to manage itself, in particular, more freedom to select staff, manage budgets, and be involved in policy decisions regarding waste. These stakeholders believe that establishing a more equal collaboration between the LWMA and MEECC policymakers will produce realistic legislation with effective enforcement. In any case, the overseeing of the LWMA by the DE and MEECC should be improved by establishing specific performance indicators and responsible managers to ensure that contracts are followed and objectives are being met. In the strategic plans of each organisation, the roles in collaboration should be established between partner government bodies.

Similarly, there is a lack of delegation of specific tasks to government bodies in documents including the SWM Policy, SWM Plan and SSDS. When objectives are not broken down into concrete actions, they become easily ignored. While some stakeholders argue that the SWM Plan is irrelevant and that the LWMA should instead be responsible for setting deadlines, others believe that an updated National Waste Management Master Plan would help the government to set deadlines and allocate tasks in the SWM Policy and SSDS. However, this master plan will not be developed unless an organisation is made responsible for it.

Another source of ambiguity identified by stakeholders concerns the lack of proper verification while updating the EPA. There is no clear procedure for how the EPA is cross-checked with other documents, such as the SSDS . As a result, there may be incongruous objectives and responsibilities distributed between the EPA and SSDS. Many stakeholders indicate that the SSDS may also require revision to specify and delegate tasks and obligations between the relevant organisations. An example demonstrated by past analysis shows that while the Seychelles agrees to partake in international conventions, it does not oblige itself to follow membership criteria until the objectives are included in its legislature. Therefore, these objectives should also be concretised and included in the SSDS and SWM Policy.

Additionally, the lack of financial flexibility provided to government bodies and contractors in legislation is a source of concern. The Ministry of Finance must approve any levies, taxes or other financial mechanisms before they can be introduced to the public. However, this procedure introduces a significant time lag for the waste management system. In practice, this means that while the MEECC is given the flexibility to introduce its own financial instruments, it must wait for official approval from the Ministry of Finance. Until then, EPA revisions cannot be completed, which also prevents a new SWM Plan from being developed. This also delays other policies like the complete ban of plastic bags from taking place.

Another financial challenge for waste managers is the allocation of money. The WMTF causes money transfer to follow a closed loop, in which funds earned from the levy directly support the refund and redeem centre operations. This implies that there will always be money to sustain the levy scheme. However, when services are taxed, this tax revenue flows into the consolidated fund which does not necessarily apportion money according to the services provided. Therefore, stakeholders believe that waste managers are not always fairly compensated for their operations and cannot carry out all of the policies, enforcements, and other implementations mandated in their contracts. By allowing organisations control over their finances and revenues, they would have more flexibility and potentially responsibility to improve waste management.

Finally, we believe that stakeholders in the waste management system may require more incentives or mechanisms. One example is STAR, who is paid a flat fee per month, without any incentive to separate waste or process it in other ways besides landfilling. If STAR were paid according to tonnage of waste fractions or deducted for not meeting deposition or diversion goals, some stakeholders believe that STAR would be motivated to divert more waste from the landfill. Interviewed stakeholders have provided many more recommendations to the government for methods to improve waste management. They vary in ease and cost of implementation, but can be considered by policymakers.

Stakeholders mention that it is a challenge to recruit qualified employees in the waste management sector. Currently, there are no experienced waste management experts working in the government, though there is a staff member with a Master's degree in waste management who has a low level of responsibility. It appears that instead, the experts tend to be self-employed consultants that work for the government on certain projects.

The current waste management contract with STAR expires at the end of 2016. The Seychelles government has indicated that it is interested in improving its contractual agreements with the future waste manager, including by decreasing the length of the contract to five years from 20. As is the case with other agreements and documents, the contract's effectiveness depends strongly on clear allocation of responsibilities. The terms for the contract must be clearly defined and assigned to a responsible position who will oversee the fulfillment of these terms. Additionally, because five years is significantly shorter than the previous contract length, the government should establish clear indicators to measure performance to determine possibilities for renewal.

1.4.1 Limitations of the study

Most of the information in this study is qualitative and entirely based on literature and stakeholder input on the topics addressed in this chapter. While we attempted to capture as many viewpoints as possible on the issues presented, there are likely more opinions that were not covered due to time constraints, including those of recyclers and consumers. Many of the interviews contained information that could not be presented in the report due to confidentiality.

Additionally, the lack of an online database prevented us from obtaining clear data and information about waste in the Seychelles. We believe that future researchers, policymakers, and other interested persons would benefit from online resources regarding the waste system and the management behind it.

1.5 Conclusion

The government holds a lot of power in determining the fate of the WMS in the Seychelles, as the legal and policy framework ultimately allows and prevents waste infrastructure implementations. Establishing clear tasks with allocated responsibilities is required to enforce the goals and laws identified in the framework. Otherwise, as has been seen in various cases in the Seychelles, implementations are severely delayed or even forgotten. A significant reason is that many of the agreements, plans, policies, and other documents do not lay specific, tangible actions with liable people responsible for management or enforcement.

Implementations must be properly financed, and many current stakeholders within the WMS feel constrained financially, preventing them from engaging in more waste reduction. The organisations involved would benefit from increased financial independence to manage their own funds. Additionally, the government has many tools – including taxation, the levy/deposit system – to raise money to encourage waste reduction implementations in the Seychelles. Incentives, financial or otherwise, must come from the government to encourage other stakeholders to participate in waste reduction.

As an outlook, the current contract with the waste manager expires in 2016, opening opportunities to introduce new policy and waste management strategy into the Seychelles. With the input of all stakeholders in the WMS, the government should revise its long term vision to include tangible tasks to that will help it achieve its waste reduction goals.

1.6 References

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2 Optimising Recycling Markets

2.1 Introduction

The Seychelles SWM Policy 2014-2018 indicates that increasing recycling processes is one of its objectives to divert waste fractions from the landfill. Recycling represents an attractive opportunity to lower the amounts of waste deposited in the landfill through two ways: recycling waste materials directly diverts them from the landfill, and recycled products displace incoming products made from raw materials, further minimising waste production.

Because recycling processes often form specialised markets, stakeholders introduce new recycled products, systems and technology into the economy and civil infrastructure, which in turn require capital investments and would therefore imply financial risk. It is important to analyse available recycling opportunities before investing in technology to prevent unsuccessful business ventures. Therefore, waste materials should be considered for recycling potential.

Recycling potential comprises the economic value, recovery rate and ecological potential of a waste material. Waste fractions with high recycling potential include certain glass, organics, metals, plastics, and paper (Kim et al, 2009). Additionally, the type of recycled products should be considered. Processing options in recycling include downcycling, recycling, and upcycling, which decrease, maintain, and increase the value of the product after processing, respectively. Exporting waste materials out of the system, defined here as Mahé, may also be a solution when a country does not have the capacity to process the waste itself.

In the Seychelles, stakeholders from the public, private, and informal sectors currently conduct some recycling. However, as indicated by stakeholders from our study, after the free trade market was liberalised, cheap imported goods began to dominate the market, discouraging businesses from creating recycled products to enter the same markets. Additionally, few materials are recycled and previous research has shown that such programmes occur at relatively small scales compared to the amount of waste that is landfilled. Many past recycling initiatives, such as for glass and organic waste treatment, have also become obsolete (Talma and Martin, 2013). We believe that little cohesive analysis has been conducted on past recycling failures and the obstacles for implementing recycling infrastructure in the Seychelles.

Our goal is to provide a broad analysis of the recycling system in the Seychelles. To accomplish this objective, we investigate past failures, current, and future opportunities, and stakeholder opinions on recycling technologies. For this study, we have chosen to investigate the following waste streams: PET, aluminium cans, paper, and glass (for more information on organic waste streams, see Chapter 6). We selected these streams based on economic and ecologic potential, recovery rate, and current landfill deposition rates in the Seychelles. We propose the following

research questions to guide the methods and results of this study:

1. What is the current state of the recycling systems in terms of the relevant stakeholders and recycling initiatives, past and present?
2. What options for waste separation and collection exist and how can they be improved?
3. What are perspectives on recycling and recycled products at the household level?

2.2 Methods

Our primary goal was to understand the current recycling system of the Seychelles in terms of its infrastructure and stakeholders. To accomplish this, we combined literature and stakeholder information to address our knowledge gaps. First, we reviewed papers, studies and other informative material regarding past and present recycling projects in the Seychelles. Our next step was to acquire further information and opinion from stakeholders to broaden our understanding of the social, economic and political aspects of the recycling system. We engaged in semi-structured interviews, questionnaires, and surveys with stakeholders, who included waste experts, recycling business owners, government officials, and consumers.

2.2.1 Literature Review

We consulted a variety of existing documents about the recycling system in the Seychelles. These include government reports, studies by NGOs, presentations by stakeholders, and leaflets for recycling. A full list with citations is provided in the Annex, and includes:

- Assessing Public Awareness towards Waste Management in Seychelles
- Seychelles Strategic Land Use and Development Plan
- S4S Sustainable Management of Glass Waste Project Hotels & Resorts Survey
- The status of waste management in Seychelles
- Reduce, reuse, recycle: tips for reducing waste going to landfill in Seychelles
- Sustainable Waste Management Workshop
- Increase public awareness of the 3 Rs of sustainable waste management
- Survey with waste producers on Mahé

Through this literature review, we achieved an overview of the waste management system with a special focus on recycling systems in the Seychelles. The outcome of overview is a diagram depicting the relationships between the stakeholders involved in recycling in the Seychelles. Additionally, because the documents provided specific information about these stakeholders, this information gave us guidance as to which were the most appropriate stakeholders to interview.

2.2.2 Stakeholder interviews

We conducted semi-structured interviews and questionnaires with stakeholders to guide our questions and provide flexibility and discussion. The choice of interviewees reflects our objective to gain a broad understanding of the recycling system in the Seychelles from multiple perspectives. Therefore, we selected stakeholders such as waste management companies, PET and can Redeem Centres, recycling businesses, NGOs, and government agents knowledgeable in waste and recycling issues.

We structured the topics of the interview questions according to the stakeholder. For recyclers, Redeem Centres and the waste management companies, the focus was on the state of business, infrastructure, collection, finances, cooperation, government involvement and public awareness. For the government officials, we asked specific questions about recycling infrastructure, government involvement and financing. The interview guideline for NGOs included further questions about current and past projects. We used these interviews to provide supplementary literature analysis of recycling opportunities.

Additionally, we conducted an "Options Analysis," a multiple-choice questionnaire (MCQ) with stakeholders. In the MCQ, we provided ideas for improvements to the current recycling system based on stakeholder interviews. Our goal was to quantify stakeholder preference for these improvements. Each aspect of the recycling system was formulated into a question, such as "Who should be the collector?" or "What financial incentives should be used?" We provided a list of answers and the stakeholders marked their choice with a short explanation. We compiled these results and identified the most popular options. The full questionnaire is available in Appendix 2. Table 2.1 lists the stakeholders interviewed between June 30 and July 5, 2016 in Mahé, Seychelles.

2.2.3 Household surveys

We conducted surveys with members of the public regarding household waste, specifically PET bottles, glass, paper and aluminium cans. 23 consumers were surveyed at random, and were of different age groups and different genders. We conducted the surveys in different districts of Mahé, namely in Anse Royale, the North region, and Victoria. The language used was mostly Créole.

The purpose of the surveys was to learn about public views regarding recycling. In contrast to the semi-structured interviews, these surveys were to some degree comparable between the different respondents. We could not conduct any statistical analyses of the results due to the small sample size, meaning that the results are not necessarily representative of the entire population of Mahé. Still, data may show some trends.

Table 2.1
List of interviewed stakeholders. A cross in the MCQ column indicates that the stakeholder completed a MCQ.

Sector	Interview partner	Contact person	Function	MCQ
Industry (Recycling and Waste Management Companies)	Harini	Kandan Rengassamy and Mr. Antat	CEO and worker	X
	DE Recycling	Donald Ernesta	CEO	X
	Navin's Paper Recycling Company	Navin Naidoo	CEO	X
	STAR Seychelles	Bernard Croguennec and Regina Sinon	CEO and manager	–
	Providence Redeem Centre	Kandan Rengassamy	CEO	X
	Rogan's Construction Company	Patrick Rogan	CEO	X
	Anse Royale Redeem Centre	Frankie Bakas	CEO	X
	Maag Recycling (Switzerland)	Judith Maag	CEO	–
Government	Landscape & Waste Management Agency (LWMA)	Lemmy Payet	Consultant, waste expert	X
	Ministry of Environment, Energy & Climate Change (MEECC)	Denis Matatiken	Special advisor to minister	X
	Ministry of Education	Terry Mousbe	N/A	–
NGO	Sustainability 4 Seychelles (S4S)	Michelle Martin	CEO	X
	Citizens Engagement Platform Seychelles (CEPS)	Marie Purvis	Member	–

Questions in our household surveys covered the willingness to buy products made from recycled glass or paper products and quantify their willingness to pay for these products. Furthermore, ideas for recycling of glass and paper products were collected. Other questions included the education of school-aged children on the concepts of recycling waste materials as well as financial incentives for separation of recyclables and household waste. The full survey is provided in Appendix 2.

2.3 Results

This section describes the findings of the literature analysis and the results of the interviews, options analysis and consumer surveys. First, we present a diagram representing the stakeholders involved in the recycling system and discuss current and past recycling projects. Then, we focus on the options analysis and stakeholder opinion on recycling potentials from interviews. Finally, we present the results of the consumer surveys.

2.3.1 Current and Past Recycling Systems

The 2014–2018 Solid Waste Management Policy and 2012–2020 Seychelles Sustainable Development Strategy indicate that there are objectives for increasing recycling (SWM Policy). However, clear targets or policies in these documents have yet to be established.

The current recycling scheme concerning PET bottles, aluminium cans, paper and glass is displayed in Figure 2.1. All material streams enter the Seychelles through import because local production is on a small scale, if existent, and is therefore negligible. Typically, the goods are sold, consumed and deposited. Deposition is the primary point at which infrastructure for recycling begins to be needed. The primary deposition sites are municipal and commercial bins, Redeem Centres and littering.

According to stakeholders, the government-contracted company STAR collects waste from the municipal and commercial bins and brings it unsorted to the landfill. Some have stated that even if hotels and companies separate their waste, the segregated fractions are ultimately mixed together upon collection. Stakeholders say that previously, the government and STAR attempted to separate the waste. However, some stakeholders argue that STAR is not compensated enough to separate the waste, and others argue that segregation stopped when stockpiles of the separated waste were left unused.

Paper and glass fractions remain at the landfill, while the informal sector collects large proportions of PET and cans from the bins, littering, and landfill. The informal collectors are financially compensated when they bring these items to the Redeem Centres, which in turn distribute them to DE-Recycling and Harini to be processed and exported to countries such as Mauritius, Russia, China and India, according to stakeholder interviews. There are four Redeem Centres on Mahé and one each on Praslin and La Digue.

Secondary streams from typical deposition are managed by Navin's Paper Company, Rogan's Construction Company and Seychelles Brewery (Seybrew) for paper, glass, and glass waste, respectively. These recycling businesses provide deposition alternatives that divert a small fraction of the waste from typical deposition streams. Seybrew's products re-enter the market through recycling while Navin's Paper Company upcycles and Rogan's Construction Company downcycles the waste.

Literature and stakeholder information on the current and past states of each waste stream's recycling system are presented in the following sections.

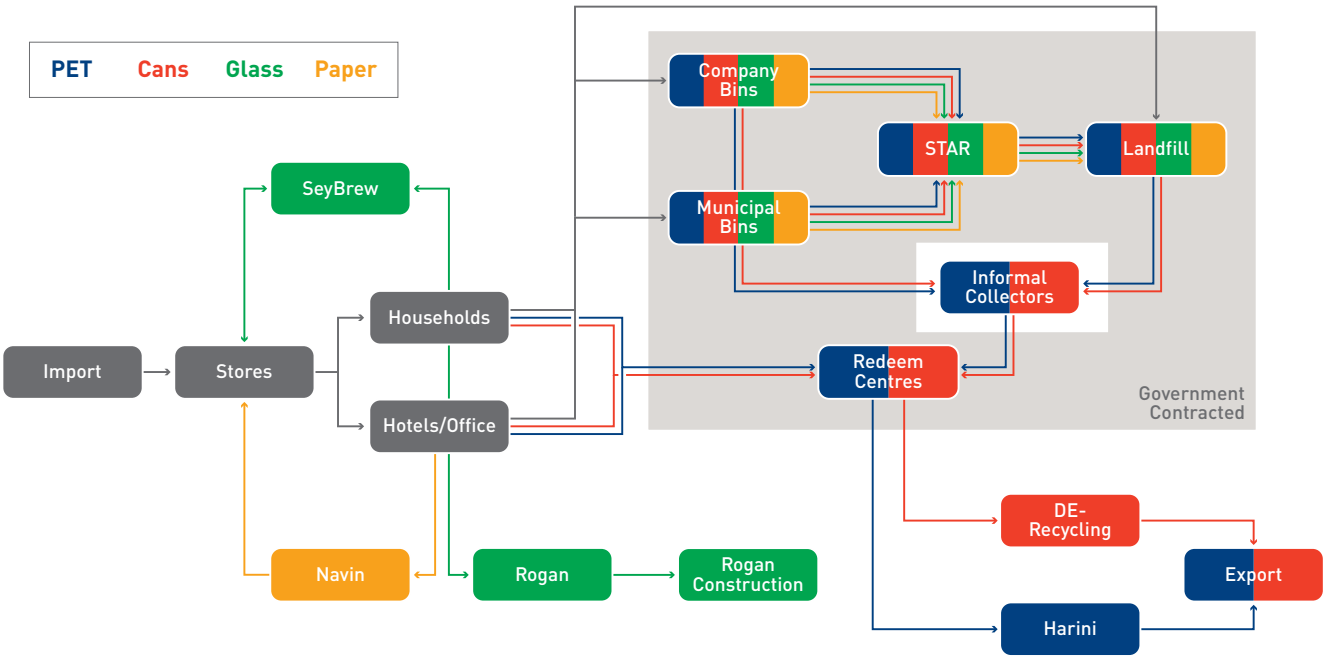

Figure 2.1
System diagram of the recycling scheme in the Seychelles for the waste streams, PET, aluminium cans, paper and glass. Arrows indicate the material flows. For a more detailed and quantitative depiction, refer to Chapter 3.

PET and aluminium cans

This subsection describes PET and aluminium streams together because they have recycling systems which function similarly. All PET and aluminium beverage cans are imported into the Seychelles. The financial scheme in place to support PET and aluminium recycling is provided in Figure 2.2, and is based on values provided by stakeholders. The government collects the levy upon importing, making the financial burden ultimately fall on the consumer who pays an elevated price on goods to cover the levy. As represented in Figure 2.2 below, the levy for PET and aluminium cans is 70 cents and 1 SCR respectively causing the consumer to lose 20 cents and 50 cents for PET and aluminium cans, respectively, due to the levy system. The government then gives the Redeem Centre 65 and 70 cents, respectively, per PET and aluminium can. This money covers operational costs and the refund that Redeem Centres return to the consumers. In both cases, consumers can bring PET bottles and aluminium cans to the Redeem Centres to receive a 50-cent refund.

Full estimates for PET and aluminium material flows are provided in the material flow analyses conducted in Chapter 3. As demonstrated, most of the PET and aluminium is collected after deposition and does not remain in the landfill. Stakeholders believe that the high collection rates can be attributed to the informal sector. Informal collectors can collect up to 5'000 items per day per person from municipal

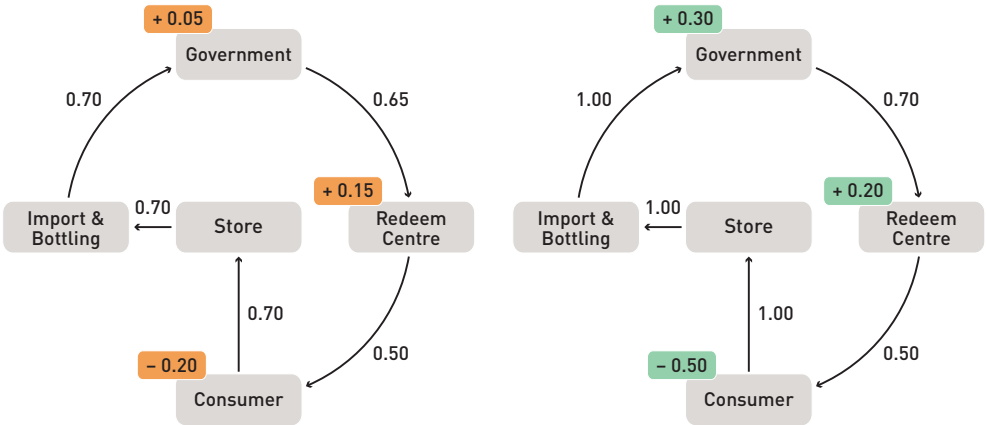

Figure 3.2
Money flux for PET (left) and aluminium cans (right) recycling system. All values are in SCR.

waste bins, beaches, roads and the landfills (Informal Collectors, personal communication). They bring collected PET and aluminium to the Redeem Centres and often rely on the refund they receive as a source of income.

Stakeholders state that hotels and businesses are the only other consistent collection points for PET and aluminium. The government does not provide a collection service specific for PET and aluminium. Some Redeem Centres arrange a collection service that picks up stockpiled PET and aluminium from hotels and other businesses. Interviews indicate that some individuals buy bottles and cans from their neighbours or hotels and companies for less than 50 cents, and resell them to the Redeem Centre. Many stakeholders believe that collection of these items should be improved to decrease landfilling rates.

Ultimately, stakeholders say that PET bottles are shredded at Harini and then exported. Aluminium cans go to DE-Recycling, where they are compressed and also exported.

Glass

As estimated in Chapter 3, more than 90% of the glass entering the Seychelles has an end-of-life on the landfill. Stakeholders indicate that there are two functioning recycling systems for glass waste in the Seychelles. Seybrew bottles can be returned to any shop for refund. There is a deposit of 2 SCR per bottle. After cleaning and relabelling the bottles, Seybrew directly reuses them. Currently, Seybrew process about 125 tonnes of bottles per year. Rogan's Construction Company conducts the only other current glass-recycling project to the best of our knowledge. It is in possession of a glass crusher that can crush glass bottles to be used as concrete aggregate on internal construction projects. According to Rogan, crushing is not on a regular schedule, collection occasionally occurs at hotels, and that crushing glass is not always profitable.

In conjunction with STAR, LWMA, and others, Sustainability for Seychelles (S4S) attempted a glass collection project in 2011. The glass was intended to be collected at public sites, hotels and restaurants on Mahé by a government-hired contractor, crushed by STAR and then used by the construction company UCPS as aggregate for construction. A promotional campaign encouraged hotels and consumers to be involved in the project. However, the project was not fully implemented. LWMA hired a subcontractor to collect the glass from 500+ bins dispersed throughout Mahé, but this service was discontinued when the crushed glass simply remained unused at the landfill (S4S, 2013). Stakeholders say that management changed at UCPS, and the new director was not interested in using the crushed glass. After that, collection and crushing stopped. Some stakeholders stated that some bins are still intact and that private collection by Rogan's Construction Company still involves a few of these bins , and that Rogan is in possession of the original glass crusher from the project.

Stakeholders also indicated that Redeem Centres had previously collected tomato sauce jars. While this service was discontinued, many believe that a similar refund system like that with PET and aluminium could incentivise consumers to collect their glass. Stakeholders believe that large portions of glass could be diverted from the landfill through recycling, but for this to happen, a collection service and use for the downcycled material must be established.

Paper

As estimated in Chapter 3, more than 90% of the paper entering the Seychelles has an end-of-life on the landfill. To the best of our knowledge, there is only one active initiative to recycle paper. Stakeholders say that Navin's Paper Recycling Company collects paper from hotels and businesses on an irregular basis, which is reprocessed into egg trays, take-away boxes and other products. Some stakeholders were unaware of the company's existence and others believe that he struggles to sell enough products to offset the operational costs. Others believe that collection must be improved to upscale supply and increase profits.

The Seychelles Government plans to use paper waste for a proposed biogas plant. However, stakeholders indicate that the biogas project is still in its concept phase and it is unclear at the moment how and if the paper waste will be used for energy. For more details, refer to the Chapter 6.

2.3.2 Recycling opportunities

The following section summarises significant results from the options analysis. Following the options analysis, we provide stakeholder-identified recycling systems, opportunities and improvements and an overview on stakeholder opinion for PET and aluminium, glass and paper.

Options analysis

The following section summarises the MCQ results on collection and separation options. We provide the results in Tables 2.2 and 2.3. We compiled the individual MCQs together in the table with the total number of respondents that favour each option for each question.

Table 2.2 summarises stakeholder preferences for collection and separation options which reflect the most desirable scenarios. Almost all interviewees envision separation to be done at household level since it will facilitate collection. One stakeholder proposed that after collection, the waste manager could sort recyclables since most people do not have much space at their homes to store their recyclables. Another suggested that separation can be done at the Redeem Centres since the hotels do not have enough staff to do the separation.

Most agree that refunds would provide the best incentive for consumers to recycle their waste. Some suggested that a refund of SCR 1 or 1.50 per item would be appropriate, which could be sponsored by

Table 2.2
Results for collection and separation. Stakeholders were allowed to select more than one answer for each question. The most popular answer for each question is italicised.

Collection and Separation	# Resp.
Who does separation?	
Households & businesses	*7*
Informal sector	0
Waste manager	0
Redeem Centre	1
No separation	0
Which incentives for recycling?	
Refund for recyclables	*5*
Increase fees on unseparated trash	0
Education & public awareness	3
Enforcement	1
Environmental consciousness	1
Social pressure	0
Who collects?	
Informal sector	3
One waste manager	0
Multiple waste managers	3
Redeem Centres	*5*
Location of collection?	
Households	*3*
Municipal bins	*3*
Redeem centres	*3*
Who pays for collection?	
Consumers (fees by volume)	3
Government	*5*
Recycling companies	0
Redeem Centres	0
Influenced by government	4

a levy. On the other hand, some stakeholders believe that environmental education, regulations and enforcement must complement financial incentives to support consumers to recycle. Others argue that regulations and enforcement alone will be difficult to implement as incentives for the separation of waste.

With regards to who provides collection services, the preferred mode is collection by Redeem Centres. Some stakeholders state that the informal sectors and multiple waste managers should conduct collection. One respondent suggested that a successful collection system would integrate all three parties. None of the interviewees believes that one waste manager should conduct collection.

The favoured location of collection is divided equally among municipal bins, redeem centers and households, which includes hotels and schools. One stakeholder pointed out that since bins are located fairly close to the households it would be an ideal location. Someone also suggested that there should be drop off points for recyclables at community centres and "hotspots" in the districts. However, another stakeholder believes that households are too remote to serve as efficient collection points. One respondent suggests that PET and cans should be placed in special bins to facilitate collection by the informal sector.

Respondents generally agree that the government should directly sponsor or influence payment for collection. This can be achieved by introducing packaging tax at point-of-import to be used to fund waste management. On the other hand, still others believe that this depends on who the collectors are. Therefore, in certain cases like collection at households, some stakeholders believe that the consumers should pay for collection.

Table 2.3 summarises stakeholder opinion on processing. Respondents hold mixed opinion about how products can be processed. Potential opportunities they indicated are through upcycling to produce art materials, downcycling to useful materials, e.g., glass to construction aggregate, and raw material recycling. One interviewee thinks waste-to-energy would be interesting, but that it has not been explored yet.

Table 2.3
Results for how products can be processed.

Processing	# Resp.
Products	
Upcycled	*2*
Downcycled	*2*
Raw material (recycle)	*2*
Energy	1
Reuse	0
Location of processing	
Seychelles	4
Abroad via exportation	*5*
Recycling product markets	
Monopoly	0
Competition	5
Government influence	4

Stakeholders believe that processing should take place both in the Seychelles and abroad. Some state that the location of processing depends on whether there is a profitable market locally or if it is more financially efficient abroad.

Regarding market forms for recycling products, opinion is divided as respondents prefer both competition-driven and government-influenced markets. Some suggest that the government can also promote competitive markets through financial mechanisms such as taxes on imported products or subsidies on recycled products. However, others believe that the government should not have any influence on what is happening on the market.

In the following sections, we elaborate on specific recycling opportunities identified by stakeholders in interviews. These often relate to points mentioned in the options analysis. We complement these recycling opportunities with opinions collected and compiled from government, NGO, recycling business and other stakeholders.

PET and aluminium cans

Many stakeholders argue that the current levy system implemented for PET and aluminium can recycling is well-functioning. This is because large fractions of waste are diverted from the landfill and

the system is financially self-sustaining. Some suggest, however, that collection can be improved to increase recycling rates further. Potential aluminium and PET collection systems are explored in this section and include:

- Collection at households, schools and businesses;
- Collection at centralised bins; and
- Collection of a wider range of PET and aluminium items.

Additionally, we present stakeholder opinions on the role of the informal sector in PET and aluminium can collection.

Collection at households, schools and businesses

Stakeholders mentioned that encouraging consumers to bring their cans and PET to the Redeem Centres is challenging. Several stakeholders believe there is a "social stigma" related to PET and can collection in the Seychelles because of associations with informal collectors. Therefore, they indicate that if a collection service could go to pick-up points at households, schools and businesses – including hotels, restaurants and other large-scale consumers – then consumers would separate their waste for recycling.

The interviews show that opinions differ between who should conduct this collection. Some believe that the government should be responsible for contracting a waste manager to collect PET and aluminium. One stakeholder believes that informal collectors could be paid by the government to travel through neighbourhoods and directly give consumers money for their recyclable items. However, others believe that the informal collectors are too unreliable. Still others say that the Redeem Centres are already occasionally going to hotels and businesses to collect their recyclables, and that they could include a regular collection service. The Redeem Centres we interviewed demonstrated interest in increasing PET and aluminium collection, as long as it is profitable or if they are able to break-even at minimum. Interviews show that to reach their break-even points, the Redeem Centres must cover labour and fuel costs. Typically, this is between 5,000 and 10,000 cans or bottles per truckload. They indicate that they would provide a smaller refund of approximately 30–40 cents per item to consumers to meet operational costs.

Stakeholders in favour of household collection argue that the government must promote and organise the infrastructure to achieve a sustainable collection system. Some points of government intervention include promotion, establishing regular weekly or monthly collection dates, setting up collection points and introducing recycling regulations for consumers. Some suggest that the government begin pilot collection programs in estate complexes which are smaller residential areas with well defined system boundaries.

Collection at centralised bins

Stakeholders mentioned that centralised bins in carparks, supermarkets, town centres, schools and other high beverage consumption points would increase separation and collection of PET and aluminium. Collection could continue to be done by the informal sector or those collecting from household and businesses could extend their scope to include centralised bins.

There have been some initiatives to establish central collection bins for PET and cans. In collaboration with LWMA, S4S put PET and aluminium collection bins next to municipal bins to facilitate collection for informal collectors. They chose locations based on research and interviews with the informal collectors. S4S also aired television promotional campaigns to raise awareness. It was observed that the general public ignored PET signs on the bins and put mixed waste into them. Stakeholders also claimed that some stores illegally dump their waste into the PET bins and that the television campaign could have been aired for longer.

Some stakeholders suggest that the bins can be designed to prevent mixed waste from being deposited. One option is to put PET- and can-sized holes for waste entry into the bins. Another is to secure the metal containers so that the bins cannot be easily opened. However, one stakeholder argues that if the informal collectors will still gather PET and aluminium from these bins, they have to be able to access these items without damaging the bins.

Collection of a wider range of PET and aluminium items

Many stakeholders indicate that the government should include a levy/refund scheme for more PET and aluminium items so that the Redeem Centres can collect them. The Redeem Centres claim that they can process and export different sized bottles and other shapes of PET and aluminium as long as the item has a high content of these materials. In particular, stakeholders identify PET oil bottles as potentially levied items. They advise the government to collaborate with the Redeem Centres to ensure that the considered items can be processed and exported.

Role of the informal collectors

Stakeholders have mixed opinions on the informal sector. Most argue that they are an integral part of the recycling system and that the Redeem Centres would struggle to function without the informal collectors. However, some believe that they hurt the tourism industry because it is unpleasant for tourists to see people digging through garbage. These stakeholders assert that a formalised collection system without the informal collectors should be developed.

Stakeholders who support the informal sector, claim that theft has decreased in the Seychelles because the informal collectors can now earn money without stealing. Some say that another method to reduce theft and find a role for the informal collectors is to employ them within the recycling system. Redeem Centres have hired informal collectors in the past, but

one interviewee claims that they were unreliable workers. Others pointed out that informal collectors can be given gloves, masks and t-shirts for health and identification reason.

Glass

As identified previously, there is currently no formal collection scheme for glass, nor large-scale usage of recycled products from glass waste in the Seychelles. This section focuses on potential collection strategies and recycled product opportunities identified by stakeholders, and is organised as follows:

Collection strategies:
- Levy/refund system at Redeem Centres
- Recycler-operated collection
- Bottling company-sponsored collection
- Government-contracted collection

Product opportunities:
- Exported glass
- Downcycled construction aggregate
- Upcycled art materials
- Landfill stabiliser

Glass collection schemes

Deposit/levy system

Stakeholders identify that the government could impose a levy on glass, which the consumers would return to Redeem Centres or stores for a refund. The Redeem Centres expressed interest in recycling glass and have collected glass tomato jars in the past. Many stakeholders believe that the deposit/levy system for PET and aluminium is successful. The government could introduce the same scheme for glass containers like wine bottles, with a levy of about 2 SCR. The government states that it requires significant information about the products for levies to be approved by the cabinet of ministries. One concern of stakeholders is that the informal collection of heavy glass bottles will be a challenge.

Private collection by recyclers

Some stakeholders believe that glass could continue to be collected by recyclers, like Rogan's Construction Company, without government management. They favour a semi-formalised collection system involving more hotels and restaurants with scheduled weekly collection, standardised glass collection bins, or company-sponsored bins at car parks and other hotspots. Interviews indicate that the 65 hotels and restaurants on Mahé that participated in the original glass-recycling project could easily be included (S4S, 2010).

Collection sponsored by glass bottling companies

Interviews show that Takamaka, Soleil and other glass bottling companies could introduce a collection and reuse system for their products, modelled after Seybrew's currently functioning system. Many stakeholders state that the government should create policies and regulations to encourage companies to recycle glass. Other stakeholders point out that creating market-wide policies for recycling has

been difficult after the economic downturn in 2008. Stakeholders indicate that the Ministry of Finance provided financial support to Seybrew with an initial investment; stakeholders expressed that they prefer to be provided initial investments and tax exemptions to aid recycling projects, rather than long-term payments.

Government contracted collection

Some stakeholders stated that the government could manage glass collection. However, the waste manager would require more money in its contract to do glass collection and recycling, to cover the cost of additional trucks and glass crushing. Some interviewees believe that additional income taxes could support a waste management fund for glass collection. They also indicate that separation should take place at the consumer level. However, others believe that the glass bins will be broken and rules for waste separation will not be obeyed in the Seychelles.

Products of glass recycling

Exported glass

Some stakeholders believe that since there is a worldwide market for glass, the collected glass could be exported abroad. They indicate that since a market already exists, the exporting will be cost effective. However, others state that the extra cleaning, sorting, and exporting costs are too high for the relatively small volumes of crushed glass available for exporting to be a profitable solution.

Aggregate for construction

Stakeholders say that crushed glass can be used as aggregate in non-structural concrete. Benefits include less cleaning and sorting needed than for other glass products. Currently, Rogan's Construction Company and/or the government could collect and manage the crushed glass. His company would use it internally, guaranteeing an end product and usage. On the other hand, the government would store the crushed glass on the landfill and sell it to construction companies. We gathered stakeholder information about the costs of implementation, and we propose rough cost estimates for both scenarios below, assuming 150 tonnes of glass are produced per month (Tables 2.4 and 2.5). As a basis for comparison, we assume that Rogan's Construction Company will receive an economic benefit from displacing its current aggregate demand with crushed glass.

The total monthly cost for Rogan's Construction Company would be 13'500 SCR per month while for government crushed glass, we estimate costs would be 7'500 SCR per month. Labour costs for Rogan's Construction Company includes collection, management and other operations; therefore, government intervention in collection would decrease his costs. In general, these values should simply provide a rough estimate of how much implementation would cost. Factors that would impact these values include production scale, inclusion of landfill area displacement and valuation of aggregate.

Table 2.4
Monthly cost estimate for Rogan's Construction Company. Negative values represent revenue.

Item	Cost (SCR) per unit	Unit	Units	Cost (SCR)
Aggregate displacement	–200	ton	100	–20'000
Labour and maintenance[1]	40'000		1	40'000
Selling price	–130	ton	50	–6'500
Total				**13'500**

[1] Labour includes two workers and one manager

Table 2.5
Monthly cost estimate for government-handled crushed glass project.

Item	Cost (SCR) per unit	Unit	Units	Cost (SCR)
Selling price	–200	ton	150	–30'000
Administration	250	ton	150	37'500
Total				**7'500**

Upcycled art materials

Several stakeholders indicate that the scale of these projects is small, the energy consumption and operational costs are high, and the market for decorative art from recycled glass is uncertain. They also say that upcycled art projects have happened in the past, but failed because they did not have enough customers to create a profitable business.

Fill for landfills

Various stakeholders suggested the opportunity to use the crushed glass as cover for the landfill. Because it is chemically inert, it can act as a cover for the landfill. One stakeholder states that crushed glass is more expensive than using sand or coral fill, and would therefore prefer to keep importing these materials instead. Additionally, glass in the form of bottles decreases eightfold in volume when crushed, and therefore this stakeholder does not believe that it would receive enough glass to

meet its needs to cover the landfill. Others agree that the volume was too small for using crushed glass as fill to be a sustainable option.

Paper

As identified previously, there is currently no formal collection scheme for paper, and therefore no large-scale usage of recycled products from paper waste in the Seychelles. This section focuses on potential collection strategies and recycled product opportunities identified by stakeholders, and is organised as follows:

- Collection at businesses and schools;
- Upcycling to biodegradable containers;
- Export; and
- Biogas plant feedstock

Many stakeholders state that there is a latent potential for paper recycling. Members of government agencies would only like to support recycling initiatives that have a clear market potential.

Collection

To the best of our knowledge, there exists no official collection scheme for paper. As indicated previously, most paper ends up in municipal or commercial bins and is brought to the landfill for its end-of-life. Stakeholders indicate that paper recovery once deposited is challenging because the material is easily contaminated when mixed. Therefore, they believe that separation must occur before deposition. Navin's Paper Recycling Company collects some wasted paper from offices, stores and other businesses at irregular intervals. Newspapers and the printing industry reuses paper materials on a small scale.

There is currently no infrastructure or initiative to collect paper and carton from households. Many stakeholders believe that efforts should first be concentrated on collection at large-scale paper waste producers, like hotels, businesses, offices, schools and stores. Navin's Paper Recycling Company could continue to engage in collection with a wider range of businesses, and stakeholders also say that the government could help facilitate paper collection similarly to glass collection. Suggestions for government intervention include organising regular collection dates, increasing public awareness and managing collection itself.

Upcycling

Navin's Paper Recycling Company specialises in processing waste paper into secondary biodegradable products. It has the equipment to produce the following products: egg trays, egg cartons, paper plates, paper bags, meat & vegetable trays, take-away boxes and lunch boxes.

Many stakeholders believe his business is not profitable. One reason they argue is that there is very little public awareness of his products. Therefore, NGO and government support could help promote his products so he can reach a wider range of customers. Additionally, they argue that his recycled products are in competition with cheap plastic or Styrofoam products. Cost estimates show that while Navin's egg trays (SCR 1.50) are more expensive

than imported plastics (SCR 1.00), their egg cartons (SCR 3) are cheaper than the imported plastic products (SCR 5). Some of the products, like seed pots, are sold at the same price as imported equivalents (SCR 0.50).

It is difficult to sell the recycled products at a cheaper price, as the fixed and variable costs of the infrastructure are very high when Navin's is not operating at full capacity. The most significant costs include maintaining the molding equipment, electricity, fuel for collection, and waste disposal.

Generally, some stakeholders believe that Navin's products are more expensive and have a lower reusability rate, so they argue people prefer not to buy his products. For example, one interviewee claims that paper egg trays cannot compete with imported plastic egg trays used by farmers because they are destroyed by rain or moisture after one use. However, Navin's company indicates that they have a special coating that allows them to be reused. Our personal observation at farmers' markets indicates that many people use paper egg trays. One stakeholder says that there is a large mismatch of information presented about Navin's Paper Recycling Company's products.

Involved stakeholders identified some options for the government or its contracted companies to support the paper recycling industry. Firstly, government could ban or tax imported competing non-degradable plastic products, e.g., plastic egg trays and Styrofoam boxes, and encourage the use of the locally produced recycled alternatives. Governmental stakeholders indicated that there is currently a levy planned on Styrofoam take-away boxes, which will support the usage of imported or locally produced biodegradable take-away boxes, such as those made by Navin's Paper Company, but that this will take some time to come into effect.

Many interviews show support for government-based financial incentives, like concessions for fuel, subsidies for sustainable energy production, e.g., photovoltaic installations, tax exemptions or tax deductions on imported chemicals and equipment. Some governmental stakeholders feel that subsidies are not preferred incentives for recycling businesses since they may not be sustainable if the products are in unprofitable markets. Rather, they indicate that the better methods of support are through direct market improvements, such as by providing land. They also note that the recyclers have already been exempted from many taxes.

Export

According to Navin's Paper Recycling Company, it used to export paper to a paper recycling factory in India. It never operated at full capacity of export because it could not cover the cost of waste paper collection from willing suppliers. During recent economic downturns, costs of exporting

rose significantly. Therefore, Navin's paper recycling shut down the export of waste paper in 2014. Stakeholders indicate that STAR also considered exporting paper to India, but could not find a buyer. They discontinued paper export because the paper was damaged by the humidity, resulting in poor paper quality.

Feed for digestion

There is disagreement among the stakeholders concerning digestion of paper. Digestion could take place to simply lower the volume of waste going to the landfill, or it could be used as feedstock for the proposed biogas plant. Some stakeholders believe that the paper section of waste will be fed into the biogas plant and should not be considered for recycling. Others report issues with using paper in the biogas plant. One interviewee stated that the government must focus its financial resources on either recycling or the construction of the biogas plant. See Chapter 6 for a full analysis on biogas potentials.

2.3.3 Household Surveys

The following results are based on the interviews with members of the public (N=23) regarding recycling in the Seychelles which were conducted to gauge motivation at the household level. Not all respondents answered each question, which explains why the number of respondents vary between the results. The ages of the respondents vary between less than 20 years up to 60 years. The full questionnaire is provided in Appendix 2.

We first asked whether consumers are interested in buying recycled products. As depicted in Figure 2.3, most respondents express a general willingness to buy recycled products. We also asked how much more consumers were willing to pay for products made from recycled materials. Responses varied among individuals. Some indicate that their willingness to pay depends on product quality and type. Other respondents express that they are willing to pay any amount of money for a recycled product. Some claim they would not pay more for recycled products.

Next, we asked if respondents would be willing to separate their recyclables. Almost all said that they would separate their recyclable materials, as demonstrated in Figure 2.4. In follow-up questions, 17

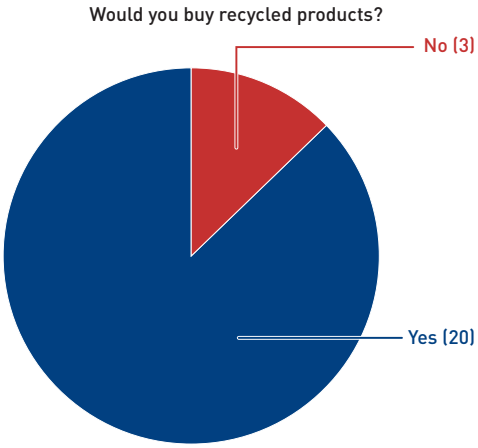

Figure 2.3
Willingness to buy products from recycled materials.

of 19 respondents state that they would separate without a financial incentive in such a collection system. However, many respondents indicate that government provision of household bins and a formalised household collection system would be required to encourage consumers to separate their recyclables. As demonstrated in Figure 2.5, most respondents agree that recyclables should be collected approximately monthly.

The final survey questions asked the public for ideas for recycled glass and paper products. The most often mentioned items were take-away boxes, jewellery and decoration products. Together these three items account for more than 50% of all ideas suggested. Other ideas mentioned only once or twice included egg cartons, napkins, paper bags, toilet paper, lamp shades, shoe boxes, cups, furniture, flower pots, drum sets, fruit trays, plates, books and file covers.

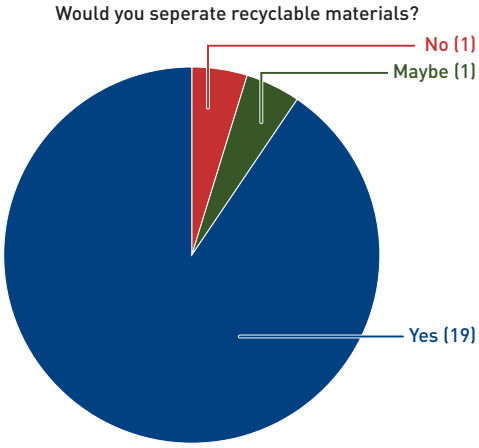

Figure 2.4
Household willingness to separate waste materials.

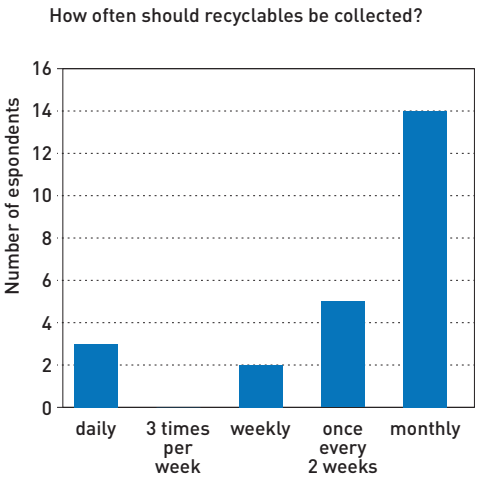

Figure 2.5
Opinion on frequency of collection.

Regarding glass products, ornaments were mentioned most frequently, followed by candle holders, and jewellery. Considering the potential of glass in construction mentioned by experts, it is remarkable that concrete was only mentioned once. Further ideas were boxes, plates, flower vase, lamps, kitchen tops, bulbs, glass blocks for construction, containers to store water, and jars.

2.4 Discussion

In the following discussion, we analyse the results from the stakeholder and household interviews and address the three research questions of this chapter.

Our research shows that past and present recycling projects have struggled to sustain themselves in the long-term. S4S's attempted glass collection project lacked the full cooperation from some partners, and when certain actors involved did not fulfil their agreements, the system as a whole collapsed. Navin's Paper Recycling Company lacks adequate promotion, financial aid, and consistency, which ultimately reduce its marketability in the container business. The cheap imported goods entering the Seychelles have financial advantage in their markets, and this can be attributed to the liberalised trade agreements that took place in the 2000s. In this case and in others, the government had the ability to help these businesses that failed in the past.

Recycling businesses particularly struggle because operation, processing, and collection costs are high. Additionally, the influx of waste fluctuates greatly in a country as small as the Seychelles. This challenges recycling businesses to consistently produce goods, especially when they do not have consistent collection systems. In comparison, stores and consumers can rely on imported products that come regularly to the Seychelles.

However, stakeholders generally agree that PET and aluminium recycling is a functioning system that can provide a model for other recyclables. Many people like the levy/refund scheme because it provides incentive for recycling and is financially self-sustaining. This system greatly relies on the contribution of the informal sector, which cannot be overlooked. The informal sector is responsible for the majority of the PET and aluminium that is diverted from the landfill. While we did not analyse the effects of removing the informal sector from the waste system, we would expect theft and landfilling rates to rise.

When comparing what has worked well in the past and what has not, financial stability appears to be the deciding factor. Navin's Paper Recycling Company and the S4S glass collection project struggle because they lack the infrastructure, scale, and customer base to succeed in the long-term. Ultimately, when there are no funds left, these people involved will discontinue vital services that recycling systems need. On the other hand, the levy drives PET and aluminium recycling, the Redeem Centres, and informal collectors.

Therefore, financial assistance – in the form of collection services, infrastructural provisions, levies, subsidies, taxes and other incentives – is critical in future recycling projects. Opinions are mixed as to where the funds should come from, but most experts agree that the government and consumers should play primary roles in driving recycling projects, according to the polluter pays principle. Education and public awareness must complement any project implementation so that consumers can contribute. While it appears that consumers are currently unwilling to recycle,

the results of our survey indicate that if provided bins and a functioning collection system, people would recycle even without a financial incentive.

Collection is the backbone for future recycling projects, and therefore, stakeholders should collaborate to determine productive collection systems. Opportunities depend on the waste stream, but those with high recovery rates can be included in the existing Redeem Centre collection portfolio. Options include PET oil bottles, more aluminium products and certain glass products. The government should consider whether their collection would require a levy or not. To reach households, businesses and schools, the levy does not appear to drive collection. Therefore, our research shows that the government should work with Redeem Centres and recycling businesses or contract waste management companies to conduct collection at targeted collection points. Stakeholders believe that the collection could begin with businesses and a pilot project at an estate community, and that it should be specified and regular with a fully developed infrastructure plan. The government can collaborate with other stakeholders to determine a collection scheme, and our interviews stress that education, advertisements and other promotion drive consumers to partake in recycling.

In the case of glass and paper collection, our research shows that household-level collection may not be appropriate yet. Therefore, the government and recycling businesses should focus their efforts on businesses, schools and other large-scale paper and glass waste producers while the paper recycling market scales up. This way, the government avoids early overinvestment in the market when capacity for recycling processing is too low.

Opinions for the best choice of recycled glass products varied among stakeholders. However, it appears that using glass for non-structural concrete aggregate may be the most favoured option. This is because the processing equipment and a market for this material already exists. Other options, such as export and landfill stabilisation, may not be successful because of the small supply scale. Operating costs are high in both cases and the businesses may not be financially sustainable. We would recommend a detailed cost estimate be conducted when stakeholders have agreed on the collection method, processing capacity and labour requirements for using crushed glass as aggregate.

It appears that stakeholders favour Navin's Recycled Paper Company's products for recycling paper. He has the existing infrastructure and processing capabilities to generate recycled paper products, but it is done inconsistently at a small scale. Therefore, our research indicates that he requires additional support that can assume many forms. One is by discouraging stores from purchasing competing products, which implies that his products must have a legal or financial advantage, in the form of bans, import taxes or subsidies on his products. Another could be through provision of collection services, electricity, land or other infrastructure that could lower his financial costs. His business

would greatly benefit from increased public awareness and promotion. It is clear through the mismatched information we received that there is insufficient knowledge of his business amongst customers.

In all cases, our research shows that the government must assist any recycling business and project if it is to be successful. The recycling businesses have small budgets and therefore cannot face significant financial risk if they are to last long-term. The government indicates that it is only willing to support products with a market potential, but our research shows that many markets require investments or initial aid to attract recyclers. Therefore, a robust financial plan, involving consistent sources of revenues, is required for the government to contribute to recycling markets.

But not all intervention requires financial input: the government can also help by promotion, education, infrastructure organisation for collection, market intervention with taxation and bans, legal reform and many other instruments. When the government is involved and provides the tools for consumers to recycle, then they are willing to help businesses.

2.4.1 Limitations and Next Steps

We briefly discuss the limitations of this study in this section of the report and provide potential next steps.

The significance of the household surveys is limited, especially in regard to the representativeness for the whole population. This is mainly due to the fact that we only interviewed a small amount of households and as a result, no statistical analysis could be conducted. In addition, there are open questions as for instance the variety in responses for the willingness to pay for recycled products. Future research should investigate these causes and drivers and should contain a sample size large and random enough to allow for statistical analysis.

Another significant limitation of the results of this study lies in the cost analyses. Most cost information provided through the interviews reflect rather estimates than actual costs, prices or revenues. Therefore, our cost information does only indicate general information. In the future, more thorough cost assessments should be conducted to determine the true costs and values of collection systems and products. Analyses could include cost-benefit analyses as well as the inclusion of external costs. These values and analyses would be valuable for policymakers and recyclers interested in knowing the prices and benefits of a recycling system.

Other next steps in the study could include looking at the impacts of government financial mechanisms or policies, optimised collection system infrastructure and paths, and process optimisation for recycled products and markets. Furthermore, the potential of other fractions of recyclables in the Seychelles could be analysed. Role models for such analyses are available from other small island development states, such as Barbados, and might have already been considered by stakeholders in the Seychelles.

2.5 Conclusion

The driving force for a successful recycling business is financial stability. The business must consider what potential customers find attractive in recycled products, which often include downcycled materials. If the business needs aid from the government to enter a market, it should be able to provide specific cost information to the government. Their main challenge is that they need to compete with imported goods. Policy makers could aid recycling businesses by regulating or taxing imported products, developing more formalised collection schemes, and providing financial support in the form of tax exemptions, subsidies, land, fuel, or electricity.

The government could play a role in establishing formalised collection schemes, financing recycling projects, and working with recycling businesses to meet their needs. A proposed collection scheme from the study would integrate the following components:

- Regular collection of glass, paper, PET, and aluminium at hotels, restaurants, and businesses;
- Regular collection of glass, PET, and aluminium at household collection sites;
- Regular or informal collection of glass, PET, and aluminium at car parks and other municipal collection sites; and,
- Inclusion of a levy on glass, other plastics, and aluminium products to incentivise their collection at Redeem Centres.

Finally, public awareness is crucial to the success of any recycling initiative. The government, the media, and NGOs can help educate the public and promote businesses that need financial contributions from the government in cases where there is no market. By collaborating with and engaging all stakeholders, the government can create long-lasting, effective recycling systems in the Seychelles to reduce the landfilling rates.

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3 Material Flow Analysis of Waste Streams in Mahé

3.1 Introduction

Landfilling remains the predominant form of Solid Waste Management (SWM) in the Seychelles, despite issues relating to land scarcity and increasing waste generation over the last decade (Talma and Martin, 2013). One method to divert waste fractions from the landfill is recycling. Increasing recycling processes is one of the objectives of the Seychelles' Solid Waste Management Policy 2014–2018, but as is the case for most other Small Island Developing States (SIDS), recycling activities in the Seychelles are often hindered by the high costs of transportation, lack of infrastructure, and lack of education and sensitisation of local communities. Currently in the Seychelles, recycling is undertaken by stakeholders from the public, private and informal sectors. However, few materials are recycled and previous research has shown that such programmes occur at relatively small scales compared to the amount of waste which is landfilled (Talma and Martin, 2013).

To the best of our knowledge, data describing these recycling programmes in terms of the amounts recycled compared to waste generated have not yet been published or in some cases, even collected. Furthermore, some of these recycling programmes are not widely nor fully understood. As a result, little comprehensive documentation exists to provide information on the complex interplay between sectors in the management and implementation of these programmes.

Material Flow Analysis (MFA) is an established method used to describe and interpret complex systems by visualising the mass flows and stocks of goods or materials (Hellweg, 2015). This quantification of flows and stocks provides a system-level understanding of the investigated material. Furthermore, all of the involved stakeholders are identified with their magnitudes of impact on the overall material flow. Conducting MFAs is a concrete way of addressing knowledge gaps related to recycling quantities and indicating infrastructure needs to inform policy-making.

Our research goal is to conduct MFA on the PET, Cans (Steel and Aluminium), Glass, Scrap Metal, and Paper and Cardboard streams in Mahé. These streams were selected based on the following criteria: existing recycling programmes and data availability, demand for and value as commodities in international markets, well-defined materials which do not change over time, and (economic) potential to be recycled and therefore diverted from landfills in the Seychelles. By performing material flow analyses of these streams, we hope to address our three research questions:

1. What types of products (classified by material) enter the Seychelles and in what quantities?
2. How do materials in each stream exit the Mahé system and in what quantities?
3. How are the materials used in terms of their flows between stakeholders?

We expect our results to inform future policy in the Seychelles and to also provide preliminary information potential entrepreneurs who wish to assess the economic viability of starting recycling businesses involving these selected materials.

3.2 Methods

In order to gain a quantitative understanding of the PET, Glass, Cans (Aluminium and Steel), Scrap Metal, and Paper and Cardboard systems, we performed Material Flow Analyses on each of these streams. Our main data sources were the Landscape and Waste Management Agency (LWMA), the Customs Division in collaboration with the Seychelles National Bureau of Statistics (NBS) and the Waste Management Fund (WMF). Using the data collected from these sources, we constructed preliminary material flow charts.

To collect further data to complete our flow diagrams, we conducted semi-structured interviews with relevant stakeholders such as waste exporters, recyclers, and informal collectors which took place from 27th June to 5th July 2016 in Mahé, Seychelles.

Material Flow Analysis (MFA)

We conducted MFAs for the following materials: Polyethyleneterephthalate (PET), Glass, Cans (Aluminium and Steel), Scrap Metal, Paper and Cardboard. Our geographical system boundary is Mahé, Seychelles. We chose to perform our MFAs for the year 2014 based on preliminary data collection and evaluation of available data which revealed that the most recent data the majority of stakeholders could provide was for this year.

In Box 2 we briefly explain MFA and the procedure involved:

Box 2 – Material Flow Analysis

MFA can be used to describe and interpret complex systems. The results can be interpreted by the visualization of mass flows and stocks of goods or materials (Hellweg, 2015). Furthermore, the results can be used to improve the management of the materials and set up monitoring programs to evaluate policy measures (Binder, 2007). The aforementioned characteristics of an MFA answer our research questions. The procedure of a MFA is explained according to Hellweg (2015) below:

1. **Concept:** Describe the system according to the underlying research questions. This means setting the system boundaries and clarifying the goods/materials and the processes to be examined in the system. The result of this step is a list with the system elements and a qualitative flow chart of the goods.
2. **Data collection:** Collect, measure or estimate the material flows and stocks. Describe interviews, analyse data (estimates, etc.)
3. **Simulation:** Calculate the remaining unknown flows through the mass-balance principle.
4. **Analyse:** Representing schematically the system, conducting a sensitivity analysis and interpretation of the results are the main points in this step. Key parts of the interpretation are:
   a. The identification of sources and sinks of the goods/materials.
   b. Description of processes in terms of e.g. orders of magnitude of flow turnover.

3.2.1 Data Sources

In this section we describe our main data sources from which we obtained both information on the materials in terms of the relevant stakeholders and direction of the flows, as well as quantities in units of metric tonnes.

Landscape Waste Management Agency

At the entrance to the Providence Landfill every truck bringing waste is weighed at the weighbridge. This waste is categorised according to the 12 classes (see Table 3.1). The categorization is mainly based

Table 3.1
Overview of waste classes used for waste classification at the Providence weighbridge (Source: LWMA). The composition of the MSW and the composition of all the waste disposed on Providence landfill can be found in Appendix 3.

Waste Class	Waste Type	Waste Content
1	Municipal Solid Waste (MSW)	Waste usually collected in communal waste bins (household waste)
2	Commercial waste	Waste usually collected from commercial, tourism and industrial establishments and litter bins
3	Green Waste	Vegetative matter from litter bins and private trucks
4	Liquid waste	Mostly sludge from Indian Ocean Tuna industrial factory
5	Mixed waste	Unsorted waste brought by private trucks
6	Metal waste	Ferrous and non-ferrous metal
7	Putrescent waste	Remains of animals from abattoirs
8	Waste oil	Waste oils from hotels, restaurants, garages, ports (boats)
9	Construction waste	Waste usually originating from construction sites and demolition works (not including excavations)
10	Inert waste	Mostly glass waste and un-powdered asbestos
11	Hazard waste	Includes batteries, medicines, expired goods, reagents
12	Others	Ashes, sawdust etc. (sometimes used as landfill cover)

on visual audits (STAR landfill employee, personal communication, 30.06.2016). These data were provided to us as daily records from the LWMA and were further processed using the open-source software R for the year 2014 in a scenario analysis. For further details on this scenario analysis, see Chapter 7.

Customs Division in collaboration with Seychelles National Bureau of Statistics

All Seychellois imports and exports are classified using the Harmonised Commodity Description and Coding System (HS). The Customs Division collaborates with the Seychelles National Bureau of Statistics (NBS) by sharing all import and export data in kg with NBS, who then further processes and stores them. The HS categories used for our analyses are shown in Appendix 3.

Waste Management Trust Fund (WMTF)

The WMTF coordinates the levy on aluminium cans and PET bottles. In this way, the total amount of collected aluminium cans and PET bottles by the six redeem centres on the Seychelles is recorded. However, we were not able to attribute the amounts amongst the six redeem centres and it remains unclear to us to what extent this distribution of PET among the redeem centres exists.

Seychelles Solid Waste Master Plan 2003–2010, Issue 04

Scott Wilson Kirkpatrick & Co Ltd conducted a waste audit of the waste going to the Providence landfill in 2003 (Seychelles Solid Waste Master Plan 2003–2010). They performed a quantitative audit of the Municipal Solid Waste class and a semi-quantitative visual audit for Total Waste disposed at Providence landfill (Wilson, 2004, p. 12). The results are shown in Appendix 3. We used the fractions (expressed as %) of the different waste classes and the total waste amounts to calculate the amounts of each waste class entering the Providence landfill.

3.2.2 Interviews

To complete information on material flows, we conducted semi-structured interviews with relevant stakeholders. We requested data on how much material (tonnage) the respective stakeholder(s) received, processed, recycled and/or exported, and we discussed our preliminary qualitative material flow diagrams with the stakeholders we interviewed. The choice of experts interviewed reflects the different processes within each of the material systems. Therefore, we conducted interviews with several stakeholders and individuals from different sectors, including but not limited to: waste management companies, recycling businesses, beverage manufacturers, informal collectors, and govern-

ment employees. The interviewed stakeholders are listed in Table 3.2 and were interviewed between 27th June and 5th July of 2016 in Mahé, Seychelles.

3.2.3 Mathematical modelling

The mathematical modelling was conducted using an open source software called STAN v.2.5 (http://www.stan2web.

Table 3.2
Stakeholders interviewed.

Sector	Interview partner	Contact person	Function & Expertise
Industry	Surya	Sanjay Naidoo	CEO; Export Business
	Seychelles Breweries Ltd.	Russell Finesse	Engineer; Glass Bottle Recycling
	Navin's Paper Recycling Company	Navin Naidu Rajasekarah	CEO; Paper Recycling
	STAR Seychelles	Bernard Croguennec	CEO; Solid Waste Management
	Samlo and Sons	Vijay	Manager of Providence Scrap Yard; Scrap Metal and Exporting
	Sodepak Industries Ltd.	Luc Banane	Project Manager; PET Bottles and Beverage Bottling
	DE Recycling	Donald Ernesta	CEO; Can Recycling and Exports
	Providence Redeem Centre and Harini Company	Rengassamy Eandassamy	CEO; PET Export Business and Redeem Centre
	Rogan Recycling	Patrick Rogan	CEO; Glass Recycling Business
	Anse Royale Redeem Centre	Frankie Bakas	PET and Cans Redeem Centre
	Informal Collectors	–	Informal Collection of PET and Cans
Government	Landscape Waste Management Agency	Lemmy Payet	Consultant; Solid Waste Management
	Seychelles National Bureau of Statistics	Laura Ah Time, Marina Roucou, Sheena Saldanha, Aubrey Fock-Tave	CEO, Assistant Statistician, Statistician, Statistician; Customs Data (Imports and Exports)
	Customs Division	David Zeine	Customs Technical Advisor; Import and Export Data

net/). We used the data from the NBS and LWMA to identify all import, export and landfill deposition flows. If a certain material was exported by a private sector stakeholder, most of these export flows were estimated by the exporter(s) of the corresponding materials themselves.

To estimate the tonnages of the unknown flows of each material, we either simply summed up the values in the 'Net weight' column from the raw data provided by NBS, or had to do back-calculations using the mass balance principle based on reasoned assumptions. More details are provided in the Results.

Below, we describe our assumptions for each material stream.

PET Assumptions

- All PET bottles are imported. We assume this because there is no PET manufacturer in the Seychelles. The average weight of a PET bottle is 31g. We estimated this weight by manually weighing different bottles bought locally using an electronic balance, and then averaging their weights (see Appendix 3). This estimation was required to calculate the flows of full PET bottles into the Seychelles and the amount of empty bottles received by the Redeem Centres. (A more accurate average bottle weight could have been calculated using a beverage market analysis developed by Kuczenski and Geyer (2014). The same method could be applied to get a more accurate picture over the packaging of animal and vegetables oils and fats. However, this is beyond the scope of our research.)
- PET bottles collected and recorded at the Redeem Centre originate in equal shares from the informal sector, and from households and businesses. This assumption is based on a statement from an interview.
- The informal sector has a 90% collection rate of littered and landfilled PET bottles, and PET bottles disposed of in public bins. We made this assumption using expert judgement based on information from stakeholder interviews. This rate allowed us to calculate the consumption and informal collection flows.
- The quantity of PET bottles collected informally is proportional to the average earnings of informal collectors. This assumption was based on statements from stakeholders and allowed us to calculate flows of empty PET bottles recovered from the landfill.
- The share of origin of PET is based on a statement from one Redeem Centre. It is however important to obtain more information from other Redeem Centres to be able to estimate the importance of the informal collectors.

Steel and Aluminium Beverage Cans Assumptions

- All beverage cans are imported.
- The average weight of an steel can is 29g, while that of an aluminium can is 13g. As in the case of PET, we derived these values from manually measuring cans using a balance. This estimation was needed to calculate the flows of filled beverage cans and the amount of cans received by the Redeem Centres.
- The steel and aluminium cans collected and recorded at the Redeem Centre originate in equal numbers from the informal sector, and from households and businesses. This assumption is based on a statement from an interview.
- The informal sector has a 90% collection rate of littered and deposited cans. This assumption allowed us to calculate the consumption and informal collection flows.
- The quantity of cans collected informally is proportional to the average earnings of informal collectors. This assumption was based on statements from stakeholders and allowed us to calculate flows of empty cans recovered from the landfill.

Glass Assumptions

- All glass is imported. As far as we know, there are no local glass manufacturers.
- Glass bottles for beverages are limited to 280mL or 330mL beer bottles, weighing 0.3kg (empty weight), and 750mL wine and spirits bottles weighing 0.5kg (empty weight). These estimations were based on stakeholder interviews, online research, and personal observations.
- The glass fraction of MSW identified in past sampling studies (Solid Waste Master Plan 2003–2010) is representative of all MSW streams entering the landfill. The total glass fraction of the Construction, Mixed, and Commercial Waste streams is taken to be the difference between the fraction of glass in Total Waste (as defined in the aforementioned) SWM Plan and the fraction of glass in MSW.

Scrap Metal Assumptions

- All the products which eventually become scrap metal are imported, and therefore, there are no sources in the Seychelles.
- The selected imported products are the only sources of metals entering the Seychelles in our material flow model. In reality, this is not a comprehensive assumption because there are many products which contain metal but which are unaccounted for in our study. However, we deliberately selected imports which have a high proportion and mass of metal.
- All the imports we considered for the scrap metal material flow analysis are made of 100% metal. This assumption also applies to vehicles imported.

Paper and Cardboard Assumptions

- All paper and cardboard (PC) products are imported.
- PC fractions identified in past sampling studies (Solid Waste Master Plan, 2003–2010) are assumed to be representative of the MSW and Commercial Waste streams. Therefore, we calculated the fractions by multiplying the proportion of paper and cardboard (%) found in MSW and total waste to landfill sampling with the total MSW and Commercial Waste tonnages for 2014.

Limitations

We received limited data that prevented us from fully completing MFAs for each material. The aforementioned assumptions which were required to fill knowledge gaps in the data likely decrease the accuracy of our MFA, but represents what we believe to be the most reasonable assumptions considering our data limitations. Each MFA presented hereafter should therefore be considered as best-guess MFA. We indicate our varying levels of certainty in the actual material flow diagrams using a 'traffic light' scheme: we assume high, moderate and low uncertainty for the flows coloured in in red, orange and green respectively.

3.3 Results

In this section, we present the results of our Material Flow Analyses for the five waste streams based on data from 2014: PET, Can (Aluminium and Steel), Glass, Scrap Metal, and Paper and Cardboard.

A brief overall system description explaining the main stakeholders, flows, sources, and sinks is provided to give some guidance for interpreting the material flow diagram and to highlight some of the driving forces within the systems. All the values presented in our diagrams are rounded to 2 significant figures, as is accepted practice when dealing with uncertainties in Material Flow Analyses (Rechberger et al., 2014). Then, more in-depth analyses of the most important flow processes, namely Import, Consumption, Collection (where applicable), and Export and End-of-Life are presented.

A deliberate attempt has been made to minimise the amount of calculations presented in this section to ensure that our key findings are highlighted. Instead, our calculations are provided in detail in Appendix 3.

3.3.1 PET

System Description

PET bottles and preforms are wholly imported into the Seychelles (Figure 3.1). PET has an associated levy, which represents an economic incentive for their eventual collection. Therefore, the role of private businesses in the form of Redeem Centres (RC), informal collectors, and exporters is significant, particularly in their contribution to the export of 240 tonnes of PET, roughly half the total quantity which entered the system in 2014. As a result, relatively little PET is landfilled.

Import

We assumed all PET is imported and therefore refer to the quantities provided by Customs classified according to HS code. We divided PET imports into three categories according to their HS number upon entry into the Seychelles. Their relative proportions of the total are as follows:

1. PET preforms (55%)
2. Immediate packaging of beverages (32%)
3. Immediate packaging of animals or vegetables oils and fats (13%)

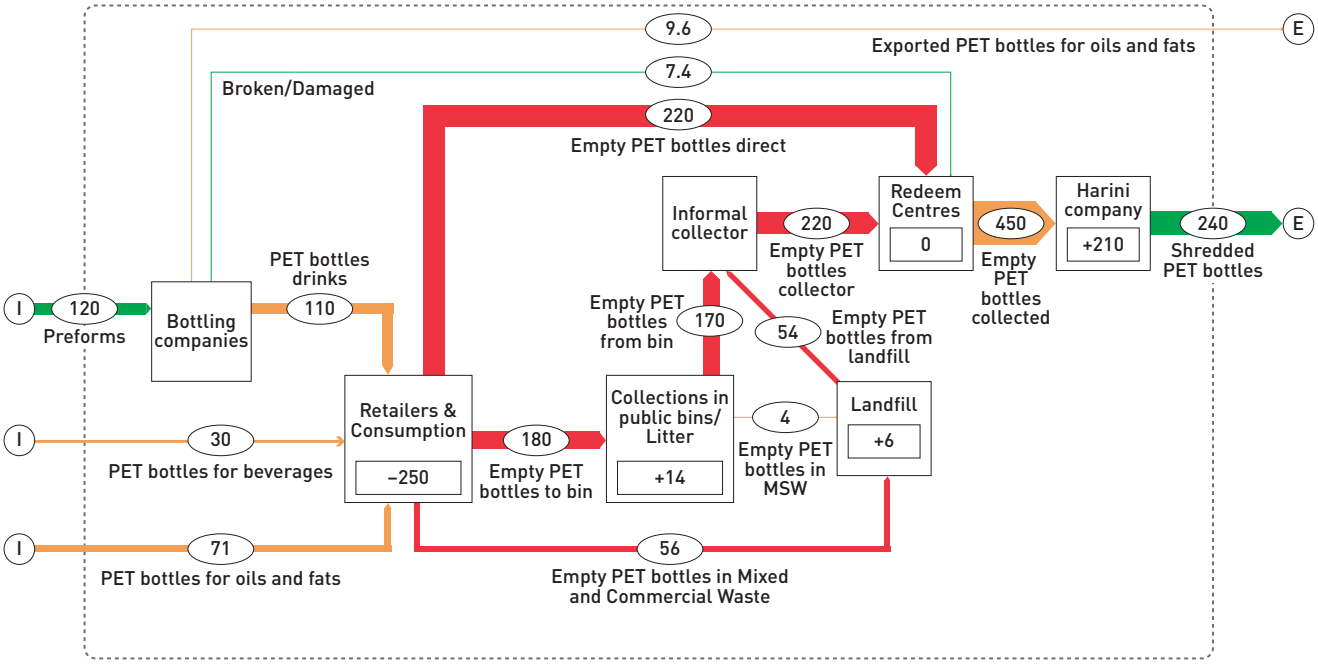

Figure 3.1
System flow of PET in Mahé. Numbers are in tonnes. I: Import flows. E: Export flows. The colours of the arrow reflect uncertainty assumptions: red: high uncertainty, orange: moderate uncertainty, green: low uncertainty.

Category 1 is the largest category of PET imported into the Seychelles. These preforms are further processed in beverage bottling companies in the Seychelles. We assume that Categories 2 and 3 are either directly imported by retailers or that distributors sell the products to retailers.

Most notably, there was a significant depletion in the Consumption stock in 2014. This could be explained by the trend of Category 1 preforms imported versus time as shown in Figure 3.2. From 2009–2013, imports are nearly double or higher than in 2014. There was no information available to explain why the imports of PET peaked in 2011 and then rapidly decreased, but it may explain why there was such a large a depletion of the Consumption stock in 2014. Our MFA is based on a yearly balance (for 2014), but the consumption flow does not adhere to a yearly basis.

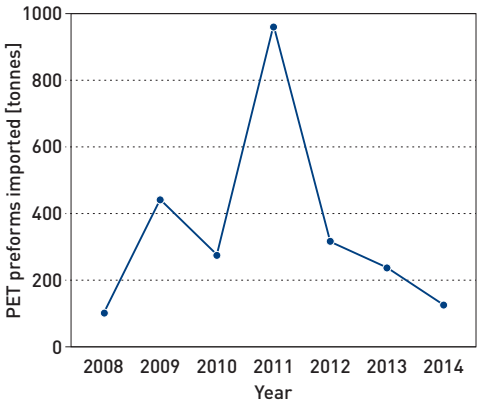

Figure 3.2
Category 1 PET imports from 2008–2014 (Source: WMF).

Consumption

Category 1 PET is blown and filled with water, soft drinks or alcoholic beverages by bottling companies. There are many bottling companies in the Seychelles, and interviews indicate that the largest are Seychelles Breweries, Sodepak, and Eden Springs (Praslin). The bottling companies tend to avoid keeping a large stock of PET preforms due to quality issues relating to moisture. A stakeholder says that Category 1 PET should therefore be processed within three months. During the process of blowing, around 6% of the imported Category 1 PET becomes damaged. These damaged preforms are brought to a Redeem Centre to be later exported. The bottling companies either distribute their final product themselves (Sodepak) or have several distributors (Seychelles Breweries). The products are distributed to retailers and hotels. An interviewee estimates that Sodepak distributes over 80% of its products to private retailers.

All categories of imported PET are ultimately stored or sold by households and retailors. Due to the large imports of Category 1 PET in previous years, we presume that households stored large quantities of PET bottles in their homes, or retailors and/or hotels kept large stocks in their

shops or warehouses until 2014, which was when a large stock depletion occurred as shown in Figure 3.1.

Collection

Consumers have three options for disposal of PET. These options and the relative proportions of the total we calculated are:

- Bring the empty PET bottles to a Redeem Centre (48%)
- Dispose of PET bottles together with other household waste in a public bin site (40%)
- Bring empty PET bottles together with other Mixed or Commercial waste to Providence landfill (12%)

The informal sector is the only significant collection service that removes PET bottles from public bins and the landfill and brings them to the Redeem Centres. According to our calculations, about 74% of the collected amount is from public bin sites, while 26% is from the landfill. We also found that the amount of PET collected at the Redeem Centres in 2014 was more than double the amount imported in 2014. We highlight that the import data and the collection amount provided to us came from two different sources and were in different units. We were provided with the number of bottles received by the Redeem Centres, therefore the total weight received is highly dependent on the average bottle weight. Hence it is possible that we overestimated the average weight of a bottle in the market on Mahé, leading to an inappropriate amount collected by the redeem centres.

Export and End-of-life

Due to informal collection, the share of PET bottles in MSW is only 1.6% (Seychelles Solid Waste Master Plan 2003–2010, Issue 04, p. 11). However, there is still a stock accumulated as litter and in the landfill. Stakeholders also say that PET bottles used as packaging material for oils and fats cannot be brought back to the Redeem Centre because of contamination. Therefore, Category 3 PET is often simply deposited at the landfill.

The PET bottles collected from the Redeem Centres are shredded and then exported by Harini Company. According to interviews, Harini exported about 240 tonnes of shredded PET bottles in 2014. We calculated that this is approximately half of the amount that was originally collected by the Redeem Centres. Furthermore, a small amount of PET material was exported in the immediate packaging of oils, fats and beverage products produced in the Seychelles. As the amount for exported packaging PET for beverages is minor, we neglected this stream.

Summary

We expect that all the PET material is imported to the country. Further we assume a big stock either at retailers or consumers. However, we hypothesise a data inconsistency in this part of our analysis

because we possibly overestimated the average weight of a PET bottle. Nevertheless, our analysis shows that the major part of the PET imported is brought to the Redeem Centres either by households, hotels or informal collectors. To the best of our knowledge the informal collectors contribute a lot to the success of the collection process. Only a small fraction ends up at the landfill. The collected PET material is eventually exported.

3.3.2 Cans

System Description

Cans made from aluminium and steel enter the Mahé system (Figure 3.3) purely as the immediate packaging of beverages and not as empty or unprocessed cans to be filled in the Seychelles. They have an associated levy, which means that like in the case of PET, Redeem Centres and private businesses which process and export the cans are important stakeholders. The

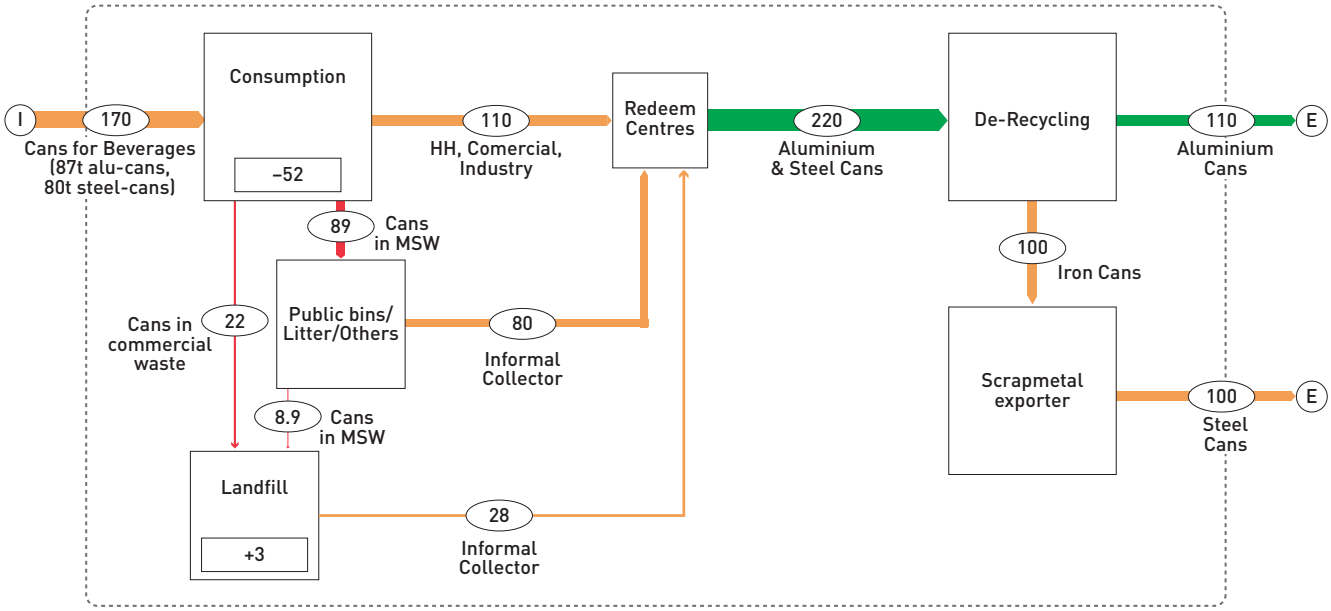

Figure 3.3
System flow of beverage cans in Mahé. Numbers are in tonnes and were rounded to two significant figures. I: Import flows. E: Export flows. The colours of the arrow reflect uncertainty assumptions: red: high uncertainty, orange: moderate uncertainty, green: low uncertainty.

largest sink of cans in the system is the landfill, but like in the case of PET, this quantity remains relatively small because of the effectiveness of informal collectors who remove a significant amounts and bring them to Redeem Centre.

Import

All beverage cans are full when imported to the Seychelles. While some of the cans are exported later, the biggest long-term sinks on the island are the landfill and the environment (littering). We assume that the export proportions – 52% aluminium and 48% steel – remain constant for all flows and processes across the material flow system. This proportion was calculated using data obtained from DE-Recycling and is further explained in the export description.

In total, 2,915 tonnes of canned beverages, including the weight of the can and the beverage, were imported in 2014 under the import classification HS 22. The imported beverage subcategories considered are provided in Appendix 3. For this study, we assume all 'metal containers' as specified in the HS classification are cans, and therefore have an associated levy in the Seychelles. Assuming an average beverage volume and an average weight of the empty can, the total amount of aluminium and steel, imported as the immediate packaging of imported beverages, was estimated. The estimation of cans entering the country with beverages is presented in Appendix 3.

Collection

The disposal pathways are similar to those for PET, and are as follows:

- Bring the empty cans to a Redeem Centre (49%)
- Dispose of cans together with other household waste in a public bin site (41%)
- Bring empty cans together with other Commercial or Mixed waste to Providence landfill (10%)

According to stakeholders, households, hotels or other enterprises bring roughly half of the total number of cans received by Redeem Centres, while the informal sector collects the other half either from public bins, littering or from the Providence Landfill. We estimated the number of cans the average informal collector brings to the Redeem Centre over the course of one year based on information from interviews and found that in 2014, the informal sector removed 14 tonnes of aluminium and 13 tonnes of steel cans from the landfill. Appendix 3 contains further details on this estimation.

Export and End-of-life

Based on the assumption of a 90% collection rate by the informal sector, we assume that 10% of the beverage containers entering the landfill remain deposited on the landfill. The other end-of-life scenario is export. Aluminium cans are exported by DE-Recycling, which accepts all beverage cans, segregates aluminium from steel, and directly exports only aluminium cans. One stakeholder indicated that in 2014, DE-recycling exported 112 tonnes of aluminium. The quantity of steel cans was therefore calculated as the difference between the collected amount of cans at the redeem centres and the aluminium exported. The flow of steel cans is redirected to Samlo and Sons and Redeem Centres from DE-Recycling for further processing and export together with other scrap metal. The proportion of exported aluminium and steel was taken to be 52% and 48% respectively, which we assumed to be true for the whole material flow analysis.

Summary

Like PET, the levy associated with cans is a crucial factor for their collection and the relatively small stock in the landfill. Redeem Centres and exporters are responsible for removing a large fraction of cans, made of both aluminium and steel, from the Mahé system, partly facilitated by the activities of informal collection.

3.3.3 Glass

System Description

Glass is a versatile material and is imported in a variety of forms into the Seychelles. Unlike the PET and Can streams, there is no associated levy for glass and therefore relatively little incentive to collect it. (To the best of our knowledge, there is only one small-scale private business which does so.) Glass is technically classified as Inert Waste according to the LWMA Waste Classification, and should be disposed of at the Anse Royale landfill according to current best practices. However, private individuals do not dispose of glass as such because there is no collection of Inert Waste at the household level. Furthermore, the intrinsic properties of glass (cumbersome, hazardous if broken etc.) makes it difficult to transport, so unless there is a large quantity of glass (e.g. at least a whole truckload) which can be brought to Anse Royale, individuals and organisations simply dispose of glass as part of other waste streams. More than 99% of glass entering the system remains in Mahé in landfills or as stocks in buildings (Figure 3.4).

There are several flows depicted in our chart which do not have numbers because these flows could not be quantified during our study and remain active fields of research. Nevertheless, we present the flows to show in detail the processes glass undergoes in terms of which stakeholders are involved.

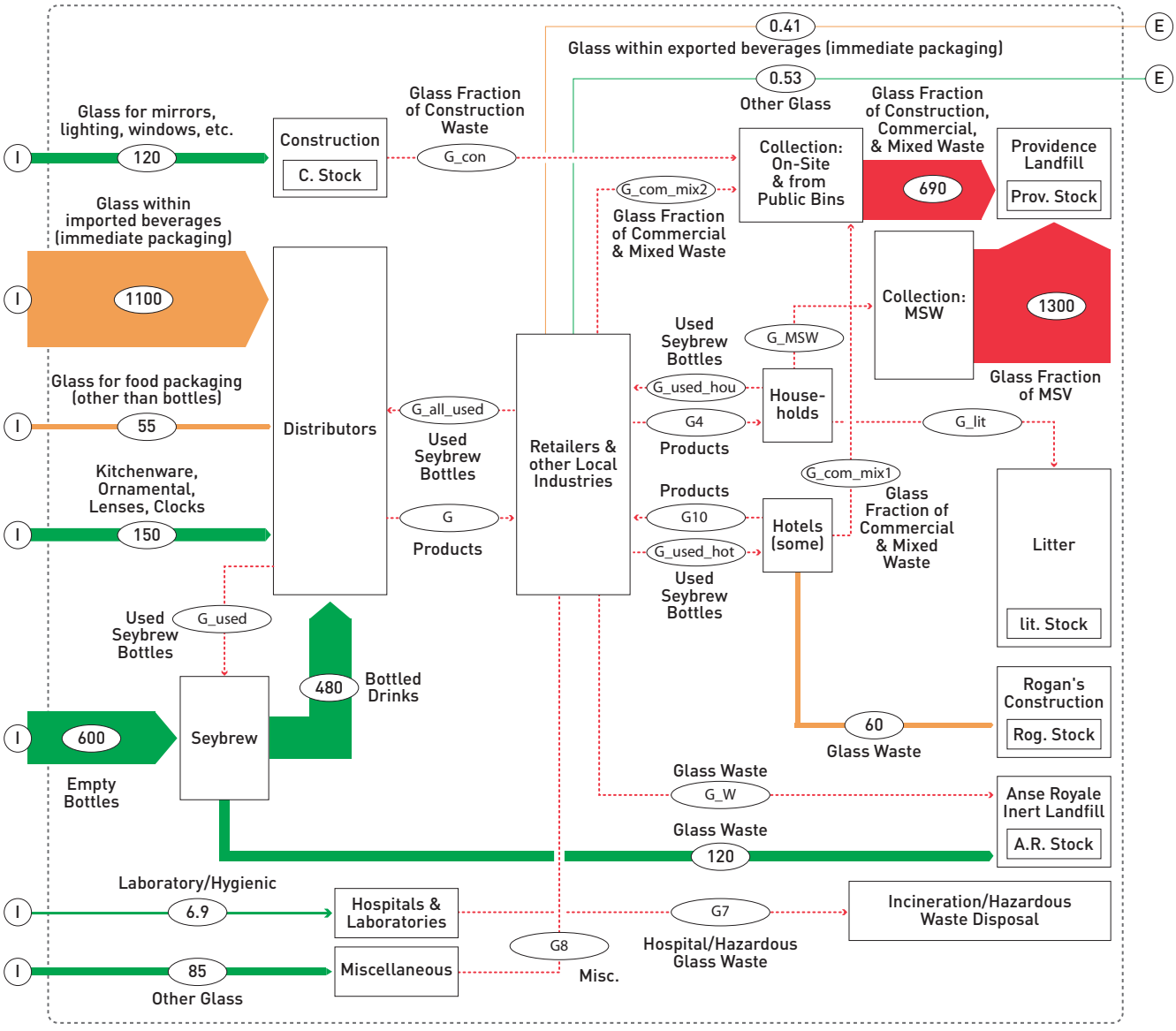

Figure 3.4
System flow of glass in Mahé. Numbers are in tonnes and were rounded to two significant figures. I: Import flows. E: Export flows. The colours of the arrow reflect uncertainty assumptions: red: high uncertainty, orange: moderate uncertainty, green: low uncertaintyy.

Import

We have divided these glass imports into 6 broad categories by grouping together classes of imports by HS number (provided in Appendix 3) based on the way(s) each class of glass would be used:

1. Construction, e.g., as mirrors, lighting, windows, panels (25%)
2. Immediate packaging of imported beverages (40%)
3. Food and beverage packaging (includes 'Empty Bottles' as in Figure 3.4) (25%)
4. Decoration, e.g., as kitchenware, ornaments, lenses, clocks (6%)
5. Laboratory and hygienic glass (<1%)
6. Other unspecified uses (3%)

Glass quantities in Categories 1, 3, 4, 5, and 6 were found by simply summing the tonnages provided by Customs across each respective category. The distinction between 'Empty Bottles' for Seybrew and the rest of the glass packaging in Category 3 could be made because Seybrew provided us with the tonnage of imported bottles.

Category 2 glass refers to glass which enters the Mahé system as already-packaged, ready-for-consumption beverage products such as wine, beer, spirits, and other forms of liqueur and alcoholic drinks. (This is in contrast to Category 3, which consists of empty bottles and other types of empty glass containers.) Because these glass items are classified as the beverage it contains and not as the glass itself which is used as the packaging, glass entering the system in this way is technically unaccounted for by Customs in their import/export data. Therefore, we had to make estimations based on reasoned assumptions in order to obtain the tonnage of Category 2 glass.

Category 2 constitutes the bulk of total imported glass by weight, entering the Seychelles classified as beverages (HS 22). However, glass imports as categorised by the HS code 70 are dominated by both Categories 1 and 3 (both 25%).

We chose to focus on imported beverages and neglected imported food products which may come in glass containers for two reasons: food products are more likely to also be packaged in alternative materials such as plastic, carton, or metal than beverages are in the Seychelles which would make it difficult to estimate the amount of glass packaging, and we believe that the amount of glass packaging for food products is minimal compared to that for beverages.

Consumption

Glass is consumed in various ways. In the case of Category 1 glass, most of it enters and remains in buildings as stock. Glass for food and beverages, and for kitchenware, ornaments, lenses, and clocks flow to distributors and then to retailers who sell them to consumers. The remaining types of glass have specific uses and therefore go to their respective importers such as Seybrew (empty bottles) and hospitals (laboratory and hygienic glass).

Collection

There is no dedicated large-scale collection of glass for recycling. Organisations which wish to dispose of large amounts of glass must bring their loads to the Providence Weighbridge to first be weighed so that the appropriate disposal fees owed to the LWMA can be calculated before then depositing their load at Anse Royale landfill. The only form of recycling individuals at the household level and hotels can do is to bring their used Seybrew bottles back to shops, which then return them to the distributors who bring them back to Seybrew to be washed and re-used. Rogan obtains his glass waste directly from certain hotels in the vicinity of Baie Lazare where he operates, and at a very small scale, from some households.

Export and End-of-Life

Amongst the 12 different waste classifications according to the LWMA, we assumed that significant glass fractions only exist in the MSW, Construction, Mixed, Commercial, and Inert Waste classes. The proportions of glass in the remaining waste classes are assumed to be negligible.

The 5.2% glass fraction of MSW is assumed to be representative of all the MSW streams entering the landfill through the Providence weighbridge. This fraction was identified in a past sampling campaign of MSW generated in Mahé and deposited at the Providence landfill (Seychelles Solid Waste Master Plan, 2003). Therefore, glass in MSW was (back)calculated by finding 5.2% of the total MSW (2014 Providence Weighbridge).

The total glass fraction of Construction, Mixed, and Commercial Waste is unknown because no sampling of these waste classes has been performed in the past to the best of our knowledge. Therefore, we estimated this quantity of glass by taking the difference between the 2.6% glass fraction of Total Waste deposited at Providence Landfill and the 5.2% glass fraction of MSW to be the total glass content of the Construction, Mixed, and Commercial Waste streams. (The glass fraction of Total Waste was found in the same aforementioned sampling campaign.) This is a reasonable assumption because Inert Waste is deposited at Anse Royale Landfill, not Providence, and hence is not part of Total Waste on Providence Landfill (as defined in the Methodology of the Seychelles Solid Waste Master Plan (2003).)

Summary

Like PET, all glass is assumed to be imported into the Seychelles. There is virtually no recycling mechanism, nor is there any dedicated collection service at the household level. Seybrew's well-functioning bottle reuse programme significantly decreases the amount of glass which would be imported if such a programme did not exist. However, these reused bottles ultimately enter the Anse Royale landfill once their operational lifespan has been surpassed.

3.3.4 Scrap Metal

System Description

Scrap Metal is a broad category which consists of products which are either 100% metal such as corrugated sheets and metal tubes, or products which contain mostly metal, for example, cars and batteries. Beverage cans made of metal which were previously described are excluded in the consideration of this waste stream (Figure 3.5). Before metals eventually become Scrap Metal upon disposal, they are imported as products and therefore enter the Seychelles not classified as metal per se. Because of metal's versatility and durability, most of what is imported remains as stocks. The existence of an international market for scrap metal fuels scrap metal exports by private companies, but exported quantities are still far less than what is landfilled.

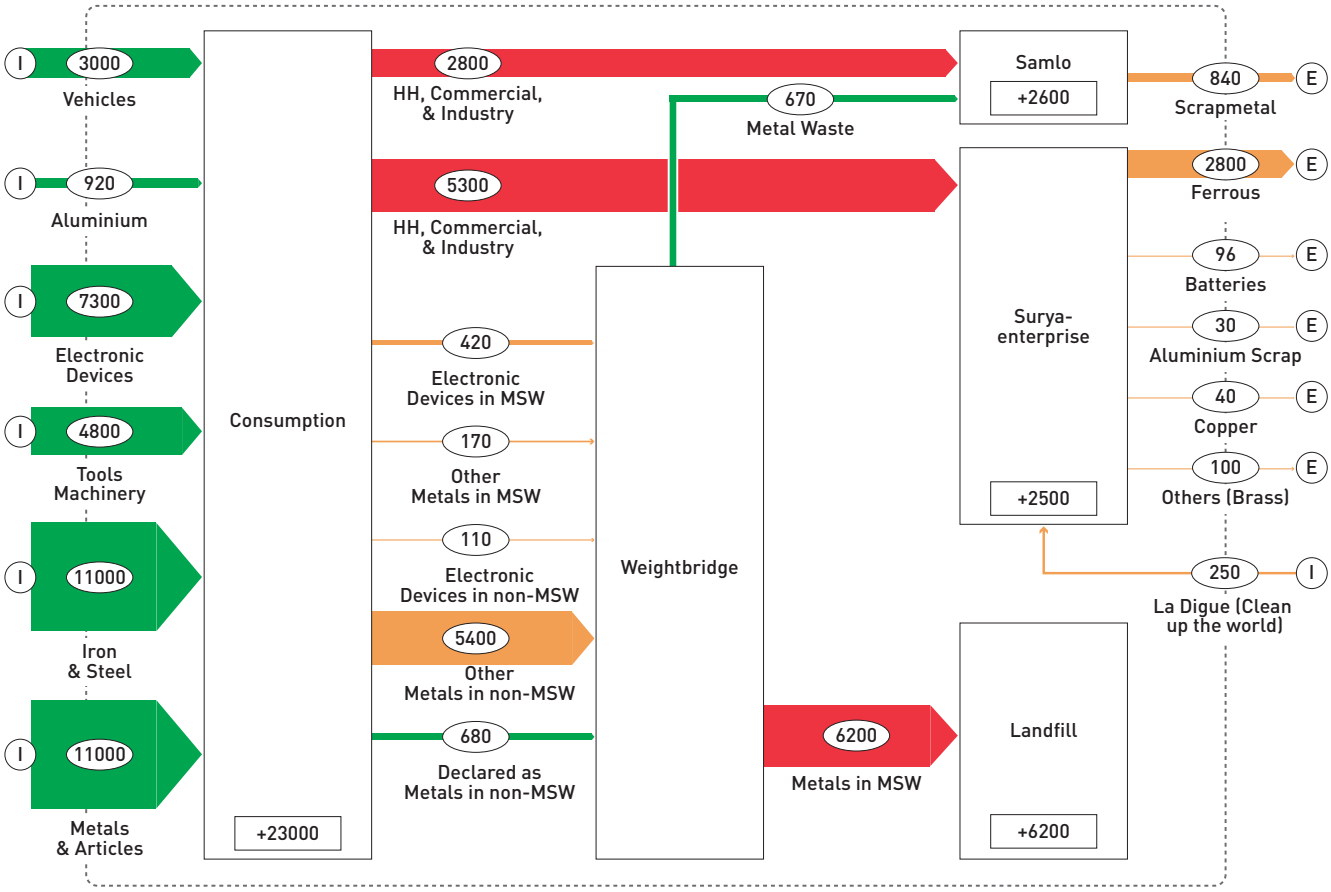

Figure 3.5
System flow of scrap metal in Mahé. Numbers are in tonnes and were rounded to two significant figures. I: Import flows. E: Export flows. The colours of the arrow reflect uncertainty assumptions: red: high uncertainty, orange: moderate uncertainty, green: low uncertainty.

Import

All metal products which eventually become scrap metal are assumed to be imported. The products considered were chosen based on the aforementioned criteria, and are specified according to the HS categorisation as follows: vehicles, aluminium, iron and steel, metals and articles thereof, electronic devices, and tools. These imports correspond to HS 72–76, 78–86, 88, and 89. A full list of these HS categories is provided in Appendix 3.

We are aware that the list of metal-containing imported goods we chose is not exhaustive, and that there are other imported goods containing metal. We also acknowledge that some of the imports we do consider are not made of 100% metal. Because of these uncertainties, we chose not to estimate the fraction of metal in these flows, but include them in our flow diagram to give an idea of the contributions to the system.

Consumption

The biggest fraction of metal imported enters the built environment and therefore has a long-term usage and lifespan. Vehicles and electronic devices on the other hand have shorter life spans and leave the system relatively earlier, not only because of degradation associated with the humid climate and coastal proximity, but also because of how quickly these products become obsolete due to issues of quality and societal perception: stakeholders indicate that Seychellois tend to buy new devices instead of repairing malfunctioning ones because of the lack of expertise required to repair such products and therefore high repair costs. For this material flow, we assume that the yearly growth of the total metal stock results from the import minus the total export of metal scrap.

Collection

There are two scrapyards in the vicinity of the landfill: Surya, and Samlo and Sons. The disposal of scrap metal is unrestricted and is open to any individual who wishes to dispose of metal there. The personnel at the yards therefore cannot keep track of the amounts disposed in their yard and instead can only estimate the stock on their yard. Interviews show that both companies do not have a fixed export schedule, but rather depend on the global scrap metal market. Surya exports a specific class of scrap metal when the market price is elevated, while Samlo and Son exports to their parent company located in Mauritius, which recycles the scrap metal, when they have sufficient stock.

Export and End-of-Life

In 2014, 667 tonnes were classified as metal waste on the weighbridge of the Providence Landfill. To the best of our knowledge, this metal waste was redirected to Samlo and Sons for further processing and eventual export. Using the fraction of metal from the waste classification exercise in 2003 (SWM Plan, Figure 6), we

calculated the metal flow contained in MSW deposited on landfills, shown in Appendix 3.

Summary

Scrap metal is a highly voluminous and heavy material, whose export thanks to its economic value significantly decreases the amount which goes to landfill.

3.3.5 Paper and Cardboard

System Description

Unlike the other materials described so far, paper and cardboard have neither a levy (PET and Cans) nor international market value (Scrap Metal). Furthermore, PC cannot be attributed to a specific waste class like glass can be to Inert Waste. As a result, there is virtually no recycling of paper and most of it is landfilled as fractions

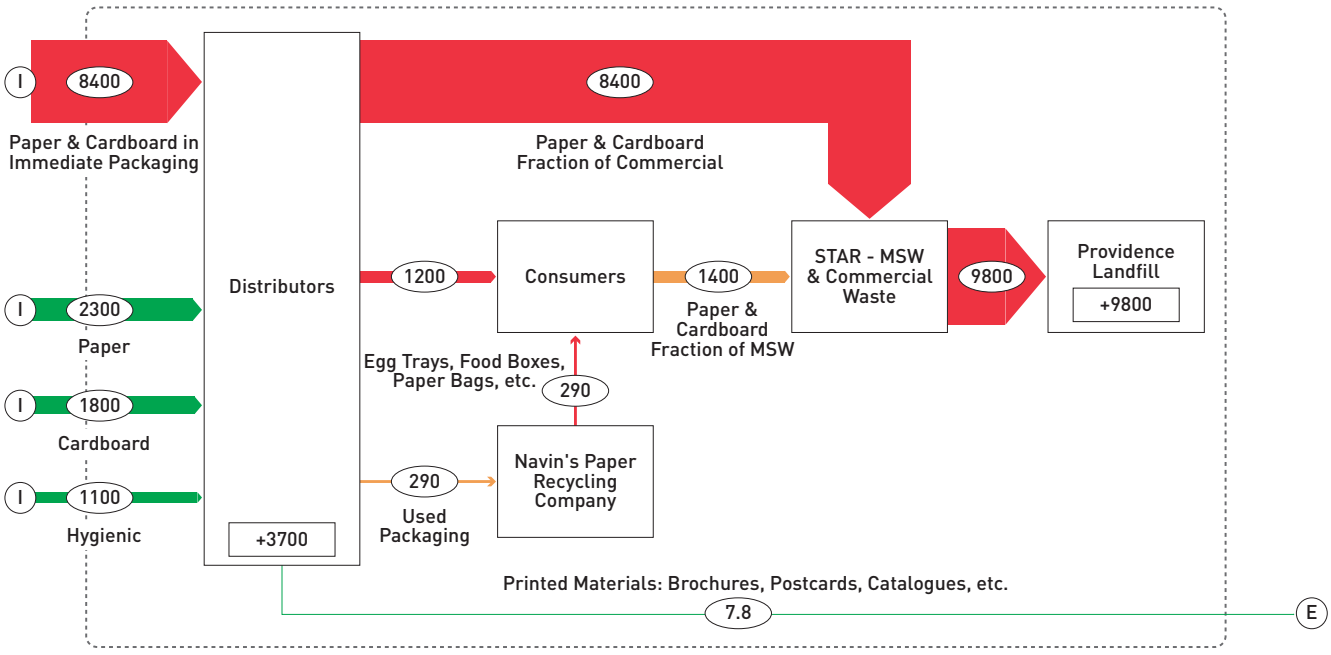

Figure 3.6
System flow of paper and cardboard in Mahé. Numbers are in tonnes and were rounded to two significant figures. I: Import flows. E: Export flows. The colours of the arrow reflect uncertainty assumptions: red: high uncertainty, orange: moderate uncertainty, green: low uncertainty.

of other waste streams (Figure 3.6). There is one private business which recycles PC to products such as egg trays and takeaway plates, but it operates on a very small scale. The landfill is therefore by far the greatest sink of PC in the system.

Import

We assume all PC is imported into the Seychelles and that there is no local production. PC enters the Mahé system in two ways. The first is that PC can be imported as a finished product, to be used for commercial or home use. These types of import are accounted for by Customs under HS codes 47, 48, and 49. For this MFA, we subdivide corresponding paper imports into three categories based on type and recyclability:

1. Paper, mass < 150gm/m^2 (Category 1)
2. Cardboard, mass > 150gm/m^2 (Category 2)
3. Hygienic Paper, e.g., napkins, diapers, kitchen paper (Category 3)

Categories 1 and 2 have recycling potential if uncontaminated by organic substances such as oils. Category 3 PC must be landfilled or be treated at a waste water treatment plant. It will eventually be decomposed into carbon dioxide, methane and water.

The second way paper enters Mahé is as the immediate packaging of various products. We expect the quantity of PC estimated under HS 47–49 to grossly underestimate the actual total amount of PC imported into the Seychelles. This is because there are a wide range and large quantity of products, including but not limited to electrical appliances, food, furniture, and glassware, which are packaged in PC when imported into the Seychelles. In other words, businesses such as supermarkets and electronics stores receive their imported stock in PC packaging. We therefore estimate that the PC fraction of Commercial Waste equals the imported quantity of PC in immediate packaging because businesses dispose of mostly PC, according to stakeholders.

Consumption

Consumers use PC products for a wide range of purposes, including for packaging, hygiene, decoration, businesses, and education. A lot of paper remains in the system as stock in the form of printed materials, office records, and books because we observed that in many offices, records are kept as hard copies and not in electronic form. However, because of the humid climate in the Seychelles, we expect paper to have a relatively short lifetime and high turnover rates.

Export/End-of-Life

The majority of PC (>93%) is landfilled. We estimate that STAR collects most PC in Commercial Waste and MSW, of which the fractions of PC are estimated by stakeholders and the literature to be 50% and

5.9% respectively (Solid Waste Master Plan 2003–2010). Approximately 2% of the total quantity of PC imported is recycled by Navin's Paper Company. Navin's Paper Company processes PC, creating products that re-enter the market as egg trays, paper bags and other goods. However, some stakeholders believe that the majority of the paper collected by Navin's Paper Company remains as stock because their operations are relatively irregular. A small fraction leaves the system as exports of printed materials such as postcards, brochures, and leaflets (<1%).

Summary

Practically all the paper and cardboard which enters the Mahé system remains within the Mahé system boundaries, with the largest long-term sink being the Providence Landfill. The only recycler of paper operates on a very small scale and even then, processing of PC is on an irregular basis. PC does not have its own classification in the waste system as shown in Table 1 and is therefore be disposed of as fractions of other waste streams.

3.3.6 Summary

We provide a summary of the tonnages of each material which we calculated to have entered the Providence Landfills in 2014 (Table 3.3), and the corresponding change in the landfill stocks. The changes in landfill stock of PET and Cans respectively are roughly ten times smaller than what enters the landfill because of the effective removal of these materials by informal collectors.

Table 3.3
Tonnage to Landfill and Change in Landfill Stock in 2014.

Material Stream	Enters Landfill as: Waste Class(es)	Tonnage to Landfill in 2014	Change in Landfill Stock 2014
Paper & Cardboard	MSW, Commercial, Mixed	9800	+9800
Scrap Metal	Metal, MSW, Commercial, Mixed, Construction	6200	+6200
Glass	Inert, Commercial, MSW, Mixed, Construction	1990	+1990
PET	MSW, Commercial, Mixed	60	+6
Cans (Alu & Steel)	MSW, Commercial, Mixed	31	+3

3.4 Discussion

In this section, we will further analyse each waste class and discuss the most significant results of the MFA as well as indicate points where interventions can take place which include recycling, lower waste production or other relevant processes. The results demonstrate that landfilling is the primary end-of-life scenario for most waste streams. However, data were limited and we cannot provide as comprehensive of an analysis as if we had better data. The challenges of data inaccuracy are mentioned briefly in this section, and are further elaborated upon in detail in Section 3.2.

3.4.1 MFA Output

Our results show that the Glass, and Paper and Cardboard streams have the highest proportion (>90%) of end-of-life to the landfill. We believe there are multiple factors which contribute to this outcome, principal of which being that these materials do not have an associated levy and are not officially 'recognised' by the Waste Classification system in terms of having their own specific waste classes 'Glass' and 'Paper and Cardboard'. As a result, these materials are rendered 'invisible' in the waste management system and are therefore mixed with other types of waste which are then disposed of as fractions of MSW, Commercial, Mixed, and Construction Waste. Although glass can be disposed of as Inert Waste, this mechanism only functions on large scales i.e. with businesses which have large quantities of glass and the means to transport this glass to Providence to be weighed, then to Anse Royale to be dumped. Like for Paper and Cardboard, Glass is not collected at the household level and there is accordingly no convenience for households to sort these materials. Additionally, because there are no levies on these materials, there is no economic incentive for businesses to open Redeem Centres for these materials.

However, we recognise that there exist some inherent obstacles to implementing recycling programmes for these materials. In the case of glass, it is usually in the form of whole bottles which are very cumbersome. (Stakeholders estimate that the volume ratio of whole bottles to crushed glass is 8:1.) Crushing glass, particularly on a large scale, requires equipment and expertise because crushed glass is sharp and therefore hazardous. Nevertheless, we believe that there exists unexploited potential for the use of glass cullet in industrial/production processes. For the case of Paper and Cardboard, there are concerns with quality issues relating to the humid climate of the Seychelles which prevent the stockpiling of paper and cardboard over long periods of time. One stakeholder, who used to export PC for recycling, claims that partly because of not being able to stockpile PC, they could not take advantage of lower freight costs due to market fluctuations of oil prices. As a result, this stakeholder had to stop exporting PC because it was no longer financially viable.

We identify two possible intervention points to decrease the fraction of these products entering the landfill. First, increasing the lifetime of goods would create lower demand for these materials. This includes the lifetime of products that require paper and glass as secondary materials, such as packaging. Another intervention point could be to increase the recycling or upcycling production capabilities of available recycling technologies. The levy system can be modified to include glass products. Seybrew has a functioning deposit/refund scheme for its bottles so that they can be recycled, and this could be modified to include other glass containers. Increasing upcycled paper products in the form of making handicrafts could also be a viable option in the Seychelles, especially because of the large tourism industry which would likely demand these products. This initiative would decrease the size of the paper and cardboard waste streams entering the landfill.

In contrast, the effective levy system on PET and Cans is a huge factor in the success of their recycling programmes. The levy system provides an incentive for stakeholders to divert bottles and cans from the landfill so that they can be processed and exported. As demonstrated in both MFA diagrams, this diversion is highly dependent on the informal sector who collect cans from the landfill, litter, and municipal waste bins and bring them to the redeem centres. Additionally, the collection schemes established with hotels provides an efficient method for diverting bottles and cans to the Redeem Centres. Because the PET bottles used for oils and fats cannot be brought to the redeem centres for a refund, they have an end-of-life at the landfill. As discussed in Chapter 1 and Chapter 2, many stakeholders agree that the PET and aluminium and steel can levy system is an effective, self-sustaining method to reduce landfilling.

Similarly, exporting scrap metal allows diverting a large portion of waste from the landfill, but still, we believe that a majority of the scrap metal still ends up in the landfill. An intervention point could be at the quality of the products introduced in the Seychelles. There is a diverse amount of metal products entering the market that have different lifetimes. By introducing products with longer lifetimes and providing more opportunities for customers to repair rather than replace their metal products, the amount of metal waste produced could decrease. (The repair sector could be fostered through introducing a landfill tax for example.) Furthermore, we wish to highlight that because scrap metal has a high volume, it poses a storage challenge to exporters. The exporters cannot sort and quantify their stocks accurately because they do not have enough space in their scrap yards. This further decreases the data accuracy and may prevent exporters from exporting as much metal as possible.

The imported metal data are incomprehensive and our results are based on only selected products entering the Seychelles. More specific data regarding the imported products, including product metal content and lifetime, are required to further analyse the flows of scrap metal. Additionally, a better understanding of lifespans of construction materials and other non-consumer goods will improve stock and flow estimations within the Seychelles. Finally, data collection could be more thoroughly conducted at the scrap yards. These uncertainties indicate that this MFA should be seen as a system overview for Scrap Metal instead of a typical analysis for a single material. The picture can help decision makers, entrepreneurs, teachers or interested people to better understand the system. However, the numbers shown in the flow chart should not be regarded as highly accurate.

For all streams, we recognise that the imported amounts often did not correspond to those which were consumed or recycled. We believe that the fluctuating import trends over previous years contribute to this discrepancy by introducing stocks in previous years which are only later consumed. For example in the case of PET, nearly 4 times the amount of PET bottles were imported in 2011 than in 2014, so it is most likely that retailers had still beverages of previous years in stock.

In general, the results demonstrate that there are functioning recycling and waste diversion systems currently in place in the Seychelles that can be extended to other waste streams. The amount going to the landfill can also be decreased when long-living, repairable goods enter the market, but perhaps more effectively, through fostering a repair sector and upcycling or downcycling.

3.4.2 Limitations

Every system picture presented in our results was constructed using a combination of data we believe to have low uncertainty (green arrows), and estimates based on data with moderate to high uncertainty (orange and red arrows respectively). We believe that the data obtained from the Customs Division have the lowest uncertainties for several reasons: data were not conveyed as rounded estimates verbally during interviews but through tables in Excel spread sheets; compared to private businesses, the Customs Division is a government agency which is obliged to maintain transparent practices; and because levies and taxes collected by the Division are calculated based on the weight of a given import, precise accounting is imperative. Additionally, we presume that no human errors were made in the process of extracting the data from their databases and conveying it to us. Taken together, we believe that these data are a strong basis for the other calculations and estimations made for the flows within the system.

Data obtained from stakeholder interviews were considered to have moderate levels of uncertainty because of the way they were collected – usually through quick, informal interviews. These values were mostly given as estimates rounded to the nearest tenth, hundredth, or even thousandth tonne during verbal interviews. After conducting our interviews, follow-up correspondence was rarely possible with our stakeholders which would have been helpful for further data interpretation. In some cases, we were given the value equivalent in Rupees of the quantity of material processed, and quantities had to then be back-calculated to obtain the corresponding tonnage; this scenario was often the case during interviews with informal collectors who are legally not supposed to operate at the landfill and for whom monetary value is more tangible and relevant than tonnage. Furthermore, there is the issue of the lack of obligation to be transparent, especially amongst private business owners who may wish to keep their data confidential or because of conflicts of interest pertaining to satisfying contractual obligations with other parties. In certain cases, there were also stakeholders who did not appear to have good knowledge of their own data because they are either not involved in day-to-day accounting or do not keep good records. Despite these factors, we accept these data as reasonable estimates.

The data with the highest uncertainties are those which were calculated based on waste characterisation fractions. The waste characterisation exercises which were performed by Scott Wilson in 2003 are outdated for the purposes of our research and likely do not reflect the current composition of waste in Mahé. Furthermore, there are inherent uncertainties associated with these original waste characterisation exercises, principal of which is that the samples taken for characterisation were small compared to the total waste amounts and likely not representative because of the heterogeneity of certain classifications of waste, namely MSW, Commercial, and Construction Waste. A more recent waste characterisation has been performed by Technische Universität Darmstadt (TUD) in 2015–16, but our requests for their data have not been served at time of writing.

We further acknowledge the limitations of imposing a system boundary which only includes Mahé. The choice to do so was deliberate for what we believe are justifiable reasons: Mahé serves as the hub for all imported and exported goods, and the majority of inhabitants and tourists live on Mahé which we assume reflects the greatest proportion of consumption activity. Nevertheless, we remain cognisant of the fact that there are inhabitants and tourist activities on other islands in the Seychelles (especially Praslin and La Digue), and that these have not been completely accounted for in our analyses.

Because of time limitations, we were unable to perform a sensitivity analysis on the aforementioned assumptions or information. However, we acknowledge that such a test would be crucial for determining which assumptions may bias the results more than the others. We therefore suggest that future researchers perform a sensitivity analysis on our calculations to assess the impacts of our assumptions.

3.5 Conclusion

The material flow analyses we conducted demonstrate that most waste enters the landfill. We find that the PET and Cans systems most effectively divert materials from the landfill. The functioning levy system drives the informal sector and hotels to collect PET and cans, resulting in low fractions of waste entering the landfill. Scrap metal is currently being exported in a significant proportion, but it is still less than what we estimate is going to the landfill. Our analysis could be improved with better data. The Paper and Cardboard and Glass streams have >90% end-of-life in the landfill and represent an unexploited potential for recycling. Existing recycling systems can be built upon and upscaled.

Data gaps and poor data quality affect the accuracy of our MFAs and the results derived. Therefore, the analyses of these waste streams are limited, especially for Scrap Metal. The accuracy of future MFAs would therefore not only rely on the use of the mass-balance principle, but also on a comprehensive and precise datasets for all waste fractions.

3.6 References

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4 Environmental Impacts of the Providence Landfills

4.1 Introduction

Landfilling is the main way of dealing with waste in the Seychelles. There are currently four landfill sites in operation: one on Praslin, one on La Digue, and two on Mahe called Providence I and Providence II. The latter two landfills are located on reclaimed land situated directly along the coast. Providence II (PII) is the newest of the two, and is considered to be a sanitary landfill because unlike the other landfills it is lined with a composite plastic material to prevent leaching. The construction of PII was funded by the EU to replace Providence I, which has been in operation since the beginning of the 1990s and has virtually reached its full capacity. PII is expected to have enough capacity to be in operation for 9 years. There is practically no separation of the different types of waste at PII, which include but are not limited to municipal solid waste (MSW), industrial waste, commercial waste, liquid waste, and construction waste. According to a study conducted by Scott Wilson (2004), the MSW contains a large proportion of organic waste, in addition to cardboard, paper, plastics, metal, electronic equipment, and even batteries.

Despite it being a cost-effective and simple waste management strategy, landfilling has been shown to have considerable adverse effects on the environment. The environmental impacts of landfilling solid waste had been reported almost two decades ago by El-Fadel and colleagues (1997), who focused on the production of leachate and gases from the microbial degradation of waste. Leachate poses the threat of polluting ground- and surface waters, which according to Kjeldsen et al. (2002) who reported on MSW landfill leachate, can contain inorganic macro components such as ammonia, dissolved organic matter, and heavy metals. Landfill leachate has been observed to have highly toxic effects to species from different trophic levels, but in spite of this, there is little knowledge on the best practices of leachate monitoring beyond the US's guideline of 30 years' post-closure of the landfill (Kjeldsen et al. 2002). The gases released from the landfill are also of concern as they contribute to anthropogenically induced climate change; not only is carbon dioxide produced from aerobic decomposition, but so is methane from anaerobic decomposition, which is a more potent greenhouse gas (Lashof & Ahuja, 1990).

To date, there exist to the best of our knowledge no extensive studies on the environmental impacts of landfilling in the Seychelles. The very heterogeneous nature of the waste entering the landfill is of particular concern, because the high fractions of organic waste could lead to favourable chemical conditions for toxic heavy metals to become more mobile and enter

aqueous systems – this can be groundwater, surface water, and finally the ocean. Because the leachate collected from the PII landfill remains untreated in practice (even though it could in theory be pumped into a leachate treatment plant), such a situation could arise. Besides the possible ramifications on human health, the lack of knowledge regarding the environmental impacts of these landfills is all the more pressing in the long term considering the importance of the tourism and fishing industries to the Seychelles's economy.

Our research seeks to address this knowledge gap using a holistic approach. We focus on the following questions in our study:

1. Can we identify and measure substances in waters surrounding the Providence landfills which serve as evidence of landfill leaching?
2. Do certain stakeholders observe changes in the environmental conditions of the vicinity of the Providence landfills and to what extent do they connect this to possible leachate from the landfills?
3. How do governmental and non-governmental stakeholders perceive the state of the landfills?

4.2 Methods

In our study, we employed a dual approach to assess the possible environmental impacts of the Providence I and II landfills. Inorganic compound parameters of water samples taken from areas surrounding the landfills were measured in tandem with stakeholder interviews. We did not measure the outgassing of any of the aforementioned greenhouse gases, nor could we address the presence of organic pollutants in our study.

4.2.1 Water Sampling and Analysis

We sampled water at 10 different sites in and around the landfills of Providence I and II as indicated in Figure 1 using geographical location data determined by a Garmin Oregon 550t GPS device. These sites consisted of various outlets from the leachate pre-treatment plant (LPTP) of Providence II, coastal waters, ponds, and groundwater (Appendix 4). Sampling

occurred in the morning of the 4th of July 2016 during low tide, which was at its minimum at 9:50 am (www.tide-forecast.com, last accessed 07.07.16). July is the coolest and driest month of the year in the Seychelles, with an average of 80.3 mm of precipitation, 80 % relative humidity and a mean temperature of 26° C. During our sampling the weather was cloudy with a little bit of rain. The landfills, located on the East coast of Mahé, were under the influence of the Southeast Monsoon which is at its height in July and induced strong wind conditions (www.meteo.gov.sc, last accessed 07.07.16).

We took 5 L samples at every sampling point using an open bottle connected to a rope, plus an additional 50 mL for elemental analysis with the exception of sample 2,

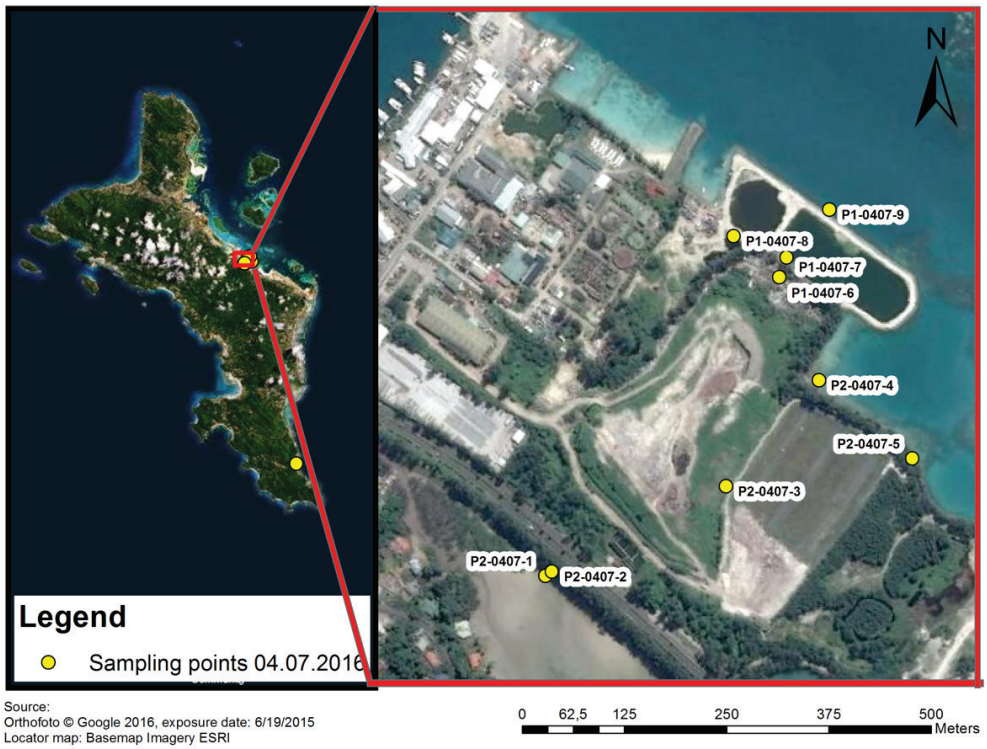

Figure 4.1
Water sampling sites around Providence I and II landfills in Mahe. The labels indicate the closest landfill, date, and sample number e.g. P2-0407-1 corresponds to Providence II, 4th July, Sample 1. Samples 1–9 were obtained on the north-east coast of Mahé (right panel), while the reference sample 10 was obtained from the south-east coast at Anse Forbans (left panel).

where only 50 mL was collected for heavy metal analysis due to low water volume at the sampling site. Sample 10 is a reference ocean water sample, taken at the coast at Anse Forbans (see Figure 4.1, left panel). Water samples were either analysed on-site, or collected in plastic containers pre-rinsed with distilled water for analysis on either the same or following day in the laboratory of the University of Seychelles, or later in the Soil Chemistry Laboratory of ETH Zurich.

Table 4.1
Water quality parameters selected to analyse landfill leaching based on the US EPA guideline for landfill effluents (Appendix 4).

Parameter	Producer	Instrumentation	Measuring range	Accuracy	Resolution
pH	VERNIER	Ag/AgCl pH sensor	0-14	±0.2	0.005
Dissolved Oxygen (and Biological Oxygen Demand)	VERNIER	Clark-type polarographic electrode Sensor	0–15 mg/L	±0.2 mg/L	0.014 mg/L
Turbidity	VERNIER	Infrared sensor	0-200 NTU	± 2 NTU below 25 NTU ± 5% above 25 NTU	0.25 NTU
Salinity	VERNIER	Conductance sensor	0 to 50 ppt	±1% of full-scale reading	0.02 ppt
Ammonia (includes NH_3 and NH_4^+)	VERNIER	Ion-selective electrode for ionised ammonia	1–18´000 mg/L	± 10% of full-scale reading	
Nitrate (NO_3^-)	VERNIER	Ion-selective electrode	1–10´000 mg/L	± 10% of full-scale reading	
Arsenic	MERCK Millipore	MColortestTM 117917 Arsen-Test Colorimetric	0.02–3 mg/L		
Zinc	MERCK Millipore	MColortestTM 114780 Zinc-Test - Colorimetric	0.1–5 mg/L		0.1 – 0.2 – 0.3 – 0.4 – 0.5 – 0.7 – 1 – 2 – 5 mg/L
Copper	MERCK Millipore	MColortestTM 114414 Kupfer-Test Colorimetric	0.05–0.5 mg/L		0.05 – 0.08 – 0.12 – 0.16 – 0.20 – 0.25 – 0.3 – 0.4 – 0.5 mg/L
Chromate (Cr (VI))	MERCK Millipore	MColortestTM 114756 Chromat-Test Colorimetric			

Eleven water quality parameters (Table 2) were selected based on the guidelines provided by the US Environmental Protection Agency (EPA) for landfill effluents (Appendix 7.2). These parameters were chosen to serve as tracers for landfill leaching (pH, salinity, dissolved oxygen) as well as to assess the quality of the leachate in terms of the presence of heavy metals, nitrate, and ammonia. Four of these parameters (Arsenic, Zinc, Copper, and Chromium (VI) in the form of the chromate ion) were measured on-site using heavy metal test kits by Merck Millipore to obtain quick results and a rough estimation for more precise elemental analysis using ICP-OES later on. The remaining parameters were measured in the laboratory using VERNIER sensors and Logger Pro software.

Samples to be measured later using ICP-OES were prepared and stored as follows: after collection, the water was filtered immediately on-site with cellulose acetate filters (pore size 0.45 µm), mixed with 1 mL of 65% nitric acid (HNO_3), and stored in 50 mL Falcon tubes. Additionally, two blank samples in the form of distilled, filtered, and acidified water were taken. Samples were kept in a cool and dark environment until they were measured at ETH Zurich on the 8th of August 2016.

Biological Oxygen Demand (BOD) was determined from measurements of Dissolved Oxygen (DO) using a method developed by Mckenzie (2003). Two DO measurements were taken for every sampling point: the first DO values were measured in the laboratory on the same day of sampling. The second measurement was conducted four days later on the evening of 8th July 2016. The mean value of each pair of measurements was calculated and used to determine BOD using the following equation:

$$BOD_5\left[\frac{mg}{l}\right] = \frac{D_1 - D_2}{P}$$

With:

D_1 = initial sample dissolved oxygen (DO) concentration (in mg/L)

D_2 = sample DO (in mg/L) after 5 days

P = decimal volumetric fraction of sample used

For quality assurance purposes, we compared our measurements of the 10 samples to 6 measurements we obtained in the catchment area of Val d'Endor in South Mahe, as well as to existing measurements performed by the Public Utilities Corporation (PUC) on tap water produced in their desalination plant located 200m from the landfill. The data are provided in Appendix 4. The measurements from Val d'Endor were conducted on the same day as the sampling, and the analyses were conducted together with the landfill samples using the same instrumentation and procedures.

4.2.2 Stakeholder Interviews

Fifteen semi-structured stakeholder interviews were conducted (Table 4.2) to complement the information from our empirical data and address our second and third research questions, namely, whether any changes in environmental conditions have been observed in areas near the landfill, and how institutional stakeholders perceived the state of the landfill.

Fishermen who work near the coast and workers on the landfill were considered 'on-site stakeholders', and were therefore consulted regarding the environmental conditions. These stakeholders were selected because their daily activities require them to come into contact with the areas possibly affected by leachate, making them the most knowledgeable about any ongoing changes in the surrounding environment and if there have been any long term trends in e.g. fish yields, health issues, occupational hazards etc. The fishermen and workers were also asked whether they were aware of the possible environmental and/or health threats of landfills.

Snowball sampling was used to identify the fishermen suitable for our interviewing purposes, i.e. those who fish along the coast and on the reef. This method was integral to finding these specific inter-

Table 4.2
Interviewed stakeholders representing institutions and who work in the immediate vicinity of the landfills. The names of all the fishermen have been changed to protect their anonymity, except Florent, who represents the Roche Caimon Fishermen Association.

Sector	Interview partner	Contact Person	Function
Industry	STAR (Management)	Regina Sinon	STAR (Management)
	STAR (6 Workers)	Diverse	Truck Drivers, Landfill Attendants and Workers
	Fishermen (4)	James, Michel, Justin, Florent	Expertise on fishing conditions
	Public Utilities Corporation (PUC)	Ibrahim Diallo	Desalination Plant Manager
Scientific Research	Insitut de recherché pour le developpement (IRD), SFA	Nathalie Bodin	Biologist (ocean fish)
Government	Seychelles Fishing Authority (SFA)	Calvin Gerry	Fisheries Section
Associations	Seychelles Fishing and Boat Owners Association (SFBOA)	Keith Andre	Chairman

viewees because of their irregular fishing activities which depend on tides. These fishermen were generally smallholders working in Cascade instead of those working on an industrial scale, because industrial fishers tend to fish far away from the coast (as later confirmed by the chairman of the Roche Caiman Fishermen's Association, who stated that RCFA fishermen are not active close to Providence and instead conduct their fishing activities roughly 10km from the coast off Eden Island). Similarly, we identified our stakeholders from the landfill through walking around in the vicinity and interviewing them at sites of interest where e.g. they perform their daily duties.

We identified our relevant institutional stakeholders upon consultation with the Advisory Board. These stakeholders represent three different sectors: Associations, Industry, and Scientific Research. While most of the institutional stakeholders were selected because their activities are directly linked to fishing, fish research, and the landfill, PUC was selected because their desalination plant takes in water in close proximity to the landfill and is therefore also considered an on-site stakeholder.

All interviews were conducted in Mahé between 27th June and 7th July 2016.

4.3 Results

This section deals with the quantitative data obtained from our water sampling and the results of our stakeholder interviews.

4.3.1 Water Quality Parameters

Samples 3 and 8 had a very high portion of organic substances and other unknown, potentially interfering substances upon visual inspection, so we chose to not use the sensors to analyse these samples. Thus, there are no data on the parameters pH, dissolved oxygen, turbidity, ammonia and nitrate for those samples.

In Table 4.3 the most informative parameters from the sampling at Providence I and II are listed. pH ranges between 7 and 8 for all measured samples. The samples show a significantly higher pH value compared with the pH-analysis of 6 water samples from the catchment at Val d'Endor, Mahé (p=0.0264, Mann-Whitney U-Test1[1]). We measured an ammonia value in the groundwater sample 6 of 11.8 mg/L. Compared to the reference values in Val d'Endor that exhibit values around 0.9 – 2.5 mg/L this value is very high. Ammonia and nitrate show a positive correlation.

[1] The Mann-Whitney U-test is a non-parametric test which compares two samples of continuous values. It does not require the assumption of normally distributed data

Table 4.3
Main measurement values from water sampling at Providence I and II. Heavy metals are semi-quantitatively measured. Empty cells indicate a measured concentration of 0 mg/L.

Name	pH	NH_4^+ [mg/L]	NO_3^- [mg/L]	Zn [mg/L]	Cu [mg/L]	Cr [mg/L]	As [mg/L]
P2-0407-1	7.17	25.9***	18.2***	0.1			0.005
P2-0407-2	– *	– *	– *	– *	– *	– *	– *
P2-0407-3	n.a. **	n.a.	n.a.	⩾ 5		0.1	0.050
P2-0407-4	7.7	32.3***	77.8***				0.005
P2-0407-5	7.78	28.8***	21.7***				0.005
P1-0407-6	7.45	11.8	3.2	0.3			0.010
P1-0407-7	7.8	31.3***	21.7***				0.005
P1-0407-8	n.a.	n.a.	n.a.	0.3			0.050
P1-0407-9	7.88	28.6***	22.4***				0.005
R-0407-1	7.86	28.1***	22.0***				–

* due to low water volume no sample taken
** water sample taken, but not analysed with VERNIER sensors because of visually observable substances (e.g. organic compounds) which would interfere with measurements
*** Values may be inaccurate due to the interference of chloride ions in water samples with high salinity

The 4 semi-quantitatively heavy metal parameters measured with the test kits show very distinct patterns: Copper and chromium are not detected in any sample apart from 0.1 mg/L chromium in sample 3. In contrast there are particularly high values of zinc, especially in Sample 3, and also to a lesser extent in Samples 6 and 8. Arsenic values match quite well with the zinc values: like the highest Zn values, the highest As values are also found in the Samples 3, 6, and 8. All measured values are within the given measuring ranges provided by the device supplier VERNIER and MERCK.

For BOD all measured values turned out to be <1 mg/L. Table 4.4, and Figure 4.2 show the As concentrations measured using ICP-OES (for further heavy metal concentration graphs please refer to Appendix). All values depicted are after the subtraction of the average blank value. The red values exceed the WHO drinking water guidelines. Empty cells mean the measured concentration was 0 mg/L. Most elements do not show critical concentrations at any site. Exceptional is sample P-3 with relatively elevated concentrations.

4.3.2 Stakeholder Interviews

A total of fifteen interviews was conducted with both on-site and institutional stakeholders, consisting of fishermen, landfill workers, and representatives from IRD, PUC, SFA, SFBOA, and STAR. Below we detail the main outcomes of these interviews.

Interviews with On-site Stakeholders

Fishermen along Mahé's East Coast

Two dominant opinions regarding fish stocks emerged amongst the fishermen interviewed. One fisherman, Florent, who was a member of the Roche Caiman Fishermen Association, mentioned that the quality and quantity of fish have generally remained stable over the years, and that the only major fluctuations are attribut-

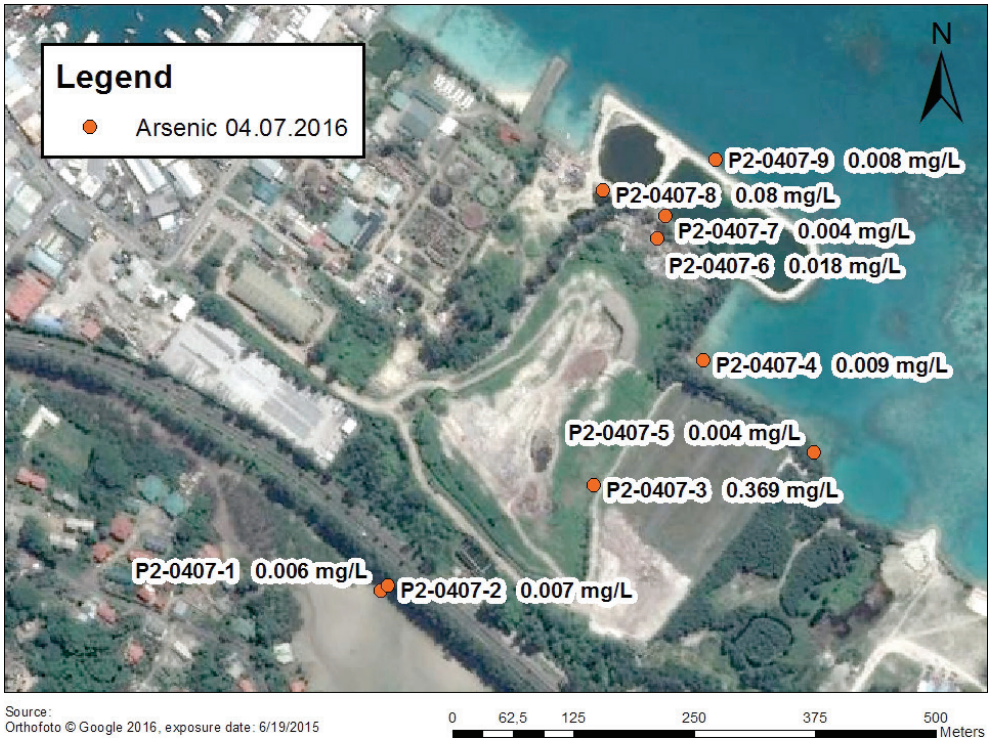

Figure 4.2
Water sampling sites around Providence I and II landfills in Mahe. The labels indicate the Arsenic values, measured on 4th of July 2016, analysed with ICP-OES.

able to changes between the north-west and south-east monsoons, when quantities rise and fall respectively. He uses fish traps like most of his fishermen colleagues and operates off the reef. When asked about the landfills, he stated that they are necessary for the Seychelles but also recognises that waste is a problem. The landfill does not affect his catch because he fishes far away from the coast. One fisherman we interviewed in Cascade made similar statements.

Other fishermen we interviewed in Cascade had different opinions. They remarked that there has been a change in the sizes of their catch over time because overfishing has caused fish populations to decrease. More importantly, they highlighted the decline of the mangroves along the east coast as a loss of breeding grounds for young fish which have resulted in smaller catches. The interviewees also pointed out the adverse effects of land reclamation along the coast which has not

Table 4.4
Heavy metal concentrations, measured with ICP-OES, after blank subtraction (values exceeding WHO drinking water guide-

Name	Al [ppm (mg/L)] 396.152 nm	As [ppm (mg/L)] 188.980 nm	As [ppm (mg/L)] 193.696 nm	Co [ppm (mg/L)] 238.892 nm	Cr [ppm (mg/L)] 283.563 nm	Fe [ppm (mg/L)] 261.382 nm	Mn [ppm (mg/L)] 293.305 nm
P2-0407-1		0.006			0.002		
P2-0407-2		0.007			0.001	0.004	
P2-0407-3	0.534	0.369	0.303	0.011	0.185	2.25	0.150
P2-0407-4		0.009	0.002	0.001	0.002		
P2-0407-5		0.004		0.001	0.002		
P1-0407-6		0.018			0.002	0.02	0.100
P1-0407-7		0.004		0.002			
P1-0407-8	0.0635	0.080	0.017	0.007	0.043	0.08	0.010
P1-0407-9		0.008					
R-0407-1		0.011			0.001		
limit values DW (WHO)	(0.1-0.2)	0.01	0.01	–	0.050		

only affected coastal fishing areas, but has also released a lot of mud and silt into the water which destroyed corals and thus impacted fish populations. One fisherman mentioned that putting traps in the coastal areas near Providence has resulted in catches with fish which '[die] just after one day'. These aforementioned processes affecting the quantities of fish cannot be attributed to the landfill per se.

However, some fishermen in Cascade have mentioned sightings of dead fish in waters near the landfill over the last few years. One interviewee, who used to set traps in these waters up until five years ago, remarked that he has observed corals receding from the reef over time and changes in the colour of the water. He still sets traps near the coast, but has experienced that fish caught in these traps do not

lines in red; empty: 0 ppm), Cd and Cu were measured to be 0 mg/L in all samples.

Ni [ppm (mg/L)] 231.604 nm	P [ppm (mg/L)] 213.618 nm	Pb [ppm (mg/L)] 220.353 nm	S [ppm (mg/L)] 181.972 nm	S [ppm (mg/L)] 182.562 nm	Si [ppm (mg/L)] 288.158 nm	Zn [ppm (mg/L)] 213.857 nm
			56.4	54.8	0.02	
	0.014		91.5	88.8	0.01	
0.061	7.86	0.011	10.3	8.80	15.6	0.242
			84.9	81.9		
0.001	0.011	0.002	87.4	84.6		
0.003	0.011		11.2	10.3	4.93	0.012
	0.003		83.0	79.7		
0.036	0.591		86.8	192	9.31	
	0.002	0.002	194	84.4		
			85.8	83.5		
0.07	–	0.01	–	–	–	–

survive more than one day in them. When asked about the landfills, this interviewee stated that they should be located further away from the coast so as to not harm the fish, corals, and water. He also mentioned that some of his colleagues who fish near the landfill have suffered from skin infections after physically entering the water.

Providence I and II Landfill Workers

Four workers operating waste trucks and two landfill attendants, all employed by STAR, were interviewed. When asked whether they knew if there had been any changes in the environment surrounding the landfill, particularly in the quality of the water around the landfill, most of the interviewees responded negatively. One worker thought that the animals living in the landfill areas such as dogs, birds, rats, and snails look healthy. Interviewees who were asked about changes in the quality and/or quantity of fish in areas near the landfill declared no expertise in the matter, but did mention that they do not see any fishermen coming to these areas. However, sightings of oil slicks and open dumping of rubbish into the sea from boats were reported amongst our respondents.

Half of the respondents mentioned that they observe changes in the colour of the seawater near the landfill during rain events. They reported that rain causes dirty water to flow from the landfill into the sea which makes the colour of the sea next to the landfill 'a bit different' because it sometimes appears 'dirty or dark' and looks 'contaminated'. One worker commented on the differences between the colour of the ocean near the landfill and that of the other side of the island. The changing colour of the seawater according to our interviewees is also dependent on ocean currents and prevailing weather conditions.

Nearly all respondents alluded to the lack of occupational safety. Three of the four truck operators believe that they lack protective attire in the workplace and should be given more durable masks, gloves, and clothing. They cited that the bad smells and dust, particularly during dry weather, give them respiratory issues, and that they sometimes start to itch when they come into contact with 'all kinds of chemicals' or even when they stay in the truck. One worker reported that despite undergoing medical tests every 6 months, some of his colleagues still suffer from respiratory or skin issues. Fires and gaseous emissions in the form of 'steam' were also reported, particularly from Providence I. Some are concerned about the possibility of explosions 'erupting like a volcano'. Despite these concerns, some of the workers maintain that accidents can happen anywhere and that risks of accidents should not hinder their work activities.

There is general consensus that the amount of waste increases each day and that space runs out quickly on the landfill. Some attribute these issues to improper disposal, and the lack of separation of waste and recycling. On the contrary, one worker remarked that he sees 'less rubbish by the road' and he thinks that the environment in the Seychelles is improving.

PUC Desalination Plant in Providence

The manager of PUC's desalination plant was interviewed because the plant's intake of seawater is located roughly 200m away from the Providence I landfill (Figure 4.3). PUC's sewage treatment plant is also nearby. According to the manager, the desalination plant uses reverse osmosis which pushes water through a membrane

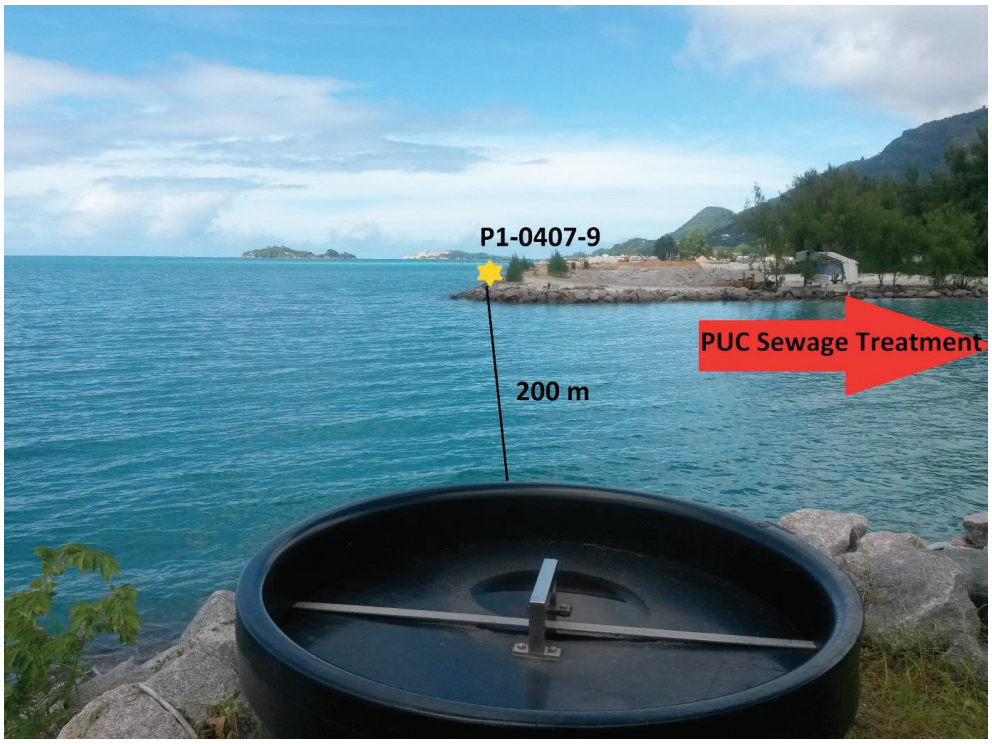

Figure 4.3
East Coast as seen from water inflow point of PUC's desalination plant. Sample point P1-0407-9 is indicated by a star, and the direction of PUC's Sewage Treatment plant is shown by the arrow.

using high pressure, resulting in 99% pure water. He believes that the technical specifications of this process allows them to handle even heavily polluted waters.

Water quality measurements to monitor pH, salinity, conductivity, mineral content, chlorine, and heavy metals are performed regularly as they adhere to the WHO's drinking water standards.

However, he mentioned that he would have liked the plant to have been situated further away from businesses and where oil spills from boats can occur. He said that for the public the location of the desalination plant is a big issue.

Water quality measurements at the intake and at the outflow of the brine are performed on a monthly basis. The data show that there is no big difference in the quality of the water intake at Providence compared to the other desalination plants on Praslin and La Digue.

Interviews with Governmental and Non-governmental Institutions

STAR

We interviewed a management-level employee of STAR. She was aware of the past sampling efforts around the Providence I landfill which took place in collaboration with the Seychelles Bureau of Statistics. However, these sampling campaigns were discontinued about 6 years ago. She did not know how to access the data collected nor the information about the sampling procedures.

She also pointed out that they tried to improve upon the leaching issues from Providence I when constructing the Providence II landfill, primarily by lining Providence II landfill and building a leachate pre-treatment plant (LPTP). However, she acknowledged that there have been operational problems with the LPTP, which has not been active for over a year at time of writing. It remains unclear based on our interview who is currently collecting the leachate, but apparently STAR has no access to it directly and that is the Ministry of Environment who does. According to the interviewed stakeholder, STAR is supposed to be overseeing the management of the pre-treatment. She cited that untreated leachate (which would otherwise be pretreated in the LPTP and then undergo main treatment by PUC) is an issue, because they do not know how to dispose of it; PUC does not want to treat it in their sewage treatment plant for fear of the leachate's possible adverse effects on the mi-

crobial communities which facilitate sewage treatment. Therefore, STAR intends to simply dump the leachate in Providence I landfill, which is apparently what is done in France but does not represent a good solution because of runoff during rain.

The lack of a long-term solution for leachate also applies to the case of the Anse Royale landfill, which would imply an even higher risk because it is situated close to residential and agricultural areas. Therefore, the landfill at Anse Royale only stores inert waste such as glass, albeit being lined, and is considered to be not fully operational because of this.

Seychelles Fishing Authority (SFA)

The two people we interviewed at SFA could not support us with any data or specific information on the environmental conditions of the areas surrounding the Providence landfills. Nevertheless, they did provide us some insights related to current research and monitoring efforts in the Seychelles.

One interview was conducted with the head of Research at SFA, who mentioned that he was not aware of any research focusing on waste specifically nor on the environmental impacts surrounding the Providence landfill in particular.

However, he pointed out that efforts are now under way to better monitor changes in the environment, such as coral bleaching and ocean temperature fluctuations, for which there now is a measurement network. He also pointed out that they are currently investigating an algal bloom event which happened along the East Coast last year, but that the species of algae as well as the reasons for the bloom are still unknown and being researched.

We also interviewed a researcher associated both with SFA and the French "Institut de recherche pour le développement" (IRD) who mainly focuses on the effects of heavy metal contamination in large fish. Her previous research interests were in mercury in swordfish, but now she is working on setting up a national ocean monitoring system for heavy metals as well as other contaminants on the shores of the major islands in the Seychelles. In her opinion, the environmental conditions in the Seychelles are generally good, but she thinks that more monitoring activities should be undertaken, especially because the Seychelles and other Indian Ocean nations are currently in rapid stages of economic development. Concerning the issue of waste, she highlighted the following crucial point: that waste ending up in the landfill does not just stay there in the figurative sense. Rather, leachate

and runoff can flow into the ocean from the landfill and that chemical substances can accumulate in fish which if consumed by humans, poses a risk to human health. She stressed the importance of building Seychellois expertise in understanding the risks associated with pollutants and contaminants.

Seychelles Fishing Boat Owners Association (SFBOA)

We interviewed an SFBOA chairman who represents 150 members of the organisation. He does not think landfills are a problem as long as they are managed properly. However, he drew our attention to the environmental degradation caused by land reclamation activities along the coast, as well as the destruction of seabeds which occurs through digging for coral fill. He was also aware of the previous summer's algal bloom, but had no further information.

He also expressed concern about marine pollution. According to him, large fishing vessels dump salt bags in the open ocean, which also damages reefs. His organisation is working to find a solution for garbage collection on small boats.

Over the course of the interview, he emphasised that fishermen are not responsible for the declining fisheries on the east coast. On the contrary, the members of his organisation are actively working towards sustainable fisheries.

4.4 Discussion

Here, we address the two sets of results we obtained separately. A synthesis of both sets of results is provided in the Conclusion.

4.4.1 Water Samples

The nitrate concentrations measured at all sample sites except the groundwater sample (Sample 6) exceed the Effluent Quality Standard's limit of 15 mg/L as stated in the Seychelles Environmental Protection Act (1994). However, all the values are well below the guidelines stipulated by the WHO and EU (both 50 mg/L). Nevertheless, we acknowledge that the interference of chloride ions may have impacted our nitrate measurements, although we were not able to quantify the extent of this effect.

On the other hand, the ammonia concentrations measured in all our samples were higher than the guideline values set by the US EPA, EU, and WHO of 10 mg/L, 0.5 mg/L, and 0.2 mg/L (groundwater) respectively. The Seychelles EPA does not have a guideline value for ammonia. With the exception of the groundwater sample (Sample 6), which we believe is within a realistic range for samples taken near

landfills, all the other samples were at least two times higher than the guideline values. From the other parameters, we predict (since we did not measure) that the NH_4^+ concentration in Samples 3 and 8 are higher than the concentrations measured in the other samples. Our reference river water samples from the inland catchment at Val d'Endor had values in the range of 0.9–2.5 mg/L which matched our predictions because this water is presumed to be uncontaminated.

Kjeldsen et al. (2010) state that ammonia is an inorganic macro-component which is present in the leachate of solid waste landfills at higher concentrations. Thus our high NH_4^+ concentrations in the groundwater is a possible indicator for leaching, as well as faecal contamination according to WHO Guidelines for Drinking Water Quality.

We acknowledge that possible interference of the chloride ions in ocean water with our VERNIER sensors could have occurred, which could have made our measurements except Sample 6 higher than they actually are.

Semi-quantitative Heavy Metal Analysis

The four heavy metals Zn, As, Cr, and Cu are some of the key elements that are expected to leach from landfills. Using our test kits, we observed Zn, As and Cr. Cu was not detected in all our samples.

While the As and Cr values are below the US EPA guideline values (both 1.1 mg/L), the Cr concentration measured in Sample 3 is higher than the EU and WHO Cr values, as are As values in Samples 3 and 8. Furthermore, the concentration of Zn in the leachate of Providence II is far above the guidelines of the US EPA, WHO, and Seychelles EPA. The sample from the scrap metal yard (Sample 6) also shows elevated Zn concentrations for groundwater, which can be an indicator that heavy metals are affecting drinking water. Because the Zn concentration decreases between the leachate and the discharge into the ocean (Samples 3 and 9 respectively), this could be a preliminary indicator of heavy metal leaching.

Element ICP-OES Analysis

The analysis of 14 elements with ICP-OES revealed that most of the heavy metal concentrations are even below drinking water guideline values. Some samples exceed the drinking water standard with respect to the elements Al, As, Cr, and Pb; however, these are not very problematic concentrations.

Sample 3 taken from the leachate tank, shows the highest concentrations of heavy metals. This was expected because the tank is designed to deliberately collect the leachate. The groundwater Sample 6 at the scrap metal yard had elevated concentrations of As, Fe and Zn, suggesting that those elements are not completely removed during percolation through

the landfill. However, the proximity to the scrap metal yard could explain these elevated heavy metal concentrations. Since we only could take one groundwater sample, we cannot conclude if it is representative of the whole landfill.

Sample 8 originates from the older pond between the landfill and ocean and shows elevated element concentrations as well (mainly Al, As, Co, Cr, Fe, Ni, P and S). The pond probably acts as a barrier and sink for substances leaching from the landfill.

The heavy metal content of the water samples is much lower than expected of the landfill, considering its high proportion of biowaste. The low heavy metal concentrations are most probably caused by the relatively high pH values that prevent heavy metals from going into solution. The proximity to the ocean could be the cause for these high pH values, as could the reducing conditions which keep the pH high.

Interestingly, there were elevated concentrations of P, S and Si not just in Sample 3, but also in Samples 2 and 8. The latter are both samples from sites that connect the landfill with the ocean; this gives further evidence of leaching.

Our measured water samples were in the same range as the reference samples taken from the coast at Anse Forbans, which is located on the east coast of Mahé, south of the landfill where are are fewer industries nearby. In the reference samples from Anse Forbans we detected As (range of 0.01–0.018 mg/L), Cr (0.001 mg/L), and S (range of 81–86 mg/L).

pH

The pH values near the landfills are generally slightly lower than the reference pH of 7.86 (Sample 10), which can suggest the influence of the landfill: the high amount of organic compounds originating from biowaste in the landfills can contribute to acidic conditions caused by bacterial degradation. However, the range of measured values is so small that measurement errors can exceed the actual pH differences.

Summary

The leachate sample (3) showed high concentrations of Zn, Cu, and As. It also likely had a high fraction of organic substances because of its strong odour and dark brown colour which are also the reasons why we unfortunately could not determine all the parameters of this sample.

The three coastal water samples were 1, 5, and 9. Samples 5 and 9 have similar ranges of measured values. In contrast, Sample 1 has much lower values for turbidity, dissolved oxygen, pH, and salinity, which could have been influenced by incoming fresh water or the fact that this water body is stagnant which could lead to poor mixing, higher temperatures, and therefore less dissolved oxygen. Additionally, the high Zinc concentrations measured in Samples 1 and 9 give evidence that both sites are influenced by leachate from the landfill. Zinc could not be measured in Sample 5, which was to be expected since it is located at the lined landfill Providence I and further away from the scrap metal yard.

Samples 7 and 8 originated form ponds which formed between the landfill and the ocean due to land reclamation. The pond from which Sample 8 was taken from is much older than Sample 7's pond, as evidenced from satellite pictures obtained from Google Maps. This explains why Sample 8 exhibits characteristics similar to those of the leachate sample (3) in terms of colour, smell, and high heavy metal content. We think it is probably a sink for leaching liquid from Providence I, as is Sample 7's pond, with the only difference being the ages of the ponds.

The most distinct sample is Sample 6, taken from groundwater accessed through a hole in the ground of the scrap metal yard. The low salinity value shows that this groundwater is likely unaffected by seawater. Sample 6 exhibited low NH_4^+ and NO_3^- values compared to the reference samples, in contrast to the relatively high heavy metal concentrations which are to be expected because the sample is located in the scrap metal yard. Because ammonia is a tracer, we believe this is evidence for leaching.

Summarizing our water quality findings, we have evidence for leaching because of the high Zn and As concentrations in the leachate as well as in the surrounding environment. Furthermore, the elevated NH_4^+ concentrations in the groundwater are of concern.

4.4.2 Stakeholder Interviews

Our interviews with both on-site and institutional stakeholders reveal multi-dimensional perspectives of the landfills' environmental impacts. The fishing communities we interviewed mentioned large-scale deaths of fish which ended floating belly-up in the bay, and drew connections to colour changes they observed in the seawater. These changes, which depend on weather and tides, but which consistently occur when landfill runoff enters the sea after rain events, may be related to the algae blooms referred to by the interviewees from SFA and SFBOA. Algal blooms are connected with high levels of nutrients in the water during periods of stagnancy. There exist alternative explanations for the blooms, like sewage treatment or other industries in the area, but it appears likely that the Providence landfills contributed to the ongoing situation, especially with the leachate treatment plant being non-operational.

The statements from the landfill workers confirmed our expectation of methane production in the Providence landfills. The fact that all of them mentioned past fires on the old landfill indicates what is likely to be a high amount of methane coming from the waste. Outgassing was also described by a landfill attendant of Providence II, thus we expect future fires to occur there too. Another important aspect of the landfills mentioned by the workers multiple times was the occupational hazards they face

while working with low-quality protective clothing. Despite the fact that most of the workers we interviewed had only started working for STAR less than six months ago, many reported that they had already experienced health issues such as itchy skin and respiratory problems. Improvements to the occupational safety measures to protect these workers are sorely needed, first and foremost through the provision of appropriate and durable protective gear such as face masks and gloves.

The interview and data from the PUC desalination plant seem to show that there are no extraordinarily high levels of contaminants. Also, from the perspective of SFA and SFBOA, there was not much evidence for acute problems connected to the Providence Landfills. However, it was acknowledged that the environment of the entire Seychelles is facing serious challenges, including climate change, coral bleaching, and coastal development. There was a consensus that more research is needed and that efforts to observe changes in the environment should be increased.

Overall, the most concerning statements concern the disposal of the leachate from the Providence II landfill. Currently, it is simply being stored in ponds on the older Providence I landfill without any form of treatment. It seems that no long-term strategy is in place, despite ever-increasing rates of waste generation.

It can be concluded that the stakeholders we interviewed did indeed observe changes in the environmental conditions close to the landfill. However, these changes are only in part attributed to adverse effects of the landfill.

4.4.3 Limitations and Future Work

In this study, we undertook a relatively broad sampling consisting of 10 samples (including one reference) of different water bodies near the Providence landfills. In this way, we aimed to gain a comprehensive understanding of the chemical impacts the landfills may be having on their surrounding environment. However, we were only able to measure the ten samples over the course of one day. A more comprehensive study with multiple measurements over a longer period of time would be necessary for more definitive and valid results.

The measurements from the catchment at Val d`Endor and our measured landfill sample values from 04.07.16 match well with previously measured data. We measured the water samples using the same

equipment as that used to measure water from the catchment at Val d`Endor and obtained reasonable results and ranges, indicating that the sensors work fine. However, some values do not match with the measurement from PUC, a matter which requires further investigation.

Several parameters turned out to not be suitable in our case. The proximity of our sampling sites to the ocean made the salinity and turbidity parameters unsuitable due to the intrinsically high values of ocean water itself. Furthermore, the sampling approach using an open bottle on a rope to collect the water samples was not completely appropriate for the determination of dissolved oxygen and BOD, as the sample could have become enriched with oxygen during collection. However, because some of the sites were hard to physically access, we maintain that this was the best option considering the circumstances. Therefore, the BOD values are only a rough estimation, since we lacked proper equipment for more accurate measurements. For the BOD method bacteria are needed that degrade the matter, which is a process that needs oxygen. On the decrease of oxygen one can infer to the organic matter content. However, if there are no bacteria in the water sample, maybe because of adverse living conditions for bacteria, there will be no degradation. A potential source of error could be the lack of bacteria in the waste water. In this case, adding a seed of bacteria to the waste water would have been needed in order to get proper data.

For future studies, it would be crucial to check if the methods and devices to be used can cope with high salt concentrations, and to see which parameters can actually be used as tracers for leaching when in close proximity to a salt water body. For instance, the electrical conductivity and salinity parameters would not work.

For sample analysis in the laboratory, both acidified and non-acidified samples should be made with sulphuric acid used instead of nitric acid so that nitrate concentrations can also be measured in the laboratory. Measuring the redox potential would also be crucial, since it would give information about the potential mobility of heavy metals.

We recommend to examine organic parameters in further work, such as persistent organic pollutants (POPs) and to a further extent, ammonia. Overall however, our results provide a reasonably good first insight into the compounds present at our sampling points and their concentration levels. To supplement this knowledge, measuring methane emissions from the landfill could be another parameter worth examining in the future.

4.5 Conclusion

The main insights from our study of the water parameters and the stakeholder interviews are that the environment on the east coast of Mahé has been negatively affected. However, not all the environmental impacts we observed can be linked causally to the Providence I and II landfills because the high levels of industry, sewage treatment plant, and ongoing reclamation of land also influence the coastal ecosystem. Nevertheless, our study shows that there is evidence that leachate is entering the surrounding environment. Elevated ammonia concentrations as well as concentrations of As, Al, Cr, P, and Zn in our samples give evidence for leaching because they are higher than in the reference sample, and are especially high in the leachate, but decrease in samples the closer they are located to the ocean.

Due to the relatively high pH values, we believe that most of the heavy metals do not go into solution. Nevertheless, we found small concentrations of heavy metals in the groundwater and in the ponds between the landfill and ocean. Although the concentrations are non-problematic, they can be taken up by plants and animals and increase going up trophic levels. This bioaccumulation could pose a risk to human health if these organisms are consumed. To further prevent the solubilisation of the heavy metals, it is crucial to continue separating the metal waste and either shelter it to prevent rain from coming into contact with the metals, or to collect and treat any resulting leachate.

We stress the necessity of leachate treatment, which we expect to first come in the form of the leachate pre-treatment plant constructed on the Providence II landfill to resume operations. In any case, even if all the leachate could be collected and treated, further processing of the residuals from the (pre)treatment has not yet been planned. The safe disposal of the leachate and any persistent impacts should be further assessed, especially when planning and implementing any additional landfills.

More importantly, efforts to improve the landfill workers' occupational safety should be mobilised. This can occur in various forms: firstly, through giving more emphasis to the separation of hazardous wastes such as old paints, batteries, and other chemicals, and more directly (and perhaps easily), through the provision of appropriate protective clothing.

To validate our observations, more research should be conducted with extended spatial and temporal frames. The examination of organic parameters such as persistent organic pollutants (POPs) would be extremely relevant to give a more comprehensive understanding of the environmental impacts of the landfills. Furthermore, because interviews with workers on the landfill gave indications of methane outgassing and the occurrence of fires was mentioned, a study about methane outgassing would be very revealing.

We believe that the east coast of Mahé and the Providence landfills should be included in the national environmental monitoring program, the first step of which would be making the landfill operator resume regular monitoring of the surrounding water bodies.

4.6 Literature

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5 Consumer Behaviour and Perspectives on Waste

5.1 Introduction

Waste is ultimately derived from the transformation of valuable products to discarded material. After product acquisition, a consumer later determines how broken, old-fashioned, and otherwise undesirable materials are disposed of. At this point in a product's lifetime, a good becomes waste.

The Seychelles has experienced economic growth in the past 25 years, which has changed the influx and types of goods entering the archipelago. The gross domestic product per capita purchasing power parity (GDP per capita PPP) in the Seychelles has roughly tripled from 1990-2015 from USD 8'700 to USD 26'000 (IMF 2016). Studies clearly indicate that economic wealth is correlated with waste production, which is also the case in the Seychelles (OECD 2015; UNEP 2015; Mazzanti & Zoboli 2008; Iglezakis, et al. 2012), where waste generation has also increased in the last 15 years. One reason for this correlation is that consumption increases with increased purchase power, which directly leads to more waste production (Lawrence & Woods, 2014; Talma & Martin, 2013).

Data collected at the Providence Landfill show that annual waste deposition has increased from 40'000 to 70'000 tonnes from 2001–2014 (Source: LMWA). This increase can be largely attributed to the increase in imported goods over time, particularly in the years following 2008 (Figure 5.1). Since the market became liberalised in 2008, fewer restrictions on imported products effectively encouraged a diverse variety of goods which could not be imported before to enter the Seychelles. Imports peaked in 2012, totalling over 2 million tonnes.

Consumer behaviour influences waste generation primarily at two critical points: at the time of product purchase and at the time of product disposal. It is crucial to understand these processes in order to distinguish the main drivers of waste

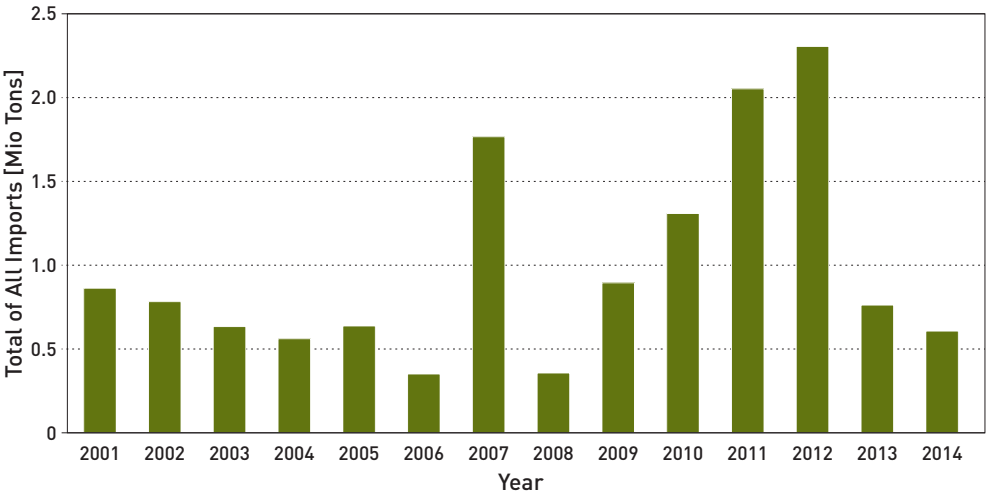

Figure 5.1
Total tonnage of all imported goods entering the Seychelles by year. Data provided by the Seychelles National Bureau of Statistics.

generation. Personal preferences and market availability affect consumers' purchase behaviour, which is understood to be the antecedent of waste production of household level. In the majority of cases, cheap, low-quality products have a shorter lifespan than high-quality products and therefore are more likely to be deposited and replaced quickly. Therefore, waste management requires an understanding of what products consumers desire and if the market does provide high quality products.

Because consumers also decide how to dispose of a product, they largely control its fate at the transformation point from good to waste. Therefore, it is important to investigate motivations behind their chosen disposal methods. For example, previous studies indicate that environmental awareness can lower undesirable waste disposal practices (Al-Khatib et al., 2007). To our knowledge, no study has been conducted on Seychellois environmental awareness, specifically regarding waste. This indicates a need for a more detailed understanding of environmental awareness and waste perception.

The motivation of this study is to understand the impacts of consumer behaviour on waste management. We have formulated our motivation into two research questions to guide this study:

1. How do consumers perceive waste management in the Seychelles?
2. What are decisive purchase criteria from the perspectives of consumers and retailers?

5.2 Methods

We used semi-structured interviews to collect data to address our research questions. Copies of the interview guide can be found in Appendix 5.

5.2.1 Interview guide and sampling procedure

We conducted interviews using three different interview guides which each addressed a different topic or perspective related to our study:

1. Consumer awareness;
2. Consumer purchasing criteria; and
3. Store employee perceptions of consumer satisfaction.

We have grouped answers given to open-ended questions into appropriate categories, e.g. cans, PET bottles, and paper fall under the category 'Recyclables', while the category 'Packaging' comprises plastic bags, food packaging not including Styrofoam take-away boxes, and cardboard packaging. Further details about each category can be found in Appendix 5.

Consumers

The target group of the first two interviews was the 'average consumer', which we define as local Seychellois we encountered randomly in Victoria, Anse Royale, and Glacis at various locations including

bus stops and in shopping centres. Forty different consumers responded to each of these two interviews (total 80) about the awareness of waste generation and management in the Seychelles, and important criteria for making purchases respectively. The separation between these two sets of interviews had this rationale: we wanted to keep each interview as brief as possible because we requested interviews spontaneously. On average, nine out of every ten people we approached agreed to be interviewed.

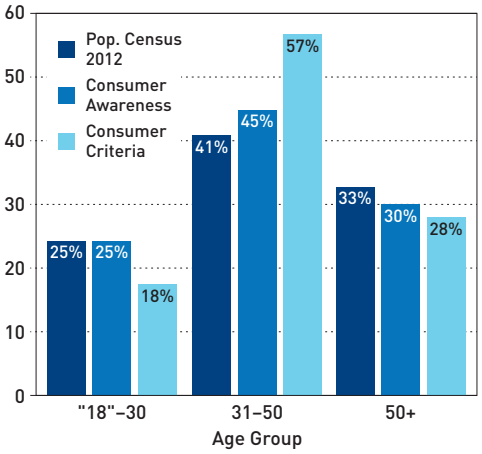

Figure 5.2
Age distribution of consumer interviews compared to 2012 Census.

In choosing our respondents for the consumer interviews, we aimed to be representative of the different genders, age groups, and education levels of the local population (Table 5.1). The education levels were divided into three categories: primary or secondary, tertiary (non-university, vocational training), and university. Roughly the same number of males and females were selected to respond to our questionnaires, while the age groups to which our respondents belong were chosen with the purpose of emulating the age demographics of the Seychelles according to the 2012 Seychelles Population Census as shown in Figure 5.2 (National Bureau of Statistics, 2015). However, the respondents we selected belonging to the youngest age bracket (18 and above) are not directly comparable to those defined by the National Bureau of Statistics (NBS) (15–19). Therefore, the youngest age group defined by the NBS forms a slightly larger percentage of the population than it does the percentage of our respondents.

Table 5.1
Demographics of consumer samples.

Type of Interview	Total Interviews	Age Group			Education			Gender		Location of Interviews	Date
		18–30	31–50	50+	Primary/ Secondary	Tertiary	University	N/A	M	F	
Awareness	40	10	18	12	13	17	10	0	21	19	Victoria / Anse Royale / Glacis	27 June – 04 July
Criteria	40	7	23	10	16	16	6	2	18	22	Victoria / Anse Royale / Glacis	25 June – 04 July

Store employees

The third sample included 15 employees working in stores which sold products mentioned by the respondents of the first two interviews (Table 5.2). These stores were located in the same areas as where we encountered respondents for the consumer interviews. This interview focused on consumer satisfaction.

Table 5.2
Demographics of store interview sample.

Type of Interview	Total Interviews	Type of Store (Main Products)			Occupation of Interviewee			Location of Interviews	Date
		Fridge, Washing-Machine	IT	Mixed	Shop Manager	Sales	Technical Manager		
Stores	15	11	2	2	3	10	2	Victoria	29 June – 04 July

5.3 Results

Here, we provide a synthesis of the results of our three samples: consumer awareness, consumer purchasing criteria, and store employees, with a specific focus on topics we believe would be of interest to decision- and policy-makers.

5.3.1 Consumer Awareness

We first investigated which types of waste are produced by our interviewees, with multiple mentions allowed in their responses. 'Biowaste' made up roughly one third of all responses as shown in Figure 5.3, as did 'Packaging', followed by plastic bags, take-away boxes and recyclables.

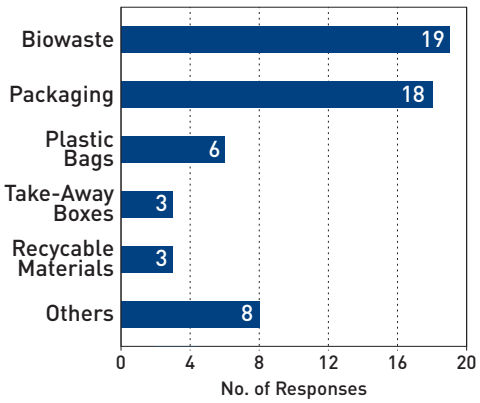

Figure 5.3
Named waste categories (N=40 consumers, multiple-mentions possible).

We then asked whether our interviewees perceive waste as a problem. 85% of our interviewees responded with yes. Eighteen problematic aspects of waste were named, which we assigned to seven categories: (in decreasing order) littering, a lack of recycling, the amount of waste, and the fact that packaging material is non-degradable (Figure 5.4).

Age did not have an influence on the responses regarding the most problematic aspects of waste (Appendix 5), but education level did (Figure 5.5). Almost half of the university-degree holders interviewed believe that the lack of recycling is the main issue. However, those with tertiary non-university and primary/secondary educations believe that littering is the most problematic aspect.

The 34 respondents who perceive waste as a problem were then asked what recommendations they would make to the government (with multiple mentions allowed). A broad range of solutions were

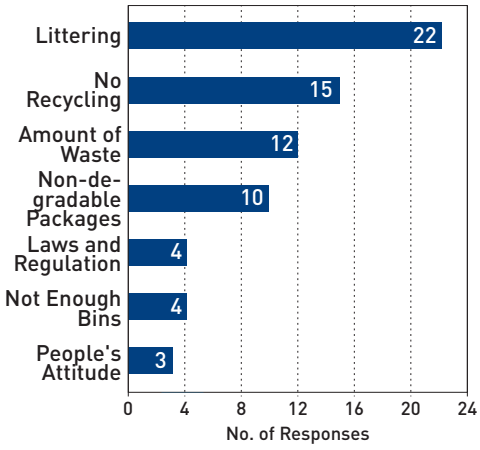

Figure 5.4
Seven aspects of waste named by the respondents as particularly problematic (n=34, consumers perceiving waste as a problem, multiple-mentions possible).

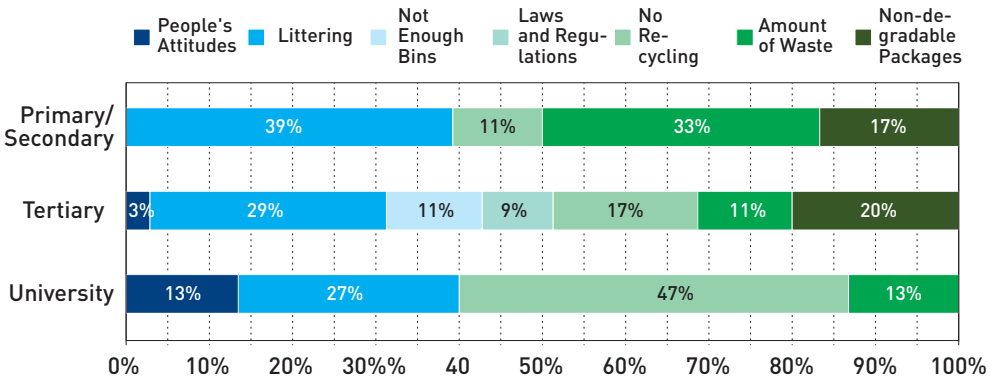

Figure 5.5
Number of mentions of problematic aspects of respondents with different educational backgrounds.

proposed as shown in Figure 5.6, with the most frequently mentioned responses (~30%) falling under the 'Law and Regulations' category which includes initiatives such as increasing levies, total bans on plastic bags, government-contracted PET collectors etc. Responses under the categories of 'Recycling' and 'Education' were offered almost as frequently in comparison. The recommendations do not significantly differ between the different age groups or education levels (Appendix 5).

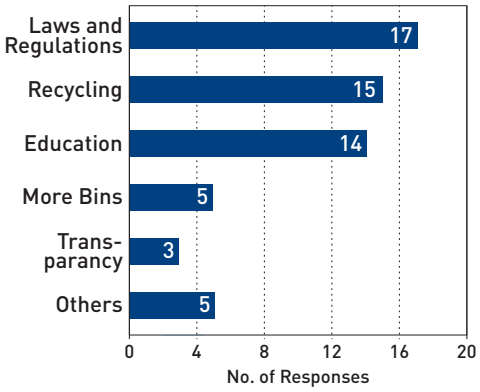

Figure 5.6
Named recommendations to improve the waste situation (N=34 consumers who perceive waste a problem, multiple-mentions possible).

Interestingly, none of the respondents named reduction of the generation of household waste as a recommendation. Directly asked for an appraisal of the potential to reduce waste in their own household, two thirds of the people (26) see a potential to reduce waste by changing daily habits.

We then asked our interviewees whether they pay for the present waste collection service. Most respondents stated that they are currently not paying for this service. 68% of respondents said that they would be willing to pay for the current service

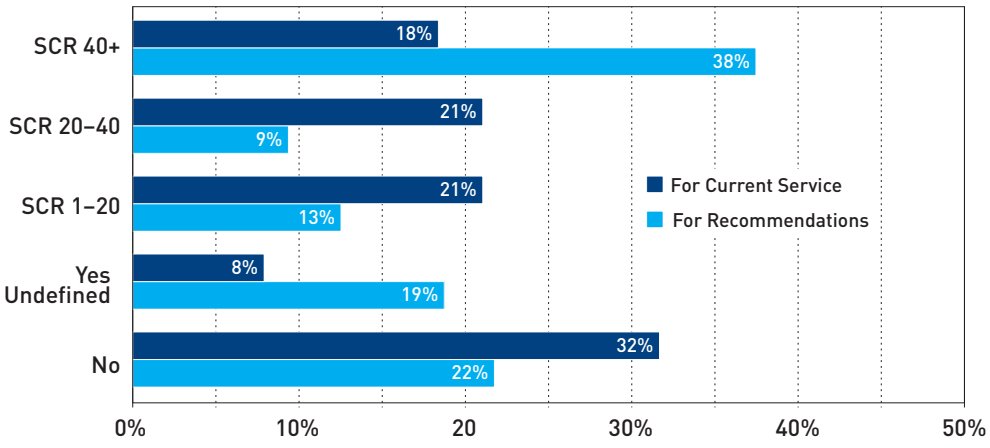

Figure 5.7
Amount per month which people are willing to pay for the current system and for a service with the proposed recommendations. Percentages refer to the total number of people who expressed their willingness to pay (N=26 for current service; N=25 for improved services according to their recommendation).

if they were asked to do so (Figure 5.7). When asked whether they would be willing to pay for a service which incorporated a recommendation they named, more than three quarters (79%) of respondents said yes. Most people are willing to contribute up to 40 rupees per month (42%) for the current service, while 38% said that they would be willing to pay more than 40 rupees per month for the improved service (Figure 5.7).

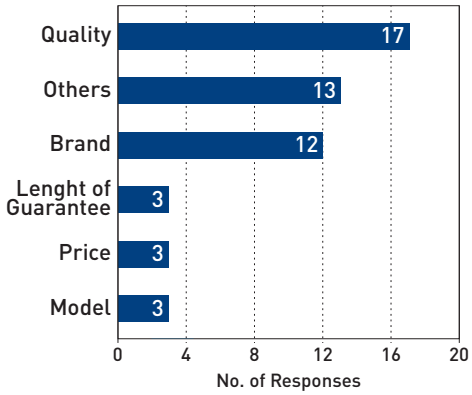

Figure 5.8
Freely named purchase criteria (N=20; multiple-mentions possible).

5.3.2 Consumer Purchasing Criteria

'Quality' was most frequently mentioned when consumers were asked which the most important criterion for making purchases are, followed closely by 'Brand' and 'Price' (Figure 5.8). There were no significant differences in the responses offered across education levels and age groups, except for the criterion 'Brand', which significantly differed between the three education levels. Interesting is the comparison of the self-perception with the external perception of other consumers:

Table 5.3
Products for which quality is the most important criterion (column 2) vs. price is the most important criterion (column 3). Numbers in each column represent the number of responses, multiple mentions allowed.

Item	Most Important Criterion	
	Quality only	Price only
Fridge	15	–
Television	14	–
Food	10	7
Audio Equipment	7	–
Electronics	6	4
Furniture	4	–
Clothes	4	15
Functional Products, Stationery, Cleaning Products, Shoes, Toilet Paper	–	4

38% (n=15) stated that for most other people on the Seychelles, price is more important than quality.

Consumers said that items they purchase for which they only consider quality as the most important criterion (and not price) include fridges, televisions, and food in that order. In contrast, products which consumers felt more price- than quality-sensitive were clothes and food in that order (Table 5.3). In addition to the perception of the current product quality, we asked our interviewees whether they have observed a change in quality over time. 14 respondents stated that the quality of the most common products decreased, 7 said that it had increased, 5 observed no change, and 11 don't know.

When asked about the selection of products which are available on the market, 50% of respondents said that they are unsatisfied (Figure 5.10). This result does not vary significantly across different education levels and age groups (Table 10 in the Appendix).

'Selective Imports' was the most frequently cited recommendation to improve the current market, which includes measures such as banning bad imports and increasing the role of National Consumers Forum (NATCOF) in ensuring product quality and durability (Figure 5.9). Other

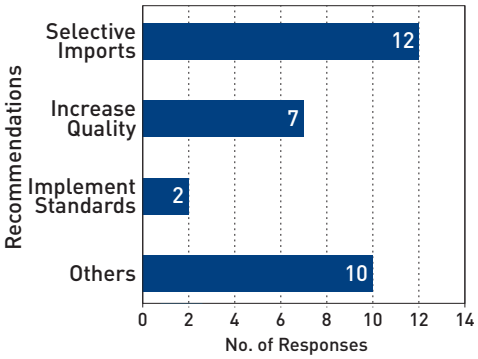

Figure 5.9
Recommendations made by respondents to improve the market situation (multiple-mentions possible).

recommendations which were also frequently mentioned and grouped in the 'Other' category include 'more repairs', 'further liberalisation', 'association to address consumers' complaints', and 'longer guarantees' (see Appendix Table 11).

5.3.3 Store employee interviews

The self-perception of consumers does not fully match the perception of managers or clerks of stores: 47% (n=7) of store employees state that most people believe price is the most important criterion. Again, half of our interviewees believe that customers expect quality higher than what can be afforded for the given price (Figure 5.10). Nevertheless, all 15 respondents stated that their stores offer what their customers are looking for.

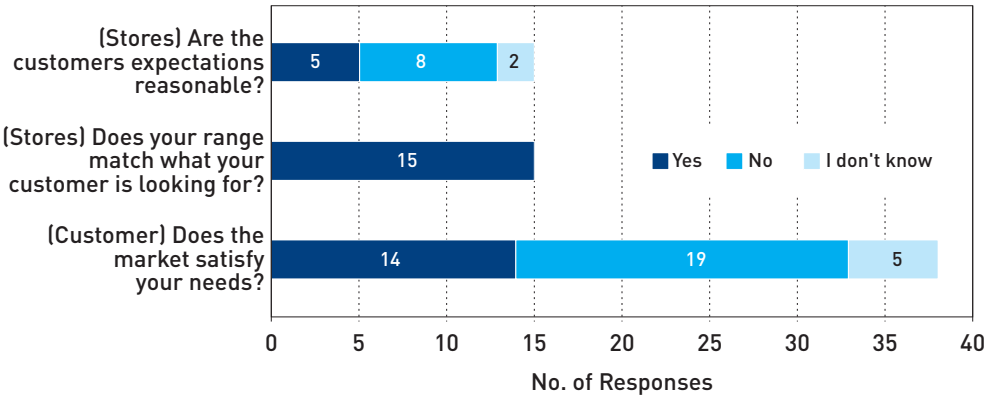

Figure 5.10
Satisfaction of customers with the market range in terms of the price-quality ratio compared to the statements of store employees.

5.4 Discussion

The results of the consumer interviews indicate that consumers are aware of waste treatment challenges in the Seychelles, and that they are willing to help improve the waste management system. In general, the opinions expressed in the questionnaires were irrespective of education, age, and gender, demonstrating that waste is a problem acknowledged among all sectors of society.

Biowaste forms a significant fraction of the waste produced by consumers. This result corresponds to actual Providence Weighbridge data, which show that biowaste is approximately 50% of all Municipal Solid Waste in the Seychelles (Wilson, 2004). The subsequently most identified shares are packaging and takeaway boxes. While these answers do not match the true fractions of waste which consumers generate most according to the Weighbridge data, they do indicate that consumers are particularly aware of these waste types. We believe that this awareness is an important first sign that consumers may be willing to adopt measures to reduce or recycle this waste where possible.

Because nearly all consumers interviewed believe that waste is a problem in the Seychelles, they are likely willing to be involved in waste reduction implementations. When asked whether they would be willing to pay for a waste collection service, more than half the people responded positively, more so if a recommendation they made themselves to improve the waste situation was implemented. Thus, initiatives which incorporate people's opinions and suggestions are likely to be more successful than those which do not.

The government could take an active role in ensuring products which enter the Seychelles are of good quality, which would be favoured by consumers. The results from the interviews demonstrate that most consumers prefer quality over price when making purchase decisions. While this depends on the type of product, consumers often care more for quality when purchasing products that are expected to last for long times such as refrigerators and cars. For more dispensable items, like clothing or food, price is prioritised instead. However, only about half of consumers feel that they receive the quality that they desire from stores.

On the other hand, store representatives believe that customers are unrealistic when expecting high quality products because these products would not fit in their price range. It is important to note that most goods sold in stores in the Seychelles are imported, and therefore, controlling the goods coming into the country would determine what is offered by the market. Therefore, if the market is altered in such a way as to exclude low quality goods, consumers will effectively be limited to purchase higher quality goods.

5.4.1 Limitations of the study

We conducted our interviews with people on the street from different education levels. Not all of them felt comfortable to do interviews in English and therefore we conducted some in Créole. The consequence is that we likely lost some information in translation. Additionally, the sample sizes, ranging up to 40 people per interview, are small in the scope of the Seychelles. In future studies, we believe that larger sample sizes should be interviewed, allowing for more rigorous statistical analyses.

5.5 Conclusion

Our results suggest that there is clear interest from the consumer side to participate in waste management and reduction. However, structural changes in the market must occur to promote higher quality goods and to ban low quality, dispensable goods. Furthermore, the consumers' willingness to pay for an improved waste management scheme, particularly one which incorporates their suggestions, represents a viable avenue for the implementation of the Polluter Pays Principle.

The government can take an active role and be involved on many levels, including incentivizing recycling, restricting imports, and supporting education to reduce waste production. These aspects were identified by consumers to be the most significant challenges in the Seychelles.

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6 Biowaste to Biogas

6.1 Introduction

A large fraction of the total amount of solid waste on Mahé consists of biodegradable waste (BW), with estimates reaching up to 50% by weight (Wilson, 2004). In the Seychelles, BW is primarily deposited on the Providence landfills, with smaller fractions used for animal feed and compost production (Ministry of Environment & Energy, 2014). Because BW is such a large fraction of the total solid waste, reducing the amount of BW deposited on the landfills would prolong landfill lifetime as well as reduce leachate pollution, methane emissions, odours, and the risk of disease transmission (Mavropoulos & Newman, 2015; Vögeli, et al., 2014).

One option to reduce landfill BW deposition is to use it as a feedstock input for anaerobic digestion (AD). In this process, microorganisms break down biodegradable compounds in the absence of oxygen. According to Campuzano, et al. (2016), AD is the most promising and sustainable process for organic waste treatment. A broad range of BW sources are suitable for AD, such as livestock manure, sewage sludge, grass cuttings, food leftovers, putrescent waste, kitchen oil, and other waste from food and beverage processing industries (Deublein & Steinhauser, 2011). The end products of anaerobic digestion are biogas consisting mainly of methane (CH4) and carbon dioxide (CO_2) and a nutrition-rich digestate, the semi-liquid output of AD (Bundhoo, et al., 2016; Deublein & Steinhauser, 2011). The digestate has several uses, including fertiliser, landfill cover, energy, and raw material for industrial processes (Evans, 2013; Mouat, et al., 2010). Biogas also has many practical uses, which include cooking, vehicle fuel, natural gas network feed, and transformation to current and heat (Deublein & Steinhauser, 2011). In the case of Mahé, electrical current from a biogas plant could reduce the electricity sector's dependence on fossil fuels (Republic of Seychelles, 2013).

Experts in the field indicate that a successful biogas plant must have both promising BW suppliers and consistent demand for its end products (EAWAG, personal communication). Possible BW suppliers for AD in the Seychelles include farmers, food and beverage processing industries, hoteliers, households, restaurants, landscaping companies, and sewage treatment plants. The end products include biogas, co-generated heat and digestate, which should all be sold to optimise the biogas plant's profits.

The aim of the present study is to therefore determine the potential of a succesful biogas plant based on feedstock suppliers and customers of its end products. We define the following research questions to guide our work:

1. Which suppliers offer high potential feedstock for an anaerobic digester?
2. What is the demand for the end products?

6.2 Methods

To answer the research questions above, we collected and analysed both quantitative and qualitative data. First, we analysed landfill data to learn about the BW currently deposited in the landfill and large-scale BW depositors. We then conducted technical expert interviews in Switzerland and identified potential BW suppliers and AD product customers. Through stakeholder interviews with local experts in the field, suppliers, and customers, we gathered the data required to conduct a Multi-Criteria Analysis (MCA). Ultimately, we ranked suppliers and qualitatively analysed potential suppliers and customers.

6.2.1 Analysis of landfill data

Based on the daily waste data from the weighbridge at Providence Landfill in 2014 received from the LWMA, we identified waste classes with high BW deposition on the landfill. We selected the waste classes Green Waste, Commercial Waste, Liquid Waste, Mixed Waste, and Putrescent Waste for future analysis due to their high BW content.

The absolute waste data values per source may include some uncertainty. While municipal solid waste (MSW) contains a high BW content, we have omitted this waste class from our study because the data showed inconsistencies: the indicated area in the raw data often included multiple districts. Therefore to avoid inaccurate data processing, we excluded it from our supplier analysis.

6.2.2 Technical expert interviews

To validate and complement the preliminary literature research, we conducted an expert interview with Imanol Zabaleta from the Department of Sanitation, Water and Solid Waste Development at the Swiss Federal Institute of Aquatic Science and Technology (Eawag). Furthermore, we contacted Christian Rui Lohri, a researcher at the Department of Sanitation, Water and Solid Waste Development at Eawag, to discuss technical questions related to assessing anaerobic digestion.

6.2.3 Stakeholder interviews

We conducted semi-structured interviews with stakeholders in the Seychelles. A list of questions and topics that were covered during the interviews were established beforehand. The questions focused on possible feedstocks and their uses, demand for products from anaerobic digestion and willingness to collaborate with a biogas plant. Below, Table 6.1 provides a list of interviewed potential suppliers of feedstock and customer stakeholders and Table 6.2 lists stakeholders interviewed about potential end-product demand only.

Table 6.1
Interviewed feedstock suppliers and customer stakeholders.

Sector	Interview partner	Contact Person	Function
Industry	Indian Ocean Tuna Ltd.	Joram Madnack Mark Benoiton Samuel Jobard	General Manager Health & Safety Manager Health & Safety Engineer
	Seychelles Breweries Ltd.	Russell Finesse	Engineer
	Public Utilities Corporation (PUC)	Frankie Dupres	Principle Engineer
	STAR Seychelles	Bernard Croguennec	CEO
Hotels	Constance Ephelia Hotel	Markus Utsch-Unrath	Health, Safety & Environment Projects Manager
	Berjaya Beau Vallon Bay Resort & Casino	Gulab Rai	General Manager
	Savoy Resort & Spa	Derek Barbe	General Manager
	MAIA Luxury Resort & Spa	Ferdinand Arenas	Maintenance Manager
Restaurants	Asian Fusion Restaurant	Venkatesh	Manager
	Kaz Kreol Restaurant	Beverly Thayladu	Unknown
	Cafe d'Horlage Restaurant	Doris	Unknown
	Butchers Grill	Guynemer Corgat	Owner
Farms	Golden Egg Farm	Jonathan Searles	Owner
	Fresh Way Farm	Guynemer Corgat	Owner
	Anse Royale Farm	Jose Pool	Owner
	Selwyn Clarck Market Victoria	12 different farmers and fishermen	Diverse
Government	Landscape & Waste Management Agency	Lemmy Payet	Consultant
	Landscape & Waste Management Agency	Landscape & Waste Management Agency	Manageress for green areas and landscaping works

Table 6.2
Interviewed stakeholders with demand for AD.

Interview partner	Contact Person	Function
Island Compost	Ms. Hoareau	Owner
Clearwater Nursery	Mr. Alex	Not known
8 farmers at the national exposition in Victoria	Diverse	Diverse

The information gathered about feedstock suppliers was used in the MCA described in Section 6.2.4. We use a combination of literature review and interview statements to analyse the end product demand qualitatively. The expert interviews mentioned in Section 6.2.2 and the literature review provided technical information about the uses of digestate, while the stakeholder interviews provided social, economic, and feasibility information specific to the context of the Seychelles.

6.2.4 Feedstock assessment using MCA

We analysed supplier feedstocks using MCA. MCA compares the possible options to determine the order of preferentiality by evaluating a set of indicators. The indicators are measured quantitatively with scores or rankings (UNFCCC 2014). For our analysis, seven indicators as shown in Table 6.3 were defined to analyse the alternative feedstocks. These indicators reflect the characteristics of promising suppliers of feedstock for anaerobic digestion, and include: small distances from the supplier to the biogas plant, low variation in waste generation, long-term contracts, high amounts generated and high quality feedstocks regarding technical parameters like biogas yield or complexity of pre-treatment (Eder & Schulz, 2007; Gnädinger, 2016; EAWAG, personal communication).

After defining the indicators, we identified each alternative feedstock's value in the indicator category. Using these values, we ranked the alternatives' potential (1 = highest rank, 2 = second highest, and so on). Each indicator has the same weight to eliminate stakeholder preference for a particular criterion. Then, we averaged the ranks for each alternative across indicators, and we ultimately ranked the feedstocks based on their scores.

We could not obtain all feedstock supplier data for each indicator. Therefore, only feedstocks where all the data were available could be rated. The potential of the remaining feedstocks are nevertheless addressed in our discussion. Additionally, since the literature often indicated ranges for the values total solids (TS), volatile solid (VS), and biogas yield, we performed a sensitivity analysis to observe the effect(s) of high or low estimates for these parameters on the final feedstock rankings. In order to do so, three scenarios were calculated based on the values from the literature: one scenario using low values, one using high values and one using the mean of these values.

Following Table 6.3, we provide a brief description of each indicator.

Table 6.3
List of MCA Indicators.

Indicator	Parameter	Measurement definition	Most Desirable for AD
Biogas yield	Cubic metre per tonne volatile solid (VS)	–	Maximum amount
Complexity of pre-treatment	No, simple, complex	No: No treatment needed Simple: Mechanical treatment, sorting or sanitation can easily be done Complex: The pre-treatment requires considerable effort	No
Seasonality	No, little, high	No: No variation of availability of feedstock throughout the year Little: Minor changes in availability during the year High: Strong fluctuation of availability	No
Amount currently going to landfill	Tonnes per day	To assess the potential for waste reduction on landfill	Maximum amount
Value of feedstock	Negative, zero, positive	Negative: Collection and disposal of feedstock is currently charged for Zero: Feedstock is collected and disposed of for free Positive: Feedstock is currently sold	Negative
Organic dry matter (VS)	Tonnes per day	–	Maximum amount
Distance to supplier	Kilometres (km) driven	–	0 km

Biogas yield: The biogas yield describes the total amount of gas produced through AD in m^3 per tonne VS. A high value is desired.

Complexity of pre-treatment: The complexity of pre-treatment describes the degree of feedstock treatment needed prior to AD. It depends on the extent of mechanical treatment, amount of sorting needed, as well as whether a feedstock has to be sanitised. Food waste contaminated with different kinds of plastics, cutlery or other non-degradable substances is an example of a feedstock where the pre-treatment is complex. A low complexity is preferred.

Seasonality: Seasonality describes the fluctuation of the supply of the feedstock within a year. For example a restaurant which is not open the whole year has a high seasonality. No seasonality is favored.

Amount currently going to landfill: This indicator describes how much of the feedstock currently is deposited at a landfill. Since reducing the dumped share of biodegradable waste is a major goal of government, a high value of this indicator is preferred.

Value of feedstock: This indicator shows the value of the feedstock for the feedstock supplier. Negative values for the value of feedstock indicate that currently costs are incurred for the collection and disposal of the waste whereas positive values show that the feedstock can be sold. Negative values are desired because this means that the biogas plant can obtain revenue for using this feedstock.

Organic dry matter (VS): Organic dry matter (or volatile solids) is "the organic matter in a sample, usually expressed as a percentage of the Total Solids" (Vögeli, Lohri, Galalrdo, et al., 2014). High values are desired.

Distance to supplier: The distance to suppliers describes how far the supplier is located from the proposed biogas plant site. Low distances are favoured.

6.3 Results

This section describes potential feedstock suppliers, followed by an analysis of demand for the end product of the anaerobic digester.

6.3.1 Potential supplier identification

We first found the largest waste producers who deposit their waste at Providence Landfill using Weighbridge data from 2014. Then, we provide a brief overview of the suppliers included in our MCA. Finally, we present the results of the MCA we conducted.

BW depositors at the Providence Landfill

We first found the total amount of waste measured for each waste class at the Providence Landfill as an initial screening to determine which classes should be considered further. The analysis of the Weighbridge data at the Providence Landfill from 2014 for relevant waste classes shows that the largest amount of waste going to landfill is Mixed Waste, followed by MSW, Liquid Waste and Commercial Waste. Putrescent waste and Green Waste only provide a marginal share (Table 6.4). In MSW, the share of BW is approximately 48% (Wilson, 2004). We have not analysed the share of BW in other waste classes.

Table 6.4
Load for 2014 measured at the Providence Landfill Weighbridge.

Waste Class	Tonnage
Mixed Waste	27'389
Municipal Solid Waste	24'571
Liquid Waste	10'483
Commercial Waste	9'185
Putrescent Waste	1'240
Green Waste	258

We then analysed the amount of each waste stream coming from individual sources in Table 6.4. As stated in the Methods, we excluded MSW due to the inability to attribute the data to the different districts. Figure 6.1 presents five boxplots demonstrating 2014 loads from sources contributing over 20 tonnes to the landfill. Each boxplot represent one waste class.

We visualised the loads through boxplots to identify the outliers for each waste stream. This is because we are interested in sources with the highest BW deposition, which could be potential feedstock suppliers for the AD plant.

The full list of outliers is provided in Appendix 6. Incorporating stakeholder input, we condensed our list to the suppliers presented in Table 6.5.

Overview of suppliers

Table 6.5 presents the following possible suppliers of biodegradable waste for AD. These are the suppliers which were the outliers, as demonstrated in Figure 6.1, and were also further nominated by stakeholders and experts. These suppliers are considered for the MCA described in the next section.

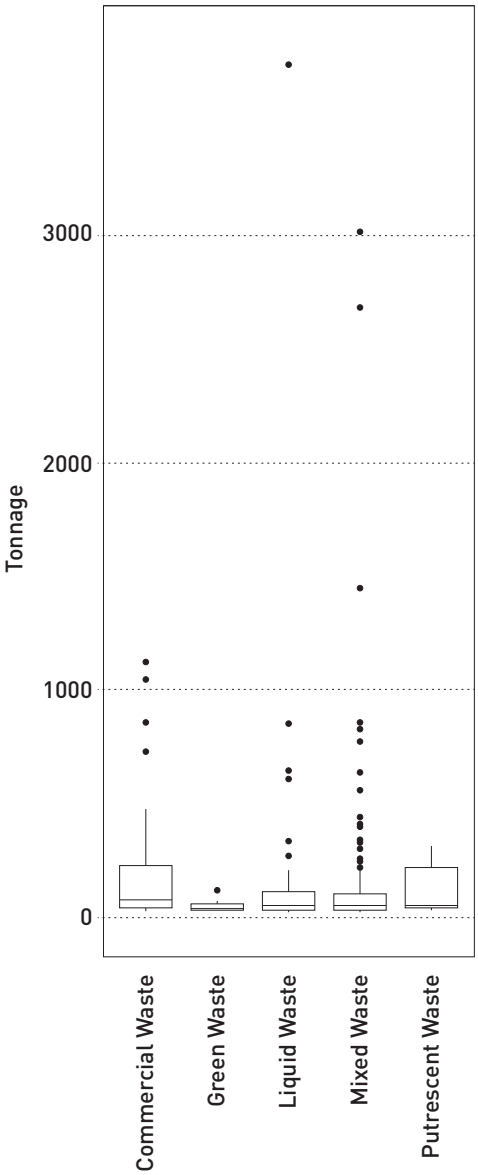

Figure 6.1
Boxplot of 2014 loads (tonnage) from individual sources by waste class. The median value is represented by the bold line inside the box. The edges represent the sources providing the 25th and 75th percentile of load, respectively. Outliers are represented by the dots.

Supplier assessment

Figure 6.2 shows the results of the MCA conducted on the suppliers identified in Section "Overview of Suppliers". A lower score equals a higher rank, and therefore higher potential of the supplier. The point values assigned to each supplier are also provided in Appendix 6. Full rankings with values for each indicator are shown in Appendix 6. The results of the MCA are discussed below Figure 6.2.

The following five feedstocks achieved the lowest scores, and are listed from highest to lowest rank:

1. IOT: Fish sludge
2. PUC Providence: dewatered sewage sludge
3. Butcher's Grill: kitchen oil
4. Seybrew: spent grain
5. Kaz Kreol: kitchen oil

The industrial companies IOT, PUC, and Seybrew, and hotels or restaurants that provide waste oil as a feedstock provide the feedstock with the highest potential. The next most promising suppliers are farmers which provide manure. The least promising are food and Green Waste. Below, we describe why particular feedstocks have high and low rankings, and reiterate which suppliers contain these feedstocks.

With the exception of spent yeast from Seybrew, all industrial companies have feedstocks that achieve low scores in the

Table 6.5
Overview of considered suppliers of feedstock.

Supplier	Type of waste	Original Load [tonnes/d]	Present use
IOT	Fish sludge Food waste	16–18 N/A	Landfilled; potentially internal AD Landfilled
Seybrew	Spent grain Spent yeast	1.8 0.6	90% animal feed; 10% landfilled 20% to farmers; 80% landfilled
PUC	Sewage sludge (Prov.) Sewage sludge (BV)	3.2 0.6	Landfilled Landfilled
Constance Ephelia, Savoy Resort & Spa, Berjaya, MAIA Luxury (large hotels)	Food waste Green Waste Kitchen oil Sewage sludge	0.33+ 0.5–1+ 0.2+ 0.18+	Some animal feed, landfilled Compost, landfilled Landfilled Landfilled
Fresh Way, Golden Egg, JoJo's (farms)	Manure Green Waste	14+ 0.14	Sell to farmers, compost Soil fertiliser, landfilled
LWMA	Green Waste	N/A	Compost, landfilled
Kaz Kreol, Butcher's Grill (restaurants)	Food waste Kitchen oil	N/A 0.7	Sold to farmers Misc: landfilled, soap

N/A indicates data unknown; + indicates a higher proportion because of unknown data by some suppliers in category.

amount of waste going to landfill, as well as in the amount of VS produced. IOT fish sludge has a particularly low VS production rate of 52% TS. In addition, all suppliers are located relatively close to Providence, which reduces transportation and other operational costs. Because they have low biogas yields, fish and sewage sludge achieved low rankings in this indicator category, while spent yeast and spent grain are ranked highly, just after the yield of oil.

Kitchen oil receives a high ranking in the biogas yield category because it yields 1'285 cubic meters of biogas per ton, which is double or more the value achieved by other waste streams. However, all suppliers of waste oil achieve low ranks in seasonal variation and in waste value indicator categories. Some of the suppliers, especially Butcher's Grill, are located near Providence, which contributes additionally to the high rank. Only Butcher's Grill Restaurant can provide a large amount of oil, the other suppliers only provide minor amounts which would substantially lower the usability of this feedstock.

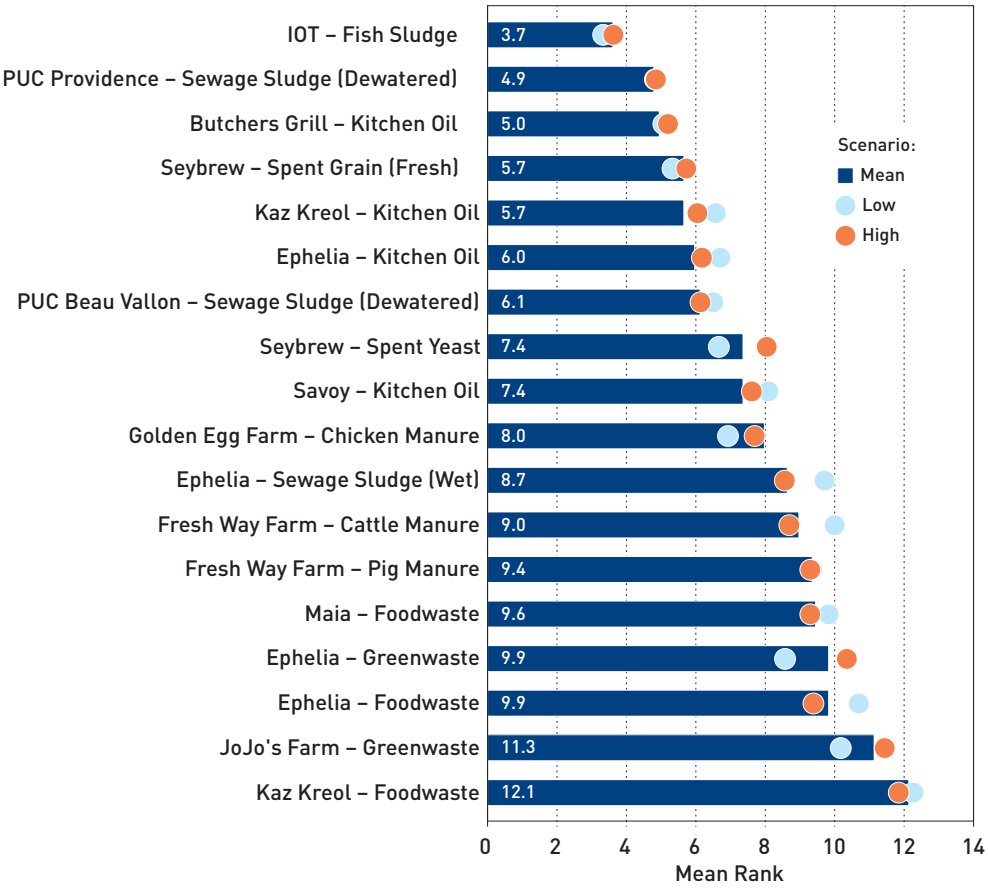

Figure 6.2
Mean rank of each supplier according to the MCA criteria, with "low," "mean," and "high" scenarios due to low, mean, and high literature values for VS, TS, and biogas yield, respectively (the higher the rank, the higher the potential of the supplier.

In addition, it has to be noted that the possible amount of kitchen oil used in AD is limited. Studies in the literature show that the addition of small amounts of grease to the influent can lead to a drastic increase of the overall biogas production (Lansing, Martin, Botero, da Silva, & da Silva, 2010). However, if the share of oil used for AD becomes too high, biogas yields decrease again. Fats are degraded relatively slowly and the use of co-substrates to increase degradation rates also increases maintenance costs (Czepuck, et al., 2006; Deublein & Steinhauser, 2011).

Manure from farmers achieved high rankings in the VS generation category, but low rankings in the Waste Currently Going to Landfill category. This is because manure is not currently dumped in the land-

fill. Low rankings are also achieved in the Waste Value category, since farmers currently sell manure. Because farmers are often located at far distances from Providence, they also receive low rankings in the Distance to Providence category. The biogas yield of manure is below average compared to the other alternatives.

Green and food waste from hotels and restaurants have the lowest overall ranking. While it has a high biogas yield compared to the average, these waste streams have a low VS production, small amount currently deposited on the landfill, and are far away from the Providence Landfill.

The sensitivity analysis shows that variability in the rankings is low when using low, mean or high literature values for TS, VS, and biogas yield. Nevertheless, the highest ranked suppliers retained their original rankings despite changing variables in the sensitivity analysis, meaning that they are insensitive according to our analysis.

Other potential suppliers

In addition to the suppliers discussed above, further potential suppliers of biodegradable waste for AD could be households. As household waste currently falls into the MSW waste stream, we did not include household BW in the supplier analysis. However, in order to use this waste stream for AD, sorting is required at either the household level or at the plant. While sorting at site increases the operational costs of the plant, stakeholders indicate that sorting at the household level would require a new collection system as well as a change in behaviour of the residents. According to one proponent of household separation, the government is already planning an educational awareness campaign for sorting of biodegradable waste at the household level. Others believe that such a significant behaviour change to integrate a working household waste separation system will take a long time.

Additionally, the Selwyn Clark Market in Victoria has a high potential. The Selwyn Clark Market is located in the centre of Victoria and mainly sells fish, vegetables, fruits, and spices. Stakeholders indicate that the market is not equipped with an official sorting system for biodegradable waste. Nevertheless, 9 out of 12 interviewees separate at least some of their biodegradable waste (fish cuts, fish heads, old fruits and vegetables etc.) to provide it to friends or farmers as animal feed.

6.3.2 End-product demand

We first provide the results of our literature analysis on end-products of AD, with particular attention given to the digestate. Then, we provide the analyses of demand for digestate, biogas and electricity, and heat to highlight stakeholders that have interest in these products.

Literature analysis

The form of the digested residue largely depends on the system of the biogas plant, which itself depends on the water content of the feedstocks. Due to the different characteristics listed in Table 6.6, a wet system (<16% TS) is considered more suitable in the context of Mahé, especially because the wet system requires less maintenance. Therefore, the characteristics of the system have to be considered when defining the mixture of feedstocks, which needs high water content. This can also be achieved by mixing the feedstock with water (Deublein & Steinhauser, 2011).

The digested residue of wet systems is in most cases used as liquid fertiliser or solid compost. In order to use the digestate as compost, it has to be dehydrated or further dried. The final composting of the digestate then had to be done in an aerobic environment. The quality of the compost out of digestate from AD can be considered nearly as good as compost from a completely aerobic process.

Depending on the feedstocks and considering special hygiene requirements, sanitation of the compost is additionally needed. When the digestate is not dewatered, it can be used as liquid fertiliser. Also, the press water from dewatering can be used as liquid fertiliser, for example in agriculture. If the wastewater cannot be used as fertiliser, it has to be processed in a sewage plant before it can be discharged into waters (Deublein & Steinhauser, 2011).

According to an interview partner, local farmers do not use large amounts of liquid manure to fertilise their soils, potentially due to the low level of mechanisation and hilly landscapes. Therefore, we assume that there is no need for liquid fertiliser

Table 6.6
Comparison of dry and wet systems for AD.

	Wet System	(Semi-) Dry System	Sources
Dry matter content (TS)	16% or less	22–40%	(Vögeli, Lohri, Galalrdo, et al., 2014)
Commonness	Common	Rare	(Vögeli, Lohri, Galalrdo, et al., 2014)
Feeding	Continuously	Batch-wise	(Vögeli, Lohri, Galalrdo, et al., 2014)
Complexity of operation	Less complexity	Higher complexity	(Deublein & Steinhauser, 2011)
Range of application	Higher	Lower	(Deublein & Steinhauser, 2011)

from AD. In our analysis we therefore focused on the demand of solid fertiliser derived from the digestate from AD.

Demand for biogas

Stakeholders indicate that most Seychellois households use gas for cooking. At the moment, the Seychelles Petroleum Company (Seypec) dominates the gas market in the Seychelles. Biogas is more expensive than conventional fossil fuels because of the high generation costs (The Greenage, 2016). Stakeholders argue that people would not buy biogas instead of traditional gas if the price were higher. Therefore, they believe that converting biogas to electricity is more feasible than selling it directly as biogas. A further indication that biogas to electricity is popular in the Seychelles is that IOT's planned biogas plant, which would be used solely to generate electricity.

Demand for compost

In this section, we discuss potential compost customers on Mahé.

Large farms

We interviewed four large farms: Golden Egg Farm, Fresh Way Farm, Anse Royale Farm and D&S Rising Farm. Golden Egg Farm and Fresh Way Farm rear livestock, while Anse Royale and D&S Rising do not. Golden Egg Farm and Fresh Way Farm have excess manure and compost, and therefore sell packages to smaller farms when possible for approximately 50 SCR per 50 kg bag. Packages not sold are stored on site. Fresh Way Farm indicated interest in building a biogas plant to use the excess manure, while Golden Egg Farm indicated that many local farmers now use imported fertiliser with super phosphate. Anse Royale Farm does not produce enough fertiliser itself because they have no livestock, and therefore buys imported concentrated fertiliser at a price of 200 SCR per 40 kg bag.

Anse Royale Farm indicated an interest in buying local fertiliser if it is of the same price and quality and is safe to use and accepted by customers, as there is concern about using sewage sludge as feedstock. D&S Rising Farm stated that they buy 4–5 tonnes of local compost from farmers each month at a price of 1'800 SCR per tonne.

Hotels

The interviewed hotels demonstrated varying levels of demand for compost from digestate. Some internally produce all of their required compost demand and even sell excess. Others buy small amounts of fertiliser or compost. Sometimes, an external company does landscaping services for the hotel.

Landscaping companies

The landscaping department at LWMA is able to produce their own compost from leaves and grass collected from their cleaning activities. However for larger projects, it buys compost at a price of 3'000 SCR per tonne. They also purchase 5 tonnes of manure per month from local

farmers at a price of 5'000 SCR per tonne. Another landscaping company we interviewed states that it produces its own required compost. When there is excess, it sells the Green Waste as compost locally or it is deposited on the landfill.

Small farms and households

We identified a demand for local compost from small farms, gardeners and households. Stakeholders indicated that there is a lack of compost amongst households and small farms that cannot produce their own compost. One interviewed stakeholder said that she sells 40 kg bags of compost made from Green Waste for 100 SCR. She stated that she sells about 20–50 bags per month to households and some hotels and farmers, and that demand is growing. Other interviewed stakeholders stated that they sell small amounts of manure from their livestock for 2–2.5 SCR per kg. One stated that he would sell more if he had higher manure production. Some interviewees say that they prefer to buy inorganic nitrogen-phosphorous-potassium fertiliser, while others prefer to use local chicken manure.

Compost as landfill cover

Another idea is to use the dried digestate or low quality compost as landfill cover material. Digestate could be a cost-effective cover material applied to the landfill to prevent birds from digging in the trash as well as to reduce windblown litter (Sailola, 2011; LWMA). Digestate could substitute or supplement the coral sand which is currently being used, which stakeholders mentioned is expensive.

However, some stakeholders believe that the use of digestate as landfill cover material is undesirable due to possible odours and its permeability. Literature shows that about 12–24 hours after discharge, the digested residue will become odourless (Deublein, et al., 2011). One researcher assessed the use of municipal waste compost as daily cover material and showed that this could actually decrease odorous emissions (Hurst et al., 2005). We did not assess whether the digestate has the same odour prevention as clay, which stakeholders indicate has been used in the past as landfill cover material (Sailola, 2011). Additionally, we believe that mixing clay together with the digestate could make the material less permeable.

Demand for electricity and heat

Electricity production from renewable sources is desirable in the Seychelles, where the government has expressed interest in increasing its share of electricity derived from renewables from the current 4.5% to 15% by 2030 (Amla, 2015), (Van Vreden, Wigan, Kruze, Dyhr-Mikkelsen, & Lindboe, 2010). This could be achieved by producing electricity from the biogas.

Three stakeholders indicated a demand for heat. Seybrew requires heat in beer production and PUC requires heat to raise the temperature of fuel in its power plant. The heat could also be used in cooling

processes at the fish port. However, none of these facilities is located near the proposed biogas plant site, and because heat loss increases substantially with distance travelled, we would expect a lot of heat to be wasted whilst being transported to these facilities. Therefore, to obtain the maximum efficiency of the plant's end products, the generator should be located near the heat customer.

6.4 Discussion

The discussion is broken into three sections: feedstock suppliers, demand for end-products, and limitations and future work.

6.4.1 Feedstock suppliers

The structure of this section follows the general order of the rankings of the MCA: Suppliers in the industry sector and kitchen oil from restaurants and hotels are ranked best, followed by big farmers. Green Waste and food waste from hotels and restaurants rank last.

The IOT fish sludge described above was ranked as the most promising feedstock. Stakeholders agree that using the fish sludge from IOT for AD is promising and would substantially reduce the amount of waste going to the landfill. However, if IOT builds its own biogas plant, it would presumably use its own waste stream and therefore render it unavailable for use in another biogas plant.

The second-best ranked feedstock is the sewage sludge from the treatment plant of PUC. As PUC currently has to pay for the disposal of their sludge, using the sludge as a feedstock instead would be an even more cost-effective option and therefore should make the collaboration attractive for them. However, the use of the digestate coming from sewage sludge is limited due to hygienic reasons or may even have to be further processed for safe use.

On one hand, Seybrew, another high potential feedstock supplier within the industry sector, would be very well suited for a collaboration with a biogas plant, because the spent grain is available in relatively high amounts and would provide high biogas yields. On the other hand, most of the feedstock is already currently being used by farmers, and using the remaining available spent grain for the biogas plant would represent only a minor reduction of the disposal on the landfill. Additionally, mixing spent grain with sewage sludge from the treatment plant could optimise the N to C ratio to improve the quality of the AD end products. Another potential feedstock from Seybrew would be beer wastewater, but we believe that most of this wastewater consists of water and would therefore not be useful for AD.

Apart from Butcher's Grill, the interviewed restaurants and hotels generate only little amounts of feedstock, which is not ideal as it is logistically easier, more reliable, and therefore economically more attractive to collect big amounts from few suppliers. Certainly, possible synergies regarding the collection of multiple feedstocks at one site would have to be investigated for a more detailed assessment. However, our research indicates that using high proportions of fatty oils may decrease the degradation rates in AD. Ultimately, we ranked kitchen oil highly in the MCA, but major limitations may occur and the use of kitchen oil in the given context would need further investigation. The results from the MCA indicate that other feedstocks – Green Waste and food waste – from hotels and restaurants have low potential.

Despite the low rank manure from large farms received, we believe manure could have high potential. On one hand, manure is ranked highly in the amount of organic dry matter generated. However, it is in any case rarely deposited on the landfill, meaning that these suppliers have a rather small potential for reducing disposed waste on the landfill. More interviews would need to be conducted with other farmers in the Seychelles to determine the total manure available and the landfilled BW displacement if some farms deposit their manure on the landfill. Further investigation of transport costs should also be conducted.

Finally, we believe that landscaping companies, Selwyn Clark Market and households have potential to provide BW as feedstock in the future. Food waste and Green Waste feedstocks may be suitable for AD because they have high biogas yields. However, more sorting at the source and collection needs to take place for the Selwyn Clark Market and for households. We recommend future studies integrating these considerations be conducted to fully assess their feedstock potentials.

While our MCA specified preferred suppliers, they may not be ideal for the actual biogas plant. This is because we believe that the decision-makers may alter their preference for certain indicators depending on their purpose of the AD. Therefore, we propose the following two goals of the AD and enumerate the suppliers who would provide the highest potential in these scenarios:

1. If the goal is to reduce the amount of waste going to the landfill, PUC's sewage sludge and hotel food and Green Waste have the highest potential. The possibility to add small amounts of kitchen oil needs further investigation. Household BW should be considered in the future as well.
2. Alternatively, if the goal is to build the most economically feasible AD, Seybrew and PUC have the highest potential for feedstock supply. Low-cost manure from nearby farms is also a viable option.

6.4.2 Demand for end-products

As mentioned previously, the three main end products of a biogas plant are:

- the biogas itself, which can be used, for example, in electricity generation and cooking and vehicle fuel;
- nutrient-rich digestate from which compost for agricultural purposes can be produced; and
- co-generated heat.

In this section, we address each of these end products in terms of the demand for them.

Despite the government's desire to produce more electricity from renewable resources such as biogas (Van Vreden, Wigan, Kruze, Dyhr-Mikkelsen, & Lindboe, 2010), an issue arises when the demand for electricity from biogas is higher than that for biogas itself, which is plausible and, according to some stakeholders, is the case. Another consideration concerning electricity generated from biogas relates to cost: although electricity from renewable sources is generally desired by the government, we expect that electricity from biogas plants without subsidies might not be competitive. A more detailed discussion of the economic aspects of this topic is beyond the scope of this present study.

Our study has shown that there might be small-scale demand for the digestate, particularly as a raw material for compost. We arrived at this conclusion considering the moderate-to-good demand for compost, as conveyed to us by a compost seller we interviewed. However, large-scale demand for compost is lacking in Mahé. Interviews with farmers show a preference for imported fertiliser because it is cheaper and of higher quality than compost, while some other farmers already produce their own compost for fertiliser and therefore do not need to buy any more. Producing one's own compost is also common amongst some of the hotels and landscaping companies we interviewed. Governmental restrictions on imported compost could increase the demand for digestate, but the economic benefits of this may be outweighed by having to sell small amounts of compost to many customers with irregular demand instead of larger amounts to fewer but more reliable customers. We believe the former scenario would predominate because no large-scale demand for compost was found in our study. Additionally, the issues of producing lower quality compost from AD compared to aerobic treatment, and the need for the treatment of the digestate obtained from sewage sludge before it can be used for agricultural purposes still remain.

An alternative to using the digestate for compost production would be to use it as landfill cover material. Although we do not know if the use of digestate as landfill cover material would be as effective as the corral sand which is currently being used, we believe that if the biogas plant produced high enough amounts of digestate, using it as landfill cover seems promising. However, further investigation on this topic is needed.

Heat, which is a by-product of energy generation, is of relatively low demand in the Seychelles because of the tropical climate. Besides the three identified stakeholders who demand heat in their production processes, there are other possible uses for this co-generated heat. For example, one stakeholder proposed providing the excess heat to the desalination plant adjacent to the proposed biogas plant. However, another stakeholder indicated that the desalination plant uses reverse osmosis, which would not require heat. Other technologies using heat exist, but a new desalination plant would need to be constructed (Visser, 2014). Another opportunity to use the heat would be in the drying of the digestate so that the compost can be more easily stored and transported (Deublein & Steinhauser, 2011).

6.4.3 Limitations and future work

Over 20 stakeholders with a broad range of backgrounds were interviewed in our study, which provided us a multi-faceted understanding of the potential suppliers of feedstocks and uses for the end products. In spite of this however, we acknowledge the time limitations and could have selected and interviewed more stakeholders in depth. This especially applies to the hotels, which were able to only provide rough overviews of their operations. Further research is needed to gain a more accurate insight of the total amount of feedstock available.

In our study, values for biogas yields, methane composition, VS, and TS were obtained from the MCA and other literature. However, because the 'true' values would heavily depend on the specific feedstock and the mixture of feedstocks available in the Seychelles, empirical measurements would be the only way to determine these values accurately. In addition, although the ranking-by-attribute MCA method used allowed us to obtain results quickly, it is relatively unsophisticated because it only takes the relative differences between the feedstocks into account. There also exists a certain risk of double counting, since the attributes may not be entirely independent. More accurate results could be obtained by converting each attribute value into a score by an attribute-to-score-table.

Additionally, our analyses only considered the designated site for the future biogas plant at Providence. Other possible sites were not investigated and would require further research. Other sites could include decentralised biogas plants at large farms which would mainly operate using locally produced animal manure, possibly aggregated with some food and Green Waste, as feedstock.

Lastly, the following feedstocks have not been considered in our study: paper, cardboard, seaweed and fish guts. The literature indicates that these feedstocks could be used in varying amounts in the anaerobic digester (Fonoll, Astals, Dosta, & Mata-Alvarez, 2016; Vögeli, Lohri, Galalrdo, et al., 2014). Future analysis should investigate the potential of these feedstocks.

6.5 Conclusion

In our study, we identify several suppliers of high-potential feedstocks for anaerobic digestion on Mahé. However, the most promising suppliers depend on the goal of the AD plant. If the goal is to reduce the amount of waste going to the landfill, PUC's sewage sludge and hotel food and Green Waste have the highest potential. Alternatively, if the goal is to build the most economically feasible AD, Seybrew and PUC have the highest potential for feedstock supply. Low-cost manure from nearby farms is also a viable option. In each case, household BW should be considered in the future as well, but further investigation is required.

We demonstrate that there is a potential demand for the AD plant's end products, particularly electricity. The ultimate usage of the digestate is unclear and requires further investigation, but could include compost and landfill covering. We could not identify customers near the potential site of the AD plant who are interested in the co-generated heat. From our analysis, we conclude that there is potential for a successful biogas plant on Mahé. However, to assess the overall economic feasibility of a biogas plant on Mahé, a more detailed study must be undertaken incorporating financial costs and specific suppliers and customers.

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Rosabella Mangroo and Marius Wälchli

7 Landfill Scenario Modelling

7.1 Introduction

Waste management is a dynamic field. Recognising the complex interplay between and future development of the industry, the market, and society is required to design appropriate waste management systems. When decision makers implement waste management projects with incorrect assumptions, investors are more likely to be financially burdened by inappropriately designed treatment systems.

The Seychelles has made waste management a priority amidst having experienced dynamic economic growth in the past 25 years. The Seychelles' gross domestic product purchasing power parity (GDP per capita (PPP)) has tripled from 1990-2015 (IMF 2016). Simultaneously, annual waste landfilling rates have increased 30% in the Seychelles, from 40'000 to 70'000 tonnes per year from 2001–2014 (Presentation, LMWA, 22.04.16). Literature and prior research show that the recent increase in waste production can be attributed to economic growth and market liberalisation in 2008.

However, annual waste landfilling rates have been underestimated in the design phase of treatment systems, and now these systems cannot meet the current demand. For example, in March 2015, the Providence II Landfill was constructed with capacity to provide waste deposition for nine years. When designing the capacity, stakeholders incorrectly assumed that waste deposition would remain constant at 40'000 tonnes per year (Source: LMWA, 2016-04-22). Assuming that waste deposition continues to increase 30% per year as indicated by current trends, the actual lifetime of the new landfill may only be five years. The improper predictions made at the design phase have forced the government to invest in another waste treatment strategy soon.

By utilising scenario analysis, waste managers can identify appropriate treatment technologies, loads and capacities so that they do meet future demands. Scenario analysis is a well-established technique to predict possible future scenarios in scientific, long-term strategy and other decision-making (Alcamo, 2008; Weisser, 2004). This method acknowledges that uncertainties exist and provides possible future outcomes based on the occurrence of pre-defined events. While scenario analysis does not predict the future, it has merit in supporting long-term decision-making.

To the best of our knowledge, no comprehensive scenario analysis or other systematic planning method has been conducted to investigate the future of the Seychelles' waste management system. Therefore, the goal of this study is conduct a scenario analysis to propose possible amounts of waste deposited on landfills up to 2040. When conducting this scenario analysis, our findings will be guided by the two following research questions:

1. What could the total amount of waste landfilled over the next 25 years be under a "business as usual" (BAU) scenario?
2. What events, policies, and other developments affect landfilling rates?

7.2 Methods

To address our two research questions, we conducted a scenario analysis that utilised literature, expert and other information to generate models that provide possible future outcomes of the waste landfilled up to 2040. To demonstrate our methods, we first provide an overview of scenario analysis and the system boundaries for our study. Then, we identify the data and literature used to determine the impact factors for our study. We also provide the model generated from these impact factors. Next, we list our interviewed experts and the storylines generated from their discussions. Finally, we present and describe the scenario generation.

7.2.1 Scenario analysis definitions

Methodology

While the future of any current system is inherently unpredictable, its possibility space, or range of possible future states, can be determined. Figure 7.1 shows how a scenario is defined as one future state of a system within this possibility space.

Scenario analysis is the general methodology for creating a possibility space of scenarios according to the influence of drivers, known as impact factors, on a system. Scenario analysis is used widely in strategic planning across a range of fields, and therefore, methods also vary. In

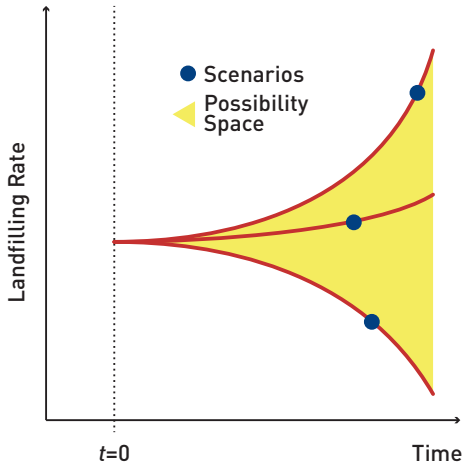

Figure 7.1
Graphic for the possibility space in a scenario analysis.

our study, we utilise the story and simulation (SAS) approach to generate scenarios, which uses storylines, or system developments, to specify a subset of the possibility space in scenario generation (Alcamo et al., 2008). Our rationale for choosing the SAS approach is two-fold. First, stakeholders can directly input their expertise into creating storylines, and therefore, the qualitative data have a direct impact on the possibility spaces. Additionally, if all storylines are independent from each other, then they can be aggregated to generate additional scenarios. Effectively, we can combine waste management policies and strategies together, as is typically conducted, to identify the possibility space.

Figure 7.2 shows our general methodology for conducting the SAS scenario analysis. The goal and scope definition must be conducted first to define the system and its temporal, geographical, and material boundaries. After we concretely defined the goal and scope, we constructed the models used to generate the scenarios. We first selected and quantified impact factors through data analysis and

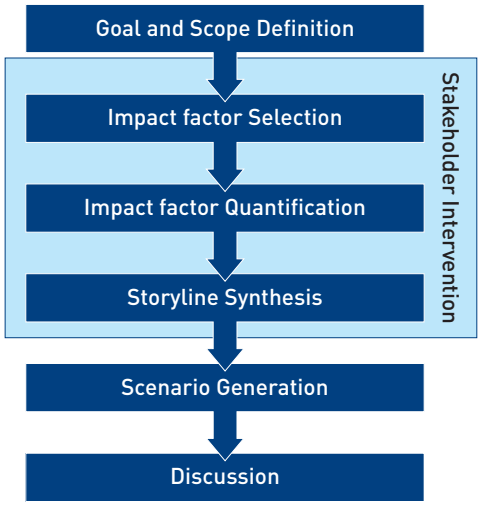

Figure 7.2
SAS general methodology.

literature review. Stakeholders verified the accuracy of these impact factors and provided viewpoints regarding their probability of occurrence. Then, with help from stakeholders, we synthesised storylines to describe potential developments in waste management that may impact our system. The impact factors are directly applied to these storylines to create a subset of scenarios within each storyline. Finally, we generate a range of potential scenarios within these storylines and conclude with an evaluation.

Each step of the methodology will be further discussed in the following sections.

Goal and scope definition

As stated previously, the goal of this scenario analysis is to provide possible annual landfilling rates up to the year 2040. The material defined in this study is waste, measured in tonnes deposited. The spatial boundary is active landfills in Providence on Mahé. The timeframe for this study will be from 2015 to 2040.

The scopes defined above for this study were chosen based on data availability and indications from literature. We selected a 25-year time horizon because of indications from the Seychelles Strategic Plan: Sustainability Appraisal report (Abu Dhabi Urban Planning Council, 2015). Current waste data are only available from the Providence Weighbridge, and therefore, we limit our spatial reference to Mahé. The analysis will be limited to the waste classes and fractions that are most relevant in terms of total weight. These are: Municipal Solid Waste (MSW), Commercial Waste, Mixed Waste, Green Waste, Putrescent Waste and Liquid Waste. Environmental impacts and financial costs are not considered in this scenario analysis.

7.2.2 Weighbridge data analysis

First, we analysed the weighbridge data collected by LWMA to determine the shares of each waste class and the fractions of waste type within each waste class. We assumed these values remain constant in the future, and therefore, we used them to determine the impacts of storylines on landfilling rates in our models. Based on Payet (personal communication, July 16, 2016), we estimate the capacity of the landfill to be 360,000 tonnes. We use this value to convert the amount of waste deposited to the number of landfills created and filled.

7.2.3 Impact factor quantification

An impact factor is a variable that has a strong influence on the future states of a system. The goal of selecting impact factors is to find a set of variables that can determine landfilling rates on Mahé. Then, we could fully explain how the landfilling rate in a given year depends on the impact factors. However, the future value of an impact factor, such as population growth, is inherently uncertain and therefore, cannot be predicted.

The number of impact factors generally depends on the complexity of the system and the data available. To find our set of impact variables, we conducted a literature review combining prior scenario analyses, reports on waste generation, and international statistical data. A list of the literature referenced in this report is provided at the end of this chapter; the list below specifies the references used in particular to aid impact factor selection:

- Analysis of Residential Solid Waste Generation at Generation Sites, Qdais et al.
- *Global Waste Management Outlook*, United Nations (UN) Environment Programme
- Modelling municipal solid waste generation: A review, Beigl et al.
- MSW Generation and Economic Growth Analysis, Inglezakis et al.
- *Towards Green Growth: Organisation for Economic Co-operation and Development (OECD) Indicators*, OECD
- Travel & Tourism Economic Impact 2016 Seychelles, World Travel and Tourism Council
- World Population Prospects, UN Department of Economic and Social Affairs

As stated before, the impact factors carry the uncertainty in scenario analysis. Therefore, one scenario represents a unique combination of impact factors. To find the full range of scenarios (possibility space) for 2040 landfilling rates, we determined the low, medium, and high trajectories for each impact factor. The low and high values for each impact factor lie on the boundary of the possibility space, while the medium value would correspond to the scenario with a roughly average landfilling rate. Utilising the minimum and maximum values for each impact factor in our model provided the full range of scenarios, effectively defining the possibility space.

After we selected the impact factors, we quantified their relationship to landfilling rates. The ultimate result of this step was a mathematical model predicting annual landfilling rate according to the previous year's landfilling rate and the impact factor values. We then conceptualised a model that provided the basis for annual landfilling rates. The model for annual landfill deposition, d_i, in tonnes for the year i, depends on the following variables, as demonstrated in Equation 7.1 below:

$$d_i = f(IF_{1,i}, IF_{2,i}, \ldots, IF_{n,i}, d_0)$$

Equation 7.1
Baseline annual landfilling rate model

$IF_{x,i}$ is the value of impact factor x for year i (unitless), and d_0 is the waste deposited in the first year of the simulation (e.g., 2015 for the BAU storyline). We consulted the stakeholders identified in Table 7.1 to verify these impact factors to determine their potential significance in a model. In this report, Equation 7.1 will be referred to as the baseline model.

7.2.4 Storyline synthesis

Our next step was to construct storylines. A storyline is an idea of what the waste system could look like in the future. Possible storylines could be new waste management policies, bans on incoming goods, or any other developments that could influence landfilling rates.

When a storyline is fixed, it selects a subset of the total possibility space of scenarios. Within each storyline's possibility space, the impact factors and the respective values vary to generate the range of landfilling rates. Each storyline tells a particular story regarding how waste management could develop, but the ultimate outcome of each story is still uncertain because it depends on how the impact factors change over time. Figure 7.3 visually depicts how each storyline selects a section of the total possibility space; because the impact factors are still uncertain, each storyline still contains several possible future states.

The storylines strongly influence the subset of scenarios generated through the analysis. Therefore, it is critical that they represent possible and accurate developments in Seychelles waste management. We selected experts in a variety of fields impacting waste management to guide the storylines that we constructed.

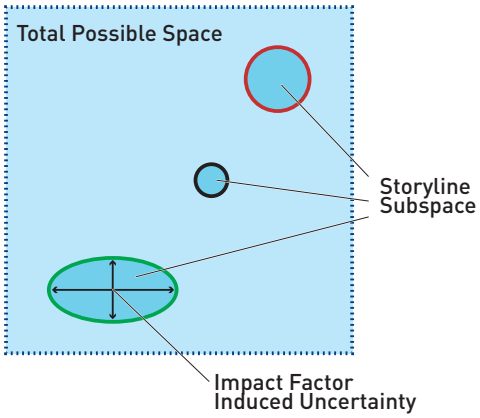

Figure 7.3
Graphic to demonstrate storyline subspaces. The variability for each storyline comes from the impact factors.

Stakeholder interviews

Stakeholders were included as often as possible in the conducted scenario analysis. SAS combines qualitative and quantitative knowledge from stakeholder and data information; the stakeholders, who are often experts in the field, can provide valuable insight when data are insufficient (Allen et al. 2014; Alcamo et al. 2008). The role of experts, government, NGOs, and other stakeholders is to identify important drivers, information on future developments and other information not easily accessible in the literature. Ultimately, the stakeholders collaborated with us to create the scenarios we identified in Section

7.2.6. We selected stakeholders that each possess a unique expertise in Seychelles' waste management (Table 7.1): technical waste expert, government, NGO and finance (Mieg & Näf 2006; Harrell & Bradley 2009). The interviews took place between June 28 and July 8, 2016.

Storyline identification

After discussions with stakeholders and conducting literature review, we compiled a list of future developments that could influence landfilling rates on the landfill. After incorporating the needs and information identified by our stakeholders, we generated five storylines that each represents a possible waste management development on Mahé. We explain the formulation of these storylines in the results section.

6.2.5 Scenario generation

Once the storylines were identified, our next step was to model the storylines so that we could generate scenarios for landfilling rates up to 2040. The outcome of this step was to demonstrate the possibility spaces for landfilling rates in each storyline.

To accomplish this, we were required to quantify the storylines. Quantification of the storylines included deriving values for various storyline development, trends, and definitions, as well as providing numerical assumptions, as guided by stakeholder interviews and literature review. We ultimately altered the baseline model to include these quantifications in each storyline. We created these storyline-specific models using the open-source modelling R Studio as software.

Table 7.1
List of interview partners.

Name	Organisation	Function	Expertise
Lemmy Payet	Landscape Waste Management Agency (LWMA)	Consultant	Waste management
Michelle Martin	Sustainability for Seychelles (S4S)	Executive Director	Waste management
Jean Weeling-Lee	Corvina Investment Company	Managing Director	Finance
Didier Dogley	Ministry of Environment, Energy & Climate Change (MEECC)	Minister	Waste policy

Finally, we created the possibility spaces for landfilling rates. We defined three scenarios of interest – low, medium, and high landfilling rate. To create these three scenarios, we inputted the low, medium, and high values of each impact factor into each storyline's model, effectively determining the low, medium, and high landfilling rates, respectively. The low and high scenarios represent the minimum and maximum bound, respectively, of the possibility space. As metioned, the story and simulation approach allows the user to aggregate storylines to generate further scenarios.

To educate and aid policymakers, students, and others interested in our scenario analysis, we created an interactive online tool that allows the user to change impact factors and other variables to determine possible landfilling rates. The web-tool was implemented in R using Shiny package (Winston Chang, et al., 2016). This online tool can be found at:

https://landfill-scenario.shinyapps.io/scenario_app.

7.3 Results

In this section, we present the results of the scenario analysis. First, we identify the impact factors we selected, their low, average, and high values, and the model used to quantify their influence on landfilling rates. We then discuss the results of the stakeholder interviews and identify the five storylines found with stakeholder collaboration using their underlying assumptions and mathematical implications. Finally, we provide the possibility space for each storyline, as conducted through our simulation using R. Additionally, we identify scenarios when combining several storylines together.

7.3.1 Weighbridge data analysis

We first analysed available data on waste deposition at the Providence Landfills to determine the composition of the waste deposited. Figure 7.4 shows the share in weight of the different waste classes for the year 2004. As demonstrated, the waste entering the landfill is diverse and therefore indicates that many different kinds of waste contribute to deposition in the Seychelles. However, because these data are from 2004, we expect that the proportions have deviated from those shown, especially because of the influx of imported goods.

An overview of the major waste classes, their share of total waste, and their composition are provided in Table 7.2. By tonnage, the three waste classes MSW, Commercial, and Mixed Waste account for 81% of the total waste. Liquid Waste is accounting for another 14%. The residual 5% are Green Waste, Putrescent Waste, Waste Oil, Construction Waste and Metal Waste.

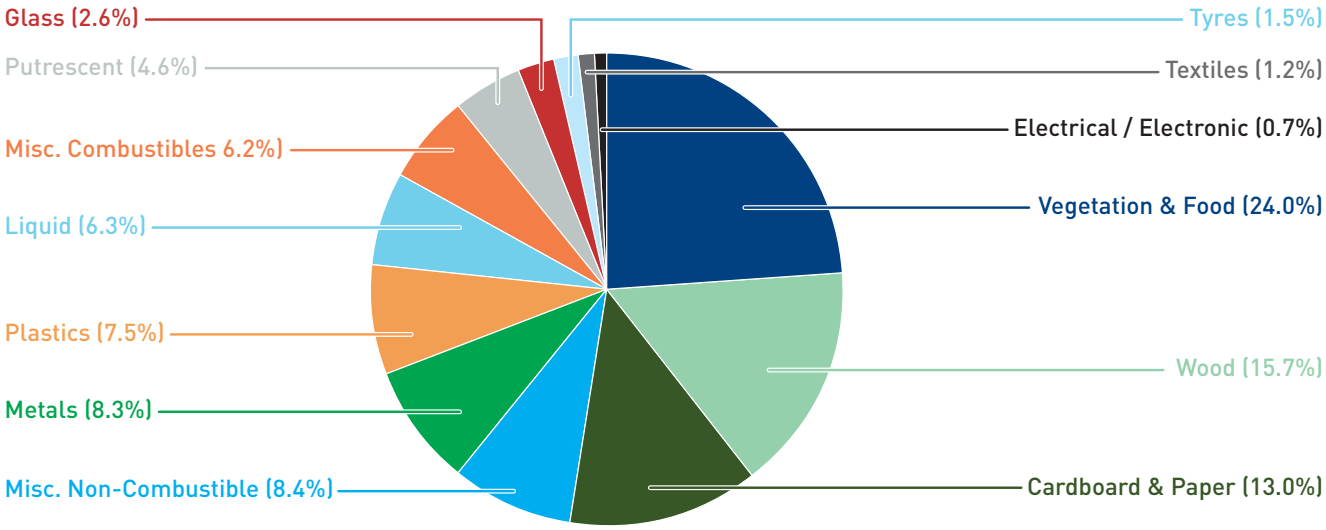

Figure 7.4
Proportions of different waste streams of the total waste on Mahé (Wilson 2004).

Table 7.2
Overview of different waste classes used as waste classification at Mahé weighbridge.

Waste Class	Waste type	Waste Content	Percent of total
1	MSW	Green & Kitchen, 48%; Misc. combustible, 11.1%; Misc. non-combustible, 9.4%; Plastic film, 6.7%; Card & paper, 5.9%; Glass, 5.2%; Metal cans, 3.9%; Textiles, 3.1%; Electronics, 1.7%; Other plastics, 1.6%; Plastic bottles, 1.6% (Wilson 2004)	33%
2	Commercial	Waste collected from commercial, industrial and tourism businesses.	12%
3	Green	Vegetative matter from litter bins and private trucks	2%
4	Liquid	Mostly sludge from I.O.T industrial factory	14%
5	Mixed	Unsorted waste brought by private trucks	36%
6	Metal	Ferrous and non-ferrous metal	1%
7	Putrescent	Remains of animals from abattoirs	2%
8	Waste oil	Waste oils from hotels, restaurants, garages, ports (boats)	<1%
9	Inert oil	Contains mostly glass and un-powdered asbestos	<1%
10	Hazardous	Includes batteries, medicines, expired goods, reagents etc.	<1%
11	Other	Ashes, sawdust, etc.	Unknown

LWMA has provided daily weighbridge data for the Providence Landfill since 2000[1]. These aggregated data from 2000–2014 are shown in Figure 7.5.

7.3.2 Impact factor quantification

In this section, we discuss the impact factor selection. Then, we provide the low, average, and high estimates for each impact factor and ultimately provide our final waste deposition model.

Selection of impact factors

Through our literature review, we identified two major impact factors – population and economic growth – to be used in our scenario analysis. Waste generation per capita is strongly correlated with economic wealth and thus the national income (UNEP 2015). We assume that population and economic growth can therefore sufficiently explain total waste generation.

Impact factor 1: population growth

We assume that population and waste generation per capita are coupled, and therefore, one increment in population growth causes an equal growth in total waste generation. To determine possible population growth developments, we utilized projections created by the UN Department of Economic and Social Affairs. The UN Department of Economic and Social Affairs produced three projections – low, medium, and high population growth – until the year 2100. These developments are demonstrated in Figure 7.5 with historical data from 1950–2016.

We assume a current population of 92'000 inhabitants, as identified by a UN Department of Economic and Social Affairs estimate. We then found the population estimates for each projection in 2040 to determine the growth rate. The high, medium and low growth projections corresponded to a population of 103'000, 96'000 and 89'000, respectively, in 2040 (United Nations Department of Economic and Social Affairs 2015). As seen in Figure 7.5, the growth rates are not constant over time; in our model, we implement the annual populations provided by the UN Department of Economic and Social Affairs.

Impact factor 2: economic growth

Many sources indicate that waste generation correlates strongly with economic wealth (UNEP 2015; OECD 2011; Mazzanti & Zoboli 2008; Inglezakis et al. 2012). To verify this assertion, we compared landfilling rates with GDP per capita (PPP), as shown in Figure 7.6. We chose to normalise both time series to values from the year 2000, which are indexed at 100, to correct for the differences in units. Annual landfilling rates were derived from LWMA weighbridge data while GDP per capita (PPP) values were extracted from an International Monetary Fund report in 2016. Because annual waste deposition and GDP per capita (PPP) appear to increase at a similar rate, we confirm that these rates are correlated (Mazzanti & Zoboli 2008).

Notably, there is one particularly high spike in waste production in 2009-2010. According to stakeholders, one possible

[1] This data are unpublished

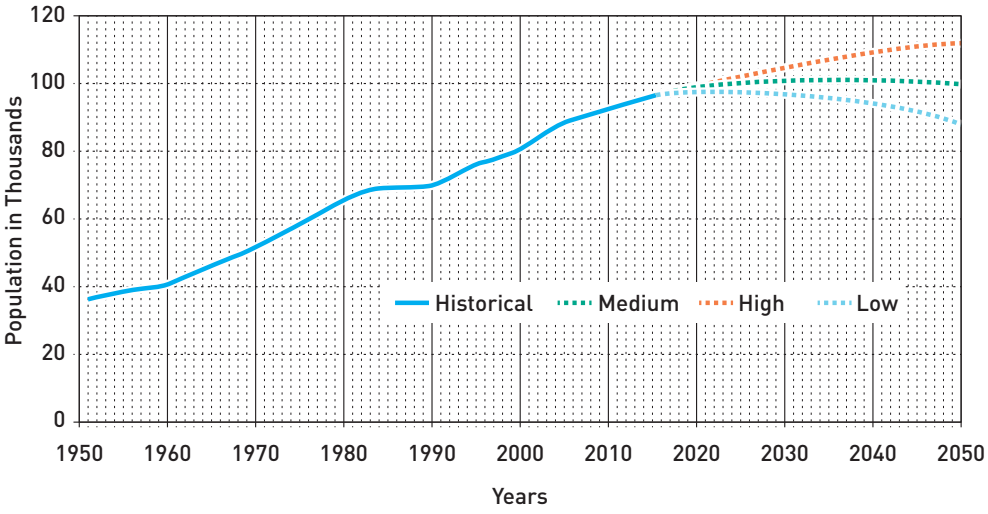

Figure 7.5
Historic Seychelles population growth (1950–2016) and projections (2016–2050) (United Nations Department of Economic and Social Affairs, 2015).

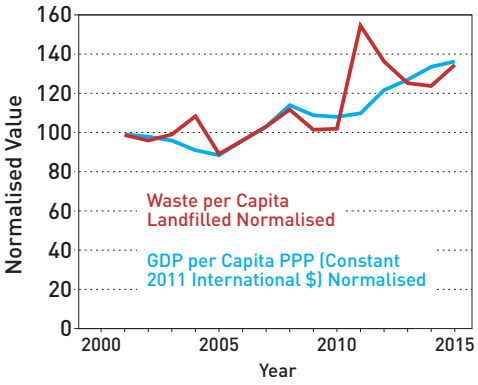

Figure 7.6
Seychelles waste per capita versus GDP per capita (PPP), normalized from 2001–2014. Graph based on weighbridge data provided by LWMA and economical data (IMF 2016).

reason for this increase in landfilling rates is LWMA's founding in 2009. They implemented systems that collected residual waste from around Mahé, which in turn, increased the annual landfilling rates until stabilisation occurred in 2011.

In our analysis of the Seychelles economy, we found that it is largely dependent on tourism, which accounted for more than 60% of the country's GDP in 2015 when considering direct (24%), indirectly and induced contributions (World Travel and Tourism Council 2016). The second largest contributor is the fishing industry.

We determined three economic projections – low, medium, and high growth – for the economic growth impact factor. We assume that annual growth is logistic for each projection. Figure 7.7 shows how GDP per capita (PPP) would change with time according to each projection.

In the high economic growth projection, we assume that the Seychelles economy grows at a rate similar to that of the United States. The 2015 Seychelles GDP per capita (PPP) is roughly equal to the 1990 United States GDP per capita (PPP) (IMF 2016). Assuming that the Seychelles' economy grows at an equal rate as did the United States from 1990–2015, the 2040 Seychelles GDP per capita (PPP) would equal the 2015 United States GDP per capita (PPP). Therefore, the high economic growth projection GDP per capita (PPP) would be $56,000 (IMF 2016).

The low economic growth projection could occur if the tourism sector does not boom. We assume that this would result in moderate economic growth to $34,000 GDP per capita (PPP) in 2040. This projection assumes a significantly lower growth rate than observed in selected countries such as the United States, Switzerland or Malta in the past two decades (IMF 2016). Finally, the medium economic growth projection would be $45,000 GDP per capita (PPP) in 2040, which is the average of the low and high projections.

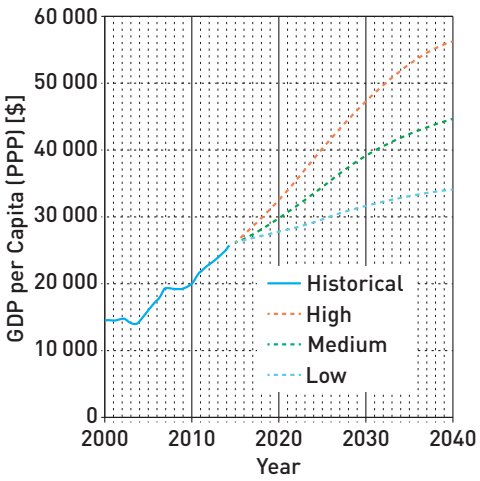

Figure 7.7
Future GDP per capita (PPP) values for high, medium, and low economic growth projections.

A summary of the impact factors and their low, medium, and high trajectories in 2040 is provided in Table 7.3 below.

Table 7.3
Impact factors and their low, medium, and high projection values for the year 2040.

Impact factor	Low projection	Medium projection	High projection
Population growth	89,000	96,000	103,000
Economic growth [GDP per capita (PPP)]	$34,000	$45,000	$51,000

Waste landfilling rate model

Equation 7.2 provides our finalized annual landfilling rate model. We assume that there is no decoupling of waste generation and GDP per capita (PPP), meaning that a unit increase in economic wealth causes an equal relative increase in waste deposition. However, it has been shown that in OECD countries, there was a relative decoupling of 0.8 between economic growth and MSW generation between 1990 and 2010 (OECD, 2011). We assume that this decoupling was a result of the changing waste management system in the OECD countries, as incineration and recycling have become increasingly more favoured over landfilling (OECD, 2011).

$$d_{i,j} = \frac{pop_{i,y}}{pop_0} \cdot \frac{econ_{i,y}}{econ_0} \cdot d_{0,j}$$

Equation 7.2
Baseline model for annual landfilling rate, by waste class

Where $d_{i,j}$ (tonnes) is total waste landfilled on Mahé in year *i* for waste class *j*: $pop_{i,y}$ (persons) is population for projection *y* (low, medium, or high growth): $econ_{i,y}$ ($/person) is GDP per capita (PPP) for projection *y* (low, medium, or high growth); $econ_0$ ($/person) is GDP per capita (PPP) in 2015; and d0,j (tonnes) is total waste landfilled on Mahé in year 0 (year 0 for the simulation is year 2015) for waste class j.

We determined the annual waste landfilled for each category, assuming that the proportions identified in Figure 7.4 hold true (Equation 7.3). These proportions are held constant in the projections because analysis of data did not show a clear trend over time. Additionally, we assume that the total waste deposited can represent the sum of all 11 waste class depositions.

$$d_i = \sum_{j=1}^{11} d_{i,j}$$

Equation 7.3
Total landfilling rate (di) with aggregated waste classes

7.3.3 Storyline synthesis

Summary of stakeholder interviews

Below, we describe the key findings from our interviews conducted with LWMA, S4S, Corvina Investment Company, and the Ministry of Environment, Energy and Climate Change. We discussed three topics: economy, population and society, and solid waste management, and we present significant findings from stakeholder opinion about prospective waste management developments. The results of these interviews guided our scenario construction.

Stakeholders suggested that the government could implement various waste management strategies and solutions within the next years. Some of those being discussed include banning certain imported materials, increasing education, and forcing polluters to pay for their waste. They believe that these actions could reduce waste generation, which may lead to a decoupling of landfilling rates and economic growth. Additionally, some say that anaerobic digestion is a popular solution in the Seychelles, and a plant may be developed within the next 3–5 years.

Stakeholders also show that paper is a major waste fraction that can be treated if recycling systems are implemented. Some believe that the Seychelles is too small to manage and operate a full recycling system. Therefore, they believe that exporting paper could be a practical solution to lowering waste. One states that waste could be exported on ships leaving the Seychelles with empty containers. Others believe that the government could increase education, require Seychellois to pay, and implement other methods to encourage citizens to separate their waste so that paper can be collected, diverted from the landfill, and recycled. Another significant waste fraction discussed with stakeholders was plastic. While there is a current system in place to recycle PET, stakeholders say that this only represents a fraction of the non-degradable plastic materials going to the landfill, which includes Styrofoam, plastic bags, and non-PET bottles. They indicate that the government could enact restrictions on the plastic coming into the Seychelles to reduce the amount landfilled.

Storyline identification

We developed four storylines, demonstrated in Figure 7.8. Additionally, we identify the zero intervention storyline, "business as usual" (BAU) as the control storyline to which the others are compared. This BAU storyline was constructed in close collaboration with the other research groups in this case study, selected stakeholders from the Seychelles and ETH Zürich. The waste hierarchy principle uses a list of waste management options ranked according to their resource use and hence environmental impact and desirability, and it is a guiding principle of the Solid Waste Management Policy (Ministry of Environment & Energy 2014).

The objective of these storylines is to provide examples of future waste management developments that could happen in the Seychelles. While based on stakeholder input, the storylines are at their core rough simulations of what waste management changes may take place and are not predictions of what will happen in the future.

Figure 7.8 provides an overview of the generated storylines and classifies them according to the waste hierarchy, a waste management principle that applies the 3 Rs (reduce, reuse, recycle). The waste hierarchy follows the rationale that measures applied at the top of the hierarchy are more desirable than those at the bottom. The arrows point to each storyline's position within the waste hierarchy.

Storyline 0: BAU

The BAU scenario assumes that existing trends in waste generation continue until 2040 and neither the government nor the private sector change the solid waste management system. Hence, the government does not implement any new policy concerning solid waste management. This provides the baseline against which all other storylines are compared, which is the simple application of Equation 7.2.

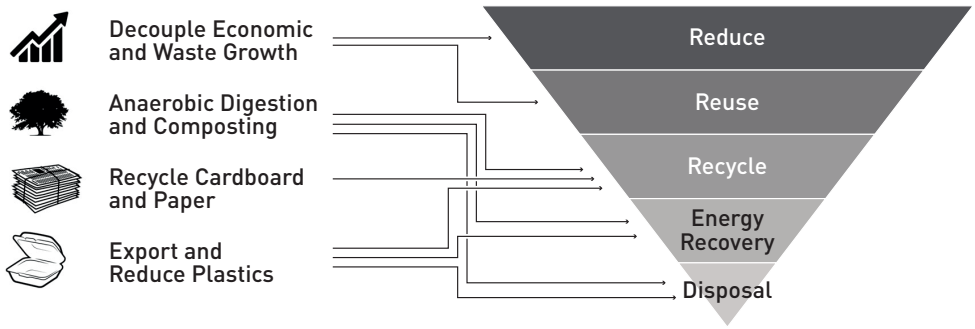

Figure 7.8
Waste hierarchy and corresponding storylines.

Storyline 1: decouple economic and waste growth

As previously demonstrated, Equation 7.2 assumes that there is no decoupling of economic growth and landfilling rates. Stakeholders indicate that the Seychelles government could implement the following waste reduction strategies together:

- Introduction of EU standards for selected product categories,
- Applying a "polluter pays" principle at the household level,
- Banning plastic bags and containers, and
- Promoting waste education and public awareness

This would lead to a quicker reduction in waste generation in the MSW, Commercial, and Mixed Waste classes than seen in previous years, resulting in a decoupling of economic wealth and landfilling rates in these classes. We assume that this decoupling has a value of 1 in 2015 and linearly decreases to a value 0.8 in 2040, as observed in OECD and EU-27 countries who have implemented waste reduction strategies in the past (Inglezakis et al. 2012; OECD 2011; Mazzanti & Zoboli 2008). The model assumes that these developments would be effective in 2016. Effectively, what the Storyline 1 model becomes is shown in Table 7.4.

Table 7.4
Waste deposition models by waste class for Storyline 1.

Waste Classes	Model
MSW, Commercial, and Mixed Waste	$d_{i,j} = (1 - 0.08 \cdot i) \cdot \frac{pop_{i,y}}{pop_0} \cdot \frac{econ_{i,y}}{econ_0} \cdot d_{0,j}$
Others	Baseline model (Equation 7.2)

Where i=0 is 2015

Storyline 2: anaerobic digestion and composting

The Seychelles government is considering building an anaerobic digester. This storyline is assuming that the digester could be built in 2018. In parallel, the government would re-implement the already existing composting infrastructure. NGOs, the government, and other stakeholders would also introduce education and awareness campaigns to encourage consumers to separate their waste. Through these developments, we make the following assumptions, which are estimations loosely based on stakeholder input:

- 25% of the total biodegradable waste will be separated and digested in MSW, Commercial, Mixed, and Green Waste Classes,
- Commercial and Mixed waste have the same fraction of biodegradable waste as MSW (58%),
- 100% of Liquid and Putrescent Waste classes will be used for anaerobic digestion, and
- Due to the presence of high-lignin elements, 5% of total MSW, mixed, and commercial waste classes and 50% of Green Waste will be composted.

These developments are reflected in Table 7.5. In (1), x_{ad} = (0.58)(0.25) = 0.15 and x_c = 0.05, to reflect the proportion of the total amount of waste in these classes that can be used for anaerobic digestion and composting, respectively. Additionally, in (1), i=0 is 2018. We assume that all of the Green, Liquid, and Putrescent Waste are diverted from the landfill due to composting and anaerobic digestion, and therefore, after 2018, $d_{i,j}$ = 0 for these waste classes, as demonstrated in (2). Finally, because implementation will not be until 2018, we assume that all classes retain Equation 2's implication from 2015–2018, and that classes without significant biodegradable waste fractions are not impacted by this storyline.

Table 7.5
Waste deposition models by waste class for Storyline 2.

Timeline	Waste Classes		Model
2018–2040	MSW, Commercial, and Mixed Waste	(1)	$d_i = (x_{ad} + x_c) \cdot \frac{pop_{i,y}}{pop_0} \cdot \frac{econ_{i,y}}{econ_0} \cdot d_{0,j}$ $= 0.8 \cdot \frac{pop_{i,y}}{pop_0} \cdot \frac{econ_{i,y}}{econ_0} \cdot d_{0,j}$
2018–2040	Green, Liquid, and Putrescent Waste	(2)	$d_i = 0$
2016–2040 2016–2018	Others MSW, Commercial, Liquid, Putrescent, Green, and Mixed Waste	(3)	Baseline model (Equation 7.2)

Storyline 3: recycle cardboard and paper

Stakeholders pointed out that another possible development is for the government to support the cardboard and other paper product recycling markets. This storyline assumes that by 2020, if the government provides financial incentives for recyclers, bans Styrofoam products, implements collection systems, and improves public awareness, then cardboard and paper landfilling rates will be substantially reduced. We assume that 2/3 of the cardboard and other paper in MSW, Commercial, and Mixed Waste classes will be diverted from the landfill, starting in 2020. As shown in Figure 7.4, 15% of these classes contain paper, so we assume a 10% reduction in waste production in these three classes.

Table 7.6 shows the models implemented for Storyline 3. As demonstrated, for MSW, commercial, and mixed waste, we assume that the 10% reduction begins in 2020, therefore, (2) applies from 2016–2020, while (1) applies from 2020–2040 for these classes. In (1), i=0 is 2015, while in (2), i=0 is 2020.

Storyline 4: export and reduce plastic

The Seychelles government is interested in reducing the non-PET plastic going to the landfill. There are two mechanisms that would lower plastic landfilling rates: reduction of imported plastic and exporting of a broader range of plastics. The Seychelles lack the economies of scale to treat their plastic waste locally, and therefore, they could export it to interested customers abroad. Additionally, they could implement bans, impose import taxes, and introduce levies on imported plastic, which would reduce the amount entering the Seychelles. For Storyline 4, we assume that these developments take place in 2022, which would cause the entire plastic fraction (10%) of MSW, Commercial, and Mixed Waste to be diverted from the landfill.

Table 7.6
Waste deposition models by waste class for Storyline 3.

Timeline	Waste Classes		Model
2020–2040	MSW, Commercial, and Mixed Waste	(1)	$d_i = 0.9 \cdot \frac{pop_{i,y}}{pop_0} \cdot \frac{econ_{i,y}}{econ_0} \cdot d_{0,j}$
2016–2020 2016–2040	MSW, Commercial, and Mixed Waste Others	(2)	Baseline model (Equation 7.2)

Table 7.7
Waste deposition models by waste class for Storyline 4.

Timeline	Waste Classes	Model
2022–2040	MSW, Commercial, and Mixed Waste	(1) $d_i = 0.9 \cdot \frac{pop_{i,y}}{pop_0} \cdot \frac{econ_{i,y}}{econ_0} \cdot d_{0,j}$
2016–2022 2016–2040	MSW, Commercial, and Mixed Waste Others	(2) Baseline model (Equation 2)

Table 7.7 shows the models implemented for Storyline 4. As demonstrated, for MSW, Commercial, and Mixed Waste, we assume that the 10% reduction begins in 2022, therefore, (2) applies from 2016–2022, while (1) applies from 2022–2040 for these classes. In (1), i=0 is 2015, while in (2), i=0 is 2022.

7.3.4 Scenario generation

In this section, we present the results of the scenario analysis and generation.

Storyline scenarios

We present the low and high scenarios generated for each storyline in Table 7.8, which represents the probability space for each storyline. These scenarios were generated using the models discussed in Section *Storyline identification* and the impact factor projections identified in Section *Selection of impact factors*. As indicated previously, we determined the capacity of a landfill of the same size as Providence II to be approximately 360'000 tonnes, and

Table 7.8
Low and high scenarios (to both population and economic growth projection) for number of landfills filled by 2040 under each storyline.

Scenario	BAU	Storyline 1	Storyline 2	Storyline 3	Storyline 4
Low growth	7.0	6.4	4.9	6.6	6.6
High growth	9.7	8.8	6.7	9.1	9.1

therefore we indicate the total amount of waste deposited in the landfill by the total number of landfills filled. As demonstrated, the largest reduction in landfill deposition occurs under Storyline 2, by approximately 2.11 and 3.01 landfills for the low and high growth scenarios, respectively. Additionally, there is a significant difference in total waste landfilled between the low and high growth scenarios, of up to 3.66 landfills.

Aggregated storyline scenarios

We present an example of an aggregated storyline scenario in Figure 7.9. This scenario for future landfilling rates reflects the aggregation of Storylines 1–4 and the low economic and population growth projections. Because the storylines indicate a reduction in waste production and we use the low growth scenarios, we assume that this scenario reflects the lowest landfilling rate assessed within our study. According to our scenario analysis, landfilling rates would be nearly halved if all storylines were implemented under a low economic and population growth projection. This would lead to the filling of 2.5 additional landfills of the same size as the already existing one by 2040.

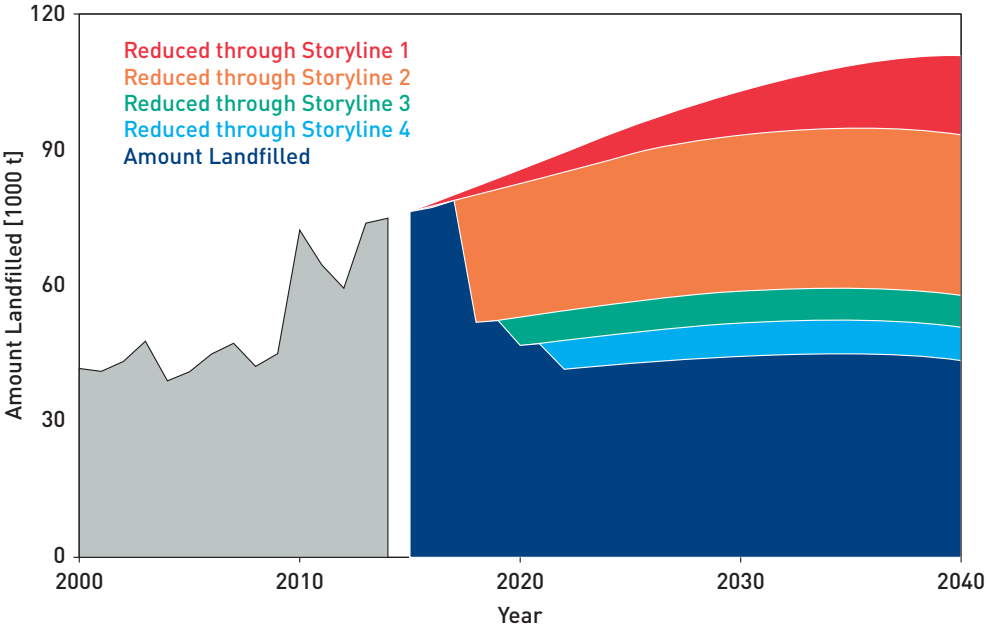

Figure 7.9
Annual amount landfilled under the low growth scenario in Storyline 1–4 Aggregation.

7.4 Discussion

Our scenario analysis provides significant findings regarding strategies that can potentially limit waste landfilling amounts in the Seychelles. While we provide direct values for the amount of waste landfilled in each storyline, it is important to note that these results are not predictions, but rather possible future outcomes.

The results demonstrate that the ranges of economic and population growth in the Seychelles may affect the total amount landfilled by up to 30%. In the BAU storyline, the possibility space for total amount of landfills by 2040 is 7.0 to 9.7 landfills. This indicates that these factors under zero decoupling have a very significant impact on landfilling rates. While stakeholders have little control over population and economic growth, waste management implementations can decouple them from waste generation, which would result in lower landfilling rates.

Individually, Storylines 1, 3, and 4 each have <10% reduction potential for the amount landfilled for both low and high scenarios in each case. This is likely because the waste fractions targeted in these storylines only reflect a small proportion of the total amount deposited on the landfill. However, with an increased decoupling of waste generation and economic growth, i.e., <0.8 decoupling ratio, Storyline 1 could have a larger effect on landfilling rates. To accomplish a higher decoupling, the government and other stakeholders would have to increase waste management reduction measures. This could include banning disposable goods from being imported to the Seychelles, increasing recycling rates by investing in recycling systems, and educating the public about reducing their waste.

On the other hand, Storyline 2 can possibly remove 2–3 landfills from being required by 2040, which is up to a 30% reduction in landfilling rates. This is likely due to the fact that organic waste has such a high content in the waste streams, and a fully functioning anaerobic digester could remove a large proportion of the organic waste going to the landfill. However, to achieve the digestion rates required, a more efficient separation and collection scheme must be implemented to extract as much organic waste as possible from MSW, Commercial, and other waste classes.

When combined, the four storylines prove to be very effective. This is because they each tackle a different type of waste entering the landfill, and therefore have effects that are nearly independent of each other. Our Scenario 1–4 Aggregation result demonstrates that there could be a very high reduction in landfilled waste, especially in the high growth scenario, which

could potentially avoid the filling of five landfills. Some of these storylines have a low cost of implementation, and therefore demonstrate that significant waste reductions can be achieved without requiring high financial investments. However, a cost estimate should be conducted in the future to predict the true cost of implementation. Furthermore, we have to acknowledge that Seychelles would still need additional landfills by 2040 even under the most favourable waste management options. The only option to further reduce the amount of waste going to landfills is incineration.

Ultimately, our scenario analysis demonstrates that the government, recyclers, NGOs, and other stakeholders must implement systems, policies, and technologies that target each major waste fraction. This must be accomplished by an effective sorting system so that the different waste fractions can be removed and treated.

7.4.1 Limitations of the study

The aim of this study was to provide an idea of the waste management system in 2040, and therefore, does not provide predictions for how much waste will be landfilled. The interactive tool we developed will help future policymakers implement their own assumptions into the model, which can be adjusted according to developments in the waste management system.

Many assumptions made in this study relied purely on expert opinion or were presumed based on facts from the literature. Quantifying these assumptions was a challenge because often, they were not backed by quantitative data or information. There were also many variables not considered in this study, including consumer behaviour, cost, and ease of implementation, which could all have significant impacts on the outcomes of the scenario analysis. We had limited access to data, and therefore, we recommend in the future, that an in-depth study be conducted to understand the full range of variables that can impact landfilling rates. This includes updated weighbridge data.

The improvement of the data underlying this modelling would reduce uncertainty and increase the robustness of the scenario analysis presented. In order to improve further research, we suggest that the focus of the data collected should shift more from the source related waste classes to a quantitative assessment of the different components of the waste streams itself.

At their core, the storylines are just ideas of what could happen. Therefore, they should not be taken as predictions of what the future developments in waste management will be, nor are the assumptions necessarily valid for each storyline. They are simply examples that can provide insight into how different developments could change landfilling rates in the Seychelles.

7.5 Conclusion

Our scenario analysis demonstrated that the no-intervention storyline could result in nearly 10 landfills being created and filled by 2040. However, with decoupling of economic growth and waste generation by implementing waste reduction strategies, landfilling rates can decrease. Building an anaerobic digester was shown in our study to reduce landfilling rates the most out of all storylines considered in our study. Implementing an anaerobic digester alongside paper recycling and reduction strategies for other waste fractions effectively reduces landfilling rates. Still even under optimistic waste management assumptions, as shown in the aggregated storyline under the low growth scenario, Seychelles would need another 2.5 landfills of the Providence II size by 2040. Given that land is a very scarce resource in the Seychelles, waste management planning should start now and consider all options available to reduce landfilling rates.

7.6 References

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Section III

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General Conclusions and Outlook

General Conclusions

Waste management in the Seychelles poses a complex and multi-faceted challenge; a challenge whose solutions can only be effective if all stakeholders – government, businesses, and households – take a concerted, integrative, and stepwise approach. Our research, which has combined expertise in social science, environmental chemistry, and engineering, sought to investigate not just the current state of the waste management system, but also to highlight potential areas of further work which stakeholders can undertake towards the goal of a sustainable, long-term solution for waste management in the Seychelles.

Urgent action needed

We believe urgent action is needed from policy makers. At current landfilling rates, which are projected to rise in tandem with population and economic growth in the coming years, as many as 7–10 additional landfills will be filled by 2040. Land scarcity and the high costs of land reclamation likely make this scenario physically unfeasible, which means more drastic measures would have to be sought if landfilling rates do not decrease.

The results of our research have also given us reason to believe that the present landfills have negatively impacted their physical environment. Stakeholders have reported landfill runoff entering the ocean, while heavy metals have been detected in landfill leachate at levels exceeding international health guidelines. Furthermore, the widely-reported health issues amongst landfill workers may prove devastating in the long term if the lack of protective gear provision persists. Because of these reasons, we compel policy makers to not allow 'business-as-usual' practices to continue, and stress the need for intervention sooner rather than later.

Leadership from government

It is the responsibility of government to demonstrate leadership in and a clear commitment to tackling waste management. There already exists some legislation to address the core issues, but what is sorely needed is a more effective implementation of the various waste management strategies and master plans. In concrete terms, this would involve several initiatives on two distinct levels: on an operational level, both a clear assigning of responsibilities and forming actionable objectives are imperative. We believe these two aspects go hand-in-hand; according to our research, ambiguities in both respects in the SSDS, SWM Policy, and SWM Plan have hindered the clear delegation of specific tasks to the appropriate stakeholders within government. This lack of specificity, as our research shows, has hindered the effective implementation of the current policies outlined in the aforementioned documents.

On an administrative level, more long-term planning from a policy standpoint is critical. The EPA has been in a state of revision for some time and remains thus with no foreseeable completion, the outcome of which complicates the proper implementation of the SWM Policy and SSDS which are not lawfully mandatory like the EPA is. Besides introducing more specific language, new strategies could be added to the next revision of the EPA, for example, policies which pre-empt intensive waste generation from the outset by banning low-quality imported products from entering the Seychelles. Our survey with Seychellois indicate that product quality as well as price are decisive criteria for making purchases, which suggests that some consumers would be open to such an initiative. Another strategy which the government could adopt is to exploit the high volumes of biowaste generated in the Seychelles by producing biogas. We studied the potential of such an approach to divert waste from the landfill and concluded that it is one of many feasible solutions to do so.

We acknowledge that human resources are central to achieving both these goals, and that the lack of necessary expertise is a challenge in the Seychelles. However, we believe that existing resources are not being as fully exploited as they could be; in some cases, it is merely a question of restructuring through distributing responsibilities more optimally, or simply giving more autonomy to stakeholders where appropriate. From an academic viewpoint, the prospective graduates of the Environmental Sciences programme at the University of Seychelles represent a viable source of future human resources which should be taken advantage of, as should any collaboration with the University itself in aspects of research and training.

Improving financial mechanisms

The financial mechanisms which underlie waste management initiatives in the Seychelles could also be further streamlined to avoid lengthy delays in the implementation of strategies, as well as helping projects become more financially self-sustaining in the long run. For example, closer collaboration between the Ministries of Finance and Environment could expedite the approval of the latter's financial instruments, particularly as they relate to the new revision of the EPA. Additionally, the levy systems for PET bottles and metal cans would benefit from a more closed-loop structure; the levies collected should be considered as fees instead of taxes, meaning that any revenue collected would go back into the Waste Management Trust Fund instead of 'disappearing' in the overall state budget, where they would no longer be specifically allocated for the levy system and waste management in general.

Collaboration amongst stakeholders and creating markets

Finally, we believe that genuine cooperation amongst stakeholders is essential. The governmental levies on PET and Cans have been effective in ensuring relatively minimal amounts of these materials have an end-of-life in the landfill because of the financial incentive associated with their collection. However, it must be acknowledged that the role of private recycling businesses and informal collectors have been fundamental to the success of these programmes. These businesses could be further supported by the government in various ways, for example by introducing better infrastructure for collection in the form of decentralised collection points, or by even simply providing more physical space for businesses to carry out their operations. Other support mechanisms include tax breaks, subsidies, or even loan schemes for new projects or investments. Such initiatives could even attract more entrepreneurs to set up new recycling businesses which would make the entire system more efficient through competition.

Furthermore, levies could be introduced for materials which do not yet have one. Our research shows that glass in particular is a candidate material because of its ability to be down- and recycled, as well as the fact that diverting glass from the landfill would reduce the volume of waste-to-landfill significantly. Overall, we acknowledge that finding a market for recycling all the waste fractions may be difficult, especially in the case of paper and cardboard. In such cases, we believe that it is the government's responsibility to be proactive in tackling such issues, for example by implementing the Polluter Pays principle to facilitate the collection, management, and treatment of such waste. In all cases, we argue that genuine cooperation between government and businesses is paramount, and that the former should take the initiative to provide conducive legal, economic, and administrative conditions for the latter.

A new phase of waste management ahead

Waste management in the Seychelles has now reached an important point where a clear vision of its future and urgent action to achieve its goals are needed. Considering the environmental and health impacts of current landfilling practices, and the fact that the validity of many of its policies expires in the next 3-4 years (as does the contract with its primary waste contractor), we emphasise that the time to act is now and that seeking solutions to problems will be easier now than in the future. We believe a step-wise approach is key to tackling the various issues we have

highlighted in our research, for which a list of priorities should be made with a view towards creating a long-term strategy.

Ultimately, effective waste management does not come 'for free', and we realise that it will take time for the Seychelles to transition from primarily dumping to recycling its waste, as other countries such as Switzerland have over the course of the last 50 years. We emphasise that this transition will be a prolonged effort on the part of government, particularly because more sustainable solutions will inevitably require changes in the behaviour of Seychellois as consumers and generators of waste. Such behavioural changes, for example sorting waste more carefully, will likely take more time than expected. This transition to a new phase of waste management will therefore require patience and persistence, especially in the face of potential setbacks. However, we are confident that through demonstrating strong leadership, political will, and taking an integrative approach involving other stakeholders, the government is taking crucial steps to putting the Seychelles on a path towards a more sustainable waste management system for the future.

Outlook

Based on our experience and results, we believe future studies on the waste management system in the Seychelles would benefit greatly from improved data sources in the form of databases containing comprehensive information on e.g. all the relevant legislation and policies relating to waste management. Better data collection practices vis-à-vis the Providence Weighbridge and levy system could be developed in cooperation with researchers to ensure that useful data are generated in an optimal form which can be used for future research or policy-making.

The long-term monitoring of environmental parameters related to the landfill, for example through environmental impact assessments, should also be prioritised. More in-depth consumer surveys could also be conducted to gain an understanding of which waste management strategies would be most effective to implement on a societal level.

USYS TdLab Transdisciplinary Case Study 2016

The topic of the 2016 Transdisciplinary Case Study was solid waste management (SWM) in the Seychelles.

SWM is a significant challenge for the Seychelles because landfilling, the currently employed waste management strategy, poses direct threats to the island nation's specific weaknesses, through greenhouse gas production, consumption of scarce land, and leachate release to the nearby environment. However, due to the small scale of the Seychelles economy, there is little capital available to stimulate innovations in SWM. The focus of this case study was to understand the current SWM system in the Seychelles and to gain insights into the obstacles and opportunities related to waste reduction.

The case study was split into seven groups to gain comprehensive and in depth knowledge about the SWM system. The following topics were investigated: Legal & Institutional Framework, Recycling Markets, Material Flow Analysis, Environmental Impacts of Landfills, Consumer's Perspective, Potential for Biogas Production, and Landfill Scenario Modelling. The methods employed varied across groups, and included literature review, semi-structured interviews, and analysis of landfill data.

Existing data indicate that landfilling rates are increasing every year, and our simulations suggest that up to 10 landfills could be needed in the next 25 years if current waste generation trends continue. Our material flow and other data analyses give qualitative data to show that PET and aluminium cans are primarily diverted from the landfill, while other waste fractions, notably glass, paper, and organic waste, have high landfilling rates despite a high recycling potential. In particular, organic waste has the highest contribution to landfill composition, which could be substantially reduced while contributing to the energy supply via anaerobic digestion. To consider the local impact of landfilling, we measured nearby water quality, which demonstrated possible landfill leaching to the environment and the presence of nitrate and heavy metals in the leachate. The government has outlined goals in its policies and plans to take on waste management, but many have not been realised. Our analysis of the legal framework found that governmental organisations face three significant obstacles preventing their implementation: unclear allocation of responsibilities, lack of financial flexibility, and unspecific policy. Based on the results from a questionnaire, if they are provided an adequate collection system, consumers have a willingness to be involved in waste reduction. Overall, our research suggests that major SWM stakeholders require a government-driven, integrative approach to reduce waste in the long-term.

The case study consisted of 18 ETH master's students with diverse scientific backgrounds and 18 bachelor's students at the University of Seychelles (UniSey). Research was conducted over six months, including a three-week field phase in the Seychelles. Researchers and teachers from ETH and UniSey guided students throughout the case study, which was supplemented by additional support from an advisory board of local experts. Students intensively engaged with a variety of stakeholders from government, administration, business, NGOs, and civil society.

This teaching-research course is the first of a series of upcoming activities as part of a collaboration agreement between the Transdisciplinarity Lab (TdLab) of ETH's Department of Environmental Systems Science and the University of Seychelles. The Seychelles' Ministry of Environment, Energy & Climate Change is major partner in the collaboration as well.

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