Universitat Autònoma de Barcelona

Understanding Waste Flows
An industrial ecology approach to the generation of waste, its flows and the connection it has with economic shifts. A case study of the Maltese Islands

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The present thesis titled "Understanding Waste Flows. An industrial ecology approach to the generation of waste, its flows and the connection it has with economic shifts. A case study of the Maltese Islands" has been carried out at the Institute of Environmental Science and Technology (ICTA-UAB) at the Universitat Autonoma de Barcelona (UAB) under the supervision of Prof. Xavier Gabarrell Durany, Dr Jordi Oliver i Sola and Dr Ramon Farreny Gaya.

Bellaterra, 2020

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LIST OF ACRONYMS, ABBREVIATIONS AND NOTATIONS

ABC – Attitude, Behaviour, Context

AD – Anaerobic Digestion

C&D - Construction and demolition

C&I – Commercial and industrial

CBA – Cost-Benefit Analyses

CBM – Central Bank of Malta

CE – Circular Economy

CHP – Combined Heat and Power

CO_2 – Carbon Dioxide

DE – Domestic Extraction

DME – Domestic Material Extraction

DMI – Direct Material Input

DPO – Domestic Processed Output

EC – European Commission

EEA – European Environment Agency

EfW – Energy from Waste

EIO – Environmental Input Output

ERA – Environment & Resource Authority

EU – European Union

EU ETS – European Union Emission Trading Scheme

EUMS – European Union Member States

EWC – European Waste Code

EW-MFA – European-Wide Material Flow Analysis

FAO – Food and Agriculture Organisation

FM – Forecasting Models

FOD – First Order Decay

GDP – Gross Domestic Product

GHG – Greenhouse Gas

GST – General Systems Theory

GVA – Gross Value Added

GW – Global Warming

HACCP - Hazard Analysis and Critical Control

HDPE – High-Density Polyethylene

HFC - Hydrofluorocarbons

IE – Industrial Ecology

IMS – Integrated Modelling Systems

IO – Input Output

IOA – Input-Output Analysis

IOT – Input-Output Table

IPCC - Intergovernmental Panel on Climate Change

IPPC – Integrated Pollution and Prevention Control

ISWA - International Solid Waste Association

IWMS – Integrated Waste Management System

IWM – Integrated Waste Management

ISWM – Integrated Solid Waste Management

ISWM – Integrated Sustainable Waste Management

LN – Legal Notices

MBT – Mechanical Biological Treatment

MBT-AD – Mechanical Biological Treatment Plant - Anaerobic Digestion

MEPA – Malta Environment and Planning Authority

MFA – Material Flow Analysis

MGSS – Malta Government Scholarship Scheme

MHRA – Malta Hotel and Restaurant Association

MIS – Management Information System

MRA – Malta Resources Authority

MRF – Material Recovery Facility

MSDEC – Ministry for Sustainable Development, Environment and Climate

MSW – Municipal Solid Waste

MTA – Malta Tourism Authority

MTP – Mechanical Treatment Plant

MW – Municipal Waste

NACE Rev.2 - Statistical classification of economic activities in the European Community

NIMBY – Not in My Backyard

NIR – National Inventory Report

NSO – National Statistics Office

ODZ – Outside of Development Zone

OM – Optimization Models

PA – Planning Authority

PAM – Policies and Measures and Projections Report

PET – Polyethylene Terephthalate

PPM – Parts per million

RCV – Refuse Collective Vehicles

RDF – Refuse Derived Fuel

ROW – Rest of the World

SA – Scenario Analysis

SAWTP - Sant’ Antnin Waste Treatment Plant

SD – Scenario Development

SEPA – Swedish Environmental Protection Agency

SIOT – Supply Input-Output Table

SL – Subsidiary Legislation

SM – Simulation Models

SoEA – Socioeconomic Assessment

STAN - SubSTance flow ANalysis

SUT – Supply Use Table

TPB – Theory of Planned Behaviour

UK – United Kingdom

UNEP – United Nations Environmental Programme

USA – United States of America

WEEE – Waste Electronic and Electric Equipment

WFD – Waste Framework Directive

WIO – Waste Input Output

WMP – Waste Management Plan

WRAP- UK – Waste Resources Action Programme United Kingdom

WSUT – Waste Supply Use Table

WTTC – World Tourism and Travel Council

ABSTRACT

The generation of waste is not a contemporary phenomenon. It is the sheer volumes, variety and complexity that have become a seemingly ubiquitous and insurmountable challenge to current society. In recent years the generation of waste has become intricate enough to demand complex technologies, specialist attention, while requiring that higher financial resources are directed to its management.

This research concentrates on the Maltese Islands. It includes three original research chapters (Chapters 3, 4 and 5) which explore the generation of waste and its management at varying stages and utilising different perspectives are presented. The thesis uses Industrial Ecology (IE) as its basis. IE fosters a concern for environmental well-being while allowing economic systems to be viewed jointly with the environment where they operate. In so doing, IE places special emphasis on the development and implementation of the solutions and policies at the system level, which can reach up to, and include the global system.

Motivated by the direct relationship that waste generation displays with economic shifts and the need to delink this positive correlation together with the linear modus operandi that the world's throughput has continued to develop, this thesis sets out to examine and comprehend the connections that the production of waste holds with operational and economic functions. Through the results achieved, the thesis does not aim to establish or measure the rate of decoupling between different waste streams and economic growth but to supply information that guides the introduction and application of an integrated waste management system and assists in the implementation of a circular economy with the final goal of guiding policy towards the decoupling of waste generation from economic expansion.

Escalating waste figures were initially met with increased treatment and disposal facilities. In the majority of cases, this culminated in the tossing, burying or burning of whatever waste is produced. However, the social, environmental and economic externalities of these treatment practices grew in a direct and positive manner with the volumes, necessitating a rethinking of these approaches. The results of the research studies point towards the need to shift to an integrated approach which examines the occurrence of waste at different phases of the production and consumption process. This means that, while earlier on, waste management was an after-thought, often featuring in bolt-on, end-of-pipe treatment systems, a modernist and integrated approach requires knowledge and evidence-based studies that are grounded in studies which encompass a multidisciplinary and multisectoral intervention and coordination. Establishing this methodology is crucial if a country wants to establish a system that accounts for the social, economic and environmental aspects of waste impacts and work towards their abatement.

The three research studies presented here approach waste generation at the treatment and inception stages on a macro level and in connection with the operational process on a micro level. In IE, the anthroposphere is linked to

its surroundings, thus providing a basis to analyse and improve the effectiveness of the measures that form part of efficient material management strategies. This analysis is carried out using an array of data collection and analyses tools including material flow analysis (MFA), carbon footprinting, input-output analysis, waste audits, focus groups and semi-structured interviews, to examine the management of waste at a macro and a micro level, and at pre- and post-generation to highlight the complexities that characterise it.

The complexity involved in the management of waste is, in fact, one of the aspects highlighted in this thesis. This is more so in a densely populated island which is experiencing rapid economic growth. The practice of landfilling, prevalent in Malta, contributes to space limitation issues which are an undeniable challenge to islands. This challenge is further amplified by the prevalent linear operational systems. The thesis also emphasises the need for an interdisciplinary approach to the management of waste which would allow for the interaction of complex systems in society, science, nature and technology, to promote the perception of waste as part of the overall system and increase the potential for the development of an Integrated Waste Management System, a Circular Economy and ultimately a move towards an economic growth that is not riddled with externalities.

ACKNOWLEDGEMENTS

A PhD is a struggle of different dimensions. Thick methodological books, extensive review comments, revisions and rejections from journals which are coupled with satisfaction when you receive a positive review, getting that article published and reaching another milestone.

Working on this thesis was a long-drawn aspiration that commenced during my masters' degree in Sweden. The subject had long been in my head, but two daughters were born in the meantime, so things got postponed until I attended an eco-design course ran by Ramon and Jordi, where the idea was discussed and soon after a proposal was drawn. However, a PhD on a part-time basis carries several frustrations mainly because of the equal attention demanded by other commitments.

Eight years is a long time. A lot of changes can take place in a person's life. Starting as a mother of two young children, things took a bitter turn when my husband developed a rare sickness which saw him wither away and eventually take his life. In such circumstances, my studies took the second stage. However, the necessary support and help that was provided when things went astray, allowed me to carry on and for this, I have a lot of people to thank.

Starting with my supervisors, Prof. Xavier Gabarrell Durany for his accurate comments, guidance and continuous help with administrative aspects at UAB, Dr Ramon Farreny Gaya and Dr Jordi Oliver i Sola, for their many meticulous reviews and their assistance with the tools used as part of this research. Thank you for not adding pressure when things got tough and for seeking to help me as much as possible.

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DEDICATION

To Joseph, who saw this thesis start but not finish.

To my parents, for their incessant support.

To my daughters, Madeleine and Estelle, who at a young age learned the pain life can bring.

To Frank, who I can never thank enough for being exactly as he is.

To all those who have a dream.

SUMMARY OF CHAPTERS

A description of the chapters forming part of this thesis is provided below.

Chapter 1 - Introduction and framework

The introductory chapter provides an overview of the current situation in the Maltese Islands with regards to the economy, politics and waste generation. It points to the various constraints that the management of waste on islands with including limited space, the proximity of treatment and disposal facilities to the local population and insularity that hinders waste export. In Malta, these limitations are further corroborated with a robust economic growth which has driven waste figures even higher.

Malta's entry in the EU in 2004 set requirements for the introduction of new waste legislative standards which obliged the country to heighten its efforts to reduce, reuse and recycle waste, and establish lifecycle and circular thinking. These requirements set an ongoing challenge for the Maltese Islands. Between 2012 and 2017, an average of 83 per cent of the MW waste generated was persistently landfilled. Further to this, Malta is burdened with a higher than average rate of MW per capita and soaring C&D waste figures. Although C&D waste is inert, this is a source of concern as landfilling it is not feasible due to space limitations and it cannot simply be left to accumulate in nature.

It is therefore vital to fully understand the relationship between urban waste and operational and economic functions. This thesis attempts to identify the operational and economic functions to supply critical information that could assist the country to move towards an integrated waste management system, circularity and a delinking of waste generation from economic growth.

Chapter 2 - Methodology

Chapter 2 presents an overview of the different methodological approaches used in Chapters 3, 4 and 5. This chapter discusses the use of Industrial Ecology (IE) as the basic approach taken by this thesis and analyse the factors that connect the different research studies and possible alternative methodologies. IE emphasises the optimisation of resource flows by taking a system view that establishes a boundary to optimise the use of these resources. This approach is maintained in the three research chapters. Through the use of different tools, the studies seek to provide a system view of the specific phases that characterise the generation and treatment of waste to identify the factors that are conducive to waste generation. The chapter examines the use of tools such as Material Flow Analysis (MFA), carbon footprint, input-output analysis and waste audits supplemented with semi-structured interviews and focus groups.

Chapter 3 – Where do islands put their waste? A material flow and carbon footprint analysis of municipal waste management in the Maltese Islands

Chapter 3 (hereby referred to as Research 1) offers the first research study of this thesis. It presents two material flow studies for 2012 and 2018 using the methodology developed by Brunner and Rechberger (2005). The MFAs provide a system-oriented view which highlights the interlinkages that connects the processes and flows to supply a comprehensive overview of the MSW management system and its interaction with the surroundings. Starting at the point where municipal waste is collected from households and then transferred to the treatment facilities for either landfilling or export, the MFAs identify the flows and stock that characterise municipal waste management in the Maltese Islands and evaluate the performance of the present and projected scenarios due to changes introduced with the new treatment facilities. In the projected 2018 scenario the need to augment the separation of both dry recyclables and biowaste is stressed as this would result in a higher efficacy of the present infrastructure and augment the introduction of a circular economic system.

The MFAs also serve as a basis for a carbon footprint analysis using the CO2ZW® tool. This analysis pinpoints the connection between waste and GHG emissions and emphasises the importance of adopting a lifecycle approach during the inception of waste policies. In the 2012 scenario, a total of 175,003 tonnes of waste are sent directly to landfill. This figure is augmented with an additional 35,153 tonnes which enter the Mechanical Biological Treatment (MBT) plant but are then landfilled without prior processing resulting in a total carbon figure of 290,793 tonnes (1,169 Kg CO_{2eq} /tonne of MW). This figure was ameliorated with the introduction of biowaste separation and the installation of a new MBT plant into an average of 413 Kg CO_{2eq} /ton-yr.

This chapter presents an examination of waste processes that support infrastructure-related decisions and helps to identify where effort needs to be made to introduce an integrated waste management system. It also highlights how the present system will improve when additional infrastructure, supplemented with a separate bio-waste collection system, is introduced and identifies the weaknesses that must be addressed to enable the shift to circularity.

Chapter 4 – Examination of the economic-ecological connections of waste generation in Malta -development of a sectoral waste intensity indicator based on Leontief input-output analysis

Chapter 4 (hereby referred to as Research 2) presents an in-depth examination of the connection between waste and economic shifts. on a macro level. While the relationship is generally portrayed in graphs that exhibit waste flows shifting simultaneously with the gross domestic product (GDP), this chapter uses the Leontief input-output analysis to understand the intensity of this connection specifically between waste generation and the industrial sectors. Excluding municipal waste, this study focuses on the production side of commercial and industrial and construction and demolition waste.

The Leontief input-output analysis is based on the year 2010 and aims to explain how the quantity of waste generated shifts when there is an increase of €1 million in final demand. Besides, the study develops waste intensity indicators for specific economic sectors for the 2010 – 2016 period, making it possible to identify the efficiency of economic sectors in terms of waste generation.

Chapter 5 – A snapshot of solid waste generation in the hospitality industry. The case of a 5-star hotel on the island of Malta.

In Chapter 4 the waste multiplier for the tourism industry was determined to reach 128.9 tonnes of waste, out of which 22.3 tonnes are generated directly and 106.6 tonnes are generated indirectly. On the other hand, the output multiplier for the industry reaches 1.651. Waste generated from the hospitality industry is landfilled.

Inspired by the results of Chapter 4, Chapter 5 (hereby referred to as Research 3) provides a bottom-up examination of waste flows within the hotel sector on the micro-level. Chapter 5 moves away from the top-down approach adopted in Chapter 3 and 4 to conduct a micro-level analysis which seeks to understand the flows and processes relating to the waste generation that characterise the operations of a 5-star hotel. The hotel was established in 1997 and operates under the requirements of an international chain and comprises 252 residential rooms and 3 restaurants. It is one of the 13 hotels operating in this category in Malta. The restaurants are both a-la-carte and buffet style.

The research uses a mixed methodology approach that is based on waste audits, focus groups and semi-structured interviews to provide an in-depth analysis of both solid and food waste production. These are accompanied by an examination of purchasing records. As well as identifying the types and quantities of waste generated, Chapter 5 highlights the direct relationship between portion sizes and food wastage and emphasises the need for standardised audits. The research also stresses the need for the hotel industry to provide the contextual (external) factors that would support pro-environment behaviour and underlines the fact that a system view which encourages firms to think beyond short term profits and internalise their externalities must be adopted. Adopting this approach is critical to protect the very feature that the country is selling.

Chapter 6 – Discussion and Transfer of knowledge

This chapter presents and discusses the overall results of the three research studies. Although different locations offer distinctive geographies and social conditions, waste management is constrained by the availability of viable technologies and international regulatory frameworks. The chapter advocates a systems approach to waste management. While end-of-pipe solutions are typified by compartmentalised approaches, the integrated approach advocated in this thesis stresses that waste policies must adopt this approach at the operational level. This is necessary also in the context of lowering GHG emissions. The crucial importance of including waste generation at the inception of economic policies is also emphasised. As discussed in Chapter 4, the adaptation and mitigation costs imposed on society by the mitigation of waste dampens the Gross Value Added generated by individual economic sectors. The research further advocates the introduction of policies designed to address individual economic sectors to accommodate the different operational characteristics within specific sectors. A necessary step towards this shift is the quantification of flows since it provides empirical evidence and creates a perspective which allows managers to set targets that move away from the prevailing situation. Adopting this approach means that the country is moving towards improved comprehensive prevention and the long-term survival of the industry that sustains it.

Chapter 7 – Conclusion and suggestions for future research

The chapter notes the general conclusions on the thesis in line with the initial objectives. As the MFAs underline, the escalating waste generation figures, particularly given the constraints resulting from island geography, can no longer be sustained. The same applies to the long-standing practice of landfilling. As was noted in all three research studies the operational processes within the economy still function in a linear manner. The recognition of this fact, together with the quantification of waste generation figures, can serve to induces a demand to move towards an integrated waste management system. A call is made for the introduction of a discount factor which reports the impact of economic development on environmental degradation and its repercussions.

The thesis can be viewed as a support base for strategic management measures which aim to include the generation of waste from their inception. While in Chapter 3 emphasis is made on the collection and treatment stages on MW, Chapter 4 emphasis the connection that waste has with different economic sectors. The chapter is concluded with a list of possible future research topics that were identified during the thesis.

Chapter 1
Introduction and Framework

1.1 Introduction

Waste has become an integral element of contemporary society. Its ubiquitous presence is a feature of the townscape that many prefer to ignore. With its generation inextricably linked to the evolution of human communities, population growth and the emergence and development of commerce (Shulman, 2011), waste has become the most visible side-effect of modern society. Following the end of the Second World War, the world underwent a transformational process that was characterised by increased economic welfare and digitalisation. The impacts of this change are symbolised by a transformational success in the quality of life which led to astounding progress in, amongst others, medicine, technology, education, communication and entertainment sectors, among others, but also resulted in various side effects, or negative externalities, that culminated in different types of pollution. However, with success being so far-ranging, it is little wonder that these externalities, which accumulated steadily from the beginning, went largely ignored (Senge et al., 2008).

An undeniable side-effect was solid waste generation. Technological innovation brought with it a change in the variety, availability and use of synthetic chemicals and complex compound materials which changed the nature of the products consumed every day and were, therefore reflected in the waste discarded (Silva et al., 2016). In the last 50 years, growth in waste figures accelerated to the extent that it now warrants its engineering discipline (Letcher & Vallero, 2011). The challenge for waste managers is not only characterised by the staggering waste figures but also by the heterogeneous nature of the discarded items which demand complex structures to handle it. Within contemporary society, the discarded waste can range from a simple apple core to complex electronic equipment that contains multiple metals, plastics and minerals.

The diverse and increasing quantities of waste set various demands on local populations. For a long time, an 'out of sight, out of mind' approach was adopted with waste driven away to secluded landfills or incinerators. While landfilling and thermal incineration remain widespread, extensive advances in treatment technologies and regulation of waste disposal have been registered in many causes regulated both at the European Union (EU) and the international level through established agreements including the Basel Convention on the Control of Transboundary Movement of Hazardous Wastes and their Disposal (1989) and the Barcelona Convention for Protection of the Marine Environment and Coastal Region of the Mediterranean Sea (1995). These regulations aim "to protect human health and the environment against adverse effects which may result from waste" (Shulman, 2011, p.9). At the EU level, regulations such as the Waste Framework Directive turned the management of waste towards two fundamental requirements - the generation of fewer discarded items and an effective treatment system for what is generated (White et al, 2011).

The design of an effective waste management system varies from location to location and is influenced by economics, geography and demography. While the only treatment that can accommodate all types of waste is landfilling, the land is finite and this treatment is marred by several environmental and social problems which are enhanced in small islands that host densely populated communities. The physical separation from other landmasses constrains the flow of materials, organisms, and information, and also limits the ability of islands to outsource some of their problems, notably the management of modern waste streams (Eckelman et al., 2014). Their limited land resources, high energy costs, large seasonal fluctuations in waste volumes and the complex social and political dynamics that stem from their often close-knit societies can discourage typical waste management practices but also provide opportunities for island governments and businesses to explore alternative technologies and policies that suit their particular circumstances and that may be environmentally preferable (Eckelman et al., 2014).

This research is focused on the Island of Malta which comprises six Isles, the largest being Malta followed by Gozo (Għawdex), Comino (Kemmuna), Cominotto (Kemmunett), St Paul's Islands and Filfla (PSTEC, 2010) The latter three (3) are uninhabited, while Comino has a permanent population of only 4 people. Malta is located 93 km south of Sicily and 290 km north of the African Continent. The general topography of the island can be described as a series of low hills in the northern area with terraced slopes and plains on the southern side. It has no mountains or rivers. The Maltese Islands cover a total area of 330 km² with a total coastline perimeter of approximately 140 km. The Island of Gozo which is the second-largest landmass and lies about 6 km northwest of Malta, has a total land cover of 67 km² with a coastline perimeter of 43 km. Its topography is similar to that of Malta (PSTEC, 2010).

Figure 1-1: Malta in the Mediterranean

Source: Google Maps

On 1st June 2004, Malta joined the EU. Entry in the EU required the island to introduce new standards particularly with regards to the environment. Due to the EU application, the Environment Protection Act of 1991 was updated in 2001, followed by further updates in 2010 and 2016. The Environment and Planning Act 2016 (Cap.549) encompasses various regulations (referred to as Legal Notices (LNs), transposed from EU legislation, that regulate different aspects of waste management. Waste management has been a focus of EU environmental policies since the early 1970s, with their targets and objectives becoming more ambitious over time. These policies, which impose stricter efforts to reduce, reuse and recycle waste and establish life cycle thinking are helping to close the loop on the use of materials throughout the economy (Pires et al., 2011). Among, other areas regulations focus on municipal solid waste, batteries and accumulators, the deposit of waste and rubble, Waste Electronic and Electric Equipment (WEEE) and packaging waste. The Waste Framework Directive 2008/98/EC, which is one of the blanket directives of the EU, was transposed in Malta through L.N. 184 of 2011 (Subsidiary Legislation 549.63 Waste Regulations). The Directive establishes the 'end-of-waste status' which refers to waste that ceases to be waste because it has undergone a recovery procedure including recycling operations and it can be used for specific purposes, there is a market demand for it and meets the standards applicable to it. It also establishes the remit applicable for extended producer responsibility and includes directions for treatment, recovery and the necessary preparations prior to disposal or other operations. While recovery refers to any operation the principal result of which is waste serving a useful purpose by replacing other materials which would otherwise have been used to fulfil that function, disposal, is defined as "any operation which is not recovery even where the operation has a secondary consequence the reclamation of substances or energy (*European Parliament and Council,* 2008, p.312/10).

For many decades the growth of wealth and well-being enjoyed in Europe was based on intensive material use and energy resources. However, the mounting externalities made evident that the unbridled economic growth attained in the past could not continue unabated without causing irrevocable damage to the environment. The discussions that were initiated in the 1960s culminated in a proposal for change at a global level that was marked by the Stockholm Conference of 1972 (Shulman, 2011). The same year also saw the publication of *Limits to Growth* by (Meadows et al., 1972)., which argued that the usage rates of the Earth's finite material and energy resources could not continue indefinitely. Twenty years later, the sequel, recounts the same story, but with increased urgency (White, P.R., Franke, M., & Hindle, 2012). These factors, together with emerging issues such as China's ban on the import of certain waste following decades where it was a leading destination for recycling, reuse and disposal of solid waste from all over the world (Qu et al., 2019), brought to light the potential impact that the poor management of waste has on the environment and human health (White et al., 2012).

Therefore, a policy framework was required to promote the efficient use of resources that compensate innovation and efficiency and would harness the importance of resource efficiency through redesign, savings and the increased reuse, recycling and replacement of primary products (Zaccariello et al., 2015). A step in this direction was taken in 2015 with the adoption of the Circular Economy (CE) Package by the EU (European Commission, 2019). The concept of a circular economy challenges the present linear economy model which is based on the ''take-make-consume and dispose of' growth pattern that was developed with the Industrial Revolution that assumes that there is an abundant supply of resources which can be sourced easily and disposed of at a cheap price (European Commission., 2014). A circular economy, on the other hand, aims to keep resources within the economic system when a product has reached its end, thus eliminating waste generation. Waste items contain the same materials which are found in items which are still in use, but which now lack value because the items are broken or in some other way rendered useless. Therefore, a basic method to deal with waste is to restore its value (White et al., 1995). The circular economy concept encompasses production, consumption, waste management, and the market for secondary materials together with sectorial action on plastic, food waste, critical raw materials, construction and demolition (C&D), biomass and bio-based materials, innovation and investments (European Parliament & Commission, 2014). On 14th June 2018, the EU adopted a new waste legislative package. Directive 2018/851 replaced Directive 2008/98/EC, more commonly known as the Waste Framework Directive. The Directive's immediate focus is on improved resource efficiency and the valuation of waste as a resource to reduce the economy's dependence on imports of raw material and the transition towards a circular economy.

The Act shifts waste management from treatment and emphasises that the generation of waste needs to be managed from the inception of a product until it reaches its end-of-life, thus advocating sustainability in consumption and production while further promoting opportunities for the life of the product to be extended. It also states that waste separation is not considered as a means to an end, but its implementation must account for financial, technical and environmental considerations. It places prevention at the forefront. It stresses the importance of preventing the generation of waste at source, particularly waste that is not suitable to prepare for re-use or recycling and requires the establishment of reliable quantitative and qualitative indicators for measurement and sets targets on the quantity of waste that can be generated (European Parliament, 2018)

1.2 The generation and management of waste in Malta

Land constraints, physical separation and rapid economic growth make waste a mounting challenge for the Maltese Islands. This is coupled with escalating population density figures which are presently the highest within the EU and ninth in the world (Review, 2019). The local population, which in 2011 stood at 417,546 inhabitants, reached 460,297 in 2016 and 475,701 in 2017 (NSO, 2018). This further widens the density gap with other European countries which in 2011 stood at 1,325 persons/ km^2 against an EU average of 117 persons/km^2 (NSO, 2011). The island is additionally burdened by the annual inflow of approximately two million tourists (Attard, 2018).

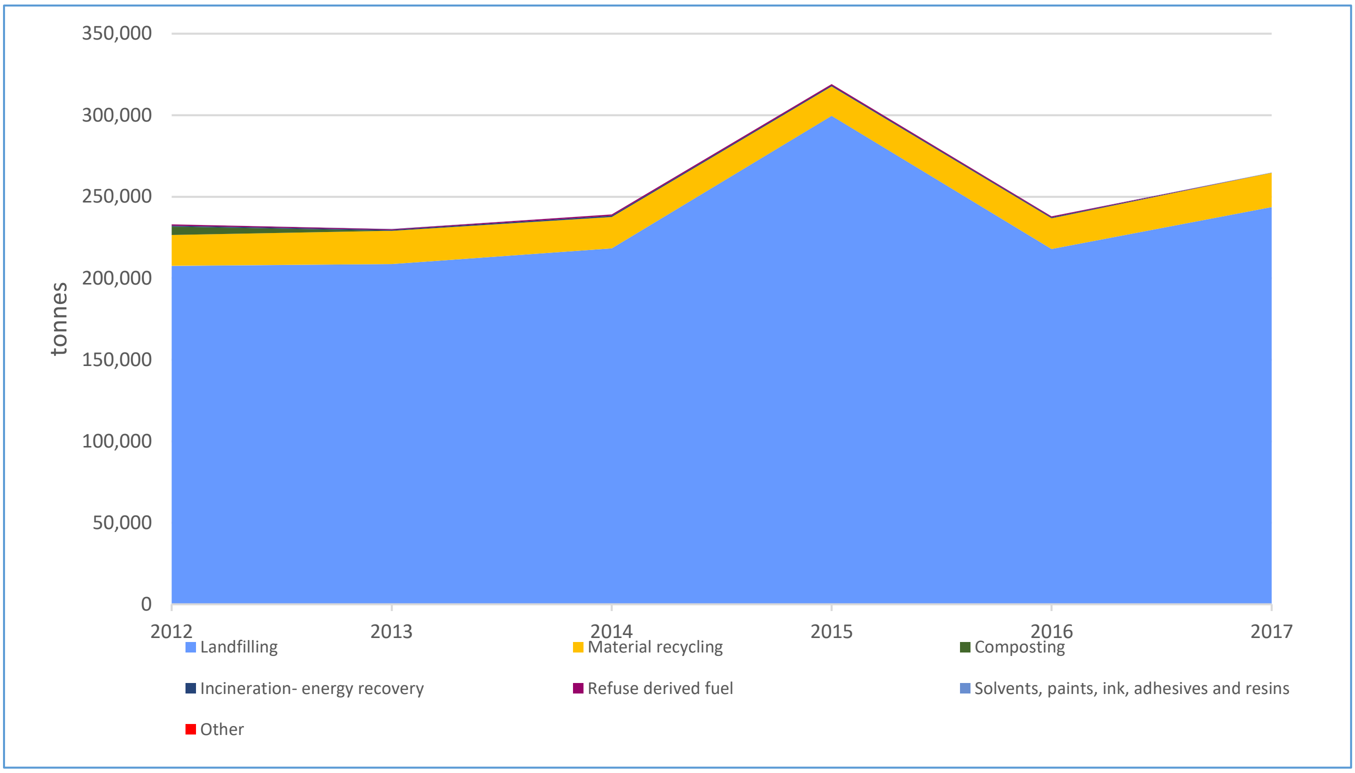
In Malta, following the year 2002, major developments were introduced in the waste sector. The old un-engineered landfill was decommissioned, and waste started to be disposed of in the new engineered landfill which included gas recovery. Furthermore, the Sant' Antnin Waste Treatment Plant (SAWTP) was upgraded with mechanical biological treatment (MBT) and anaerobic digestion (AD) plants. Finally, a new incinerator was commissioned to treat clinical waste, animal by-products and certain types of hazardous waste (Falzon et al., 2013). More recently, a Mechanical Biological Treatment Plant (MBT-AD) (commonly referred to Malta North) started its operations. The plant is coupled with an AD and can handle 76,000 tons/year of MW with 15 per cent allowed for extra capacity. It is designed to recover recyclables (e.g. metals), produce Refuse Derived Fuel (RDF), recover energy from the Combined Heat and Power (CHP) plant fuelled by biogas and produce a refined digestate. A biogas CHP plant is included to maximise energy recovery. The plant will also be able to handle 47,000 tons/year of bulky waste, 35,000 tons/year manure and 4,000 tons/year of poultry dung. Furthermore, a waste transfer station for the receipt, sorting, processing, interim storage and transfer of wastes originating from Gozo and Comino with a capacity of 11,800 tons was introduced in Gozo (MSDEC, 2014).

In 2017, Malta generated a total of 2,827,914 tonnes of waste (out of which 2,263,747 tonnes was mineral waste (NSO, 2019c), while municipal waste reached 295,330 tonnes or 621 kg per capita (NSO), 2019b). In 2015, MW figures stood at 269,660 tonnes with 599 kg generated on a per capita basis (NSO), 2019b). In the same year, the average amount of MW generated in the EU amounted to 480 kilograms (Eurostat, 2018). A staggering increase was registered in the case of hazardous waste, wherein 2015, figures stood at 16,806 tonnes, while in 2016 the figure increased to 107,671 tonnes. This is in view of the inclusion of discarded vehicles which in 2015 stood at 15,472 tonnes but increased to 104,844 tonnes in 2016 (NSO, 2019c)

1.3 Municipal solid waste

For a long time, the treatment of waste in Malta was strongly based on an out-of-sight, out-of-mind approach. This resulted in a ‘waste mountain’ which soon became visible from all over the island. Figures from the National Statistics Office show that this trend persisted for years. In fact, since 2013, the Island has persistently landfilled an average of 83 per cent/annum of the MW it generates. This trend can be noted in Figure 1-2, which shows the treatment of MW between 2012 and 2017. Landfilling continues to be the main disposal method used for the management of MW. Recycling, on the other hand, is relatively stable with no significant changes.

Figure 1-2 Treatment of Municipal Waste between 2012 and 2017 in Malta



Source: National Statistics Office, 2018

MW is among the most troublesome waste streams to manage (Fischedick et al., 2014). Furthermore, as noted in Council Directive 2018/851, the management of MW generally provides an indication of the level of the overall waste management system within a country given its highly complex and mixed composition which require various waste treatments. Additionally, it is generated in direct proximity to citizens and is subject to high public visibility and is a threat to human health (European Parliament and Council, 2018)

This demands effective MW policies. The management of waste provides a prime example of a sector which needs to further integrate environmental, social and economic considerations to achieve sustainability (Silva et al., 2016). In the case of islands such as Malta, where the size and population density make the landfilling of large volumes of waste as a primary method of disposal unfeasible, the treatment facilities must incorporate processes for recovery, and/or pre-treatment of waste, both to minimise the final volume and reduce pollution potential. Additionally, storage facilities are required to store waste before it is exported for final treatment and disposal elsewhere. Therefore, the present landfills are intrinsically a valuable resource that should be preserved for the landfilling of those waste fractions for which no other technically feasible or economically viable disposal route exists (MRRA, 2008). Further to this, waste policy in Malta cannot depend solely on treatment but, as emphasised by the recently enacted waste legislation, it must underline the importance of managing waste from the inception of the product until it is disposed of ore recycled/reused.

The composition of MW in Malta is also a matter of interest. Waste composition is influenced by many factors, such as the level of economic development, cultural norms, geographical location, energy sources, and climate. As a country urbanises and populations become wealthier, consumption of inorganic materials (such as plastics and aluminium) increases, while the relative organic fraction decreases. Generally, low and middle-income countries[1] have a high percentage of organic matter in the urban waste stream, ranging from 40 to 85 per cent of the total. Paper, plastic, glass, and metal fractions increase in the waste stream of middle- and high-income countries (World Bank, 2012). Malta still has a relatively large biodegradable waste fraction. This was confirmed by two household waste composition surveys carried out by the National Statistics Office (NSO) in 2002 and subsequently in 2012 (although it needs to be pointed out that there were some differences in the descriptions of the fractions), the organic waste fraction has decreased from 59.64 per cent to 52 per cent in the intervening period.

1 The report classifies countries according to the World Bank 2008 estimates of Gross National Income (GNI) per capita. The classification is as follows:

Low-income countries are those earning $975 or less;

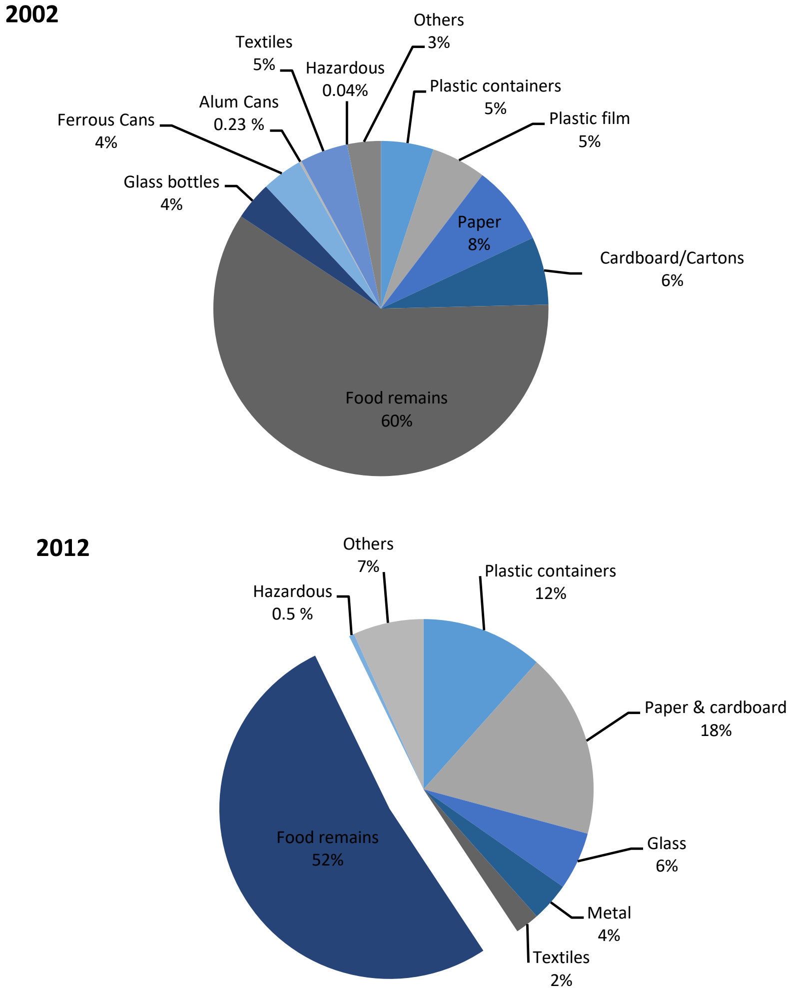
Lower middle refers to those earning $976 - $3,855;

Upper middle refers to those earning $3,856 - $11,905;

High $11,906 or more

The report classifies Europe, North America, some parts of the Middle East and Australia as high income, while the majority of Africa and Asia are listed as low and lower middle income. South America (except for Bolivia, Ecuador, Guyana and Paraguay which are listed as lower middle income) is classified as upper middle income.

Figure 1-3: Percentage changes in waste composition between 2002 and 2012 in Malta



(Source: National Statistics Office, Malta)

The figures offer an interesting comparison with the situation in neighbouring countries. Italy, Malta's closest neighbour, presents a different picture. In 1975, 43.10 per cent of Italy's waste consisted of organic waste followed by 19.5 per cent paper and 6.7 per cent plastic. Thirty years later, in 2005, the organic fraction plummeted to 21.9 per cent while paper and plastic increased to 25.8 per cent and 14.6 per cent respectively (Massarutto, 2010). Italy reports that in 2010, a total of 32.5 million tonnes of MW were generated while waste generation per capita amounted to 531kg, a slight increase from the 2001 figure of 516 kg. An interesting point is that there are remarkable differences in the per capita production figures across the Italian regions – for example, in 2010, MW generation ranged from 413 kg/inhabitant per year in Molise to 677 kg/inhabitant per year in Emilia Romagna (Bertossi et al., 2013).

Sweden, an EU country where recycling is an established practice, presents different waste composition figures. Historically, Sweden's commitment to environmental considerations has always been strong, particularly in waste management. According to Avfall Sverige's (Swedish Waste Management) 2012 report, in 2011, households generated a total of 4,349,910 tonnes of waste of which 33 per cent was recycled, 15 per cent was treated biologically, 52 per cent incinerated in waste-to-energy plants and 1 per cent were landfilled. Concerning household waste composition, the Swedish Environmental Protection Agency, notes the following percentages for 2004–18 per cent paper and textiles, 13 per cent garden park waste and diapers, 43 per cent food waste and 1 per cent wood (SEPA, 2010). In per capita terms, there was a gradual increase between 2001-2007 with MW generation peaking at 516 kg per capita (SEPA, 2010). However, from 2008 onwards there is a steady decrease, with the figure dropping to 465 kg per capita in 2010. A possible explanation for this decrease is the economic recession (Milios, 2013).

1.4 Construction and demolition waste

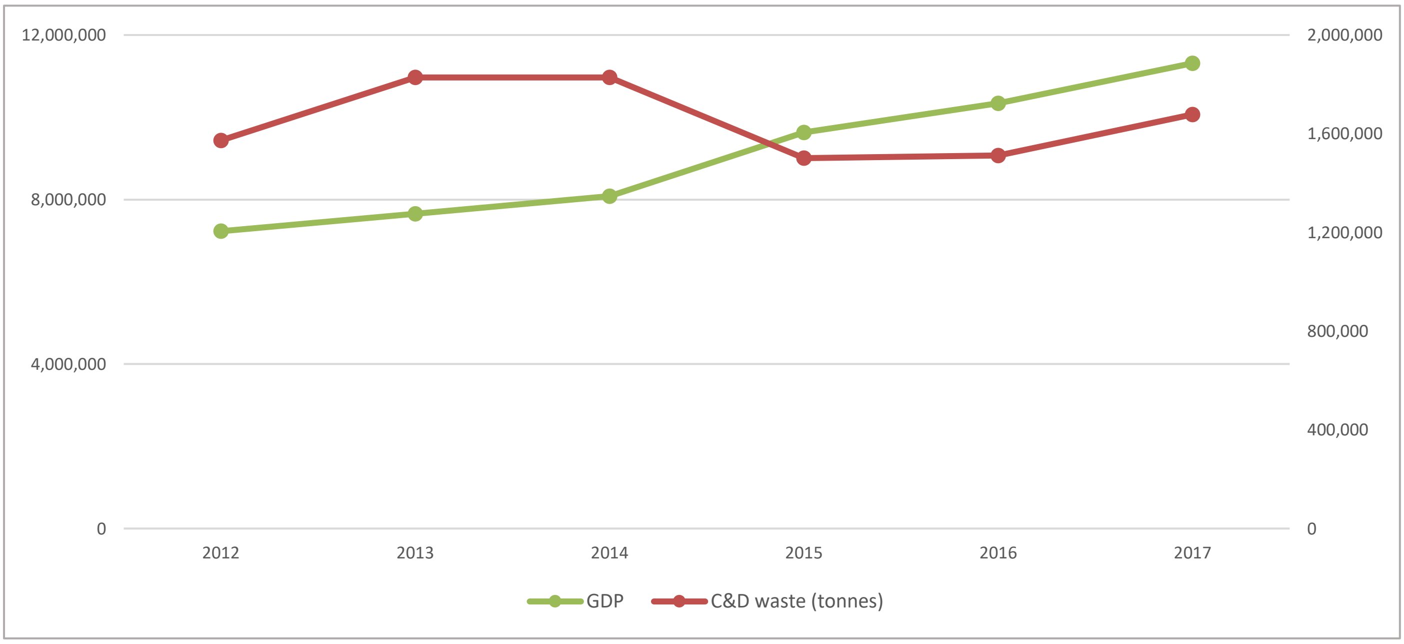
For a long-time, the C&D fraction dominated Malta's waste stream. In 2014, this fraction amounted to 2,904 kgs/capita, placing Malta in sixth place in the EU (Eurostat, 2017). The high generation of C&D waste causes various difficulties. While inert in nature, and usually not recognised as dangerous, its disposal is space-intensive and allowing it to accumulate in nature can generate serious environmental problems. On the other hand, landfilling is not feasible given the space limitations. The latter issue forced Malta to redirect the disposal of this type of waste away from the Maghtab and Qortin dumpsites[2]. This move became possible after 2003 when a five-year contract was awarded to a private entity to rehabilitate disused quarries by infilling them with inert material. Therefore, in 2004, a large part of Malta's inert waste (98 per cent) began to be deposited in approved disused quarries (backfilling), thus reducing pressure on other waste facilities.

Unfortunately, the materials generated from construction and demolition activities are often considered to be disposal items rather than resources for processing and reuse (Zangmo & Sharp, 2017). The construction industry is often lauded because it has a valuable output. The gross output generated by the construction industry refers to the value of all the buildings and works produced by the industry in a given period, normally a year (Hillebrandt, 2000). In Malta, construction and real estate account for less than a tenth of the total GVA. However, these sectors affect activity in other areas, given their intricate supply chain. A simple illustration of this can be obtained from the distribution of output in the construction sector – in 2015, the sector generated an output worth €974 million, using material and services from within the industry and other industries worth around €652 million, which is more than twice the sector's €322 million direct contributions to GVA (Central Bank of Malta, 2016). An important element that fuels the value of the construction industry is its generation of investment goods, which means that the output it generates is not wanted for their own sake but on account of the goods and services they create or help to create (Hillebrandt, 2000). This, together with the multiplier effect it elicits, has backed the industries' demands for expansion. However, environmental accounting requires that the industry takes

2 The Maghtab dumpsite is located on the island of Malta, while the Qortin dumpsite is in Gozo. The sites were developed when the full environmental impacts of such operations were not known. For a long time, the landfill sites had no systems in place for the proper control of leachate or gas the presence of deep-seated fires was common. [WasteServ Malta Ltd. March 2004. Development of rehabilitation strategies Maghtab, Qortin and Wied Fulija landfills. Summary Report, Final.]

responsibility for several externalities and this includes the generation of C&D waste. Table 1-1 lists the generation figures relating to this waste stream and its treatment.

Figure 1-4 C&D waste and GDP



Source: NSO, 2018

However, the generation of this waste fraction leaves very little space to manoeuvre. The limited availability of empty quarries and ongoing backfilling practices have caused extensive pressures which have made the country resort to disposal at sea (see Table 1-1: Treatment of construction & demotion waste (tonnes) 2011-2017

Treatment method	2012	2013	2014	2015	2016	2017	Trendline
Landfill (D1)	2,844	1,157	1,885	171	260	152	
Recovered (Backfilling in quarries)	392,945	819,329	513,781	963,637	933,180	1,329,437	
Recycling	139,181	241,092	311,642	488,302	278,105	230,341	
Storage	-	87,775	239,919	-	-	44,800	
Disposal at sea	1,037,680	678,640	433,817	59,720	16,000	-	
Total	1,572,650	1,827,993	1,501,044	1,511,830	1,227,545	1,604,730	

This practice is regulated under Legal Notice 184 of 2011 where Regulation 14 notes that the action must be covered by a permit specified in Schedule 9 of the same legislation with a prior inspection carried out before disposal.

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Source: Environment and Resources Authority, 2017, Malta

In 2015 and 2016, 32.29 per cent and 22.65 per cent of C&D waste were recycled respectively. The figure went down to 14.35 per cent in 2017. The recycling practice is carried out mostly in quarries that have permits to recycle waste stone and bricks into aggregate materials. This activity requires an end-of-waste status before placement on the market. Additionally, the metals, glass and plastics emanating from C&D waste are sent abroad for recycling (D.Cordina, personal communication, December 15, 2012). As stated in Article 11, 2(b) of the Waste Framework Directive (Directive 2008/98/EC) (WFD), Malta is required to recover 70 per cent of C&D waste by 2020. The target is reached mainly through backfilling practices which between 2011 and 2015 increased from 5.5 per cent to 63.7 per cent of the total C&D waste generated.

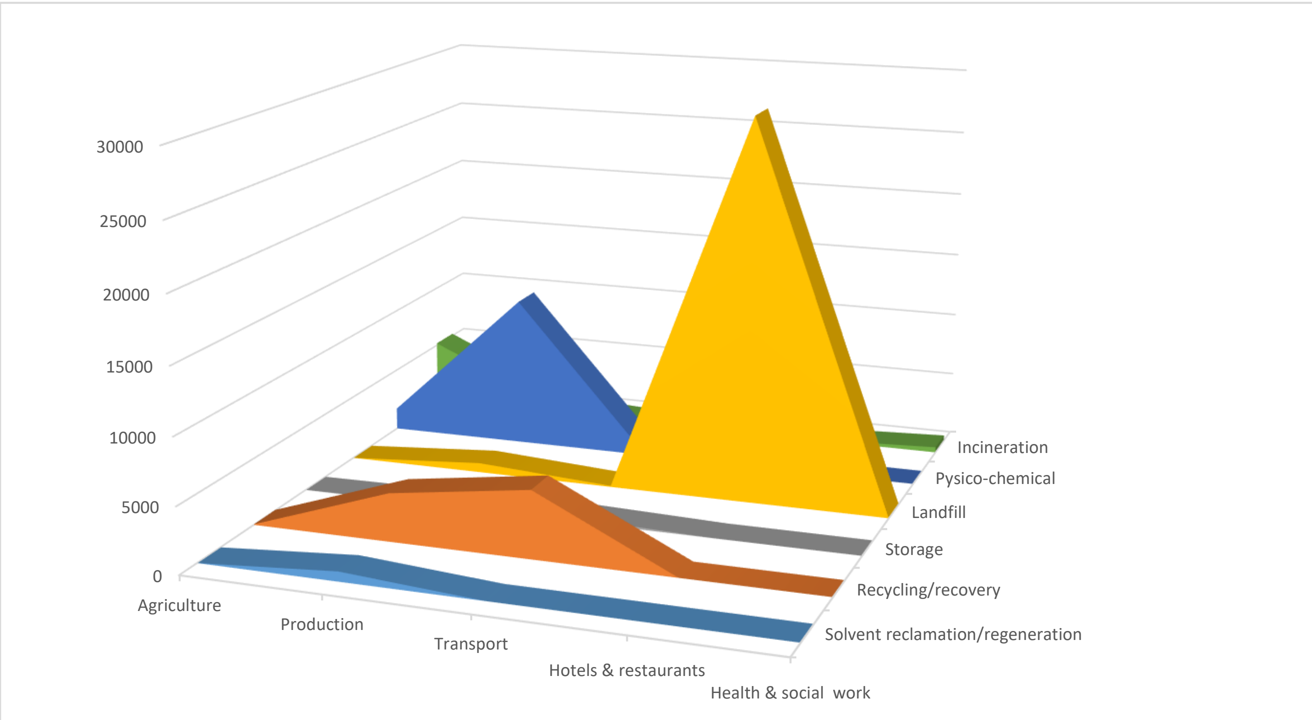
Permits for the construction of new buildings, issued by the Planning Authority (PA), do not hold any specific requirements for the re-use of part or all the stone generated from the demolition of an existing building. This is found only as a non-binding provision where applicants are encouraged to, as much as possible, re-use material particularly that was generated during the demolition process. In such cases, applicants indicate the amounts of materials generated from demolition which will be re-used. However, in cases where development is planned in an Outside of Development Zone (ODZ), the PA may impose a condition to re-use weathered stone and re-use stone from demolition. Developments within the Urban Conservation Area (UCAs) may be requested to re-use stone on the same site from where it was demolished. Although such a measure is imposed from a heritage point of view, it also prevents waste generation (D. Cordina, personal communication, August 14, 2014).

1.5 Commercial and industrial waste

The use of material resources – both renewable and non-renewable – has been central to our economies for centuries. Over the past century, the use of materials increased globally by a factor of eight: this has supported our way of life but has also resulted in negative environmental consequences including an increase in the waste generation (EEA, 2012). Material resources support commercial activity, which is central to every economy, but, like every process, it has its repercussions. The diversity of commercial and industrial activities that causes waste creates a wide range of waste types. The list includes waste items resulting from agriculture, horticulture and food preparation and processing which would be unsuitable for either consumption or processing; waste from the production of wood processing, the textile industry, paints and varnishes and waste from metal shaping among many others. It also includes street cleaning residue and waste from sewage cleaning. Given this, waste is often fragmented into small, sporadic quantities that originate from specific industries, each requiring a particular treatment method (see

Figure 1-5). Legal Notice 184 of 2011 (S.L.549.63 – The Waste Regulations) defines commercial waste as "waste from premises used wholly or mainly for the purposes of a trade or business or the purposes of sport, recreation or entertainment excluding (a) household waste; (b) industrial waste; and (c) extractive waste. Industrial waste, on the other hand, is defined as waste originating from premises used for (i) contractual or sub-contractual works, (ii) voluntary organisations, (iii) provision or in connection with public transport services by land, water or air, (iv) supply of public gas, water or electricity or the provision of sewerage services and (v) the provision to the public of postal and telecommunications services."

Figure 1-5: The treatment of C&I waste according to the sector of production in 2015



Source: Environment and Resources Agency, 2018

As can be noted in Figure 1-5, landfilling remains the preferred option, also for C&I waste, although there is some recycling/recovery of material. Unlike MW, C&I waste originates from specialised sources and people handling it are familiar with its properties. This sector also has a financial incentive to maximise resource use and therefore minimise waste. These factors facilitate the examination of possible solutions to reduce waste at source and improve recycling.

1.6 The Maltese economy

In recent years Malta experienced a robust surge in its economy. However, the Central Bank of Malta (CBM), notes that this growth slowed down during 2019. The CBM quarterly report notes that during the first quarter of 2019, GDP rose by 4.9 per cent in annual terms – a more moderate growth as compared to the last quarter of 2018 which registered a 7.6 per cent increase. CBM further states that economic growth in Malta was almost five times the rate recorded in the entire euro area, with the economic expansion entirely driven by domestic demand particularly since the contribution of net exports was negative (Central Bank of Malta, 2019).

Despite its widespread criticism, GDP per capita continues to be used as a measure of wellbeing. Shifts in this indicator suggest that the conditions of the average Maltese person if one accounts for inflation, have risen 11-fold since 1964. The increased affluence is confirmed by indicators such as home ownership which, in 2011, stood at 76 per cent (Grech, 2015b). A transformational process was registered in Malta's economy. The shifts resulted from the introduction of new service operators rather than the disappearance of existing ones. As can be noted in Table 1-2 by the start of the 2000s, the Maltese industry experienced a robust growth which shifted away from labour-intensive operational modes to more technology-based manufacturing. However, growth in manufacturing started to decelerate. This is reflected in the slower rate of growth, where the share of industry in total value added declined to around 20 per cent during the period 2006 – 2013 (Grech, 2015b).

The table below portrays the changes in the composition of the Maltese economy from the 1980s onwards.

Table 1-2: Share of Gross Value Added by broad Economic Sector

	1980	**1990**	**2000**	**2004**	**2014**	**Trendline**
Agriculture & fisheries	4	4	3	2	2	
Industry	38	31	27	28	17	
Services	59	65	70	70	81	

Source: Grech, 2015

In contrast, a surge in the service sector moved ahead. Liberalisation measures, the increased availability of higher educated labour resources and a targeted strategy to attract foreign direct investment opened new service sectors. Besides the traditional areas of tourism, education, health, retailing and banking activities, the service sector expanded to include higher value-added activities generated by the financial segment, specialised forms of tourism – such as language schools and dive centres, maritime activities, information technology and gaming. During the

2006-13 period, the service sector rose from 75 per cent to 81 per cent in 2013. This compares well with the euro area where the sector constituted less than 74 per cent of total activity, just 2 per cent points higher than in 2006. While the latter had an external services surplus of 1.3 per cent of GDP in 2013, up from 0.5 per cent in 2006, Malta had an 18.8 per cent surplus, up from 13.8 per cent of GDP seven years earlier (Grech, 2015b). The surge of the service sector has caused the Maltese economy to become a net exporter, with exports of goods and services exceeding imports, which provides a sharp contrast with the double-digit trade deficits that characterised the Maltese external sector until the mid-1990s (Grech, 2015b).

From 2014 onwards various shifts were experienced. The year 2015 registered the strongest increase. During this year, the annual percentage change in GDP increased to 9.9, meaning a 1.8 per cent increase over 2014. However, following 2015, CBM reported a slowdown in GDP growth. In 2016 and 2017, the percentage annual increase was reduced to 5.5 per cent and 6.6 per cent respectively (Central Bank of Malta, 2018).

1.7 Resources

The land is probably the scarcest resource in Malta (PSTEC, 2010). The only exploitable mineral resource is limestone, which is quarried and used for construction. For a long time, Malta was dependent on imported fossil fuels to supply its energy needs; however, renewable sources are registering a substantial increase. In fact, between 2013 and 2016, energy from renewable sources increased from 35,447 to 133,419 megawatt-hours. During the latter year, the majority of renewable energy (93.7 per cent) was produced from photovoltaic cells, while the remainder was derived from other sources. These shifts contributed to a decrease in CO_2 equivalent emissions which in 2007 stood at 2,034 kilotons but decreased to 578 kilotons in 2016 (NSO, 2017).

A major issue for the Maltese Islands is water. The recently published State of the Environment Report (2018) notes that water use is at an estimated 110 L/capita/day. This figure, which has been constant for several years (M.Cremona, personal communication, September 13, 2019), corresponds to one of the lowest consumption rates within the EU. Malta also has the lowest access to natural fresh water sources in the EU. This, coupled with a dense population, means that water is a scarce resource. The four main water sources: groundwater (regulated by mean annual recharge) (61 per cent), desalinated water (29 per cent), rainwater (7 per cent), and treated wastewater (3 per cent) are strained (Environment and Resources Authority, 2018). Despite the challenges involved in the production of water, both the local population and the tourism sector are served with good quality drinking water, but groundwater depletion in terms of both quantity and quality and a growing dependence on oil imports for water desalination remains a constant concern. The public is poorly educated about national water issues and ill-prepared to assimilate information and contribute to shaping the required action (FAO, 2006).

1.8 Political system

Malta was a British colony from 1800 to 1964. During this time a highly polarised dual party-political system was developed. The origin of this system revolved around the strongly pro-Italian Nationalist party against a pro-British, but a simultaneously indigenist political movement, that eventually evolved into the Malta Labour Party (Mitchell, 2003). This polarisation continued to influence Maltese politics throughout the years, with the local population becoming increasingly divided along party lines (Mitchell, 2003). Evidence of this are election turnouts which are among the highest in the world with the majority of political allegiance ascribed to the family and/or by geographical area (Mitchell, 2003) and not according to idealism and policy proposals.

The Maltese political system has come under extreme criticism several times. Jeremy Boissevain, a Dutch anthropologist who studied Malta's social life for 40 years, notes that the political division is a major problem. His studies show that the Maltese have a pronounced tendency towards dualism. This is evident in the political scene where the two larger parties alternate power and exhibit a strong tendency for political bickering which has changed very little since their inception. He further adds that, in recent years, due to the increased financial donations entering the system, this bickering has grown more intense with political parties funding their television and radio stations as well as their newspapers. Prof. Boissevain says it is common for small scale, family-centred societies to view things in black and white, or rather, in Malta's case red and blue[3]. He further stresses that an "A country with no perception of grey areas and the middle ground is doomed to antagonism. Perhaps an experiment with a different electoral system that would give space to other political parties would decrease the corrosive political division. As things stand, Malta is a one-party State for five years," (Sansone, 2001).

1.9 Motivation

This dissertation is motivated by the following realities:

The direct relationship between economic growth and waste generation is often portrayed in graphs showing waste generation plotted against GDP figures. This trend is not exclusive to MW but is reflected by all types of waste. Akin to the management of MW, the effective strategic planning of the industrial fraction requires a sound knowledge of the waste streams within the economy (Liao et al., 2015). This necessitates an in-depth examination of the connections between the economic and ecosystem segments to distinguish which segments are causing the highest waste generation compared to their economic contribution. Defining this relationship allows future economic policies to integrate waste generation already at their inception.

IE takes into consideration an entire system of interested parties that produce the desired products and engage in waste exchange to generate a positive system result. This framework suggests that an industrial system can follow

3 Red and blue are the two (2) colours representing the 2 major parties in Malta with red used by the Labour Party (formerly the Malta Labour Party) and blue the Nationalist Party.

the principles of ecology in using waste and doing so in an economic way (Smith et al., 2015). However, despite the advances registered within the field of sustainable development and the progress of IE, together with shifts in ideologies towards sustainable consumption and production (Silva et al., 2016), the global economy has continued to progress in a linear fashion, where consumer goods are manufactured from raw materials, sold and then discarded as waste (Saavedra et al., 2018). The use of the IE philosophy assists in the examination of waste flows to identify leverage points for waste management planning (Eckelman et al., 2014). This is of crucial importance since it provides a possibility to view waste streams as a potential feedstock and reconstitute its value with the intent to preserve resources and minimise the generation of pollution (Smith et al., 2015).

The Circular Economy (CE) concept has gained more ground in recent years. CE aims to create a continuous positive cycle of development which conserves and enhances natural capital and is based on three principles – (1) designing out waste and pollution; (2) keeping products and material in use; and (3) the regeneration of natural systems. Ultimately, CE looks at the gradual decoupling of economic progression from the consumption of finite resources together with the designing out of waste from the system (Ellen MacArthur Foundation, 2017). In its initial first steps towards the introduction of CE, Malta, like other countries, is faced with various difficulties particularly in the area of solid waste management. Examining the present waste flows is, therefore, necessary to provide a basis for the implementation of effective waste management programmes that respect the requirements set forward by EU legislation, including the realisation of a CE.

Islands share many characteristics with mainland communities, particularly those with districts that are geographically isolated. However, while mainland communities can transport their waste to larger cities, islands are water-bound and therefore the export of waste is an arduous process and entails higher costs. Given this, many islands struggle with effective waste management(Eckelman et al., 2014). This necessitates additional studies that examine waste flows from an island perspective to highlight the particular difficulties faced by cases such as Malta whose GDP has experienced a steady increase and converged towards those of advanced economies within the EU (Grech, 2016).

In Malta, MW comprises 14 per cent of the total waste generated (NSO, 2018) while in the EU it amounts to 7 to 10 per cent of total waste (European Parliament and Council, 2018). When attention is directed towards per capita figures, the quantities generated in Malta are staggering – in 2017 MW reached an average of 617 kg/capita in Malta (NSO, 2019) while the EU average amounted to 487 kg/capita (Eurostat, 2019). Among the various types of waste, MW is the most visible and troublesome (Fischedick et al., 2014) and among the most complex to manage given its intricate composition (European Parliament and Council, 2018). The complex nature of the waste, its proximity to urban settlements and high visibility, together with the impact it leaves on human health and the environment, add to the challenges comprised in the management of MW (European Parliament and Council, 2018). This automatically implies that MW management requires several complex systems for the efficient collection, sorting, tracing and treatment of waste streams which must be complemented with the active engagement of citizens and businesses, combined with complex financing. It is noted that countries which develop an efficient MW system generally perform better in overall waste management (European Parliament and Council, 2018). Therefore, an in-depth analysis of the flows in MW provides insight into the quality of management of other waste streams and highlights weaknesses and identifies the barriers hindering the expansion of CE.

Landfilling remains a popular waste treatment option particularly in the Eastern and Southern parts of Europe (European Parliament, 2018). As was noted in Figure 1-2, landfilling remains the main disposal option in Malta. Moving towards a system that can boast of a high material recovery rate requires an in-depth assessment which gives insights into the present operational practices and processes to comprehend the causes of present linear functions.

The management of waste contributes to several environmental problems and health impacts. Waste generation, collection and treatment are also a source of greenhouse gases (GHGs) and therefore contribute to climate change (Cifrian et al, 2012). This relationship gaining more acknowledgement in recent years (Newman, 2016). In Malta, waste is the most significant contributor to GHG emissions following energy generation and transportation (Falzon et al., 2013). This connection is gaining more prominence on an international basis. Therefore, detailing the GHG impacts of MW, including transport, identifies the points where the system needs leverage to enhance efficiency and reduce emissions and allow for the setting of an inventory, which accounts for both direct and indirect emissions together with avoided impacts when abatement measures are introduced. Direct emissions occur in the system's waste management facilities, while indirect emissions refer to GHG emissions that occur outside the facilities but are associated with the operation (Sevigné Itoiz et al., 2013).

While the connection between waste generation and economic growth can be analysed on the macro level, placing a magnifying glass on a specific industry provides deeper insights into the processes and practices that are conducive to waste in that sector. Tourism, one of the fastest-growing industries in the world, represents a sector that has gained considerable importance within the generation of income and jobs worldwide. The sector also poses extensive threats to the environment, particularly when it is not well-planned and managed. However, if the outcome of an expansion of the tourism industry is the environmental destruction of a country, tourists will no longer have a reason to visit it (Beladi et al., 2009). Research into environmental externalities of the industry has been the subject of great but uneven interest in tourism literature, where the relationship between tourism activity and MW has been largely neglected (Arbulu Villanueva, 2014). The important role of the tourism industry in the Maltese economy, the direct connection of industry with waste, together with the gap in information on quantities of waste generated by the sector, highlights the need to address the connection more intensely and examine the trends of solid waste generation within the sector.

Food and its wastage have gained increased attention in recent years. This is emphasised in Directive 2018/851 which also establishes the EU Platform on Food Losses and Food Waste (European Parliament and Council, 2018). The report "Estimates of European food waste levels" calculates that in 2012, 88 million tonnes of food waste was generated within the EU-28. This estimate refers both to edible and inedible (avoidable and unavoidable) parts associated with food. On a per-capita basis, this equates to 173 kg per person. Households are a major source of food waste, followed by processing and foodservice (Fusions, 2016). Tourism bears a strong association with food which forms a prominent part of the experience of the host country and therefore bears a strong association with the wastage of food. This necessitates the need for a clearer measurement of food waste generation within the hotel industry as a first step in improving its management.

1.10 Objectives

The generation of waste takes place at different stages of the production and consumption process. This thesis seeks to expose the links that urban waste generation has with operational and economic functions using the Maltese Islands as a case, to supply information that is critical to the implementation of an Integrated Waste Management (IWM) system and a Circular Economy (CE), with the ultimate goal to guide strategy towards the decoupling of waste from economic growth.

This overarching aim is supplemented by the following aims:

The management of waste provides a prime example where the social, environmental and economic considerations must be integrated further in policy to achieve strong sustainability (Silva et al., 2016). This thesis underlines the need for this approach by highlighting the link between waste generation and different economic sectors and other operational processes which impact society in the form of externalities.

Identify challenges that form part of the management of different types of waste particularly in the case of islands that have to struggle with physical isolation, a limited landmass, and, in the case of Malta, an expanding economy and rising population (Chapters 4, 5, 6).

MW represents a complex type of waste. The level of its management generally indicates the quality of the overall waste management system in the country (European Parliament and Council, 2018). This thesis seeks to study the physical flows that characterise the management of MW to provide a situation analysis that pinpoints where intervention is necessary to increase CE and highlight challenges that are particular to islands (Chapter 3).

Highlight the relationship that waste has with carbon emissions and emphasize the importance of improving efficiency in the management of waste to reduce carbon emissions (Chapter 3).

Provide deeper insight into the prevalent relationship between shifts in economic growth and the generation of waste, therefore supplying policymakers with guidance on where leverage is required to endorse an economic expansion that is not riddled with waste externalities (Chapter 4).

Bring out the crucial importance of tallying the national accounts with environmental degradation through the application of discount factors thus providing a more holistic picture of the economic growth being generated (Chapter 4, 5).

Identify the operating modes and practices on a micro level within a specific economic sector that lead to high quantities of waste generation (Chapter 5).

Chapter 2
Methodology

2.1 Introduction

The concept of IE was developed following the realisation that human activity is causing unacceptable changes in basic environmental systems (Graedel, 2010). IE does not view economic systems in isolation but in connection with their surroundings (Graedel, 2010). The shift to the IE philosophy indicates a shift towards strategies which are focused on improved comprehensive prevention and planning and therefore away from "end-of-pipe" pollution control methods (Rourke et al., 1996).

IE, therefore, encompasses the interactions between human activities and the environment (Graedel, 2010), with the fundamental idea that society could reduce its impact on the environment by learning from nature (Deutz & Ioppolo, 2015). It emphasises the optimisation of resource flows to establish near-close material cycles like those found in natural ecosystems and to bring about a paradigm shift in the relations between industry and the environment (Rourke et al., 1996). It adopts a system view that draws a boundary around, for example, a group of firms, regions and sectors and questions the methods used to optimise resources. IE is therefore focused on the quantification and transformation of the Anthropocene (Weisz et al., 2015) and aims to describe and characterise the human-environment interactions with the possibility of improving them (Jelinski et al., 1992).

The goals of IE can be classified into two broad categories – (1) to establish near-close material cycles similar to those found in natural ecosystems; and (2) to bring about a paradigm shift in relations between industry and the environment. The latter goes beyond measurable reductions in material throughput and focuses on the ways we perceive industries and their interactions with the natural ecosystems which are their ultimate pillar of support (Rourke et al., 1996).

A system analysis enables an interdisciplinary approach that supports policy analysis and decision making; this approach is especially suited to the context of waste management (Chang et al., 2011). While methodological tools are generally sensitive to the boundaries allocated to them, this approach could equally be implemented on a single item or process or a complete industry or geographical area (Seager & Theis, 2002). The application of this method involves system engineering models and system assessment tools (Pires et al., 2011). System engineering models concern the synergistic interfaces of MW management systems and support decision making. Tools such as cost-benefit analysis (CBA), optimisation models (OM), simulation models (SM), forecasting models (FM) and integrated modelling system (IMS) form part of the system engineering model. System assessment tools, on the other hand, focus on the evaluation of schemes following their implementation. Tools such as material flow analysis (MFA), scenario analysis (SA), management information systems (MIS) and socioeconomic assessment (SoEA) fall under this category (Pires et al., 2011).

The three research studies forming part of this thesis seek to provide a system overview of definite phases within an economy and supply a detailed picture of the interaction of human activities with the surrounding environment.

The provision of a system overview allows for the analysis of a group of interrelated components and the examination of how they influence one another (Rotmans & Loorbach, 2009). This approach provides an insight into the dynamic features that characterise a complex, adaptive system (Rotmans & Loorbach, 2009) to optimise it.

The research is divided into three distinct categories that encompass the analysis of waste generation and management on the macro and micro level. Research 1, uses MFA and carbon footprint analysis to conduct a systematic account of the flows and stocks of materials (Brunner and Rechberger, 2005) of MW flows in 2012 and 2018 and to identify points open to optimisation. Research 2, uses Leontief input-output analysis to assesses how waste generation in an economy will change when there is an exogenous increase in final demand. The approach makes it possible for policymakers to proactively assess which economic sectors will impose fewest externalities and therefore curb social costs. Finally, Research 3, applies a case study scenario analysis on a micro-level using a mixed quantitative and qualitative methodology to characterise how particular processes and practices in a five-star hotel influence waste generation. A five-star hotel was selected with the view that luxury is expected in this category of hotel and this is generally conducive to higher waste figures.

2.2 Systems boundary

A system refers to a group of physical components connected or related to form or act as an entire unit. When a system is open it interacts with its surroundings and has either material or energy imports or both. A closed system, on the other hand, is isolated and prevents material and energy flows. Therefore, a system is defined by a group of elements, the interaction between them and other elements in space and time (Brunner and Rechberger, 2005).

In an assessment analysis, the formulation of the problem is the most important step in the decision-making process. The development of an assessment tool starts with the definition of goals and scope, which relate to the purpose of the assessment, together with the system boundary or the limits that govern the evaluation process (Morrissey & Browne, 2004). Selecting a starting and an endpoint can have a decisive impact on the results, and, therefore, the scope and system boundaries have to be selected carefully because changing the boundaries could directly influence the results (Allesch and Brunner, 2014). A boundary can be (1) material (what type of waste material is accounted for), (2) spatial and temporal (the time horizon and geographic area); and (3) functional and sectoral (areas and the functional units within the areas) (Braschel & Posch, 2013). Temporal boundaries depend on what system is inspected and the problem at hand while spatial boundaries are generally fixed by the geographical location where the process is taking place (Brunner and Rechberger, 2005). Material boundaries depend on data availability.

The actual definition of the system to be examined is a decisive and demanding task. The selection of a system boundary is dependent on various factors that include the objectives of the study, data availability, the appropriate balancing period and residence time of materials within stocks (Brunner and Rechberger, 2005). In the case of a socioeconomic system, the first boundary to be considered is whether the national economy and the natural environment from which materials are taken and eventually discarded will be used. This is followed by the political frontier to other economies and their imports and exports, since input and output flow accounting caters only for the flows that cross the system boundaries (Raupova et al., 2014).

An overview of the three research studies forming part of this dissertation is noted in Figure 2-1.

Figure 2-1: Snapshot of the three research studies

RESEARCH 1

Title
Where do islands put their waste? A material flow and carbon footprint analysis of municipal waste management in the Maltese Islands

Type of study
Scenario & comparative analysis.

Tools
Material Flow Analysis, CO_2ZW

Objectives

- Portray the challenging relationship between MW and islands;
- Emphasise the importance of carbon emissions at the inception of waste management policies

Systems boundary
Municipal Solid Waste.
Temporal boundary – 2012 and 2018.

RESEARCH 2

Title
Examination of the economic-ecological connections of waste generation in Malta – development of a sectoral waste intensity indicator based on the Leontief input-output analysis

Type of study
Input-Output analysis, indicator development

Tools
Leontief input-output; Waste intensity indicators

Objectives
- Analyse economic development in relation to sectorial waste generation;
- Establish how direct and indirect waste generation changes when final demand experiences an exogenous shift;
- Develop sectoral waste intensity indicators.

Systems boundary
C&I and C&D waste, Temporal boundary – 2010 and 2010 to 2015

RESEARCH 3

Title
A snapshot of solid waste generation in the hospitality industry. The case of a 5-star hotel on the island of Malta.

Type of study
Systems & performance analysis

Tools
Waste audits, focus groups, semi-structured interviews

Objectives
- Provide a holistic picture of the waste generated within a five-star hotel
- Understand attitudes towards waste from both staff and guests in this luxurious environment

Systems boundary
Waste generated from a 5-star hotel during Summer 2018

In Research 1 (Chapter 3), the material boundary is focused on MW which was strictly defined by the criteria identified under the European Waste Code (EWC) (Section 3.2). Focusing on MW permitted the use of the CO2ZW® tool which was developed specifically for this type of waste. The boundary also identified where the two MFAs would focus on, starting from collection until the waste is disposed of or exported. As well as identifying the activities on which the MFAs would focus, it was crucial to take transport during waste collection and its transfer it to the disposal or treatment sites when exported into account. The research is based on 2012 and 2018, an MFA and carbon footprint are performed for each year and then compared. In the case of 2018, a scenario analysis is also performed.

The material boundary in Research 2 (Chapter 4) is focused on C&I and C&D waste. In Section 4.2, it is pointed out that MW is excluded from the study since the research paper is focused on upstream impacts (production-related waste), given that the Leontief input-output analysis concentrates on the interdependencies that are present between various industries (Miller and Blair, 2009). MW, on the other hand, refers to the waste that originates from households and is, therefore, consumption-related. The 2010 temporal boundary was imposed by the publication of the NSO "Supply, use and input-output tables" (NSO, 2016) which provided the necessary domestic production and imports tables that were vital to the research. In view that Malta is one of the most open economies in the world, the input-output table for domestic production and imports were aggregated to obtain the total quantity of goods (in monetary terms) available in the economy.

In the case of Research 3 (Chapter 5), the material boundary was limited to waste streams originating from guest rooms and restaurants within a specific five-star hotel. The research excluded waste originating from offices and occasional waste that, for example, is generated during the refurbishment or replacement of items. Liquid waste is also excluded. The temporal boundary is constrained to summer 2018, during which a number of audits were conducted. Seasonal comparisons were not possible since the research was carried out during the summer.

2.3 The tools that characterise the methodology of the dissertation

2.3.1 Material Flow Analysis (RESEARCH 1)

The economy and its growth draw heavily on environmental goods which for a long time bore no price (M. Fischer-Kowalski et al., 2011). This has resulted in several sustainability issues that are often connected to the mass of resources extracted (e.g. depletion of non-renewable resources and their effects together with wastes/emissions discharged per unit of time). These factors set requirements for more frequent analyses of yearly flows of materials or energy (Haberl et al., 2017) that led to the development of Material Flow Analysis (MFA). MFA is focused on the provision of a comprehensive economic-environmental accounting framework that is integrated with the national accounting matrix (M. Fischer-Kowalski et al., 2011) and refers to a group of methods that analyse material flows in society with the final objective of matching the use of material resources and the release of wastes and pollutants with the capacity of the environment both to supply these resources and to absorb the generated wastes and emissions (MICA, 2017).

The basic premise of MFA is built on the first law of thermodynamics – matter can neither be created nor destroyed in any physical transformation process and therefore material inputs within a system must always equal material output together with net accumulation during processing (M. Fischer-Kowalski et al., 2011). The analysis of material flows on a national basis uses a methodology developed by Eurostat known as the European Wide Material Flow Analysis (EW-MFA). The general purpose of EW-MFA is to describe how the domestic economy interacts with the natural environment and the rest of the world (ROW) in terms of material flows (excluding water and air) (Eurostat, 2013). Applications using this methodology consider flows in a national economy throughout a year and provide a physical complement to the monetary national economic accounts. They are used to support government policy on resources, their use and efficiency (MICA, 2017). Present compilations of EW-MFA are focused on direct inputs of used materials, particularly Domestic Extraction (DE), imports, exports and the derived indicators Direct Material Input (DMI), Domestic Material Extraction (DME) and Domestic Processed Output (DPO) (M. Fischer-Kowalski et al., 2011).

In this dissertation, the MFA methodology used is developed by Brunner and Rechberger (2004). Similarly, to the general purpose of EW-MFA, Brunner and Rechberger's (2004) model is used to describe, investigate, and evaluate the metabolism of anthropogenic and geogenic systems and defines terms and procedures to establish material balances of systems. However, in this case, MFA is used to examine waste management systems on different levels (goods and substances) and provide a comprehensive and systematic account of a defined physical system to support decision-makers (Allesch & Brunner, 2015). This methodology has been successfully applied, to (1) simplify complex waste management processes together with their environmental, economic, and social impacts to provide an adequate basis for decision making; (2) manage wastes resulting in secondary resources; (3) model the interrelation between the regional/national economy and waste management; and (4) provide background information in aggregated form on the composition and changes in the physical structure of socioeconomic systems for waste management (Allesch & Brunner, 2014).

Research 1 presents a tabled down analysis of the MW flows. The analysis commences from collection to final disposal or recycling and aims to serve as a systems assessment tool that evaluates performance and considers how improvements could be made (Pires et al., 2011). Assessing solid waste management scenarios using systems analysis techniques allows decision-makers to learn about the complexities that a system incorporates, since such tools provide measures of complexity inside the procedures/components and in-between them and assist in the setting of optimal sizing of solid waste management facilities, together with optimal scheduling of waste flows and throughputs while evaluating new system components (Pires et al., 2011).

Two MFAs are presented in Research 1. The first one examines the flows for 2012, while the second one focuses on the projected figures of 2018. The 2018 MFA compares the changes registered following the introduction of different infrastructures with the 2012 scenario and underlines the importance of broadening bio-waste separation to improve the quality of other waste fractions and optimise the use of the infrastructure introduced. This aspect is also crucial to improve the circularity of the system which, as is noted in Figure 3-1 and Figure 3-3 in Chapter 3, presently operate in a linearly.

As well as providing a systematic analysis of flows, the MFAs served as a tool for scenario development (SD). At this stage, it should be pointed out that scenarios are not predictions or projections but supply a system analysis tool which, in this case, provides visions of future conditions in waste management to (as in this case), scrutinise specific policy decisions or assess some prescribed problems that might occur in the future (Chang et al., 2011). Two steps characterise SD – (1) the scenario design step; and (2) the scenario calculation. In the first step, driving forces, events and trends are established to construct the scenario while in the second step, models are used to finish the scenario bringing more information to characterise it. This methodology uses the interactions within all types of systems engineering models either collectively or separately to address the scenario (Chang et al., 2011). The projected scenario of 2018 uses MFA to assess how the new treatment infrastructure that was introduced will impact the waste management flows of the 2012 model and identify the adjustments required to improve performance, including circularity. An important point brought out in this assessment is that, although no direct landfilling will take place when a 120,000-tonne thermal treatment facility is introduced, Malta would still need to landfill 100,301 tonnes per annum originating from rejects, ash etc. The 2018 MFA also provides guidance on which steps are necessary to redirect waste fractions away from landfilling towards recycling and recovery. The development of this scenario highlights where measures need to be undertaken to improve circularity and emphasise the need to re-examine processes if the country is to establish an economy based on the three pillars of sustainable development. This can serve as a contribution to the development of a CE which is presently being introduced in Malta. The concept of CE has attracted increasing attention in recent years particularly due to the adoption of a Circular Economy Package in 2015 (EU Action Plan for the Circular Economy). CE aims to maintain products, components and materials at the highest level of utility and value, thereby creating a continuous positive cycle of development where natural capital is conserved and enhanced and, thus, minimising systemic risk by managing finite stocks and renewable flows (Saavedra et al., 2018).

2.3.2 Carbon footprint (Research 1 – Chapter 3)

Climate change is the defining global challenge facing this century (United Nations, 2019). In 2006, it was estimated that globally, GHG emissions generated from solid waste disposal sites ranged between 20 to 40 million tonnes of methane (CH_4). These mainly originated from industrialised countries and amounted to approximately 5 to 20 per cent of global anthropogenic CH_4, which is equivalent to 1 to 4 per cent of total anthropogenic GHG emissions (IPCC, 2006). These issues have forced new measures to be implemented at EU level that include the bio-waste diversion from landfills, improving energy efficiency at waste treatment and disposal facilities, enhancing quality in waste management outputs (including recycled materials) to reduce resource consumption and raising materials utility (Pires et al., 2011). These measures have left a positive result - in 2017, GHG emissions originating from the EU-28 sourced from the waste sector amounted to 138,866 million tonnes. This means a 57.8 per cent reduction since 1990 when emissions reached 240,241 million tonnes (EEA, 2019).

The accurate measurement and quantification of GHG emissions is a vital factor in the setting and monitoring of realistic reduction targets at all levels. The examination of GHG emissions in relation to waste treatment processes requires the estimation of; (1) the direct effects from energy, raw materials and pollutant emissions before and after the waste treatment processes; and (2) all the factors which are linked to external functions. These are required by the waste-based individual material flow indicators that, in turn, support decision making and policy analysis and assess waste management technologies and strategies under the global change impacts (Cifrian et al., 2012).

Malta currently uses the methodology of the Intergovernmental Panel on Climate Change (IPCC) to calculate waste-related GHG emissions. Since the inventory is concerned with gathering information on emissions generated within the country and across all sectors, GHG emissions recorded under the waste section are limited to direct discharges from the disposal/treatment systems. These relate to emissions from landfilling, incineration, organic waste treatment and MBT. The impact of treatment systems such as incineration and anaerobic digestion of biowaste, once energy is generated, is no longer recorded under the "waste" section but under the stationary combustion section (Ballinger & Hogg, 2015). Benefits which arise from targeted waste prevention, life extension of products, recycling and avoiding the use of primary material are recorded under reduced emissions in the industry part of the inventory (Ballinger & Hogg, 2015).

In Research 1, a carbon footprint assessment of different MW management scenarios using the CO2ZW® tool is provided. CO2ZW® is an environmental and management tool which focuses on the identification and quantification of emissions of GHG, measured in carbon dioxide equivalents, generated over a complete life cycle of MW management (Sevigné Itoiz et al., 2013). Using global warming potential as a measure, the results are disaggregated as direct, indirect and avoided impacts. GHG emissions that are generated directly within the waste management facilities and are associated with their operation are listed as direct. These are complemented by emissions arising from fuel combustion in waste treatment facilities. Indirect emissions, on the other hand, are generated outside the system's waste management facilities but are associated with their operation (upstream emissions). Finally, avoided impacts refer to the amount of GHG emissions reduced from the system when recovered or recycled products are used (Sevigné Itoiz et al., 2013).

The results of Research 1 account for both waste collection and treatment. Figures point to high carbon-related emission, which improves with the introduction of the new infrastructure in 2018, particularly the MBT. Even at the assumed 30 per cent success rate in a bio-waste separate collection, improvement is registered in all three options presented in the study, with the introduction of a 120,000-tonne incinerator displaying the highest avoided impacts. However, as noted in the study, the decision to introduce an incinerator needs an analysis that goes beyond a carbon footprint analysis, particularly because of the extensive impact caused by the incinerator itself and the continuous demands for landfilling infrastructure which cannot be excluded in an island whose landmass reaches 330 km^2. Waste transport is undoubtedly the main area where system optimisation can easily be implemented, particularly concerning route optimisation which affects urban transportation.

2.3.3 Leontief Input-Output Analysis (Research 2 – Chapter 4)

The human economic system can be regarded as a living organism with a metabolic system which is maintained through a steady inflow of useful inputs (resources) and a corresponding outflow of unwanted outputs into the ecosystem (Nakamura & Kondo, 2009). This system can be referred to as the socio-economic metabolism which is a concept that has its branch within the field of industrial ecology. The term 'metabolism' borrows from biology and refers to the internal processes of a living organism which maintain a persistent flow of material and energy within the environment they live in to sustain their growth and reproduction. Similarly, the social-economic system converts raw materials into products and services and finally into waste (Marina Fischer-Kowalski & Haberl, 1998).

The motivation behind IE is its concern for the well-being of the environment. The discipline emphasis the development and implementation of solutions and policies which can range from local to global systems. It explicitly acknowledges that modern industrial activities operate interdependently with every industry performing a number of interconnected processes that depend on energy and material inputs and waste discharges (Duchin & Levine, 2008). Therefore, IE focuses on the sustainability of industrial systems keeping in mind that they are supported by natural systems (Nakamura & Kondo, 2009).

Research 2 (Chapter 4) applies the waste input-output (WIO) methodology to the various technical issues arising in waste management (Nakamura & Kondo, 2009). Its versatility and ability to track the path of flows which account for both indirect and direct interactions allow for an accurate estimate of the total energy and biomass needs (Duchin & Levine, 2008). Furthermore, IO provides a systems approach that describes and analyses an entire economy with regards to the inputs and outputs of industries, thus portraying the complex interplay of ecological and industrial system concepts. The use of this methodology in IE has grown substantially in recent years in view of its ability to describe both physical stocks and flows and the associated money costs and prices. This has been assisted by the availability of the databases required on a periodic basis by national statistics offices around the world (Duchin & Levine, 2008).

While waste-related research tends to focus on municipal waste (Allesch & Brunner, 2014), Research 2 is focused on C&I and C&D waste. As can be noted in, these waste streams have a positive, direct relationship with economic growth. Another factor is that the research methodology requires waste to be classified according to the NACE code. This is not possible for MW since it is generated at the consumption phase, while C&D and C&I waste are generated during the production stage. This corresponds to the Leontief input-output analysis which emphasises the economy's production side and accounts for the interdependency between industries with outputs from one industry used as inputs for another industry (Whipkey et al., 1985). The method assesses the level of output that each of the industries in an economy produces, for it to be sufficient to satisfy the total demand for that product (Chiang & Wainwright, 2005). The research provides a guide to policy and decision-makers on which economic sectors should be invested in if the reduction of waste externalities is a priority. In the case of the Maltese Islands, this is a crucial factor because of the constant challenge of space limitation and population intensity.

2.3.4 Mixed methodology

Focusing on the micro-level, Research 3 (Chapter 5), presents a case study which examines waste generation in a five-star hotel. The study uses the qualitative and quantitative methodology and provides a holistic picture that identifies the waste that is generated within this luxury environment. The quantitative tools used are waste audits, while the qualitative methods used are focus groups and semi-structured interviews. While allowing for the quantification of different waste streams, this methodology also incorporates local knowledge about these particular waste streams and allows for the identification of new information, site-specific details, and explanations of waste stream conditions while pinpointing the potential solutions for reusing, reducing and recycling waste (Newenhouse & Schmit, 2000). Waste characterisation studies and the examination of purchasing are used to determine the quantities and composition of waste generated and the factors contributing to it.

The research ties in with one of the main broad goals of IE – that of bringing a shift in relations between industry and the environment (Rourke et al., 1996) which, in this case, is tourism. It further aims to provide actionable input to policy and decision-making about particular industrial systems which can range from an individual entity to an entire industry (Duchin & Levine, 2008). Although based on a single case study, the use of mixed methodology supports this goal by going beyond measuring material flows to provide a glimpse into how the tourism industry perceives its relationship with waste generation. Waste generation is that most visible impact the industry exerts on the environment and the natural ecosystem which are integral product the country has to offer.

In Research 3, the case study offers a bottom-up approach that is suited to the assessment of waste production and consumption systems within a five-star hotel. While IE was originally focused on the production side, in a consumer society, stocks and flows are demand-driven and, in industrialised economies, have control not only on *how* much gets consumed but also *what* gets produced and consumed and potentially over how it gets produced (Duchin & Levine, 2008). The production-driven waste generation is examined through purchasing records, demands made by the mother brand and food preparation waste audits. Consumption led waste generation is examined mainly through several post-consumer waste audits and the audits of customers' expectations in a luxury environment.

Chapter 3

Where do islands put their waste? A material flow and carbon footprint analysis of municipal waste in the Maltese Islands.

This chapter is based on the paper published in the Journal of Cleaner Production.

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ABSTRACT

The issues created by waste management on small islands do not have any straightforward solutions. The numerous difficulties include limited space availability, restricted recycling and resale opportunities and impacts on the local environment which are magnified particularly when the island is small, densely populated and tourist-dependent.

The well-documented impact on the local environment includes resource loss, damage to the marine and local environment and continuous nuisances created by littering, trucks and treatment facilities. However, waste management can also leave its mark beyond the local border. The generation and treatment of waste are gaining attention because of its connection with greenhouse gas (GHG)emissions. Although in the past, GHG emissions were mainly associated with energy generation, today it is commonly acknowledged that improved waste management can also mitigate such emissions.

This research paper analyses the flows involved in the management of municipal waste (MW) from an island perspective. Focusing on the island of Malta, which comprises 316 km^2 and sustains a population density of 1327 people/km^2, it presents a Material Flow Analysis (MFA) and a carbon footprint for 2012. The same analysis is then made for three prospective scenarios proposed in the Waste Management Plan for the Maltese Islands 2014-2020 using projected 2018 data.

The paper tables an analysis of the collection, treatment and disposal/export flows involved in the management of Municipal Waste in Malta carried out using STAN 2.5. The flows were then translated into a carbon footprint analysis using CO2ZW® tool. The objective was to emphasise the relationship between GHG emissions and existing waste management flows and identify how this relationship changes when different collection, treatment and disposal options are selected. The aim was to underline the importance of placing climate concerns in waste management policies.

The results indicate that, in terms of carbon emissions, Malta stands to benefit from the introduction of a second Mechanical Biological Treatment (MBT) plant since, based on 2012 estimates, there is expected to be an extensive reduction in carbon emissions. However, further reduction of carbon emissions should be accompanied by an increase in dry material recycling, separate organic collection and an analysis of the current collection system, particularly route optimisation.

Keywords

CO2ZW®, STAN 2.5, Waste Management Plan 2014 -2020, Greenhouse Gas Emissions

3.1 Introduction

The management of MW is complex. The multitude of generators and its varying composition makes the collection, disposal and treatment both multifaceted and problematic. On islands, issues with disposal and treatment are intensified by the definitive space challenges (Deschenes & Chertow, 2004) which greatly reduce the possibility to landfill waste (Zsigraiová et al., 2009); isolated geographies and limitations to outsourcing some of the waste streams (Eckelman et al., 2014) making recycling and recovery of materials problematic due to both the absence of a market for recycled materials and the distance from larger markets (Zsigraiová et al., 2009). This is why, for most islands, waste is a very serious problem (United Nations Economic and Social Council (UNESC), 1999). The limited availability of suitable locations, particularly in densely populated and tourist-dependent islands (UNESC, 1999; Agamuthu & Herat, 2014), render the demand for land rife with conflict.

An additional hitch, particularly when the island is tourist-dependent, is visual impact, with landfill sites often being in full view of tourist sites (Eckelman et al., 2014). Local authorities are, therefore, at a loss when it comes to finding solutions since waste issues seem to encompass "everyone and everything" and tend to magnify the Not In My Backyard (NIMBY) syndrome (Eckelman et al., 2014; Agamuthu & Herat, 2014).

The management of waste provides an administrative, societal and market challenge. It is also a source of environmental hitches which can become magnified on islands. The well-documented impacts include land and beach degradation, increased surface and marine pollution and increased risks for human health (UNESC, 1999). A perhaps less documented impact, but one that is gaining wider recognition, is the direct relationship that waste has with GHG (Chen & Lo, 2016). It is generally accepted that human activities have caused GHGs to accumulate in the environment (Chen & Lo, 2016). Excessive GHGs are the cause of more frequent occurrence of extreme weather which threatens the safety of human society and natural systems (Fischedick et al., 2014). Two of the sharpest spears created by global warming – flooding and draught – account for more than half of the world's deaths from a natural disaster (McCann Fenton, 2007). In the past, 1 million years, atmospheric CO_2 has ranged between 172 and 300 part per million (ppm). Now, the crossover for concentrations that stay above 400 ppm is nearly complete (McGee, 2015). Reducing GHGs is essential to ease global warming and achieve the sustainable development of human ecological and economic societies (Jiang et al., 2016). This is, however, an extremely complex problem for which there is no single solution. It is a noted fact that over time discussions about climate change mitigation have started and ended with energy consumption (Ackerman, 2000; Messenger, 2015). Although the ability of the waste management sector to reduce GHG emissions has been underestimated (Bogner et al., 2007), it has the potential to reduce GHG significantly particularly when a life-cycle approach is adopted (European Environment Agency, 2011) , that is, when GHG emissions are accounted for during the production and usage of a product, and, also, in its end-of-life phase during the treatment processes (Braschel & Posch, 2013).

The pivotal report, “Waste and climate change. Global trends and strategy framework”, published in 2010 by the United Nations Environmental Programme (UNEP) brought this idea to the forefront. It noted that the “waste sector is in a unique position to move from being a minor source to becoming a major saver of global emissions” (United Nations Environmental Programme (UNEP), 2010 p.1). The role of waste in GHG reduction is gaining centre stage both academically and politically. An example of this can be drawn an article authored by, Zeng & Chen (2016), which includes waste treatment as part of the carbon-industrial chain index that forms part of the overall low-carbon economy index evaluation. The garbage treatment rate, as referred to in the article, represents the absorption of carbon emissions and the prevention of secondary carbon dioxide generation after garbage treatment. The value of this index is expected to increase as treatment rate improves, therefore, strengthening the low-carbon economy. Politically, the relationship became more pronounced during the Paris Agreement negotiations, where the head of the International Solid Waste Association (ISWA), David Newman, noted that “after years of fighting for a seat at the table ……the contribution of waste is recognized for what it is – equally as important as renewable energy, electric cars and solar panels” (Newman, 2016). This assertion came particularly from donor countries who recognised that “waste was a critical issue to tackle” (Newman, 2016). Specific contribution from the waste sector can go towards short-lived climate pollutants such as methane, black carbon and hydrofluorocarbons (HFC) gases (Newman, 2016).

This research paper portrays the challenging relationship between MW and islands and accentuates the complexities involved in such systems. Furthermore, it emphasises the importance of giving GHG emissions due to attention during the inception of waste management policies. Focusing on MW management on the island of Malta, it presents two material flow analysis (MFA) and their respective carbon footprints to examine the current (using 2012 as a base year) and envisaged (2018) waste management flows and how the carbon emissions will change when alternative scenarios are implemented.

3.2 The management of Municipal Waste in Malta – Infrastructure and legal framework

Malta is an archipelago of six (6) islands with a total landmass of 316 km^2. Three of the islands are uninhabited, while most of the population inhabits the largest land-mass, Malta. The islands sustain a very high population density (highest in the EU and third in the world) which in the 2011 demographic review reached an average of 1,327 persons per km^2 (NSO, 2011). This stress is further accentuated by one million tourists every year (NSO, 2012). Malta joined the EU on 1st June 2004.

Malta’s membership in the EU exerted considerable influence on waste management. Before 2004, the management of waste formed part of Act XX of the 2001 Environmental Protection Act. The Act itself did not give extensive detail about how and what should be done in relation to waste. However, following EU accession, waste management became extensively regulated and confronted with various targets mainly falling under the

Waste Framework Directive (Directive 2008/98/EC transposed in Maltese legislation through Legal Notice 184 of 2011) and the Landfill Directive (Directive 1999/31/EC transposed through Legal Notice 168 of 2002). In 2014 the Maltese Government published the Waste Management Plan 2014 - 2020 which positions the parameters for the different waste streams with the aim of reaching the targets set by the prescribed directives.

As noted earlier, this study is focused on MW. The Landfill Directive defines MW as "waste from households, as well as other waste which, because of its nature or composition, is similar to waste from households". Further elaboration of this definition comes from Eurostat (2011) which points out that MW is waste mainly produced by households, though similar wastes from sources such as commerce, offices and public institutions are included. It notes that the amount of MW generated consists of waste collected by, or on behalf of, municipal authorities and disposed of through the waste management system' (Eurostat, 2012). Maltese legislation includes this observation in Legal Notice 184 of 2011 (transposes the Waste Framework Directive) which, in Article 4 specifies that "household waste refers to waste originating from (a) domestic property; (b) a residential home; (c) premises forming part of a university or school or other educational establishments and (d) premises forming part of a hospital or nursing home". The specific calculation is based on the European Waste Catalogue which includes items listed under Chapter 20 Municipal Wastes together with item 15 01 06 - mixed packaging (G. Mizzi, personal communication, November 11, 2013).

Therefore, MW includes the following types of material – paper, paperboard and paper products, plastics, glass, metals, food and textiles, together with bulky waste (e.g. white goods, old furniture, mattresses) and garden waste, leaves, grass clippings, street sweepings, the content of litter containers, and market cleansing waste if managed as waste (Eurostat, 2012). The management of waste in Malta creates considerable challenges. The high population density coupled with an intensive tourism industry leads to a higher than average MW generation rate. Although the seasonal population is not considered in waste management policies (Saladie, 2016), a study conducted in 2006 noted that tourists generate an average of 1.56 kg/person/day or 569 kg/person/year (Galdes, 2007). In 2012, the Maltese produced 590 kg per capita (the European average is 481 kg/capita (Eurostat, 2015) of MW. An examination of monthly flows shows an increase in July and August; however, further analysis is required. These factors, coupled with a small, physically separated, land area, leave very little space for landfilling (Falzon et al., 2013) and make the siting of other waste facilities difficult. Physical separation also means limited recycling capacity and resale market pressing recyclers to tap foreign markets and escalating costs. A final point of contention is aesthetics - waste and its management do not go well with the profit-generating tourism industry – apart from the pervasive litter scattered around the island, Maghtab, the main un-engineered, (now closed), dumpsite has reached a height that makes it visible from almost every part of the country.

In Malta, MW forms on average 14 per cent of the total waste generated. Although it is not the most prevalent type of waste, it is the most visible and troublesome residues of human society (Fischedick et al., 2014). This is due to its diverse composition, multitude collection points and disparate treatment processes which require various players, processes and tools that are not present in the collection of other types of waste, particularly since generators, are less dispersed and in some cases, the waste is more homogenous (Organisation got Economic Co-operation and Development (OECD), 2013).

After 2002, major developments were undertaken in the waste sector. The old dumpsite was closed, and landfilling commenced in a new engineered landfill with gas recovery known as Ta' Zwejra (Falzon et al., 2013). Upon exhaustion, another non-hazardous landfill known as Ghallis, with a 3 million m^3 capacity, was constructed (Ministry for Sustainable Development the Environment and Climate Change (MSDEC), 2013). In the case of Gozo, a waste transfer station for the receipt, sorting processing, interim storage and waste transfer was set up (Ministry for Sustainable Development the Environment and Climate Change (MSDEC), 2013).

Furthermore, a Mechanical Biological Treatment (MBT) plant (known as Sant' Antnin Waste Treatment Plant (SAWTP) was constructed with the intention of moving up the waste management hierarchy. However, a report commissioned to examine the operations of the facility highlighted the need to improve its efficiency since the plant has failed to generate the anticipated renewable energy (Mallia et al., 2013). One of the main causes cited was the quality of waste arriving from the 'black bag' (mixed waste) which contains a heavy load of non-organic material (Ministry for Sustainable Development the Environment and Climate Change (MSDEC), 2013). In April 2013, the then Malta Environment and Planning Authority (MEPA) approved the planning permission for a new MBT plant. The proposed facility aimed to have waste processed to extract the organic fraction and RDF (MSDEC, 2014).

3.3 GHG emissions, waste and related policy

The EU, with its pioneering role in environmental management, has not ignored the connection between waste and GHG and has adopted both an end-of-pipe and proactive approach through different instruments. The Landfill Directive obliges member states to reduce the disposal of biodegradable MW going to landfills to 35 per cent of the total amount (by weight) of biodegradable MW produced in 1995. This, in turn, has increased the popularity of MBT in Europe (Intergovernmental Panel on Climate, 2006), which is significant since waste material undergoes a series of mechanical and biological operations that, together with reducing volume, stabilises it to reduce emissions from final disposal (Intergovernmental Panel on Climate, 2006) and therefore significantly contributes to the reduction of GHG (Gosten et al., 2011).

A more proactive approach comes from the European Commission in COM (2014) 398 "Towards a Circular Economy: A zero waste programme for Europe". This document connects waste and GHG by intensifying technological innovation for processes, materials and products and resource management of raw materials through the promotion of waste reduction at source and recycling.

However, as noted by Zero Waste Europe (2015), further efforts are required. The report notes that "waste management policies are still not driven by climate concerns, even though the potential for GHG emission reductions through waste management is increasingly recognised and accounted for" (Ballinger & Hogg, 2015, p.5).

In Malta, the Waste Management Plan for the Maltese Islands 2014-2020, does not tackle the two areas jointly. However, the focus of the plan on increasing recycling and the introduction of source separation of biowaste to further process it in MBT and enhance its action to reduce food waste should assist in the reduction of carbon emissions.

3.3.1 Accounting for waste-related GHG Emissions

Malta signed the Paris Climate Agreement with the first wave of countries on 22nd April 2016 (United Nations, 2016). Although the Kyoto Protocol did not impose an emission reduction target on the island (Malta Resources Authority (MRA), n.d.), Decision 406/2009/EC, commonly known as the Effort Sharing Decision, which addresses anthropogenic emissions of GHG that are not covered by the EU's Emissions Trading Scheme (EU ETS), lays down the minimum contribution of member states (MSs) to meet the reduction commitment for the period from 2013 to 2020 for specific emissions. Malta is obliged to retain its emissions to +5 per cent relative to its 2005 levels until 2020 (MRA, n.d.). Therefore, since the CO_2 emissions from the two local energy plants fall under the EU ETS, Decision 406/2009/EC includes all non-carbon emissions from the two plants, together with emissions from road transport and domestic navigation, waste, agriculture, industrial processes, solvent and other product use, fuel combustion in industry and in the residential, institutional and commercial sectors, as well as fugitive emissions from fuels. These emissions currently account for approximately one-third of Malta's total GHG emissions (MRA, n.d.).

As an EU member state (EUMS), and in accordance with the EU's Monitoring Mechanism Articles 3(1) and 3(2) respectively, Malta has the obligation to submit an annual National GHG Emissions Inventory (National Inventory Report [NIR]) and a biennial report on Climate Change policies, measures and projections (also known as the Policies and Measures and Projections Report [PAMs] Report) (MRA, n.d.). The former is the key instrument used for the monitoring and reporting of emissions, both in terms of sources and of removals by 'sinks'. The latter, on the other hand, is to assess the projected potential progress by the MS on GHG emissions limitation and reduction up to a defined year (MRA, n.d.). The National GHG Emissions Inventory Report uses the First Order Decay (FOD) method, which is one of the two methods provided by the Intergovernmental Panel for Climate Change (IPCC) Guidelines.

The PAM report for Malta notes that in 2011, 88.5 per cent of total waste-related GHG emissions was methane. In view of this, the report notes that in 2008, landfill gas extraction infrastructure was installed to treat odour and noxious gas emissions from these closed sites in a regenerative thermal oxidizer. Landfill gas extraction is expected to continue until 2028 (MRA, 2013). Since landfill gas management is a condition of the IPPC permit for both facilities, both sites will be required to cap waste mass and carry out the extraction of gases for flaring or possibly combusted for energy generation (MRA, 2013).

Reports from the European Environment Agency (EEA) using the IPCC methodology under the NIR, note that the waste sector in the EU-28 in 2012 amounted to 3.3 per cent of total GHG emissions (EEA, 2012). In Malta, the waste sector reports an average of 4.6 per cent of total GHG emissions (MRA, 2013). A criticism often made regarding the IPCC inventory mechanism is that in the case of waste it caters for emissions generated within the country borders and covers impacts of landfilling, incineration, organic waste treatment and MBT. However, no reference is made to ‘recycling’ or ‘preparation for re-use’ or ‘re-use’. The “waste” section emissions are limited to the recordings of direct emissions from disposal/treatment systems, while several key impacts which arise from changes in the management of waste do not appear in this section. This also means that benefits arising from improved resource and waste management are effectively recorded under other sectors (Ballinger & Hogg, 2015).

3.4 Materials and methods

3.4.1 System boundary

The system is the actual object of the MFA (Brunner & Rechberger, 2005) and carbon footprint investigation. A system is defined by a group of elements, their interaction and the boundaries between these elements in space and time (Brunner & Rechberger, 2005). The system requires a temporal and spatial boundary (Brunner & Rechberger, 2005) together with a material boundary to specify which type of emissions will be accounted for (Braschel & Posch, 2013).

The focus of the system in this chapter is MW management in Malta. In the MFA, MW is divided according to the European Waste Code (EWC) classification discussed in 3.2. The research includes two MFAs– the first one is based on 2012 showing the system prior to the implementation of the Waste Management Plan 2014 – 2020. The second MFA focuses on the projected 2018 system while analysing three proposed scenarios, namely: (1) incineration; (2) export; and (3) landfilling of the mixed waste fraction. The two MFAs use the same system boundary. Therefore, the analysis will identify how the changes that were implemented (or changes that are planned) altered (or will alter) the flows and how this will affect the relative carbon footprint.

The same boundary is used for the carbon footprint analysis but includes urban and interurban transportation, with GHG emissions being calculated in carbon dioxide equivalents (Farreny et al., 2012). Urban transportation refers to collection from urban disposal points, while inter-urban refers to the transport of residual material from MBTs to landfill (Farreny et al., 2012) or export to foreign countries. A transport analysis was undertaken since GHGs are emitted in the combustion of fuel, during waste collection (bulk and selective) and when MW is distributed for treatment or export. Although waste carbon analysis seldom refers to transport because it is considered to be relatively insignificant (Falzon et al., 2013), it is necessary to acknowledge its contribution (Cifrian et al., 2012) particularly in view of the fact that the development of modern waste management systems in Europe has led to a remarkable increase in the distance covered (Salhofer et al., 2007). Bottlenecks in the regional treatment capacities and overcapacities in other regions, more complex collection schemes for the separate collection of recyclables and the longer distances covered to specialised treatment plants have contributed to this increase (Salhofer et al., 2007). The extensive increase in exports between 1999 and 2011 was also noted by the EU (EEA, 2012). Driven by policies such as the Packaging and Packaging Waste Directive (Directive 94/62/EC), which requires MS to recycle a minimum percentage of certain waste types, countries were incentivised to trade waste, particularly since recycling usually requires specific infrastructure such as sorting plants. Additionally, a critical quantity of waste is required to make recycling profitable (EEA, 2012). These factors, together with an un-optimised urban collection system, offered sufficient justification to include transportation in the analysis.

Both analyses take a lifecycle approach with the MFA providing a complete picture of the flows involved in MW management distinguished by category and following sequentially performed steps starting from the household collection, followed by treatment - through sorting facilities, biological treatment, landfilling and, in some cases, export (Braschel & Posch, 2013; Sevigné Itoiz et al., 2013).

3.4.2 Materials

The MFA is based on data provided by the then MEPA and WasteServ Malta Ltd. For the 2012 MFA, input and output data about the quantities of MW reaching the different treatment facilities was provided by WasteServ Malta Ltd. Data about exports was provided by MEPA.

Since the 2018 MFA is based on a proposed system, some of the data used are estimated based on 2012 figures, while other data is based on valuations prepared by the referred entities. The figure for the total MW generation (263,809 tonnes) is derived from the Waste Management Plan 2014 - 2020 (p. 208). This quantity is then divided according to the treatment capacity of different facilities. Inputs into the bulky waste, recyclables and the Gozo transfer station streams are estimations based on the 2012 figures. Figures for the inputs into the Malta North plant were obtained from the Integrated Pollution and Prevention Control (IPPC) permit application submitted to MEPA (WasteServ Malta Ltd., 2015).

Information for the carbon footprint analysis was based on the MFA's. However, additional information was required to determine the nature and efficiency of specific processes. In the 2012 CO2ZW® analysis, since there is no separation of organic waste, mixed waste is processed under MBT type 1 (22.9 per cent) while the remaining is landfilled (77.1 per cent). The lower efficiency of this practice (Farreny et al., 2012), is noted in the Review of Operations of the SAWTP (2013) which points out that both biogas production and compost (in view of the heavy metal content) are not of adequate quality (Mallia et al., 2013).

The 2018 analysis (applicable to all three scenarios) notes improved efficiency due to the introduction of biowaste separation. A point of contention was the efficiency of source-separated recycling material. Unfortunately, the operator of the MBT plant – WasteServ Malta Ltd – does not keep separate records of each fraction of the rejects and records only total figures. To obtain a better idea of the make-up of rejects, a sample analysis of the grey bag was obtained from MEPA which showed an efficiency of 94.6 per cent in the case of plastic, 88.7 per cent in the case of metals and 91.2 per cent in the case of paper and cardboard (D.Cordina, personal communication, January 13, 2015,). Since glass is not collected in the grey bag, a 1-month sample of discarded glass, taken by WasteServ officials, pointed to a 99 per cent efficiency (R.Grech, personal communication March 17, 2015,). In the case of the 2018 MFA, it was noted that the operator planned to introduce near-infrared (K.Ghio, personal communication July 6, 2015,); therefore, the sorting efficiency would be expected to increase to 98 per cent (Shelnick, n.d.).

The collection of transportation data offered another challenge. All the municipalities (68 in total) were contacted and asked for the route used for household waste collection; however, only three localities (Fontana [Gozo], Pembroke and Santa Lucia [Malta]) provided the relevant information. The general reply was that routes are left to the waste collector. When the waste collection companies were contacted, they confirmed that there were no fixed routes and that the driver decided on the route to take at any given time. To obtain an insight into what constitutes a typical route and calculate the distance covered, the author ventured onto the waste collection truck providing service in the locality of St Paul's Bay. This route, together with the provided three routes, served as a base for the calculation of the total kilometres covered during household waste collection.

The prevailing no-fixed route situation causes various problems with regard to collection times as sometimes drivers change the routes without prior notice to householders who, then, end up taking their waste out too early or too late[4]. In addition, no route optimisation measures are being implemented, despite the fact that route optimisation is one of the most common measures implemented to reduce GHG emissions during waste collection and transport (Braschel & Posch, 2013).

The number of routes per locality, which were worked out on the basis of total km of roads per locality, were used as a basis for the calculation of the total tonkm (tonnes x km) covered by the collection trucks daily. The routes covered for bring-in sites collection (kerbside bin facilities) were also worked out based on the map coordinates of every bin location (Tartaglia, 2015) with the distance covered by the trucks being calculated using Google Maps. In the case of export, the list of countries that import waste from Malta was obtained from MEPA and the distances covered by ships and trucks were calculated using Google Maps.

The CO2ZW® tool considers the waste collection truck used for *urban* waste collection to be a 21-ton diesel-run waste collection and hydraulic compression vehicle. Air emissions from fuel combustion are influenced by stop and go driving, tyre, brake and road lining abrasion (Farreny et al., 2012). In the case of *inter*-urban transportation,

4 In Malta, households are generally expected to take out their waste 1 hour prior to collection time

the emission factor considers the vehicle to be a diesel-run lorry (with a capacity greater than 16 tons). This vehicle does not require stop and go driving (Farreny et al., 2012). The CO2ZW® tool was adapted to account for freight transport emissions that were estimated at 0.116 kg/km of CO_{2eq} (Ecoinvent 2.2, 2015).

3.4.3 Methods

The MFA was carried out using STAN 2 Version 2.5©. STAN (short for subSTance flow Analysis). This MFA methodology was selected because it describes, investigates and evaluates the metabolism of anthropogenic systems. Additionally, it defines terms and procedures to establish material balances of a system (Brunner & Rechberger, 2005). Based on this methodology STAN 2 was utilized to demonstrate the MFAs graphically, making it possible to display the complex MW systems in a systematic manner (Cencic & Rechberger, 2008). The carbon footprint was calculated using the CO2ZW® tool. Although Malta currently uses the IPCC FOD method to do this calculation, the use of the CO2ZW® tool allows for the identification and quantification of emissions of waste-related GHG in carbon dioxide equivalents (CO_{2eq}) produced over the entire lifecycle (Sevigné Itoiz et al., 2013) The approach allows for the clear designation of emission sources thus avoiding any possible circumvention related to origin (Braschel & Posch, 2013).

3.5 Results and discussion

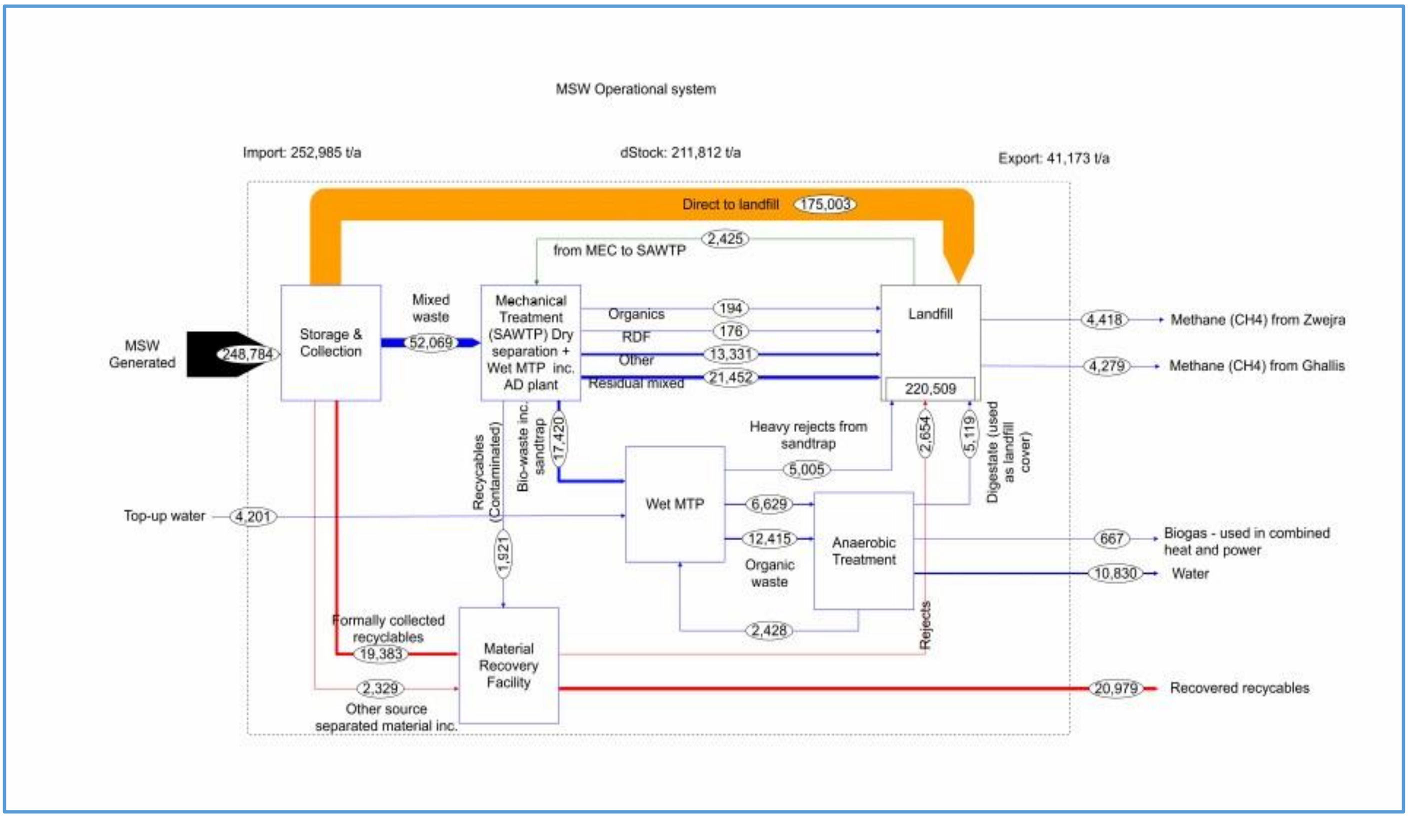
The MFA presented in Figure 3-1, is based on 2012 figures and shows a total MW input of 248,784 tonnes, out of which 41,173 tonnes are exported. Figures for water inputs are estimates since no official statistics are kept.

Figure 3-1 displays a system that is based on landfilling. The thick orange line shows a total of 175,003 tonnes of MW that are directly landfilled. The MBT receives 52,069 tonnes (blue line), out of which 35,153 tonnes (67.5 per cent) are also directly landfilled. The remaining 19,341 tonnes are sent to the Wet MTP (17,420 tonnes) and the Material Recovery Facility (MRF) (1,921 tonnes). A total of 21,712 tonnes of dry recyclables are separately collected (red line), while 2,425 tonnes (consisting mainly of dry recyclables) are redirected from the landfill back to the MBT.

Figure 3-1 illustrates a directed graph (left to right) with a waste disposal system that is predominantly linear. It is only 20,979 tonnes (8.43 per cent) of waste that is recovered as recyclables. As noted in the Review of Operations, 667 tonnes of biogas (generally of poor quality) are recovered (Mallia et al., 2013).

Since in 2012 there was no separation of organic waste a loss of resources is prevalent. MFA proves to be a valuable tool to use to assess the circularity of the system that is currently employed particularly in view of Malta's preparation for the Circular Economy package.

Figure 3-1: MFA of the management of municipal waste in Malta in 2012 (in tonnes)



Source: WasteServMalta Ltd and Waste Management Unit, MEPA

The MFA in Figure 3-1 also identifies the gas collected from Ghallis and Zwejra, the two engineered landfills together with the closed Maghtab landfill. Gas collected from Ghallis and Zwejra amount to 4,279 tonnes and 4,418 tonnes respectively. In the latter case, the gas has a higher calorific value in view of the fact that waste disposed of in the old land rise has a high content of construction and demolition waste, while in the case of the engineered landfills the waste consists mainly of mixed MW. Given this, a different treatment is used, namely the Regenerative Thermal Oxidiser (A.Casha, personal communication, September 2, 2014).

3.5.1 The 2012 CO2ZW® analysis

From the landfill-based MW system displayed in Figure 3-1, one can also deduce the carbon footprint that is mainly in the form of direct emissions. The CO2ZW® calculations show a total carbon footprint of 290,793 tonnes of CO2eq out of which 274,349 tonnes are direct emissions and 2,803 tonnes are indirect emissions. Transport emissions amount to 13,641 tonnes, while, in total, 14,568 tonnes of CO2eq is avoided.

Comparing indicators makes it possible to appreciate their value. The figures obtained for Malta were compared to the figures pertaining to Catalonia, Spain as both regions are affected by the seasonality of the tourism industry and have similar waste generation figures, with the Catalan region producing 1.35kg/capita/per day in 2012. Table 3-1 denotes that the figures pertaining to Malta are much higher than those pertaining to Catalonia (Inedit, 2015), however, this disparity is set to decrease with the introduction of the new facilities.

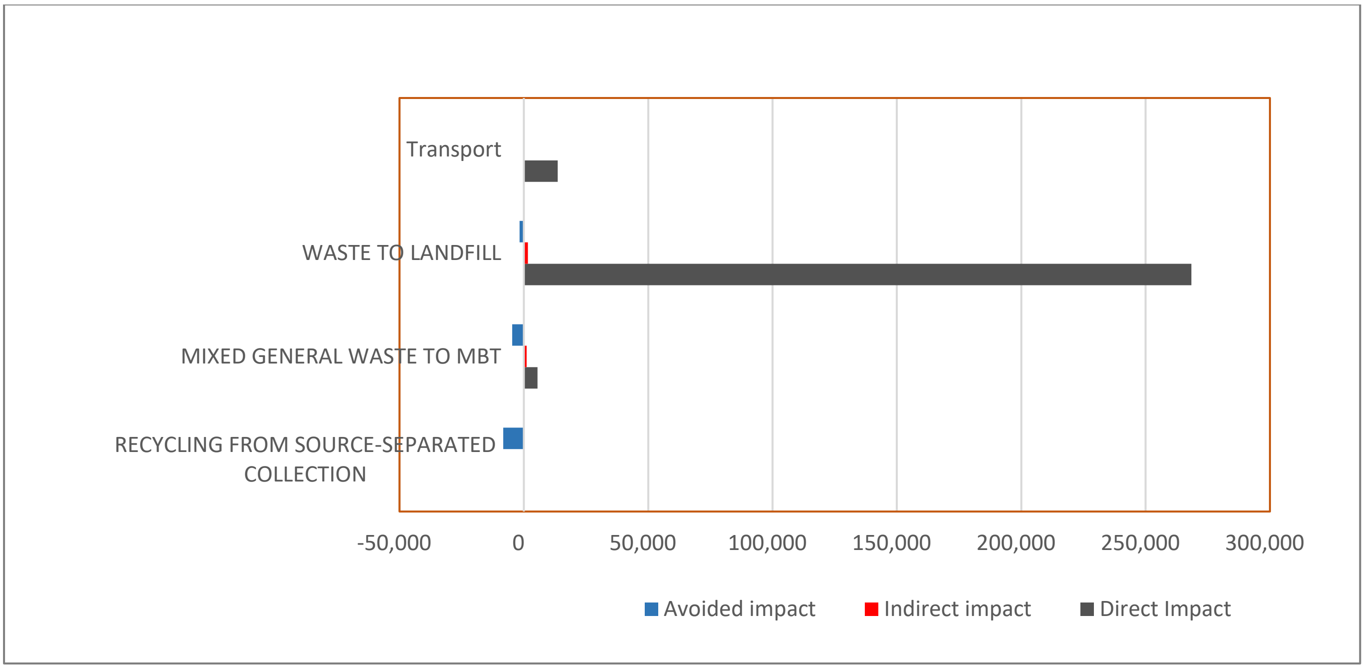
Table 3-1 Comparisons of CO2eq emission in figures from Malta and Catalonia

	Malta	Catalonia, Spain
CO2eq/tonne of municipal waste/year kg of CO2eq	1,169	401
CO2eq per inhabitant/year kg of CO2eq	690	191

Source: Authors' calculations & Catalonia Waste Agency

Figure 3-2 (below) shows the analysis of the carbon footprint per waste flow. Landfilling is the main source of direct emissions, producing 268,463 tonnes of CO2eq, while indirect impact amounts to 1,664 tonnes of CO2eq and avoided impact amounts to 1,694 tonnes of CO2eq. On the other hand, the mixed waste treated through the MBT causes a direct impact of 5,481 tonnes of CO2eq and an indirect impact of 1,049 tonnes of CO2eq, while recycling of source-separated collection reduces 7,778 tonnes of CO2eq. As noted earlier, transport contributes 13,641 tonnes of CO2eq or 4.9 per cent of the total emissions.

Figure 3-2: Flows of waste in Malta with their respective carbon footprint in tCO2eq



While some might argue that the 4.9 per cent of the total emissions produced by transportation should not be taken into consideration, it can be counterargued that transportation constitutes an inseparable part of an integrated MW management system and is part of every stage of the process from collection to final disposal (Braschel & Posch, 2013). These results correspond to those of the EU-27 where the collection and transport of waste account for less than 5 per cent of the estimated GHG emissions (Skovgaard et al., 2008). The economic and environmental problems associated with waste transportation include energy and fuel consumption and significant amounts of emitted pollutants (Zsigraiová et al., 2009). The research presented here is the first attempt to include waste transport-related emissions as part of the carbon footprint in Malta.

The importance of route optimisation should not be underestimated. Optimisation, together with the development of routes that meet each locality's needs, has led to savings of between 10 and 15 minutes of collection time (Mcleod & Cherrett, 2008)and an 11.3 per cent reduction in distance travelled by each garbage truck in some cases (Nguyen-Trong et al., 2017). Collection and transportation of solid waste often account for a substantial percentage of the total waste management budget (including labour costs) (Tavares et al., 2009). Depending on the geographical location and fuel price, this figure can reach 70 per cent (Ghose et al., 2006). Vehicles emit significant levels of undesirable atmospheric pollutant emissions, including carbon dioxide (CO_2) and nitrogen oxide (NO_x) which contribute to GHGs and acid rain respectively. In conclusion, optimisation yields both environmental and financial benefits (Tavares et al., 2009) and deserves attention not least because public institutions are increasingly expected to apply the principles of economy, efficiency and effectiveness (García-Sánchez, 2008), to communal waste removal services which are expected to meet essential environmental and social demands for GHG reduction and sustainable resource management (Gosten et al., 2011). The Waste Management Plan 2014 - 2020 notes that "a study to determine the ideal size/s of Refuse Collection Vehicles to reflect dimensions of Maltese roads and their respective standards" will be commissioned and that municipalities will be required to integrate green public procurement in their criteria (MSDEC, 2014).

3.5.2 Material Flow Analysis of the proposed 2018 system(s)

The Waste Management Plan 2014 – 2020 sees the introduction of several facilities to assist with the treatment of waste. An overview of these facilities is provided below:

A Mechanical Biological Treatment Plant (MBT-AD) (known as Malta North) started operations in 2016. The plant is coupled with an Anaerobic Digester (AD) which can process either MW or at source separated biowaste in a series of mechanical and biological treatment steps (WasteServ Malta Ltd., 2015). The plant (denoted in pink in Figure 3-3) handles 76,000 tons/year of MW with 15 per cent allowed for extra capacity (S. Dimech, personal communication, October 15, 2015). It was designed to recover recyclables (e.g. metals), produce RDF, recover energy from the Combined Heat and Power (CHP) plant fuelled by biogas and produce a refined digestate. A biogas CHP plant is included to maximise energy recovery. It was also designed in a way that allows electricity to be exported to the grid, while waste heat from the exhaust systems could be used within the process (WasteServ, 2013). The waste is processed to extract the organic fraction and RDF with the remaining waste which shall be directed from the landfill (MSDEC, 2014). The plant can handle 47,000 tons/year of bulky waste (denoted in orange in Figure 3-3), 35,000 tons/year manure and 4000 tons/year poultry dung (C. Toscano, personal communication, June 12, 2015).

In Gozo, it was planned to introduce a waste transfer station for the receipt, sorting, processing, interim storage and transfer of wastes with a capacity of 11,800 tons (MSDEC, 2014). The transfer station was planned to have three main functions and would allow for closed environment processing – (1) the pre-treatment of dry recyclables; (2) the hermetic sealing of MW; and, where possible, (3) the shredding of bulky waste. All materials would then be transferred to Malta for further treatment (Association of Cities and Regions for Sustainable Resource Management (ACR+), 2015).

Further to the technologies described above, additional treatment options would be required to deal with the fractions generated from the facilities themselves (RDF and, rejects from MBT and MRF plants) and, the non-recyclable/non-recoverable waste that remains once the available capacity is exceeded.

The Waste Management Plan 2014 - 2020 points out that these waste streams will be managed using any one or a combination of the following options: (1) the introduction of a waste-to-energy 120,000-tonne facility; (2) increasing export of recyclable materials and refuse-derived fuel (RDF) and the material recovered from the MBT mainly for energy recovery and (3) the landfilling of all material.

The projected MFA is shown in Figure 3-3. Similar to, Figure 3-1, it presents a directed graph which runs from left to right with all the figures being presented in tonnes. According to the projections made in the Waste Management Plan 2014 - 2020 in 2018 MW generation was expected to reach 263,809 tonnes (MSDEC, 2013), while the population was expected to reach 438,166 inhabitants (Eurostat, 2015).

The additional treatment facilities and the introduction of separate biowaste collection denote a more complex treatment system than that presented for 2012. Figure 3-1 denotes Option A which focuses on the introduction of a 120,000-tonne Energy from Waste (EfW) facility (green line) and a new MBT (Malta North) plant (pink line).

The heavy green line signifies that the EfW facility would handle most of the mixed waste. A separate collection for biowaste was launched in 2015 in five localities and was later extended to other localities. The system requires that the organic waste fraction be collected three times a week from households and recyclables be collected through the existing grey bag system and kerbside (bring-in sites) collection system (MSDEC, 2014). A 30 per cent success rate is assumed for the separate biowaste collection. This is based on the Catalonian experience where a door-to-door waste collection and the bring-in system was introduced in 2008 (Regions for Recycling, 2014).

Figure 3-3 displays how different fractions would be treated. Taking a top-down approach, the first fraction represents (orange line) bulky waste. Based on 2012 figures, it is estimated that 25,632 tonnes would be generated. Following treatment, these would be divided into 12,327 tonnes of RDF, 7,420 tonnes of recyclables and 5,885 tonnes of rejects which would be landfilled.

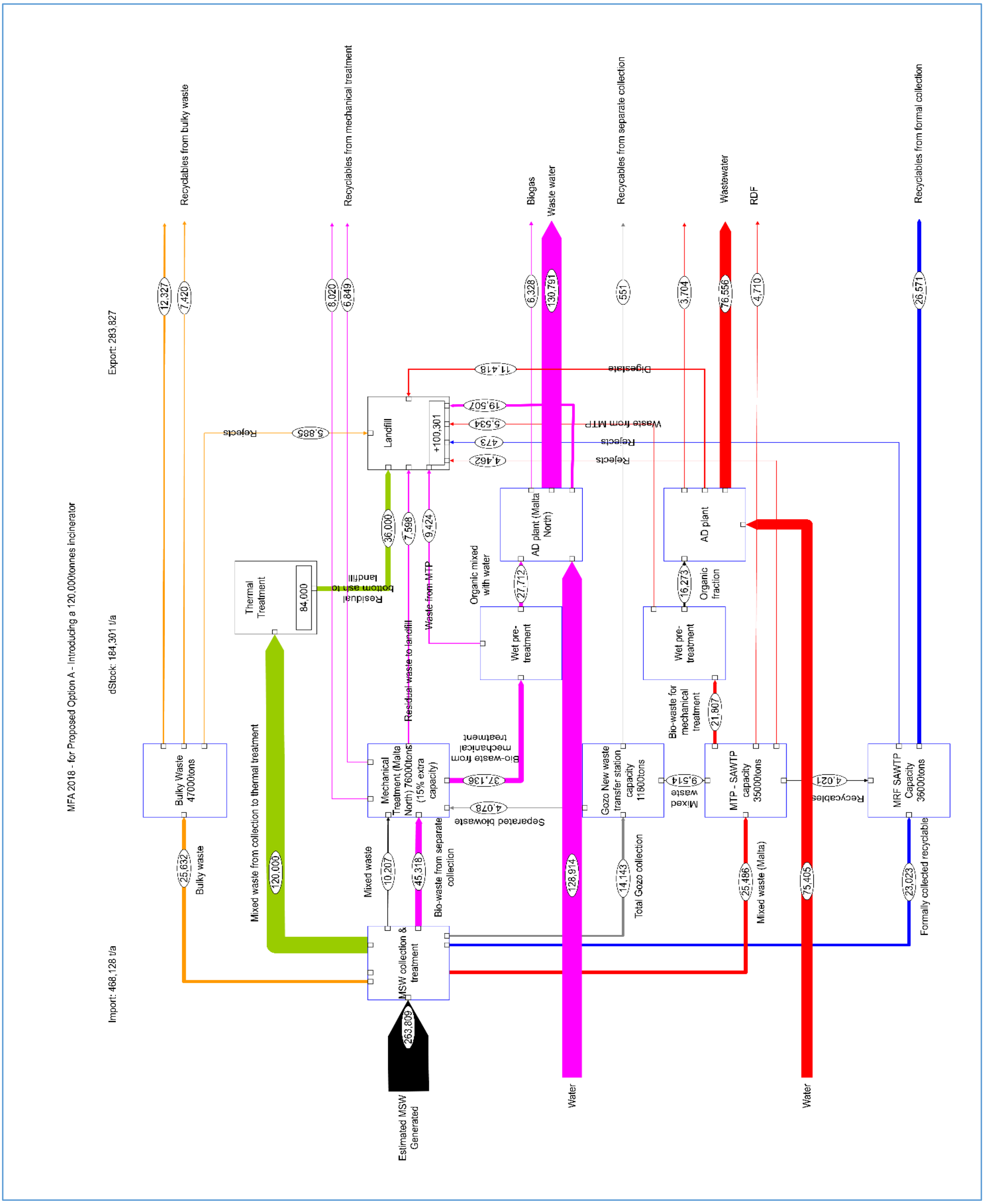
The heavy green line shows the thermal treatment facility which is expected to handle 120,000 tonnes of waste p.a. Incineration eliminates the organic part which means that the final products of the combustion are no longer reactive making the waste chemically and physically stable (Pelloni, 2014). Assuming a weight reduction of 70 per cent (MSDEC, 2014), 36,000 tonnes of bottom ash per annum would need to be landfilled.

It is assumed that the MBT facility (Malta North) (pink line) will handle a total of 59,603 tonnes, out of which 10,207 tonnes would be mixed waste, while 49,396 tonnes (45,318 + 4,078 tonnes) would be separated biowaste. Figure 3-3 shows that residual waste to landfill amounts to 7,598 tonnes and 9,424 tonnes (waste from MTP) would be landfilled while 8,020 tonnes and 6,849 tonnes would be processed into RDF and recyclables respectively. Figures for water are based on the IPCC permit application (WasteServ Malta Ltd, 2013).

The Gozo waste transfer facility (grey line), would handle an estimated 14,143 tonnes, out of which 551 tonnes would be recyclables. At a 30 per cent success rate, 4,078 tonnes would consist of separately collected bio-waste which would be processed at the Malta North Facility, while 9,514 tonnes would be mixed waste and would be treated at the SAWTP. The SAWTP (red line) would be handling 35,000 tonnes, which would generate 4,710 tonnes of RDF, while 4,462 tonnes would be rejects and would, therefore, be landfilled. The MRF would handle 27,044 tonnes. In this case, 473 tonnes would be rejected and sent to landfill, while 26,571 tonnes would be exported.

The 2018 MFA shows that, although no direct landfilling would take place, following the different treatment processes, 100,301 tonnes would still need to be landfilled. Furthermore, Figure 3-3 assumes that RDF would be exported. If this waste had to be landfilled, additional space for 25,057 tonnes would be required. Figure 3-3 also shows that more effort is required to increase the assumed 30 per cent success rate since the denoted system needs to handle large quantities of mixed waste while operating under capacity in the case of separated recyclables and bulky waste. This also requires that the Malta North facility handles 10,207 tonnes of mixed waste with the clean biowaste fraction, leading to a less than desirable digestate.

Figure 3-3: A flow analysis of the first proposal system in the Waste Management Plan 2014 -2020 presenting Option A - introducing a waste-to-energy plant (in tonnes)



Data Source: WasteServ Malta Ltd and Waste Management Unit forming part of the MEPA

An MFA representing Option B, that is, the export of mixed waste would see the line denoted in green redirected outside the system boundary for export purposes. Selecting Option B would mean that the 120,000 tonnes of mixed waste which, under Option A (Figure 3-3), would be incinerated, must be exported, most likely for incineration (in view that the waste is mixed). This means that 329 tonnes of mixed waste would need to be exported every *day*, making the process both administratively and financially burdensome.

Selecting Option C, that is, introducing an additional landfill, would see the line denoted in green redirected towards the landfill. This means that an additional 120,000 tonnes of mixed waste would need to be disposed of every year, causing the total landfilled waste amount to reach 170,258 tonnes. In an island where space is very limited, a new landfill siting would be subject to extensive scrutiny and widespread NIMBY-ism complicating this option from inception. It should be noted that the current landfill facility is expected to last until 2020 with the present landfilling rate of 0.27m^3/year (MSDEC, 2013).

The three options also mean a different carbon footprint. The results are presented in the table below:

Table 3-2 Results of carbon footprint analysis under different scenarios

	Total carbon footprint tonnes of CO2eq	Kg CO2eq/inhabitant-yr	Kg CO2eq/ton-yr
2012	290,793	690	1,169
2018 Option A scenario – Introduction of a 120,000ton energy to waste facility	95,468	218	362
2018 Option B scenario – Export of waste	105,753	241	401
2018 Option C scenario – Landfilling of waste	125,580	287	476

Data Source: WasteServ Malta Ltd and Waste Management Unit forming part of the MEPA

Table 3-3 GHG emission analysis of the 2012 and the three 2018 scenarios as per CO2ZW

	Source separated waste (t CO_{2eq})	Mixed general waste to MBT (t CO_{2eq})	Incineration (t CO_{2eq})	Landfill (t CO_{2eq})	Transportation (t CO_{2eq})
2012	-7,778	1902	28	268,432	13,641
Option A – Introducing a 120,000-tonne incinerator	-11,218	-7,599	37,677	17,728	13,905
Option B – Export of mixed waste for incineration	-11,035	-10,392	40,345	23,516	14,088
Option C – Introducing an additional landfill	-12,559	-10,414	777	97,947	13,905

Introducing an incinerator generates a carbon footprint of 95,468 tonnes of CO_{2eq} with a direct impact of 76,521 tonnes, while the indirect one amounts to 5,042 tonnes. Avoided emissions amount to 44,975 tonnes. Transportation generates 13,905 tonnes.

Option B denotes an increase in the carbon footprint, which would amount to 105,753 tonnes of CO_{2eq} resulting from the increase in the use of transport. Direct emissions amount to 86,638 tonnes, while indirect emissions amount to 5,028 tonnes. Avoided emissions reach 49,230 tonnes. In this case, transport contributes to 14,088 tonnes of CO_{2eq}, while in the two other options, it contributes to 13,905 tonnes. Since exports are mainly carried by ship, the CO2ZW® tool was amended with freight transport emissions calculated at 0.116 kg/km of CO_{2eq} (Ecoinvent 2.2, 2015). As the CO2ZW® analysis takes a lifecycle approach the calculation also includes the emissions from the incineration of mixed waste that is exported to other countries.

Under Option B, CO_{2eq} per inhabitant would amount to 241 kg while 362 kg of CO_{2eq} per tonne of waste is generated. Landfilling would generate 23,516 tonnes of CO_{2eq}, while CO_{2eq} generation from incineration would amount to 40,345 tonnes. Recycling, on the other hand, would save 11,035 tonnes of CO_{2eq}, while waste processed in MBT plants would save 10,392 tonnes of CO_{2eq}.

If an additional landfill were to be built, the total carbon footprint would reach 125,580 tonnes of CO_{2eq}, with direct impact amounting to 106,215 tonnes and indirectly impact reaching 5,460 tonnes. The avoided impact would amount to 35,924 tonnes, while transport would generate 13,905 tonnes.

In Option C, the total CO_{2eq} emissions amount to 125,580 tonnes out of which 106,215 tonnes are direct while 5,460 tonnes are indirect. In this case, avoided impact amounts to 35,924 tonnes of CO_{2eq}. Choosing this option means that a total of 287 kg of CO_{2eq} per inhabitant or 476 kg of CO_{2eq} per tonne of waste is generated. This option would also entail locating a site for a new landfill, a task which will not prove to be easy.

3.6 Conclusions

MW is not homogenous and therefore requires several systems to handle and treat it. This can be noted in the two MFAs presented, which, despite their complexity, provide a detailed picture of every process starting from collection to disposal and/or export.

The scenarios presented for 2018 clearly illustrates that source separation of both dry recyclables and biowaste needs to be augmented. With the current figures, both the bulky waste facility and the MRF are running under capacity. In addition to this, the assumed 30 per cent biowaste separation rate, would still require that mixed waste is processed with the clean fraction leading to less than desirable digestate output.

The carbon footprint analysis brings out the importance of taking GHG emissions into consideration when designing waste policies. The close relationship between the two factors can be noted since most waste management technologies and processes are sources of GHGs. These can be reduced by minimising landfill gas emissions and transport or by reconfiguring the system through, for example, the avoidance of landfilling, and redesigning collection routes. Such measures would result in savings which are usually gained outside the waste management system, leading to an environmental benefit at the societal level (Gentil, Clavreul, et al., 2009).

Sorting MW prior to collection has been the preferred approach (Chen & Lo, 2016) in various countries. Both the separation of recyclables in the MRF and biowaste are of great benefit in terms of lowering GHG emissions. This is backed up in the carbon footprint studies for the three options presented, where the recycling of dry material saves an average of 11,604 tonnes of carbon equivalents while the treatment of separated biowaste saves an average of 9,468 tonnes of CO_{2eq}.

It can, therefore, be concluded that the new MBT facility would benefit the Maltese Islands. The new site is in the disused Maghtab landfill and, since it is already in a derelict state, will have minimal impact on the surrounding environment. Even assuming a 30 per cent biowaste separation success rate, carbon emissions would be reduced in all the three options presented.

The 2018 options analysis points out that the introduction of a 120,000-ton incinerator would have the lowest carbon footprint. However, in the case of a small island state such as Malta, the decision cannot exclude the land footprint requirements. The analysis of the three options presented notes that landfilling waste would cause the highest carbon footprint and would also make an extensive demand for land.

Transport accounts for an average of 13,966 tonnes of CO_{2eq}. A definite improvement would be to work on route optimisation of daily waste collection. Presently, in their procurement process municipalities, specify that trucks must have Euro 3 or 4 specifications (A. Agius, personal communication, March 27, 2015), however, routes are left entirely in the hands of collectors, leaving room for extensive improvement.

All in all, the management of waste in Malta remains a constant challenge. The size and population density of the Maltese Islands play an important role in waste-related decisions. However, this research has proven that the use of MFA tools and carbon footprint analysis can effectively guide waste management policies towards improved efficiency.

Chapter 4

An assessment of the economic and ecological connections of waste generation in the Maltese Islands. An input-output approach.

Abstract

Waste generation is intrinsically connected to economic activity. This research applies the Leontief demand-driven input-output model to provide a comprehensive examination of the relationship between economic activities and waste generation using the year 2010 and the Maltese Islands as a case study. The analysis provides an economy-wide examination where estimates are used to indicate how a one-million-euro increase in final demand would impact waste generation, both directly and indirectly. The construction sector registers the highest waste multiplier, with a total of 1650.34 tonnes of which 1385.32 is direct waste. This is followed by 'other services' which has a waste multiplier of 222 tonnes. The analysis also examines the impact that the economic activity has on treatment and disposal facilities, with the worst consequences being landfilling and disposal-at-sea. Finally, a waste intensity multiplier is developed for every economic sector. The results show that the waste implications of every economic activity and assist in determining which activity might be unfeasible from a waste perspective for an island economy that is restrained by size and population density which is seeking to shift towards a circular economy.

Key Words

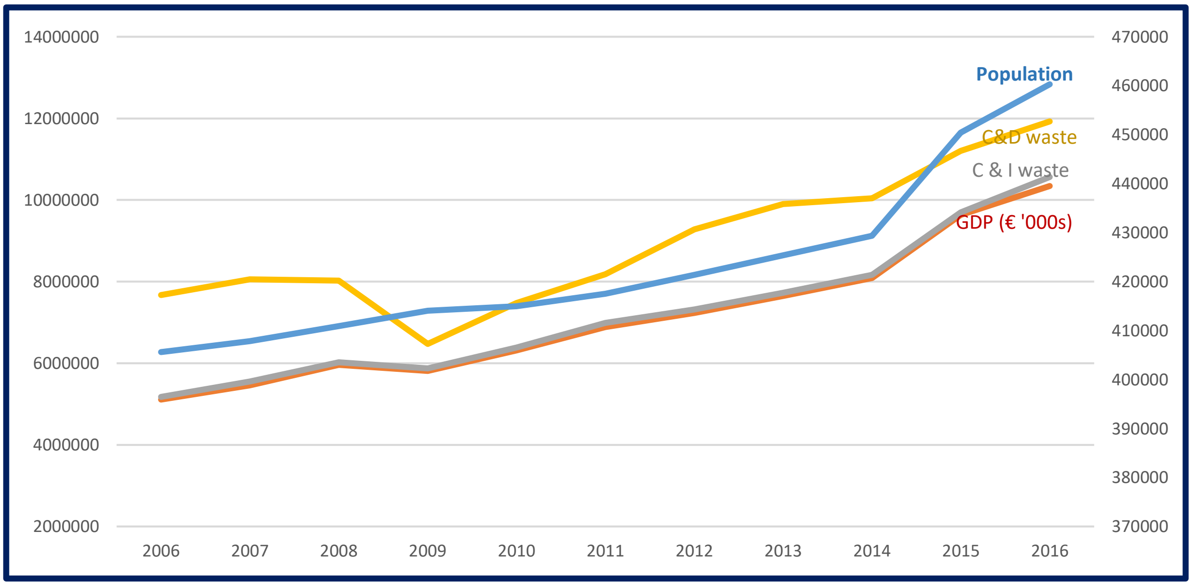
Input-output methodology, waste multiplier, economic growth, waste intensity indicator, circular economy

4.1 Introduction

The positive relationship between waste generation and economic shifts is generally portrayed in graphs that exhibit the close relationship between waste and Gross Domestic Product (GDP) Figure 0-1. Despite its simplicity, Figure 0-1, portrays a close connection between unrivalled economic growth and direct waste externalities. The indelible impact exerted on the environment has led to heavy criticism of the traditional economic model and amplified demands to move away from it. A remark, made in the renowned Bruntland Report (WCED, 1987, p. 7) – 'Our Common Future' – sealed the need to retreat from the traditional emphasis on unabated economic growth:

> *"What is needed now is a new era of economic growth - growth that is forceful and at the same time socially and environmentally sustainable – one that must be based on policies that sustain and expand the environmental resource base".*

Figure 0-1 Generation trends in C&I and C&D waste between 2006 and 2016



Source: ERA & NSO (GDP is expressed in €'000s, C&D and C&I waste in tonnes)

Few will argue that the pursuit of economic development at all costs will not yield undesired externalities and result in outcomes that veer well away from the principles of sustainable development (Hamilton & Kelly, 2017). The perception that intensification of economic activities has a direct positive relationship with improved quality of life generally fails to take the pollution that is the by-product of such economic activities into account. Therefore, to sustain economic growth, pollution issues must be "solved" (Johnson et al., 2011).

The research presented here examines the waste generation scenario within the context of economic development in the Maltese Islands based on the year 2010. Since the acquisition of Independence in 1964, the Maltese economy registered an eleven-fold improvement in nominal GDP/capita – from €1,600 in 1964 to €17,300 in 2014, with private and government consumption registering a nine-point and eleven-point increase respectively (Grech, 2015b). EU accession also resulted in a shift in the industries that made the largest absolute increase in Gross Value Added (GVA) and employment. In fact, prior to accession, construction, real estate, financial services, education and public administration contributed with 39 per cent increase in value-added and 88 per cent increase in employment. In the following decade, these shifted to computer programming, legal and accounting services, gambling and betting, financial services and education. Together, the latter made a joint growth of 49 per cent in value-added but only a 25 per cent increase in employment (Grech, 2015a). However, shifts in the Maltese economy were caused by the introduction of a large swathe of innovative services and not the disappearance of prevailing industrial operators, for example, traditional industries such as agriculture and fisheries, despite a 50 per cent decline in the share they commanded during the last two decades, witnessed a 47 per cent increase in value-added (Grech, 2015a).

In Malta, the literature linking waste to the economy is very limited. An initial contribution is registered in the proceedings of a 2008 seminar entitled 'Waste management and a viable economy' which highlighted the importance of putting a value on waste through the Eco-Contribution Act (now-defunct). The proceeds emphasise the fact that efficient resource use is crucial to building a sustainable economy (APS, 2008). Conrad & Cassar (2014) put several indicators under the magnifying glass in an attempt to understand the strength of the link that cojoins the economy with the environment and the resulting spectrum of environmental impacts. The study also examined the nature and extent of the decoupling of the two factors. An analysis of the total amount of waste managed between 2005 and 2012 per unit of GDP and per capita points to a sharp decrease in 2009 followed by an increase between 2010 and 2012 (Conrad & Cassar, 2014).

The Maltese Islands provided an ideal scenario for this analysis, given the extensive growth experienced since the 1964 Independence that resulted in several negative externalities, not least a significant increase in waste generation. The problem of waste was, however, approached in an out-of-sight, out-of-mind manner, with precedence given to economical activity. This meant that waste was often rendered 'invisible' or possibly explained in theories and models that related to waste in a marginal manner (Gille, 2010).

Using the Leontief input-output analysis (IOA), as a foundation, more specifically the Leontief demand-driven model, the research aims to provide an in-depth examination of the connection that waste generation has with economic intensification and how this impacts treatment facilities.

This study aims to characterise the physical dimension of the economy. It can serve as a basis upon which to establish targets for waste prevention and recycling (Moriguchi, 2007). It also provides an in-depth examination of the connection that waste generation has with economic intensification and how this impacts treatment facilities. The results assist in the setting of targets resource efficiency targets and help redirect economic policy towards increased sustainability. The research does not aim to contribute to IO methodology but to illustrate the ability of this methodology to highlight the interdependence of waste generation to shifts in final demand and to assist in shifting the economy towards improved sustainability.

The research uses the methodology applied by Butnar and Llop (2007) in their study on greenhouse gas emissions (GHG) in Spain. A similar methodology can be transferred to the waste generation classified by the industry of origin and treatment methodology. In Butnar and Llop (2007), allowance is made for GHG impacts by assuming a matrix of pollution output or direct impact coefficients, where each element represents the amount of pollution generated per dollar's worth of industry output. Furthermore, a 17-sector industrial division is used to quantify the changes in emissions and their relative composition when there is a shift in exogenous final demand. These factors, together with the objective set for this research (to provide an in-depth examination of the connection that waste has with economic intensification and its impact on waste treatment facilities), made it possible to adapt the approach taken by Butnar and Llop (2007) to the Maltese situation. Additionally, while other research, for example, that presented by Liao et al. (2015) had at its disposal an extensive waste generation database that allowed them to build a high-resolution WIO, in the case of Malta the data was limited and Table 0-1 needed to be compiled by the authors, necessitating a 17-sector analysis.

The waste problem has intensified on a worldwide basis. In Malta, the problem was exacerbated by the economic expansion experienced in recent years. The open nature of the Maltese economy[5] means that control over the characteristics and composition of the waste generated is limited. The geographical, physical and population constraints of Malta give this study particular relevance because, while larger countries can afford to shift waste to their peripheries, possibly making the issue appear to be a marginal problem of modern economic production and consumption functions (Savini, 2019), this is not possible for an island the size of Malta. This applies to other islands that are unlikely to host the same dense population but face similar physical and geographical constraints. In Malta, the approach adopted to waste management is strongly based on landfilling, a fact that contradicts the constraints discussed earlier. Additionally, industrial operational processes remain, in their majority, linear (Camilleri-Fenech et al., 2020).

Further to the IOA, the research establishes waste intensity indicators between 2010 and 2016 for 5 NACE sectors. These performance and production side indicators can serve as a measure of waste intensity pertaining to each economic sector and can be used to provide answers to questions such as how to boost recycling rate or divert waste from landfill and demonstrate if any possible decoupling between waste and economic growth has taken place.

Ultimately, the study emphasises the necessity for an integrated approach between economic and environmental policy to achieve a win-win situation where upstream (source) factors and downstream (sinks) factors are concurrently accounted for (Moriguchi, 2007). While in the case of Malta, this is of particular value because of its geographic and physical constraints, other countries are also facing continuous challenges with waste generation. The methodology allows for the examination of all sectors simultaneously and identifies which sectors are the major contributors to waste generation (Song et al., 2018). This approach can, therefore, be of assistance in the restructuring of economic development (Miernyk, 2020) and could help guide policymakers on which economic sectors to invest in on the basis of which have the least externalities and therefore increased sustainability.

4.2 Materials and methods

4.2.1 Materials

The research is based on 2010 figures. This is in view of the fact that the National Statistics Office's (NSO) Supply, Use and Input-Output Tables (NSO, 2016) are referenced to this year. Waste generation data, including treatment figures when exported, were supplied by the National Statistics Office and the Waste Management Unit within the Environmental Resources Authority (ERA). Minor statistical clarifications were made with WasteServ Malta Ltd.

5 Already at Independence, exports and imports were the equivalent of 165 per cent of GDP (Grech, 2015b) with the figure reaching 271 per cent in 2018 (NSO, 2019).

The tables were aggregated into a 17 industry-by-industry Supply Input-Output Table (SIOT) which follows the European Statistical Classification of Economic Activities (NACE) Rev 2 of 2010 SIOT published by NSO (2016) which classifies economic activities corresponding to International Standard Industrial Classification of All Economic Activities Rev. 4 at European level (NSO, 2014). The imports and the domestic production tables were summated in view of the fact that the items listed in the imports table refer to materials imported by economic sectors to supplement production and therefore contribute to process waste. This is of particular relevance to Malta's open economy. Furthermore, the approach corresponds to the life-cycle methodology, whereby waste generated is assessed from the various economic sectors until it reaches its final treatment, including export.

In the methodology NACE Sector E 38-39: water supply, sewerage, waste management and remediation was individualised and excluded. This follows the WIO construct of Nakamura and Kondo (2002, 2009, p. 161) and the approach adopted in similar studies, namely, Salemdeeb, Al-Tabbaa, and Reynolds (2016). Therefore, the research is limited to flows of inputs from the environment into the economy and flows of ecological commodities[6] which focus specifically on solid waste from the economy into the environment. This avoids issues of double-counting since the output from Sectors B-E excludes Sectors 38-39 which refer to waste management and remediation activities and, therefore, their inputs originate from within other economic sectors. In Malta, the sector is limited to material treatment and recovery. This means that items falling under Chapter 19 00 00 of the European Waste Code (EWC) including rejects Refuse Derived Fuel (RDF) and other wastes arising from mechanical treatment are not included in Table 0-1. Sectors 37-39 were also excluded in the Intermediate Demand table. In 2010, waste managed by Sector E:38-39 reached 35,595.64 tonnes. Table 0-1 refers to process waste (listed as C&I and C&D waste) including hazardous waste generated in 2010. Waste figures listed under Chapter 20 of the European Waste Code (EWC) referring to Municipal Solid Waste (MSW) are excluded. MSW refers to "mixed and separately collected waste from households" which "does not include waste from production, agriculture ... or construction and demolition waste" (European Parliament and Council, 2018). WIO methodology, on the other hand, emphasises the economy's production side, accounts for the interdependence between industries and focuses on upstream environmental impacts (production-related waste), not consumption (Kitzes, 1987). Furthermore, C&I and C&D waste are classified according to the European Waste Code (EWC), with their origin allocated according to NACE Rev.2. This categorisation does not exist for MSW since it refers to waste originating from households that are acting as consumers, not producers. Therefore, it is not possible to classify MSW according to the NACE code. This means that the inclusion of MSW in Table 0-1 is not viable.

While the figures in the input-output tables are taken as given by the NSO (excluding Sector E), the sectoral waste generation and treatment table had to be compiled. A table supplied by NSO, listing waste according to NACE sector and type, together with waste generation figures allocated according to EWC supplied by ERA with minor clarifications from Wasteserv Malta Ltd, were reviewed and collated by the authors. As noted in Directive

6 Miller and Blair (2009, p.473) refer to non-market materials inputs extracted from the environment and outputs generated during interindustry production processes as ecological commodities. These are measured in physical units.

2018/851 "Industrial waste, certain parts of commercial waste and extractive waste is extremely diversified in terms of composition and volume." Figures for C&I waste were highly fragmented; for example, in 2010, used oils from the agricultural sector amounted to 0.34 tonnes, while healthcare and biological waste reached 231.54 tonnes. This means that the figures shown in Table 0-1 needed to be drastically aggregated, particularly in the case of Sector B to E-Production. Although the data aggregation simplifies the analysis and facilitates transferability, it provides a low-resolution table. In a high-resolution analysis, more sophisticated waste types and treatments are accounted for, thus making it possible to outline the flows of detailed waste streams into their corresponding treatments and identify waste embodied in those streams that are driven by each category's final demand (Liao et al., 2015). Furthermore, the use of a high-resolution WIO analysis to examine the embodied waste of various drivers enables the assessment of the influence of detailed final demand categories on the direct and indirect generation of specific waste types. This facilitates the practical planning of prospective waste management strategies (Liao et al., 2015). A low sector resolution, on the other hand, means that tracing impacts associated with particular sectors might not be possible (Kitzes, 1987).

Table 0-1 also specifies the treatment or disposal method to indicate whether waste fractions are composted, recycled, landfilled, etc. In some cases, the fractions were already categorised according to NACE[7]; in other cases, however, only the respective EWC is provided. Classification, in this case, is based on Annex II of the WFD.

In Section 4.4, a waste intensity indicator of the production phase is calculated from the waste generated (in tonnes) for the manufacturing and services sectors when compared to GVA (in million euro) (EEA, 2015). No waste intensity indicator is developed for the MSW in view of the fact that this covers the consumption phase (EEA, 2015). These indicators, considering the issue of time-lag, between the publication of input-output tables and the resulting input-output analysis, provide a timelier estimate of the direct waste impact per euro of GVA at a sectoral level.

The Waste Management Plan for the Maltese Islands 2014–2020 (WMP) (p.72) refers to C&I as "waste from industries such as factories and industrial plants and commercial waste arising from activities of wholesalers, hotels and catering establishments and the service sector, of which these can be hazardous". The plan notes that, between 2004 and 2011, waste was mainly landfilled but also pinpoints that this might be "somewhat misleading as a high percentage of C&I waste was captured under MSW data" since C&I waste was being classified under Chapter 20 of the EWC. Finally, the WMP points out that the storage of waste, particularly metals, was a common practice, as these were generally exported when the right opportunity arose depending on international market prices (MSDEC, 2014).

C&D waste refers to 'mixtures of concrete, bricks, tiles and ceramics' together with 'waste gravel and crushed rocks' and 'dredging spoil', which do not include hazardous substances and are, therefore, inert. The Landfill

[7] The NACE classification is already assigned to C&D waste and to Green list waste exports

Directive (Council Directive 1999/31/EC) defines such waste as "waste that does not undergo any significant physical, chemical or biological transformations. Inert waste will not dissolve, burn or otherwise physically or chemically react, biodegrade or adversely affect other matter with which it comes into contact in a way likely to give rise to environmental pollution or harm human health. The total leachability and pollutant content of the waste and the eco-toxicity of the leachate must be insignificant, and not endanger the quality of surface water and/or groundwater." However, it should be noted that items such as plastic, metals e.g. copper, bronze and brass that are usually found in construction, are also included under Chapter 17[8]. These are listed as recycled, while insulation material containing asbestos is landfilled. C&D waste figures for 2010 do not include recovery items because waste that was deposited in quarries for backfilling purposes was listed as landfilled, *not* recovered. This also applies for 2011. Following this quarried C&D waste is listed as recovered (G. Mizzi, personal communication, February 21, 2019).

4.2.2 Method

The research studies economic expansion in relation to sectoral waste generation including its impact on treatment facilities. The methodological approach adopted in this case is the standard Leontief demand-driven model which uses as its main dataset country-specific input-output tables and views the economy as an interconnected system where industries affect one another directly and indirectly (Miller & Blair, 2009, p. 2). The model comprises flows of products which arise from "n" producing sectors and flow to "n" sectors purchasing input requirements to generate output (Miller & Blair, 2009, p.11). The Leontief model is expanded to include the "dynamics of waste treatment" and determine the waste footprint, which Nakamura and Kondo (2009, p. 220), defined as "the amount of waste that was generated directly and indirectly to deliver a unit of its product to the final demand". Direct waste arisings refer to waste originating from the industries being examined and refer to the actual mass of material or product and therefore they do not take into consideration any accumulative material requirements along the production chain (M. Fischer-Kowalski et al., 2011). Indirect flows refer to all the materials required along the production chain to manufacture a final product (Salemdeeb et al., 2016) and originate from industries that do not directly supply industries but are suppliers to the suppliers of the industry (Salemdeeb et al., 2016).

Extending the model to accommodate the waste input-output (WIO) methodology makes it possible to understand the relationship that waste flows (Nakamura, 1999, Salemdeeb, Al-Tabbaa, & Reynolds, 2016) have with economic activity (Nakamura, 1999) including its connection with particular economic sectors (Reynolds et al., 2014). Additionally, following the model of Nakamura (1999), which examined policy efficiency with respect to saving landfill space and energy demand, Table 0-1 provides waste generated by the respective economic sectors allocated according to their treatment methods.

8 This refers to chapter 17 04 which lists metals found in construction waste items. The chapter includes other items such as cables which contain oil, coal tar and other dangerous substances and aluminium (Office for the Official Publications of the European Union, 2002).

This generalised input-output model augments the technical coefficients matrix with additional rows and/or columns to reflect pollution generation together with abatement activities (Miller & Blair, 2009, p.446) and therefore assumes that waste generation varies linearly with output (Miller & Blair, 2009, p.447). This research connects the physical environmental flows (waste generation in tonnes) to IOTs which provide feedback loops by contrasting the physical and monetary measures of the supply and use of products (Mahajan et al., 2018, p. 5). The key assumptions underpinning the Leontief model are that each industry produces one homogenous product; there are no resource/supply constraints; the constant returns to scale i.e. when inputs increase by m, outputs increase by m; and, (4) the input ratio (or factor combination) is fixed to produce its output (Chiang & Wainwright, 2005). A detailed discussion of the Leontief demand-driven model is provided in Chiang and Wainwright (2005) and Miller and Blair (2009).

The standard methodology used in this case can be transferred to other locations with minimal effort. As an analytical tool, IOA brings forward the structural interdependence of the economy to help determine which type of investment would stimulate growth (Miernyk, 2020) without, as in this case, burdening it with waste externalities. Such an analysis, therefore, makes it possible to examine the present structure of the economy while assisting in the necessary restructuring (Miernyk, 2020). The research can, thus, guide the shift of the economy towards sustainability. Furthermore, IOA can provide a consistent forecasting tool which examines how a €1 million increase in final demand impacts waste generation. However, it must be pointed out that, while for a period of two to three years it can be safely assumed that the structural relations and, thereby, the input coefficient of the economy will remain constant, going beyond this period might be somewhat riskier (Miernyk, 2020).

In recent literature (Lenzen & Reynolds, 2014), the WIO model was extended into the Waste Supply-Use Table (WSUT) which is similar to the supply-use (SUT) framework. This allows two representations of the waste data – by type and by treatment method – to be presented simultaneously in one table (Lenzen & Reynolds, 2014) and permits the development of industry and product multipliers (Lenzen & Rueda-Cantuche, 2013) to allow for waste generation and recycling to be adjusted separately in waste flow scenario analyses (Lenzen & Reynolds, 2014).

In this research, final demand refers to final consumption (that is, household final consumption expenditure, the expenditure of non-profit institution serving household (npish) and government final consumption expenditure), gross capital formation, exports of goods and exports of services (NSO, 2016).

The equations below describe the input-output methodology undertaken:

Equation 1 Leontief Inverse

$$L = (I - A)^{-1}$$

Where A = matrix of technical co-efficient of imports + domestic consumption. This measures the fixed relationship between outputs & inputs of a sector, and, thus, calculates the proportions that the Leontief model assumes to be constant.

I = Identity matrix

L = Leontief Inverse Matrix obtained from the matrix of technical co-efficient of imports + domestic consumption.

The elements of every column in the A matrix sum up to less than 1. This means that every column is a representation of the *partial* cost of the input (excluding costs of primary inputs) which are sustained when a euro's worth of a commodity is produced. When the summation is equal or greater than 1€ it is not economically justifiable to produce this output. Finally, the payment made to the primary inputs which originate from the open sector is represented by the amount by which the column falls short of 1€ (Chiang & Wainwright, 2005). Equation annotations can be found in Annexe 1.

Although different studies have used different notations for the waste allocation matrix (e.g. 'W' in Salemdeeb et al., 2016), here it is noted as 'Matrix G' which is the standard annotation used for the waste allocation matrix in Nakamura and Kondo (1999, 2002, 2009). This denotes the matrix of sectoral waste output per unit of production, whereby every element represents the quantity of waste generated *i* (in tonnes) as per monetary unit of final production in activity *j* (Miller & Blair, 2009, p. 476). From Matrix G $(I - A)^{-1}$ the *waste generation multipliers* by type of waste treatment are obtained which illustrate the quantity of type *i* waste that is generated directly and indirectly as a result of the production processes required to satisfy € 1 million increase in the final demand for each *j* sector. From the summation of each *j* sectoral column within this matrix the aggregated sectoral waste multipliers are obtained.

Equation 2 Sectoral waste generation linked with final demand

$$F = G(I - A)^{-1} Y$$

Where

F = a column vector of aggregated waste generation by type of treatment

G = Matrix of sectoral waste output per unit of production

Y = Final demand

Equation 3 (below) measures the changes in the quantity of sectoral waste generated (δY) which is the result of an exogenous shift in final demand (δY) (Nakamura, 1999).

Equation 3 Quantity of sectoral waste generated due to an exogenous shift in demand

$$\delta F = G(I - A)^{-1}\,\delta \mathrm{Y}$$

The expression presented in Equation 3 notes an entire sequence which commences with an exogenous shock in sectoral demand causing impacts on the total amount of waste generated (Butnar & Llop, 2007, p. 390). The input-output model follows the simple logic that, when demand increases, the sectoral production of waste generation will also increase. This methodology allows the examination of the way a shift in the demand of activities, for example, a change in consumption, exports and investment, will cause an effect on the amount of generated waste, including both direct and indirect effects of production, across all sectors necessary to satisfy a unit of final demand for the respective sector. This analysis provides valuable information which can assist decision-makers to understand the avenues through which environmental burdens are transmitted throughout the economy and allows for the development of a waste policy which is fully integrated with economic policy, thus limiting externalities and costs to society.

Ultimately, the analysis aims to examine changes in final demand and how these affect the generation of waste in terms of percentages of waste output.

Equation 4 Changes in final demand and how these affect the waste generation

$$g = \frac{G(I - A)^{-1}Y}{e'G(I - A)^{-1}Y} = \frac{F}{e'F}$$

Where

e' = a unitary row vector

g = a column vector which represents the relative composition of total waste generated by the type of waste treatment

4.3 Results and discussion

4.3.1 The waste coefficient matrix

This section examines the results following the application of the Leontief input-output model. Table 0-1 and

Table 0-2 note the collation of C&I and C&D waste according to the economic sector from which it originates based on the NACE Rev.2 classification and its respective treatment. The construction sector [41-43] is by and large highest contributor, followed by transport [49-53]; production & manufacturing [5-36]; and the hotels and restaurants [55-56]. Construction, production and other services are also the main contributors to the recovery and recycling of materials. Table 0-1 is collated by the authors with figures sourced from ERA, NSO and WasteServ Malta Ltd.

Table 0-1 Waste generated in 2010 from different economic sectors (in tonnes)

	A: Agriculture [1-3]	B to D: Production [5-35]	F: Construction [41-43]	I: Hotels & restaurants [55-56]	Q: Health & Social work [86-88]	S: Other services [94-96]	Total
Landfill	2191.09	778.58	688,061	15,788	0	203.94	707,022.61
Composting	302.72	0	0	0	0	0	302.72
Incineration	504.98	14265.07	0	0	233.38	0	15,003.43
Recovered	12.8	68,470.9	0	0	0	309.96	68,793.66
Recycled	202.53	8,965.69	119,639.82	0	0	13,826.13	142,634.2
Pysico-chemical	0	82.7	0	0	0	0	82.7
Stored	0	94.051	0	0	0	462.76	556.811
Dumped at sea	0	0	290,120	0	0	0	290,120
Total	3,214.12	92,657	1,097,821	15,788	233.38	14,802.79	1,224,516.29

Only those sectors that generate waste are included in Table 0-1. A percentage comparison is shown in Table 0-2. Waste generated from hotels and restaurants [55-56] is landfilled. As noted in the WMP 2014-2020, "no separate kerbside collection of bio-waste from households, restaurants, caterers and retail premises" exists (p.71). The WMP further adds that "the contracts entered into by Local Councils are an avenue to abuse by commercial and industrial establishments" (p.59) and proposes that "commercial entities are obliged to have their waste carrier" (p.3). However, to date, most of the entities have "rode on local council collection systems to the detriment of public finances" (p.3). Initiating separate bio-waste collection for hotels and restaurants could provide a solution to boost composting rates and improve the operation of the Mechanical Biological Treatment (MBT) plant.

The waste generated by sector F: Construction [41-43] is mainly landfilled (62.7 per cent), while 26.4 per cent is dumped at sea. The remaining 10.9 per cent is recycled. It is important to point out that in 2010, C&D waste disposed of in quarries was listed as landfilled *not* recovered. The figure for recycled waste, which reaches 119,639.82 tonnes, includes plastic and metal which originates from construction (G. Mizzi, personal communication, February 28, 2019).

Sector B to D: Production & Manufacturing [5-35], which incorporates a vast array of waste ranging from paper to copper to paint to bilge oil used in navigation, is the second-highest generator. Despite the fact that the waste originating from the two sectors (production *and* manufacturing) is highly fragmented, it contributes to recovery and recycling with 55 and 35 per cent respectively. Waste listed under Chapter 19 of the EWC code, that is, waste produced from waste treatment facilities e.g. ash and the output from the MBT plants, is listed under Sector E and is excluded from this analysis. This is in view of the fact that items listed in this sector would already have been accounted for under the respective industry and including them would lead to double counting that happens when items of different degrees of fabrication are counted twice (Nakamura & Kondo, 2009 p. 271). The same approach is adopted with figures originating from the NACE sectors, where the output from facilities falling under Sector E is excluded. This methodology is customary in the waste-related input-output analysis (Tonini, Albizzati, & Astrup, 2018; Salemdeeb et al., 2016).

Waste originating from the agricultural sector [1-3] mainly refers to plant-tissue, plastics, animal manure and materials unsuitable for consumption. Abattoir waste is incinerated. The sector "other services" [94-96] includes items such as plastic, wooden and mixed packaging. The recycled items, amounting to 13,826.13 tonnes, comprise non-ferrous metal, paper and cardboard, plastic, metallic and composite packaging, while 462.76 tonnes refer to waste wood which is stored.

Table 0-2 provides a percentage analysis of Table 0-1.

Figure 0-2 and Figure 0-3 provides a graphical examination of Table 0-1.

Table 0-2 Percentage of waste generated in 2010 from different economic sectors

	A: Agriculture [1-3]	B to D: Production [5-35]	F: Construction [41-43]	I: Hotels & restaurants [55-56]	Q: Health & Social work [86-88]	S: Other services [94-96]
Landfill	68.2	0.8	62.7	100	0	1.4
Composting	9.4	0	0	0	0	0
Incineration	15.7	15.4	0	0	100	0
Recovered	0.4	73.9	0	0	0	2.1
Recycled	6.3	9.7	10.9	0	0	93.4
Pysico-chemical	0	0.1	0	0	0	0
Stored	0	0.1	0	0	0	3.1
Dumped at sea	0	0	26.4	0	0	0
Total	100	100	100	100	100	100

Source: Authors' calculations

Figure 0-2 Total waste (in tonnes) generated by different economic sectors

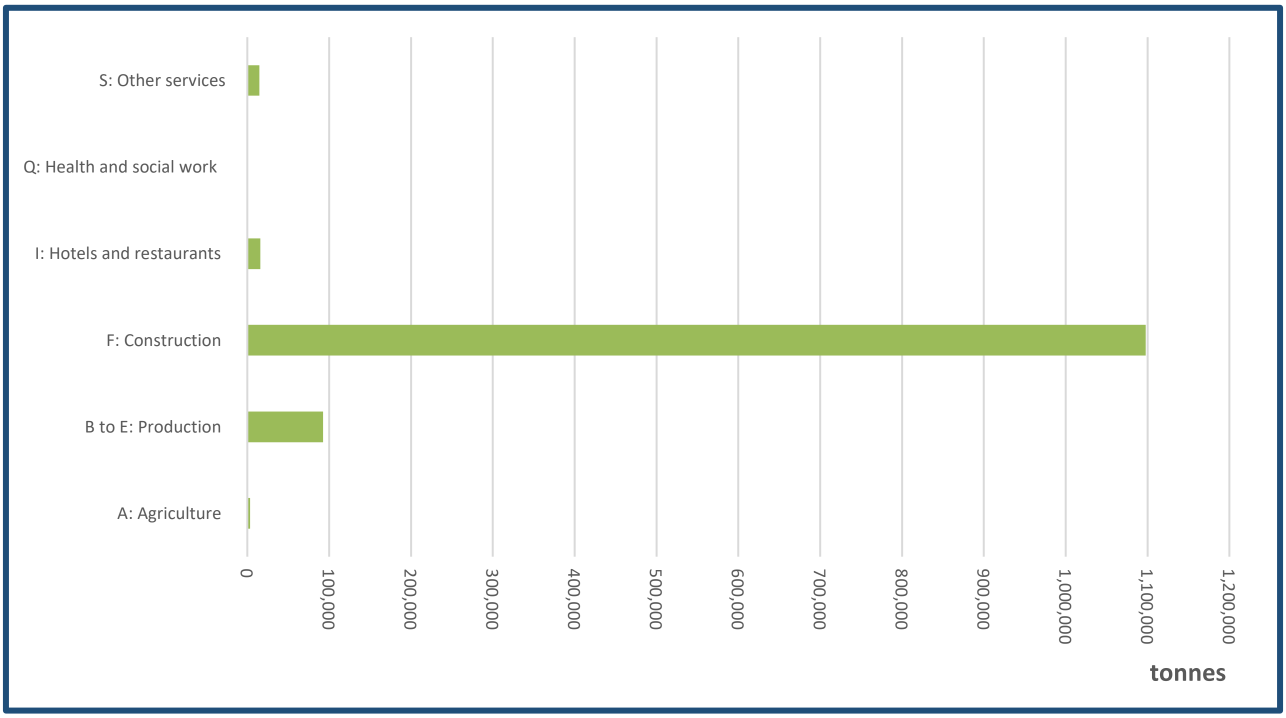
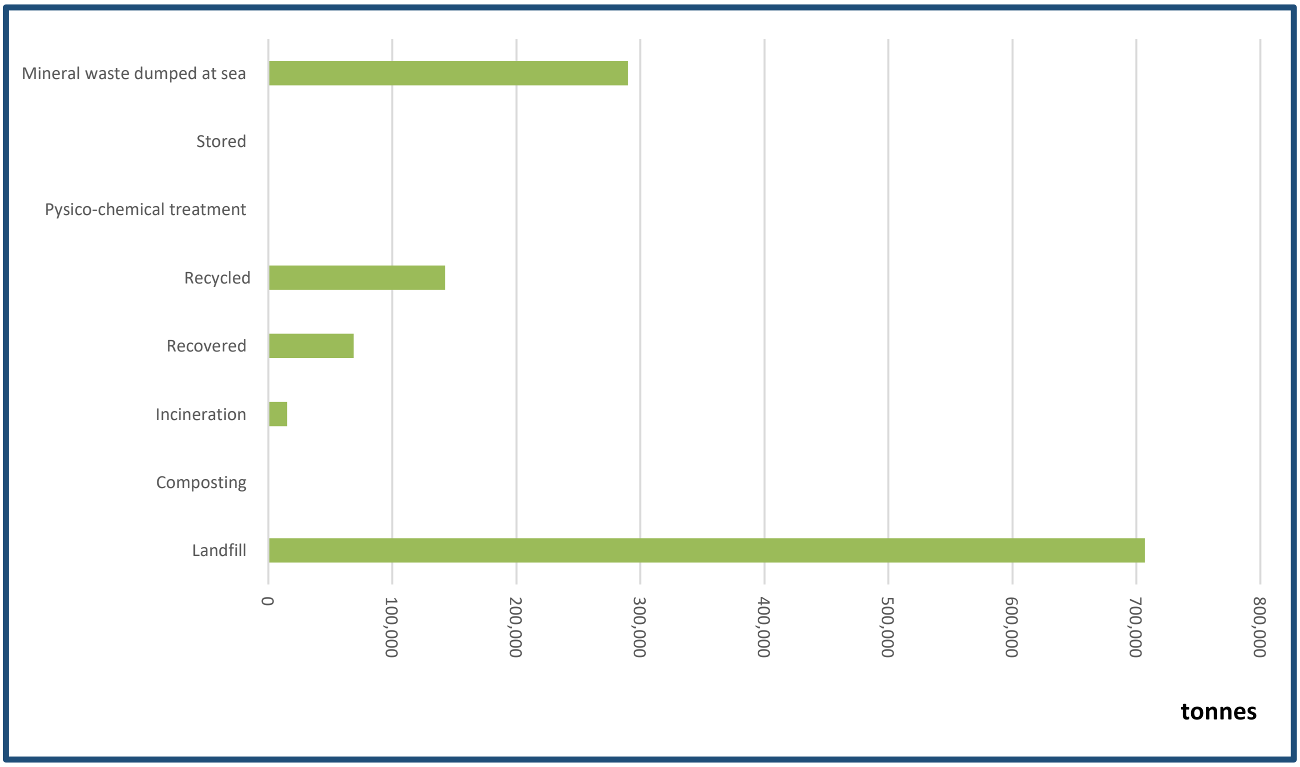


Figure 0-3 Waste generated by treatment category (in tonnes) in 2010



4.3.2 Waste multiplier analysis for the Maltese economy

A major application of the input-output framework is to evaluate outcomes when there are changes in elements that are exogenous to the model of that economy (Miller & Blair, 2009, p. 243).

Figure 0-4 presents an analysis that incorporates *simple* multipliers which display both indirect and direct generation figures (in tonnes), according to every economic sector when final demand increases by 1 million euro (see definition of direct and indirect waste generation in Section 2.2). Multipliers demonstrate in which area an additional 1 million euro spending would cause the highest waste generation. The size of the sector output multiplier is driven to a large extent by the level of intermediary inputs that a sector generates as a ratio of total inputs compared to its primary inputs. The higher these are, the stronger the multiplier effect. Furthermore, the higher the backward inter-industry linkages which the sector has with other sectors, the larger the magnitude of the output multiplier (Cassar, 2013). These effects are reflected by the elements which compose the Leontief Inverse, that is $(I–A)^{-1}$. The size of the multiplier is also influenced by the elements of Equation 4, i.e. $G (I-A)^{-1}$, where G (which represents the matrix of sectorial waste output per unit of production) is multiplied by the Leontief inverse which shows the number of products required directly or indirectly for each unit of final demand.

The results, shown in Table 0-3 and

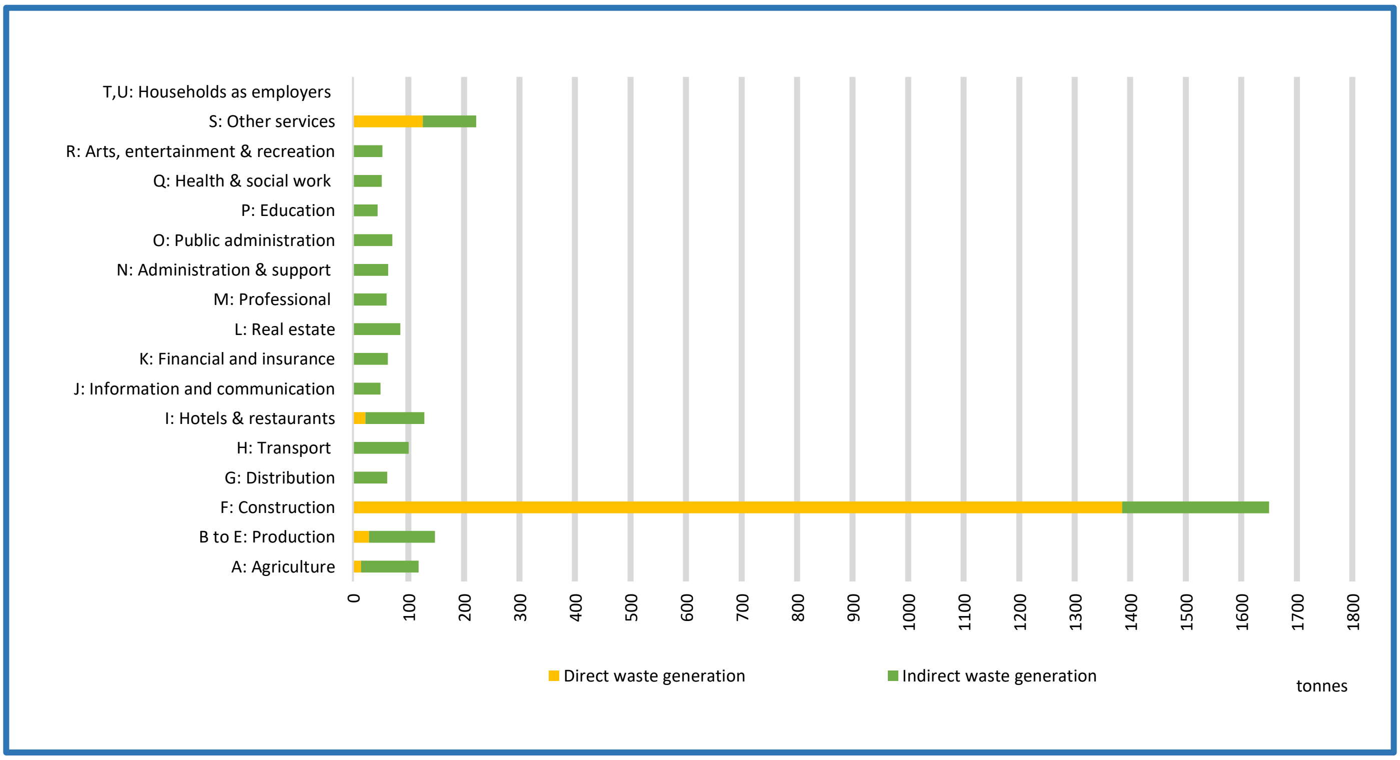
Figure 0-4, provide the upstream waste emissions from the different economic sectors including imports. While making it possible to identify which sectors cause the highest quantities of discards, including changes in the composition, following an increase of 1 million euro in exogenous (final) demand, examining the columns downwards reveals *how* the waste generated by every sector is reassigned among the different treatment methods. For example, from the first column, one can infer the impact in terms of additional waste generated across the various treatment methods as a result of both direct and indirect production activities across the economy required to satisfy 1 million euro of final demand for the agricultural sector which, when aggregated, yields a total sectoral waste multiplier of 118.34 tonnes. On the other hand, reading *across* the rows one can note the changes within the relative waste generation in the different economic sectors when final demand for that sole sector experiences a unitary increase.

Table 0-3 Waste Input-Output Multiplier $G(I-A)^{-1}$

tonnes	A: Agriculture [1-3]	B to E: Production [5-39]	F: Construction [41-43]	G: Distribution [45-47]	H: Transport [49-53]	I: Hotels and restaurants [55-56]	J: Information and communication [58-63]	K: Financial and insurance [64-66]	L: Real estate [68]	M: Professional [69-75]	N: Administration and support [77-82]	O: Public administration [84]	P: Education [85]	Q: Health and social work [86-88]	R: Arts, entertainment and recreation [90-93]	S: Other services [94-96]	T,U: Households as employers &Extra-territorial organisations [97-98]
Landfill	57.84	48.91	1015.21	32.12	50.75	73.09	24.30	33.94	50.35	32.28	33.62	40.52	25.66	26.07	28.34	50.32	0.54
Composting	1.56	0.09	0.05	0.02	0.04	0.10	0.02	0.02	0.01	0.02	0.04	0.01	0.01	0.02	0.02	0.03	0.00
Incineration	6.86	11.01	4.80	1.64	3.01	3.95	1.68	1.36	0.84	1.41	1.57	1.00	0.56	2.02	1.19	2.73	0.02
Recovered	20.52	52.16	22.67	7.75	14.19	18.22	7.93	6.39	3.94	6.63	7.29	4.73	2.64	7.39	5.59	15.55	0.10
Recycled	12.03	15.58	179.81	6.97	11.28	12.56	5.61	7.11	9.37	6.80	7.24	7.86	4.91	5.87	5.98	129.09	0.11
ysico-chemica	0.02	0.06	0.03	0.01	0.02	0.02	0.01	0.01	0.00	0.01	0.01	0.01	0.00	0.01	0.01	0.02	0.00
Stored	0.04	0.09	0.05	0.03	0.04	0.07	0.02	0.02	0.01	0.02	0.03	0.02	0.01	0.02	0.02	4.00	0.00
Mineral waste dumped at sea	19.46	20.01	427.72	13.34	20.99	20.92	10.05	14.04	21.14	13.40	13.75	16.90	10.75	10.82	11.75	20.26	0.23
TOTAL SECTORAL WASTE MULTIPLIER	118.34	147.90	1650.34	61.89	100.31	128.92	49.63	62.88	85.66	60.57	63.56	71.05	44.55	52.21	52.90	222.00	1.01

Source: Authors' calculations

Figure 0-4 Graphical representation of total sectoral waste multiplier



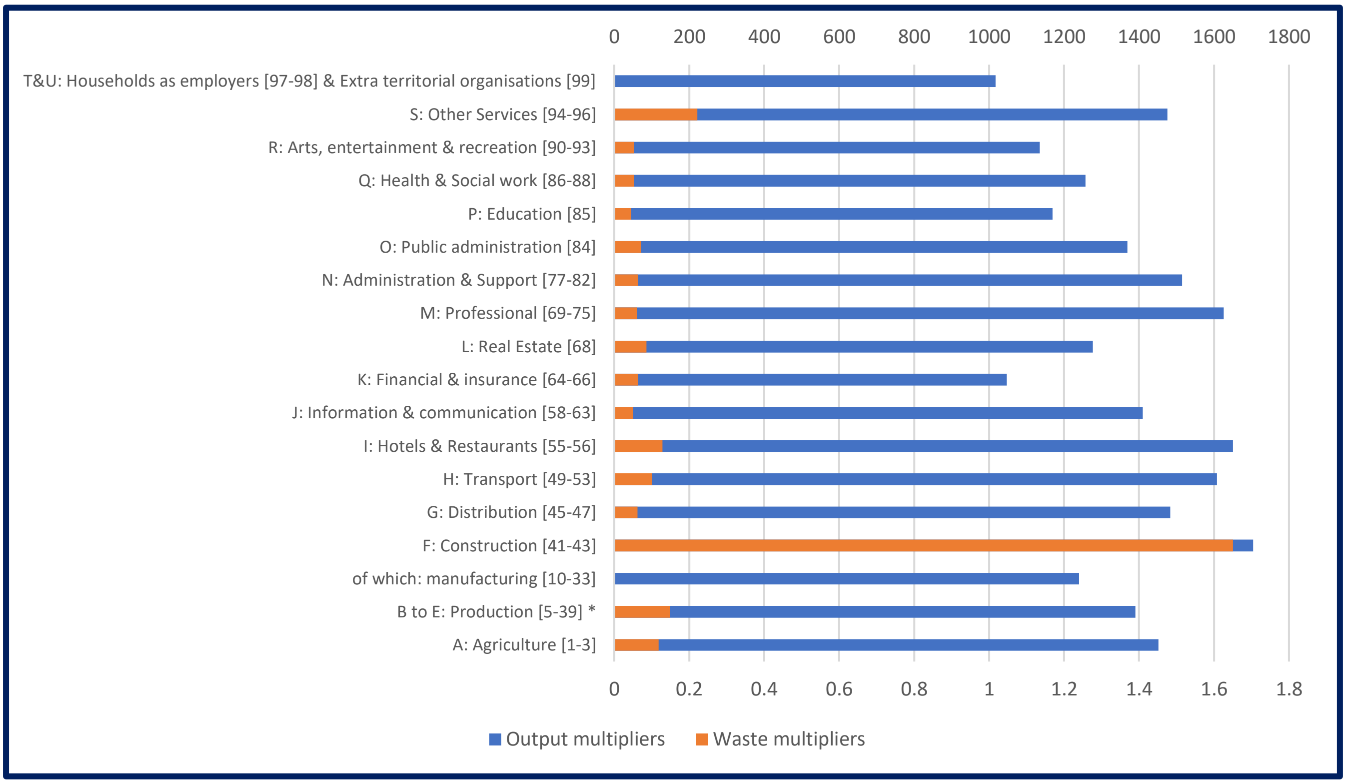
The strongest and most pervasive waste multiplier is exhibited by Sector F: Construction [41-43] which poses a clear cause of concern for the treatment/disposal facilities. Direct waste generation (from the sector itself) amounts to 1385.32 tonnes, while indirect contribution (from other economic sectors) reaches 265.02 tonnes. Table 0-3 notes that absorption of waste by the industry itself, through recovery and recycling, amounts to 202.48 tonnes (12.26 per cent), although it is important to repeat that in 2010 waste disposed of in quarries was listed as landfilled and not recovered. The production sector, on the other hand, absorbs 67.74 tonnes (45.8%) of its total waste generation.

In Table 0-3, a comparison is made with the simple output multipliers sourced from the NSO report "Supply, Use and Input-Output Tables 2010"(2016). This table provides a perspective on how a 1 million euro expansion benefits the economy but also on the impacts it has on waste generation. The construction industry features the highest output multiplier, reaching 1.704 (NSO, 2016), which means that for every €1 increase in final demand for this sector, an additional €1.704 is generated across the economy. This reflects the outcome of both direct and indirect multiplier effects (Cassar, 2013). However, while the output multipliers are lauded from an economic perspective, they are accompanied by waste externalities which reach a total of 1,650.34 tonnes (1,385.32 tonnes direct + 265.02 tonnes indirect). As noted earlier, reading down the columns shows how the waste generated by every sector is reassigned among the different treatment methods – this means that for every 1 million euro increase in exogenous demand, C&D waste dumped in landfills increases by 1015.21 tonnes, while waste dumped at sea increases by 427.72 tonnes and recycling by 179.81 tonnes.

Hotels and restaurants are the sectors with the next highest *output* multiplier which reaches 1.651; these sectors are, however, burdened with a waste multiplier of 128.92. Service sectors such as professional services, transport services and administration and support services display an output multiplier of 1.704, 1.651 and 1.608 (NSO, 2016), respectively. The waste multipliers for these sectors, which are indirect, reach 60.57, 100.31 and 63.65 respectively.

The sectors with the highest waste multipliers following construction, are (1) other services; (2) production and manufacturing; and, (3) the hotels and restaurants sectors which reach 222, 147.90 and 128.92 respectively. In the case of 'other services', waste generation is mainly direct (125.67 tonnes), while indirect waste generation reaches 96.32 tonnes. In view of the fact that waste originating from this sector consists mainly of packaging, this is the sector whose multiplier contributes most extensively to recycling compared to the total waste multiplier. The waste multiplier of the hotel and restaurant sectors is mainly indirect (106.6 tonnes) while direct waste generation reaches 22.3. Further comparisons are found in Figure 0-5.

Figure 0-5 Comparison of the simple output multiplier and the waste multiplier (see Annexe 1)



Source: Simple Output Multipliers – NSO, 2016

The calculations are shown in Table 0-3 also allow for an examination of the impact exerted on the waste treatment and disposal facilities. Landfilling, which is the most extensively used disposal method in Malta, bears the worst aftermath with 54.6 per cent of additional waste being landfilled. This is followed by the dumping of waste at sea, with 22.4 per cent of waste being disposed of in this manner, while recycling and recovery increase by 14.39 and 6.84 per cent respectively. Finally, treatment methods such as incineration would also experience a demand intensification with the major contribution originating from agriculture, with an additional 45.67 tonnes needing to be treated. This refers to animal tissue. A positive push to recycling would be given from all sectors.

An island with severe space constraints, where tourism holds an important economic role, cannot ignore the impacts of landfilling and dumping of waste at sea resulting from an exogenous growth in final demand. The impacts of waste generation go beyond the tonnage figures and issues such as general environmental conditions and the quality of the product offered to the tourist industry need to be considered, particularly in view of the fact that Malta, as a tourist destination, has reached a dangerous saturation point, plausibly due to a mismatch between the product and market requirements, carrying capacity, and sustainability concerns (Croes et al., 2018).

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In Table 0-3 the low interest in waste sourced compost can be observed. This is despite the fact that soil in Malta is a scare resource that is diminishing (Rolé & Attard, 2007). The use of quality compost has a positive impact on the fertility of the soil, plant growth and health. Quality compost, for example, increases soil humus and improves soil structure and helps suppress plant diseases (Fuchs et al., 2014). In Table 0-3, it can be noted that a 1 million euro expansion generates a multiplier of only 1.56 in the case of composting (1.32 per cent of the agricultural waste multiplier).

An additional observation made in Table 0-3 is the contribution made by every economic sector to landfilling and dumping at sea of mineral waste. The latter practice is only permitted for C&D waste under the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter 1972, also known as the "London Convention" and the Protocol for the Prevention of Pollution of the Mediterranean by Dumping from Ships and Aircraft – 1976 (part of the Barcelona Convention). While some argue that C&D waste is inert, various issues might arise with the continuous dumping of waste at sea. The practice of dumping large quantities of insoluble or soluble material into a steady-state system, for example, a marine benthic system, is likely to cause both short and, possibly less understood, long-term effects, that vary according to the biotic and abiotic baseline of the site and its surroundings. Such dumping can be of detriment to both the water column and the seabed, with impacts varying according to the hydrodynamics of the area, the type of material dumped, the dumping rate and the method of dumping (Axiak, 2005). In the case of islands such as Malta, the sheer volumes dumped are an additional concern. C&D waste, which is generated throughout every project's lifecycle, is responsible for land, air or water pollution and is sometimes contaminated with asbestos and other chemicals (Boussabaine & Khairulzan, 2006). Furthermore, it can include products such as metals and plastics which release contaminants, with metal influencing freshwater and terrestrial toxicity potential and plastics influencing human toxicity potential. Less consequential are toxicity impacts caused by stone, which is inert, except for human toxicity due to particle emission to air (Ortiz et al., 2010).

Finally, in the sector [5-37] production and manufacturing, which generates a diverse quantity of waste, the waste multiplier reaches 147.9 tonnes, out of which 28.8 tonnes are direct and 106.6 tonnes are indirect Figure 0-5. In its majority, waste is either recovered or landfilled. However, output multipliers for the production [5-37] and the manufacturing sectors [10-33] reach 1.39 and 1.24 respectively (NSO, 2016). Sector [5-37] demonstrates a case where, while the output multiplier is considerable, the impact on waste generation is contained. This highlights the need for the sector to maximise its input use and minimise losses that materialise into waste.

4.3.3 Composition of the sectoral waste generation multiplier

In this section, an analysis of the relative composition of the waste generated from each NACE sector is conducted. Table 0-4 demonstrates the relative share of each treatment type as a proportion of the total multiplier. The table provides invaluable information to waste planners projecting the design of future facilities as it can help them ensure the right capacities and to policymakers, as it helps them identify the sectors that will be responsible for the highest waste externalities, thus helping them to tweak policies in order to boost recycling and recovery rates.

Table 0-4 Relative compositions of waste generated from each NACE sector (equation 4)

waste tonnes	A: Agriculture	B to E: Production	F: Construction	G: Distribution	H: Transport [49-53]	I: Hotels and restaurants	J: Information and communication	K: Financial and insurance	L: Real estate	M: Professional	N: Administration and support	O: Public administration	P: Education	Q: Health and social work	R: Arts, entertainment and recreation	S: Other services	T,U: Households as employers &Extra-territorial organisations
Landfill	48.9%	33.1%	61.5%	51.9%	50.6%	56.7%	49.0%	54.0%	58.8%	53.3%	52.9%	57.0%	57.6%	49.9%	53.6%	22.7%	54.0%
Composting	1.3%	0.1%	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Incineration	5.8%	7.4%	0.3%	2.7%	3.0%	3.1%	3.4%	2.2%	1.0%	2.3%	2.5%	1.4%	1.3%	3.9%	2.2%	1.2%	2.2%
Recovered	17.3%	35.3%	1.4%	12.5%	14.1%	14.1%	16.0%	10.2%	4.6%	11.0%	11.5%	6.7%	5.9%	14.1%	10.6%	7.0%	10.2%
Recycled	10.2%	10.5%	10.9%	11.3%	11.2%	9.7%	11.3%	11.3%	10.9%	11.2%	11.4%	11.1%	11.0%	11.2%	11.3%	58.1%	11.3%
Physico-chemical treatment	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Stored	0.0%	0.1%	0.0%	0.0%	0.0%	0.1%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.8%	0.0%
Mineral waste dumped at sea	16.4%	13.5%	25.9%	21.6%	20.9%	16.2%	20.2%	22.3%	24.7%	22.1%	21.6%	23.8%	24.1%	20.7%	22.2%	9.1%	22.3%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Source: Authors calculations

The relative share of each treatment type as a proportion of the total multiplier differs significantly among economic sectors. While all NACE sectors make an average contribution of 55.5 per cent of the waste generated to landfilling, Sector F: Construction tops the list with 61.5 per cent, followed by Sector E: Hotels & Restaurants at 56.7 per cent. Contribution to recycling reaches an average of 13.8 per cent by all sectors with 'Other Services' contributing 58.1 per cent. Here the effects of policies focused on packaging waste can be observed.

The waste multipliers, together with their relative composition, emphasise the need to establish holistic economic policies that take account of the impact that economic expansion has on the physical environment, particularly in small countries such as Malta. The analysis made in this research dampens the contribution of various economic sectors and emphasises the need for national environmental accounting. In the discussion surrounding Figure 0-5 Comparison of the simple output multiplier and the waste multiplier (see Annexe 1), a more balanced view of the economic contribution of various sectors, coupled with their negative waste externalities, is provided. This calls for a discount factor that accounts for environmental degradation and, therefore, provides a more realistic view of the economic progress registered.

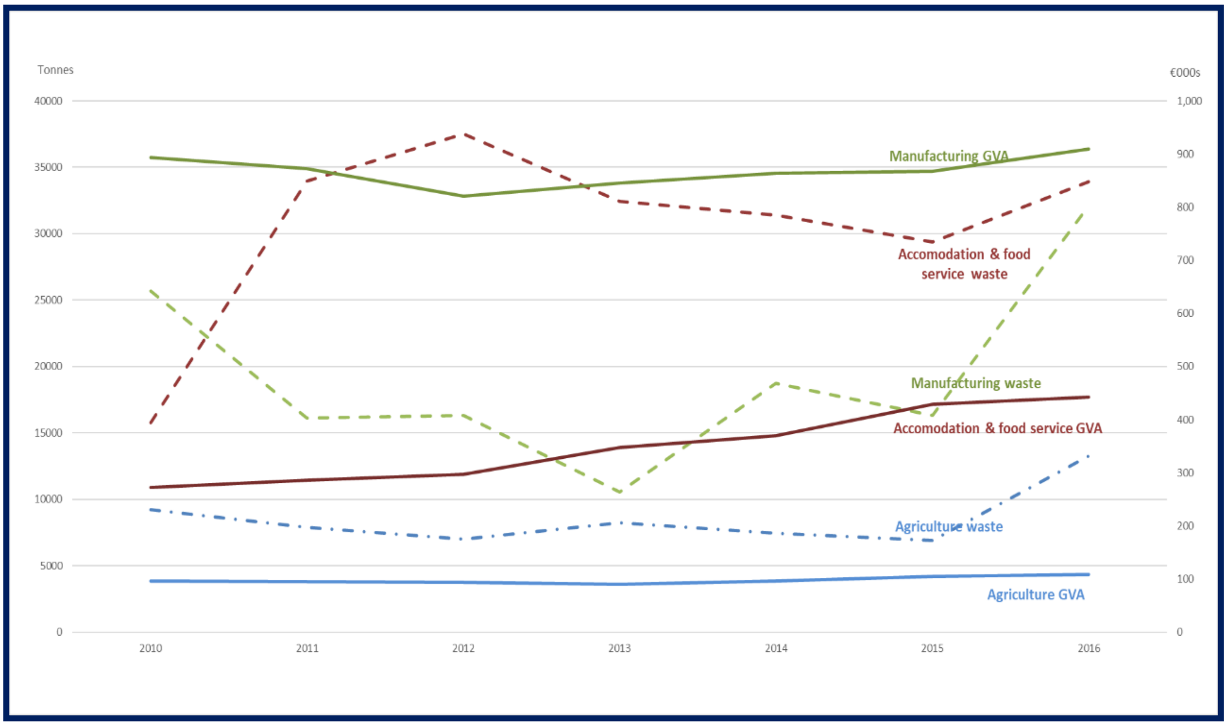
4.4 Waste generation and Gross Value Added (2010 – 2016)

The input-output analysis emphasised the link that economic development has with waste generation. Waste policies are generally developed to target specific waste streams or economic sectors but they seldom account for the impact caused by changes in demand and production processes which affect other sectors within the economy. Undertaking a holistic strategic approach is necessary when a country wants to build an economy that is both circular and sustainable (Salemdeeb et al., 2016) and is not focused on end-of-pipe solutions.

This section provides a production-side waste intensity indicator for 2010-2016 for 5 NACE sectors. While waste intensity indicators can be examined from both the production and the consumption side, the focus of this paper is the production side and therefore only C&I and C&D waste are included. In the production phase, these indicators examine indexed values of GVA generated by various NACE sectors and their respective waste volumes (EEA, 2015). Waste indicators are used to determine whether targets sets by policies are being reached (Vergara & Tchobanoglous, 2012) and therefore provide support for the evaluation of policies (OECD, 2003) together with programmatic comparisons and communication regarding systems (Wen et al., 2009).

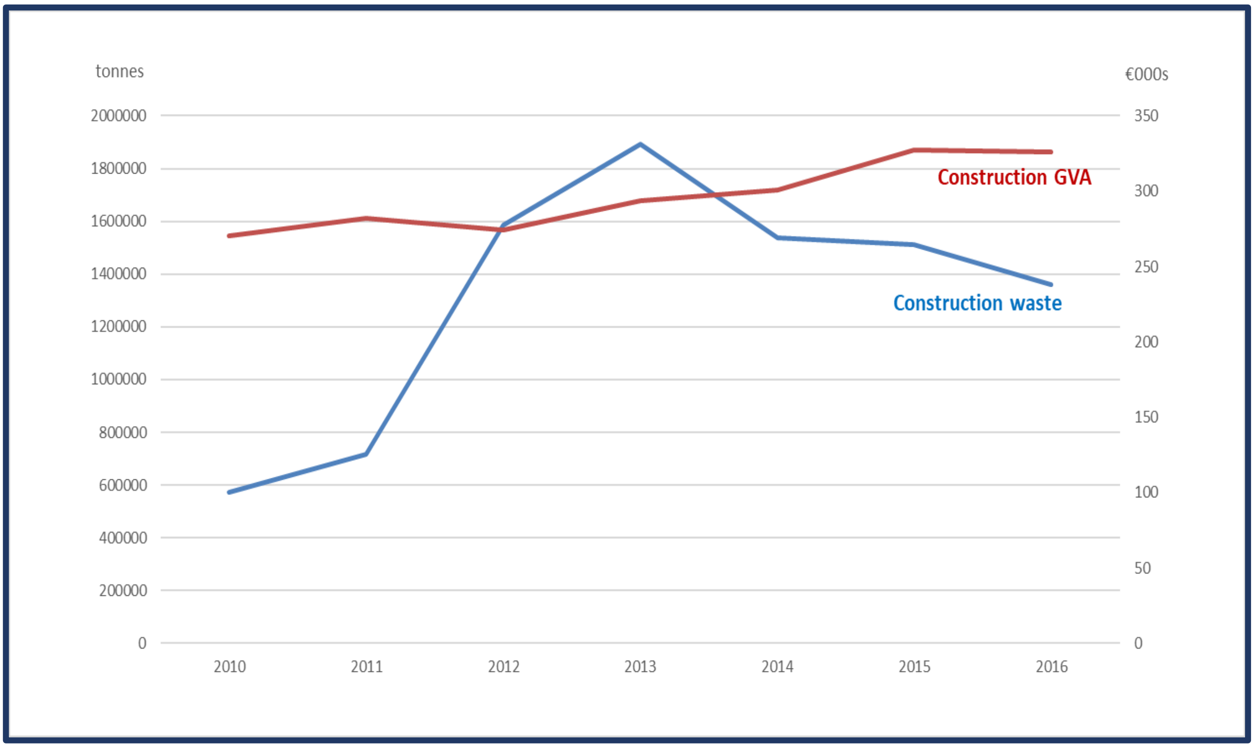
These indicators can, therefore, be classified as performance indicators and are used to address relevant policy questions, for example, how to boost recycling rates or divert waste from landfill. Waste generation, both absolute and relative, to GVA or GDP, is the indicator used to measure the closest approximation to waste prevention that gives the strongest link with both economic development and production and consumption structures (EEA, 2015). The level of economic activity and the generation of waste are interconnected and serve to reflect society's consumption and production patterns. Therefore, an indicator that measures waste intensity is a driving force indicator which demonstrates the response to improved eco-efficiency of human activities. The total waste indicator (that is, waste generated per unit of GDP) also indicates whether there is any possible decoupling of waste generation from measured levels of economic growth (EEA, 2015). Therefore, when waste generated per unit of GDP experiences a decrease, this indicates that the economy is shifting towards production patterns that are less waste intensive (UNECE, n.d.). In this case, the GVA measure is used since it is considered a superior measurement of a specific sectoral economic contribution compared to total output. This is in view of the fact that it captures the value which is added by the specific sector of the economy, that is, the difference between the total output of the sector and the cost of intermediate inputs (Miller & Blair, 2009, p. 256).

Figure 0-6 Waste generated in the agriculture, manufacturing and accommodation & foodservice sectors as compared to sectoral GVA (Eurostat, 2018a)



Source: Authors' Calculations, Eurostat (GVA data as at 10/11/2019)

Figure 0-7 Construction waste generation compared to construction GVA



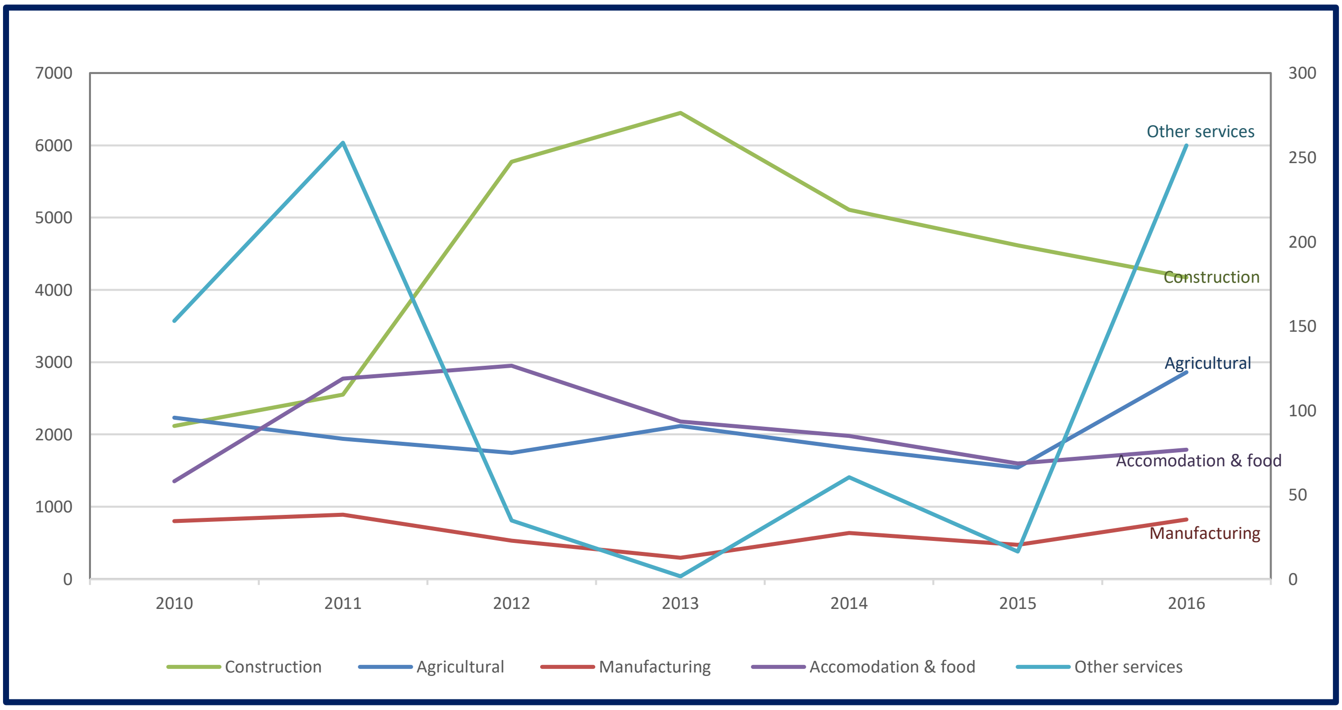
Source: Authors' Calculations, Eurostat (GVA data as at 10/11/2019)

Source: Authors' Calculations, Eurostat (GVA data as at 10/11/2019)

Figure 0-7 provides a comparison between waste generated in manufacturing, construction, accommodation and food services and agriculture compared to their respective GVA. Construction is presented separately in view of its magnitude. The waste figures are based on the primary axis, while GVA is based on the secondary axis. The graph highlights which sector is providing the highest GVA, while expending the lowest externalities. Manufacturing generates a high GVA without troubling society with excessive waste quantities. Although waste generated can be hazardous and, therefore, depending on its pysico-chemical properties, has the potential to ignite, explode, react with water or cause biological issues including infections, skin irritations or other chronic effects like cancer, harm to endocrine, immune or nervous systems etc. (Ortiz et al., 2010), a degree of efficiency within the sector is noted. Waste represents a loss of resources for manufacturing which the industry has an incentive to minimise. Between 2014 and 2016, although the GVA of this sector increased from €864.4 to €867.3 million, waste decreased from 18,729.4 to 16,331.5 tonnes. Increases are however again noted in 2016. The same trend can be noted in the accommodation and food services industry where the waste intensity indicator shifted from 84.8 (2014) to 68.5 (2015) to 76.6 (2016).

Construction, as noted in Figure 4-6, has a relatively stable GVA but burdens society with high quantities of waste. Although a decrease is noted between 2015 and 2016, the waste impacts are considerable in relation to all other sectors in the economy. The industry is responsible for a disproportionate environmental impact which can also be noted in the waste intensity indicator in Figure 0-8 where the construction indicator is on the primary axis and the remaining sectors are plotted on the secondary axis (see Annex 2).

Figure 0-8 Graphical representation of the waste intensity indicator for various NACE sectors (Table with figure representation is found in Appendix 2)



Source: Authors' calculations

Therefore, basing the comparison solely on volume, while the manufacturing sector generated 35.3 tonnes of waste per million euro of GVA in 2016, the construction industry generated 4,172.7 tonnes of solid waste per million euro of GVA in the same year.

A possible solution to counter this inefficiency is the creation of a secondary market which would yield value for by-products generated during the construction process and incentivise the storage of items presently considered as waste for resale to be reused or recycled in other construction projects. In Malta, the emphasis is on the need to have a deconstruction standard in place. While this was recommended in the strategy to establish the recycling of C&D waste (Car et al., 2008), to date, there is still no such standard[9]. Furthermore, the shift from recovery to recycling proposed in the WMP 2014-2020 still needs to be implemented. Measures such as the development of storage facilities have been proposed but have never materialised. Other limitations which include a market that is unprepared for reused limestone and the unwillingness of the construction sector to integrate the technique since the practice is more time consuming, thus increasing costs, must be overcome before deconstruction is integrated (Sciberras, 2014)

4.5 Conclusion

The examination of how the expansion of economic sectors impacts society and the environment, both directly and indirectly, is crucial to building a sustainable economy that generates wealth without expending the natural resources and creating externalities for the local population to deal with (Salemdeeb et al., 2016). This research provided an in-depth analysis of the correlation between economic growth and waste generation. While the study is focused on the Maltese Islands, the methodology used is a standard one that can be adapted to any other country.

The research emphasised the intrinsic connection that waste streams have with different economic sectors. The study is, therefore, an appeal for the introduction of economic policies which account for externalities at the outset. The input-output methodology highlights the least efficient sectors. These results are further corroborated through the waste intensity indicators which stress where policy effort should be directed to achieve economic growth without burdening society with waste externalities and attain a sustainable and circular economy.

Waste has become a pressing issue, not only for islands. It is now evident that an out-of-sight-out-of-mind policy is no longer viable. The cruciality of investing in industries with more contained waste multipliers that, therefore, impose less stress on the already strained environmental resources and waste disposal facilities cannot be sufficiently underlined. The results emphasise that waste policies can no longer focus on the provision of adequate treatment facilities but need to be integrated with economic policies that acknowledge waste before its creation.

[9] Presently, the Malta Standards Authority is working on two standards, namely - DSM820 – Recycling oriented deconstruction - Demolition and excavation (Process based approach) and DSM840 - Recycling oriented deconstruction – Guidelines for recycled material from excavation and demolition waste (technical specification based) (Cutajar, G., personal communication, November 15, 2019).

The results also provide guidance on treatment/disposal facilities and the requirements imposed on them when the economy expands. This is of crucial importance, particularly for islands such as Malta where landmass is severely limited, where there is high population density and which are subject to isolation with limited possibility to outsource their problems. The waste multipliers reveal that the most extensive impact is on landfilling and disposal of waste at sea–two practices that have extensive environmental impacts. Additionally, the results point towards the need to enhance practices such as composting and recycling, which absorb waste and assist in the implementation of a circular economy. The adoption of this approach would apply waste reduction and recycling instruments towards particular sectors that would divert economic activities away from 'dirty' industries.

Finally, the research emphasises that seeking economic growth without acknowledging its side effects is no longer viable. The introduction of reliable national environmental accounting that provides a holistic picture which incorporates social and environmental aspects is a necessity. This will ensure a long-term view of decisions that shift the present structures towards a sustainable and circular economy.

Chapter 5

A snapshot of solid waste generation in the hospitality industry. The case of a five-star hotel on the island of Malta

This chapter is based on the paper published in the Sustainable Consumption and Production journal.

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ABSTRACT

The history of tourism in Malta dates back 60 years. While widely hailed for its economic contribution, very little reference is made to waste externalities that riddle the industry. The impacts of waste generation are even more pronounced on islands, particularly small ones with a high population density like Malta. Furthermore, waste originating from the hospitality establishments is, in its majority, landfilled.

Five-star hotels are generally expected to be more waste intensive than hotels in the lower star categories. This research focuses on an established five-star hotel to present a comprehensive case study that uses a mixed methodology approach. The case study presents quantitative figures of waste generated in the a-la-carte buffet restaurants and residents' rooms, together with information and insights about waste generation and reduction initiatives yielded through quantitative methods.

The results point to the pervasive problem of plastic and single-use items. In one week, 692.5 kg of waste is generated from the residents' rooms, 50.3 per cent of which consists of plastic. This is also evidenced in the buffet breakfast audit, where, the 'other waste' fraction reaches 0.05 kg/person. In the other four fractions waste generated per person reaches 0.01 kg.

Food waste is an aspect of the hospitality industry that cannot be side-lined. Plate-waste, measured through a month-long audit performed at the a-la-carte restaurant, reaches an average of 0.21 kg/person and 0.16 kg/person at lunch and dinner, respectively. The buffet dinner exposes greater wastage at 0.48 kg/person. Preparation waste was calculated at 0.08 kg/person. The relationship between portion sizes and food waste is exposed when the removal of a side plate decreases waste generation from 0.059 kg/person to 0.043 kg/person.

Keywords: hospitality industry, waste audits, five-star hotel, linear systems.

5.1 Introduction

Tourism is a mature industry in Malta (Croes et al., 2018). Interest in the island as a tourist destination commenced in the 1950s when the government initiated a capital spending programme that saw the first passenger terminal inaugurated in 1958, coupled with improved access to beaches and the necessary promotion and advertising (Attard, 2018). Over the years, tourism continued to grow to become one of Malta's economic pillars, with the World Tourism and Travel Council (WTTC) claiming a direct contribution of 14.2 per cent and a total contribution of 27.1 per cent to the total GDP (WTTC, 2018). A more conservative estimate is provided by Cassar et al. (2016) who estimate tourism's contribution at 5.7 per cent of the total Gross Value Added (GVA) and 6.1 per cent of the GDP when only direct effects are taken into account. When indirect and induced effects are included, the figures increase to 12 per cent and 17.1 per cent respectively (Cassar et al., 2016).

Tourist arrival figures have grown drastically over the past 60 years. In its 2018 Annual Report, the Central Bank of Malta (CBM) describes the tourism sector's continued growth as a 'buoyant performance' that has been ongoing since 2010. This success, however, is tempered by a decline in the average length of stay (Attard, 2018).

Tourism is generally considered a desirable industry. From a host community perspective, it is synonymous with a high income and employment multiplier, while from a visitors' perspective it offers recreation, adventure and other benefits associated with travelling (Briguglio & Avellino, 2019). However, the economic contributions it generates are marred with far-reaching negative social and environmental externalities (Greco et al., 2018). This creates a contradictory scenario for tourism because, while the essentiality of short-term profits cannot be denied, its long-term survival depends on the protection of the country's natural resources (Juvan et al., 2018). Despite this, tourism is generally not well managed from an environmental perspective and rising arrivals are often a precedent to further stress resulting from overcrowding and exploitation of resources (Beladi et al., 2009). Among other infrastructural impacts, such as excessive development (Briguglio & Avellino, 2019), solid waste generation is one of the most noticeable environmental impacts of tourism flows, particularly given the large quantities of consumer goods used by hotels and restaurants (Bohdanowicz, 2005; Arbulú et al., 2015). Tourism flows constitute an additional waste source which influences the appeal of a particular destination (Arbulú et al., 2015). Therefore, the expected growth in tourism both globally (WTTC, 2018) and in Malta, calls for an effective waste management system (Dileep, 2007). However, before waste can be managed, it is necessary to accurately identify and quantify what is being generated (Eriksson et al., 2018).

Waste figures relating to the hospitality industry are generally higher than those relating to the local population, with the disparity worsening in the case of five-star hotels (NSO, 2003; Bajada, 2017; Galdes, 2007). These factors, together with the increasing number of tourist arrivals, highlight the need for a detailed assessment of waste generation by the tourist industry which would help direct policy towards the most critical areas.

Focusing on an established hotel in the Maltese Islands, this research aims to provide a comprehensive case study of waste generation in five-star hotels. Since hotel waste generally comprises various fractions (Pirani & Arafat, 2014), it aims to measure its magnitude and composition within a setting that is generally associated with higher waste figures. As quantitative measures do not allow for the analysis of the practices, motivators and behaviours of waste producers (Papargyropoulou et al., 2016), the research is supported with a qualitative study that aims to examine practices that are conducive to waste, determine the role that waste holds in the decision-making process, assess the predisposition of staff towards waste reduction methods and identify the clients' standpoint on the topic, particularly since hotels tend to presume that guests are likely to not take kindly to, for example, being asked to segregate waste.

The focus on the hospitality industry was motivated by a previous study conducted by the same authors (Camilleri-Fenech, M. et al., 2018) which noted that waste originating from this industry is landfilled in its entirety and that the waste intensity multiplier for the industry reached 128.92[10], stressing the need for more in-depth analysis. However, while the previous study was conducted on the macro-level, applying a top-down approach using input-output tables, the necessity for depth called for a micro-level analysis that is performed using a bottom-up approach (Tonini et al., 2018).

5.2 Literature review

The direct relationship between tourism and waste generation is acknowledged both globally and within the EU (Ezeah et al., 2015). WRAP UK estimates that each year the Hotel and Food Service sector generates 2.871 million tonnes of waste, out of which 920,000 tonnes is food waste (WRAP, 2013).

In a macro-level study concentrated on Mallorca, Arbulu et al. (2016) demonstrated that a 1 per cent increase in tourist arrivals instigates a 1.25 per cent increase in waste, while a 1 per cent increase in tourist expenditure instigates a 0.51 per cent increase in waste. Saito (2013), who focused his study on Big Island in Hawaii which welcomes more than 1 million tourists annually, established that the industry is responsible for 244,920 tonnes/year or 10.7 per cent of island-wide waste generation. The research was conducted within five tourism-related sectors including restaurants, accommodation, golf courses, tours and car rentals. It was estimated that 62 per cent of waste originated from restaurants, 27 per cent from accommodation and 7 per cent from golf courses.

The Rezidor Group (2009) calculates that waste per guest night reached 1.69 kg for Radisson Blu and 1.51 kg for the Park Inn Hotels (Rezidor, 2009). These are the latest figures available since, in view of the differences in the methodology employed to collect the figures, the practice was stopped (S.Wiltink, personal communication, January 23, 2019). A more generic estimation of 1 kg per night, out of which more than 50 per cent consists of paper, plastic and cardboard, is provided by the Green Hotelier (The Green Hotelier, 2009). WasteServ Malta (2002) observe that tourists resident in hotels generate 1.25 kg of waste while locals generate 0.68 kg (NSO, 2003).

The growth of tourism necessitates effective waste measures (Dileep, 2007, Pirani & Arafat, 2014). Papargyropoulou et al. (2016) proposed a conceptual framework methodology which included both quantitative and qualitative strategies to link the biophysical flows of food provisioning and waste generation with the social and cultural practices associated with food consumption. The framework was tested on a restaurant within a five-star international hotel in Kuala Lumpur, Malaysia, that operates both a buffet and an a-la-carte service. Over a 7-day audit, with an average of 172 customers/day being served, it was calculated that the food waste reached an average of 173 kg/day, out of which preparation waste amounting to an average of 95.4 kg (74 per cent of which is unavoidable). Finally, plate-waste from the breakfast buffet reached 1.2 kg/customer, while from the lunch and dinner buffet and a-la-carte service it reached 1.1kg and 1 kg/customer respectively. More plate-waste is caused by

10 This means that waste generation increases by 128.92 tonnes when final demand increases by 1 million euro.

buffets due to leftovers, but buffets generate less preparation waste than the a-la-carte service. The total waste figures are, however, ultimately higher for a buffet style service.

Pirani & Arafat (2014) provide a comprehensive review and analysis of the status and practices of waste management within the hospitality industry. Focusing on solid waste, the paper proposes waste mapping as a tool to understand where waste is generated, what type of waste is generated, the quantities of waste and its location. This information could be used to improve the management and reduction of waste.

Although actual quantifications of waste generated in the hospitality industry are limited in the Maltese academic literature, concern about the impact of tourism on the environment, with a focus on waste generation, featured early. Briguglio and Brigulio (1996) examined the concept of sustainable tourism in small islands and referred to the stress that tourism causes through increased waste production.

In the year 2000, a tourism carrying capacity study noted that there are no figures relating to the volume of waste generated by tourists (Mangion, 2000). In view of this, together with the introduction of the Waste Statistics Regulation (Regulation EC 2150/2002), the National Statistics Office (NSO) published an official study in 2003 which provided an examination of waste generated in three, four and five-star hotels in terms of composition and quantity per star category. No subsequent studies were conducted on a national basis, but individual studies were conducted by Galdes (2007) and Bajada (2017).

In 2002, an audit was carried out within the same hotel which is the focus of this study. Waste from skips (resident rooms and offices) amounted to 0.42 kg per guest per night, while waste originating from the swill room reached 1.8 kg per guest per night (WasteServ Malta, 2002).

A 2007 study calculated an average amount of solid waste per capita per bed night of 1.56 kgs, which translates into 16 million tonnes of waste per year generated by tourists in Malta. This study was carried out in two five-star hotels, where one hotel was calculated to generate 2.43 kg per capita per night and the other 1.89 kg per capita per night. These figures are in direct contrast with the figures pertaining to a four-star hotel which reached a mere 0.37 kg (Galdes, 2007).

Bajada (2017) focused her study on food waste generated from three hotels with a five-, four- and three-star rating and nine restaurants with different specialisations. She undertook waste audits ranging between 3 to 12 days. The 3-day audit of a five-star hotel revealed 1,143.1 kg of preparation and plate waste (756.4 kg + 386.7 kg) generated from 2,931 covers. The total average waste generated per meal was calculated at 0.248 kg (breakfast), 1.532 kg (lunch) and 0.545 kg (dinner). In comparison to the four- and three-star hotels, the five-star hotel had the highest total average waste generation per cover in all three meals (Bajada, 2017).

5.3 The case study

This study puts a leading five-star hotel located in Malta and operating within the requirements of a foreign international label under the magnifying glass. In view of the fact that superior ranking hotels are conducive to higher waste generation figures (NSO, 2003, Galdes, 2007, Bajada, 2017), this case study delves further into the practices of a luxurious sector to highlight mainstream practices that are synonymous with waste generation.

There are presently 13 five-star hotels in the Maltese Islands that supply 6,476 beds or 19.2 per cent of total available accommodation (Malta Tourism Authority, 2018). The hotel that is the subject of this case study is located in the Northern Harbour District. It commenced its operations in 1997 and hosts 252 residential rooms (550 single beds), 6 meeting rooms and 3 restaurants (Muscat, 2018). The restaurants include a buffet, an a-la-carte service with an adjacent cafeteria/bar and a summer-only, a-la-carte diner. The hotel also caters for weddings and other special events. The a-la-carte restaurant operates a farm-to-fork concept based on three factors – local food provision (80 per cent of the ingredients used are locally grown and use of seasonal and fresh produce. The menu has a Maltese flavour and changes regularly to maintain seasonality, while the buffet restaurant rotates its menu daily.

In 2002, the hotel participated in a 6-day waste audit survey conducted by WasteServ Malta Ltd and NSO. During this audit, the total waste generated amounted to 5,161.62 kg or 860.27 kg per day. The figure includes the swill room waste (waste from the kitchen, restaurants and bars of the hotel) and the area allocated for skips (waste from the offices and residents' room). Swill room waste reached 4,504 kg or 82.27 per cent of the total waste, while waste from the residents' rooms and offices reached 657.22 kg (12.73 per cent). During the audit, the hotel hosted 1,579 residents with an additional 1,255 guests attending functions. The average waste per capita from the swill room reached 1.80 kg, while figures from the skips reached 0.42 kg which works out as 2.22 kg per resident per day (WasteServ Malta, 2002).

Although this is not indicated on the hotel's website, the hotel was eco-certified both at a local and EU level (the latter certification is no longer held). It also holds an Environmental Permit from the Environment and Resources Authority (ERA) which obliges the entity to "store waste within a designated and controlled storage area prior to ultimate disposal" and to label liquid and hazardous waste and store them in closed containers. The permit requires that recyclable waste be stored in designated containers, however, no mention is made of food waste. Finally, the hotel's environmental policy for 2018 sets a target to reduce landfilled waste by 5 per cent, however, no specific strategy backs this objective.

This hotel was selected for this case study as, as a five-star hotel, it allows for a deeper examination of a star category that has been proven to generate a higher amount of waste. The fact that both the general manager and the culinary director offered their support also had some bearing on the choice, as this facilitated the data collection process. Basic the case study on this hotel made it possible to examine buffet and a-la-carte service in a setting that boasts a strong food and beverage department and attracts the highest average expenditure per guest within its group while keeping overheads at the lowest rate (R. Muscat, direct communication, 20th January 2019). Carrying this study out in an established hotel allowed the researcher to benefit from the insights offered by experienced staff that provided several suggestions and who also made it possible to compare waste figures with those obtained in a study carried out 16 years earlier.

5.4 Materials and methods

This research is divided into three segments – (1) the waste audits, (2) focus groups with the managerial and line staff and (3) semi-structured interviews with clients. It is also supported with additional informal interviews and consultations with the sous chef, the cost controller and the culinary director who provided invaluable insights. The mixed methodology provides additional depth to the statistics (Reutter et al., 2017) and therefore, makes it possible to obtain a more acute understanding of waste generation within a five-star hotel environment than either approach taken on its own (Creswell, 2014). While waste audits provide an objective and rational measurement of observable data, focus groups and interviews assess phenomena such as ideas, opinions and patterns (Ashley & Boyd, 2006).

Using a mixed methodology complements the integrated waste management approach which stresses the inter-relationships within parts of the system, with the overriding objective in order to optimise the whole system rather than parts of it, to make it both environmentally and economically sustainable (White, P.R., Franke, M., & Hindle, 2012).

5.4.1 Quantitative data

Waste audits were used in view of the unavailability of high-quality data originating from five-star hotels. Audits are an effective tool to provide a detailed picture of waste at the generation point (Newenhouse & Schmit, 2000). Additionally, audits assist in making informed purchasing decisions which reduce costs and landfilling, provide insight to determine the proper disposal of potentially problematic materials and identify what can be diverted and possibly turned into commodities to generate revenue. Finally, they identify the stage at which waste is occurring to determine its best use (Karidis, 2018) or possible elimination.

However, waste audits account for only the physical aspects without incorporating local knowledge of the stream (Newenhouse & Schmit, 2000) or identifying the possible drivers (Papargyropoulou et al., 2016). Furthermore, the assessments supplied are *spatial,* i.e. the waste generated is typified by *where* it is produced thus limiting possibilities to compare with hotels, that, for example, are not five-star or are located on other islands, and *temporal*, i.e. subject to seasonal variations (Felder et al., 2001). In this research, audits were carried out in June, July and August of 2018. Despite these limiting factors, it should be pointed out that this hotel operates under an international brand that sets specific standards within its chain. In view of time and financial limitations, as well as labour requirements no additional audits were carried out during the winter season, which precludes the possibility to account for seasonal variations.

Presently, there is no international standard format for waste audits which hinders possibilities for comparison among different studies. While it may difficult to establish a standardised format for waste audits, doing so would facilitate the duration and format of audits. The first difficulty is adapting the waste fractions to the specific menu offered. Since there is no standard format for waste audits, the fractions were determined through an examination of the literature, complemented by the suggestions of the hotel staff. In this research, bread was accounted for separately upon the suggestion of the cost controller and the sous-chef, who both commented on its high wastage. Accounting for bread separately is a recommendation for future research as it is a staple and because restaurants present it to clients on the table throughout the year, meaning that this fraction is not subject to either spatial or temporal variations. This facilitates the comparison and analysis of audit results. Other fractions were selected according to meal courses; for example, sweets were accounted for separately, while meat, fish and pasta denote waste from main courses. The waste resulting from vegetable, potatoes and side plates, was accounted for separately in view of the planned change in portions, while the 'other' fraction needed to be included to cater for items such as napkins. The buffet service rotates the menu daily and therefore fractions needed to be generalised. For the dinners, however, the fractions were divided similarly to the a-la-carte restaurant to facilitate comparison. The breakfast audit was subject to small variations in view of the differing food intake.

In the a-la-carte restaurant, audits were held of both the preparation and plate-waste, while in the buffet restaurant only plate-waste was examined. The kitchen size, the different processes and a large number of staff involved in the preparation of buffet meals, made it very difficult to execute an audit that supplied reliable data. The separation of waste into fractions and record taking was carried out by the staff. Table 5-1 provides a list of the audits conducted.

Table 5-1 Details of waste audits

	A-la-carte	**Buffet Breakfast**	**Buffet Dinner**	**Room**
Dates	1/06 to 30/06	23/06 to 29/06	6/08 to 12/08	25/06 to 1/07
Duration	1 month	1 week	1 week	1 week
Preparation waste	Yes	No	No	n/a

Waste Fractions	(1) bread (2) sweets (3) meat, fish & pasta (4) vegetables, potatoes & side dishes (5) other	(1) sweets (2) meats, chicken & fish (3) vegetables, potatoes & eggs (4) bread (5) other	(1) sweets (2) meats, chicken & fish (3) vegetables, potatoes & eggs (4) bread (5) other	(1) plastic (2) metal (3) glass (4) paper (5) organic (6) other
Average guests in audit per day	106	445	95	331

A month-long audit (1st to 30th June 2018), was carried out in the a-la-carte restaurant focusing on both preparation and plate-waste. Furthermore, a list of perished sweets is kept by the restaurant manager. Records of preparation waste were kept by the kitchen staff, with chefs noting the type and quantity (in kg) of the discarded items and the reasons why the items were disposed of (see Annex 3, Figure 8-1). This method provided high-quality, reliable data which made it possible to identify both avoidable and unavoidable waste and understand trends in waste generation. The buffet breakfast audit was conducted between 23rd and 29th July 2018 - a busy period with an average of 445 guests daily, - while the buffet dinner audit was conducted between the 6th and 12th August 2018, where there was an average of 95 guests daily. Waste was classified according to the definitions of the Food and Agriculture Organisation (FAO) and WRAP. These definitions are noted in Table 5-2.

Table 5-2 Definitions used to classify food waste

Terms	Definition
Food waste	The term food waste refers to a decrease in the quantity or quality of the food which results from decisions and actions by retailers, food service providers and consumers. The loss results when (1) fresh produce deviates from what is considered as optimal, (2) foods are close to or beyond the 'best before' date, and (3) large quantities of wholesome edible food are often discarded by retailers and consumers.
Avoidable food waste	Food that could have been eaten if it had not gone mouldy or spoilt or if it had not been leftover on a plate at the end of a meal'.
Unavoidable food waste	Waste generated during preparation or items that are inedible, for example, bones, vegetable or fruit peel, tea bags and coffee grinds.
Preparation waste	Discards generated during food preparation due to rotting, burning or simply because it does not meet the necessary quality expectations.
Direct waste	Discards generated by clients during food consumption and use of residential rooms.

Additional waste	Waste generated during food preparation, together with waste generated to provide service to clients.

Source:-http://www.fao.org/platform-food-loss-waste/food-waste/definition/en/ and https://wrap.s3.amazonaws.com/the-food-we-waste.pdf

Between Monday 25th June and Sunday 1st July 2018, a room waste audit was conducted. The discarded items were sorted into five fractions. Although waste composition and quantities vary according to the type of hotel, guest attributes, the activities engaged in by both guests and employees, and rate of occupancy (Pirani & Arafat, 2014). The main fractions consisted of recyclable waste, in view of the fact that this was the most common waste fraction generated together with the organic fraction because of the food consumed within their rooms.

Records of waste items such as edible oil and batteries, as well as, the purchasing records and sales figures were also reviewed. Liquid waste, together with waste originating from offices and refurbishment or replacement of items such as deck chairs were excluded from this research.

5.4.2 Qualitative data

Qualitative research methods were used to determine the role that waste generation has in the decision-making process, examine the predisposition of staff towards waste reduction initiatives and investigate requirements (both perceived and actual) that are conducive to waste generation. In this case study, qualitative data collection was actualised through focus groups and semi-structured interviews. Focus groups take the shape of a relatively structured group conversation or discussion group interviews guided by a moderator where a specific topic is discussed (Morgan, 1998). They aim to gain insights from a purposely selected group of individuals (Refsgaard & Magnussen, 2009) and provide depth to the statistical data collected (Gill et al., 2008). Semi-structured interviews, on the other hand, served to attune the researcher to the relationship that clients of a five-star hotel have with waste (Gubrium & Holstein, 2002) and examine the predisposition they have towards waste recycling and reduction initiatives.

Two focus groups, with managerial and line-staff, were conducted on the 20th and 22nd June 2018 respectively, both lasting about an hour. The focus groups took the form of an interactive discussion facilitated by the researcher (Refsgaard & Magnussen, 2009). Thirty, face-to-face, semi-structured interviews were conducted with the hotel residents during June and July 2018.

The questions posed in both the focus group and the questionnaire were based on the Theory of Planned Behaviour (TPB) and the Attitude-Behaviour-Context (ABC) theory (See Annex 3,

Figure 8-3 and Figure 8-4). The TPB has been extensively used to predict and explain environmental behaviour (Russell et al., 2017). TPB is based on three, conceptually independent, determinants of an "individual's intention to perform a given behaviour" where intention, that is, how much effort a person is willing to make to perform a particular behaviour is the central factor (Ajzen, 1991).-The other two factors are the subjective norm and volitional control. Subjective norm refers to the influence of the significant others, while volitional control indicates whether a person can decide at will whether or not to perform a particular behaviour (Ajzen, 1991 Page 182).

The ABC theory extends the TPB (Shove, 2010). Stern (2000) states that behaviour (B) is an interactive product of personal-sphere attitudinal variables (A) and contextual (external) factors (C) which can either support or oppose behaviour. Therefore, ABC theory joins the study of behaviour as a function of internal individual processes and external factors. When the required behaviour is difficult, inconvenient or expensive for the majority (negative C), the actual action is rare. On the other hand, when the action is associated with strong positive conditions (positive C), the action becomes more common (Guagnano et al., 1995).

5.4.2.1 Management focus group

The management focus group aimed to determine the role that the generation of waste has in the decision-making process, together with the management staff's predisposition towards waste reduction methods. Prior to commencing, the participants signed a consent form and were notified that the session would be recorded. The focus group comprised the culinary director, the learning and development executive, a restaurant manager, the assistant sales manager and the revenue and e-commerce manager. All five participants were Maltese; therefore, the session was conducted in the Maltese language.

The researcher prepared a set of six questions together with some figures and pictures to prompt discussion. The introductory question focused on how they perceive the waste generated by the hotel, that is, whether it is a problem that simply requires a waste collector or an issue that needs to be managed. Figures about the number of water bottles distributed in the residents' rooms in 2017, together with the costs involved, were provided, while ideas about the use of items such as water dispensers were floated. Participants were also quizzed about their green purchasing practices and the roles that associations such as the Malta Hotels and Restaurant Association (MHRA) and the Malta Tourism Authority (MTA) should adopt to expand the uptake of these initiatives, together with the adoption of a more intensive eco-certification.

5.4.2.2 Line staff focus group

In the case of line-staff, the focus group examined the views of operational staff about waste generation and their predisposition towards reduction initiatives. It also sought to identify practices that generate waste, understand how initiatives such as exchanging plastic straws were working, and elicit ideas about waste reduction from the operational staff who have to implement them and, therefore, have a crucial role to play in their success.

As in the earlier focus group, participants were handed a consent form and notified that the session would be recorded. The meeting was attended by a supervisor, two waiters, a barman and an assistant pastry chef. Two participants were Maltese, while the remaining three were Serbian, Macedonian and Portuguese. The workshop was therefore held in English. The introductory question focused on the views they held regarding the waste generated regarding the hotel and whether it was simply a matter of aesthetics. Waste reduction initiatives, such as the use of water dispensers, the use of sealed food trolleys to preserve food instead of cellophane and the introduction of paper straws instead of plastic straws were discussed. Participants were quizzed about the difficulties they perceive in the more widespread adoption of pro-environment initiatives and if they would participate willingly or would view them as another chore.

5.4.2.3 Semi-structured interviews

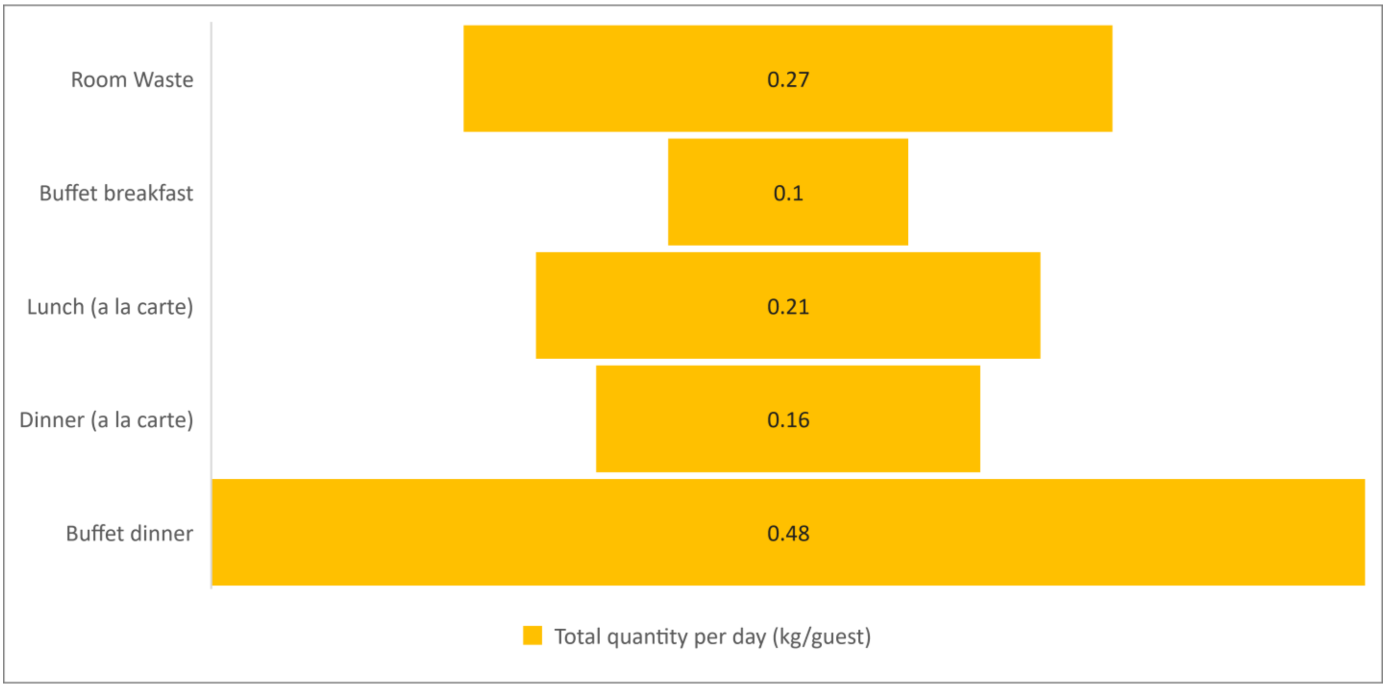
Semi-structured interviews follow a set of guiding questions but allow the researcher to delve into topics of interest without having to adhere to specific questions (V. Wilson, 2012). This approach allows greater flexibility and makes it possible to discover or elaborate information that the researcher might not have considered pertinent (Gill et al., 2008). In this case, the interviews included seven open-ended questions. Respondents were picked randomly, generally, people sitting in the hotel lounge or near the pool and lasted between 10 to 30 minutes depending on how willing the interviewee was to interact. No specific rules exist with regards to the appropriate sample size for this kind of research (Statistical Solutions, 2018) but Mason (2010) notes that for case studies this varies between 1 and 95. This sample size allows for more detailed insights (Gill et al., 2008), but loses the ability to generalise the result to many (Creswell & Plano Clark, 2011; Newenhouse & Schmit, 2000). Although a larger sample could have been obtained by using close-ended questionnaires, which could, for example, have been placed in the residents' room, this approach was avoided in view of the fact that this methodology does not allow respondents to reflect on their true feelings.

5.5 Results

5.5.1 Quantitative Data

The first results are shown the waste generated by a hotel guest who spends a day at the hotel and consumes a buffet breakfast, a-la-carte lunch and a-la-carte or buffet dinner. Additional waste is shown in Table 5-3.

Figure 5-1: Direct waste produced by a hotel resident in one day



Therefore, it can be calculated that a resident generates 0.74 kg or 1.06 kg of waste depending on whether they consume an a-la-carte dinner or a buffet respectively. Both plate and room waste are included in the figures.

Table 5-3 includes waste generated during food preparation which adds up to 0.08 kg/guest (0.03 kg of avoidable and 0.05 kg of unavoidable waste). Other items such as packaging that includes cartons and plastic discarded from the bars add up to 1.73 kg/guest, while batteries are calculated on a per room basis in view of the fact that they are used to operate the rooms' door opening and closing systems and are not influenced by guests visiting the restaurants.

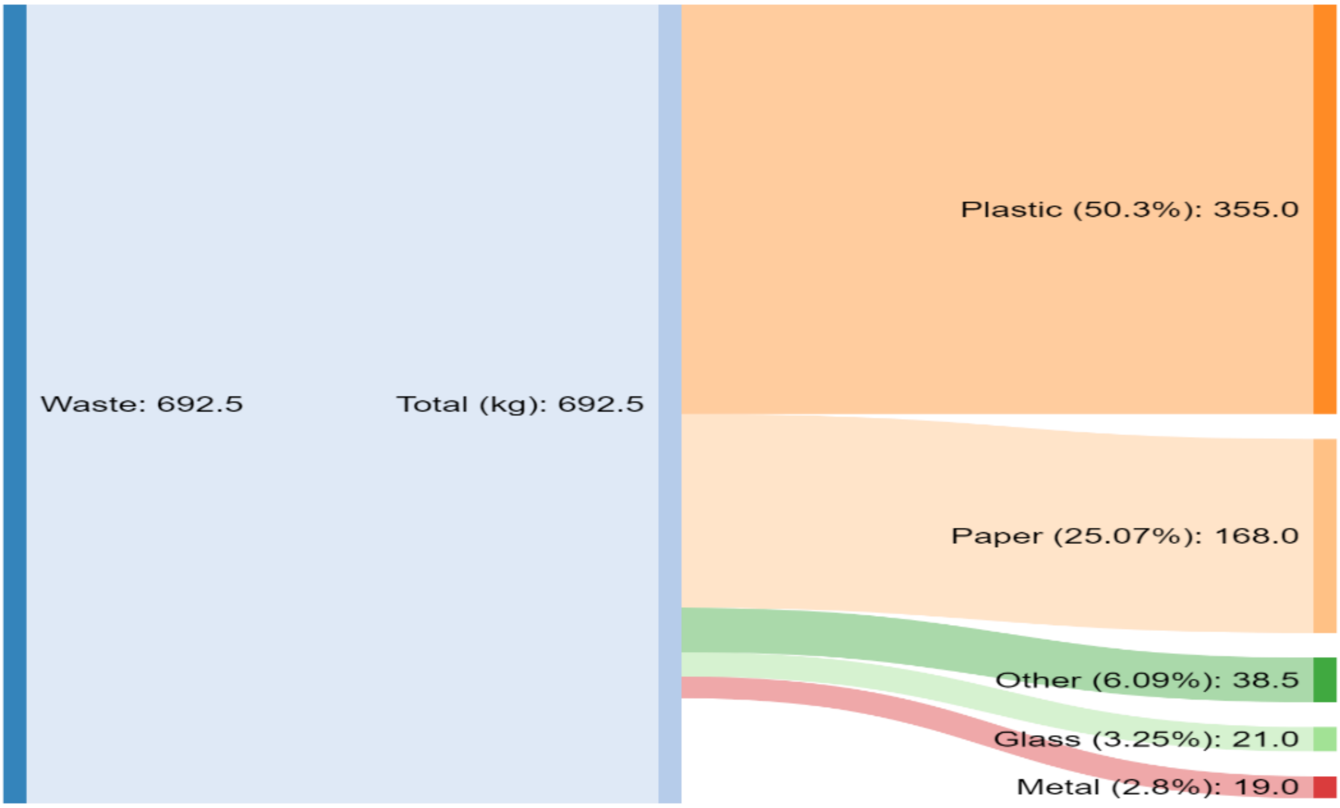
Table 5-3 Additional waste (food preparation, packaging and batteries)

Type of waste	***Total waste (June 2018)***	***Waste/room***	***Waste/bed night***	***Waste/guest***
Avoidable preparation waste	122.1 kg	--	--	0.03 kg
Unavoidable preparation waste	116.96 kg	--	--	0.05 kg
Packaging waste	1,440 kg	5.7 kg	0.14 kg	1.73 kg
Batteries	1,500 g	5.95 g	0.14 g	--

5.5.2 Room waste

The room waste audit was held between the 25th June and 1st July 2018. During this week, the hotel registered an average occupancy of 92.68 per cent (an average of 231 out of 252 rooms were occupied). This occupancy rate is relatively high compared to the 73.83 per cent occupancy rate during the rest of 2018 (A.Meli, personal communication, October 9, 2018). Figure 5-2 shows that a total of 692.5 kg of waste was collected from the residents' rooms in one week. This can be translated into 0.27 kg/resident or 0.44 kg/room/day of waste. The most prevalent fraction is plastic which amounts to 50.3 per cent of the total waste or 0.14 kg/resident reflecting the widespread use of the material. Furthermore, practices such as the daily distribution of 0.75 cl plastic water bottles and toiletries leave a clear impact on the amount of waste generated. Metal and glass, on the other hand, have an intensity ratio of 0.01 kg/resident respectively, while organic waste adds up to 0.03 kg/resident.

Figure 5-2 Room waste composition (Kg) (25/07 to 1/07/2018)



Further distinctions are made in Figure 5-3 and Figure 5-4. Waste generation volumes peaked on Thursday 28th June 2018 at 129 kg. This day was also characterised with the highest number of arrivals (89 rooms) and departures (124 rooms). High numbers of arrivals (105 rooms) and departure (70 rooms) were also registered on Friday 29the June, with the amount of waste generated reaching 126 kg. On the other hand, on Wednesday 27/06, only 49 kg of waste were generated. During the day, while occupancy reached 95.63 per cent (241 rooms were occupied with 294 residents), only 18 arrival and 25 departure rooms were registered. However, on Saturday 30th June and Sunday 1st July, waste generation remained high (116.5 kg and 114 kg respectively) despite the drop in departures and arrivals (Saturday 30th June registered 27 arrivals and 32 departure rooms and Sunday 1st July registered 30 arrival and 25 departure rooms). This, therefore, provides scope for additional research.

Figure 5-3 Waste fractions originating from the residents' rooms

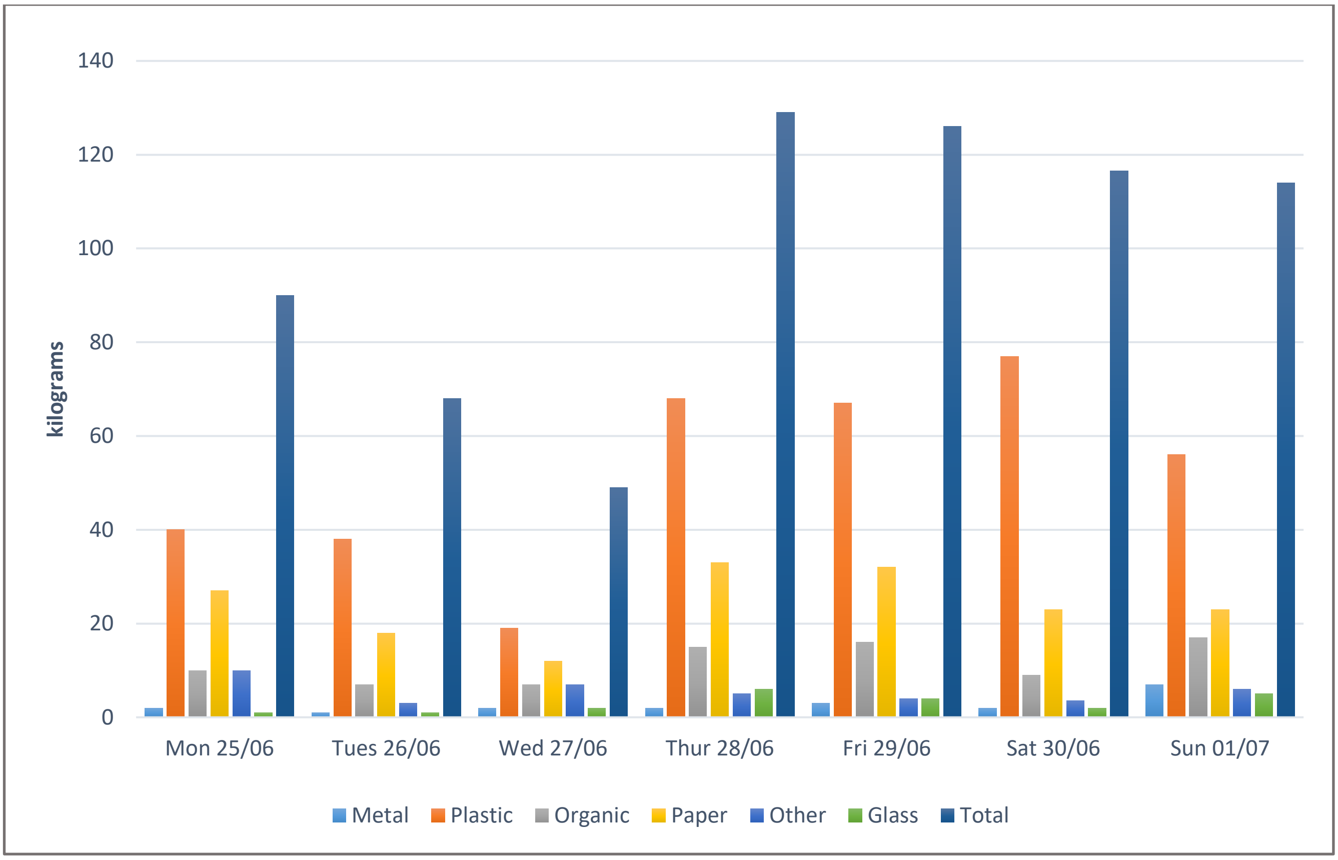
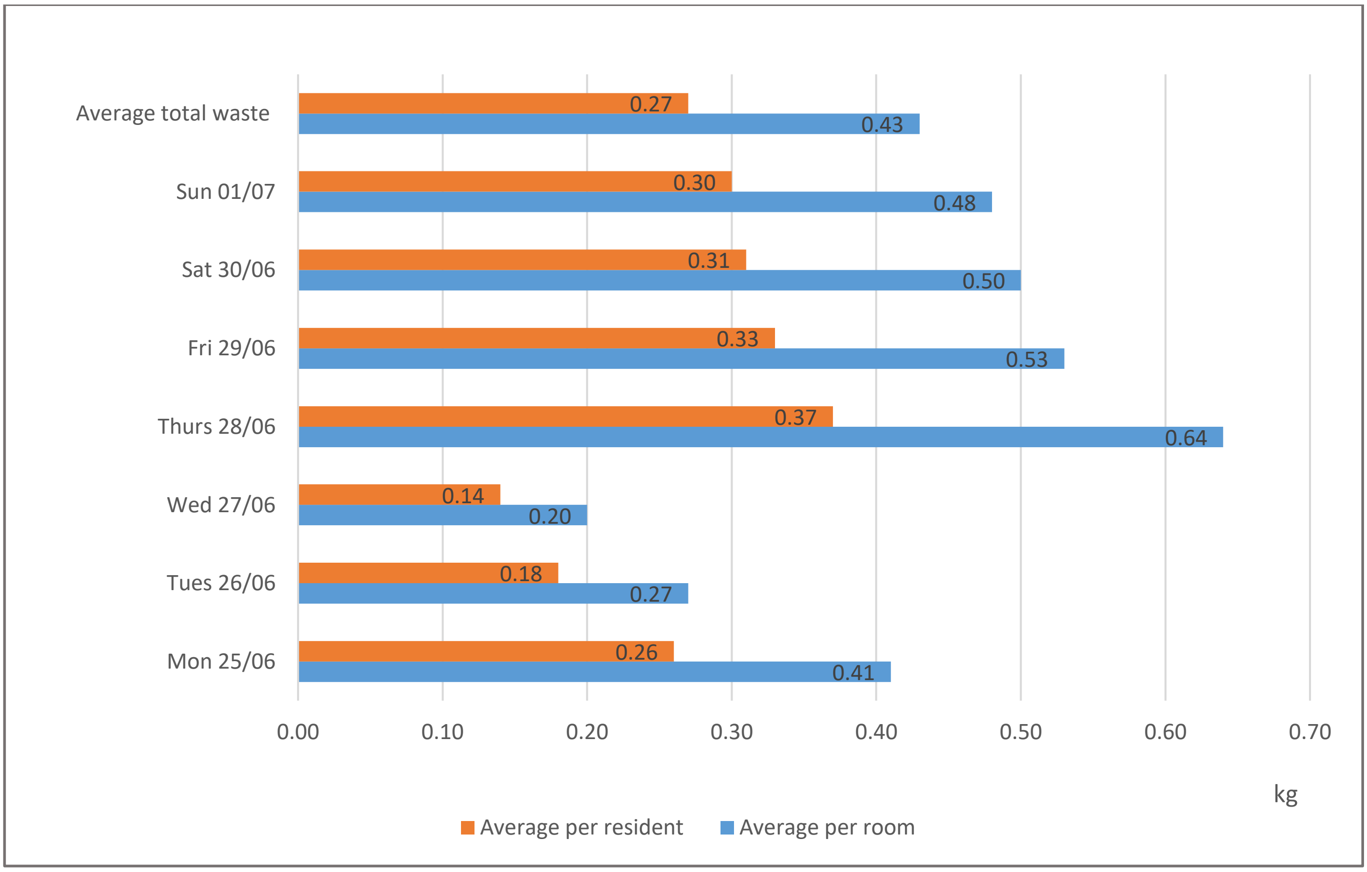


Figure 5-4: Average waste generated per resident and per room (kg)



5.5.3 Restaurant waste – buffet and a-la-carte *

5.5.3.1 A-la-carte waste generation audit

Foodservice has acquired a central role in tourism products which is combined with place and promotion strategies (Henderson, 2009). The food experience is linked to the authenticity of the visit and tourists often want to test unfamiliar dishes (Sims, 2009). Food has also been used as a medium for the regeneration of specific regions through the promotion and distribution of local produce and therefore acts as a vehicle for the implementation of sustainable development (Everett & Slocum, 2013). However, the hospitality industry is also connected with high food waste figures with the foodservice industry generating 12 per cent or 11 million tonnes of food waste in the EU in 2012 (Stenmark et al., 2016).

This section assesses food waste at the preparation and post-consumer stage. The month-long audit at the a-la-carte restaurant, as well as identifying waste in the selected fractions, notes trends in preparation waste. Fractions are allocated according to the definitions shown in Table 5-2.

During June 2018, 3,184 people (1,230 at lunch and 1,954 at dinner) were served (including room service). Waste figures reached 814.512 kg (preparation - 236.021 kg and plate-waste 576.34 kg). This means an average of 27.15 kg per day or 0.26 kg per client of waste. In Papargyropoulou et al., (2016), food waste calculated as a total of preparation waste, buffet and customer leftovers reached an average of 173 kg/day or 1.1 kg per person.

Figure 5-5 portrays preparation waste according to the day of the week. Total preparation waste reached 236.021 kg in one month or an average of 7.867 kg per day or 0.073 kg per client. On Saturday 16th June, avoidable preparation waste soared to 26.7 kg due to a cooking mistake which saw 20.3 kg of pork discarded. On Tuesday 26th June, due to clearance of beef bones (2.9 kg), calamari (8 kg) and potatoes (3.5 kg), another abnormality in waste figures can be noted. In Figure 5-5, a clear relationship can be observed between the operational mode of the restaurant and waste generation patterns. Following the weekends, Mondays are generally low in preparation waste, while Tuesdays register a high level of both unavoidable (30.45 kg) and avoidable (18.83 kg) waste in view of the fact that new food items are purchased while perished ones are removed. On Fridays and Saturdays, both unavoidable and avoidable preparation waste can be observed. On Fridays the weekend preparation commences, causing an increase in unavoidable preparation waste (36.1 kg), while on Saturdays the avoidable fraction (35.26 kg) increases.

Figure 5-5 Avoidable and unavoidable preparation waste in the a-la-carte restaurant

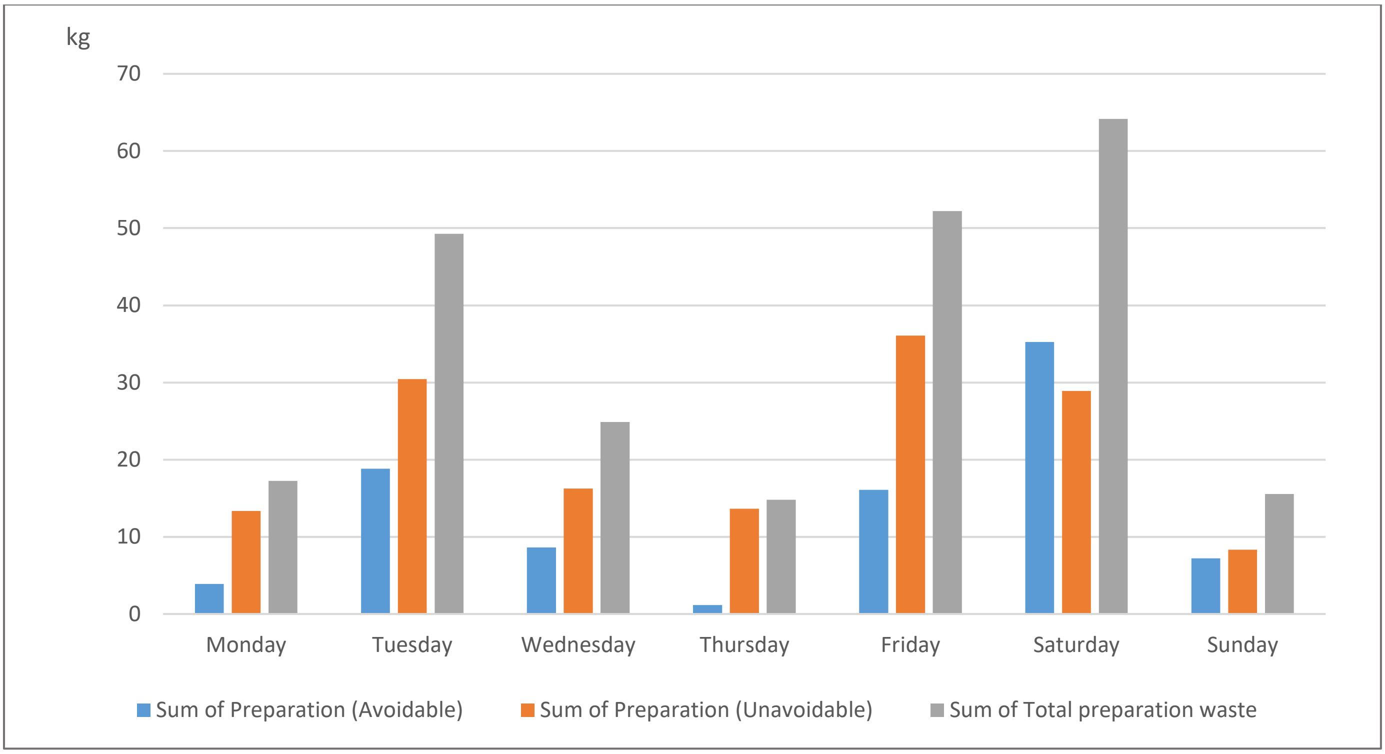


Plate-waste generated during the June audit, reached a total of 576.34 kg, with 257.831kg generated at lunch and 318.51kg at dinner. Waste per guest reached 0.21 kg at lunch and 0.16 kg at dinner. No differentiation is made in portion sizes between lunch and dinner. As pointed out by the chef the main course is designed to be a full meal and therefore conducive to food waste if additional plates are ordered.

Fathers' day fell on June 17th in 2018. The restaurant served 143 people resulting in 15.99 kg of waste or an average of 0.11 kg of plate waste per person (consisting of side plates – 5.54 kg, other – 5.47 kg, meat, fish and pasta – 3.3 kg, bread – 1.53 kg and sweets – 0.15 kg). Only 12 people were served at lunchtime on June 18th. This resulted in 4.325 kg of waste or 0.36 kg per person (bread – 1.175 kg, other – 1.6 kg, sweets 1.1 kg, vegetables, salads and side plates – 0.45 kg, meat, fish and pasta – 0).

On June 16th the restaurant hosted 126 guests for dinner generating 17.66 kg of waste or an average of 0.14 kg per person, (vegetables, salads and side plates – 8.29 kg, meat, fish and pasta – 4.54 kg, other 3.07 kg, bread – 1.56 kg and sweets – 0.2kg). Avoidable preparation waste during the weekend shot up mainly due to a cooking mistake probably caused by the stress that the busy weekend brought with it. Only 35 people were served at dinner time on Sunday 10th June, resulting in 4.8 kg of waste or 0.14 kg per person (other – 2.2 kg, bread – 1.1kg, vegetables, salads and side plates – 0.8 kg, meat, fish and pasta – 0.6 kg and sweets – 0.1 kg).

5.5.4 Waste fractions

A further distinction of the waste fractions generated per person is noted in Table 5-3.

5.5.5 Buffets

5.5.5.1 Breakfast

Buffets allow guests to select and self-serve food from several stations in an all-you-can-eat format and are associated with higher guest satisfaction and the reduction of service staff costs (Juvan et al., 2018) but higher food waste figures (Silvennoinen et al., 2015) since at buffets guests are provided with an indefinite opportunity to experiment with unknown foods which ultimately might not turn out to their likings thus creating waste. Additionally, guests are charged a blanket price for the consumed food and therefore tend to overload their plate only to throw the food away practically untouched (Silvennoinen et al., 2015).

Table 5-4 and

Table 5-5 note the waste quantities generated from the buffet breakfast.

Table 5-4 Waste generated during buffet breakfast

	Mon 23/07	Tue 24/07	Wed 25/07	Thu 26/07	Fri 27/07	Sat 28/07	Sun 29/07	Total
Total people served	399	314	455	481	484	500	480	3113
Total waste Generated (kg)	41	36	52	42	42	38	44	295
Average waste generated (kg)	0.1	0.11	0.11	0.09	0.09	0.08	0.09	0.09

Table 5-5 Average waste generated per fraction during buffet breakfast

	Sweets kg	Meats, chicken & salmon kg	Vegetables, potatoes & eggs kg	Bread kg	Other kg
Average total plate waste/person-generated during the audit week (kg)	0.01	0.01	0.01	0.01	0.05

The waste fractions indicate a relatively uniform leftover rate except in the case of the ‘other’ fraction which sees waste increase to 0.05 kg/person mainly due to the large quantities of disposables used during breakfast. This highlights the implications and costs of single-use items the replacement of which can also be advertised as a social responsibility initiative.

A comparison can be made with Bajada (2017), who, in a study carried out over 3-days in a local five-star hotel, noted that the average plate waste generated during buffet breakfast to reaches 0.09 kg, while for lunch and dinner, this figure amounts to 0.249 kg and 0.238 kg respectively. In this context, the chef noted that at breakfast items are served in small-sized portions to reduce waste. Furthermore, clients often opt to have a good-sized breakfast and then skip lunch, thus consuming all the items taken from the buffet (Bajada, 2017). Therefore, the total figures from the two studies tally with both buffets using small-sized plates. The restaurant manager agreed that overfilling plates is no longer a 'fashionable' practice, which brings in the subjective norm, one of the central factors of the TPB, that refers to "the extent to which "important others" would approve or disapprove of their performing a given behaviour".

5.5.5.2 Dinner

Figure 5-6 and Table 5-6, provide an overview of the waste generated during the buffet dinner audit. Highest wastage is registered in the vegetable and potatoes fraction. This is similar to the results obtained the a-la-carte audit where waste in the vegetables, salad and side-dishes fractions reached 0.06 kg and 0.05 kg during lunch and dinner respectively. This can be an indication that; (1) portion sizes are large; and (2) people prefer to eat their main course and discard the side-plate food.

Figure 5-6 Total and average waste from buffet dinner (06/08 to 12/08)

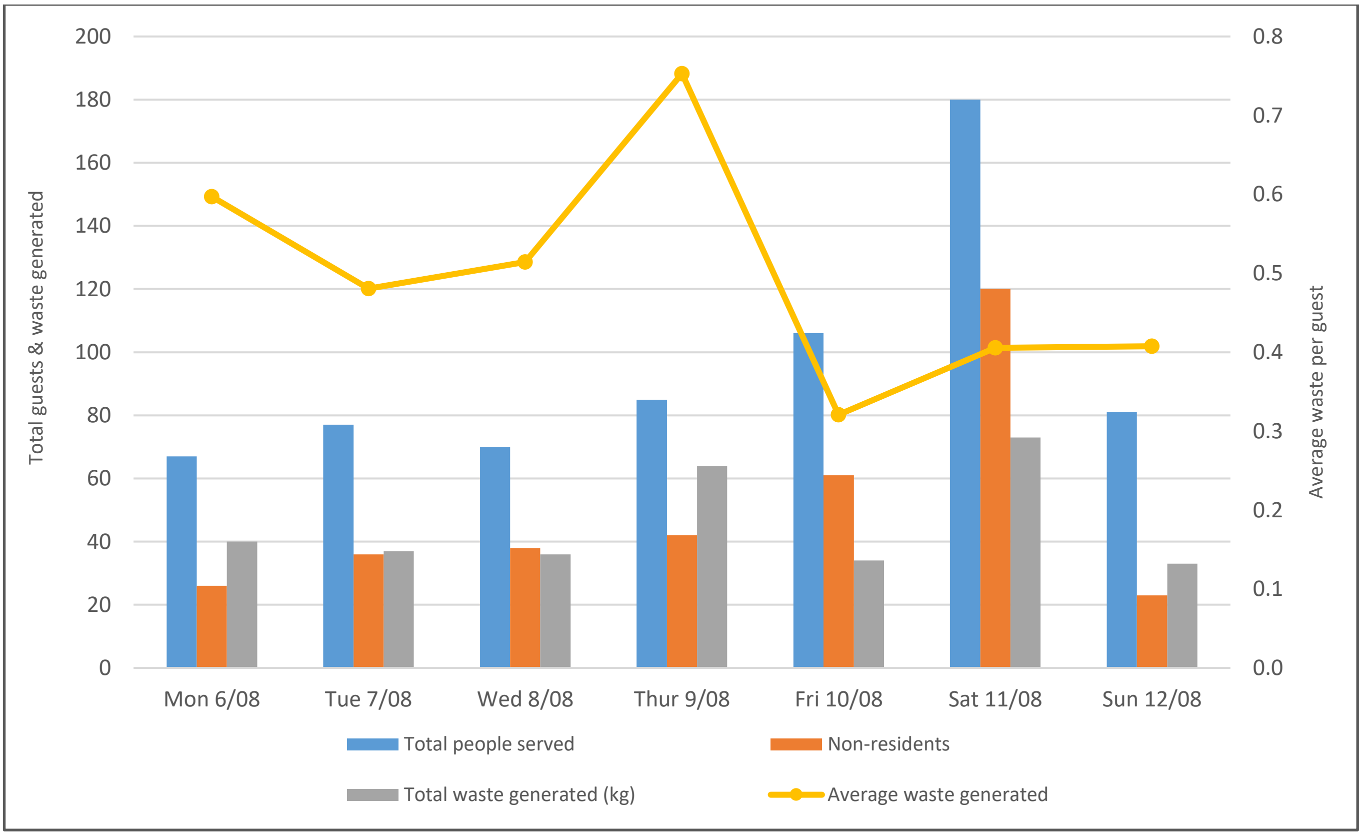


Table 5-6 Average waste generation from buffet dinner per item

	Sweets (kg)	Meats, chicken & salmon (kg)	Vegetables, potatoes (kg)	Bread (kg)	Other (kg)
Average plate waste/person	0.07	0.11	0.23	0.02	0.05

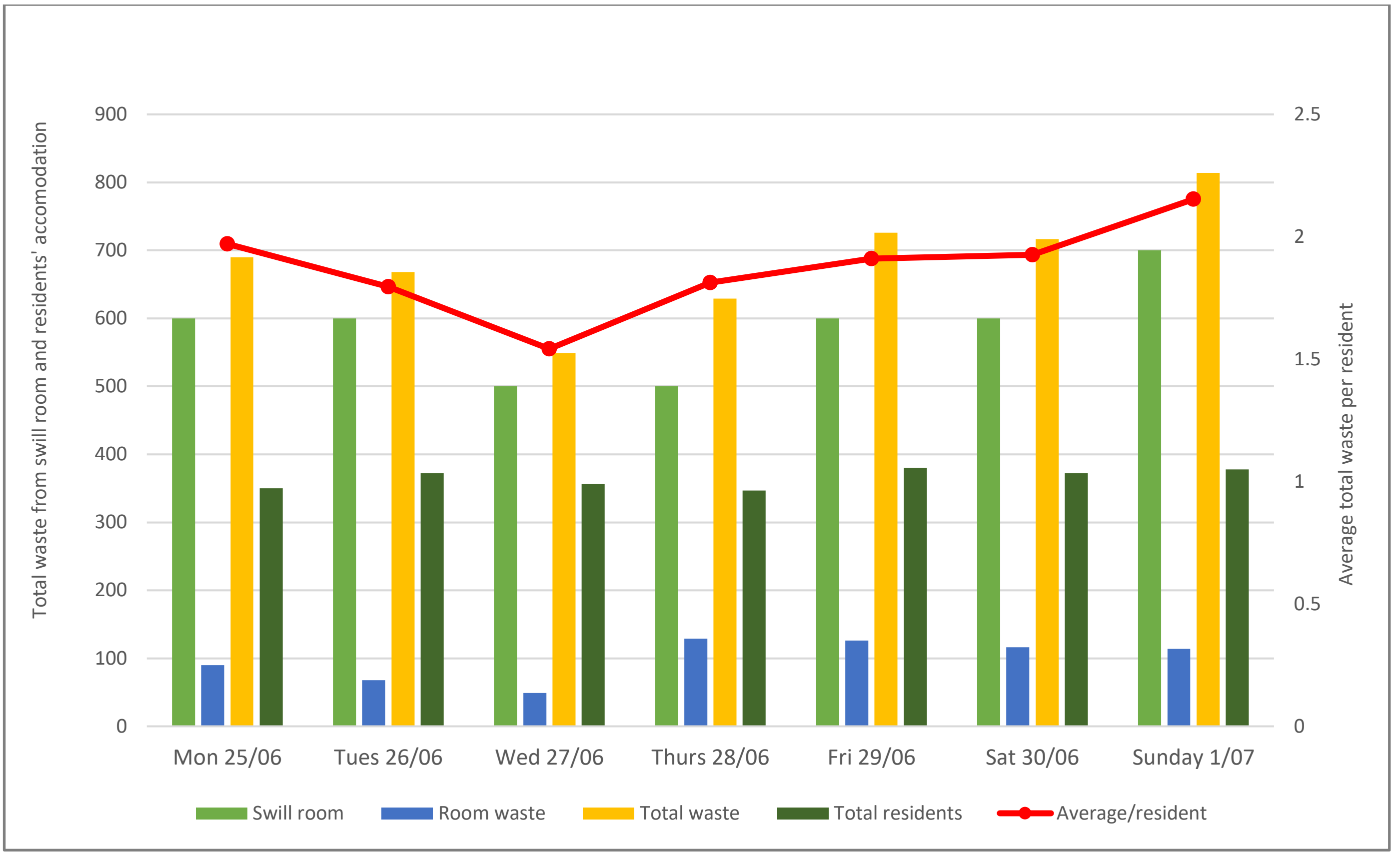
In the buffet, eight menus are rotated to ensure that food choices differ from one day to the next. Menus vary according to seasons. Figure 5-6 shows the total and average waste generated for dinner. It is interesting to note that while the number of guests increases during weekends, the average waste per person decreases, putting more emphasis on the role of the subjective norm. Figure 5-6 also refers to non-residents who have dinner at the hotel. This was included as an effort to examine whether non-residents influence waste generation. However, no conclusions could be made in this regard.

5.5.6 Swill room waste

Waste in the swill room was weighed during the week of 25th June to 1st July 2018. Swill room waste refers to waste originating from the kitchen of the three restaurants, the pool bar and the spa together with the skips area (waste from the offices and residents' room) and includes organic waste mixed with packaging material and any other discarded material.

This part of the study made it possible to compare figures with the 1-week waste audit commissioned in October 2002 where total waste generated in one week reached 4,504.4 kg or 87.27 per cent of the waste produced by the hotel which translates into an average of 750.73 kg of waste per day or 1.8 kg per person (WasteServ Malta, 2002). Therefore, in 16 years, waste originating from the swill room has increased slightly reaching an average of 1.87 kg per person.

Figure 5-7 Total and average waste generated in residents' rooms and swill room



5.6 Qualitative data

5.6.1 Focus groups

This section examines the qualitative data collected from the two focus groups. Initially, participants were probed about their views of the waste generated by the hotel and whether they see it as a problem that simply requires a waste collector or an issue that requires management. The restaurant manager felt that the waste generation figure was high and that an appropriate management system was required. All the participants agreed that the successful implementation of a waste management system required employee co-operation which might not be forthcoming. However, the culinary director pointed to the ongoing success of the a-la-carte audit which had full compliance from the staff. Subsequently, when asked if they perceived the hotel as a high waste generator, the participants noted that it probably was and pointed to wastefulness during buffets but emphasised that buffets attract clients.

The line staff gave more explicit examples. The assistant pastry chef immediately pointed to sweets that need to be discarded if not consumed within two days. Extensive waste occurs if forecasts buffet dinner is over catered. The waitress who participated in the focus group brought up the issue of portion sizes. She emphasised the fact that the portions were too big and this was directly connected to plate-waste. Reference was also made to the replacement of plastic straws with paper straws which was well received. However, the paper straws tended to become soggy, leading clients to request another. Additionally, paper straws cannot be used in drinks with crushed ice and it was recommended that stainless-steel alternatives should be investigated.

The assistant sales manager remarked on the motivation needed from external factors to induce hotel participation. He pointed to the limited efforts coming from central government and stressed that if, for example, the relevant authorities published research that proves that tourists preferred pro-environment accommodation, there would be a greater uptake of environmental initiatives.

Cling-film and plastic bottles have a hefty impact on the environment (Khan et al., 2018). Despite their well-documented consequences, the suggestion to replace them was met with hesitation. Items such as cling film are an essential part of everyday operations, with their use increasing when there is outside catering. Catering size rolls (45 cm by 300 m) are one of the top six items purchased monthly. To replace its use, the hotel needs to introduce items such as closed trolleys which require an initial high investment cost. The line staff also referred to items such as small plastic cups and teaspoons that are only used once for sweets because once washed they become dull or break down.

Expectations of luxury were the main concern voiced in both the focus groups when it was suggested that the water bottles distributed in residents' rooms be replaced with dispensers. Management was also concerned with the demands of the mother brand. The assistant sales manager highlighted the fact that no complaints were registered about plastic bottles and that people visiting Malta for business might consider dispensers to be a nuisance. A similar concern was expressed by the line staff.

5.6.2 Semi-structured interviews

The nationality of clients at the hotel varied from Iraqi to Irish to Swedish and to Maltese. Waste was initially associated with cleanliness and aesthetics; however, when probed about the hospitality industry, all the respondents pointed to the high wastage. Ideas such as refillable bottles were well received by 29 out of 30 interviewees. Some suggested the reuse of toiletry items and the introduction of thicker plastic cups for use by the pool and complimented the introduction of paper straws instead of plastic ones. None of the interviewees was influenced by the green practices of hotels when selecting their accommodation, with some assuming that hotels took care of these issues themselves.

The interviews brought out the role of contextual factors. A clear example is the adoption of the towel reuse initiative, the success of which highlights the importance of facilitating pro-environment behaviour by facilitating the means. Enabling mechanisms are therefore crucial to achieve a shift in behaviour; for example, introducing thicker plastic cups that would ensure safety near the pool but would also allow for reuse and providing dispensers for water distribution to reduce plastic waste. Despite possible scepticism, hotels that demonstrate sensitivity to the environment within their daily tasks are likely to enrich their attractiveness to guests with a possible boost in occupancy (Tsai et al., 2009). Singh, Cranage and Lee (2014) note the success of waste segregation measures where guests not only feel part of the sustainability movement but also feel that they are a partner in the hotel's efforts. Although hotels sometimes presume that since guests are paying, they might feel offended if asked to segregate waste, this perception is often baseless since they exhibit sensitivity towards these issues and generally participate willingly.

5.7 Discussion - interpretation of empirical results.

The introduction of a waste management programme requires the hotel administration to expand its normal operational boundaries to incorporate larger systems (Senge et al., 2008). This must be supported by management systems and professional skills, otherwise, the risk of failure amplifies (Heikkilä et al., 2016). The management of waste in hotels is affected by factors including the prevalent legislation, economic constraints (Pirani & Arafat, 2014), management attitudes to environmental issues, brand requirements and clients' demands. An effective waste management system requires a good relationship with the waste service provider, an analysis of closely located treatment facilities, regular waste audits that calculate costs for different waste treatment options and green purchasing which would lead to more efficient procurement of items with the aim of generating less waste (Pirani & Arafat, 2014).

Waste generated in hotels can vary from food to recyclable items to hazardous material. Food waste signifies a loss of resources that translates into a considerable environmental impact due to the multiple processes incorporated in the life cycle (Tonini et al., 2018). Therefore it is an ecological, economic and social problem that epitomises an unsustainable system of production and consumption (Martin-rios et al., 2018). Impacts arise also from items such as paper, that is subject to wear and degradation every time they are recycled (Scott, 2012); container glass, that despite being 100 per cent recyclable presents a number of challenges to be collected that could easily outweigh the benefits (Butler & Hooper, 2012) and plastic, the seemingly ubiquitous material, which this research proved to be the most common item originating from residents' rooms that faces issues of degradation.

Purchasing records note that in 2017 alone the hotel acquired 57,274 plastic water bottles to be distributed in residents' rooms. Toiletries records show that in June 2018 *only,* a total of 1,600 body lotion, 3,200 hair conditioner, 3,400 shampoo and 3,000 shower gel30 ml HDPE bottles were purchased. Also purchased were 1,400 cotton slippers. The trajectory of the linear flows of single-use items immediately implies that the hotel should seek to reduce its waste. On a positive note, the mother brand is presently seeking the elimination of single-use plastic from meetings and events by 2020 (S. Wiltink, personal communication, January 15, 2019).

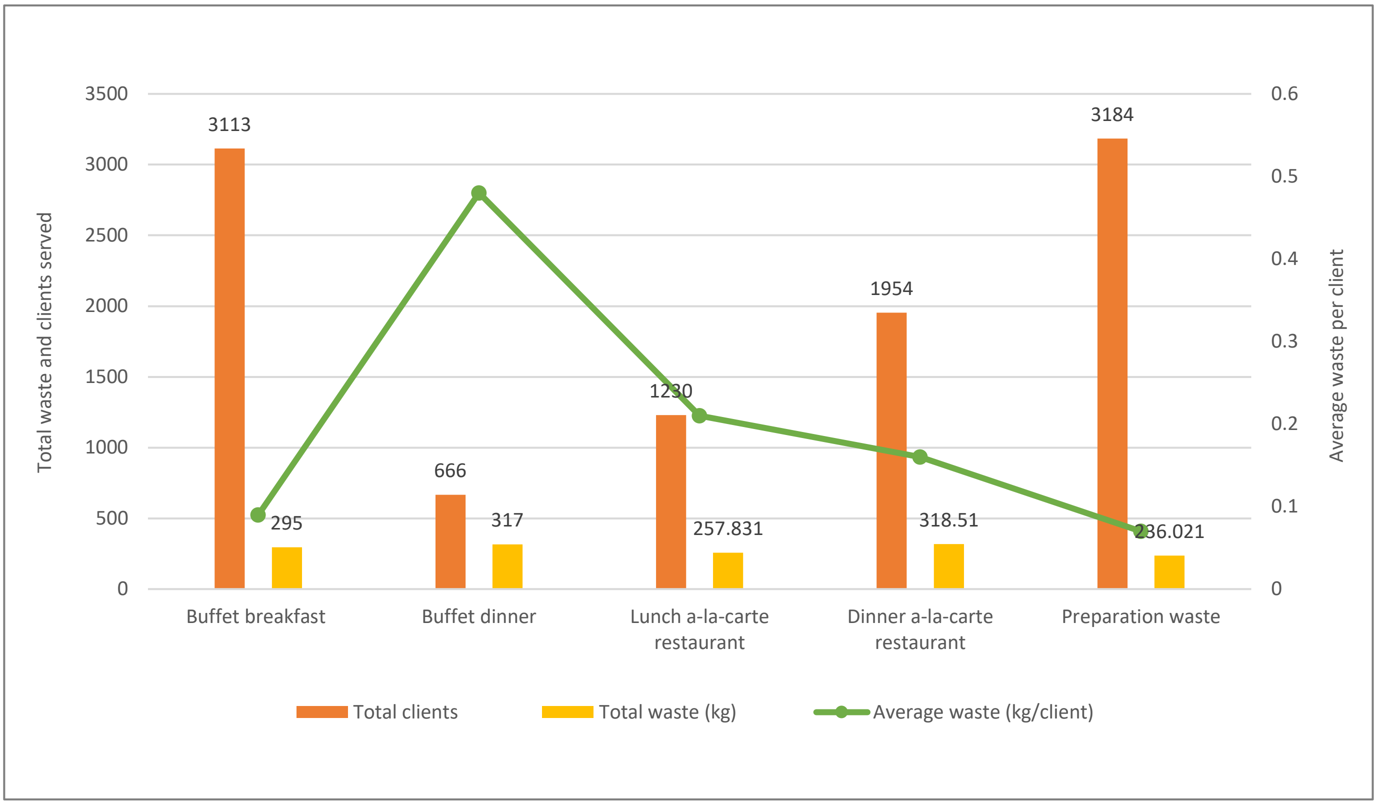
5.7.1 Food waste arising from the buffet and a-la-carte service

The issue of food waste surfaced in both the staff focus groups and client interviews. Both segments emphasised wastage during buffets. Here, the interplay of the subjective norm can be noted where, although clients expect to be provided with variety, they frowned upon plate overfilling and emphasised the fact that, if necessary, one can always return to the food counter for an additional helping. Staff pointed to wastage particularly in relation to the consumption of sweets where guests take a portion of every item displayed only to consume a mouthful and discard the rest. In the dinner buffet audits, the sweets fraction registered a wastage of 0.07 kg/client (Table 5-6) while the figure in the a-la-carte audit is negligible.

In 2015, the hotel underwent a breakfast restyling exercise that included a change in menu and décor to emphasise the farm-to-fork concept. The nudging exercise included a review of the setup and crockery to make the breakfast buffet look bigger than it actually was. This exercise served to satisfy the clients' demand for variety and reduced pressure on the kitchen (R. Muscat, personal communication, January 14, 2019). Such non-intrusive 'nudges', for example, plate size reduction and providing social cues, can assist in the reduction of food waste by even 20 per cent (Kallbekken & Sælen, 2013).

Figure 5-8 displays the number of clients served in the various food service areas offered by the hotel and the respective waste generated. The highest wastage is noted during buffet dinners. No distinction is made between avoidable and unavoidable waste. This means that inedible items such as shellfish and bones can be a cause for waste figures to increase. However, during the week, the average waste per client remains stable despite the different menus. The perceived abundance of food during buffets can also contribute to waste figures; when more dishes are set up, waste generation tends to be higher (Juvan et al., 2018). The audits show that in the a-la-carte dinner the average waste per client is 0.16 kg while in the buffet dinner this figure escalates to 0.48 kg per client.

Figure 5-8 Total and average waste during various food services



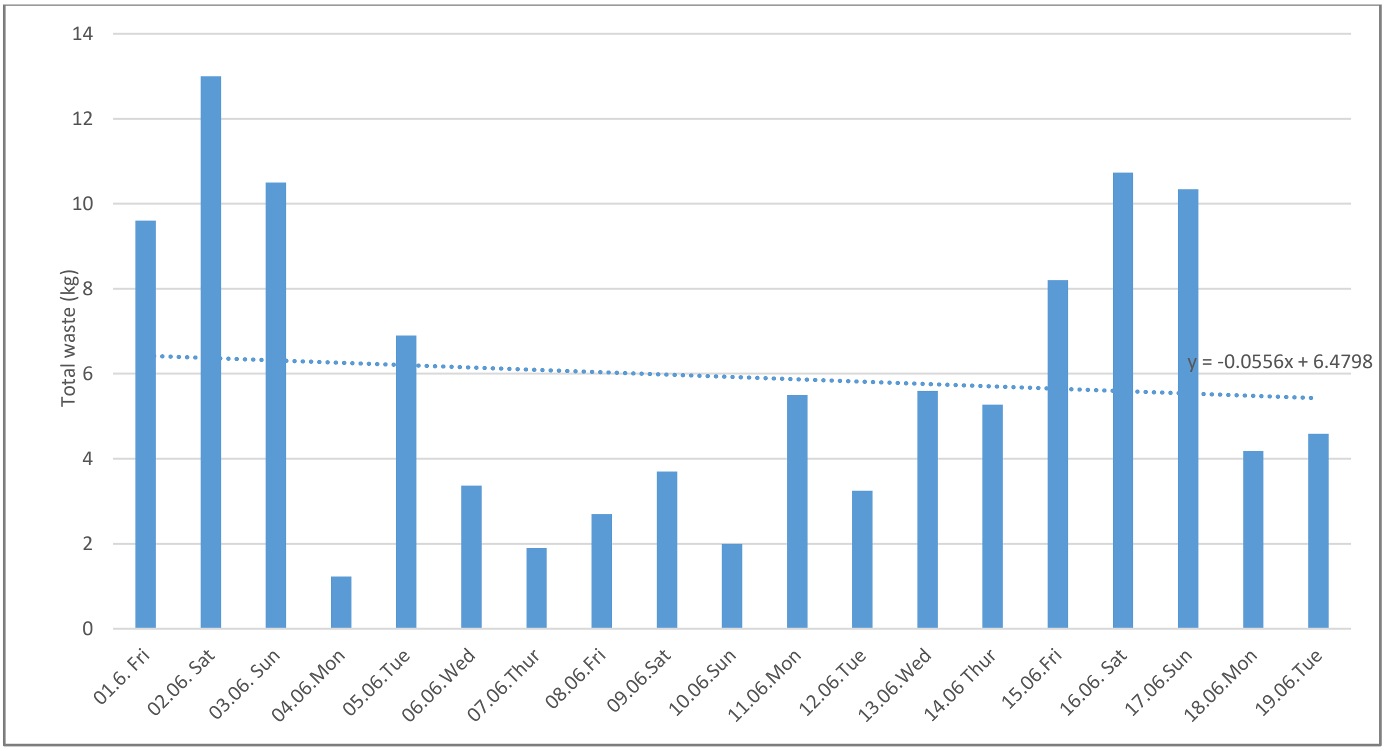
5.7.2 Portion sizes

Portions' size was given prominence in both the focus groups and the interviews. Various clients observed that portions are too large however staff pointed out that Maltese customers expect such portion sizes and often use them to rate the quality of the restaurant. During the line staff focus group, a waitress noted that the 'Charcuterie board', the largest and most expensive menu entry, was a favourite order. Despite the fact that it includes a description stating its size, it is often ordered only to be returned almost untouched. A positive aspect is that the request for 'doggy bags' which in Malta has become a norm even in five-star hotels.

The positive relationship between portion sizes and food waste is affirmed in various studies (Freedman & Brochado, 2010, Berkowitz et al., 2016). The month-long audit at the a-la-carte restaurant provided the opportunity to examine this standpoint. As from June 20th, 2018the restaurant stopped serving main course meals accompanied by a portion of both potatoes *and* vegetables but offered a choice of only one. Guests who wished to have both needed to pay extra.

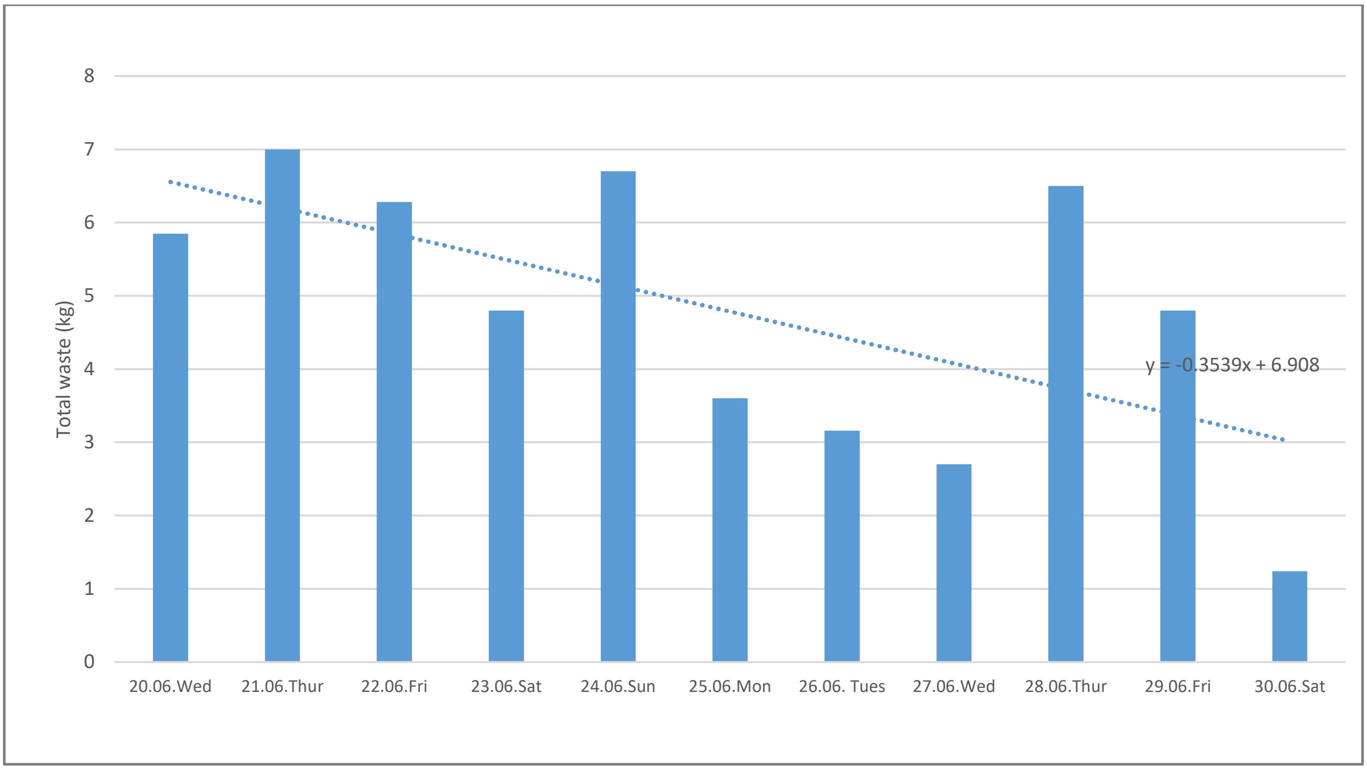
Figure 5-9 and Figure 5-10 provide an analysis of waste generated between the 1st and 19th and the 20th and 30th June 2018.

Figure 5-9 Vegetables, salads and side dishes (kg) fraction between the 1st and 19th June



Waste was reduced immediately upon the introduction of the initiative. Between the 1st and 19th June, the average waste discarded under the 'vegetables, salads and side dishes' fraction amounted to 0.059 kg/person. Following the 20th June, this dropped to 0.043 kg. Food served on plates weighs an average of 0.28 kg. This would, therefore, mean a waste reduction of 5.7 per cent.

Figure 5-10 Vegetables, salads and side dishes (kg) fraction between the 20th and 30th June



In Figure 5-10, a lower negative slope in waste generation is noted (slope of -0.3539x). this can be compared to the linear regression of other waste fractions, which, in the case of bread, for example, amounts to -0.0372, while in the case of the 'other' fraction amounts to -0.1256. For the fractions 'sweets' and 'meat, fish and pasta', it amounts to -0.0139 and -0.0024 respectively. The steeper slope on the vegetable, salad and side dishes (Figure 5-10) in comparison to the aforementioned fractions support the conclusion that the removal of one side-plate contributed to waste reduction.

5.8 The shift towards waste reduction

In their literature review, Boons & Lüdeke-Freund(2013), identify four elements that distinguish the generic business model. These include (1) the value proposition (what value is embedded in the product/service of the firm); (2) the supply chain (the management of upstream relationships with suppliers); (3) the customer interface (the management and structure of customer relationships) and (4) the financial model (costs and benefits from the three elements before and after their distribution across the business model stakeholders).

The protection of the environment, particularly waste management, can be a cross-cutting issue that affects businesses in all four elements. Its implementation is perceived as being instrumental in the development of a positive corporate image which can be an important element of success (D'Souza et al., 2006). Going green has long been perceived as a positive business practice that promotes efficiency, reduces costs, helps to improve the commitment and motivation of employees and builds customer loyalty (Forte & Lamont, 1998).

Improving waste management practices can be considered pivotal from a sustainability perspective (Pirani & Arafat, 2014). Recognising the quantities of waste generated is often frustrating therefore waste reduction activities offer a good start that builds momentum. This is more so when the reduction in waste quantities becomes more visible creating an active interest that is both practical and symbolic - practical because they cut waste and subsequently costs, symbolic because they are visible and signal that the organisation is committed to reducing its internal footprint (Senge et al., 2008).

The audits, together with providing an accurate measure of current waste generation figures, direct effort where it is required. For example, the high presence of plastic in-room waste provides leverage for the introduction of water and soap dispensers. Although the staff was hesitant, all the clients interviewed, except one who voiced concern over hygiene, welcomed the idea. This, together with the logistical requirements to wash and clean the bottles, could be overcome by creating a reusable bottle that is given to residents as a hotel souvenir. The preventative approach should, therefore, commence with the setting of goals or backcasting rather than moving away from the current situation (Greyson, 2007), where the hotel establishes specific waste reduction targets and works towards them.

Different initiatives could be used to reach this goal. As suggested by a waitress, the hotel could start with using water dispensers instead of bottled water to make coffee and other drinks in the bar, while clients could be served in glass bottles. Such an initiative would leave a tangible impact. In June 2018 only, the three restaurants consumed a total of 498 (84+378+36), 2 litre PET bottles to prepare drinks, while 192, 50 cl bottles were distributed during room service. This initiative would pose no changes to the clients but could result in some difficulties for the bar staff in view of the space required for the dispersers. This emphasises the role of hotel management in creating the right contextual factors to facilitate pro-environment behaviour.

The issue of food waste has acquired more prominence in recent years. Food waste has cost implications on food production and purchasing as well as final disposal with prevention being the most favourable option (Papargyropoulou et al., 2014). This further justifies the revision in the side plates handed to customers discussed in Section 6.2. Additionally, revisions are suggested to the bread loaf handed to customers since an average of 0.03 kg is discarded during both lunch and dinner.

Restaurants do not want to their buffets to be caught short-handed so they tend to overproduce. This point was emphasised by the assistant pastry chef, who noted that, if the forecast for dinner is not correct - for example, if the forecast is for 70 people and only 30 turn up, wastage is high. This calls for improved predictability of the foodservice requirements, for example, by offering a percentage discount to people who pre-book their table.

5.9 Conclusion

The research set out to provide a comprehensive case study of waste generation in a five-star hotel. Hotels in this star category tend to be responsible for higher waste generation per person. This study aimed to identify the quantities and type of waste generated in the hotel's restaurants and residents' rooms. To this end, five audits were performed in the breakfast and dinner buffets and a-la-carte restaurant (preparation and plate-waste) and residents' rooms. The limitations of audits to identify the reasons leading to waste generation, necessitated the examination of purchasing records supported by qualitative research which sought to identify practices and processes that characterise five-star hotels, determine the role that waste holds in the decision-making process, survey the predisposition of the staff to waste reduction initiatives and identify the standpoint of clients on the topic.

The bottom-up approach applied in this research identified leverage points that can guide the introduction of a thorough plan that sees the decoupling of waste generation from luxury-tourism. The results recognise that the hotel operates in a linear modality – an attribute that to date continues to characterise the hospitality industry in Malta. Recognition of this aspect by the relevant authorities provides immediate leverage to improve waste management and reduce waste at the source.

The provision of contextual factors that facilitate pro-environment behaviour is underlined. Successful initiatives such as towel reuse and use of paper straws stress this point, downplay pre-existing volitional control and augment the role of the subjective norm. The hotel should, therefore, investigate the clients' suggestions, for example, to introduce reusable plastic cups for use in the pool area, and introduce dispensers for toiletries including shampoo and water, and provide cues that increase awareness of the waste generated. While these suggestions were met with scepticism during the two focus groups, the clients interviewed provided a more positive response, thus emphasising the importance of contextual factors to capitalise on intentions. The promotion of such initiatives is supported by research which indicates that hotels that introduce such measures enrich their attractiveness to guests.

Food waste provides an avenue that hotels and the hospitality industry need to explore further. Generally, hotels operating in this star category offer a buffet service, which, as was noted, results in a higher waste generation per person. Various measures, such as nudging, can assist in reducing waste. This case study proved that the elimination of a side-plate is an effective measure which also lowers costs for the hotel. Hotels often focus on maximising their profits through sales; therefore, such measures suggest that initiatives that decrease both waste and costs require more attention.

The dependence of the industry on the attractiveness of the natural environment requires a mutual and more assertive approach both from the hotel operators and the authorities regulating this sector that does not shy-away from pro-environment initiatives but comprehends the need to protect the environment as a prerequisite necessary for the industry's survival.

Chapter 6
Discussion and Transfer of Knowledge

6.1 Introduction

Waste managers are faced with myriad distinctive geographies, cultures and economies that they have to adapt their waste strategies to. Regardless of this, technological constraints and international regulatory frameworks generally direct countries towards similar waste treatment and disposal combinations. Furthermore, globalisation has resulted in more comparable categories of waste being produced that call for more global solutions.

The generation of waste can be considered as a living open system which maintains continuous exchanges with the environment but which also creates extensive entropy at the disposal stage. Entropy reflects one aspect of the irreversible nature of environmental impacts (Soderbaum, 1987) and is now reflected into widespread adversities such as the dispersion of micro-plastics and waste related GHG which result from identifiable sources including single-use plastics, over-packaging and food wastage. This chapter sets out the main points learned during the groundwork of this thesis which can be adopted in the planning of waste-related policies in countries other than Malta where this study was carried out.

6.2 Adopting a systems approach to waste management

Sustainability is often regarded as a normative goal that is approached in a piecemeal fashion. However, adopting a piecemeal approach to sustainability is unlikely to yield effective results, since sustainability requires a systems methodology that discloses the underlying structures which characterise the relationship between the parts and the whole and that aims to understand cause and effect. Adopting, a systems methodology allows for the proactive design of new structures and mechanisms that are required if the efforts made are to be effective (Ben-Eli, 2018).

The importance of adopting a systems approach is emphasised throughout this thesis. Adopting a systems approach requires moving away from policies focused on end-of-pipe solutions towards a more holistic approach known as Integrated Waste Management (IWM). The latter provides "a frame of reference for designing and implementing a new waste management system and for analysing and optimizing existing systems. Integrated Solid Waste Management is based on the concept that all aspects of a waste management system (both technical and non-technical) should be analysed jointly since they are in fact interrelated with developments in one area frequently affecting practices or activities in another " (UNEP, 2005, p. 7). A variation of the definition proposed by UNEP is that suggested by Waste, in Den Haag, who refers to the model as Integrated Sustainable Waste Management (ISWM). ISWM recognises three important dimensions: (1) the stakeholders that are involved in and affected by waste management; (2) the practical and technical elements of the waste system; and (3) the sustainability aspects of the local context that should be taken into account when a waste management system is being planned. The introduction of an ISWM commences with an in-depth assessment of the existing situation to establish the feasibility and need for new investment and different technologies and evaluate the proposed waste project, facilitate a smooth implementation and provide a useful baseline for decision making (Anschütz et al., 2004).

Developing a plan for the implementation of an integrated system involves the evaluation of local needs and conditions and the selection of the most appropriate combination waste treatment for them (United Nations Environment Programme, 2009a). White et al., (2012, p. 21) provide a model for ISWM which suggests that all disposal options have a role to play. Unlike the waste hierarchy, this approach does not predict the "best" system but seeks to build a system that best suits the local conditions, where the choice of approaches, including the technologies, to be used, depending on variables including costs, waste quantities and characteristics, regulations, and policy considerations (ISWA, 2009). The final aim of this approach is to bring about a transformational change in the way urban societies handle and view waste as a resource (UN ESCAP, 2017).

The adoption of a systems perspective is also central to IE thinking as it avoids narrow and partial analyses that overlook important variables and can result in unintended side-effects (Lifset & Graedel, 2002). Adopting IE thinking means that the approach to waste as shifted from end-of-pipe pollution control methodology towards strategies that are focused on the comprehensive prevention and planning of environmentally sound industrial development (Rourke et al., 1996). Furthermore, while approaches such as cleaner production emphasise the reduction of risks, IE emphasises the optimisation of resources flows (Lifset & Graedel, 2002) and stress that environmentally related issues are both multisectoral (not limited to one sector or society) and multidisciplinary (assessed from different viewpoints/angles), which means that no single discipline can provide sufficient knowledge and information to manage a particular issue (Soderbaum, 1987).

6.2.1 Collection and treatment

The response to waste has often been reactionary (Vallero, 2011) and has, thus, generally taken the form of end-of-pipe solutions that focus on collection and treatment. In conventional approaches these stages are often compartmentalised, with the generation, collection and disposal treated as independent operations. The three stages, however, are closely interlinked and their design and implementation influence one another (Seadon, 2006). The methodological approaches used in Chapters 3, 4 and 5, bring the importance of using a systems approach to the forefront. This is highlighted not only in relation to the operational processes such as collection and treatment but also in the inclusion of a waste generation analysis at the inception stage of economic policies.

On an operational level, the emphasis on collection and treatment made in Research 1 points out that the integration between the two functions is a crucial first step, not only in terms of the quality of the material collected but also in terms of the operational efficiency of the infrastructure. This implies that if the collection is randomly organised, subsequent steps in the waste management process are likely to be jeopardised. As noted in Research 1, the introduction of an MBT facility is beneficial because, among other reasons, it reduces the carbon footprint generated by waste. However, the operational success of the facility and the improvement of the recycling rate is dependent on the success of the biowaste separation process. The 2018 MFA, which is based on a 30 per cent biowaste separation rate, stresses that more effort is required to increase the assumed rate since the denoted system would still handle large quantities of mixed waste, while the facilities that process recyclables and bulky waste would operate under capacity. The assumed 30 per cent biowaste separation rate, would also mean that the Malta North facility would be required to handle 10,207 tonnes of mixed waste with the clean fraction leading to a less than desirable output. Having an effective separation and collection system is therefore essential, both for the effective use of the infrastructure and, since one of the basic attributes of CE is the boosting of recycling, to ensure that the implementation of the concept is successful.

Another inseparable link in the waste management chain is transportation (Braschel & Posch, 2013). The transport process is crucial, both at the collection stage (urban transportation) and when waste is transported for treatment locally and abroad (inter-urban). Urban transportation needs to accommodate requirements such as frequent stops as well as provide assurance that the collection method and schedule does not impair the quality of the separated material. Inter-urban transportation, on the other hand, needs to ensure that the distance covered is justified by the type of treatment received. Transportation is also directly related to carbon emissions. Although some might argue that the GHG impact originating from waste transportation, that amounts to only approximately 5 per cent of total emissions, is relatively insignificant (Falzon, Fabri, & Frysinger, 2013; Skovgaard, Hedal, Villanueva, & Larsen, 2008) the results of Research 1 emphasise the need to improve the efficiency of the transport system. In the case of Malta, the introduction of the MBT facility reduced carbon emissions from treatment but emissions originating from transport increased from 4.9 per cent of the total in 2012 to between 11 and 15 per cent of total emissions in 2018 (depending on the scenario). Revaluating transport needs is of particular relevance for islands that are constrained by space and have limited resale markets and recycling possibilities. An effective urban transportation system assists in the reduction of congestion and vehicle emissions associated with refuse collection vehicles (RCVs) (Mcleod & Cherrett, 2008). Furthermore, the constraints imposed by limited resale and recycling possibilities on a local basis make ensuring an effective waste separation and collection system that minimises resource loss and guarantees the quality of the material sent for recycling a requirement.

Research 1 also advocates consideration of GHG emissions at the inception of waste management policies. Waste and GHG emissions have a direct relationship, with direct emissions from the sector almost doubling between 1970 and 2010 on a global basis (Fischedick et al., 2014). While Malta, as a member of the EU, has the obligation to treat waste prior to its disposal in the landfill (Waste Management (Landfill) Regulations, 2002), the research emphasises the need to integrate GHGs mitigation into waste management policies which would lead to savings outside the collection and treatment/disposal system, thus improving the societal interaction with waste (Gentil, Christensen, et al., 2009). The carbon footprint calculations in research 1, show that recycling dry material saves an average of 11,604 tonnes of CO_{2eq} while the treatment of separated biowaste saves an average of 9,468 tonnes of CO_{2eq}. This points to the need to enhance these two processes and stress the importance of a joint operational system approach to the collection and treatment process.

The importance of integrating GHG emissions in waste management policies was also referred to in Research 3. Although the study does not focus on carbon emissions, it underlines food wastage within the hotel industry. The issue of food waste has come to the forefront in recent years and is associated with various negative environmental externalities during both the processing and the post-consumption phases, including loss of resources such as water, land-use conflicts, labour issues and the fact that food waste contributes to global warming. Quantifications of GHG emissions originating from food waste vary. In a study based in the UK, Tonini et al., (2018), focused on four sectors of the food supply chain, namely, processing, wholesale and retail, foodservice and households and estimated a total a Global Warming (GW) impact for avoidable food waste that ranged between 2000 kg $CO_{2\text{-}eq}$ for wholesale and retail and 3600 kg $CO_{2\text{-}eq}$ for the processing sector. In while in the case of foodservice and households, emissions reached 3100 and 2500 kg $CO_{2\text{-}eq}$ respectively., in a study focused on the Australian food supply chain, Reutter et al., (2017), estimated that food waste embodied a total of 57,507 Gg $CO2_{\text{-}eq}$, which represents 6 per cent of the total Australian GHG emissions, while GHG emitted due to food waste produced by final demand accounted for 2.8 per cent of the total GHG. FAO, have estimated the carbon footprint of the food that is produced but not consumed to reach 3.3 G tonnes of CO_{2eq}, which ranks wasted food as third top emitter after the USA and China (FAO, 2013).

On an operational basis, a piecemeal approach creates various inefficiencies. For example, operational stages, like collection and treatment, must be planned for in an integrated manner because of the infrastructural issues and also GHGs emitted. Operational efficiency represents one dimension of an ISWM system the effective implementation of which would also be reflected in the minimisation of the negative impacts which the management of waste exerts on society, thus appeasing the stakeholders.

6.2.2 Integrating waste generation at the inception of economic policies

The need to integrate waste externalities at the inception of economic policies is another argument put forward in this thesis. The escalating waste quantities have made it unfeasible for many countries focused on economic growth to exclude the resulting externalities. Consequently, the setting of economic policies with a sustainability perspective has acquired fundamental importance. Adopting this approach would direct regions and countries to invest in industrial sectors with a more contained waste multiplier, thus keeping negative externalities, together with their associated mitigation and treatment costs in check. This is more so in the case of islands, where treatment and disposal facilities are constrained and export is both problematic and expensive, thus underlining the need to take care of waste before it is generated.

The points discussed above are emphasised in Research 2 that discusses the importance of balancing the benefits of economic growth with its negative externalities, particularly waste generation. It distinguishes between the direct waste and the indirect waste that is generated as a result of economic growth and describes their impact on the capacity of treatment facilities. The results dampen the economic contribution of sectors such as construction and hospitality that, despite their high output multiplier, is also responsible for the generation of extensive waste quantities. This study calls for the introduction of a discount factor that accounts for the externalities generated and provides a more realistic picture of the growth achieved through economic progress. The adoption of this methodology would bring economic policies in line with the pillars of sustainable development and ensure a multisectoral systems approach to waste generation and management. It would also imply that the country is shifting its priorities from the economy towards the environment, particularly in view of the fact that economic well-being is dependent on the environment both as a source of inputs and as a sink.

Building on the arguments made in Research 2, the subsequent chapter (Research 3) emphasises the need to develop waste policies that target individual economic sectors. Research 3 notes the desirable nature of tourism, particularly due to its high income and employment multiplier which, however, do not account for the far-reaching negative impacts that the industry exerts on society and the surrounding environment. The drive to make short-term profits conflicts with the need to protect natural resources and ensure the long-term survival of the industry. Through a detailed examination of the modus operandi of a five-star hotel, Research 3 highlights wasteful practices and points out that, alongside the desirable benefits it accrues, the hotel is also responsible for a number of repercussions. The industry, which is associated with high waste generation figures, is gathering momentum on a global basis and therefore requires more attention from local governments who need to ensure that the natural assets on which the very industry depends are protected.

This call is aligned with the IE philosophy which strives to develop methods to restructure the economy and turn it into a sustainable system that mirrors a natural ecosystem (Brunner and Rechberger, 2005). The call made in Research 2, to integrate the environmental abatement and restoration costs into national financial accounting, if implemented would imply that the costs of managing the waste generated from individual industrial sectors are deducted from the GVA produced by the same economic sector, thus creating a more realistic picture of their economic contribution. As was seen in Research 2, the input-output analysis and waste intensity indicators pour cold water on the GVA recorded in financial accounts, particularly in the case of construction. The waste input-output assessment is necessary to identify which economic sector impacts the economy in the most damaging manner and, therefore, to provide a clear indication on where resources need to be directed to minimise these externalities.

6.2.3 Quantification

The right policy and investment decisions are only made when correct empirical evidence is available (World Travel & Tourism Council (WTTC), 2017). Quantification of waste externalities is a necessary step to create perspective and allow managers to set targets and move away from the prevailing situation. Quantitative tools make it possible to generate value-free, objective, rational and tangible measurements of observable phenomena. Furthermore, this type of research is independent of context, is based on facts, uses procedures that are often standardised and allows replication making it transferable (Ashley & Boyd, 2006). The tools discussed in this thesis, namely, MFA, carbon footprint, input-output analysis, waste audits, focus groups and semi-structured interviews, provide a possibility to quantify and characterise the waste generated and underline points where the system needs to be tweaked to close material cycles and prevent the generation of waste.

An MFA, as well as, providing a comprehensive overview of the material system and its interaction with the surroundings, quantifies accumulations and environmental releases (Allesch & Brunner, 2017). The tool is highly instrumental in its ability to link the anthroposphere with the environment and assist in the early recognition of possible issues, in the setting of priorities and in the analysis of the effectiveness of strategies that seek to shift towards improved sustainability (Brunner & Baccini, 1992). The mass balance approach requires that all inputs into the system are equal to outputs, together with changes in stock. This principle applies to all levels of goods (e.g. wastes) as well as substances (e.g. lead) and must be observed for every process and the total system. It provides a reliable, reproducible, and transparent database for evaluating a waste management system. On a different level, it also allows for a check on national data and displays the degree of parallelism and mixing present within the system (Wilson, Velis, & Rodic, 2013).

The separation of biowaste instigates an improvement in efficiency which can be noted in the 2018 MFA when compared to the 2012 MFA. While neither of the MFAs points to the duplication of effort in waste treatment, both highlight that more waste than that stated in the official figures is landfilled. In 2012, together with the 175,003 tonnes which are landfilled directly, an additional 35,153 tonnes are landfilled without treatment after arriving at the waste treatment plant. This is supplemented by a number of rejects which result from various treatment processes, resulting in a total of 220,509 tonnes of waste to be landfilled. The 2018 MFA, together with underlining the need to amplify the assumed 30 per cent success rate in biowaste separation, points out that the introduction of a 120,000-tonne WtE facility will not eliminate the need for a landfill as 100,301 tonnes of waste would still need to be buried.

The CO2ZW tool quantifies and categorises GHG impacts and therefore directs effort towards the inefficiencies in the waste collection system. The 2018 carbon footprint analysis shows that, following the introduction of the MBT facility, GHG emissions are reduced from 1,169 Kg CO_{2eq}/ton-yr to an average of 413 Kg CO_{2eq}/ton-yr or 690 Kg CO2eq/inhabitant-yr to an average of 248 Kg CO2eq/inhabitant-yr. The introduction of the MBT facility can, therefore, be concluded to be of benefit to the Maltese Islands. An additional advantage of the CO2ZW tool is the categorisation of emission sources since this shows that further reductions could be achieved with the extension of the bio-waste separation rate possibly through the inclusion of the hospitality sector and the revision of the waste collection routes.

Research 2 is based on a hypothetical example which uses the Leontief input-output analysis to examine how waste generation figures will change when there is a 1-million-euro increase in the (exogenous) final demand. As well as with providing a comprehensive overview of the flow of goods and services among different sectors of the economy and the inter-relatedness between these sectors and waste generation, this framework furnishes an extensive amount of data that describes the economic system and can be used to predict its behaviour (Tanaka, 2011). As can be noted in Sections 4.3.1 and 4.3.2, the sectoral multiplier of the construction sector reaches 1,630.74 million tonnes, out of which (assuming 2010 practices) 1,015. 21 tonnes are landfilled, and 427.72 tonnes are disposed of at sea. A similar concern is raised by the hospitality industry which displays a strong waste multiplier by the hotels and restaurants sector (this reaches 114.25 tonnes, where 73.09 tonnes are landfilled, 20.92 tonnes are disposed of at sea and 13.62 tonnes are recycled). The results of the analysis provide an objective and tangible measurement of how economic growth will impact waste generation which is the main point of concern for Malta due to the strict geographical limitations that also impinge on treatment and disposal facilities. Research 2 points to extensive impacts on landfilling, which, as indicated in Research 1, is the most extensively utilised waste disposal measure in Malta. An additional impact is identified on mineral waste dumped at sea. In an island where tourism plays a major economic role, the need to pay attention to this practice is heightened.

The subject examined in Research 3 was selected in view of the strong waste multiplier of the industry highlighted in Research 2. The results of this research point to the need to adopt to bottom-up approach on a micro level to place its operational practices under scrutiny. The audits conducted in Research 3, serve both to quantify the waste generated in a five-star hotel and to identify the prevailing operational practices that are responsible for the high figures. They create a picture that assists management to make informed decisions about the practices that need to be eliminated for the organisation to adopt a more sustainable approach. Therefore, quantification also creates awareness and stimulates internal stakeholders to aspire to change current procedures for more environmentally sustainable ones.

The research notes that direct waste generation for every hotel resident reaches 1.06 kg per day. The figure excludes items such as preparation food waste which reaches 0.08 kg/guest, carton and plastic packaging waste from bars and restaurants and batteries which are calculated on a per room basis. Although the study is based on only one hotel, the quantification this hotel's waste figures put the industry under scrutiny for being waste intense. Tourism is generally regarded as being a desirable industry due to the high employment and profit-generating figures associated with it, but the costs of collection and treatment of waste generated by the industry are rarely accounted for. As well as renewing the call for environmental accounting, this study emphasises the need for waste policies that focus on specific economic sectors.

6.2.4 Longevity

Longevity refers to the ability of a system to survive for a long time. The sustainability of a system is directly related to its longevity and life duration (Pater & Cristea, 2016). While the survival of industries, in the long run, is desirable, agents often do not see the economic gain of engaging in activities that have long term benefits when they are outweighed with activities that yield benefits in the short-term due to forces exerted by the business drivers and market structures that they operate within (Christoph, 2014). An example of this misalignment can be drawn from Research 3. The tourism sector is generally considered to be an intensive waste producer which results in several repercussions for the local community. These negative repercussions impinge on the attractiveness of the destination since the use of environmental resources is vital in the creation of the tourist experience (Arbulu Villanueva, 2014). However, while it is dependent on the quality of the product it offers, the industry is focused on short-term profits, a factor that has often clashed with its long-term survival needs and that demands more proactive initiatives to internalise impacts such as waste. This is of concern for islands like Malta where tourism plays an important economic role, particularly since, as stated in previous studies, Malta is noted to have reached a dangerous saturation point that involves a mismatch between the product and the market carrying capacity, coupled with sustainability concerns (Croes et al., 2018).

Taking the waste that is to be generated into account at the inception phase of economic policies and introducing environmental costs as part of the national financial accounting would help shift thinking towards sustainability and longevity as economic growth would be fuelled without generating excessive burdens. This would also have the additional benefit of curtailing abatement and treatment costs. In his review, Ben-Eli (2018) refers to five domains (the material, economic, social and spiritual domains together with the domain of life) that represent the core principles of sustainability. The introduction of environmental accounting on a national basis addresses the economic domain. It calls for the adoption of appropriate accounting systems that do not ignore important cost components such as the impacts of depletion and pollution and therefore supply comprehensive biospheric pricing to guide the economy (Ben-Eli, 2018). The material domain, on the other hand, refers to the containment of entropy of the present economic systems which are wasteful, destructive, fragmented and grossly inefficient. This would require that operational processes and practices, such as those examined in Research 3, are revised to contain the current inefficiencies.

Longevity is also related to the long-term capacity of waste treatment and disposal facilities, particularly in the case of islands. The matter is examined in Research 1 and 2. Implementing a waste management system that seeks longevity requires addressing the sustainability aspects within the local context which need to be accounted for during the planning stage. Here focus shifts to the treatment stages which have a crucial role to play in operational sustainability. As noted in Research 1, Malta displays an alarming bias towards the practice of landfilling. Further elaboration is made in Research 2, where it is noted that, when an exogenous shift in the final demand amounting to €1 million is experienced, the major stress exerted would be on landfilling followed by the disposal of waste at sea (Figure 0-3 and Table 0-3). Here the requirements set by a longevity policy reveal an interplay between the requirement of waste treatment and the building of disposal facilities and the preservation of the island's differing and expanding economic systems. An exogenous increase in final demand of €1 million would increase waste generation by 2,973.73 tonnes, out of which 1,953.45 tonnes would be landfilled. An additional impact would be felt on the disposal of waste at sea which in 2010 reached 290,120 tonnes and is subject to an increase of 665.53

tonnes when there is a shift of €1 million in (exogenous) final demand. This impacts directly on the quality of the tourism product that the island has to offer and, therefore, clashes with the long-term survival of the same industry.

6.2.5 Linearity

An IWM system looks at waste generation from its inception, rather than focusing on end-of-pipe solutions. It reflects an approach that views the totality of matter and energy, reduces leakage from the system and commences long before the product is discarded. However, despite the knowledge gained in the area of sustainable development, the increasing recognition of the IE field and wider attempts to implement the CE concept, the global economy is characterised by linear production models, where consumer goods are manufactured from raw materials, sold, used and ultimately discarded as waste (Saavedra et al., 2018). The three research studies prove that this linearity is present at both the macro and micro levels of the economy and can also be seen at the waste generation and treatment stages. The adoption of a systems approach for waste generation and management requires a more in-depth knowledge of flows and the economic decisions that cause waste to be generated. Rather than implementing a bolt-on approach (White et al., 2012, p. 20) that is based on the classification of waste flows and the allocation of possible solutions to treat waste, an integrated system examines the factors and processes that lead to the generation of waste and identifies possible ways to eliminate it. The approach requires expertise from a variety of sectors but would result in a range of monetary to non-monetary savings for any country that adopts it. This approach optimises the whole system rather than disprate parts of it as happens in a piecemeal approach.

An MFA, when designed based on reliable figures, allows the overall efficiency of material fluxes to increase and consequently the negative impacts to decrease (Brunner & Baccini, 1992). It also ensures that the whole system is included in the analysis and provides a structure for the identification of material leaks and recovery rates (Brunner & Rechberger, 2005). The processes examined in the three research studies are remarkably linear. The MFA study can be used as a basis to create loop-closing industrial practices (Brunner and Rechberger, 2005). Research 1 highlights the linearity of the present waste disposal and treatment system in Malta and, thus, provides precise information on where adjustments need to be made to increase circularity. The MFA analysis for 2012 notes a total of 248,784 tonnes of MW generated out of which 175,003 tonnes were directly landfilled. The MFA demonstrates that only 20,979 tonnes (8.43 per cent) are recovered recyclables displaying gross inefficiencies. The infrastructure introduced in 2018, shifts the system away from linearity with 65,897 tonnes of waste (24.97per cent) exported for recycling. However, the system continues to be characterised with strong linearity with the majority of waste being disposed of or incinerated.

Strong linearity is also evident in Research 2 and Research 3. The figures for 2010, examined in Research 2, show that a total of 707,022.53 (59.7 per cent) tonnes of C&D and C&I waste were landfilled. An additional, 290,120 tonnes (24.5 per cent) of C&D waste were dumped at sea. The waste multiplier analysis (shown in Table 0-3) shows that, with the exogenous shift in final demand of €1 million, the total waste generated by the construction sector will reach 1,650.34 tonnes, out of which 1,015.21 tonnes would be landfilled and 427.72 tonnes would be dumped at sea. In 2015, recycling and recovery figures show 488,302 tonnes of C&D waste being recycled and 963,637 tonnes backfilled in spent quarries, a measure which, to date, continues to be considered as a recovery activity. In the case of C&I waste, a total of 30,199 tonnes of C&I waste are landfilled, while the figure for recovery, recycling and oil refining reaches 12,824.1 tonnes. The hospitality industry also displays practices which are strongly linear. In Research 3, practices such as the distribution of water bottles and toiletries in guest rooms serve to highlight this predominance. The waste audits also display linearity. For example, the largest fraction in the breakfast buffet audit is “other” where disposables are placed.

What is of most concern is that initiatives to move away from linearity still require extensive effort. Products are driven by their function and, therefore, must be considered with respect to their life cycle. Consequently, a paradigm evolution which challenges the single-purpose thinking that follows a direct, sequential and linear approach and which entails that products and processes have a less tangible impact on the individual, society and ecology is necessary (Vallero, 2011). The adoption of this approach would mean that the generation of waste is accounted for during the design of economic policies, where injections into the economic sector would account for both economic growth and the waste impact the costs of which continue to be borne by society at large.

Chapter 7
Conclusion and suggestions for Future Research

7.1 Final general conclusions

The environmental problems humanity is facing today differ from those of most of the Earth's history. The difference is not only in kind and degree but also in complexity since changes are being inflicted on entire ecosystems that have functioned uninterruptedly for centuries (Vallero & Letcher, 2011). This complexity is amplified in view of the deep connections that these processes have with established social practices and economical processes and which now demand extensive revisions.

The physical separation of islands from other landmasses constrains the flow of materials, organisms and information making it difficult to outsource part of their problems, as in the case of modern waste streams (Eckelman et al., 2014). Waste management on islands, as was noted in this thesis, is hindered by the lack of space, proximity to treatment facilities, limited resale markets and problems to export waste. In the case of Malta, the definite physical space coupled with the high population density play a crucial role in the selection of treatment methods. Additionally, the quantities generated often do not justify the introduction of specific treatment facilities on a local basis. This is the case with C&I waste: the size of the country and the limited industrial activity means that the quantities produced are sporadic and, generally, small, requiring the assistance of mainland countries for treatment. A completely different situation was revealed in the case of C&D waste, where the sheer quantities generated, despite being inert, are a constant challenge to space necessitating the issue to be 'solved' by disposing of waste at sea.

In the 20th Century, waste has become an inevitable by-product of, economic development which is often dealt with in a reactionary manner (Vallero, 2011). This thesis departed from the key objective of exposing and comprehending the connections that urban waste generation has with operational and economic processes as a necessary first step of delinking waste from economic growth. This process provided insight into the operations and flows which contribute to the generation of material waste in a direct and indirect manner. The study, therefore, provided an opportunity to examine established practices in a proactive manner and start viewing waste generation light of the processes that cause it.

Escalating waste generation figures make it evident that Malta can no longer depend on end-of-pipe treatment technologies and disposal facilities. This, together with the pressure exerted by urbanisation, creates an unyielding need to adopt a proactive approach towards waste generation. The results emanating from the three research studies demonstrate that the management of waste is influenced by the interaction of several dimensions thus offering a continuous challenge to policymakers (Goulart Coelho et al., 2017). However, a delinking process requires that intricate administrative measures be undertaken and that decisions be knowledge-based and supported with studies which are system focused and which allow for waste generation, collection and disposal processes to be planned jointly while identifying components that exert influence on one another. Viewing waste as part of a system reveals the relationship it has with other parts within that same system, thus increasing the potential for the introduction of sustainability measures (Seadon, 2010). The IE philosophy, together with the different methodologies used, was crucial in understanding the inventory of flows, together with the relevant stocks and treatment requirements that are involved in the generation and management of waste.

The following concluding remarks can be drawn from this study.

The research supplies specific information on the changes that are necessary to shift towards a strong sustainable development approach. The IE approach emphasised the optimisation of resource flows by holding a system view that placed boundaries around the MW management system (Research 1), C&I and C&D waste (Research 2) and waste generated in a five-star hotel (Research 3) and questioning the methods that are currently in place with the aim of optimising resource use and identifying the paradigm shifts that need to be made to create an economy that is not burdened with externalities.

A point emphasised in the thesis is the need for an approach that integrates waste generation with economic policies during their inception. The model proposed here (shown in Figure 7-1) takes a step backwards from that proposed by White et al., (2012), which called for a holistic approach that recognises that all treatment/disposal selections have a role to play and from the proposal made by the organisation Waste (Den Haag), which seeks to include stakeholders, the practical and technical elements and the sustainability aspect of the local context. These models fail to connect waste generation with economic policies at their inception and do not make the necessary links to the processes that are the actual cause for the generation of waste and, ultimately, view waste as an unavoidable by-product as indicated in the definition of waste used in EU legislation (Malinauskaite et al., 2017).

The in-depth examination of the connection that waste has with economic growth and other operational processes within the economy moves away from viewing waste as an afterthought. The need to include GHG emissions is pointed out in Research 1. Waste generation displays a direct relationship with GHG emissions, however, the connection between the two has only gained recognition in recent years. While this chapter focuses on MW, in Research 1, it is shown to encompass all subsequent steps in view of the vital role held by climate. While in most cases waste policies are still not driven by climate concerns, introducing this approach would target GHG emissions generated before and after the waste management process. The waste intensity of specific economic sectors, identified in Research 2, indicates the efficiency of the individual economic sectors when compared to their GVA and, thus, helps identify the sectors that an economy should focus on to achieve growth without carrying the burden of a high waste multiplier. The need to introduce waste management policies that are focused on specific economic sectors is highlighted in Research 2 and Research 3 as this would target the complexities that are present within these sectors and pinpoint which operational processes need to be revised to reduce waste. Figure 7-1, looks at the final operational stages of waste management which are interlinked with what takes place at earlier stages and are, therefore, subject to the decisions that were made at the outset. This approach is displayed in the figure below:

Figure 7-1 Waste generation as part of the overall economic policy

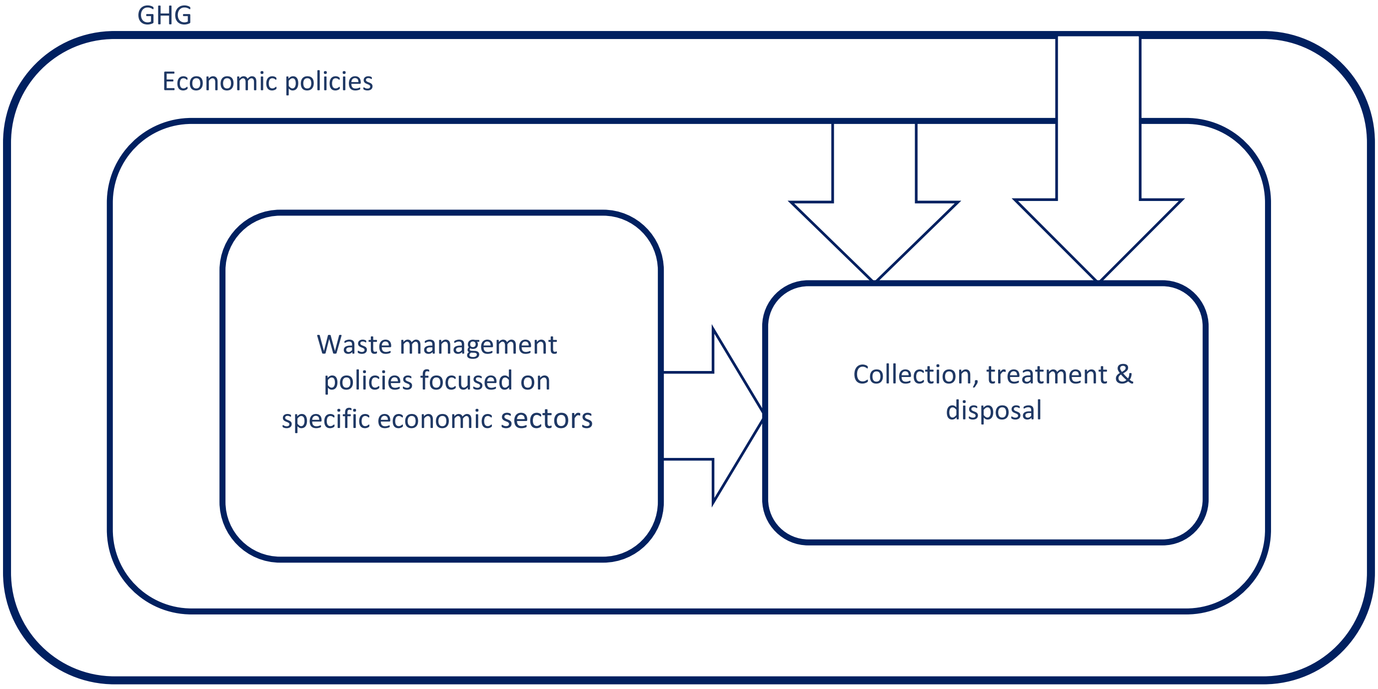


Figure 7-1 echoes the systems approach propagated by the thesis which stresses that waste management must be integrated not only at the final operational stages of disposal and treatment but already when economic policies are drawn.

The development of this approach depends on obtaining a system view of the prevailing situation. Tools such as the MFA methodology and Input-Output Analysis are instrumental in the provision of a comprehensive macro overview of the collection, treatment and disposal processes in the management of MW in Malta. The MFAs shown in Figure 3-1 and Figure 3-3 provides a complete examination of MW management which is characterised by complexity. This is in view of the number of actors involved and the diversified nature of waste. In Figure 3-3, the projected treatment of 263,809 tonnes of waste requires five specialised facilities that are reinforced by additional processing together with a local landfill and recycling and treatment facilities in mainland Europe. Complexity is also reflected in the management of C&I waste. Table 0-1 makes this evident when it highlights that figures are highly aggregated particularly in Sector B to E – Production. This is in view of the contained industrial sector which generates a marginal and relatively specialised type of waste in quantities that do not justify the introduction of treatment facilities, requiring it to be exported to mainland Europe.

The bottom-up approach employed in Research 3 provides a detailed picture of the waste generated in a hotel and examines the processes and operational aspects to establish the sources of the generation of waste. The five-star hotel on which the case study is based displays strong linear systems that result in high waste generation figures. While the research provided an in-depth analysis of only one hotel, the practices noted are generally representative of the practices of the hospitality industry in general. This research, therefore, offers an overview of the quantities of waste generated by industry. Although this can be a cause of frustration, it can also be a way to induce action. A simple step is to target waste generation per capita, as this offers a measurable indicator for policies aiming to reduce waste at source. This is often an effective and efficient way to handle the issue in the long term (Mazzanti & Zoboli, 2008).

Developing the approach illustrated in Figure 7-1 would be of particular benefit for Malta, where space limitations are a major concern, but would also be helpful to any country facing waste escalation figures. In the case of Malta, the ongoing dependence on landfilling, coupled with the dismal records in material recovery (European Parliament, 2018) has left an indelible mark on the island's environment which, as noted in Research 1, features a dumpsite of sufficient height to be visible from almost every part of the country. An island measuring 316 km^2 cannot depend on landfilling as its main disposal option and, thus, needs to re-examine the present linearity of flows which are evident throughout the three research studies. The need to review the present modus operandi to integrate and, where possible, eliminate waste externalities is evident.

The recommendation emanating from Research 2 is unequivocal– if waste is to be reduced at source, economic policies must account for the externalities generated by individual industrial sectors during their inception. This is of relevance not only for islands, in view of their constraints of space, but also for other countries. The generation and management of waste is the cause of several environmental, financial and societal costs. To move towards an economy that is sustainable, the research suggests that the output multiplier of different economic sectors be compared to the waste multiplier. A case in point can be drawn from the output multiplier of the construction sector which reaches 1.704 but is crippled with a waste multiplier that reaches 1,650.34 tonnes when there is a €1-million injection. While the waste multiplier for other industrial sectors is more contained (see Table 0-3) pressure on landfilling is sustained by every industrial sector. The analysis, therefore, assists in both quantifying the waste generation impacts of a €1 million injection and in measuring the stress it induces on the constrained waste treatment and disposal facilities.

Tying in with Figure 7-1 is the crucial importance of tallying the national accounts with environmental degradation. This is emphasised in both Research 2 and Research 3. The results of Research 2 provide a holistic overview of the impacts of economic growth which, in many countries, continue to be excluded from the national financial accounting system. Maintaining this position has now become outdated. While growing Gross Domestic Product (GDP) and Gross Value Added (GVA) figures provide a 'confidence boost', the need to introduce a discount factor that accounts for environmental and social waste-related costs is underlined. If a country is to move towards increased circularity and implement an integrated approach to waste, economic policy must account for environmental degradation. The introduction of environmental accounting is, therefore, a first step that signifies the commitment of the country towards providing a holistic picture of economic development.

Waste is the result of inefficient operating practices which, as was noted in this thesis, continue to function in a linear fashion. The linear systems exposed during this research highlight the fact that the implementation of a circular economy still requires an extensive review of production and supply flows together with their connection to waste generation. This approach is necessary for the development and implementation of an integrated system which necessitates measurable data for the provision of comprehensive information on present and anticipated waste situations and requires the support of policy frameworks, knowledge-based decisions, appropriate use of environmentally sound technologies and suitable financial instruments to be implemented successfully (United Nations Environment Programme, 2009b). This means that solid waste generation and management need a long-term plan that combines institutional, social, financing, economic, technical and environmental aspects (United Nations Environment Programme, 2002). This research demonstrates the direct connection that waste has with factors that are often not directly targeted in waste management policies. When focusing on location-specific exigencies, it is necessary for waste to be part of economic policy at its inception and choices about this externality to be integrated early on as part of the decision-making process related to the future well-being of the country. On a micro level, additional emphasis needs to be placed on the provision of contextual factors that facilitate waste responsible behaviour. All three research studies shed light on where efforts need to be directed to discontinue linear processes and increase circularity. While the identification and quantification of major waste flows provides a grounding for interventions to modify existing systems and reduce the environmental impact caused through increased efficiency of resources (Duchin & Levine, 2008), the systems approach advocated highlights the importance of viewing waste generation not merely as a problem to be tackled with an efficient waste treatment system, but as an issue to be targeted at the very inception of non-waste related policies.

7.2 Future research

Additional future research possibilities were identified during this dissertation. Future research should be focused on the expansion of the economic-ecological concept and the extension of knowledge focused on waste generation and its reduction at source. Below is a list of suggested future research studies.

A potential area of research identified in the first paper is the development of optimised routes for waste collection. Transportation plays a vital role within every stage of the waste management process, from waste treatment to final disposal and represents an inseparable aspect of an integrated waste management system (Zsigraiová et al., 2009). The collection of waste (and its disposal) is an expensive undertaking and generally comprises a substantial proportion of a local government's expenditure (McLeod & Cherrett, 2011). Investment in the waste collection system must be justified in terms of environmental, technological and economic feasibility (Zsigraiová et al., 2009). Therefore, route optimisation would help achieve a more efficient and effective collection system which would assist in the reduction of carbon emissions.

An MFA describes, investigates and evaluates the metabolism of anthropogenic and geogenic systems (Brunner & Rechberger, 2005). The two MFAs presented here analysed waste treatment from collection to final disposal, thus providing a precise quantification that would guide interventions to, for example, increase circularity. Ideally, an MFA would be developed for wastes streams other than MW as this would provide policymakers with an evaluation of the flows characterising the different waste streams from collection to disposal and assist the decision-making process.

Malta's GDP growth reached 6.9 per cent in 2017. This was mainly driven by growing services exports and residential construction (European Commission, 2018). However, GDP is criticised extensively as a measure of welfare and a clear need was identified for the introduction of environmental accounts and the possible development of a Genuine Progress Indicator.

There is potential to develop a European Wide-Material Flow Analysis (EW-MFA) as an environmental accounting tool to describe how the domestic economy interacts with the natural environment and the rest of the world in terms of material flows and therefore provide a physical complement to the monetary national economic accounts which can be used to support government policy on resources, their use and efficiency.

As was noted in the research, different economic sectors have varying waste intensities. Therefore, an analysis of each economic sector would provide a system review of the waste flows and the factors leading to it. This is required to quantify waste generated per unit of output and develop a relevant strategy to reduce waste at source and decouple it from the economic growth of that sector.

The research demonstrated that a reduction in portion sizes in the food served in restaurants can significantly reduce plate-waste. Further research on this topic to determine standard food portions to minimise wastage would help minimise waste generated at the source.

Chapter 8
Appendices

ANNEXE 1: COMPARISON OF THE SIMPLE OUTPUT MULTIPLIER AND THE WASTE INPUT-OUTPUT MULTIPLIER

Industry	Simple Output Multipliers**	Waste Input-Output Multiplier
A: Agriculture [1-3]	1.452	118.34
B to E: Production [5-39] * of which: manufacturing [10-33]	1.39 1.24	147.9
F: Construction [41-43]	1.704	1650.34
G: Distribution [45-47]	1.483	61.89
H: Transport [49-53]	1.608	100.31
I: Hotels & Restaurants [55-56]	1.651	128.92
J: Information & communication [58-63]	1.410	49.63
K: Financial & insurance [64-66]	1.047	62.88
L: Real Estate [68]	1.277	85.66
M: Professional [69-75]	1.626	60.57
N: Administration & Support [77-82]	1.515	63.56
O: Public administration [84]	1.369	71.05
P: Education [85]	1.169	44.55
Q: Health & Social work [86-88]	1.257	52.21
R: Arts, entertainment & recreation [90-93]	1.135	52.9
S: Other Services [94-96]	1.476	222
T&U: Households as employers [97-98] & Extra-territorial organisations [99]	1.017 0.00	1.01

** The output multiplier for the production sector includes sectors 37-39, which in the case of the waste input-output multiplier are excluded.*

ANNEXE 2: WASTE INTENSITY INDICATOR OF FIVE ECONOMIC SECTORS (WASTE GENERATED/GVA) (CHAPTER 4)

	Agricultural	*Manufacturing*	*Construction*	*Accommodation & food*	*Other services*
2010	95.7	34.4	2117.2	58.0	153.06
2011	83.2	38.1	2549.8	118.9	258.68
2012	74.7	22.8	5771.3	126.5	34.68
2013	90.8	12.6	6448.4	93.5	1.59
2014	77.6	27.4	5109.4	84.8	60.37
2015	66.1	20.2	4617.2	68.5	16.34
2016	122.6	35.29	4172.72	76.6	257

Source: Authors' calculations

ANNEXE 3: SUPPLEMENTARY INFORMATION FILE (CHAPTER 5)

This section supplements the research study **“**A snapshot of solid waste generation in the hospitality industry. The case of a five-star hotel on the island of Malta”. The supplementary information file examines additional literature and supplies items such as the preparation food waste audit template.

8.1 Introduction – Tourism in Malta

Waste is in itself the visible face of inefficiency and represents an expense that goes beyond disposal and handling fees (Dileep, 2007). Developing an environmental approach makes economic sense for hotels since it increases effectiveness, reduces costs and improves the image with different stakeholders (Pirani & Arafat, 2014). However, the management of waste is an encompassing issue that necessitates administration to establish strategies that involve staff at different operational stages and provides guests with the appropriate contextual factors that encourage waste elimination. The coordination requirements among management, employees, and guests often discourage hotels from establishing a waste programme (Pirani & Arafat, 2014).

Waste generation is a commonly acknowledged externality of tourism both within the EU and globally (Ezeah et al., 2015) with quantities arising from hotels generally higher than that of the local population. Waste originating from the sector consists of both wet (biodegradable) and dry waste, with food waste topping the list (Pirani & Arafat, 2014).

The tourism industry is buoyant, both in Malta and on a global basis. Currently, in Malta, waste generated under the “accommodation and food service” falls under Commercial and Industrial (C&I). Table 8-1notes that waste produced by the sector between 2011 and 2016 was mainly mixed and consequently landfilled.

Table 8-1 Waste generated by the hotel industry between 2011 and 2015 in Malta

Year	Mixed waste generated by the hotels and restaurants sector (tonnes)	Treatment
2011	33,982	Landfill
2012	37,534	
2013	32,432	
2014	31,377	
2015	29,378	

Source: WasteServ Malta Ltd.

The figures in Table 8-1 are not representative of the total waste generated by the industry because, as noted in the Waste Management Plan 2014 – 2020, “the contracts entered into by Local Councils are an avenue for abuse by commercial and industrial establishments”(p.. 59) and proposes that “commercial entities are obliged to have their own waste carrier but most of whom have, to date, rode on local council collection systems to the detriment of public finances ” (p. 3). Statistics from the UK show a different picture –WRAP notes that in 2009, UK hotels, out of an estimated 485,000 tonnes, recycled, reused or composted 303,000 tonnes, where171,000 tonnes were mixed and therefore landfilled, while 11,000 tonnes were managed through other means (Wrap, 2013).

With stiffening competition in the Mediterranean and popular destinations such as the Balearic Islands setting ambitious environmental targets (Fortnam, 2018), Malta needs to ensure that the product it offers is preserved. As stated by the Ministry of Tourism “the importance of quality continues to increase at all levels of the tourism value chain” (Ministry for Tourism, 2015, p. 7). Tourists, today place greater emphasis on the distinctiveness and uniqueness of the destination, seeking travel experiences with a difference, therefore putting the quality issue at centre stage (Ministry for Tourism, 2015). This aspect is crucial for the Maltese tourism product and pressures Malta to give environmental issues a higher priority, particularly in view of the fact that signs of diminishing returns from the sector are becoming more evident (Croes et al., 2018).

However, initiatives to counterbalance the externalities of the industry and shift its operations towards sustainability have been very limited. One of them was the introduction of a local eco-label, which in the case of waste, necessitated the provision of recycling bins in rooms and public areas. Furthermore, hotels require an environmental permit that sets various obligations, including the storage of waste within a designated and controlled area and the labelling of liquid and hazardous waste.

8.2 The case study

In a five-star hotel, clients expect a certain level of luxury. In the last three years, the occupancy rate fell between 73 and 79 per cent. This was accompanied by an increase in the revenue per room – in 2013, revenue reached €76.72 while in 2017 it reached €112.83 (Muscat, 2018). The hotel offers both a buffet and a-la-carte service and is long-established, one which, allowed the researcher to draw upon the extensive experience and knowledge of the staff.

The research uses a mixed methodology approach, using quantitative and qualitative data collection methods conjunctively. Qualitative and quantitative research methods supply a different picture with distinctive perspectives and limitations (Creswell & Plano Clark, 2011). Quantitative methods, seek to characterise flows and measure quantities, volume, and composition (Newenhouse, 2000), thus guiding the effort to maximise effectiveness. However, waste management requires the comprehension of flows and the specific practices that contribute to them. This necessitated the use of qualitative research to comprehend how people operating within this environment view the generation of waste and the factors that hinder practices that reduce waste at source.

8.3 Templates

The template below was used by the chefs and kitchen staff to record preparation waste.

Figure 8-1 Preparation a-la-carte waste audit template

Waste Audit June 2018 Date: ______________________

Waste discarded during preparation

Number of people served: _______

Number of children served: ______

Time	Recorder	Waste type	Reason for discarding	grams

Figure 8-2 Questions used as guidance during the management focus group

1. What do you think of waste generated by the hotel? Which waste do you perceive to be most problematic?
2. Is waste a problem that simply requires a waste collector? Or is it something that needs to be managed?
3. During 2017, the hotel purchased 57,000 bottles which costed €36,000. This presents a linear waste flow. What do you think if the practice is replaced by water dispensers?
4. What do you think of food waste?
5. What do you think of green practices in hotels, for example, green purchasing?
6. Do you think the hotel would be interested in seeking more assertive eco-certification?
7. If your competitors initiated more aggressive green practices, for e.g. focused on waste reduction at source, or if, for example, MTA or MHRA, were to take a more active role towards green practices, what would be your reaction?

Reserve question:

This new type of word of mouth (WOM) (internet) has become an important venue for consumer opinions (Mayzlin, 2006) and it is assumed to be even more effective than WOM in the off-line world due to its greater accessibility and high reach (Chatterjee, 2001). The internet also allows an individual to provide feedback to many others by means of broadcast e-mails, web blogs, or discussion board postings, resulting in a "written" form of eWOM which has **higher credibility** than marketer created sources of information on the internet"

Would you see the introduction of improved waste management as a possibility to improve eWOM?

Figure 8-3 Questions used as guidance during the line-staff focus group

1. What do you think of the waste generated by the hotel? Which waste do you perceive to be most problematic?

2. Is waste a problem that simply requires a waste collector (an out of sight out of mind issue)? Or is it something that needs to be managed?

3. In your interactions with the hotel clients, which activities do you think generate more waste?

4. What do you think of the use of paper straws?

5. What about other green practices? How would you feel if practices like water dispensers are implemented more intensively?

6. Would you participate solely because they are imposed?

7. What difficulties do you perceive in the implementation of such practices?

Figure 8-4 Questions used during semi-structured interviews with clients

Date: ______________________

Age: ________________________

Nationality: ___________________

Level of education: _____________

1. Is it your first visit to Malta? What is the general impression?

 ____

2. What do you think of the waste generated by the hospitality industry?

 ____

3. What do you think of the use of items like paper/ metal straws, refillable bottles in rooms, washable napkins etc?

 ____

4. Does any of your friends/family stay in hotels that promote their green waste management practices?

 ____

5. What influence does the Corporate Social Responsibility (CSR) or environmental policy when selecting a hotel have when you are selecting a hotel? ____

6. What practices do you think you could do for your visit to be less waste intensive?

 ____

7. If you had to suggest any waste related improvements which areas would you think of?

 ____

8.4 Transcript of management focus group held on the 20th June 2018 between 11.30 and 12.45.

The focus group was attended by the culinary director, the learning and development executive, the restaurant manager, the assistant sales manager and the revenue and e-commerce manager. All participants were of Maltese origin and therefore it was conducted in the Maltese language. Prior to the commencement of the meeting, the participants were handed a consent form and requested to sign it. The attendees were notified in the consent form what the focus of the research was and were also given a short introduction at the beginning of the discussion. Additionally, a request was made by the researcher to record the session using One Note. The participants were notified when the recording started.

Questions 1 and 2: *How do you perceive the waste generated by the hotel? Which waste do you perceive to be most problematic? Is it a problem that simply requires a waste collector or is it something that needs to be managed?*

The restaurant manager was the first one to break the silence. She said that at home bio-waste separation and recycling have become a habitual practice. When at the hotel, she is constantly faced with wastage of items including food, office materials etc. Therefore, she often thinks about waste and feels that it is a pity that there is no formal recycling system within the hotel. She also added that setting the recycling system might pose some difficulties.

A problem, highlighted by the Assistant Sales Manager, is that employees might take time before they actually 'own' the system and participate in it. He also added that, at the administration level, a paperless communication structure which avoids a lot of printing from administration to the front office, had been introduced. Soft copies of all documentation are then stored in a specific server. However, he also noted that the separation of waste originating from the offices is not carried out.

The restaurant manager observed that it is of vital importance that whatever waste is separated is not mixed by the contractor upon collection. This had happened earlier when the hotel had decided to introduce a waste separation system and had demotivated all the staff's effort, to the extent that it was abolished.

The e-commerce and revenue manager observed that, in a meeting with the Malta Tourism Authority (MTA), it was pointed out that at the government level, very little interest was shown to introduce waste separation systems within hotels. Therefore, very little scope existed amongst hotels to implement it. He further added that the Maltese have a culture of 'short cuts' and unless fines are introduced nothing will be achieved.

To this, the assistant sales manager noted the importance of feedback information, for example, if food waste is collected a certain amount of carbon is saved, as this will definitely motivate participation. The importance of enforcement was underlined by the culinary director. He stressed that in any case things are not carried out simply because there no fines or other deterrents are present. Because there was a rumour that a fee on plastic waste was going to be introduced, the administration had already started thinking about the possible practices to separate it from other materials.

> *Question 3. During 2017, the hotel purchased 57,000 bottles which cost €36,000. This presents a linear waste flow. What do you think if the practice is replaced by water dispensers?*

The assistant sales manager started by saying that the choice of giving water daily in plastic bottles was based on costs. In earlier days, a glass bottle which was recycled (not reused) was handed out. However, this was later replaced with a plastic bottle. He also noted that the hotel shifted from glass to plastic to reduce costs. No complaints were ever registered.

The researcher suggested the possibility of using water dispensers to replace the daily water provision in individual plastic bottles. The possibility of using attractive and reusable water bottles which hotel guests can refill was suggested. Pictures of different bottle alternatives were shown to the participants.

The first observation, made by the assistant sales manager, is that such practices were feasible in three, possibly four-star hotels but not in five-star hotels. At this point, the researcher intervened and said that different literature states that people are starting to expect such initiatives. According to a specific offer, the costs of water dispensers would amount to €4 for every 19 litres together with the cost of the dispenser. The researcher also added, that generally pro-environment initiatives generally require a higher initial investment which is then covered by a shorter payback period.

Other participants agreed that the initiative might not be perceived as luxurious. When guests book in a five-star hotel they expected luxury. The assistant sales manager added that people visiting the island for business purposes might see the need to refill bottles as a nuisance. The possibility to have the maids the bottles up was proposed by the restaurant manager. This would be part of the cleaning procedure, where instead of having the present water bottle replaced, it would be refilled for the guests. The culinary director added that guests might see the water refillers as a positive initiative, an effort from the hotel to reduce the impact it imparts on the environment. However, the assistant sales manager noted that some guests might complain because they see it as a nuisance. Complaints are likely to be registered because guests would think that they are paying €300 per night but are not handed bottled water daily which is customary practice in higher category hotels. The assistant sales manager also said that he expects more complaints from those paying €70 a night than those in the higher brackets. He also added that the dynamics of the business have changed, and it cannot be assumed that those spending €300 a night will automatically be high spenders.

The influence of nationality was also brought in. The revenue and e-commerce manager noted that Scandinavians and northern Europeans would accept the initiative more than for example the Southern Europeans. The sales executive concluded that whether guests pay €300 or €70, he would still expect an extensive amount of complaints.

Question 4: What do you think of food waste?

The restaurant manager immediately pointed to buffets as contributing to high food wastage. However, the culinary director intervened by stating that buffets attracted people. The researcher mentioned that when she visited the restaurant, she felt that the portions were too large and because she had had a starter, the main course was practically wasted. The possibility of initiating composting was also brought up. However, the restaurant manager said they might produce too much which might be an opportunity to sell it, particularly if it was of good quality. Composting, within the hotel, would need to be carried out through mechanical equipment and then used as a fertilizer within the hotel grounds. The researcher noted that as a hotel they had a better ability to produce good quality compost since they were able to control what is allowed in the organic bin. The possibility of composting was preferred by the assistant sales manager as compared to introducing dispensers, however, difficulties from line staff might arise. At this point, the culinary director intervened with saying that difficulties to introduce initiatives were often less than perceived. He added that an audit was ongoing at the a-la-carte restaurant and the staff had found no difficulties in collaborating. Initially, some clarifications to the line-staff were necessary, for example, which waste goes in the different fractions but once this was settled, it ran smoothly.

The size of portions was brought up by the learning and development executive who questioned if the portions are too big. The participants agreed that Maltese patrons seem to prefer larger portions so if these were decreased, an increase in complaints might be registered. The Culinary Director noted that in some time, in the a-la-carte restaurant, guests having the main course would not be given a vegetables/salad and potatoes/chips side-plate automatically but would have to select between the two. If someone wished to have both they would need to pay extra. However, the assistant sales manager pointed out his scepticism and said that they would eventually retract from this initiative due to the increase in complaints.

Question 5: What do you think of green practices in hotels, for example, green purchasing?

The researcher explained that green purchasing refers to the selection of items with a lower environmental impact. An example, introduced at the hotel are paper straws which have received no complaints.

Here the possibility of using stainless steel straws was noted by the Culinary Director. However, he also added that these might pose a danger when used in mass events like weddings, particularly when alcohol consumption was higher than usual. The researcher also suggested the replacing high impact items like cellophane (also known as stretch and seal). This would require extensive changes since the item was ubiquitously used. However, the culinary director added that the introduction of such initiatives also required approval from higher management.

Question 6: Do you think the hotel would be interested in seeking more assertive eco-certification?

The researcher started with suggesting the possibility of introducing an environmental certification which would be more ambitious than the current eco-label. To this, the culinary director noted that hotel was seeking to introduce the Hazard Analysis Critical Control Point (HACCP) (food safety regulation). Although the hotel embarked on the initiative, few other hotels in this category had shown interest. This is in view of the complexity involved. He added, that, for example, to buy certified cheeselets (ġbejniet), it had proven to be complex since there was only one certified supplier who refused orders which added to less than fifty cheeselets. These factors had caused other hotels to avoid certification. However, since the present General Manager wanted to implement it, he was working on it. The certification was also very intensive. The Culinary Director added that he received about thirty emails per day solely on it. For example, the certification required that staff that registered sick needed to be examined when re-entering work. Spot checks are also formed a regular part of the HACCP certification. The certification also made it difficult to locate suppliers since its rigidity alarmed them particularly because of the intensity of spot checks. Another example of Thai noodles was brought up – no one is certified that the noodles bought are Thai and this posed difficulties to procure them. He concluded that a particular supplier when he realised that the hotel was seeking HACCP certification, refused to provide them with the required product. No checks were ever made by the government about their supplies. However, acquiring the certification would safeguard the hotel if any problems related to food safety had to arise.

Question 7: If your competitors initiated more aggressive green practices, e.g. focused on waste reduction at source, or if, for example, MTA or MHRA, were to take a more active role towards green practices, what would be your reaction?

The researcher explained that the ideally waste should be reduced at the source. It was stressed that recycling has its limitations, since, for example, polymers lose their quality when recycled. Besides, recycling items to reuse as food packaging is extensively regulated. This stresses the importance of green purchasing, which can assist to reduce costs in the long run and build a positive image for the hotel.

Final comments were made by the assistant sales manager who noted that green practices would be boosted if influential organisations like MHRA and MTA advocated them more frequently. If, for example, information or research was published stating that tourists are shifting their preferences towards more environmentally conscious hotels, more hotels engage in it.

8.5 Transcript of line staff focus group held on the 22nd June 2018 between 10.00 and 11.00 am

The focus group was attended by a restaurant supervisor, two waiters, a barman and an assistant pastry chef. Two participants were of Maltese origin whilst the other three were a Serbian, Macedonian and Portugues. The focus group was therefore held in English.

All participants were handed a consent form a priori and asked to sign it. The researcher requested permission to record the session using One Note. The attendees were notified in the consent form what the focus of the research is. A short introduction was given before the commencement of the session. The participants were notified when the recording started.

Questions 1 and 2: What do you think of the waste generated by the hotel? Which waste do you perceive to be most problematic? If it is it a problem that simply requires a waste collector (an out of sight out of mind issue)? Or is it something that needs to be managed?

The silence was broken by the waitress who said that waste is something that needed to be addressed at the individual level. To this, the researcher explained the research was related to waste generated by the hotel, for example, during the buffets. To this, all participants agreed that buffets generated a large amount of waste. The assistant pastry chef added that, for example, if sweets are not used by the day after manufactured, they are thrown away. The forecast for the buffet was an additional issue. If staff were instructed to prepare enough for seventy guests but only 30 turns up, a large amount of food would be wasted.

> *Question 3: In your interactions with the hotel clients, which activities do you think to generate more waste?*

The restaurant supervisor pointed out that waste was present also in the a-la-carte restaurant particularly because the size of food portions were often viewed as too large. The latter seemed to be a frequent comment from guests, except the Maltese, who seem to expect large portions. The latter point was further corroborated by the assistant pastry chef who said that when hosting an event for 300 people, if they are Maltese, extra food is prepared and the amounted wasted is very low. She further added that another source of waste is disposables, which included, small plastic cups and teaspoons. These could only be used once because of their low quality that led to a large number of breakages. Additionally, if they are washed they become dull. She concluded that in the kitchen the main items discarded consisted of disposables and food.

The point of over-ordering was brought up by the researcher. To this, the restaurant supervisor noted that people were encouraged to take food home with them. It was customary to ask guests if they would like to take the leftover food in their plate with them. This was the case also with hotel guests. No problems ever arose with this practice and many were those who accepted.

Questions 4: What do you think of the use of paper straws?

The waitress started by saying that when plastic straws came under extensive scrutiny the hotel decided to replace them. However, she pointed out that when plastic straws used to be distributed only one straw needed to be handed out with every drink. Since the paper straws were introduced, two or three had to be given with every drink because the paper straws disintegrated in the drink.

The researcher asked about the possibility of using stainless steel straws. The waitress noted, that for example, usually in an Aperol fritz they put 2 or 3 straws, so the image might be an issue. The fact that stainless still can be washed at high temperatures is an advantage in view that can be sterilised. She further added that when crushed ice is used in drinks, paper straws disintegrated very quickly making them unfeasible despite that they have a protective wax layer. The researcher noted that plastic straws are not recycled and their decomposition takes a very long time. The waitress concluded that soft drink companies are bringing back glass bottles. The participants agreed that when you are on holiday you tend to be less careful and therefore become more wasteful.

The researcher intervened and asked if receive any complaints about paper straws from guests.

The restaurant supervisor noted that children like them. She further added that people found them attractive and sometimes ask for them even when usually they are not given one. This often happened with a local soft drink – Kinnie – which is generally served without a straw. However, with drinks like pina colada, the straws disintegrated very easily. They agreed that ultimately no straws are required to drink even in the case of children.

The assistant pastry chef pointed to the convenience factor and how this goes hand in hand with habit formation. She drew an example from her husband who worked in a butcher shop – after the shop started to distribute meat in polystyrene trays, expectations for it were established and clients asked for the try, despite that it is often removed immediately when they reach home particularly due to space issues in their freezer.

Question 5: What about other green practices? How would you feel if practices like water dispensers are implemented more intensively?

The researcher then shifted the discussion to the introduction of green practices, for example, the replacement of bottled water by water dispensers and whether they would see any difficulties to carry them out.

Immediately the issue of theft was brought up since guests tend to take anything available in hotels, including sheets and towels. Thus, it might be necessary to charge guests if the bottle is kept. The waiter noted that this would be strange in a five-star hotel and that when a person is spending so much money for a room, he would expect to find a bottle of water available in his room and not having to fill it himself. He further added, that if he was the guest, he would simply walk out and check in somewhere else. This was further corroborated by the waitress, who said that being a five-star hotel they try to keep their guests as comfortable as possible. She suggested using these dispensers within the bars where a large of bottles are used to used for the preparation of cocktail drinks and coffee. Placing dispensers near the pool was deemed as unfeasible since selling water brought in income for the hotel and charging guests for water purchased through the dispenser did not seem feasible in a five-star hotel.

Question 6: Would you participate solely because they are imposed?

The researcher then said that, as line staff, they would be the ones ultimately implementing the suggested green practices. How would they feel about it? Would you participate solely because they are imposed?

The assistant pastry chef said that when there is collaboration, participation from staff is likely to be higher. She added, that if as a hotel, they put up signs that they are initiating a pro-environment shift, it would also induce participation. This would also become part of the hotel's image which would encourage a corporate policy that sends the message that the hotel management does not care only about profits but understand its environmental responsibility.

The researcher asked if working in a hotel implementing these practices would make them proud.

The participants replied that they would. The researcher noted that hotels that are located in a prime area and that the hotel is not only selling only the service but also the location and the surroundings offered.

The researcher then asked whether any factors would encourage them to participate and the difficulties they would perceive to implement environmental initiatives?

Participants said that being given information and gaining knowledge about the topic would encourage them as this would help them understand why the initiatives are being implemented and increase their awareness. Additionally, the initiative would not be another order imposed by the management but something they feel part of.

Question 7: What difficulties do you perceive in the implementation of such practices?

In the case of difficulties faced, the assistant pastry chef shifted to the use of clingfilm or cellophane. She noted its use in the kitchen was ubiquitous. A replacement for it, particularly small items, is the use of hard lid containers.

She further added that trolleys, which are full of different food items, are wrapped in cling film to preserve the food freshness. The use of cling-film increased when they engaged in outside catering. The assistant pastry chef noted they it was possible to replace open trolleys with closed ones which would preserve the food freshness, however, these were more expensive. In the case of stretchable items to replace cling film that was trending online, they were still waiting to see if these items are practical.

8.6 Final comments

Waste is often cited as being an out of sight, out of mind issue. During the interviews, clients frequently associated waste with cleanliness and littering with many stating that the hotel is kept very clean. None of the respondents said that their choices were influenced by the hotels' green practices or that any of their friends typically lodged in these places. This brings to the forefront of the absence of the subjective norm. An interesting observation came from a Maltese respondent who noted that major hotel booking websites did not refer to aspects such as hotel ecolabelling or other pro-environment initiatives. Social media can have a crucial role in influencing the demand for more pro-environment practices, thus concluding that its potential to open opportunities for participation in pro-environment tourism decision-making still needs to be harnessed (Budeanu, 2013).

An example of successful sustainable action is the reuse of towels by guests. This initiative helps to reduce both the environmental footprint and the operating costs of the hotel (Juvan et al., 2018). All the guests who were interviewed said this was the one practice they regularly adopted. The initiative proves that whatever perceived volitional and behavioural control might have existed before its introduction has been eliminated and it is now being considered a norm.

Pursuing a more intensive eco-certification is subject to both volitional control and subjective norm. An eco-label gives assurance that the transaction or tourist activity is being conducted according to a known standard that improves the environment or, at least, minimises impacts. Its adoption is influenced by perceived complexity, together with the apparent relative advantages gained (Leroux & Pupion, 2018). During the focus group, its introduction was compared with the Hazard Analysis and Critical Control (HACCP) food safety certification pursued by the hotel which imposes extensive demands that can generate 'fear' in suppliers because of the checks and requirements intensity. However, the certification is designed to prevent food hazards and contamination through appropriate controls during each stage of the food handling and production flow (Hemminger, 2000), thus enhancing food safety management to ensure product quality and demonstrate the hotel's commitment to producing and trading in safe food (SGS, 2018).

8.7 Concluding remarks

The linear modus operandi of hotels can no longer be sustained particularly in view of the dependence of the industry on the attractiveness of the environment. Introducing a waste management plan requires a holistic approach that inspects and reworks the existing processes forming operational and managerial processes. This is an arduous task that requires co-ordination with both staff and guests and therefore, represents a challenge that goes beyond the daily operational remit. However, its introduction is both a cost-saving measure and a means to enhance the image of the hotel.

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