E-WASTE MANAGEMENT, PRACTICES, KNOWLEDGE, AND BEHAVIOUR: A CASE STUDY OF STELLENBOSCH UNIVERSITY

by

TAMMY LEE JEFTHAS

Thesis presented in fulfilment of the requirements for the degree of Master of Arts in the Faculty of Arts and Social Sciences at Stellenbosch University.

Pectora roborant cultus recti

SUPERVISOR: DR S WILLIAMS

Department of Geography and Environmental Studies

March 2023

DECLARATION

By submitting this thesis electronically, I declare that the entirety of the work contained therein is my own, original work, that I am the sole author thereof (save to the extent explicitly otherwise stated), that reproduction and publication thereof by Stellenbosch University will not infringe any third-party rights and that I have not previously in its entirety or part submitted it for obtaining any qualification.

Date: ______________________________

ABSTRACT

Electronics and electrical equipment (EEE) have revolutionised modern life since the early 1990s and have penetrated every aspect of our lives. The rise of disposable income and urbanisation, coupled with advances in technology and shorter product lifespans, have resulted in higher consumption of EEE (Forti et al. 2020). Once these devices reach their end-of-life (EOL), they generate a waste stream called e-waste. Considering its hazardous nature and rapid growth in global quantities, e-waste poses a serious environmental threat worldwide. The global quantity of e-waste in 2019 was 53.6 million metric tons (Mt), equivalent to 350 cruise ships in weight. Global e-waste production is expected to reach 74.7 Mt by 2030, making it the fastest-growing domestic waste stream in the world. If it is not managed and disposed of correctly, e-waste can negatively impact the environment and human health. Consumers of EEE play an important role in reducing the rising global quantities and negative impacts of this waste stream. Only by educating and empowering consumers about e-waste and responsible disposal, can e-waste be effectively managed.

Through a case study of Stellenbosch University in South Africa, this study presents a qualitative method for investigating and documenting e-waste management, knowledge, awareness, and practices. Structured interviews and online questionnaires were used to collect data for this study. This study reveals that Stellenbosch University has the potential to generate a large amount of e-waste, generating 6 678 kg in 2019, 2 714 kg in 2020, 4 847 kg in 2021 and 7 599 kg in 2022. Two e-waste management strategies implemented have been identified that focus on recycling, i.e., *The Non-Asset Registered E-waste* (recycling of e-waste generated by the University community) and *The Stellenbosch Asset E-waste* (recycling e-waste generated by the University). The results show low e-waste practices which were linked to low awareness of e-waste recycling programmes and facilities on campus. Furthermore, the survey population had a general understanding of what e-waste is and recognised that a global e-waste problem exists, however, they had limited knowledge about the hazardous materials found in e-waste and how this impacts the environment and human health. Mobile phones were the most frequently used electronic devices among the survey population, with an average possession lifespan of 2.3 years, and obsolete hardware and software were the most common reason for replacing them. As a result of a lack of information about e-waste recycling facilities, personal storage was identified as the preferred method for disposing of waste mobile phones (WMP). There was, however, a positive attitude towards e-waste recycling among the survey population

as they were very willing to recycle their e-waste on campus if more information was provided. The results reveal that more awareness is needed among the survey population, particularly about hazardous materials found in e-waste and the e-waste recycling programme on campus. Through information and education, Stellenbosch University can contribute to increasing e-waste awareness, which may encourage the University community to recycle their e-waste more.

OPSOMMING

Elektronika en elektriese toerusting (EET) het die moderne lewe sedert die vroeë 1990's gerevolusioneer en het elke aspek van ons lewens binnegedring. Die toename van besteebare inkomste en verstedeliking, tesame met vooruitgang in tegnologie en korter produklewensduur, het gelei tot hoër verbruik van EET (Forti et al. 2020). Sodra hierdie toestelle hul lewenseinde (EOL) bereik, genereer hulle 'n afvalstroom genaamd e-afval. Met inagneming van die gevaarlike aard daarvan en vinnige groei in globale hoeveelhede, hou e-afval 'n ernstige omgewingsbedreiging wêreldwyd in. Die wêreldwye hoeveelheid e-afval in 2019 was 53,6 miljoen metrieke ton (Mt), gelykstaande aan 350 vaartuie in gewig. Wêreldwye e-afvalproduksie sal na verwagting teen 2030 74,7 Mt bereik, wat dit die vinnigste groeiende huishoudelike afvalstroom ter wêreld maak. Indien dit nie reg bestuur en weggedoen word nie, kan e-afval die omgewing en menslike gesondheid negatief beïnvloed. Verbruikers van EET speel 'n belangrike rol in die vermindering van die stygende globale hoeveelhede en negatiewe impak van hierdie afvalstroom. Slegs deur verbruikers op te voed en te bemagtig oor e-afval en verantwoordelike wegdoening, kan e-afval doeltreffend bestuur word.

Hierdie studie bied 'n kwalitatiewe metode om e-afvalbestuur, kennis, bewustheid en praktyke te ondersoek en te dokumenteer deur gebruik te maak van 'n gevallestudie van die Universiteit Stellenbosch in Suid-Afrika. Gestruktureerde onderhoude en aanlynvraelyste is gebruik om data vir hierdie studie in te samel. Hierdie studie dui aan dat die Universiteit Stellenbosch die potensiaal het om 'n groot hoeveelheid e-afval te genereer aangesien 6 678 kg in 2019, 2 714 kg in 2020, 4 847 kg in 2021 en 7 599 kg in 2022 genereer is. Twee geïmplementeerde e-afvalbestuurstrategieë is geïdentifiseer wat fokus op herwinning, dit wil sê, Die Nie-Bate-Geregistreerde E-afval (herwinning van e-afval wat deur die Universiteitsgemeenskap gegenereer word) en Die Stellenbosch-Bate-e-afval (herwinning van e-afval wat deur die Universiteit gegenereer word). Die resultate toon lae e-afval praktyke wat gekoppel is aan lae bewustheid van e-afval herwinningsprogramme en fasiliteite op kampus. Verder het die opnamebevolkinge 'n algemene begrip gehad van wat e-afval is en erken dat 'n wêreldwye e-afvalprobleem bestaan, maar hulle het beperkte kennis gehad oor die gevaarlike materiale wat in e-afval gevind word en hoe dit die omgewing en menslike gesondheid beïnvloed. Selfone was die mees gebruikte elektroniese toestelle onder die opnamebevolking, met 'n gemiddelde besitleeftyd van 2,3 jaar, en verouderde hardeware en sagteware was die algemeenste rede vir die vervanging daarvan. As gevolg van 'n gebrek aan inligting oor e-afval-

herwinningsfasiliteite, is persoonlike berging geïdentifiseer as die voorkeurmetode vir die wegdoen van afvalselfone (WMP). Daar was egter 'n positiewe houding oor e-afval-herwinning onder die opnamebevolking aangesien hulle baie gewillig was om hul e-afval op kampus te herwin indien meer inligting verskaf word. Die resultate toon dat meer bewustheid onder die opnamebevolking nodig is, veral oor gevaarlike materiale wat in e-afval gevind word en die e-afval-herwinningsprogram op kampus. Deur inligting en opvoeding kan die Universiteit Stellenbosch bydra tot die verhoging van e-afval-bewustheid, wat die Universiteitsgemeenskap kan aanmoedig om meer e-afval te herwin.

ACKNOWLEDGEMENTS

Words cannot express my gratitude to my supervisor, Dr Williams who has helped me turn my vague ideas into a coherent thesis. Thank you for your continual support, patience, and kindness. I would like to express my deepest gratitude to the Facilities Management team at Stellenbosch University for their willingness to participate in my research. Additionally, I would like to extend my sincere thanks to Mrs Karla Coombe-Davis, who has aided me throughout my data collection process; thank you for taking the time to respond to my every email and answer to all my concerns. I am also grateful to all the participants who agreed to partake in my research.

To my sister, thank you for allowing me to monopolise every conversation with my research-related talks. You have been so supportive and understanding. And thank you to my parents for everything.

Table of Contents

LIST OF FIGURES

LIST OF TABLES

ACRONYMS AND ABBREVIATIONS

ADHD	Attention-Deficit/Hyperactivity Disorder
Ba	Barium
BRF	Brominated Flame Retardants
Cd	Cadmium
Cr	Chromium
CRM	Critical Raw Materials
CRT	Cathode Ray Tube
DEA	Department of Environmental Affairs
EEC	European Economic Community
EEE	Electronic and Electrical Equipment
EOL	End-of-Life
EU	European Union
EU WEE Directive	European Union Waste Electronic and Electrical Equipment Directive
EPR	Extended Producer Responsibility
eWASA	E-Waste Association of South Africa
GPS	Global Position System
Hg	Mercury
ICT	Information and Communications Technology
ILO	International Labour Organisation
IQ	Intelligence quotient
ISWM	Integrated Solid Waste Management
IT	Information Technology
Kg	Kilogram
Kt	Kiloton
LCD	Liquid Crystal Display
LED	Light-Emitting Diode
MSW	Municipal Solid Waste
Mt	Metric Tons
NEMA	National Environmental Management Act, 107 of 1998
NEMWA	National Environmental Management Waste Act, 2008 (Act 59 of 2008)
NGO	Non-Governmental Organisation
OECD	Organisation of Economic Cooperation and Development

PAEs	Phthalic Acid Esters
PC	Personal Computer
PCB	Printed Circuit Board
Pd	Lead
POPs	Persistent Organic Pollutants
PWB	Printed Wiring Boards
RAM	Random Access Memory
SDG	Sustainable Development Goals
StEP	Solving the E-waste Problem Initiative
SU	Stellenbosch University
TMA	Theory of multi-attribute-attitude
TPB	Theory of Planned Behaviour
TRA	Theory of Reasoned Action
UNEP	United Nations Environmental Programme
UNIDO	United Nations Industrial Development Organisation
UNTC	United Nations Treaty Collection
UNU	United Nations University
USA	United States of America
WEEE	Waste Electrical and Electronic Equipment
WH	Waste Hierarchy
WHO	World Health Organisation
WMP	Waste Mobile Phones

CHAPTER ONE: INTRODUCTION

1.1 BACKGROUND TO STUDY

There has been a steady increase in the number of people who have joined the technological society over the last few decades. Globally, there is a growth in the consumption and usage of Electronic and Electrical Equipment (EEE). EEE has infiltrated many parts of our everyday lives, from simple tasks such as cooking and cleaning to connecting us with friends and family thousands of kilometres away to more complex lifesaving medical equipment. EEE has become an indispensable part of modern-day life, improving living standards while contributing to the already challenging task of waste management (Forti et al. 2020). Due to higher levels of disposable income and urbanisation, coupled with further industrialisation in some regions around the world, the amount of EEE consumption is proliferating (Widmer et al. 2005). It has been forecasted that by the end of 2025, approximately 75.44 billion devices will be connected to the internet, which is more than nine times the global population (Edmonds et al. 2019). This amount is estimated to continue to increase in the future. EEE does not last forever; all EEE eventually reaches its end-of-life (EOL). When EEE reaches its EOL, it is disposed of and generates a waste stream known as e-waste. E-waste is defined as any EEE and its added components that have been discarded as waste by its owner with no further intention of use (StEP Initiative 2014). E-waste constitutes a small part of the solid waste stream but is the fastest-growing waste stream globally (Widmer et al. 2005).

Globally, it has been estimated that 41.8 million Metric Tons (Mt) of e-waste were generated in 2014 (Baldé et al. 2015). By 2016, this figure grew by 2.6 Mt, the equivalent of approximately 4 500 Eiffel Towers in weight (Baldé et al. 2017). By the end of 2019, the total quantity of e-waste generated had increased to approximately 53.6 Mt. In addition, it is anticipated that the global quantity of e-waste will continue to increase in the coming decades. Forti et al. (2020) project that by 2030, the global quantity of e-waste will exceed 74.4 Mt – almost doubling in 16 years. Managing e-waste presents a major challenge because most e-waste largely remains undocumented, of which most is likely dumped, traded, recycled using environmentally unsound methods, or disposed of in household bins (Forti et al. 2020).

E-waste differs from other waste streams, such as paper and glass. Due to its distinctive chemical and physical composition, e-waste contains toxic and hazardous materials, which, if not handled and recycled correctly, may negatively impact the environment and humans. At the same time, it contains many valuable materials which require sophisticated handling and recycling facilities (Robinson 2009). This prompted the Basel Convention on the Control of Transboundary Movement of Hazardous Waste and their Disposal (Basel Convention) as an important international agreement to regulate the movement and disposal of hazardous waste across borders.

On the African continent, South Africa is one of the largest generators of e-waste. Although there has been no quantification of how much e-waste is generated in South Africa, the Department of Environmental Affairs (DEA) has estimated that each South African citizen produces approximately 6.2 kilograms (kg) of e-waste each year, of which only 12% is documented and recycled (Mhlanga 2018). While the exact figure on the total quantity of e-waste generated in the country has not been quantified, the Department of Environmental Affairs (DEA) estimated that each South African generates approximately 6.2 kilograms (kg) of e-waste annually, of which only 12% is recycled (Mhlanga 2018). Despite South Africa being among the few African countries with formal e-waste recycling facilities, these facilities operate in conjunction with a large informal sector of recyclers (Forti et al. 2020). E-waste is not explicitly regulated by South African law. Instead, acts such as the National Environmental Management Waste Act No. 59 of 2008 govern its disposal. Due to South Africa's relatively young e-waste industry, very little information about this industry is documented and available. Understanding consumers' knowledge, attitudes, and behaviours about e-waste and expanding information about e-waste in South Africa are key aspects to addressing the challenges and impacts posed by e-waste.

1.2 RESEARCH PROBLEM AND RATIONALE

Most people's lives today are heavily influenced by electronic devices that have become indispensable to their daily routines. These devices have infiltrated every part of modern society's functionality, making people highly dependent on these technologies. In his article Verma (2021) notes that electronic devices have revolutionised people's lives all around the globe; however, at times, they made people highly dependent on these devices in their daily lives. According to Aboelmaged (2020), people consume EEE at double the rate 50 years ago. The electronic industry is the world's largest and fastest-growing due to the high dependency on and consumption of EEE. Although this growth is a positive sign of increased global living standards, globalisation, and technological advancement, it produces a global tsunami of e-waste. Increased EEE consumption and higher obsolescence rate have caused e-waste to increase at an alarming rate globally. The e-Waste Association of South Africa (eWASA) reports that e-waste is the fastest-growing waste stream in South Africa, and this trend is expected to continue if poor management is implemented (Lydall et al. 2017). Several toxic and hazardous materials could be found in e-waste, and these materials, if not handled and disposed of properly, can adversely affect the environment and human health. Unfortunately, these adverse effects have remained under-reported until the early 2000s, escaping the global and national attention of governments, academics, and society as a serious waste management threat, and therefore will continue to cause havoc if it does not gain serious global attention from all stakeholders.

Discourses and strategies about waste management, pollution, and recycling at international, national, and individual levels are usually centred around Municipal Solid Waste (MSW), such as plastic, paper, and glass. At the same time, little attention is placed on the global and national rapidly increasing e-waste problem and its negative impacts. As previously stated, consumers of EEE are highly dependent on these devices as part of their daily lives; however, they are often unaware or do not give much thought to what happens to these devices once they have reached their EOL. In their study on the growth of e-waste quantities, Bhutta et al. (2011) note that most consumers are unaware of the potential negative impacts of the rapidly increasing use of EEE, specific computers, televisions, and mobile phones. People often do not know how to dispose of their EEE once it has reached its EOL and therefore resort to improper disposal methods. Moreover, consumers of these products are often also unaware of the potential negative impact their devices may have on the environment and human health if not disposed of correctly. Consumers of EEE often do not know that their old devices are contributing to a rapidly rising waste stream, in which they play a crucial role in combating this environmental issue.

With e-waste quantities rising at a staggering rate, increasing globally from 44.4 Mt in 2014 to 53.6 Mt in 2019, and with future projections to reach 74.7 Mt by 2030, e-waste must be emphasised in waste management practices amongst EEE consumers to increase their knowledge and awareness. When consumers have a better understanding of this type of waste and its potential environmental hazards, this might foster better e-waste management practices. Therefore, this study investigates e-waste practices and, amongst others, will document and analyse the level of awareness, knowledge, attitudes, and behaviour toward e-waste. By using Stellenbosch University as a case study, this research is deemed as relevant as it considers the following:

1. Globally, e-waste generation is rising at an alarming rate, with signs of continuous upward projection in the future if not managed.
2. A greater amount of attention and awareness must be directed toward e-waste, as this waste stream contains hazardous materials that, if not managed appropriately, can pose a severe threat to the environment and human health.
3. Often, EEE consumers are unaware of the environmental and health risks associated with e-waste and often lack knowledge and awareness of the proper disposal of these devices.
4. Knowledge and awareness amongst consumers of EEE are necessary as they play a crucial role in creating the rapid increase in e-waste and, at the same time, play a key role in combating this waste management issue.

This study will provide information and recommendations to enhance and promote e-waste management practices that could improve Stellenbosch University's current e-waste management systems. To the best of the researcher's knowledge, studies have been conducted in several parts of the world on consumer awareness, attitudes, and behaviour regarding e-waste at universities; however, none have been conducted in South Africa. Thus, this study will broaden the current literature on e-waste in South Africa. As mobile phones have a high obsolescence and disposal rate, this study will also focus on this form of e-waste. For these reasons, using Stellenbosch University as a case study will be an appropriate case study for investigation.

1.3 AIMS AND OBJECTIVES

The overarching aim of this study is to document and investigate the quantity of e-waste generated at Stellenbosch University and analyse the current e-waste management systems employed. This study seeks to identify the University community's e-waste knowledge, attitudes, and behaviours.

To achieve the aim stated above, the following six objectives will be explored:

1. Conduct a literature review on the past and current discourses on e-waste
2. Identify the amount of e-waste generated at Stellenbosch University
3. Document and analyse e-waste management systems and practices employed at Stellenbosch University
4. Document and analyse the University community's knowledge, awareness and attitudes related to e-waste
5. Explore the primary disposal methods and reasons for the disposal of waste mobile phones in the university community
6. Identify strategies and recommendations that could enhance current e-waste management practices at Stellenbosch University

1.4 RESEARCH QUESTIONS

Based on the predefined objectives of the study, the following research questions have been identified:

1. What are the past and current debates on e-waste globally?
2. What types of e-waste are produced at Stellenbosch University?
3. How much e-waste was generated at Stellenbosch University?
4. What are the e-waste management systems and disposal methods employed at Stellenbosch University?
5. What are the positive and negative aspects of the selected e-waste management and disposal methods at Stellenbosch University?
6. What are the University community's knowledge, awareness and attitudes toward general waste and e-waste?
7. What electronic devices are used most in the university community?
8. What are the university community's primary disposal methods and reasons for waste mobile phones (WMP)[1]?
9. What recommendations and strategies could improve Stellenbosch University's e-waste management and the University community's knowledge and awareness?

---

[1] Waste Mobile Phone: Any mobile phone that has reached its end-of-life and is no longer used by consumers (Yan 2019)

1.5 STRUCTURE OF THESIS

Chapter 1 of this thesis provides the context and background of the study and outlines the problem statement and the aims and objectives of this study. Chapter 2 provides the theoretical framework underpinning this study. This chapter outlines concepts and theories about waste management, sustainability, and development. Chapter 3 of this thesis reflects on the literature review of e-waste, both internationally and nationally, to provide insight into the current global e-waste status. The literature review details e-waste within the broader context by giving insight into definitions of e-waste, global e-waste quantities, e-waste as a hazard and value, transboundary movement of e-waste, e-waste management, and consumer attitudes. This chapter provides insight into the current e-waste status in South Africa.

The methodology and methods employed for this study are discussed in detail in Chapter 4 of this thesis. This chapter describes the underpinning research philosophy, research approach, research methods, research design, data collection and analysis techniques, as well as the limitations of this study. Chapter 5 of this thesis presents the study's findings, and Chapter 6 revisits the study's aims and objectives in the context of the study's findings. The study is concluded in Chapter 7 and provides recommendations and strategies that could enhance e-waste management at Stellenbosch University.

CHAPTER TWO: THEORETICAL FRAMEWORK

2.1 INTRODUCTION

This chapter is dedicated to detailing the important frameworks, models and specific theories underpinning this study. This chapter will first introduce the concept of ‘waste’ and detail the current global scenario. Moreover, two waste management strategies will be described, namely: the waste hierarchy and integrated solid waste management plan. As part of this chapter, the Extended Producer Responsibility model, which has gained much attention in the past decades as one of the most appropriate approaches when dealing with end-of-life products, will be explored. The focus will then shift to describing the economic approaches to waste management, namely the linear and circular approaches. Finally, this chapter will conclude by examining how waste management aligns with the sustainable development goals.

2.2 THE WASTE CONCEPT

Waste is an inevitable by-product of human activity, and its management is essential for protecting the environment and health of communities in the global north and south. Due to rapid urbanisation, population growth, and economic development, the global quantity of solid waste is rising alarmingly, resulting in one of the world's largest environmental problems. According to the World Bank's report, the effects of urbanisation and economic progress are nowhere more visible than in society's ‘detritus’, or solid waste (Hoornweg & Thomas 1999). Solid waste production has remained a significant environmental concern since the pre-historic period (Chandler et al. 1997). This makes it a widely researched topic throughout the literature (Hazra & Goel 2009).

Throughout the literature numerous definitions of solid waste are offered across the literature. In their integrated solid waste management study, Tchobanoglous et al. (1993) define solid waste as any discarded solid or semisolid waste generated by human activity. Beranek (1992) further states that solid waste is generated from various human activities such as agriculture, landscaping, and other commercial and residential operations. The World Health Organisation (WHO 2013) points out that solid waste could be categorised according to where it is generated, for example, MSW, healthcare waste, and e-waste. Similarly, Basu (2009) adds that it includes municipal, biomedical, electronic, and hazardous waste. Hoornweg & Bhada-Tata (2012) identified a comprehensive classification of the diverse types and sources of solid waste (as seen in Table 2.1). Regardless of how solid waste is classified, its presence and growth are undeniable. Tchobanoglous et al. (1993) conclude that because solid waste remains in the environment for a more extended period than other waste, its management is much more difficult and complex.

Table 2.1: Generators and types of solid waste

Source	Typical Waste Generators	Types of Solid Wastes
Residential	Single and multifamily dwellings	Food wastes, paper, cardboard, plastics, textiles, leather, yard wastes, wood, glass, metals, ashes, special wastes (e.g., bulky items, consumer electronics, white goods, batteries, oil, tires), and household hazardous wastes (e.g., paints, aerosols, gas tanks, waste containing mercury, motor oil, cleaning agents), e-wastes (e.g., computers, phones, TVs)
Industrial	Light and heavy manufacturing, fabrication, construction sites, power and chemical plants (excluding specific process wastes if the municipality does not oversee their collection)	Housekeeping wastes, packaging, food wastes, construction and demolition materials, hazardous wastes, ashes, special wastes
Commercial	Stores, hotels, restaurants, markets, office buildings	Paper, cardboard, plastics, wood, food wastes, glass, metals, special wastes, hazardous wastes, e-wastes
Institutional	Schools, hospitals (non-medical waste), prisons, government buildings, airports	Same as commercial
Construction and Demolition	New construction sites, road repair, renovation sites, demolition of buildings	Wood, steel, concrete, dirt, bricks, tiles
Municipal Services	Street cleaning, landscaping, parks, beaches, other recreational areas, water and wastewater treatment plants	Street sweepings; landscape and tree trimmings; general wastes from parks, beaches, and other recreational areas, sludge
All of the above should be included as municipal solid waste. Industrial, commercial, and institutional (ICI) wastes are often grouped together and usually represent more than 50% of MSW. C&D waste is often treated separately: if well managed it can be disposed separately. The items below are usually considered MSW if the municipality oversees their collection and disposal.		
Process	Heavy and light manufacturing, refineries, chemical plants, power plants, mineral extraction and processing	Industrial process wastes, scrap materials, off-specification products, slag, tailings
Medical waste	Hospitals, nursing homes, clinics	Infectious wastes (bandages, gloves, cultures, swabs, blood and body fluids), hazardous wastes (sharps, instruments, chemicals), radioactive waste from cancer therapies, pharmaceutical waste
Agricultural	Crops, orchards, vineyards, dairies, feedlots, farms	Spoiled food wastes, agricultural wastes (e.g., rice husks, cotton stalks, coconut shells, coffee waste), hazardous wastes (e.g., pesticides)

Source: Hoornweg & Bhada-Tata (1999:5)

2.3 THE GLOBAL WASTE SCENARIO

There has been a massive increase in global waste generation over the last decade, and this trend shows no signs of slowing down. Every year, people generate millions of tonnes of waste, causing a massive strain on the environment. Global waste generation is predicted to rise by more than twice the population's growth rate by 2050 (Kaza et al. 2018). The World Bank published a follow-up report to its report in 1999, investigating and reporting on the global waste problem. The report estimated that cities globally produced approximately 1.3 billion tonnes of waste in 2012, which is projected to grow to 2.2 billion tonnes by 2025 (Hoornweg & Bhada-Tata 2012). However, the most recent study released by the World Bank indicates that in 2016, a total of 2.1 billion tons of waste were generated, exceeding the expected amount (Kaza et al. 2018). Twenty-three per cent of the world's total waste is generated in East Asia and the Pacific region, making them the world's leading waste generators (Tiseo 2022). Sensoneo's Global Waste Index of 2022 reports that each United States (US) citizen produces approximately 811 kg of waste, making it the top waste-producing country in the world. In terms of future estimates, it is anticipated that worldwide waste will rise by 70% by 2050, reaching 3.4 billion tonnes (Kaza et al. 2018). Waste generation in developing countries is expected to more than triple by 2050. With rising population growth, urbanisation, economic growth, and industrialisation in certain nations, global waste is expected to continue upward with no sign of slowing down.

Waste generation across the globe is increasing at alarming rates, making appropriate waste management and disposal increasingly critical (The World Bank 2019). However, only 20% of waste is recycled each year, while landfilling and open dumping of hazardous waste remains prevalent, particularly in developing countries (Ferronato & Torretta 2019). Studying the global perspective of MSW, Vergara & Tchobanoglous (2012) argue that plastic and electronic devices are becoming more prevalent. As a result, waste has changed in nature, becoming more complex and posing a challenge to municipalities in terms of protecting their residents. Vergara & Tchobanoglous (2012) conclude that solid waste is a complex issue which requires urgent action.

2.4 WASTE MANAGEMENT

Throughout history, human interaction with the environment has resulted in waste, and these continuous interactions have overburdened the environment (Marchettini et al. 2007; Amasuomo & Baird 2016). Therefore, Vergara & Tchobanoglous (2012) argue that proper waste management planning and approaches are key to preventing adverse environmental and human health effects- and should be prioritised. Poor waste management can lead to adverse health outcomes, for example, through water, air, and soil contamination. Waste management approaches can take a variety of forms depending on the characteristics of the waste stream and the context in which they are used (Cheremisinoff 2003). However, regardless of the context or type of waste, all waste management follows the same basic processes and paths.

2.4.1 A safe management system for solid waste

Waste management is essential for every society to protect its residents from pollution and safeguard their health. Solid waste management is provided by almost every local government and is arguably the most important municipal service (The World Bank 2022). Solid waste management comprises six key components, i.e., waste generation, collection, transport, treatment, and disposal (Vergara & Tchobanoglous 2012; WHO 2013). Vergara & Tchobanoglous (2012) add that although these complements may take different forms in various places, the elements remain universal. As White et al. (1995) report, central to all waste management decisions are two guiding frameworks: The Waste Hierarchy (WH) and Integrated Solid Waste Management (ISWM).

2.4.1.1 The waste hierarchy

The waste hierarchy is a widely accepted principle that has long been integrated into many solid waste management policies worldwide. Moreover, it is widely used to prioritise waste management methods domestically and globally (ENVASS 2020). Vergara & Tchobanoglous (2012) state that the WH has guided waste management policy since the early 1990s. It identifies which waste management techniques should be prioritised. However, according to Kaza et al. (2018) study, Ontario's Pollution Probe is an early example of the WH, which dates back to the early 1970s. The WH began with the ‘three Rs’ - reduce, reuse, and recycle - but a fourth R - recovery - has recently more frequently been cited. The WH aims to produce optimal environmental results. This is done by describing waste management options during the waste lifecycle and arranging them in descending order of priority. According to Williams (2005), the WH flows from most to least ecologically friendly, reducing waste at the top (as seen in Figure 2.1). Similarly, the WHO (2020) states that the waste hierarchy ranks waste management from most favourable (reduce) to least favourable (disposal).

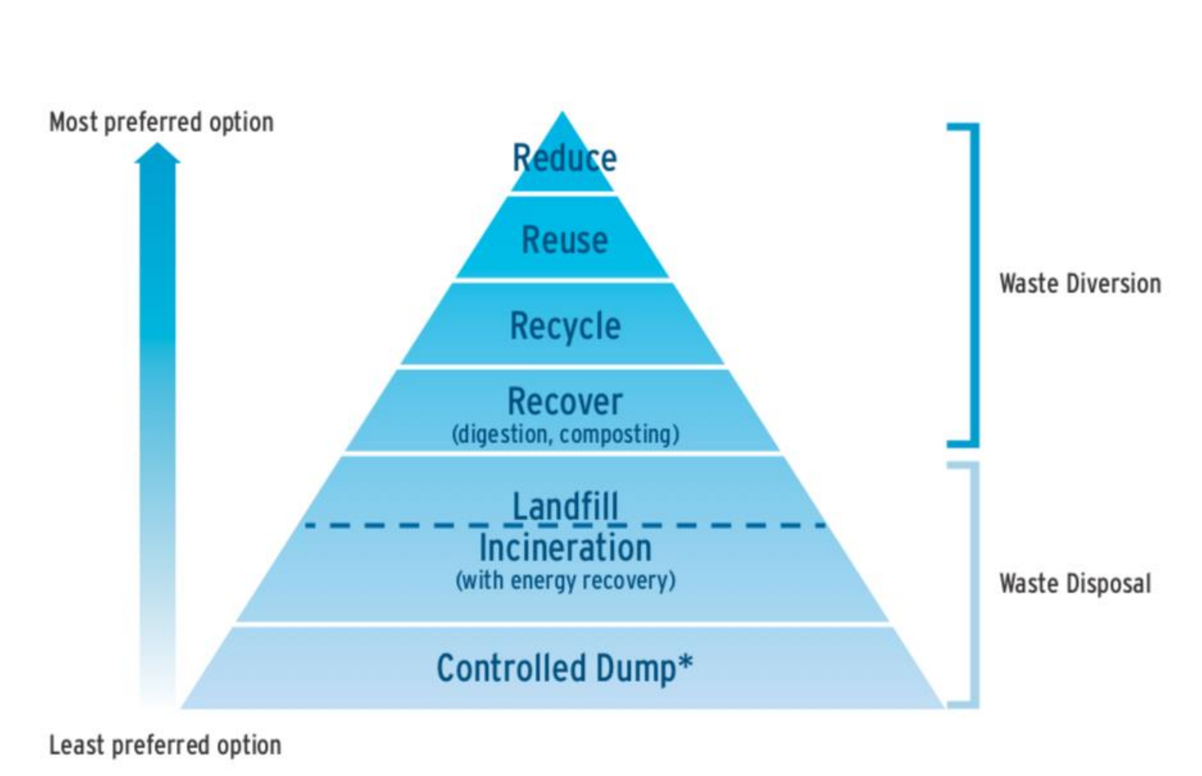


Figure 2.1: The waste hierarchy *Source: Hoornweg & Bhada-Tata (2012:27)*

The WH aims to minimise waste quantities while maximising the extraction of practical benefits from products (ENVASS 2020). Van Ewijk and Stegemann (2016) add that one of the WH's key objectives is to divert waste from landfills. When applied correctly, the WH can reduce pollution and greenhouse emissions, conserve energy, preserve resources, and stimulate job opportunities (Vergara & Tchobanoglous 2012; DEA 2018). It is a systematic and holistic waste management approach focusing on reducing, avoiding, reusing, recovering, treating, recycling, and safe disposal as a last resort (DEA 2011; DEA 2012).

2.4.1.2 Integrated solid waste management plan

Integrated solid waste management is the second major framework that has guided many waste management decisions worldwide. According to the United Nations Environmental Programme’s (UNEP) regional coordinator for resource efficiency, ISWM is “a strategic approach to sustainable management of solid waste covering all sources and all aspects, including generation, segregation, transfer, sorting, treatment, recovery, and disposal in an integrated manner, with an integrated emphasis on maximising resource use efficiency” (Memon 2013:7). Furthermore, it is a set of principles that address the sustainable disposal of waste from an economic, environmental, and social perspective (McDougall et al. 2001).

Vergara & Tchobanoglous (2012) note that the framework is integrated because it aims to control solid, liquid, and gaseous emissions from all types of waste streams. According to Kaza et al. (2018), the ISWM establishes a 'social license' so the community and local governments will be able to manage waste efficiently (Figure 2.2). As the WH, the ISWM has numerous benefits, such as ensuring cleaner and safer neighbourhoods, higher resource efficiency, and local ownership and responsibility.

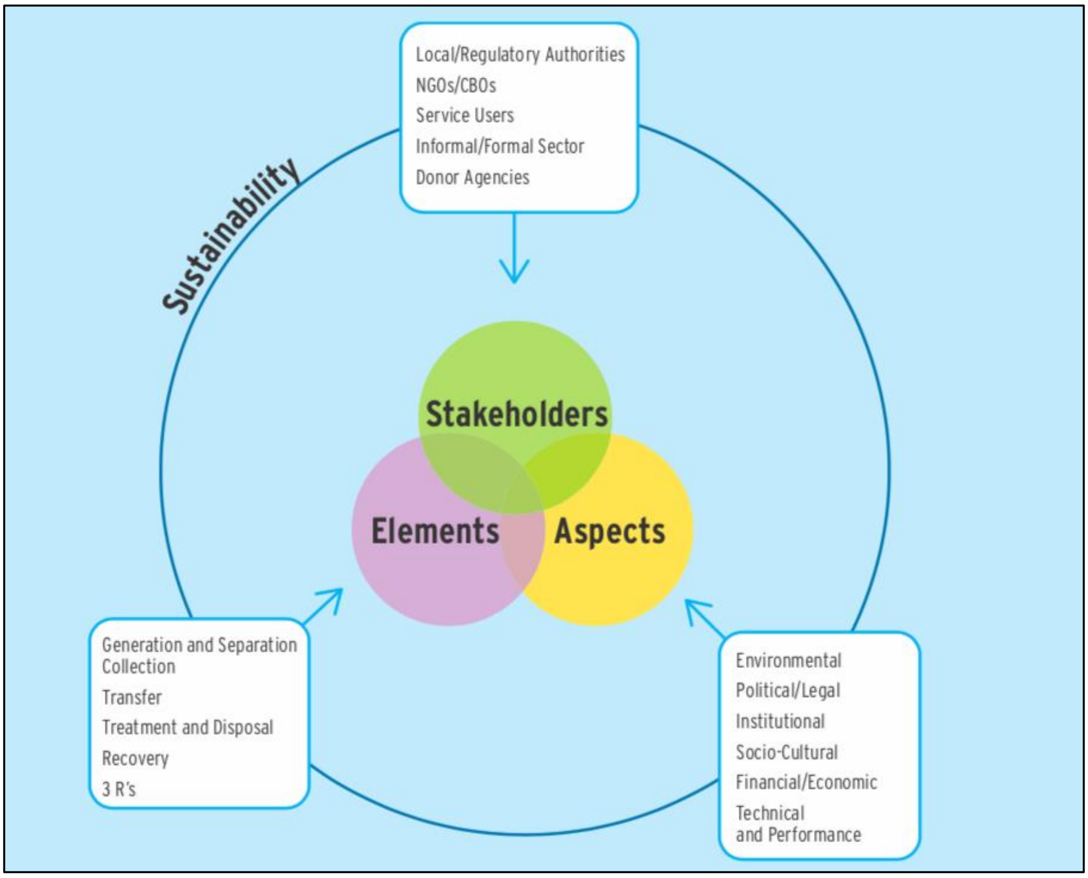


Figure 2.2: Integrated solid waste management *Source: Hoornweg & Bhada-Tata (2012:26)*

2.5 EXTENDED PRODUCER RESPONSIBILITY

As global technological innovation has become more sophisticated, products have become more complex and durable (as previously mentioned). As a result, it has become a serious environmental threat. All these products eventually reach its end-of-life; these products require sophisticated waste management systems and waste facilities and are often costly. As a result, large quantities of end-of-life products are generated, causing an environmental problem (Gupt & Sahay 2015). To mitigate this environmental problem, many waste management agendas have focused on employing the most sustainable and appropriate treatment of complex end-of-life products. Therefore, in the global waste management arena, on the agenda, much attention has been placed on how to handle these end-of-life products best (Atasu & Subramanian 2012). Treatment of end-of-life products has already been prioritised by many governments, with legislation already in place or in the process of being adopted, including 27 Member States of the European Union, 25 States in the United States and Japan (Atasu & Subramanian 2012). These legislations are based on the Extended Producer Responsibility (EPR), as seen in figure 2.3.

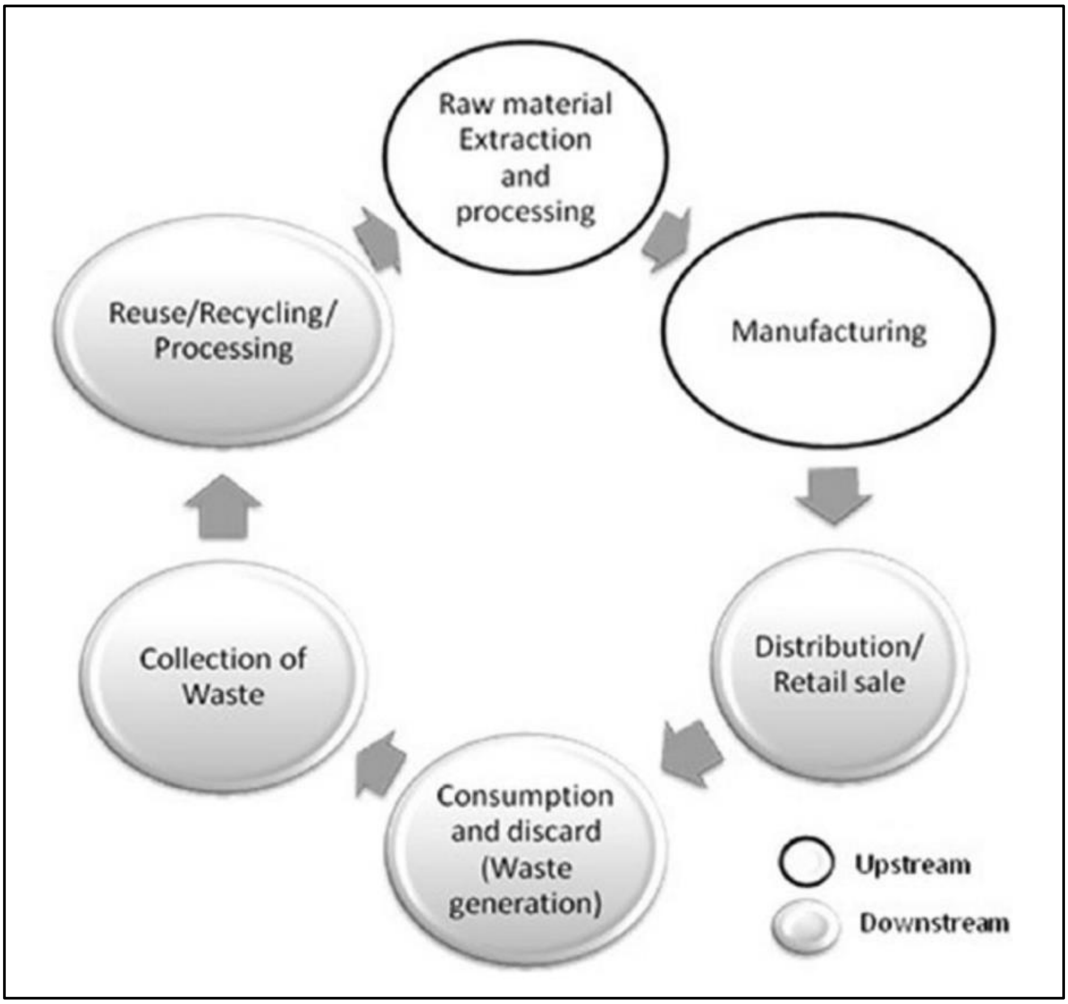


Figure 2.3: Extended producer responsibility Source: Gupt & Samraj (2015:596)

The EPR approach is an environmental policy that places responsibility for end-of-life products on producers or manufacturers of products of these products. The EPR is an environmental approach that lends sole responsibility to produce. Under the EPR approach, a cradle-to-grave approach is followed whereby the producers are responsible for the environmental impacts of the products throughout its life cycle (Driedger 2002). As Atasu & Subramian (2012) explain, EPR requires producers to be physically and financially responsible throughout the product's life cycle, i.e., from design until end-of-life. It is important to note that EPR encompasses both upstream and downstream responsibilities of the product life cycle from the extraction of resources, manufacturing, and distribution of products - to the disposal and collection of products, and finally - to recovering, recycling, and processing of end-of-life products (see figure 2.3). The EPR approach aims to divert complex materials away from landfills. As Kosior & Mitchell (2020) argue, as opposed to the prevailing linear approach, the ERP approach implements a circular approach to the rest of the supply chain.

2.6 THE CIRCULAR ECONOMY

In recent decades, many environmentalists have argued that there needs to be a re-shift in our environmental and economic system to a more sustainable approach which they believe is key to reducing waste and pressure on our virgin materials. Oberti & Paoletti (2020) argue that our environmental and economic system is positioned in a way that is causing a major global issue. Currently, our system operates in a linear approach, where we extract, use and design products throughout its life cycle with little regard for raw material waste, see Figure 2.4 (Oberti & Paoletti 2020). Furthermore, Cibrario (2018) points out that currently, our linear economic approach entailing ‘take, make use and dispose of’ generates large quantities of waste that could and should be reduced throughout the life cycle of end-of-life products. With the continued recognition of end-of-life products as a valuable source of resources, there has been growing recognition by environmentalists that there should be a shift from the current linear approach towards a sustainable circular approach.

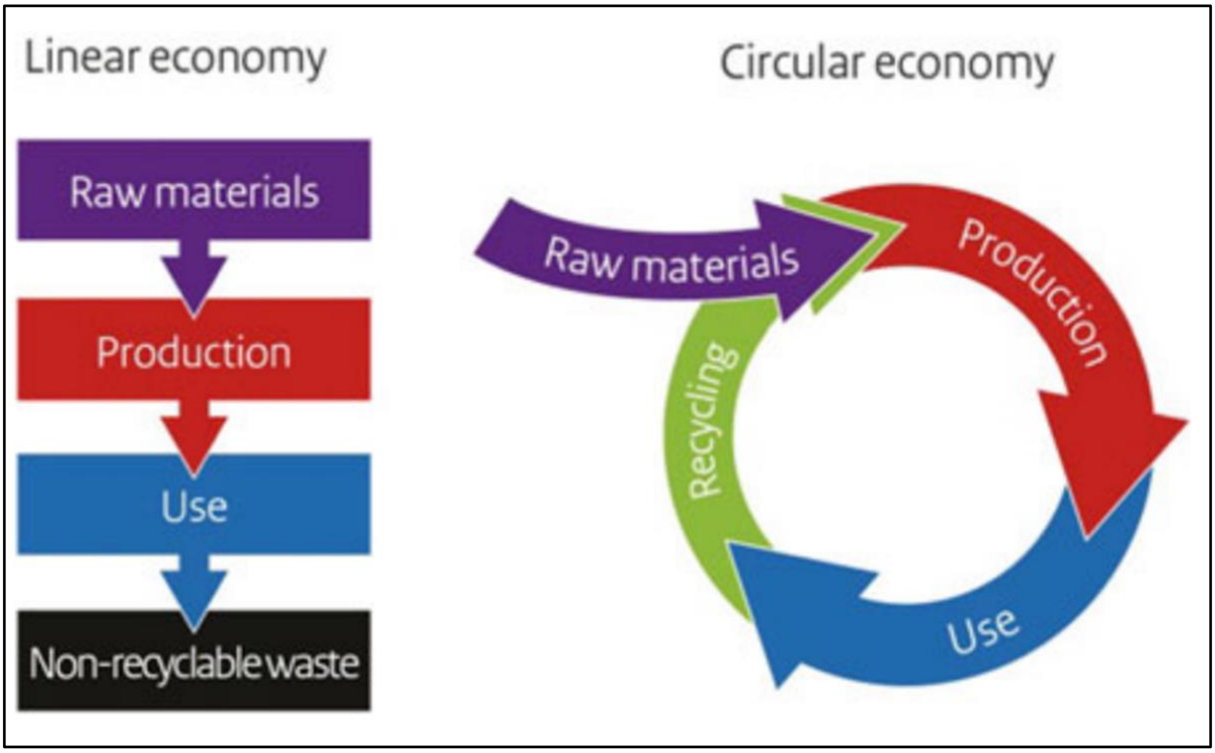


Figure 2.4: From linear to circular economy Source: Oberti & Paoletti (2020:89)

Walter R. Stahel, a Swiss architect, first produced the earliest thoughts about the circular approach, which was included in a report presented to the European Commission in 1976. According to the approach, producers and manufacturers of complex products should rethink their product design to last longer, and recover, reuse, and recycle materials more throughout the product life cycle (Figure 2.4). As a result, this would reduce the demand and pressure for virgin materials while at the same time reducing the amount of waste that would be generated from the extraction of raw materials. Cibrario (2018) states that by fully adopting a circular approach, there would be a vast reduction in resource extraction and waste generation. There has been a call for producers to think about the end-of-life process for their products and redesign it to be more reusable or easier to recycle (Kosior & Mitchell 2020). The circular approach involves sustainable activities, which include recycling, rental, repair, and remanufacturing (Cibrario 2018). If the circular approach is fully adopted and embraced, end-of-life products are seen as valuable resources; if managed appropriately, it could be a source of livelihood and employment, become an important source of second-hand commodities, and, above all, benefit the environment.

2.7 SUSTAINABLE DEVELOPMENT GOALS AND WASTE MANAGEMENT

Waste collection and management are essential public services for every community worldwide to protect public health and the environment (Cibrario 2018). The issue of solid waste management has become part of the more proactive drive for sustainability since the establishment of the 2030 Agenda for Sustainable Development (Figure 2.5).

Figure 2.5: Sustainable development goals and waste management *Source: Adapted from United Nations (2013:32)*

Waste services are crucial to achieving several Sustainable Development Goals (SDGs). According to Cibrario (2018), waste services are included in the SDG 11 and SDG 12 targets and indicators, notably with pledges to avoid, reduce, recycle, and reuse. Furthermore, as well as correctly collecting and disposing of urban solid waste and halving global food waste by 2030, and handling and treating chemical and other hazardous waste following international standards throughout the whole life cycle Cibrario (2018).

2.8 THEORY OF PLANNED BEHAVIOUR

The Theory of Planned Behaviour (TPB) is an inherent social psychology theory which has been widely used across a broad spectrum of research disciplines, including economics, social science, and health science, among others. In the early 1990s, as part of Icek Ajzen's attempt to predict human behaviour, he developed the TPB as an extension to the Theory of multi-attribute-attitude (TMA) and the Theory of Reasoned Action (TRA) (Ajzen & Fishbein 1973; Ajzen 1991; Connor & Armitage 1998). Asare (2015:44) states, "The TPB posits that attitude toward the behaviour, subjective norm, and perceived behavioural control influence behavioural intention". Zhang (2018) points out that the TPB provides an explanation of how individuals make behavioural decisions to explain and predicate their behavioural reactions and argues that individuals are primarily determined by their will. Ajzen's TPB has been met with some degree of success in predicting a variety of behaviours (Connor & Armitage 1998). The TPB has successfully predicted and explained smoking, drinking, and substance abuse, among others.

The TPB details the determinants of an individual's decision to react to a particular behaviour (Connor & Armitage 1998). According to Sansom (2018), behavioural intent must be considered in a theory of behaviour; attitudes and subjective evaluations regarding the likelihood of the expected outcomes influence behavioural intentions. The TPB identified three variables influencing an individual's behaviour: attitudes, subjective norms, and perceived behavioural control, as seen in figure 2.6 (Ajzen 1991; Ajzen 2005; Connor & Armitage 1998).

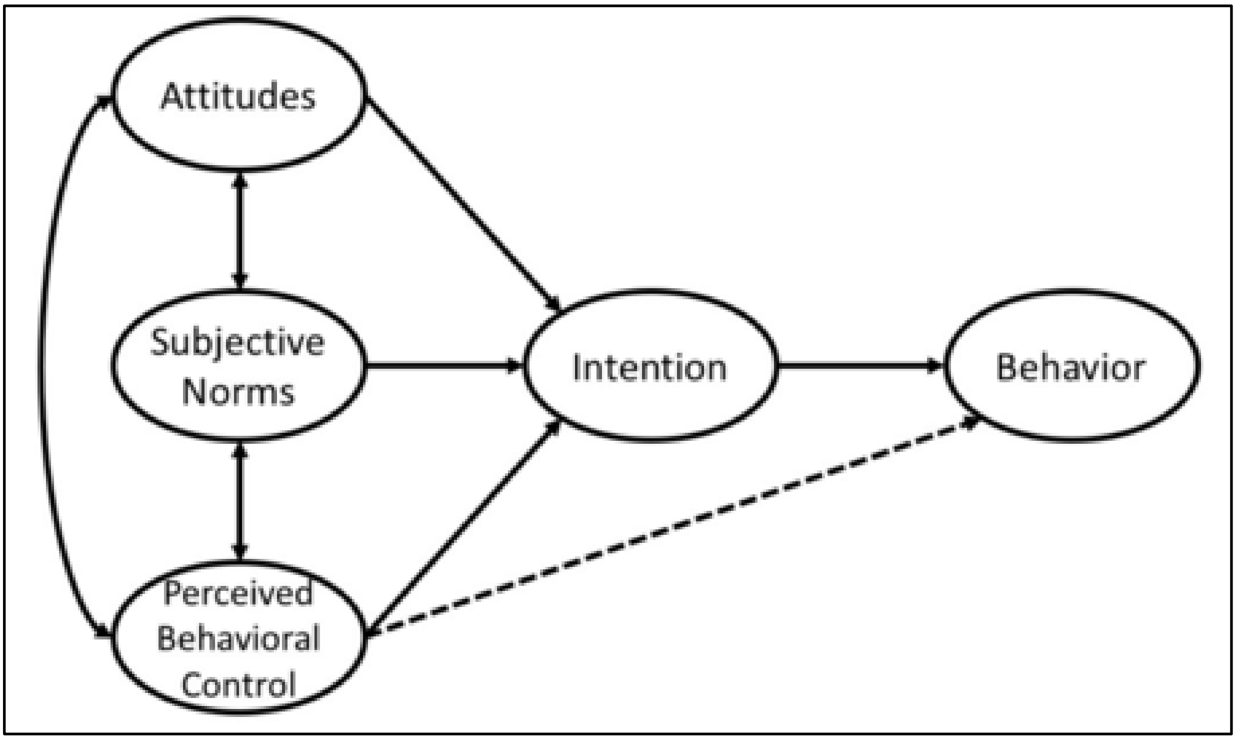


Figure 2.6: Theory of planned behaviour *Source: Adapted from United Nations (2013:32)*

The first determinate variable is attitudes; these are an individual's attitudes towards a particular behaviour (Brookes 2021). The second determinate variable is subjective norms which deal with how the ideas of others influence individuals' perceptions of a specific behaviour. It is not what others think but individuals' perceptions of others' attitudes (Brookes 2021). The third variable is perceived behaviour control which refers to the extent individuals believe they can control their behaviour (Brookes 2021). According to Sansom (2018), it is determined by individuals' perceptions of the ease or difficulty of performing a particular behaviour. Ajzen (1991:181) concludes, "Intentions are assumed to capture the motivational factors that influence a behaviour; they are indications of how hard people are willing to try, of how much of an effort they are planning to exert, in order to perform the behaviour. As a general rule, the stronger the intention to engage in a behaviour, the more likely should be its performance".

2.9 CONCLUSION

As countries experience economic development, urbanisation and population growth, it simultaneously produces large quantities of solid waste – an unavoidable by-product of human interaction with the environment. Resulting in one of the largest environmental problems globally. Global solid waste generation is increasing at an alarming rate and will increase to

3.4 billion tonnes by 2030. The composition of solid waste is much more complex than in the past; waste contains higher amounts of plastic and, due to the electronic industry, the waste contains much more hazardous materials. Due to the complex nature of hazardous waste, it poses numerous adverse effects to communities if not managed correctly. Therefore, waste management is crucial to protect the health of communities and the environment.

CHAPTER THREE: LITERATURE REVIEW

3.1 INTRODUCTION

Over the past few decades, a growing number of people have been joining the technological society. Due to the rapid influx of modern technology, there has been a global increase in the production and consumption of EEE (Sharma et al. 2020). EEE includes any product with circuitry or electrical components containing power or battery supply (StEP Initiative 2014). Amongst these products are kitchen appliances, toys, tools, and ITC (Information and Communications Technology) devices such as mobile phones and laptops, among others. EEE forms part of the electronics industry, one of the world's largest and fastest-growing industries. In 2018, the global electronics industry was projected to grow by 6% by the end of 2021. However, in the most recent study by Statista Research Department (2021), the global electronics industry grew by 9% at the end of 2021, which is 3% more than the predicated estimation. A major factor driving up consumer electronics demand is the current COVID-19[2] pandemic, which is forcing people to rely on electronics for work, learning and leisure at home. Due to the continuation of the COVID-19 pandemic, the global electronics industry's growth rate is expected to continue growing in 2022.

Electronic devices have infiltrated societies worldwide, becoming indispensable to people's daily lives – from making use of these devices for simple day-to-day tasks like cooking and cleaning and connecting friends and family worldwide to more complex lifesaving electrical medical equipment. Due to higher levels of disposable income and growing urbanisation, coupled with further industrialisation in some developing regions around the world, the global amount of EEE consumption is growing rapidly (De Vries & Stoll 2021). This can be seen in the rapid influx of global smartphone users in the past few years. According to a study conducted by Statista (2022), in 2019, a total of 5.6 billion people were smartphone users, which translates to 83.89% of the world's total population. This figure is higher than the estimated number of smartphone users in 2016, which was approximately 3.66 billion users, or 49.40% of the world's total population. The total global weight of EEE consumption rises

[2] COVID-19 Pandemic: COVID-19 is a virus that first emerged in December 2019 and has since infected 619 770 633 people globally. The World Health Organisation (WHO) declared the new Coronavirus a worldwide pandemic on 11 March 2022 (Johns Hopkins 2022).

by 2.5 Mt per year on average (Forti et al. 2020). These devices play a vital role in enhancing living standards, making life easier and more comfortable for its users while simultaneously adding to the already strained waste management systems worldwide. As Puckett et al. (2002) suggest, the information technology revolution has created numerous benefits and wealth; however, beneath this glamourous surface looms a darker reality. On the one hand, the growth in EEE consumption is a positive sign, particularly for developing countries, as it reflects increased living standards. However, on the other hand, increased EEE consumption comes with the challenge of managing these electronic devices from birth until the EOL. Bhat & Patil (2014:479) refer to the process of electronic devices' birth to EOL as the "… journey from Cradle to Grave". When these electronic devices have reached their EOL, they are discarded, creating a unique waste stream known as e-waste.

The purpose of this chapter is to review the current literature on e-waste from an international and national perspective. A major objective of this chapter is to gain an in-depth understanding of the current global e-waste problem and what constitutes e-waste. A comprehensive definition of e-waste will be presented, along with its classifications. This review will first outline the global perspective of the e-waste problem by detailing global e-waste quantities, the transboundary movement of e-waste, its impacts on global communities, international policies, and which e-waste management policies and strategies have been implemented by countries around the world. Second, this review will focus on South Africa and the state of its e-waste problem. Current national e-waste statistics, impacts and management strategies will be discussed here. Finally, the review will detail the role of consumers in e-waste management.

3.2 DEFINING E-WASTE

In recent years, e-waste has become a buzzword in environmental literature. Thus, a large and growing body of literature investigating global e-waste and its related issues exists. E-waste is often referred to by other terms such as Waste Electrical and Electronic Equipment (WEEE), e-scrap, or electronic waste. However, at the time of writing, there has yet to be much consensus on defining e-waste. Therefore, no standard definition of e-waste exists. Instead, throughout the literature, authors use many variations of definitions. The Solving the E-waste Problem (StEP) Initiative, which forms part of the United Nations University (UNU), was established in 2004 as a multi-stakeholder platform focused on developing strategies and solutions related to global e-waste. The StEP Initiative Green Paper points out that e-waste is understood, interpreted, and applied inconsistently in everyday use and legislation (StEP Initiative 2014). Similarly, Sothun (2012) notes that there are too many discrepancies between official or governmental and academic e-waste terminology. For example, EEE considered e-waste in one country might not be e-waste in another. This leads to implications when trading or flowing e-waste between countries or makes it legal for certain countries to export or import e-waste. A study by Shittu et al. (2021) on global e-waste management concluded that unifying e-waste definitions, terminologies, and standardised data are essential for managing e-waste effectively in the future. Similarly, the STEP Initiative (2014) contends that defining e-waste is crucial to addressing the global e-waste problem. Comparative e-waste statistics would be compiled between countries by classifying states, harmonising frameworks, and measuring e-waste. Therefore, the STEP Initiative advocates for one global definition of e-waste to eliminate inconsistencies across countries.

Studying the environmental impacts of e-waste, Gaidajis et al. (2010) argue that e-waste is usually misinterpreted and understood as relating to old computers and IT (Information Technology) equipment only. This could be because most e-waste research before 2010 focused on computers and their impacts, excluding all other EEE (Daum et al. 2017). However, in their seminal text, Widmer et al. (2005) conclude that e-waste is more than just obsolete computers; it is an all-encompassing term that embraces all forms of EEE. Therefore, the first point of departure when defining e-waste is to understand EEE. Therefore, it is necessary to reiterate the definition of EEE:

> "Any household or business item with circuitry or electrical components with power or battery supply" (StEP Initiative 2014:4).

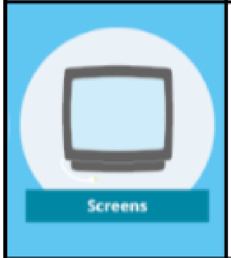
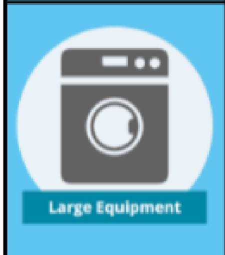
Although there is no universal definition of e-waste, there are several well-cited definitions in the literature. One well-cited definition is that brought forth by the European Union Waste Electronic and Electrical Equipment Directive (EU WEEE Directive), which defines e-waste as "waste from electrical and electronic equipment (WEEE) and it includes all components of electronic equipment, any subassemblies and consumables which are part of the product at the time it is discarded" (EU 2012: s.p.). According to this definition, 'waste' is considered any substance or object that is disposed of by its owner or required to be disposed of following national law. Furthermore, at the 12th meeting in 2015, the Conference of the Parties to the Basel Convention adopted technical guidelines on transboundary movements of e-waste. It is defined as "…electrical or electronic equipment that is waste, including all components, sub-assemblies and consumables that are part of the equipment at the time the equipment becomes waste" (UNEP 2015: s.p.).

Although the definitions of the EU WEEE Directive and Basel Convention have dominated e-waste literature, the definition by The StEP Initiative has gained recognition in the past few years as a comprehensive description of e-waste and is becoming increasingly more cited in recent literature. The StEP Initiative Green Paper, published on 14 January 2014, defines e-waste as follows: "E-waste is a term used to cover items of all types of electrical and electronic equipment (EEE) and its parts that the owner has discarded as waste without the intention of reuse" (StEP Initiative 2014:4). It is important to note that the term 'waste' in this definition implies that the device in its current condition is no longer needed or desired by its owner (StEP 2014). Moreover, it is imperative to note that StEP Initiative's definition encompasses all kinds of EEE, both functional and non-functional devices, as a global definition cannot consider regional variation or preference (StEP Initiative 2014). If the obsolete product includes circuitry or electronic components with a power or battery supply, it qualifies as e-waste. Put simply, e-waste includes any EEE such as TVs, appliances, computers, laptops, tablets, and mobile phones in functioning or non-functioning condition that their owner has discarded as waste. Studying e-waste literature in developing countries, Halim & Suharyanti (2019) argue that although there are many different definitions of e-waste, all highlight that it is any electrical-powered product of any size and function that the consumer no longer desires. The definition put forward by the StEP Initiative will be used for this study.

3.2.1 Categories of e-waste

The use of electronic devices has become an integral part of people's lives. These devices comprise a wide range of electronic products with different functions, sizes, and components. As Salhofer (2017) suggests, EEE differs in form, functionality, and level of complexity and has become a crucial part of present-day living. Due to the wide range of devices considered e-waste, the EU Directive 2002/96/EU has classified e-waste into ten categories. However, the UNU has recently reduced e-waste into six categories (Baldé et al. 2015). The six e-waste categories are *Temperature exchange equipment, Screens and Monitors, Lamps, Large Equipment, Small Equipment and Small IT and Telecommunication Equipment* (Table 3.1).

Table 3.1: Categories of e-waste

	***Temperature exchange equipment:*** more commonly referred to as cooling and freezing equipment such as refrigerators, freezers, air conditioners and heater pumps
	***Screens and monitors:*** this typically include equipment such as televisions, monitors, laptops, notebooks, and tablets
	***Lamps***: this category comprises straight fluorescent lamps, compact fluorescent lamps, high-intensity discharge lamps and LED lamps
	***Large equipment:*** such as washing machines, clothes dryers, dishwashing machines, electric stoves, large printing machines, copying equipment and photovoltaic panels
	***Small equipment:*** this typically includes vacuum cleaners, microwaves, ventilation equipment, toasters, electric kettles, electric shavers, scales, calculators, radio sets, toys, small electrical and electronic tools, small medical devices, small monitoring, and control instruments
	***Small IT and telecommunication equipment:*** this category comprises mobile, GPS (Global Position System), pocket calculators, routers, personal computers, printers, telephones

Source: Adapted from Baldé et al. (2015:12-13)

EEE is classified based on the following characteristics: size, weight, functionality, and composition (Ongondo et al. 2011). Furthermore, each device has a varied lifespan profile;

each category has various waste amounts, economic impact, and environmental and health implications if recycled incorrectly. As a result, each category has different collection and logistics processes, recycling methods, and customer attitudes toward disposing of electrical and electronic equipment (Prasad et al. 2019). Currently, this classification conforms with EU WEEE legislation and the globally accepted framework for e-waste statistics (Forti et al. 2020).

3.3 GLOBAL E-WASTE CONTEXT

In 2014, the quantity of e-waste generated globally was estimated to be approximately 41.8 Mt (Baldé et al. 2015). By 2016, this figure grew by 2.9 Mt, estimated to be approximately 4 500 Eiffel Towers in weight (Nethaji-Mariappan et al. 2017). It was forecasted that by the end of 2018, the global quantity of e-waste would increase to 48.9 Mt, accounting for a worldwide increase rate of 4 to 5 per cent (Baldé et al. 2015). This rapid rate of increase continues to rise at an increasing pace. In total, 53.6 Mt of e-waste was generated at the end of 2019. By the end of 2030, this amount is projected to nearly double in 16 years, reaching approximately 74.4 Mt. (Forti et al. 2020). There are differences in the overall quantities of e-waste generated across different geographical areas. Some regions generate double the quantity compared to others.

In 2019, Asia was the world's top e-waste-producing region, producing a total of 24 Mt, followed by the Americas with a quantity of 13.1 Mt, while Africa only generated 2.9 Mt (Forti et al. 2020). One of the e-waste management challenges is that most waste in this stream remains undocumented. In 2014, it was reported that of the 41.8 Mt of e-waste generated that year, only 6.1 Mt was documented and collected through formal systems (Baldé et al. 2015). Of the 53.6 Mt of e-waste generated globally in 2019, only 9.3 Mt (17.4%) were formally documented and collected (Forti et al. 2020). This indicates that more than 44.3 Mt (82.6%) of e-waste remain unreported and is likely to have either been disposed of in household bins alongside other waste types or traded and recycled using environmentally unsound methods (Forti et al. 2020). The total amount of formal documentation and recycling generated in 2014 has increased by approximately 0.4 Mt each year; however, the total amount of e-waste generated worldwide has grown by almost 2 Mt each year since 2014. As a result, formal documentation and recycling are failing to keep up with global e-waste growth (Forti et al. 2020).

3.3.1 Global e-waste generation

E-waste is an emerging challenge to global waste management and is growing at an alarming rate. Achim Steiner, the then Executive Director of the UNEP, stated at the Conferences of the Parties to the Basel, Rotterdam, and Stockholm Conventions in 2015, "We are facing the onset of an unprecedented tsunami of electronic waste rolling out over the world" (UNEP 2015: s.p.). If left unchecked, e-waste will have devastating effects on countries all around the world, particularly developing nations. At the time of writing, most studies on e-waste have only focused on topics such as environmental and human impacts, recycling, and policies. Although these studies are valuable and important in understanding global e-waste and its challenges, they do not show the problem's true extent through actual quantities. Throughout the earlier literature on e-waste, no reliable data on global quantities of e-waste could be found. Instead, most studies referenced outdated estimations of global e-waste quantities using different methods, definitions, and terminology of e-waste. Puckett et al. (2002), Widmer et al. (2005), and Robinson (2009) use different estimates of worldwide e-waste volumes. De Vries & Stoll (2021) note that this results in global e-waste quantities differing across literature, making it difficult to compare and trust. Furthermore, Halim & Suharyanti (2019) argue e-waste management in developing nations is compromised by a lack of reliable data. This has led to an increasing concern about the lack of reliable data on e-waste quantities worldwide.

Identifying this gap in the literature, the UNU, one of the world's leading institutions in e-waste research, published the first global monitor on e-waste quantities in 2015. The UNU set out to publish a global e-waste monitor every three years, with the second published in 2017 and the most recent in 2020. The main goal of the UNU's global monitor is to produce the world's first report on e-waste quantities, e-waste impacts, and management on a global scale (Baldé et al. 2015). It aims to fill the gap by providing a comprehensive report with reliable global e-waste quantities based on detailed scientific data. Moreover, the UNU's e-waste monitor provides a picture of the size of the e-waste challenge, progress in how countries manage e-waste, and future e-waste trends.

3.3.2 Global e-waste quantities

Electronic and electrical devices come in different forms, perform different functions, and play a pivotal role in global development. These devices are necessary for global development to continue to take place. However, at the same time, these devices produce an ever-increasing waste stream that continues on a rapid upward trajectory. With a 3 to 4% annual growth rate, e-waste is the world's fastest-growing waste stream (Puckette et al. 2002; Widmer et al. 2005; Kumar et al. 2017). The UNU's global e-waste monitor's most recent report estimates that, compared to 2014, the quantity of e-waste generated globally increased by 21% in 2019 (Forti et al. 2020). By 2030, this figure is projected to double, making e-waste the fastest-growing waste stream in the world (Forti et al. 2020). Due to factors such as rising EEE consumption rates, shortened product life cycles, and few choices for repair, e-waste quantities are expected to continue to increase unless proper management practices are adopted.

According to the UNU's first global e-waste monitor publication, 5.9 kg of e-waste was generated per capita in 2014, or 41.8 Mt of e-waste (Baldé et al. 2015). The majority of these were small equipment (12.3 Mt), large equipment (11.8 Mt) and temperature exchange equipment (7.0 Mt) (Baldé et al. 2015). The smallest share of e-waste generated was accounted for by screens and monitors (6.3 Mt), small IT equipment (3.0 Mt) and lamps (1.0 Mt). Furthermore, regarding e-waste generation, Asia generated the most with 16 Mt, followed by America and Europe, 11.7 Mt and 11 Mt, respectively. Despite generating the least amount of e-waste (0.6 Mt), Oceania produced the same amount per capita as Europe (15.2 kg). Africa generated the lowest per capita (1.7 kg), and the continent generated 1.9 Mt of e-waste. Baldé et al. (2015) found that only 61 countries, or 44% of the world's population, had legislation, policies, and regulations governing e-waste in 2014. However, it is important to note that not all 61 countries have fully implemented this law for e-waste disposal.

In 2016, the global e-waste quantity increased by 2.9 Mt since 2014 to approximately 44.7 Mt (Baldé et al. 2017). Studying global e-waste trends, Nethaji-Mariappan et al. (2017) note that the global e-waste quantity generated in 2016 was equivalent to the weight of almost 4 500 Eiffel Towers. Similarly, Edmonds et al. (2019) state that the worldwide weight of e-waste generated in 2016 equates to more than 125 000 jumbo jet aircraft, which is more than the total number of aircraft ever produced. Edmonds et al. (2019) further stated it would take more than six months to clear that many aircraft from London’s Heathrow airport. Among the regions that generated the most e-waste was Asia (18.2 Mt), followed by Europe (12.3 Mt), the Americas (11.3 Mt), Africa (2.2 Mt), and Oceania (0.7 Mt). Oceania generated the least amount of e-waste, but the region generated the most (17.3 kg) per capita, followed by Europe (16.6 kg).

By the end of 2021, it was forecast that the amount of e-waste generated globally would surpass 52.2 Mt, representing a 3 to 4% yearly growth rate (Dhas et al. 2021). However, this projection was surpassed in 2019, when the total quantity of e-waste generated was approximately 53.6 Mt, according to the most recent global e-waste monitor release by the UNU (Forti et al. 2020). This indicates that global e-waste has increased by 11.8 Mt since the findings of the first publication of the global e-waste monitor in 2014 and shows no sign of slowing down unless managed correctly. Similarly, in 2014 and 2016, Asia remained the highest e-waste generator in 2019 at 24 Mt, followed by the Americas (13.4 Mt) and Europe (12 Mt). Africa and Oceania remained the lowest at 2.9 Mt and 0.7 Mt, respectively. In 2019, Europe (16.7 kg) and Oceania (16.1 kg) remained the world's highest e-waste generators per capita, while Africa remained the lowest at 2.5 kg.

In 2019, small equipment (17.4 Mt), large equipment (10.8 Mt) and temperature exchange equipment (10.8 Mt) made up most of the world's e-waste quantity. Screens and monitors (6.7 Mt), small IT equipment (4.7 Mt) and lamps (0.9 Mt) made up a lesser portion of the overall amount of e-waste generated in 2019 (Forti et al. 2020). Temperature exchange equipment has experienced an annual increase of 7% in weight since 2014 (Forti et al. 2020). This is primarily due to the growing trend in the consumption of this equipment in lower-income countries. Small IT equipment has increased at a slower rate each year, and screens and monitors have shown a growth rate decline of -1% annually (Forti et al. 2020). This is primarily attributable to a decline in the use of large CRT (Cathode Ray Tube) monitors and screens, as well as large analogue television sets, and a surge in the usage of lighter, flatter displays, which has led to a reduction in the total weight generated annually (Dhas et al. 2021). Furthermore, in 2019, a total of 71 countries - representing 71% of the world's population - were subject to e-waste legislation, policy, and regulation, a rise of 21% since 2014. Approximately 74 Mt of e-waste will be generated by 2030, according to the latest publication of the global e-waste monitor (Forti et al. 2020), thus, indicating a growth rate of 2 Mt annually.

3.4 E-WASTE: HAZARD VERSUS VALUE

E-waste has a complex material composition, making it unique and different from other municipal and industrial waste streams. A total of 69 elements from the periodic table have been identified in e-waste, ranging from an array of precious metals, critical raw materials (CRM) and non-critical metals (Forti et al. 2020). From a materials perspective, e-waste differs from other waste streams due to its distinctive material composition, as it contains hazardous and valuable materials. Assessing global e-waste production and impacts, Robinson (2009) argues that due to its specific chemical and physical composition, e-waste is composed of hazardous materials that have several adverse effects on the environment and humans. However, at the same time, it contains many valuable materials that require special handling and recycling treatment. Recyclable materials found in e-waste are valuable secondary resources, often called the 'urban mine'. Furthermore, it also yields toxic materials that harm the environment and human health, often called the 'toxic mine'. Due to this unique material composition, specific recycling techniques are required to bring environmental and economic benefits.

E-waste is non-homogenous and consists of a mixture of toxic materials and components. If these hazardous materials are recycled using primitive methods, they are released and can negatively affect the environment and human health (Mazumber et al. 2007). In line with Mazumber et al.'s (2007) argument, Puckette et al. (2002) argue that e-waste consists of a 'witch's brew' of toxic materials that create dioxin emissions, causing environmental contamination and are detrimental to human health. Some of the most common hazardous substances found in e-waste are Persistent Organic Pollutants (POPs), Barium (Ba), Cadmium (Cd), Lead (Pd), Mercury (Hg), and Chromium (Cr). Due to these toxic constituents found in e-waste, disposal is much more challenging than in other waste streams. Each year, 50 kilotons (kt) of mercury and 71 kt of plastics containing brominated flame retardants (BRF) are thought to be transported through unreported global e-waste channels (Forti et al. 2020). Workers' health is at risk when these hazardous materials are released into the environment due to unethical recycling practices. Many of these hazardous substances pollute the global environment and human health. With e-waste generation increasing at a faster rate, global concerns are being raised about the toxic compounds found in it, which can have detrimental effects on the environment and human health (WHO 2021). While e-waste contains toxic compounds that are harmful to the environment and health, it is also considered an urban mine containing a wide array of valuable materials. Valuable secondary materials can be recovered to offer economic benefits if proper recycling methods are used.

Electronic and electrical equipment are made up of many different electronic components, which contain various raw materials. These raw materials are both environmentally and economically valuable and thus provide a unique, untapped opportunity that could be explored

(Miliute-Plepiene 2019). Among the materials commonly used in e-waste are iron, copper, gold, and aluminium (Widmer et al. 2005). Considering the issues of primary mining, fluctuating markets, scarcity, and access to resources, Baldé et al. (2015) argue that some materials found in e-waste can be a valuable source of critical resources. E-waste, therefore, serves as an important mine for secondary resources. Similarly, as de Souza et al. (2016) argue, some of the materials found in e-waste are considered critical because supply and demand mismatches are increasing, prices are fluctuating, or the supply of these materials is impacted by political influence. Worrell et al. (2016) conclude that many of these materials have important environmental and ecological value despite their small or trace amounts. E-waste, therefore, offers a unique opportunity for mining secondary resources to minimise the demand for virgin raw materials.

Valuable materials could be extracted from e-waste by using the correct recycling methods. Reusable components and base metals such as copper and precious metals could be recovered (Gaidajis et al. 2010). The urban mining[3] of e-waste can produce 40 to 800 times more gold in 1 ton of Printed Wiring Boards (PWB) than in 1 ton of ore (UNIDO 2019). Additionally, it was estimated that the world would only require 14 Mt of raw materials for producing new EEE if all the copper, iron, and aluminium were recovered from the world's e-waste in 2019 (Forti et al. 2020). The urban mining of e-waste can reduce the demand and mining for primary minerals. In addition, e-waste can provide economic value if managed and recycled using environmentally sound practices. The global quantity of e-waste was estimated to be worth approximately $57 billion in raw materials in 2019 (Forti et al. 2020). Copper, iron, and aluminium make up most of the value. If e-waste is managed correctly, it can bring environmental and economic benefits to communities worldwide.

Considering that e-waste contains hazardous and valuable materials, it is necessary to be recycled in an environmentally friendly manner to minimise the release of toxins and the loss of precious ecological and economic resources. However, there is a low recycling rate due to a lack of facilities, high labour costs, and a lack of recycling regulations. According to UNIDO (2019), there are few recycling options for critical fractions. Globally, only five smelting facilities can treat PWB according to international standards. Instead, e-waste is either disposed

[3] Urban mining: A method of recovering raw materials from waste products destined for landfills (RTS 2021).

of in landfills or shipped across borders, frequently ending up in developing countries where it is recycled using rudimentary processes without concern for environmental or occupational safety (Cobbing 2008). If managed well, e-waste can bring environmental as well as economic benefits. However, unsound recycling of e-waste can harm the environment, human health, and society. Refurbished and recycled e-waste using proper recycling methods has the potential to provide jobs, as well as access to low-cost electronics and secondary raw materials. However, as UNEP (2016) argues, what hinders this is the trading of e-waste.

3.5 TRANSBOUNDARY MOVEMENT OF E-WASTE

The transboundary flow of e-waste across the globe has occurred for many years via the world's oceans, reaching destinations outside of where it originated. In some instances, obsolete mobile phones or personal computers (PCs) originating from the United States of America (USA) travel thousands of kilometres and end up in countries such as China, India, or Ghana (Daum et al. 2017). Until the late 20th century, e-waste was primarily considered a "hidden flow" between developed and developing countries, causing adverse effects in the receiving countries (Sepúlveda et al. 2010; Lundgren 2012). In 2002, Puckette et al. (2002) were some of the first authors to report on this process, describing 'The Great Escape Valve' as a solution to their e-waste crisis where developed countries exported their e-waste to developing countries. This seminal text was one of the first in-depth reports on the transboundary movements of e-waste. It sparked a new revolution in e-waste literature as many authors reported on e-waste flow routes to developing countries and their effects. Puckett et al.'s (2002) text also influenced the documentary "The E-waste Tragedy" (2014). Throughout the early period of the e-waste problem, the flow of e-waste remained a hidden flow between countries.

Early studies on the transboundary movement of e-waste framed e-waste as a static system only occurring from developed to developing countries due to lower labour costs. Earlier studies suggested that e-waste is a 'rich' country's problem that 'poor' countries must bear. According to Puckett et al. (2002), most e-waste is generated in developed countries due to EEE's high demand and consumption. However, these countries do not want to deal with their e-waste problem, so they ship it off to developing countries, leaving them to deal with the waste (Park et al. 2017). As Puckett et al. (2002) explain, rich industrialised countries, specifically the USA, have resorted to an easy and hidden escape valve – exporting their e-waste to developing countries rather than dealing with their e-waste problem. In most cases, these shipments of e-waste end up in developing countries with little to no means to handle with this sort of hazardous waste, consequently affecting the environment and health. According to Shittu et al. (2021), these developing countries often do not have the knowledge, facilities, and resources to deal with this sophisticated hazardous waste. Consequently, e-waste is recycled using primitive methods without regard for the environment or occupational safety. The earlier literature argued that these countries were not large consumers of EEE, and most of the e-waste pollution was due to the 'dumping' of e-waste by developed countries. However, e-waste moves between all types of countries, and these changing geographies could be linked to the economic benefits of e-waste trading.

Earlier literature on the transboundary movement of e-waste suggests that these receiving developing nations are unwilling receivers of this hazardous waste, leaving them to bare the adverse environmental and health impacts. As Puckett et al. (2002) argue, developing countries 'dump' their e-waste to unwilling developing countries where they must live with its adverse effects. However, there has been a shift in thinking. Studies now suggest that the movement of e-waste is much more dynamic and complex than just from developed to developing countries. This is all due to the material value found in e-waste, which created an entirely new economy promoting the export and import of e-waste between developed and developing countries worldwide. Developing countries are now actively importing e-waste from developed countries as an entire market for e-waste in these countries is raised, and trading of e-waste takes place between all types of countries. Many authors report that these developing countries are not simply victims of the global north problem shifting (Lepawski 2015; Park et al. 2017, Shittu et al. 2021). Instead, actively importing e-waste allows for livelihoods in developing countries where work is scarce and simultaneously satisfies the demand for second-hand goods (Shittu et al. 2021). Halim & Suharyanti (2019) report that developing countries in Asia are the top importers of global e-waste due to the lucrative e-waste market.

Furthermore, Shittu et al. (2021) also report that in the late 1980s, companies in the USA and EU (European Union) could apply for UWEPA, which allowed them to export hazardous waste to developing countries. The receiving developing countries received incentives if they were willing to accept e-waste from developed countries (Shittu et al. 2021). Developing countries do not only economically benefit from e-waste imports, but so do developed countries. By shipping their waste to other destinations, the cost of disposing of their e-waste is much lower than recycling it domestically. According to Park et al. (2017), 50% to 80% of all domestically collected e-waste in the USA is not recycled domestically; it is shipped to Asia and Africa. E-waste now flows between developing to developed and developing to developed countries.

Edmonds et al. (2019) report that even though e-waste trading is much more complex than earlier studies suggest, it remains that the movement of all used EEE that is traded between countries is illegal, as it breaches either the Basel Convention on the Control of Transboundary Movement of Hazardous Waste and their disposal or national laws. Unfortunately, little data exists on the illegal trade in e-waste. Moreover, environmental regulations and enforcement in developing countries are often non-existent or too weak to protect local communities and their environment from the threats posed by uncontrolled e-waste recycling practices.

3.6 UNSOUND E-WASTE MANAGEMENT

E-waste has negatively impacted and will continue to negatively impact communities worldwide if not recycled using proper recycling practices. All e-waste recycling, whether in the formal sector characterised by technologically advanced equipment or in the informal sector characterised by rudimentary methods, causes negative impacts. As Puckett et al. (2002) argue, no e-waste recycling, even in developed countries with state-of-the-art facilities, comes with no negative impacts. According to Lundgren's (2012) results, large amounts of heavy metals in the air were detected at technologically advanced e-waste recycling plants in developed countries, causing environmental harm and harm to employees' health. However, the most severe impacts or problems are found in developing nations, characterised by high volumes of e-waste and informal, unregulated recycling practices (Breivik et al. 2014). Similarly, Cobbing (2008) argues that most research on the environmental and health impacts of e-waste has been conducted in developing nations such as China, India, and Vietnam because these nations comprise a large informal e-waste sector. Unsound practices release pollutants contaminating the air, soil, and water, ultimately affecting human health.

3.6.1 Environmental impacts of unsound e-waste practices

Examples of unsound e-waste recycling practices taking place in developing countries and their impacts include:

3.6.1.1 Soil contamination

Several primitive e-waste disposal methods are commonly used in developing countries, resulting in soil contamination, which poses threats to the surrounding environment. Open burning of e-waste commonly occurs in the informal e-waste recycling sector, where cables are burned to remove the outer coating by the recycler to recover valuable copper (Lebbie et al. 2021). During this process, persistent organic pollutants such as dioxins and furans are released and contaminate the soil. Studying the effects of unsound e-waste recycling in Vietnam, Someya et al. (2016) reported that due to the open burning of cables, there was a high concentration of dioxin compounds found in the soil, much higher than the acceptable amount based on the WHO regulations. Additionally, Elytus (2019) reports that unregulated e-waste landfilling, and illegal dumping are frequent practices in less developed nations where regulation is lacking. When this occurs, heavy metals and flame retardants found in e-waste seep into the underlying soil, contaminating nearby crops and damaging the soil for future crop growth (Elytus 2019).

3.6.1.2 Air contamination

Apart from contaminating the soil, open burning of e-waste also contaminates the air. During the burning process, persistent organic pollutants such as dioxins and furans are released into the atmosphere (EPA 2009). During an investigation of air pollution in India, samples were taken to determine the level of heavy metals and particular matter level (PM10) in the air (Gangwar et al. 2019). The results indicated that open burning of e-waste contributes to higher levels of air contamination, exposing residents to higher levels of heavy metals (Gangwar et al. 2019). Similar to the study conducted in India, a study conducted in Vietnam found that the level of Printed Circuit Board (PCB) and BFRs in indoor dust from two e-waste recycling sites where open burning occurs was much higher than in non-e-waste houses (Tue et al. 2013).

Furthermore, air contamination also occurs when e-waste is processed through primitive dismantling and shredding (Elytus, 2019). Toxic dust particles are released into the air during the process of dismantling and shredding. Any person inhaling this smoke or encountering the dust is at risk of severe health complications. Furthermore, this polluted smoke and dust can travel through the air thousands of kilometres, impacting the environment and health of regions far from the recycling site.

3.6.1.3 Water and aquatic systems contamination

When toxic materials found in e-waste seep into the soil via the process of leaching, these toxins make their way into the waterway, contaminating the water and aquatic systems (Robinson 2009). Furthermore, removing chips from circuit boards to recover precious metals involves using the primitive method of acid baths (Heacock et al. 2016). According to Chatterjee (2012), in many developing countries, e-waste recyclers dip circuit boards into acid and burn them to separate plastics from precious metals. Puckett et al. (2002) find that these baths were aqua regia[4] and this mixture ends up polluting rivers and waterways. According to Pradhan & Kumar (2014), unregulated dumping, which takes place in the informal e-waste sector, results in the contamination of waterways. Persistent organic pollutants bio-accumulate in the fatty tissues of fish and other living organisms. Furthermore, Richa et al. (2017) argue that informal e-waste recyclers often use acid baths containing a mixture of hydrochloric and sulphuric acids to separate precious metals from plastics. The vapours contain chlorine and sulphur dioxide, both of which cause respiratory issues, and acids, which are also harmful to the eyes and skin.

3.6.2 Health impacts of unsound e-waste management

It is common for people to be exposed to a complex mixture of hazardous chemicals when living and working near e-waste recycling sites. As mentioned, e-waste contains numerous hazardous substances that are dangerous to human health. As the WHO (2021) reports, e-waste recyclers aiming at recovering valuable materials are at risk of exposure to more than 1 000 hazardous substances. According to the documentary ‘The E-waste Tragedy’ (2012), which exposes the global e-waste problem, the pollutants found in e-waste expose many residents to a cocktail of cancer-inducing and hormone-disrupting chemicals. Adverse effects of exposure to these hazardous substances on human health include brain, heart, liver, kidney, and skeletal damage (Song et al. 2014). Furthermore, e-waste can also cause considerable damage to the human body’s nervous and reproductive systems, ultimately leading to diseases and congenital disabilities (Song et al. 2014). As the Geneva Declaration on E-waste and Children’s Health states:

[4] Aqua regia is a nitric acid and hydrochloric acid solution (Princeton University Environmental Health Safety 2017)

> "There is convincing evidence of short- and long-term adverse health effects caused by exposure to individual substances contained in e-waste, as well as possible synergistic effects from mixtures of compounds. These include carcinogenic effects, endocrine disruption, neurodevelopmental anomalies, negative birth outcomes, abnormal reproductive development, intellectual impairment, attention deficits, and cancer".
> (Alabaster et al. 2013: s.p.).

Heavy metals contaminate the soil, air, and water when partaking in unsound e-waste recycling practices such as open burning, manual dismantling, and acid baths. People are exposed to these toxic substances through inhaling, skin contact, and eating or drinking contaminated food and water. According to Awasthi et al. (2018), heavy metal exposure can induce acute and chronic impacts such as respiratory and reproductive issues, skin irritations, and cardiovascular and urinary disorders. Furthermore, according to Huang et al. (2014), health complications caused by directly inhaling heavy metals from e-waste recycling sites increase the risk of thyroid problems, cell growth, changes in mood and behaviour, unfavourable neonatal consequences, and diminished lung function. Additionally, Zheng et al. (2019) found that exposure to hazardous metals such as Pb and Cd produces serious health consequences such as reduced erythrocyte immunity, altered bone growth (osteoporosis), and disruption of liver metabolism. After exposure to crude e-waste recycling activities, a study in China found that approximately 81 300 children were affected by neurological disorders. Their average intelligence quotient (IQ) was reduced by 1.2 points (Illés & Geeraerts 2016). Studying people's exposure to phthalic acid esters (PEAs)[5] – abundant in e-waste recycling sites – Zhang et al. (2019) took urine samples from residents in or near to e-waste recycling sites. Urine samples from residents living in non-e-waste recycling sites were then compared to those from residents living in or near e-waste recycling sites. The study found that compared to residents in non-e-waste recycling sites, PAW concentrations were much higher in residents in or near e-waste recycling sites (Zhang et al. 2019). Furthermore, 22% of the residents in or near e-waste recycling sites have hazardous index values greater than 1, suggesting that they have been exposed above the tolerable level.

[5] Phthalic acid esters are a type of lipophilic chemical that is frequently utilised as a plasticiser and additive to increase the mechanical extensibility and flexibility of various goods

Many workers handling e-waste in the informal sector in developing countries are expecting women. When these expecting mothers are exposed to hazardous substances found in e-waste, they can be carried to the unborn child and consequently affect the development and health of the unborn child (in and out of the womb) (Marsh et al. 2021). In line with this, WHO (2021) reports that when expecting mothers are introduced to e-waste toxins, it can affect the health and development of their unborn children for the rest of their lives. This is because substances found in e-waste, such as lead (found in light bulbs, CRTs, batteries, and TVs) and BFRs (plastic casing found in EEE), are transplacental – a pregnant woman can pass them on to her baby across the placenta and through breast milk (Kim et al. 2019). Pregnant women can be exposed to these toxic substances either by breathing in these substances or eating contaminated food. Potential adverse effects include stillbirth, prematurity, and low birth weight and length; exposure to lead can cause attention-deficit/hyperactivity disorder (ADHD), behavioural problems, and sensory integration difficulties. Similarly, Xu et al. (2012), Grant et al. (2018) and Lovo & Rawlings (2022) argue that exposure to e-waste may contribute to stillbirths, spontaneous abortions, preterm deliveries, and weight and length reductions at birth.

Additionally, as WHO (2021) reports, it can affect a child's lung function and respiratory system and even cause later chronic diseases. These health risks are attributed to exposure to heavy metals, such as lead, mercury, and cadmium, as well as flame retardants and plasticisers present in e-waste. These chemicals can be absorbed by pregnant women and cause severe developmental problems for the fetus.

3.7 E-WASTE MANAGEMENT POLICY AND LEGISLATION

Many international and national laws have been enacted to counteract the 'explosion' of e-waste. As previously stated, any cross-border movement of obsolete EEE is illegal since it violates several international environmental agreements. The three most comprehensive multinational environmental agreements are the Basel, Rotterdam, and Stockholm Conventions. According to UNEP (2011), these three agreements aim to protect the environment and human health from hazardous waste. Furthermore, with their combined efforts, the Basel, Rotterdam, and Stockholm Conventions ensure that hazardous waste is managed in the most environmentally sound way from manufacturing to the moment it is disposed of – 'from the cradle to the grave' (UNEP 2011). Since e-waste contains hazardous substances, this waste stream is classified as hazardous waste. The multilateral agreements therefore govern any movement of e-waste.

3.7.1 The Basel Convention

The Basel Convention on the Control of Transboundary Movement of Hazardous Waste and their Disposal, or the Basel Convention, in short, is a multilateral environmental agreement. Initially adopted in 1989, the Basel Convention was enacted on 5 May 1992 (UNEP 2015). As Benson (2021) reports, following protests against hazardous waste from developing countries, the Basel Convention was signed by 53 countries and the European Economic Community (EEC) to aid in the regulation of the transboundary flow and disposal of hazardous waste. The UNEP (2015) describes it as one of the most comprehensive global environmental agreements on hazardous waste. One of the primary goals of the Basel Convention is to limit the environmental and human health implications caused by the global trade of hazardous e-waste.

As of October 2022, the Convention has 190 parties in total (UNTC – United Nations Treaty Collection 2022). All parties to the Basel Convention must manage and dispose of hazardous waste responsibly. Furthermore, it requires its parties to reduce and minimise the amounts of hazardous waste transported and process and dispose of hazardous waste as near the generation point as possible (Benson 2021). The parties of the Basel Convention work together to prevent the transboundary dumping of hazardous waste. As a result, on 5 December 2019, the Basel Convention approved a Ban Amendment, which restricts any transboundary movement of hazardous waste from the EU, OECD (Organisation of Economic Cooperation and Development) countries and Liechtenstein to all other countries (Basel Convention 2019).

By preventing the transboundary dumping of hazardous waste, the Basel Convention seeks to protect human health and the environment from the potentially devastating impacts of hazardous waste. The Ban Amendment is an important step towards achieving this goal as it prevents the movement of hazardous waste between countries.

3.7.2 The Rotterdam Convention

The Rotterdam Convention on the Prior Informed Consent Procedure of Certain Hazardous Chemicals and Pesticides in International Trade, or Rotterdam Convention, aims to promote shared responsibility and cooperative efforts among parties involved in the international trade of particular hazardous waste (UNEP 2016). The Rotterdam Convention was approved on 10 September 1998 and entered into effect on February 24, 2004. (UNEP 2022). It is a global system open to all countries, and as of January 2022, it has a total of 165 parties. One of the primary goals of the Rotterdam Convention is to assist its parties in protecting themselves from the import of unwanted hazardous waste and chemicals (UNEP 2016). This ensures the protection of the environment and communities worldwide from hazardous chemicals and waste. Pesticides, pesticide formulations, and industrial chemicals are among the hazardous compounds covered under the Rotterdam Convention.

3.7.3 The Stockholm Convention

The Stockholm Convention on Persistent Organic Pollutants[6] (the Stockholm Convention) is a global treaty aimed at protecting human health and the environment from chemicals that remain in the environment for an extended period, travel across a large geographical area, and accumulate in both human and animal fatty tissue (UNEP 2012). Furthermore, POPs cannot be prevented by a single country because the chemicals travel thousands of kilometres across borders (UNEP 2012). The Stockholm Convention was approved on 22 May 2001 and went into effect on 17 May 2004. (UNEP 2012). The Rotterdam Convention has a total of 186 parties as of October 2022. The Rotterdam Convention mandates its parties to take action to eliminate or decrease the release of POPs into the environment. Finally, the Convention outlines the way forward to a future free of hazardous POPs and promises to transform our economy's reliance on harmful chemicals (UNIDO 2013).

3.8 E-WASTE IN SOUTH AFRICA

South Africa is one of the countries on the African continent that generates the most e-waste (Machete 2017). In South Africa, there are no exact figures for the total quantity of e-waste generated. Still, the DEA estimates that e-waste makes up approximately 5 to 8 per cent of the total municipal solid waste stream. These are expected to increase shortly three times faster than any other form of waste (Grant 2019). In 2008, Keith Anderson, the chairperson of the

[6] Persistent Organic Pollutants: chemicals that are frequently referred to as "forever chemicals" are of global concern due to their propensity for long-distance transportation, persistence in the environment, proclivity to bio-magnify and bio-accumulate in ecosystems, and severe negative effects on human health and the environment (WHO 2020).

eWASA stated, each South African citizen generates approximately 6.2 kg of e-waste annually (Mhlanga 2018). Of which only 12% was recycled (Mhlanga 2018). Finlay & Liechti (2008) estimate that between 1 129 000 and 2 108 000 tons of potential e-waste, including consumer electronics and IT equipment, are in South African households.

South Africa is one of the countries on the African continent that generates the most e-waste (Machete 2017). In South Africa, there are no exact figures for the total quantity of e-waste generated. Still, the DEA estimates that e-waste makes up approximately 5 to 8 per cent of the total municipal solid waste stream. These are expected to grow in the near future three times faster than any other form of waste (Grant 2019). In 2008, Keith Anderson, the chairperson of eWASA, stated that each South African citizen generates approximately 6.2 kg of e-waste annually (Mhlanga 2018). Of which only 12% were recycled (Mhlanga 2018). Finlay & Liechti (2008) estimate that between 1 129 000 and 2 108 000 tons of potential e-waste, including consumer electronics and IT equipment, are in South African households.

South Africa is one of the few African countries with formal e-waste recycling facilities; however, these facilities operate in conjunction with a large informal sector of recyclers (Forti et al. 2020). The informal e-waste recycling sector mainly includes the early stages of recycling, which include collecting, crude dismantling, and sorting. Still, there is also the burning of cables and other EEE components (Finlay & Liechti 2008). According to Finlay & Liechti (2008), a significant challenge facing e-waste recycling in South Africa includes recycling CRT glass and liquid crystal display (LCD) monitors and batteries. South Africa is one of the few countries on the continent that has published e-waste legislation; other countries include, for example, Egypt, Ghana, and Nigeria (Forti et al. 2020).

Furthermore, South Africa also has formal e-waste recycling facilities, but they operate in conjunction with a large informal sector (Finlay & Liechti 2008). Although South Africa is one of the few countries on the continent with legislation that speaks to e-waste, no legislation deals specifically with e-waste; instead, acts like the National Environmental Management Waste Act No. 59 of 2008 are used to regulate the disposal of e-waste in the country. This legislation protects public health and the environment (Finlay & Liechti 2008). Some of the other legislation that speaks to e-waste includes the South African Constitution (1998), the National Environmental Management Act, 107 of 1998 (NEMA), the Municipal Services Act, 32 of 2000, the Occupational Health and Safety Act, 85 of 1993, and the Hazardous Substances Act.

South Africa's e-waste sector is in its infancy, with very limited e-waste collection and recycling; nonetheless, the industry has shown indications of growth in recent years (Sadan 2019). Moyo et al. (2022) note that, like many other developing nations, due to the relatively young e-waste sector, limited national data and information on this sector are available. This poses a challenge to understanding e-waste in South Africa regarding consumer awareness, collection, recycling procedures, and waste disposal (Moyo et al. 2022). However, a recent study of household knowledge and perceptions of e-waste management in Limpopo province was conducted by Uhunamure et al. (2021). The study adopted a descriptive research design approach, using a pre-tested questionnaire among 200 participants. According to Uhunamure et al.'s (2021) findings, e-waste knowledge was satisfactory as 70% of the respondents knew what e-waste was, and only 30% had no knowledge of e-waste. Furthermore, the study found that 76% of the respondents were aware of the risks e-waste poses to the environment and health due to improper disposal, and 24% were not. In the study, mobile phones were the most commonly used EEE (96%). Compared to the past, it is much more common for households in lower-income economies to own mobile phones and other electronic devices. The study revealed that most respondents replaced their EEE due to not functioning (38%), 16% due to modern designs and upgrades, 24% due to theft, and 22% due to social pressure. Aspects related to the knowledge and practice of proper e-waste disposal amongst the participants in the findings were low as most participants disposed of obsolete EEE in the general waste bins (41%) and 23% stored e-waste. As the study findings suggest, this might be linked to a lack of knowledge and awareness and limited e-waste recycling facilities.

The study recognises that e-waste is becoming an increasing priority waste stream in South Africa, which is slowly gaining prominence. Furthermore, the government and related organisations are attempting to build an e-waste management system. The government has pledged to divert 50% of e-waste away from landfills by 2024 (Uhunamure et al. 2021). It is intended that by doing so, possibilities for value addition would be created, leading to considerable social, economic, and environmental advantages for all residents.

3.9 E-WASTE MANAGEMENT STRATEGIES: KNOWLEDGE AND AWARENESS

E-waste management is a collaborative multi-stakeholder task in which manufacturers, government organisations, and both public and private recyclers play a role; however, Gurauskienė (2008) argues that the role of consumers is often overlooked. E-waste consumers contribute to large volumes of e-waste once their devices reach their EOL. As mentioned, this is due to the high and rapidly increasing rate of global EEE consumption. This consumption rate is expected to increase by 3% in the next two years (De Vries & Stoll 2021). According to Gurauskienė (2008), consumers play two important roles when dealing with e-waste: (1) they are consumers (users), and (2) they are holders (disposers). Furthermore, Gurauskienė (2008) asserts that each role is critical to resolving the e-waste problem. As a result, consumers directly impact the generation and treatment of e-waste. Therefore, several authors have argued that consumers play a crucial role in e-waste management and solving the e-waste problem (Gurauskienė 2008; Costoff 2020; Islam et al. 2020; Sari et al. 2021). Once EEE reaches its end-of-life, consumers hold the power to practise sustainable environmental behaviour. Their choices related to e-waste can reduce global quantities and the adverse effects on the environment and health of communities worldwide. Successful e-waste management cannot be achieved if consumers are not actively involved (Gurauskienė 2008).

E-waste, like other environmental problems, cannot be wholly eradicated; however, waste generation can be reduced and controlled through proper awareness and practice (Licy et al. 2013). Therefore, several authors have emphasised that adequate consumer knowledge and awareness of e-waste should be considered crucial for sustainable and successful e-waste management (Gurauskienė 2008; Borthakur & Govind 2019; Hansmann et al. 2006; Miner et al. 2020; Shah 2014; Laeequddin et al. 2022). De Vries & Stoll (2021) argue that adequate knowledge, information, and awareness of e-waste among consumers is key to reducing the global quantities of e-waste and its adverse impacts. Several studies have reported that adequate awareness and knowledge lead to various pro-environmental behaviours, such as a positive attitude towards recycling (Gurauskienė 2008; Islam et al. 2020; Costoff 2020; Sari et al. 2021; Murthy & Ramakrishna 2022). In Hansman et al.'s (2006) study, positive environmental behaviour (e.g., recycling) can significantly be increased by raising e-waste consumer knowledge and awareness and avoiding negative behaviours (e.g., disposing of e-waste with household waste). Better choices will be made when a population is well-informed, educated, and aware of e-waste, what e-waste is, and how to handle it (Miner et al. 2020). For example, a study conducted in Belgium found that e-waste recycling rates grew to 47% in 2005, owing primarily to many years of raising awareness about various wastes, including e-waste (Miner et al. 2020). As Shah (2014) argues, consumers need to be informed about the hazardous materials found in their devices and the risks it poses to the environment and health of communities worldwide. Awareness will empower consumers to take responsibility for their disposal behaviour and consumer choices. However, Tan et al. (2018) argues that one of the biggest hurdles to e-waste management worldwide is the lack of consumer knowledge and awareness of e-waste and its impacts.

Bhat & Patil (2014) argue that e-waste consumers are the sources of e-waste generation; however, they lack awareness of the impacts of this hazardous waste, a considerable obstacle to e-waste management. Studies conducted in Maharashtra and Gujarat, India, reported that only 59% and 35% of the survey respondents were aware of what e-waste was, respectively (Shah 2014; Sivathanu 2016). In developing nations specifically, there is poor public awareness about the risks of e-waste and proper e-waste disposal (Khan & Ashraf 2015). In Africa, poor levels of awareness amongst people on the hazardous materials found in e-waste, combined with crude and unskilled approaches to e-waste disposal, have adversely contributed to the e-waste problem on the continent (eStewards 2013). Studying e-waste awareness in Nigeria, Azodo et al. (2017) argue that a lack of awareness and cautionary information regarding e-waste and proper disposal practices poses a potential threat to human health and the environment. Lack of e-waste knowledge and awareness has consequently led to e-waste being stored or disposed of with other general household waste, eventually ending up in landfills. As noted, landfilling of e-waste has been one of the most common e-waste disposal practices worldwide (Sthiannopkao & Wong 2013). In contrast, Arpith & Patil's (2020) study in India and Uthumanure et al.'s (2020) study in South Africa reported high awareness of e-waste among its sample population. Nevertheless, many authors have emphasised that awareness of e-waste among consumers is lacking, posing a challenge to solving the e-waste problem (Bhutta et al. 2011; Mishra et al. 2017; Islam et al. 2020; Borthakur & Govind 2017; Ali & Akalu 2022).

Many authors argue that raising awareness and knowledge among consumers should be a priority in e-waste management strategies. Ola & Toth (2010), Miller (2018) and (Leroy 2021) argue that consumer education and information should be prioritised when thinking about e-waste management. Gurauskienė (2008) states that education and information are the primary tools to make people aware and to increase recycling participation. Information dissemination, education, and awareness should be ensured to achieve higher recycling rates in the entire supply chain of e-waste (Bai et al. 2018). Consumer awareness and understanding are critical components of the e-waste management process because they encourage a mindset of reuse, repair, and recycling, which protects livelihoods, health, the environment, and sustainability.

Gurauskienė (2008) argues that consumer e-waste education, information, and knowledge will empower consumers to take responsibility for their behaviour and consumption choices. Gurauskienė (2008) concludes that education and information will raise consumer awareness of e-waste. As consumers become more aware, they will be empowered to take responsibility for their environmental behaviour and choices, and people are more likely to choose pro-environmental practices such as recycling their e-waste. Therefore, e-waste management strategies should empower consumers' pro-environmental behaviour through prioritising education and awareness and raising consumer knowledge and awareness about e-waste and recycling.

As Laeequddin et al. (2022) argue, governments and manufacturers can play an important role in increasing consumer awareness through advertisements and awareness campaigns to increase safe disposal behaviour. Similarly, Davis & Herat (2008) argue that local government councils, government organisations, and manufacturers could collaborate in arranging e-waste awareness campaigns. Lim-Wavde et al. (2017) highlight that educational institutions can play an essential role in raising consumer awareness about e-waste and stimulating pro-e-waste recycling attitudes among students. Similarly, educational institutions and universities can be important in increasing consumer knowledge and awareness about e-waste and recycling. In Spain, it was reported that primary and secondary schools engaged in an e-waste recycling and collection programme have increased e-waste recycling rates among their students compared to schools that do not (Bovea et al. 2010). After conducting a study in Africa, Bagozzi (1992) suggests including e-waste awareness in educational curriculums to make the younger generation aware of the harmful impacts of e-waste.

3.10 CONCLUSION

In conclusion, e-waste consists of items with circuitry or electrical components that have power or batteries. E-waste is the world's fastest-growing waste stream, increasing at an alarming annual rate of 3 to 4%, and global recycling rates are not keeping up (Puckette et al. 2002; Widmer et al. 2005; Kumar et al. 2017). By 2030, the total global quantity of e-waste will reach 74.7 Mt, equivalent to 350 cruise ships in weight. To ensure environmental and economic benefits, e-waste requires specific recycling techniques due to its unique material composition. However, due to the valuable materials in e-waste, an entire economy of e-waste trading across boundaries has emerged. Often, this hazardous waste ends up in developing nations where it is recycled using primitive methods due to a lack of knowledge and recycling facilities, contaminating waterways, food supplies, and the human health of the surrounding community. Although, under the Basel Convention, all movement of e-waste between countries is illegal. In South Africa, the National Environmental Management Waste Act No. Along with the Constitution of the Republic of South Africa, 59 of 2008 regulates the management of e-waste generated in the country.

Literature has emphasised that consumers play an important role in reducing the global quantities of e-waste and its adverse impacts. Moreover, consumer knowledge and awareness about e-waste are crucial for successful e-waste management. However, literature has revealed that consumer knowledge about e-waste remains low worldwide. For successful e-waste management, consumer knowledge and awareness should be raised by prioritising education and information. Adequate consumer knowledge and awareness can avoid negative e-waste disposal habits; if consumers are aware of the negative impacts of e-waste, they will be more likely to dispose of their waste correctly, i.e., by recycling. Educational institutions and universities can play a crucial role in raising consumer awareness and knowledge through awareness campaigns that could increase consumer recycling participation. E-waste management strategies should empower consumers to adopt pro-environmental behaviour through prioritising education and awareness, raising consumer knowledge and awareness about e-waste and recycling.

Therefore, it is vital to understand and recognise consumers’ level of knowledge, awareness, and attitudes related to e-waste to ensure a successful e-waste management strategy. A detailed and explanation of the methodology of this study is presented in the next chapter of this thesis.

CHAPTER FOUR: METHODOLOGY

4.1 INTRODUCTION

The purpose of this chapter is to describe the research methodology that this study followed and provide justification for its application. Data collection and analysis are the most time-consuming parts of the research process; therefore, it is imperative to have a well-detailed methodology. As Brynard et al. (2014) suggest, research methodology could be described simply as the 'how' of collecting and processing data within the research process. The methodology section informs the reader how the researcher has tackled the research problem while simultaneously demonstrating the researcher's knowledge as to why the chosen approach is the most appropriate and valid in addressing the research questions at hand (Singh 2015). Selecting the appropriate methodology is pivotal to any research project as it determines whether the research will produce reliable results and findings. As argued by Bem (2021), methodology is crucial for any academic discipline, as an unreliable method will produce unreliable results; subsequently, this will undermine the value of the researcher's analysis of the findings. Furthermore, Faryadi (2019) notes that when selecting a research methodology, the researcher must ask 'whether the selected methodology will facilitate finding answers to the research questions and meeting the study's objectives'. Therefore, to achieve this study's aims and investigate *e-waste generated at Stellenbosch University, the current e-waste management system, and e-waste knowledge, attitudes, and behaviours amongst the university community,* choosing the appropriate research methodology and design was a critical step in the research process.

This study followed a qualitative research approach and employed a case study method. Data for the study was collected using standard qualitative methods, which included online surveys (Checkbox Survey), semi-structured interviews, and a literature review. After collecting the data, it was analysed qualitatively to achieve the aims and objectives of the study. This comprised a thematic analysis of the collected data. These aspects will be further detailed and discussed in this chapter and outlined as follows: i) research philosophy, ii) research approach, iii) research method, iv) study area, v) research design, data collection, and analysis methods. This section will also describe the ethical considerations and limitations of this study.

4.2 RESEARCH PHILOSOPHY

One of the key considerations' researchers need to consider early in the research process is the philosophical aspects and questions behind every research methodology (Eriksson & Kovalainen 2008). This step is referred to as the research philosophy. The research philosophy is a system of the researcher's beliefs and assumptions about knowledge development (Saunders et al. 2007). Collis & Hussey (2014) describe this as a guiding framework for research on ideas of reality and the nature of knowledge. It is the foundation of any study as it describes the beliefs the research is built upon. Several research philosophies include, among others, positivism, interpretivism and pragmatism (Table 4.1).

Table 4.1: Summary of research paradigms

Paradigm	Ontology	Epistemology	Axiology	Methodology
Positivism	*Naïve realist*	*Objectivist*	*Beneficent*	*Experimental*
Interpretivism	*Relativist*	*Subjectivist*	*Balanced*	*naturalist*
Pragmatism	*Non-singular reality*	*relational*	*Value-laden*	*Mixed methods*

Source: Adapted from Kivunja & Kuyini (2007:27-29)

This study is positioned within the interpretivist philosophical paradigm. This study focuses on e-waste from the participants' perspective and what meanings, understanding and behaviour they attach to it. An interpretive approach was selected as it enabled observation and investigation, focusing on people's thoughts, opinions, and ideas. Furthermore, interpretivism offers an effective way to explore multiple subjective realities due to varying human experiences and interpretations. This is compared to positivism which assumes that there is only one objective reality. An advantage of interpretivism is that it produces rich and in-depth results by minimising the distance between the researcher and participants. As this study is concerned with people's opinions, thoughts and meanings that cannot be accessed using empirical research methods (calculations, measurements), aligning it with the interpretivist philosophy was most appropriate. A positivist philosophy would not allow for investigation into the opinions and views of participants that cannot be calculable or measured.

4.3 RESEARCH APPROACH

When conducting research, two broad methods of reasoning are defined, namely, the deductive and inductive approaches. In deductive research, the researcher is first concerned with developing a hypothesis (or hypotheses) grounded in an existing theory and then designing the research in such a way as to test the hypothesis. According to Burney & Hussain (2008), in this type of research, reasoning flows from the general to the specific. It is also referred to as a "top-down approach", and conclusions follow logically from the premises. In comparison, inductive research starts with observations and then theories are proposed towards the end of the research process as a result of observations.

Furthermore, in contrast to the deductive approach, in the inductive approach, reasoning flows from specific to broader generalised theories (Burney & Hussain 2008). In other words, it is instead a 'bottom-up' approach, and conclusions are based on premises. This study followed an inductive approach to acquiring knowledge.

4.4 RESEARCH METHODS

When conducting research in social sciences, two main research methods can be distinguished: qualitative and quantitative. Both these research methods are important for producing diverse types of knowledge. As mentioned, a qualitative research method was selected to reach this study's aims and objectives.

4.4.1 Qualitative vs quantitative research

Qualitative and quantitative research methods are equally important for research and produce various kinds of data and findings; it is up to the researcher to select the most appropriate methods for his or her research. Gagliardi & Dobrow (2011) argue that qualitative research is exploratory since it tends to describe, explain, and understand a particular social phenomenon. It allows for a greater investigation into various social realities by exploring participants' understandings of everyday life, experiences, and the important meanings they generate (Mason 2002). An important condition for qualitative research is that social phenomena are always viewed from people's perspectives and what meanings they attach to them. Authors such as Plonsey & Barr (2007) and Brynard et al. (2014) agree that qualitative research is committed to seeing the world from the participant's viewpoint and how they experience things. A distinguishing characteristic between qualitative and quantitative research is that data collection and analysis in the latter deals with numbers and statistics, while the former deals with words and meanings. As mentioned, both research methods are equally important for gaining diverse types of knowledge. Mouton (1983) suggests that as qualitative research deals with words, it produces descriptive data without quantification. Similarly, Strauss & Corbin's (1998) publication describes qualitative research as the type of research that produces data without using any statistical calculations or other forms of quantification. Instead, when applying a qualitative approach, data is always derived from people's everyday lives, experiences, emotions, and behaviours through communication between the researcher and the participant. Lee & Krauss (2015) conclude that through the communication and interpretative process of deep reflection, meanings hidden 'inside' the participant are brought to the surface, where the researcher becomes an important instrument. A qualitative research method differs from a quantitative method in that the researcher and participant are actively involved throughout the research process.

Qualitative research is a holistic approach, where the researcher becomes an important instrument for discovery and making sense of people's experiences, emotions, and behaviours. As Creswell (1999) demonstrates, qualitative research is an unfolding model that occurs in a natural context, allowing the researcher to build a degree of depth from a high level of engagement in the event. In this way, the researcher takes on an interactive role and becomes an integral part of the research process as the researcher must intertwine the researcher's voice and the image of the participants for the findings to become apparent. As Lee & Krauss (2015) conclude, the key involvement between the researcher and participant separates qualitative research methods from quantitative research methods.

4.4.2 Justification for qualitative research method

As mentioned, this study employed a qualitative data collection and analysis approach. This was a literature study, administering online surveys (using a structured questionnaire) and conducting interviews during the data collection process. A qualitative research method was selected for this study because it allows for face-to-face interaction using interviews. This enabled the researcher to gain in-depth insight into participants' thinking while minimising the distance between the researcher and participants (Kawulich 2005). Furthermore, qualitative research avoids the problem of inflexibility. Since this study explores e-waste from participants' perspectives, the research method cannot be rigid as participants' responses cannot be anticipated. If valuable insight is not captured during the interview process or if the researcher wants greater depth to a question, he or she can ask follow-up questions (DeJonckheere & Vaughn 2019). This study aimed to investigate social phenomena from the participants' perspective; a qualitative approach offers an investigation into participants' understanding, meanings and opinions. It allows the researcher to collect, capture, analyse and report on people's understanding, ideas, and thoughts. As Stake (2010) states, a qualitative research approach is the most appropriate if the researcher aims to understand and explain complex social phenomena from the perception of people's experiences or understanding (Stake 2010). Investigating complex phenomena will be difficult or impossible to investigate and capture using quantitative methods of calculations and numbers (Kawulich 2005). Additionally, a qualitative research design has a flexible structure since it may be developed and reconstructed during the research process (Maxwell 2012); unlike quantitative research, which is rigid and structured.

4.5 CASE STUDY APPROACH

This study follows a case study design, with an in-depth analysis of e-waste management strategies employed at Stellenbosch University and documenting practices, knowledge, and behavioural responses of the University community. Many authors have provided different definitions of what a case study is. As Stake (2010) suggests, a case study is both the process of learning about the case and the product of our learning. According to Yin (2009), a case study is an empirical investigation that analyses current phenomena in depth and within its real-life environment, particularly when the boundary between phenomenon and context is unclear. Silverman (2013) argues that it allows researchers to understand the specific nature of any example and establishes the importance of both culture and context in determining how cases differ. Its advantage is that a case study approach can offer in-depth, multifaceted analyses of complicated subjects in their real-world contexts (Crowe et al. 2011). Additionally, observations of phenomena provide evidence of input processes that is verifiable through case studies (Gaille 2018). A case study approach was selected for this study as it enables the study to produce a 'rich' and in-depth understanding of data and findings.

4.6 STUDY AREA

Stellenbosch University was selected as the study area; see Figure 4.1 on the next page. Stellenbosch University is located in the Western Cape, South Africa. Stellenbosch University has five campuses: the main campus in Stellenbosch, the Tygerberg campus in Bellville, the Bellville Park campus in Bellville, the Saldana campus, and the Worcester campus. According to the latest official annual census, 34 814 students were enrolled at Stellenbosch University in 2022. Of this total, 65.34% (21 258) of students were enrolled in undergraduate programmes, 31.91% (10 381) in postgraduate programmes and 2.75% (896) as occasional students (no-degree purposes) (Stellenbosch University 2022). Additionally, 3 454 staff members are employed at Stellenbosch University, of which 1 091 are academic personnel and 2 363 non-academic personnel. This study will only focus on the main campus located in Stellenbosch.

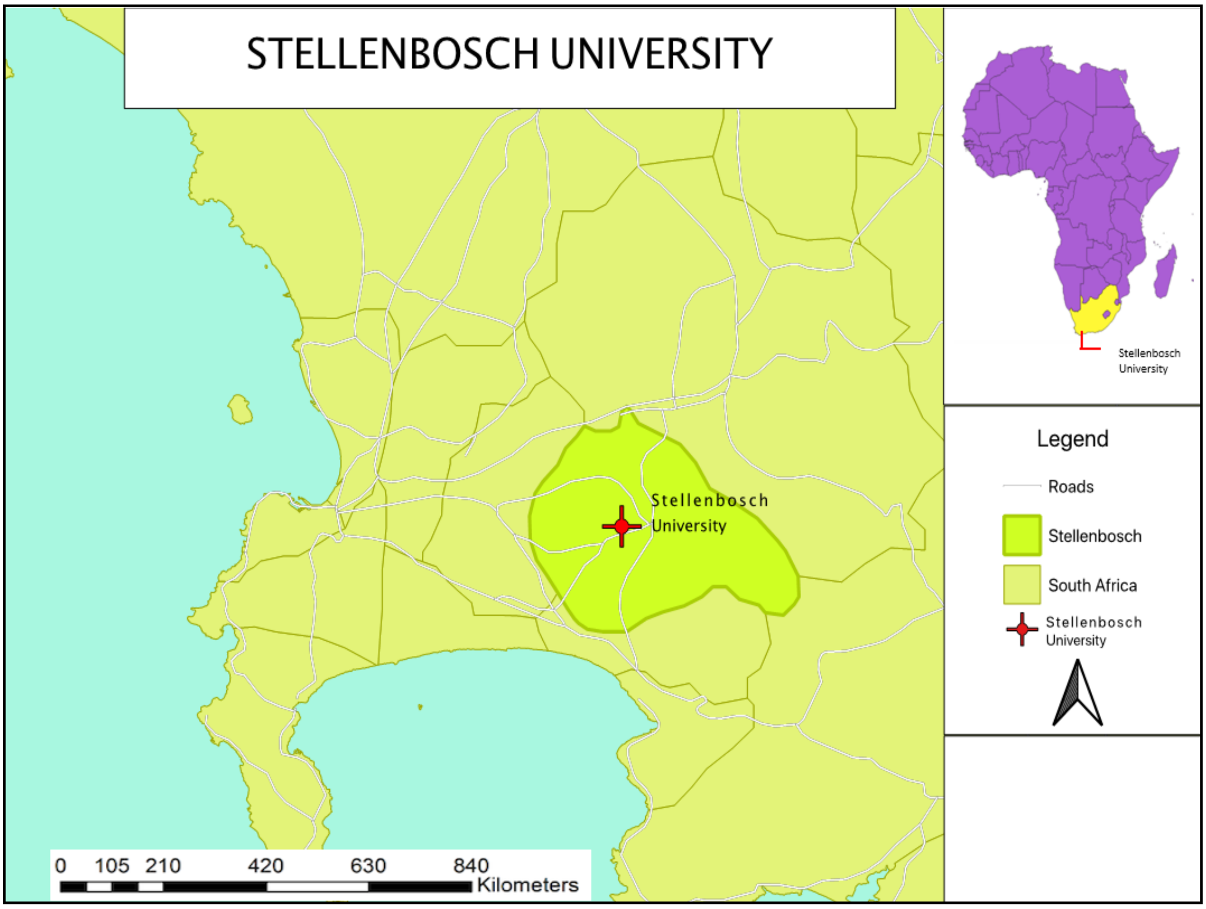


Figure 4.1: Stellenbosch University, Western Cape, South Africa. *Source: Author, April (2021)*

Stellenbosch University was selected as the study area for this study because it is a large institution that is highly dependent on EEE as part of its daily functioning and thus has the potential to generate large quantities of e-waste. Furthermore, the University community (staff and students) are all consumers of EEE, contributing to the rising quantities of e-waste.

4.7 RESEARCH DESIGN

This study followed a five-phase research process, as shown in Figure 4.2 overleaf. *Phase 1* of this study was dedicated to conducting a literature review on existing research and debates on e-waste on both an international and national scale. This phase entailed conducting an extensive review of existing literature on e-waste to construct a comprehensive literature review to provide a detailed and in-depth analysis of past and current debates on e-waste. *Phase 1* of the study differs from the other four phases as it has been an ongoing phase throughout the research process to ensure that literature on e-waste remains relevant and up to date. *Phase 1* has guided the study into the next, *Phase 2*: Research Context. During *Phase 2*, the in-depth literature review enabled the researcher to formulate the research problem, questions, aims, objectives, and rationale. In addition, the most appropriate study area was selected during this phase. *Phase 3* of the research centred around the development of the research methodology. During this phase, the most appropriate and valid research methodology was identified and selected to reach the overall aims and objectives of the study, and a qualitative research approach was selected.

Furthermore, during this phase, the following elements of the study were identified: data required, sample and sample size, data collection and analysis methods. In addition, two structured questionnaires were developed during *Phase 3* for the different target groups of the study. After reaching *Phase 3* of the research design, where an extensive literature review was conducted, the research context was detailed, and the methodology was identified. The researcher developed a research proposal to be submitted for obtaining the necessary ethical clearance from the Research Ethics Committee for Human Research.

Phase 4 of the study entailed the data collection and analysis phase. During this phase, all the required data from the respective participants were collected, analysed, and discussed using qualitative research methods. The final stage of the study, *Phase 5*, was dedicated to providing a conclusion to the study. Here, the aims and objectives of the study have been revisited, and a synthesis of the results has been presented. In addition, this phase has also been further dedicated to providing recommendations drawn from the results.

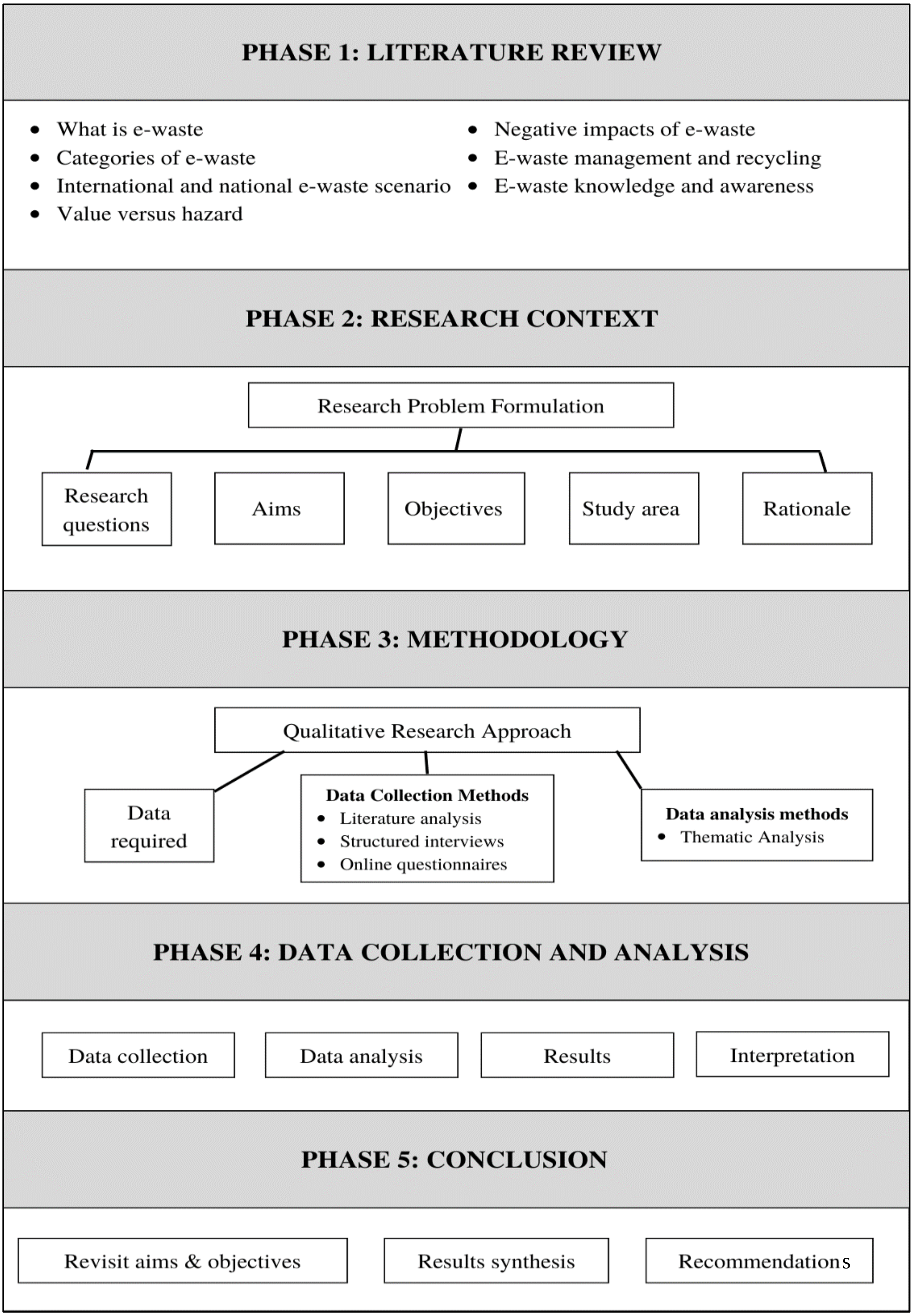


Figure 4.2: Research design

4.8 DATA COLLECTION AND ANALYSIS METHODS

This section of the chapter details and explains how data for the study was collected and analysed. This section will also explain the data sources selected for the study, research design, sample and sample size, ethical considerations, and the study's limitations.

Data collection and analysis depend on the methodological approach selected for any study (Bryman & Cramer 2012). Qualitative data collection methods include interviews, questionnaires, online surveys, focus groups, expert opinions, and literature searches (Kawulich 2005). It is up to the researcher to choose the correct or appropriate methods for the specific study, as all research differs. A poorly designed data collection and analysis method will harm the results and hinder the study's aim. Since a qualitative approach was selected for this study, standard qualitative methods for data collection and analysis were employed. To address the aims and objectives, the following qualitative data collection methods were used: (i) case study approach, (ii) in-depth literature review, (iii) structured interviews and (iv) online survey. For this study, two separate structured questionnaires have been designed for the selected target groups: one for employees at the Stellenbosch Facilities Management Department and the second for staff and students referred to as the University community (online survey). The methods employed to analyse data include thematic analysis. These data collection and analysis methods will be detailed later in this chapter.

4.8.1 Sources of data and data required

This study required primary and secondary data sources to reach this study's overarching aims and objectives. Primary data is defined as original and unique data collected by the researcher first-hand through methods such as observations, surveys, questionnaires, and oral or written interviews (Ajayi 2017). Primary data for this study include data on the amount of e-waste generated at Stellenbosch University, e-waste management strategies employed on campus, knowledge, and awareness of e-waste amongst the University community and their attitudes towards WMP. Primary data sources are required to reach objectives two to five of the study. In contrast to primary data, secondary data is derived from the work or opinions of other researchers (Martin et al. 1998). Secondary data required for this study included international and national literature on e-waste to form a comprehensive knowledge foundation of knowledge of e-waste. This data is required to reach objective one of the studies.

4.8.2 Sampling and sample size

Sampling is a technique whereby the researcher selects a small group (the sample) to determine the characteristics of the large group (the population). If selected perceptively, the population will display the same characteristics or properties as the large group. For this study, two target groups were identified. The first target group are relevant persons from the Facilities Management Offices with knowledge and insight into e-waste at Stellenbosch University. This included managers, coordinators and administrators within the relevant department dealing with e-waste. Participants were recruited by calling and/or emailing prospective participants. Additionally, the researcher searched the University's website (Stellenbosch University Environmental Sustainability webpage) for information on the University's sustainable and e-waste policies, strategies, and initiatives to gain a broader understanding of the waste management systems in place. The second target group for this study was the University community. The University community included all current students and academic staff at Stellenbosch University. Law Insider (2017) defines university communities as all university students, faculty, and staff, whether part-time, full-time, or temporary. The criteria for selecting participants were as follows:

- Full-time, part-time, or temporary students (undergraduate or postgraduate)
- Full-time, part-time, or temporary academic staff
- Studying or working at the main campus in Stellenbosch

There were no age or gender limitations for participation in this study. This criterion was selected to ensure the sample represents the entire University community. As Brynard et al. (2014) argue, the sample should represent the large group (the population) and include all the population's elements. Only responses from the main Stellenbosch campus were selected. Responses from the four other campuses were omitted since, as previously stated, this study only focused on the main campus located in Stellenbosch. A total of 986 responses were collected from the University community. Additionally, two interviews were conducted with the Facilities Management Department employees at Stellenbosch University.

4.8.3 Structured interviews

A structured questionnaire was used when conducting interviews with relevant staff at the Facilities Management Department at Stellenbosch University. In addition, a self-designed questionnaire was developed for this study. The questionnaire was designed to collect data from participants relating to e-waste management at Stellenbosch University. The questionnaire consists of 16 questions, a combination of open-ended, close-ended and scaling questions. These questions are divided into three main sections to collect specific data:

I. ***Personal Profile:*** information including participants' age, university, and employment position. This section of the questionnaire aimed to understand the participants' employment role at the University and how it relates to e-waste.
II. ***E-waste Management and Strategies:*** This questionnaire section comprised questions relating to the e-waste management systems and strategies employed at the University. These questions were included to collect data on e-waste management systems and disposal methods, as well as the positives and negatives of the systems employed.
III. ***Electronic Equipment and E-waste Generation:*** The concluding section of the questionnaire consisted of questions relating to the amount of e-waste generated from 2010 to 2020. Also, the section was dedicated to asking questions regarding the amount of electronic equipment available at the University. This section aimed to know how much e-waste is generated at the University over ten years.

The core questions of this questionnaire were divided into sections to allow for clarity and aim at addressing objectives two and three of the study from the perspective of staff at the Facilities Department at the University. On 22 March 2022, the researchers took a tour of the waste sorting facility of Stellenbosch University at Welgevallen. During this visit, the researcher understood the University's waste management strategy and how waste is sorted and recycled. During this visit, the researcher interviewed the engagement coordinator at the Facilities Management Department. Furthermore, during this visit, the researcher set up interviews with key department members. On 11 August 2022, an online interview was conducted with the environmental sustainability coordinator at the Facilities Management Department. The structured questionnaire was sent to the participant via email, which was then answered and returned to the researcher. According to Patton (2014), a structured interview refers to the type of interview where the interviewer asks every participant the same questions in the same order to gather consistent and comparable data. The study used structured interviews, which are much more time-efficient and reach a greater audience than unstructured or semi-structured interviews. As Patton (2014) explains, because of limited response categories in structured interviews, the researcher can cover a much larger population group, as they can conduct interviews faster than unstructured and semi-structured interviews. Additionally, structured interviews allow the researcher to find and compare participant responses during the data analysis phase of the research, as every participant in a structured interview responds to the same questions.

4.8.4 Online questionnaire

As mentioned above, for this study, the scope of e-waste has been narrowed and will focus on mobile phones because of their high consumption rate, their high obsolescence rate, and their large contribution to the proportion of high e-waste quantities. Therefore, a self-designed online survey targeted the University communities at Stellenbosch University. The questionnaire was designed to collect data from participants relating to their sentiment toward recycling in general, knowledge and awareness of e-waste, their e-waste disposal behaviour, and their attitudes and perceptions of e-waste. The questionnaire consisted of 34 questions and used a combination of open-ended, close-ended and scaling questions. These questions were divided into five sections:

I. ***Personal Profile:*** collecting information including age, university, gender, faculty, and position or study year. This section was intended for the collection of demographic data from participants.

II. ***Sentiment toward Recycling:*** The section aimed to determine participants' general knowledge, attitudes, and behaviours about recycling.

III. ***E-waste Knowledge and Awareness:*** questions related to e-waste knowledge and awareness. This section's objective was to collect data to better understand the University community's knowledge and awareness of e-waste.

IV. ***E-waste Attitudes and Perceptions***: The last section includes questions about their opinions on the statement of e-waste. This section's objective was to evaluate participants' attitudes and perceptions of e-waste.

V. ***Waste Mobile Phones and Disposal Methods:*** This section includes questions relating to the University community's mobile phone consumption habits and WMP disposal methods. The questions in this section aimed to understand participants' behaviours relating to mobile phones as e-waste.

This data was collected by making use of an online survey. The researcher first applied for institutional permission from Stellenbosch University to collect data from the University community. Once research permission was granted, the researcher accessed the online survey platform Checkbox Survey, where the questionnaire was designed. This is the official survey platform used by Stellenbosch University. Before sending out the online surveys, a participation email was designed explaining the study and why data would be collected.

Additionally, prospective participants were also explained the ethical considerations of the study and a consent form was attached to the email. On 11 April 2022, the first opportunity to participate in the study was sent out via email to the University community – a total of 34 824 emails were sent out. Participants had seven days to complete the survey, which took approximately 20 to 25 minutes. On 11 April 2022, a total of 117 responses to the survey were collected. By 19 April 2022, 702 responses from the University community were collected. On 2 May 2022, perspective participants from the University community were sent a reminder email. On 2 May 2022, an additional 284 responses from the University community were collected. By 9 May 2022, a total of 986 responses were collected. This study used a computer questionnaire as it is inexpensive and time-efficient, and participants had more time to think about their answers.

4.8.5 Data analysis

Patton (1987) claims that data analysis is the most important part of any research as it aims to interpret and summarise the data collected. Furthermore, LeCompte & Schunsul (1999) explain data analysis as the process undertaken by a researcher to reduce data to a story or interpretation. Literary data has been analysed through in-depth reading and categorisation according to a common theme to conduct a literature review on the past and current international and national debates on e-waste. This step has been crucial in the study as it has informed the foundation of knowledge on e-waste and allowed for identifying how this study will add value to the existing literature on e-waste. Primary data collected from both questionnaires have been analysed in two phases. The first phase involved cleaning the data. This involved analysing all the data collected from both questionnaires and deleting duplicates. The second phase of analysing the primary data collected for this study occurred through a thematic analysis. This involved using analytical and logical reasoning to find patterns, trends, and relationships in the data and place them into themes. The researcher analysed participants' responses to each question, identified common words and phrases, and grouped them accordingly. This data analysis phase made determining trends, patterns, and relationships in participants' responses possible. The results and thematic analysis were captured using computer software Microsoft Excel and IBM SPSS (Statistical Packages for Social Sciences). The results of the thematic analysis have been presented in the format of tables, figures, and graphs.

4.9 ETHICS OF RESEARCH

This study has followed all the established ethical and social research norms as outlined in Stellenbosch University's Code for Research. One of the main foundations of this study was fundamental respect for human dignity. This means that the researcher has always respected human dignity in every phase of the research process. The Norwegian National Research Ethics Committee states (NNREC 2016) that the research must always respect human dignity by protecting personal integrity, preserving individual freedom, respecting privacy and family, and safeguarding against harm and unreasonable strain. Before undertaking the data collection process, the researcher received ethical clearance from the Stellenbosch University Research Ethics Committee for Human Research, *Project number: 22193*. Furthermore, the research received institutional permission from Stellenbosch University to conduct research at the University, *Service Desk Number: IG-2086.*

All participants of this study have been provided with adequate information. This information includes the field of research, the study's aims, the study's purpose, who will have access to the information provided, and the intended use of the information provided by the participant. In addition, before conducting any interviews or online questionnaires, participants must first be asked for their consent. The consent to part-take in the study has been given freely and in explicit form. To avoid confusion among participants, the study's information and consent forms have been given to participants in their preferred language. Participants have not been forced into participating in the study, as participation is purely voluntary. Before starting the interview process, participants have been informed that they are under no obligation to answer any question that they deem sensitive and are free to stop the interview process at any stage. The confidentially of all respondents was paramount throughout this research process. All data collected from participants were stored on a password-protected flash drive and were only accessible by the researcher. All participants of this study have remained anonymous; no personal details such as names, contact numbers or street addresses have been collected from participants.

4.9.1 COVID-19

The health and safety consideration for participants and the research is paramount in the current health emergency and pandemic context. Therefore, the research design of this study followed clear health protocols and employ mitigation strategies to prevent the risk of infection and the spread of COVID-19. The key factor in preventing the spread of COVID-19 and protecting participants' health is eliminating or reducing face-to-face interaction as much as possible. The research design of this study was thus entirely based on remote interaction through online or internet-based research due to COVID-19. All participant data were collected online to eliminate and reduce the risk of infection. This non-contact method protected the researcher's and participants' health while reducing the possible spread of COVID-19. The COVID-19 outbreak, and its ramifications are difficult to measure or predict; thus, the researchers have carefully monitored any further news, directives, and guidance on this matter.

4.10 Conclusion

This study followed a qualitative research methodology based on inductive reasoning to deduce conclusions and acquire knowledge. Furthermore, the study used a case study approach, and Stellenbosch University has identified as the most appropriate study area two target groups within were identified, i.e., staff members from facilities management responsible for handling e-waste and the university community. Moreover, two questionnaires were used to collect data from the target groups via email. Two responses were collected from staff members at the facilities management department, and 986 from the university community. The data collection was sufficient to achieve the aims and objectives of this study.

CHAPTER FIVE: E-WASTE AT STELLENBOSCH UNIVERSITY

5.1 INTRODUCTION

This study aimed to document and analyse e-waste management at Stellenbosch University. It further examined the University community's e-waste knowledge, attitudes, and practices. The study's data was collected through a literature review, online questionnaire surveys, and in-depth interviews. This chapter is thus, dedicated to presenting the results acquired from the staff at the Facilities Management Department and the University community of Stellenbosch University. By the end of the data collection period, four interviews were conducted with staff at the Facilities Management Department.

Furthermore, by the end of the survey period (April 2022 to June 2022), data had been collected from 986 individuals in the University community. Therefore, this chapter will provide an overview of the current e-waste management system implemented at Stellenbosch University and the challenges it faces when dealing with its e-waste. Followed by presenting the results of the amount of e-waste generated and how it was disposed of. This aims to provide a detailed investigation of how e-waste is managed at the University and to account for what happens to obsolete EEE on campus.

After that, the focus will shift to presenting data collected from the University community. The results of the online questionnaire survey will be presented here. Furthermore, the chapter will then narrow the focus by presenting the results of respondents' disposal practices of their WMP. The results of this chapter are structured around common themes that emerged during data collection.

5.2 E-waste Management and Generation at Stellenbosch University

Objectives two and three. This section of the chapter focuses on presenting the results from the interviews conducted with staff from Facilities Management using a structured questionnaire. The interviews aimed at gaining insight into how the University manages e-waste, which strategies are employed, how e-waste awareness is created and finally, the positives and challenges the University faces in managing e-waste.

5.2.1 E-waste management strategies and generation

According to Respondent 1[7], Stellenbosch University has implemented two e-waste strategies: the Non-Asset Registered E-waste and the Stellenbosch Asset E-waste. The Non-Asset Registered E-waste strategy pertains to personal or non-asset electronic devices, i.e., electronic devices not owned by the University. Respondent 1[8] reported that "*it deals with your cell phone or your laptop*". In addition, this strategy employs yellow e-waste bin systems, which are available to the University community to recycle their e-waste, as seen in Figure 5.1 (a).

Figure 5.1: E-waste recycling bins on Stellenbosch University campus *Source: Field survey, July 2022*

These bins are marked with signage which describes what the bins are for and shows images of the different e-waste types, as seen in Figures 5.1 (b) above. Furthermore, during the Stellenbosch University's waste sorting facility tour, Respondent 1 reported seven yellow e-waste bins around campus. The locations of the yellow e-waste bins are Main IT; General

---

[7] Respondent 1: Staff member at SU Facilities Management, 11 August 2022

[8] Respondent 1: Staff member at SU Facilities Management, 11 August 2022

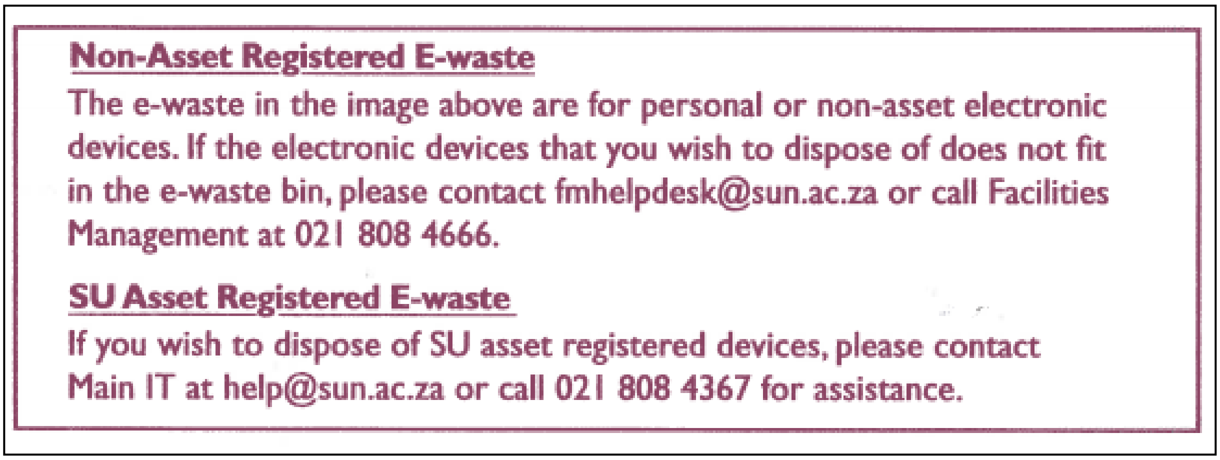
Engineering; Wimbledon Hub; Neelsie; IT Hub; Metanoia; and Sports Science Building (Figure 5.2).

Figure 5.2: Locations of e-waste bins *Source: Author, July 2022*

The University community can dispose of their e-waste in these bins. If e-waste cannot fit into the e-waste bins, the University community can contact Facilities Management via email or call, as seen on the bins' signage (Figure 5.3). The e-waste in these e-waste bins gets removed by the University's waste service provider, Wasteplan, which sells it to buyers to be repurposed and recycled. The second e-waste strategy, SU Asset E-waste, pertains to the University's electronic devices. As Respondent 2[9] reported: *"These are electronic devices that staff or students receive from the University which is issued through Main IT, and it has an asset number registered to it".* The e-waste under this strategy is collected by Main IT and then collected by Cape E-waste Recyclers and disposed of. As Respondent 1[10] reported: *"…Cape E-Waste Recyclers collect it from Main IT and disposes of it responsibly".*

[9] Respondent 2: Staff member at SU Facilities Management, 22 March 2022

[10] Respondent 1: Staff member at SU Facilities Management, 11 August 2022



Non-Asset Registered E-waste

The e-waste in the image above are for personal or non-asset electronic devices. If the electronic devices that you wish to dispose of does not fit in the e-waste bin, please contact fmhelpdesk@sun.ac.za or call Facilities Management at 021 808 4666.

SU Asset Registered E-waste

If you wish to dispose of SU asset registered devices, please contact Main IT at help@sun.ac.za or call 021 808 4367 for assistance.

Figure 5.3: Facilities Management contact details of e-waste recycling bin *Source: SU Facilities Management, August 2022*

According to the interview results, respondents felt it is very important for the University to have an e-waste management system. As Respondent 2 reported:

"Yes, definitely! Creating a stream for e-waste allows us to divert more waste away from landfill. Secondly, most components in e-waste are deemed valuable to e-waste buyers as there is a market for these components. It also contains sometimes heavy metals that need to be disposed of correctly."[11]

Respondents were asked to rate whether they agreed or disagreed with a range of statements using a five-point Likert scale (1= Strongly disagree, 2= Disagree, 3= Natural, 4 = Agree and 5= Strongly agree). Respondents agreed (scale 4) that the University has the potential to generate a large volume of e-waste, and the University could do more to create awareness about e-waste amongst the University community.

When electronic equipment at the University malfunctions (University asset), first, a call is logged to IT to have the faulty electronic equipment repaired. However, it is replaced if the electronic equipment cannot be repaired. As Respondent 1[12] reported: *"… if the issue continues to persist, the electronic equipment will be placed with e-waste that is kept separately".* A call is then logged by IT to *Cape E-waste Recyclers*, who collects and disposes of it. As Respondent

[11] Respondent 2: Staff member at SU Facilities Management, 22 March 2022

[12] Respondent 1: Staff member at SU Facilities Management, 11 August 2022

2[13] reported: *"IT will log a call for the e-waste company to collect and dispose of it responsibly".* When electronic equipment owned by the University becomes obsolete, it is collected by the e-waste company, which then disposes of it. The company first tries to repair and reuse obsolete electronic equipment. If this is not possible, it is dismantled and recycled responsibly.

According to the interviews, the University employs different strategies to create e-waste awareness amongst the University community. As mentioned during the interviews, Facilities Management has created awareness amongst the University community by developing new e-waste signage, as shown in Figure 5.4 below.

[13] Respondent 2: Staff member at SU Facilities Management, 22 March 2022

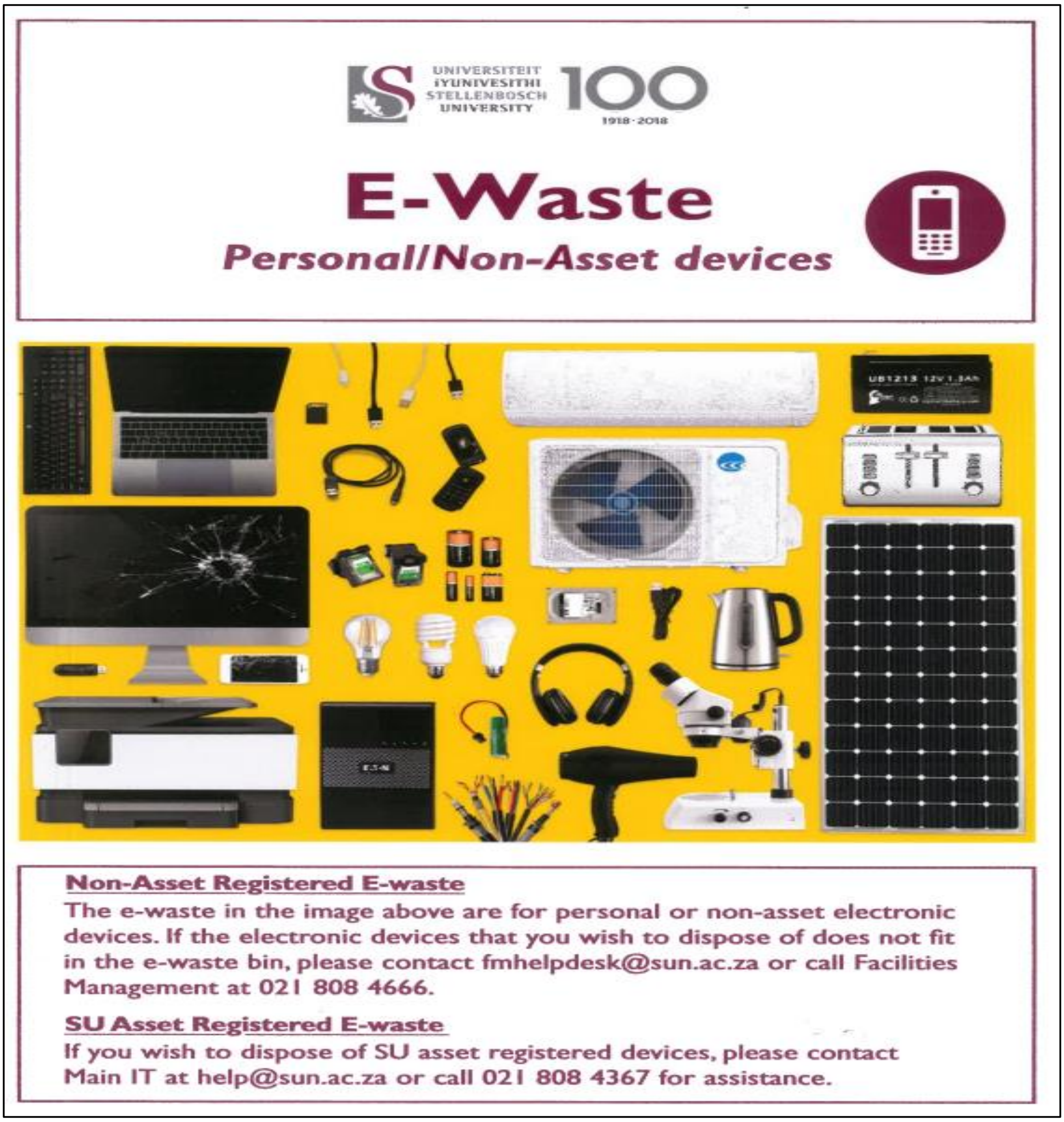


Figure 5.4: E-waste bin signage *Source: SU Facilities Management, August 2022*

One e-waste initiative on campus is the e-waste yellow bins, which is one of the University's e-waste strategies. Respondent 1[14] reported: *"Facilities Management has developed new signage specifically for e-waste yellow bins"*. A strategy the University employs to create awareness about the e-waste initiatives amongst the University community is first through having information sessions on sustainability. As Respondent 2[15] reported: *"In these sessions,*

[14] Respondent 1: Staff member at SU Facilities Management, 11 August 2022

[15] Respondent 2: Staff member at SU Facilities Management, 22 March 2022

we have launched the extended e-waste system for personal items as the need for it has grown". Another strategy the University employs to create awareness about e-waste initiatives on campus is promoting it on its Instagram page *@su.environmental.sust.* Figure 5.5 below shows one of the Instagram posts creating awareness about e-waste amongst the University community.

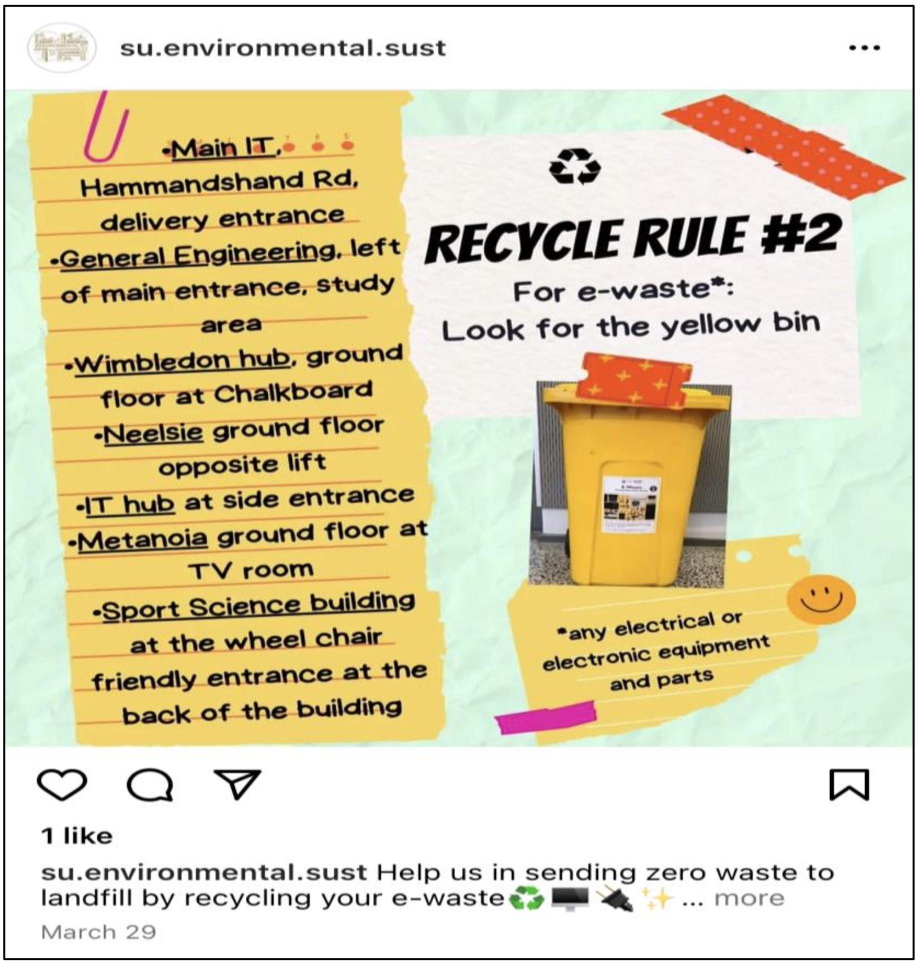


Figure 5.5: E-waste awareness social media post *Source: Instagram, August 2022*

According to the results, a positive aspect of the current e-waste management strategies employed at the University is that it reduces environmental impacts. As Respondent 1[16] reported: *"reuse electronics, recycle elements, dispose of them correctly and reduce the impact on the environment".* Some of the negative aspects of the e-waste management strategies of the University are the higher costs and the long logistical chain. According to the interview

[16] Respondent 1: Staff member at SU Facilities Management, 11 August 2022

results, mixing waste types by the University community is one of the biggest challenges facing the e-waste strategy employed at the University (see Figure 5.6 below).

Figure 5.6: Mixing of waste in e-waste bins *Source: Field survey, July 2022*

When other waste types are thrown into e-waste bins, e-waste becomes contaminated and cannot be sent to the recyclers but to landfills. As Respondent 2[17] commented, *"If e-waste is separated from other waste and disposed of in the correct bin, those e-waste items can be sent for recycling"*. Another respondent[18] reported: *"even though the e-waste bins contain clear signage, students still throw other waste types in those bins, making recycling difficult"*. Another challenge facing the university's e-waste management is keeping e-waste safe. As Respondent 1[19] reported: *"A challenge is keeping the bins in secure places as e-waste is*

[17] Respondent 2: Staff member at SU Facilities Management, 22 March 2022

[18] Respondent 1: Staff member at SU Facilities Management, 11 August 2022

[19] Respondent 1: Staff member at SU Facilities Management, 11 August 2022

valuable". One way of dealing with the challenge is by placing locks on the e-waste bins, as shown in Figure 5.7 below.

Figure 5.7: Locks on e-waste bins *Source: Field survey, July 2022*

5.2.2 E-waste generation

The next section of the questionnaire focused on the volume of e-waste generated at Stellenbosch University from January 2019 to July 2022, as seen in Table 5.1.

Table 5.1: E-waste generation at SU from 2019 to 2022 (kg)

Years	Quantity of e-waste (kg)
January to December 2019	6 678 kg
January to December 2020	2 714 kg
January to December 2021	4 847 kg
January to July 2022	7 599 kg

According to the data in Table 5.1 above, Stellenbosch University generated 6 678 kg of e-waste from January 2019 to December 2019. This amount decreased to 2 714 kg from January 2020 to December 2020. From January 2021 to December 2021, the amount of e-waste generated at the University increased to 4 847 kg, and from January 2022 to July 2022, Stellenbosch University generated the most e-waste during these four years.

5.3 E-WASTE KNOWLEDGE, AWARENESS AND ATTITUDES

This section of the chapter presents the results of the online questionnaire survey collected from the University community. Objective four of this study aimed to explore the University community's knowledge, awareness and attitude related to e-waste. This section of the chapter seeks to present the results of Sections A, B, C, and D of the questionnaire survey, which focuses on the University community's knowledge, awareness, and attitudes about e-waste.

5.3.1 Demographic profile

This section presents a demographic profile of the survey population regarding gender, age, faculty, staff and study, and study year (Section A). Table 5.2 overleaf illustrates an overview of the demographic profile of the respondents. As mentioned previously, at the end of the survey period, data had been collected from 986 respondents, 610 (62%) identified as female and 357 (36%) as male. Nineteen (2%) respondents preferred not to disclose their gender during this study. The majority of the respondents were 18 to 24, constituting 628 (64%) respondents, while only 19 (2%) of the respondents belonged to the 56 to 65 plus age group. It can be seen from the data in Table 5.2 below, most of the respondents were from the Economics and Management Sciences (21%), Arts and Social Sciences (19%), and Medicine and Health Science faculties (15%). The lowest response rates were from the Law (4%), Military (1%) and Theology (1%) faculties (see Table 5.2). The online survey documented the views of staff and students, of which the majority were student respondents (92%), while 8% were the staff. Of the student respondents, the majority were undergraduates (57%), while 43% were postgraduate students.

Table 5.2: Demographic profile of respondents

Variable	Frequency *(N)*	Percentage (%)
GENDER		
Male	357	36%
Female	610	62%
Prefer not to say	19	2%
AGE		
18-24	628	64%
25-35	192	19%
36-45	101	10%
46-55	46	5%
56-65+	19	2%
FACULTY		
AgriScience	78	8%
Arts and Social Sciences	184	19%
Economics and Management Sciences	212	21%
Education	60	6%
Engineering	114	12%
Law	44	4%
Medicine and Health Sciences	152	15%
Military Sciences	9	1%
Science	124	13%
Theology	9	1%
STUDENT & STAFF		
Students	906	92%
Staff	80	8%
STUDENT STUDY LEVEL		
Undergraduate	519	57%
Postgraduate	387	43%

5.3.2 Sentiment towards recycling

This section presents the questionnaire survey results of Section B, which aimed to determine respondents' sentiment toward recycling. However, before focusing on respondents' recycling practices, it was first important to understand respondents' general attitudes towards the environment. Respondents were thus asked to indicate whether they considered themselves environmentally conscious and were expected to justify their answers. Most respondents considered themselves environmentally conscious 749 (76%), as seen in Figure 5.8.

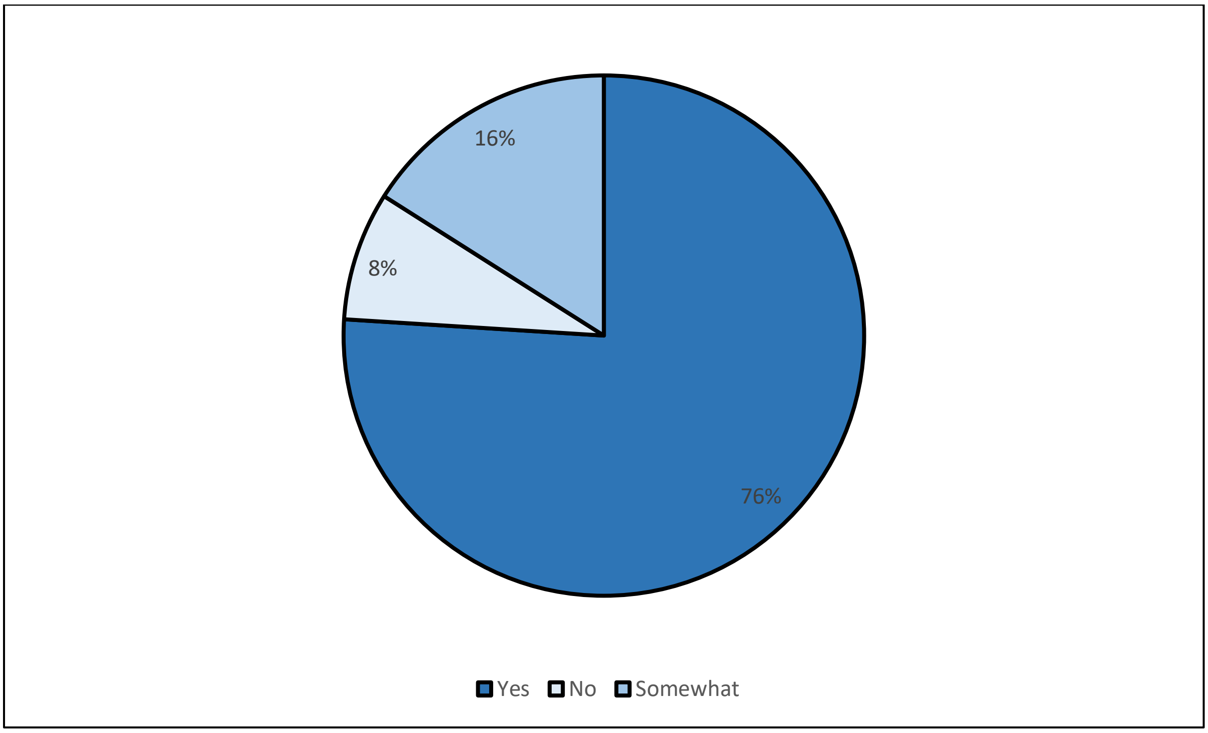


Figure 5.8: Respondents' environmental consciousness

Respondents gave multiple justifications for their answers to the question; however, five key themes were identified. The themes identified in these responses are shown in Figure 5.9. According to the results, most respondents considered themselves environmentally conscious because they reduce, reuse, and recycle their waste (89%). The four common ways respondents reduce, reuse, and recycle their waste were reducing water and electricity usage (62%), reducing single-use plastic products (72%), composting and worm farming (32%), and separating and recycling waste (70%). Interestingly, respondents reported making econ-bricks (15%) by reusing plastic bottles and plastics. Other reasons why respondents considered themselves to be environmentally conscious were because they are aware of the environmental issues (40%), use environmentally friendly products (23%) and transport (8%), and make sustainable food choices (7%). As some respondents commented:

Respondent 211 [20]: *"Yes, I carry a reusable bag, I don't buy coffee without using my cup, I bring my own Tupperware to restaurants/for takeout. I recently got a car that I named'*

[20] Respondent 221: SU student, 12 April 2022

Greta' after Greta Thunberg. I do not use the aircon unless I am about to pass out from heat exhaustion, and I am fuel conscious in that I prefer travelling with more than one person and I do not travel unnecessarily long distances. My family and I also have a vegetable compost that nourishes our vegetable and fruit garden that produces our main vegetable source of rape and pumpkin leaves. This season has been bountiful in naartjies and spinach too. We water our garden with our JoJo tanks, we have three."

Respondent 324[21]: *"Yes, whenever I can I try to be sustainable; using glass bottles instead of plastic, using glass straws, buying new clothes only when entirely necessary. I also try to incorporate environmentally consciousness in subtle ways that I can; wearing a tote bag saying 'planet over plastic', promoting sustainability on my social media accounts."*

Respondent 351[22]: *"Yes, our household doesn't eat meat, doesn't use plastic bags, recycles everything that is recyclable, fills and eco-brick with everything that's not, and feeds all compost to our worm farm."*

Another interesting finding from the responses (23%) to this question is that many respondents reported that they do not partake in fast fashion but instead invest in supporting slow fashion brands. As respondents 364 and 575 reported:

"I'd like to think of myself as an environmentally conscious being… I avoid participating in the consumption of fast fashion, as I am aware of its intense impact on the environment. I advocate for the boycott of business like Shein and Wish, who are not transparent in their practice, and make use of unethical and damaging sweatshops to complete their work. I am passionate about the topic of environmental consciousness."[23]

"Very much so, when it comes to clothing, I try get as much as possible from slow fashion brands. I am a big believer in repurposing items and fighting against over consumption of goods. I keep one-use plastics to a minimum."[24]

[21] Respondent 324: SU student, 12 April 2022

[22] Respondent 351: SU student, 12 April 2022

[23] Respondent 364: SU student, 12 April 2022

[24] Respondent 575: SU student, 13 April 2022

Overall, it can be concluded from the responses that the respondent sample of the University community felt they were environmentally conscious because they reduce, reuse, and recycle their waste.

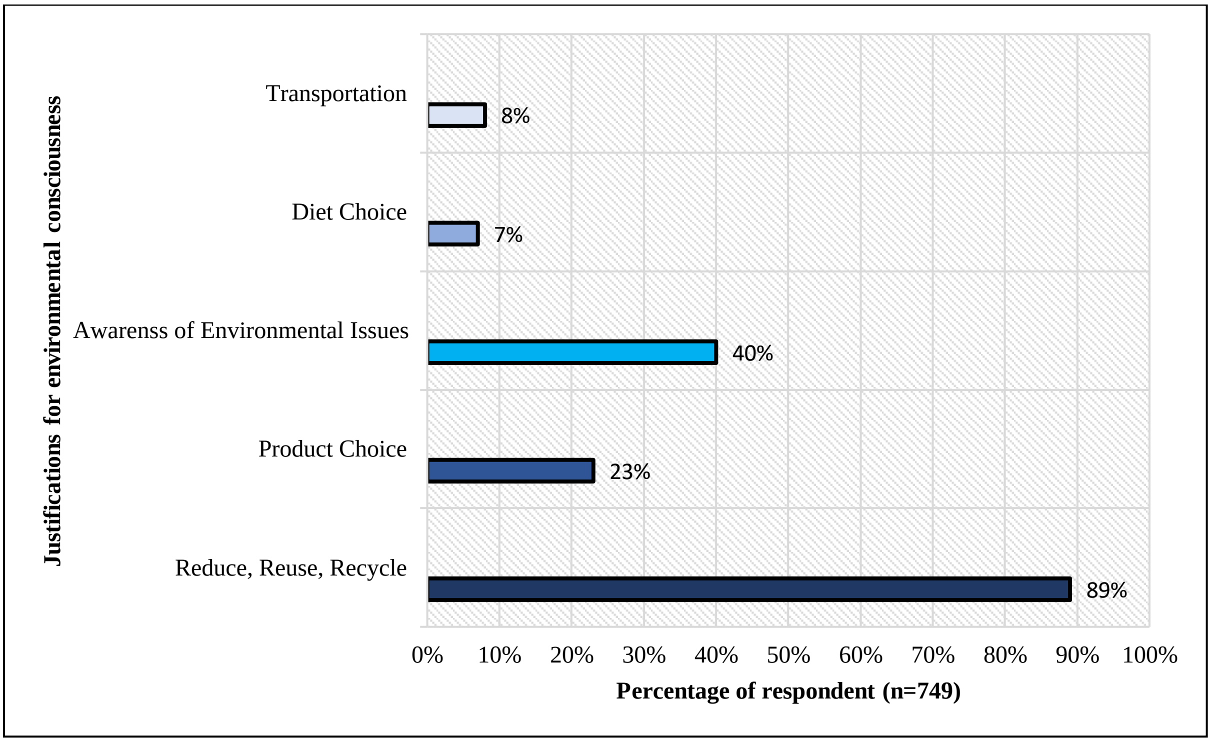


Figure 5.9: Respondents' justification for environmental consciousness (n = 749)

On a five-point system from "Not Important" to "Very Important," respondents were asked to use their judgement regarding the importance of recycling different waste types. These waste types were *batteries, electronics, paper, plastic, and metals* (Table 5.3). According to respondents, all six waste types had a high recycling importance rate, with at least 80% of the respondents reporting that recycling these waste types is either "Important" or "Very Important". However, respondents reported that the waste type with the most significant recycling importance is plastic with an average rating of 4.83, followed by batteries and electronics, with an average rating of 4.49, respectively. It can be seen from the data in the table below, although paper had a high average rating, it had the lowest recycling important compared to the other wastes, with an average rating of 4.38.

Table 5.3: Waste recycling importance

	Not Important (1)	Somewhat Important (2)	Neutral (3)	Important (4)	Very Important (5)	Average Rating
Batteries	10 (1%)	27 (3%)	75 (7%)	227 (23%)	647 (66%)	4.49
Electronics	7 (1%)	23 (2%)	79 (8%)	248 (25%)	629 (64%)	4.49
Paper	10 (1%)	45 (5%)	85 (9%)	268 (27%)	578 (57%)	4.38
Glass	8 (1%)	24 (2%)	73 (7%)	297 (30%)	584 (59%)	4.45
Plastic	6 (1%)	4 (%)	16 (2%)	99 (10%)	861 (87%)	4.83
Metals	2 (%)	21 (2%)	87 (9%)	274 (28%)	602 (61%)	4.47

Results relating to respondents' recycling practices are set out in Table 5.4 overleaf. From the data in Table 5.4, there was a high level of recycling practices reported by most respondents 866 (88%). They would justify this by noting that they are either currently or have recycled waste before, while only 120 (12%) of respondents indicated that they have never recycled any waste before. Amongst the different waste types, plastic was the most recycled, 772 (26%), followed by paper, 746 (25%) and glass, 628 (21%), while batteries 284 (9%) and electronics (8%) were the least recycled waste types amongst the respondents. Data from this table can be compared with the data in Table 5.3 above. Although batteries and electronics had a higher recycling importance rate than paper (Table 5.3 above), batteries 283 (9%) and electronics 241 (8%) had the lowest recycling rate (Table 5.4).

Table 5.4: Respondents' recycling practices

Item	Count	Percentage (%)
RECYCLED WASTE BEFORE		
Yes	866	88%
No	120	12%
TYPES OF WASTE RECYCLED		
Batteries	283	9%
Electronics	241	8%
Paper	746	25%
Glass	623	21%
Plastic	772	26%
Metal	331	11%
DISTANCE WILLING TO TRAVEL FOR RECYCLING		
Less than 1Km	271	28%
1 Km to 5 km	427	43%
5 Km to 10 Km	209	21%
More than 10 km	79	8%
PREVENT RECYCLING		
Lack of drop-off points	759	77%
Lack of knowledge	324	33%
Lack of transport	378	38%
Lack of time	433	44%
Do not care	17	2%

While the majority of respondents seemed to be familiar with recycling and are practising this, the survey also wanted to determine if there might be any factors that could potentially enhance or deter recycling practices. In response to the question: *"How far are you willing to travel to recycle your waste?"* the majority of the respondents were not willing to travel more than 5 km to recycle their waste, as most respondents reported they are only willing to either travel less than one km, 271 (28%), or 1 km to 5 km, 421 (43%). Only a few respondents indicated they were willing to travel 5 km or more (Table 5.4). According to the questionnaire survey results, lack of recycling collection points, 759 (77%), and lack of awareness, 433 (44%), were the most common obstacles preventing respondents from recycling their waste. Seventeen (2%) respondents admitted not caring about recycling. The remaining respondents attributed the lack of transport and knowledge as obstacles that prevent them from recycling, with 378 (38%) and 324 (33%) respondents, respectively.

5.3.3 E-waste knowledge and awareness

This chapter section focuses on presenting the results of respondents' e-waste knowledge and awareness. The results relate to Objective three of this study, which analyses the University community’s knowledge, awareness, and attitudes about e-waste. As part of this section, the results from Section C of the questionnaire survey will be presented which focused on respondents’ knowledge and awareness of e-waste, as well as their recycling attitude and practices.

Table 5.5 overleaf sets out e-waste awareness amongst the survey population. According to the questionnaire survey results, the respondents were highly aware of the term e-waste, as the majority reported that they had heard the term before 732 (74%) (Table 5.5). While on a minority, 251 (26%) of the survey population has never heard of the term e-waste before. Most respondents, 351 (40%), became aware of e-waste through reading about it. A respondent commented[25]: “*Yes, I have as I come across an article by the BBC about how some West African countries such as Ghana have huge issues with e-waste from Europe being dumped on their shores.”* Another respondent[26] commented: *“Just once in passing. I was reading through Google News and saw an article. I did not really have an interest to read it, but I did see the title and brief description.”* Other sources of information on e-waste were schools 168 (19%) and social media (18%).

Interestingly, six (1%) of the respondents heard of the term in-store. Respondent 27[27] said: *“Yes. My first exposure was the huge campaign by Makro, including their large e-waste containers at all their sites.”* Another respondent[28] indicated: “ Yes, *I have. I know about the Woolworths waste initiative in their stores, and there is a ready drop-off centre near Hudson’s.”* Schools, 168 (19%), were a more significant source of e-waste information than Stellenbosch University 7 (1%), as the University was the second lowest e-waste information source.

---

[25] Respondent 18: SU staff member, 12 April 2022

[26] Respondent 862: SU student, 19 May 2022

[27] Respondent 200: SU student, 12 April 2022

[28] Respondent 337: SU student, 12 April 2022

Table 5.5: E-waste awareness amongst respondents

Variable	Frequency *(N)*	Percentage (%)
HEARD THE TERM E-WASTE BEFORE		
Yes	732	74%
No	251	26%
SOURCE OF INFORMATION		
School	168	19%
Read	351	40%
Social Media	163	18%
Studies	52	6%
TV	101	11%
Store	6	1%
Friends/Family	37	4%
Campus	7	1%

In response to the question *"Have you heard about e-waste before?"*, 634 (64%) of the respondents provided their understanding of what e-waste is, while the remaining did not. The results were satisfactory in establishing what is meant by e-waste and what respondents understood when they heard the term. Amongst the respondents, there was an above-average level, 630 (63%), of understanding of e-waste. The key phrases that recurred throughout respondents' understanding of the term e-waste were *"electronic waste", "discarded electronics", "old electronic devices", and "broken electronics"*. The comments below show some of the respondents' understanding of e-waste:

Respondent 17[29]: *"Yes. It means electronic waste. It's technological gadgets/equipment that is being thrown away."*

Respondent 180[30]: *"Yes. E-waste is electronic waste. It's the reason apple claims they no longer provide a charger in the box. E-waste comes up a lot in the media lately."*

Respondent 439[31]: *"Yes, e-waste pertains to old appliances of an electronic nature that are disposed of or are no longer in use."*

Respondent 465[32]: *"Yes. It is waste from electronic devices – old devices, old parts, etc."*

[29] Respondent 17: SU staff member,12 April 2022

[30] Respondent 180: SU student, 12 April 2022

[31] Respondent 439 : SU student, 12 April 2022

[32] Respondent 465: SU staff member, 12 April 2022

Interestingly, the remaining 4 (1%) did not understand what e-waste referred to. These respondents *(n=4)* thought e-waste referred to email-related issues. As Respondent 213[33] argued: "*... from my understanding of e-waste, I have heard that sending emails can contribute to pollution, but I have yet to research the mechanisms behind this."* Another respondent argued: *"... All the unwanted emails from marketers that clog up systems."*

Table 5.6: Knowledge and awareness of the e-waste problem

Variable	Frequency *(N)*	Percentage (%)
Think there is an e-waste problem		
Yes	766	74%
No	59	6%
N/a	205	20%

While general understanding and knowledge about e-waste was important to document, the survey also wanted to link this to wider global awareness of e-waste. Table 5.6 above presents the survey community's awareness of the global e-waste problem. According to the questionnaire survey results, awareness of the global e-waste problem was high among the respondents, as most (74%) indicated that there is an e-waste problem because of various reasons (see Figure 5.10). Only a small number of respondents (6%) responded that there is no e-waste problem. As seen in Table 5.6, the 205 respondents who answered N/A were those who had never heard of e-waste before.

When asked to provide reasons for their answer, only 321 (33%) of the respondents knew why there is a global e-waste problem. From this, five key reasons were identified: *lack of proper disposal, pollution of the environment, high electronics consumption, lack of e-waste knowledge, and high quantities of e-waste* (Figure 5.10). Among the respondents (n=321), most (39%) reported there is a global e-waste problem because there is a lack of proper disposal of electronic devices. Responding to this issue, Respondent 547[34] answered: "*Yes, with electronic waste, many people do not know how to dispose of it. I am one of those people."* Another respondent[35] reported: *"Yes. A lot of electronic devices that are broken just end up at the*

[33] Respondent 213 : SU student, 12 April 2022

[34] Respondent 547: SU student, 12 April 2022

[35] Respondent 655: SU student, 17 April 2022

landfill or a dumpsite. It is not properly stripped for parts that can be re-used and people tend to throw their electronic devices away when they can upgrade to a newer version; instead of donating or selling those devices to others who can use it."

The second most common reason for the global e-waste problem according to respondents *(n=321)* was because e-waste pollutes the environment (20%), followed by high consumption of electronic devices (17%), and a lack of awareness (12%) and high quantities (12%) of e-waste, respectively (Figure 5.10).

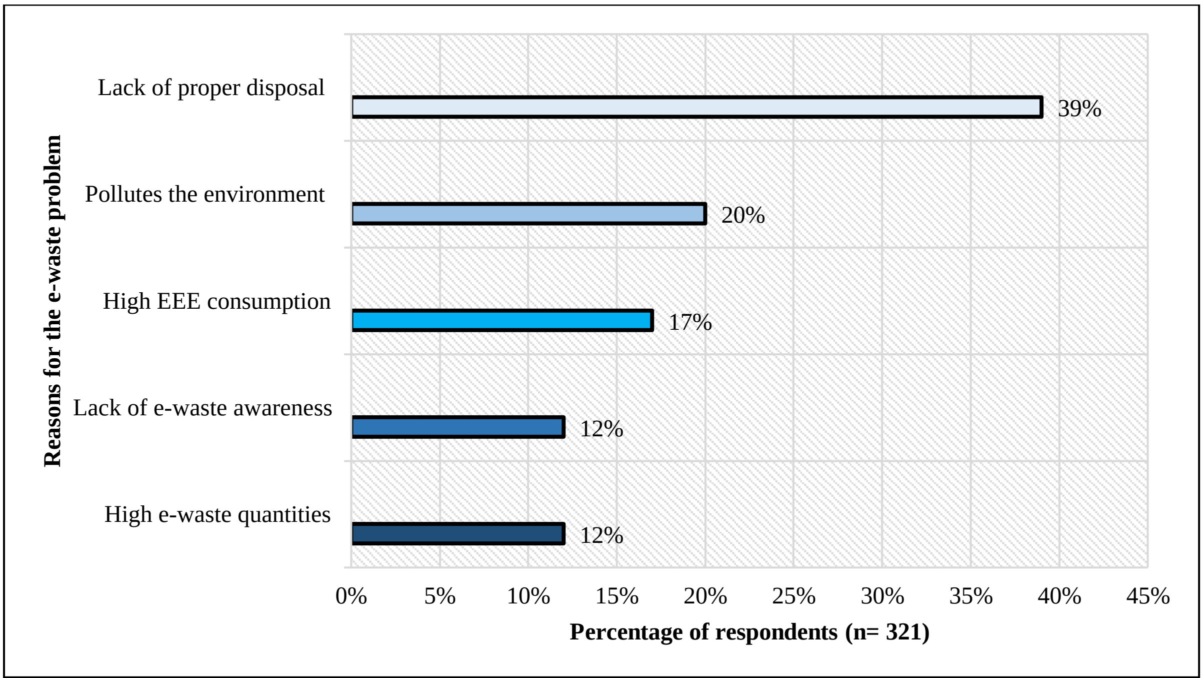


Figure 5.10: Respondents' reasons for the e-waste problem

The questionnaire survey further aimed to understand respondents' level of awareness of e-waste and its related issues. Respondents were asked to rate whether they agreed or disagreed with a range of statements using a five-point Likert scale (1 = Strongly disagree, 2 = Disagree, 3 = Natural, 4 = Agree and 5 = Strongly agree). Some of the statements were factually correct, and some were factually incorrect. This helped to determine whether respondents were aware of e-waste and to allow for an introduction to respondents' understanding of e-waste impacts and disposal methods. Table 5.7 below sets out the respondent's knowledge of e-waste. For both statements, the majority of respondents agreed (scale 4) with the notion that there is a global (42%) and national (43%) e-waste problem (Table 5.7). According to the results, respondents had a high level of awareness of proper e-waste disposal as the majority of the respondents strongly disagreed (scale 5) with the notion that e-waste should be landfilled and incinerated, 441 (45%) and 395 (40%), respectively. However, it is apparent from Table 5.7 below that respondents were unsure whether e-waste should be stored, as most reported natural (42%) to the statement.

Table 5.7: Respondents' knowledge of and attitudes toward e-waste

	Strongly Disagree (1)	Disagree (2)	Neutral (3)	Agree (4)	Strongly Agree (5)	Average Rating
Globally, there is currently a massive e-waste problem	2 (1%)	11 (1%)	119 (119%)	412 (42%)	362 (37%)	4.14
There is an e-waste problem in South Africa	3 (1%)	16 (2%)	228 (22%)	424 (43%)	315 (32%)	4.05
Broken, obsolete or redundant electronic devices are harmful to the environment and human health	3 (1%)	31 (3%)	170 (17%)	425 (43%)	375 (36%)	4.12
Electronic devices should be disposed of in landfills	441 (45%)	315 (32%)	155 (16%)	147 (5%)	28 (2%)	1.89
Electronic devices should be incinerated (burnt)	395 (40%)	302 (31%)	212 (22%)	154 (5%)	23 (2%)	1.99
Electronic devices should be stored	137 (14%)	250 (25%)	417 (42%)	142 (15%)	40 (4%)	2.69
Electronic devices should be recycled	6 (1%)	2 (1%)	52 (4%)	308 (31%)	618 (63%)	4.55

From the responses, it could also be gleaned that there were high levels of awareness that e-waste is harmful to the environment and human health, as the majority of the respondents either agreed, 424 (43%), or 375 (36%) strongly agreed with statement three (Table 5.7 above). However, when asked to rate their level of knowledge as either *"Good," "Okay", or "Poor,"* most respondents indicated they had poor knowledge of the environmental effects, 509 (52%), and health effects, 520 (56%), caused by e-waste (Table 5.8). Moreover, the majority (66%) of the respondents had "poor" knowledge of the toxic materials found in e-waste (Table 5.8). Similarly, as the data in Table 5.8 illustrates, there was minimal knowledge of the national waste management policy and e-waste policy, as the majority reported they had "poor" knowledge of the national waste management policy, 809 (82%), and e-waste management policy, 912 (12%).

Table 5.8: Respondents' level of knowledge of e-waste

Questions	Options	Number (%)
How much do you know about the national waste management policy?	Good Okay Poor	59 (6%) 118 (12%) 809 (82%)
How much do you know about the nation's electronic devices/e-waste management policy?	Good Okay Poor	19 (2%) 55 (6%) 912 (92%)
How much do you know about the materials used in electronic devices/e-waste?	Good Okay Poor	151 (15%) 210 (21%) 625 (64%)
How much do you know about the effects of electronic devices/e-waste on the environment?	Good Okay Poor	209 (21%) 268 (27%) 509 (52%)
How much do you know about the effects of electronic devices/e-waste on human health?	Good Okay Poor	169 (19%) 230 (25%) 520 (56%)
Your knowledge of any valuable materials found in electronic devices/e-waste?	Good Okay Poor	330 (33%) 186 (19%) 470 (48%)
Your knowledge of any toxic materials found in electronic devices/e-waste?	Good Okay Poor	347 (10%) 237 (20%) 406 (66%)

5.3.4 Awareness of e-waste recycling on campus

This study used Stellenbosch University as a case study to collect data on e-waste knowledge, practices, and awareness of e-waste management systems on campus. Respondents were asked if they knew of any campus e-waste management initiatives.

The survey showed very limited awareness about any e-waste management initiatives on campus (8%). Respondents were asked to elaborate on which e-waste management systems or initiatives they were aware of on campus. Four different e-waste initiatives on campus were identified from the online questionnaire surveys. Respondents were aware of the e-waste initiative that took place once a year on campus which encourages the University community to bring their e-waste for recycling on campus (n=2). Respondent 855[36] commented on the

[36] Respondent 855 : SU student,19 May 2022

question: *"Yes, there's a week in a year where we are encouraged to drop e-waste on campus."* Other respondents were aware that the IT Hub handled e-waste *(n=7)*. However, respondents did not know how the IT Hub handled e-waste on campus. Similar results were found when respondents *(n=4)* reported that they were aware that the Facilities Management of Stellenbosch University deals with e-waste on campus. However, respondents did not know what they did. As Respondent 645[37] stated: *"The facility management team does a great job of recycling e-waste on campus."* Another respondent[38] stated: *"Yes, within the Facility Management team they handle all e-waste on campus, not exactly sure how."* Furthermore, some respondents were aware of the e-waste recycling bins on the Stellenbosch University campus *(n=62)*. As some respondents reported:

Respondent 17[39]: *"Yes. There are bins put out for e-waste or you can drop it outside the IT office."*

Respondent 21[40]: *"Yes - e-waste bins are going to be more frequently available on campus."*

Respondent 200[41]: *"They have placed yellow bins in the res hubs and computer user area on campus."*

Respondent 331[42]: *"I have recently seen some yellow bins around campus initiating this."*

Respondents were further questioned on their awareness of the e-waste recycling bins around campus to gain insight into their awareness of the e-waste recycling drop-off points available on campus. Respondents were first asked whether they had access to e-waste recycling facilities or drop-off points, to which most reported that they did not have access, 755 (77%). However, most respondents, 896 (91%), were unaware of the e-waste recycling (yellow bins) available around campus. Most respondents felt there is not enough awareness of e-waste on campus (79%).

---

[37] Respondent 654 : SU student, 12 April 2022

[38] Respondent 982 : SU staff member, 30 May 2022

[39] Respondent 17: SU staff member, 12 April 2022

[40] Respondent 21: SU student, 12 April 2022

[41] Respondent 200: SU student, 12 April 2022

[42] Respondent 331: SU student, 12 April 2022

The remaining 90 (9%) were aware of the e-waste recycling bins on campus. However, when further questioned about the bins, the results revealed that these respondents had minimal knowledge of them. Most respondents were aware of what colour these e-waste bins were on campus. However, when asked to indicate the locations of these bins on campus, only 27 (3%) could indicate some of the locations. The comments below show some of the respondents' awareness of the locations of the e-waste bins on campus:

Respondent 320[43]: *"At the IT hub on the main campus, there is a drop-off point for all e-waste products…"*

Respondent 576[44]: *"They're yellow and I've seen one in the Neelsie at the mid-level lifts (around the corner from the locksmith)."*

Respondent 722[45]: *"They are yellow, in the engineering SS."*

Respondent 931[46]: *"Yellow bins, I saw one located at Wimbledon hub."*

5.3.5 E-waste recycling practices and willingness on campus

This section of the chapter will present the results of the University community's e-waste recycling practices on campus and attitudes towards e-waste recycling on campus (Section D). E-waste recycling on campus was exceptionally low, as only 25 (3%) responded positively to the question: *"Have you recycled e-waste on campus before?"* However, there was a positive response amongst the survey population when asked if they would recycle their e-waste on campus if the University created more awareness of e-waste recycling options available on campus. To this question, most respondents reported yes, 669 (68%), and 285 (29%) reported maybe. Only a small number of respondents reported that they would not recycle their e-waste on one campus.

Figure 5.11 overleaf shows the different types of e-waste recycled by the University community on campus. Batteries *(n=10)* were the top e-waste type recycled on campus. As Respondent 152[47] stated: *"I have recycled batteries of old phones on campus before."* Cables

[43] Respondent 320: SU student, 12 April 2022

[44] Respondent 576: SU student, 30 May 2022

[45] Respondent 722: SU student, 18 May 2022

[46] Respondent 931: SU staff member, 23 May 2022

[47] Respondent 152: SU student, 12 April 2022

(n=8) were the respondents' second most recycled waste type. In response to this question, Respondent 204[48] stated: *"Yes, I have. It was a cable charger that I noticed it was no longer working when I was at the campus."* Another respondent stated: [49]*"I recycled a power bank cable that no longer works."* From the data in Figure 16, other e-waste types recycled on campus by respondents were cell *phones (n=4),* laptops *(n=4),* light bulbs *(n=3),* earphones *(n=2),* ink cartridge *(n=1),* diodes *(n=1),* speaker *(n=1),* lamps *(n=1)* and keyboard *(n=1).* The comments below show respondents' comments when asked which types of e-waste they recycled on campus:

Respondent 215[50]: *"Yes. A broken fan, old headphones, and an old phone."*
Respondent 719[51]: *"Yes, diodes I used from class"*
Respondent 942[52]: *"Yes. I threw old batteries into the e-waste bin by the IT hub"*

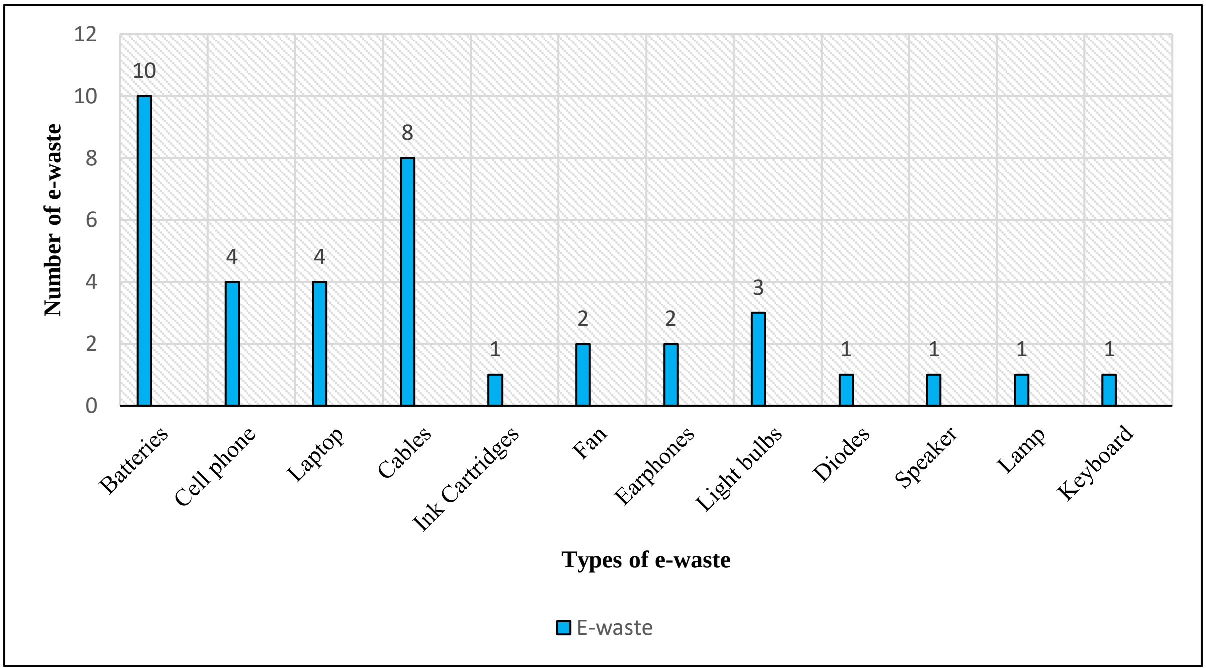


Figure 5.11: Types of e-waste recycled on campus by respondents'

[48] Respondent 204: SU staff member, 12 April 2022
[49] Respondent 727: SU student, 18 May 2022
[50] Respondent 215: SU student, 12 April 2022
[51] Respondent 719: SU student, 18 May 2022
[52] Respondent 942: SU student, 23 May 2022

Respondents were asked to rate whether they agreed or disagreed with a range of statements using a five-point Likert scale (1= Strongly disagree, 2= Disagree, 3= Natural, 4 = Agree and 5= Strongly agree), as seen in Table 5.9.

Table 5.9: Respondents' attitudes and perceptions of e-waste

	Strongly Disagree (1)	**Disagree (2)**	**Neutral (3)**	**Agree (4)**	**Strongly Agree (5)**
1. Our university has the potential of generating large quantities of volumes of electronic waste	5 (1%)	18 (2%)	108 (10%)	464 (47%)	391 (40%)
2. There is limited knowledge, information and clarity about e-waste and the university's electronic waste management and recycling	9 (1%)	12 (1%)	133 (14%)	436 (44%)	396 (40%)
3. I am interested in knowing more about e-waste and the university's e-waste management and recycling	20 2%	69 7%	148 15%	424 43%	316 32%
4. The university should do more to create awareness about electronic waste among students	2 (1%)	4 (1%)	76 (7%)	391 (39%)	513 (52%)

The majority of the respondents either agreed (44%) or strongly agreed (40%) that there is limited information available to them about e-waste and the University's e-waste management and recycling systems on campus (Table 5.9). Most respondents agreed (43%) that they would like to know more about e-waste and the University's e-waste management and recycling systems and strongly agreed (52%) that the University should do more to create awareness about e-waste among the University community. Furthermore, respondents were asked to indicate their willingness to recycle e-waste on campus ranging from *"Not very willing"* to *"Very willing."* The e-waste types listed were mobile phones, large home appliances, medium home appliances and small home appliances.

As can be seen in the data in Figure 5.12 overleaf, the e-waste type respondents are most willing to recycle on campus is small home electronic equipment. Here, most respondents reported that they are willing (46%) and very willing (37%) to recycle these electronics on campus. Most respondents were also wary to recycle mobile phones on campus (38%). For large home appliances, the e-waste type respondents were least inclined to recycle on campus, indicated by 13% of the respondents.

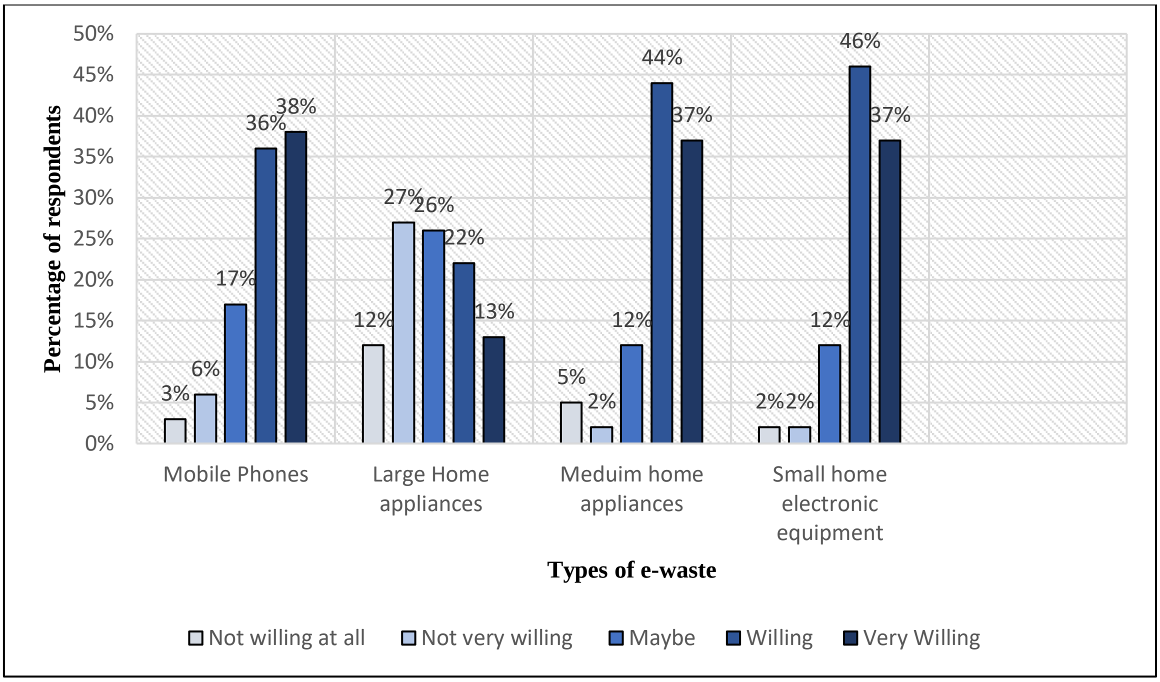


Figure 5.12: Respondents' willingness to recycle different types of e-waste on campus

5.4 WASTE MOBILE PHONES AND DISPOSAL METHODS

Objective five of this study is to explore the primary disposal methods and reasons for the disposal of WMP amongst the University community. Mobile phones are widely used by people and have become an indispensable part of daily life and work activities. Data collection, therefore, included specific questions on mobile devices and how the respondents disposed of obsolete devices. This section of the chapter aims to present the results of Section E of the questionnaire survey, which focuses on the University community's mobile phone consumption patterns, how WMP is disposed of and reasons for disposal, and which obstacles hinder recycling WMP.

5.4.1 Mobile phone consumption patterns

In this section of the questionnaire, respondents were first asked to rank the following five electronic devices from *"most often used"* to *"use least often":* desktop computer, laptop, tablet, mobile phone, and e-reader (see Figure 5.13). According to the results, respondents (85%) ranked mobile phones as the most often used electronic devices. This was followed by laptops and desktop computers, 9% and 4% respectively. E-readers 1% and tablets 1% were used the least often among the survey population (Figure 5.13).

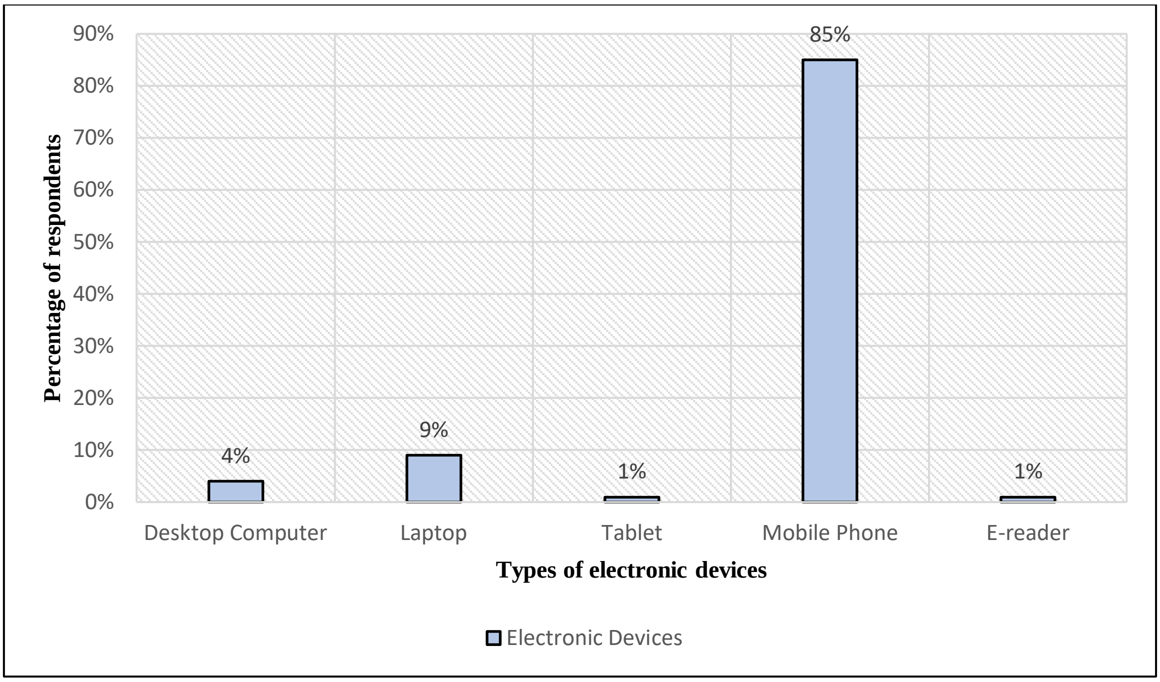


Figure 5.13: Electronic devices most frequently used

Table 5.10 further demonstrates the respondent's mobile phone ownership and usage consumption patterns. The majority of the respondents only owned and used between one and one to two mobile phones, 959 (96%). Even though the majority (59%) of the respondents do not have functioning mobile phones that they do not use, many respondents reported that they have one to two, 407 (41%), three to four, 33 (3%) and more than four, 2 (1%).

Table 5.10: Respondents' mobile phone consumption patterns

Questions	Frequency *(N)*	Percentage (%)
How many mobile phones: Working and in use?		
Less than One	4	1%
One-Two	959	96%
Three-Four	22	2%
More than Four	1	1%
How many mobile phones: Working but not in use?		
None	544	55%
One-Two	407	41%
Three-Four	33	3%
More than Four	2	1%
How many mobile phones: Broken?		
Less than One	583	59%
One-Two	333	34%
Three-Four	58	5%
More than Four	12	1%
How many mobile phones have you replaced in the past five years?		
None	4	1%
One	296	30%
Two	565	60%
Three	89	9%
Fourth	0	0%
Average: 2.3		
How do you usually get/acquire your mobile phone?		
Buy (new)	612	53%
Contract Renewal	163	14%
Gift	147	13%
Passed down	156	14%
Purchase second handy	64	6%

The survey data identified five different means of mobile phone replacement. This is either through *purchasing new, contract renewal, gift, passed down, or purchasing second-hand*. On average, the majority of the respondents replace their mobile phones every two years, 565 (60%), and the average replacement rate of 2.3 years. This was either done through purchasing a new phone, 612 (53%), or through mobile phone contract renewal (14%). As some respondents reported:

Respondent 68[53]: *"I get a new phone when my contract renews every two years."*

Respondent 179[54]: *"I purchase one whenever I need a new phone."*

Respondent 398[55]: *"Usually my parents buy me a new phone."*

Respondent 598[56]: *"Through a contract at Vodacom and I only get a new phone when my contact needs to be renewed every 24 months."*

Respondent 883[57]: *"Get a new phone on a 24-month contract."*

Of the 986 respondents, 220 (20%) of them replaced their mobile phones with second-hand mobile phones. These respondents (n=220) either replaced their old mobile phones with second-hand, passed-down mobile phones, 156 (14%), or by purchasing, 64 (4%), second-hand mobile phones. As some of the respondents reported:

Respondent 346[58]: *"I usually buy my phones second-hand,"*

Respondent 953[59]: *"Buy second-hand phone from someone,"*

Respondent 915[60]: *"Either my parents or my older sibling will give me their old phone,"*

Respondent 943[61]: *"I get my parents' old phones when they upgrade their contracts,"*

The remaining 147 (13%) respondents replaced their old mobile phones because they were gifted one. However, these respondents (n=147) did not disclose the conditions of the mobile phone. Overall, the results indicated that respondents replaced their old mobile phones every two years with brand-new ones.

5.4.2 Waste mobile phone disposal practices

Table 5.11 overleaf shows the survey population's WMP disposal practices. Five categories were identified when respondents were asked the primary reasons for replacing mobile phones:

[53] Respondent 68: SU staff member, 11 April 2022
[54] Respondent 179: SU student, 12 April 2022
[55] Respondent 398: SU student, 12 April 2022
[56] Respondent 598: SU student, 12 April 2022
[57] Respondent 883: SU student, 19 May 2022
[58] Respondent 346: SU staff member, 12 April 2022
[59] Respondent 915: SU student, 19 May 2022
[60] Respondent 953: SU student, 19 May 2022
[61] Respondent 943: SU student, 19 May 2022

better feature/new technology, software or hardware obsolescence, theft, contract renewal, and broken.

Table 5.11: Waste mobile phone disposal practices

Variable	Frequency *(N)*	Percentage (%)
Current disposal practice		
Recycle e-waste	75	6%
Leave in Storage	635	48%
Sell as second-hand	379	29%
Throwaway with normal waste	43	3%
Sell as scrap metal	22	2%
Gift/Pass down	167	12%
Primary reason for disposal		
Better features/New technology	329	25%
Software or Hardware Obsolescence	437	34%
Theft	76	6%
Contract Renewal	198	15%
Broken	254	20%
Obstacles to WMP recycling		
Cost	44	4%
Convenience	101	10%
Lack of awareness	225	23%
Lack of recycling facilities	616	63%

According to the results, most respondents replaced their old mobile phones due to software and hardware obsolescence, 437 (34%) (Table 5.11). Regarding software obsolescence, many respondents reported that their old mobile phones could not support the latest software updates, 366 (44%). Furthermore, in terms of hardware obsolescence, respondents reported hardware issues such as a faulty battery, 71 (23%), and limited phone storage, 66 (20%), while others reported that their Random-Access Memory (RAM), 61 (18%), was too old to process the latest software updates, which in turn slowed their mobile phones' functioning. The comments below show respondents' accounts of mobile phone software and hardware obsolescence:

Respondent 11[62]: *"No longer has the function capacity I need (i.e., storage, outdated software, etc.)."*

Respondent 48[63]: *"Previous phone's software is old, and the operating system is slower."*

[62] Respondent 11: SU student, 11 April 2022

[63] Respondent 48: SU student, 11 April 2022

Respondent 108[64]: *"Phone battery is weak/ slow processing speeds/ more data storage needed."*

Respondent 663[65]: *"The battery packs up and needs replacement after 2 years and phone can't be opened to replace battery like iPhone."*

Respondent 701[66]: *"Old one does not work anymore either due to not finding a good battery for it anymore, or too little storage space or cannot be upgraded with reasonably up-to-date software anymore."*

Respondent 806[67]: *"Not getting OS updates anymore and you've got battery woes."*

The second most common reason respondents replaced their mobile phones was better technology, 329 (25%) (Table 5.11). Respondents reported that newer mobile phones offered better technological features such as *applications, software, battery life, storage, RAM, and camera quality*. As some respondents reported:

Respondent 283[68]: *"I want to upgrade to a better mobile phone. A new advanced phone always seems better than the one I use."*

Respondent 673[69]: *"New features in the device, and ability to run latest programs and other apps, also better screen resolution."*

Respondent 862[70]: *"Newer phones have better software and hardware with an increased battery life."*

Respondent 576[71]: *"Upgrade to better version with better camera quality."*

Other reasons for replacing old mobile phones, according to respondents, were due to breakage, 254 (40%), followed by mobile phone contract renewal, 198 (16%) and theft, 76 (6%) (Table 5.11). When respondents were asked how they disposed of their WMP, most respondents did not dispose of the WMP using proper e-waste disposal practices. This is because most respondents reported that they disposed of their WMP by leaving them in storage, 635 (43%),

---

[64] Respondent 108: SU student, 11 April 2022
[65] Respondent 632: SU student, 12 April 2022
[66] Respondent 701: SU staff member, 28 April 2022
[67] Respondent 806: SU student, 28 April 2022
[68] Respondent 283: SU student, 12 April 2022
[69] Respondent 673: SU student, 16 April 2022
[70] Respondent 862: SU student, 13 April 2022
[71] Respondent 576: SU student, 16 April 2022

while 43 (3%) threw their WMP away with regular waste. Only a small number of respondents disposed of their WMP according to proper disposal methods either through selling as second-hand, 379 (29%), passing it down, 167 (12%), and 75 (6%) through recycling. Of the respondents who do not recycle their WMP, lack of e-waste recycling facilities, 616 (63%), and a lack of awareness of proper disposal, 225 (23%), were reasons for not recycling WMP. Other reasons were due to lack of convenience and costs involved, 101 (10%), and 44 (4%) respondents, respectively.

5.5 CONCLUSION

This chapter presented the results of the data collected from the structured interviews with staff at Facilities Management and online questionnaire responses from the Stellenbosch University community. The results demonstrate the amount of e-waste generated at the University and how it is managed. This chapter then presented the results of the survey population's knowledge, awareness of and attitudes towards e-waste, understanding of the global e-waste problem, sentiment towards recycling, and attitudes towards e-waste recycling. The chapter concluded by presenting the WMP disposal practices of the survey population.

CHAPTER SIX: DISCUSSION

6.1 INTRODUCTION

This qualitative study aimed to document and investigate the quantity of e-waste generated at Stellenbosch University and analyse the current e-waste management strategies employed; furthermore, to identify and analyse the University community's e-waste knowledge, attitudes, and disposal behaviours. The overarching aim of this study was reached with the results presented in Chapter Five of this thesis.

This chapter first discusses and interprets the key findings in the current literature on e-waste and will highlight and discuss the amount of e-waste generated at Stellenbosch University during given years, how the University manages this waste and the challenges the institution faces managing e-waste. Furthermore, this chapter will discuss patterns, trends and issues of the University community's knowledge and awareness of and attitudes toward e-waste. A key focus of this discussion will be on the patterns and trends of the WMP behaviour of the survey population. Drawing from this discussion, the implications of this on Stellenbosch University and the University community will be discussed. Finally, the contributions of this study will be discussed.

6.2 DISCUSSION OF RESULTS

Data for this study were derived from two separate online questionnaires. The first online questionnaire targets staff from Facilities Management at Stellenbosch University. This was because Facilities Management is tasked with managing waste on campus, including e-waste. A total of two responses were collected after the data collection period. The second online questionnaire targeted the University community, and 989 responses were collected. Respondents shared their knowledge and awareness of e-waste and its related issues, as well as their awareness about e-waste recycling on campus and WMP disposal practices. The discussion section is divided into five subsections below.

6.2.1 E-waste generation and management at Stellenbosch University

This study found that Stellenbosch University has the potential to generate high amounts of e-waste each year. In 2019, a total of 6 678 kg of e-waste was generated. Moreover, the most recent amount of e-waste collected during July 2022 was 7 599 kg. However, the present study found that during 2020 and 2021, the amount of e-waste generated on campus was significantly lower than that generated in 2019 and 2022. In 2020, only 2 714 kg of e-waste was generated; the following year (2021), a total of 4 847 kg was generated. The low amount of e-waste generated during these two years could be attributed to the global COVID-19 pandemic. On 26 March 2020, the national government of South Africa implemented a national lockdown which halted the operations of all nonessential businesses and institutions, including universities, to prevent the spread of the virus. Specific measures remained in place for multiple months, interrupting normal University operations from 2020 to early 2022. Therefore, during 2020 and 2021, Stellenbosch University did not operate as usual; thus, it could explain the lower amount of e-waste generated during these years. However, considering the high amounts of e-waste generated before and after the COVID-19 lockdown, the results suggest that the amounts of e-waste for 2020 and 2021 would have been much higher if there had not been a national lockdown due to COVID-19.

The high amount of e-waste generated at the University could be explained by the fact that universities are highly dependent on electronic equipment for their daily functioning (as discussed in Chapter 1); as a result, Chibunna et al. (2012) argue that these institutions undoubtedly have the potential to generate substantially high amounts of e-waste. Therefore, despite the low amounts of e-waste generated during 2020 and 2021, it is not surprising that this study found that Stellenbosch University has the potential to generate high amounts of e-waste, which makes it important to develop and implement e-waste management strategies (Chibunna et al. 2012).

Chibunna et al. (2012) suggest that universities are becoming more committed to sustainability; therefore, strategies for e-waste management are being integrated into their waste management policies. According to Stellenbosch University's website, the University is committed to enhancing systematic sustainability and envisages a greener campus through reducing, reusing, and recycling waste (Stellenbosch University n.d.). It can thus be suggested that due to the University's commitment to sustainability and high amounts of e-waste generated on campus, it is, therefore, not surprising that the present study found that Stellenbosch University has recognised the importance of managing its obsolete electronic devices and therefore developed and implemented two separate e-waste management strategies that focus on recycling, i.e., the *Non-Asset Registered E-waste* and the *Stellenbosch Asset E-waste*[72].

First, this study found that the *Non-Asset Registered E-waste* strategy focuses on recycling e-waste generated by the University community; this involves collecting and recycling any obsolete electronic equipment the University does not own. Using this strategy, the University community can recycle their e-waste by disposing of it in the yellow e-waste bins located on campus, which are then collected by the University's waste service provider *Wasteplan,* which sells it to buyers to be repurposed and recycled. Second, this study found that the *Stellenbosch University Asset E-waste* strategy recycles e-waste generated from electronics with an asset number registered to it –owned by the University. The e-waste falling under this strategy is collected by Main IT and is then collected by *Cape E-waste Recyclers*, which dispose of the hazardous waste responsibly. The recyclers will first try to repair and reuse the electronic equipment; if this cannot occur, it is dismantled and recycled.

6.2.2 E-waste management challenges at Stellenbosch University

Public and private institutions face challenges in developing policies to manage the disposal of obsolete electronic equipment generated (Islam et al. 2020). This study reveals two challenges the University faces when managing e-waste, i.e., theft and logistical issues. The theft of e-waste from the e-waste recycling bins on campus was an unexpected finding. This finding was surprising because all the e-waste bins were located inside University buildings, which many people often occupy, often security guards inside buildings (ITHub, Neelsie and others) and in some locations, only accessible via student card entry. As a means to mitigate this challenge, Facilities Management placed locks on the e-waste bins and reduced the size of the disposal openings on the bins. As a result, the University community can only recycle small e-waste types via these bins. If members of the University community wish to recycle larger e-waste items, they would need to contact Facilities Management directly via email or phone call. Small e-waste types that were recycled on campus by the surveyed population, included items such as batteries, cables, mobile phones, laptops, earphones, ink cartridges, fans, light bulbs, diodes, lamps, keyboards, and speakers.

---

[72] Respondent 1: Staff member at SU Facilities Management, 11 August 2022

As mentioned in the literature, convenience acts as a barrier to recycling; it could thus suggest that the University community would less likely recycle larger e-waste items due to the inconvenience they might face of contacting Facilities Management for recycling these larger items. Furthermore, this study found that logistical issues were another challenge to e-waste management at the University. However, no further information or explanation was given. Other studies have reported poor data management, equipment classifications, low awareness of e-waste, collection and disposal problems, and a lack of specific regulations; and policies on end-of-life electrical were challenges to e-waste management at universities, none of which this study found at Stellenbosch University.

6.2.3 E-waste recycling on campus and recycling attitudes

Smith (2009) suggests that a successful recycling programme should operate with an infrastructure for an on-site collection that is free and accessible. Several authors have suggested that convenience and cost can act as barriers to e-waste recycling; if recycling collection centres are easily accessible, located nearby, and offer low costs, people will be more likely to recycle their e-waste (Smith 2009; Laeequaddin et al. 2022). Moreover, Chibunna et al.'s (2012) on-campus accessibility will maximise recycling among students and staff. However, this study was unable to demonstrate the ideas of Laeequddin et al. (2022), Smith (2009) and Chibunna et al. (2012) that recycling will increase with convenience and lower costs. The results of the present study suggest that e-waste recycling was easily accessible to the University community as it was located at seven locations on campus (i.e., Main IT; General Engineering; Wimbledon Hub; Neelsie; IT Hub; Metanoia; Sports Science Building) and had no cost for the University community. Despite these factors, e-waste recycling by the survey population on campus was still exceptionally low (3%).

Literature has revealed that as educational institutions, universities can play a crucial role in raising e-waste awareness amongst their community (consumers). This will lead to pro-environmental behaviour, i.e., increased recycling. The study revealed that Stellenbosch University aims to create e-waste awareness amongst the University community in three ways, i.e., social media, advertising on campus, and information sessions.

First, the University promoted e-waste recycling on its social media platform (Instagram), which is considered an effective tool for raising awareness about environmental issues, particularly among younger people (Mallick & Bajpai 2019). This is a much faster way, reaching a much larger mass of people quickly (Mallick & Bajpai 2019). Second, awareness about e-waste recycling on campus is further created through posters on campus. Third, awareness is created by hosting sustainability information sessions to discuss e-waste recycling. Despite these e-waste awareness strategies on campus, the study found that the survey population lacked awareness about the e-waste recycling bins available on campus (91%). These results could be the reason for low e-waste recycling rates by the survey population on campus.

The survey population felt there was a lack of information and awareness about e-waste recycling on campus. Moreover, the survey population and staff at the Facilities Management agreed that the university could do more to create awareness about e-waste and how to recycle this waste on campus. However, the study found that the survey population had a positive attitude towards e-waste recycling on campus. The survey population has a positive attitude towards knowing more about e-waste and how to recycle this waste type on campus if the university creates more awareness about e-waste. Waste mobile phones were the top e-waste type the survey population is willing to recycle on campus. Large household appliances were the type of e-waste the survey population was the least willing to recycle on campus. The difference in willingness could be attributed to the convenience of recycling between the two e-waste types. Mobile phones, as small e-waste types, are more convenient because they are small and lightweight, making recycling much more manageable. In contrast, large household appliances are much bigger and heavier, which makes them much more difficult to transport for recycling. It can thus be suggested that awareness about e-waste recycling on campus could be increased. If more awareness is created amongst the University community, it can potentially increase e-waste recycling on campus. It can thus be suggested that awareness about e-waste recycling on campus could be increased. If more awareness is created amongst the University community, it can potentially increase e-waste recycling on campus.

6.2.4 E-waste knowledge and awareness

Licy et al. (2013) argue that e-waste, like other environmental problems, cannot be wholly eradicated but can be reduced and controlled (as mentioned in Chapter 3). This could be achieved if consumers have adequate knowledge and awareness about e-waste and its impacts. Literature has emphasised that adequate knowledge, information, and awareness of e-waste amongst consumers is key to reducing the global e-waste quantities and their adverse impacts on the environment and human health (Hansmann et al. 2006; Gurauskienė 2008; Shah 2014; Borthakur & Govind 2019; Miner et al. 2020; Laeequddin et al. 2022). However, despite this emphasis, consumer knowledge and awareness about e-waste are still low (Bhat & Patil 2014; Tan et al. 2018). This study found three themes related to knowledge and awareness of e-waste, i.e., awareness and understanding of the term e-waste, knowledge and awareness of the global e-waste problem, and knowledge and awareness of the impacts of e-waste.

6.2.4.1 Knowledge and awareness about e-waste

This study found that e-waste awareness was high among the survey population, with approximately three-quarters having heard the phrase before. Reading was their primary source of e-waste information. Moreover, interestingly, interviewees indicated that the schools (19%) they attended were sources of e-waste information. This is interesting to note in comparison to the University as a source of information (1%). Regarding what the term means and their understanding, this study found that the survey population understood what the term refers to. More than half of the survey population considered e-waste related to old, discarded, or obsolete electronic devices with the intention of not being reused. This is in line with the definition by StEP Initiative (2014:4) that was accepted for this study which states:

> "E-Waste is a term used to cover items of all types of electrical and electronic equipment (EEE) and its parts that have been discarded by the owner as waste without the intention of re-use" (StEP Initiative 2014:4).

These results support those observed in international and national studies on consumers' awareness of e-waste. In Dharwad, India, Arpith & Patil (2020) found that among medical students of Shri Dharmasthala Manjunatheshwara College of Medical Science and Hospital, 78% of respondents knew what e-waste was. Furthermore, the result of this study is also in accord with the recent study in Limpopo, South Africa, which reported that 70% of the survey population was aware of the term e-waste (Uhunamure et al. 2021). However, there are similar international studies that produced different results compared to this study, for example, the two studies conducted in India by Shah (2014) and Sivathanu (2016).

In India, separate studies conducted in Maharashtra and Gujarat found that only 59% and 35% of the public were aware of e-waste, respectively (Shah 2014; Sivathanu 2016). These results differ from the results of this study and those of Arpitha & Patil (2020) and Uhunamure et al. (2021). One possible explanation for the difference in the results could be that the studies by Sivathanu (2016) and Shah (2014) were conducted much earlier. A second explanation for the difference in the results could be attributed to the difference in education levels amongst the sample populations of the studies. Several authors suggest that there is a link between people's education level and understanding of the environment. They conclude, individuals with higher levels of education are more likely to be aware of environmental issues than those individuals with lower educational levels (Maloney et al. 1975; Ewert & Baker 2001; Meyer 2015; Santhakumar et al. 2020). For example, in China, Tan et al. (2018) found that public awareness about e-waste significantly differed among people with different education levels. In the case of this study and the study conducted in Dharwad, all respondents had or were currently involved in tertiary education. Similarly, in the study conducted in Limpopo, South Africa, 88% of the sample population had secondary and above education. However, in studies conducted in India, only 17% of the sample population had tertiary education. The results of this study concur with Maloney et al. (1975), Ewert & Baker (2001), Meyer (2015) and Santhakumar et al. (2020) who suggests people's knowledge and awareness of e-waste could be linked to education level, as this study looked at the perspective of University students and staff.

6.2.4.2 Knowledge and awareness of the e-waste problem

The current study reveals that a large percentage of the survey population recognised a global and national e-waste problem, however, most were unaware of what this environmental problem entails. Limited studies have investigated people's knowledge and awareness of the e-waste problem in international and national literature. To the researcher's knowledge, only Kwatra et al. (2014) included such data. Accordingly, the present study is in line with the finding of Kwatra et al. (2014) who reported that only 27% of the respondents could describe the e-waste problem in India.

Of the survey population who understood what the e-waste problem entails, five key themes emerged from their understanding of the global e-waste problem: (1) lack of proper disposal, (2) pollutes the environment, (3) high consumption of EEE, (4) lack of e-waste knowledge, and

(5) high e-waste quantities. These findings are consistent with those of Forti et al. (2020) and Baldé (2017) who suggest an e-waste problem because of increased EEE consumption rates, growing quantities of e-waste, improper disposal and lack of knowledge and awareness amongst consumers. However, the survey population failed to mention that e-waste is a global problem because it contains hazardous materials, which adversely impact the environment and human health, and the transboundary movement of these hazardous substances. The literature emphasises (as discussed in Chapter 3) that e-waste is a serious problem because of the transboundary movement of this waste often to developing countries, where it is handled using primitive disposal methods, which results in environmental and human health harm.

6.2.4.3 Knowledge and awareness of the impacts of e-waste

The literature emphasises two sides to e-waste, the untapped "urban mine", which contains valuable materials if recycled correctly, and the "toxic mine", which causes adverse effects on the environment and human health if recycled incorrectly. Chapter 3 mentions that e-waste contains hazardous materials that negatively affect the environment and humans. However, at the same time, it contains many valuable materials that require special handling and recycling treatment (Robinson 2009; Forti et al. 2020). This study found that a high proportion of the survey population was aware that e-waste has the potential to negatively influence the environment. Similarly, Arpitha & Patil (2020) found that 81% of the respondents knew that e-waste impacts human health, and 95% knew that e-waste impacts the environment. These findings also agree with Wibowo et al. (2022), who found that 77% of the respondents were aware that using mobile phones could harm the environment and human health.

Despite being aware that e-waste has the potential to impact the environment and human health, the survey population had a limited understanding of how and what these impacts are. These results are consistent with the findings of Wibowo et al. (2022), whose study revealed that only 41% of the respondents knew what specific environmental effects e-waste has. It is possible that the survey population’s limited understanding of the hazardous materials found in e-waste may have accounted for their lack of understanding of the impacts of e-waste. Considering the study’s results and literature, if the survey population knew about the hazardous materials found in e-waste, they would better understand how these materials may impact human health and the environment.

Overall, regarding the survey population's knowledge and awareness about e-waste, the results of this study are not entirely in disagreement with Bhat & Patil (2014) and Tan et al. (2018) who suggest that consumer knowledge and awareness about e-waste and its related issues are still low; although the results suggest they had a general understanding of what e-waste is and recognised that a global e-waste problem exists. They, however, had limited knowledge about the hazardous materials found in e-waste and how this impacts the environment and human health, and awareness about this needs to be raised.

6.2.5 E-waste disposal and recycling attitudes

Drawing from the literature on e-waste recycling and disposal, if e-waste is recycled correctly, it can bring environmental and economic benefits to communities worldwide (Chapter 3). The study revealed that the survey population held two positive attitudes toward e-waste recycling, i.e., proper attitudes toward e-waste disposal and a strong sentiment toward e-waste recycling.

First, the study's results suggest that the survey population had a pro-environmental attitude towards e-waste disposal, as more than three-quarters of the survey population disagreed or strongly disagreed that e-waste should be incinerated and landfilled. Rather, the survey population strongly supported the recycling of e-waste. There have been numerous studies conducted investigating people's attitudes towards e-waste disposal. Some similar findings could be found in a study conducted in Kampala City, Uganda, by Nuwematsiko et al. (2021). Furthermore, this study found that the survey population was unsure about storing e-waste, as 42% felt neutral about whether e-waste should be stored. These findings are not surprising as literature shows that storage is one of the top e-waste disposal methods worldwide.

In contrast, Nuwematisko et al. (2021) found that most respondents agreed that e-waste should not be stored as it harms the environment (62%). This somewhat contradictory result may be due to the difference in ages of the sample populations. In Nuwematisko et al.’s (2021) study, most respondents were between the ages of 25 and 54 (77%), whereas most of the respondents in the current study were between the ages of 18 and 24 (64%). White & Hunter (2009) suggest that different demographic factors influence people's understanding and knowledge about environmental issues. Although there was uncertainty about the storage of e-waste as a proper means of disposal, these findings suggest that the survey population had a positive attitude towards e-waste disposal; however, there is still a need for more information and education about e-waste storage.

Second, the study's results suggest that the survey population strongly support e-waste recycling. Not only did the study, as mentioned above, find that the survey population agreed that e-waste should be recycled, but it also found that the survey population felt that e-waste was the second most important waste type that should be recycled. Surprising, e-waste was the least recycled waste type. This finding corroborates the findings of Ylä-Mella et al. (2015). They highlighted in their study in Finland that respondents' awareness and attitudes toward e-waste recycling have not translated to recycling behaviour. Several authors reveal that there is often a mismatch between people's environmental attitudes and perceptions compared to their actions. Therefore, it was unsurprising that e-waste was the least recycled waste type.

6.2.6 Waste mobile phones and disposal practices

Literature has shown that there has been a "tsunami" of global e-waste quantity, with future projections to reach 74.7 Mt by 2030 due to the high rate of EEE consumption (as discussed in Chapter 3). The mobile phone industry is one of the most significant contributors to the high global e-waste quantities. Mobile phones contribute to more than 21% of the global e-waste quantities, and due to the high consumption pattern of these devices and low mobile phone recycling rates, this rate will continue to increase (Nnorom et al. 2009; Baldé et al. 2017; Bai et al. 2018). This study identified three themes regarding the University community's WMP practice, i.e., mobile phone consumption patterns, reasons for WMP disposal, and WMP disposal and recycling attitudes. This will be discussed below.

6.2.6.1 Mobile phone consumption patterns

First, this study found that mobile phones were the most frequently used electronic devices among the survey population. The current findings are constant with those reported by Kemp (2022), which found that currently, mobile phones are the most popular consumed electronic device worldwide (96.2%). In Visakhapatnam, India, Vuppala et al. (2015) found that mobile phones (87%) were the most frequently used electronic devices. Similarly, in 2022, the USA DataReportal (2022) found that mobile phones (75%) were the most frequently used electronic devices. Moreover, the results of the present study are also in line with the recent national observations (Tsirulnik 2022). Moreover, the results of the present study are also in line with the recent national observations, in which Uhunamure et al. (2021) reported on a survey sample in Limpopo, where mobile phones at 79% were the most popular used electronic devices.

However, this study finding is not unexpected as several reasons could account for this. First, (1) a higher degree of competition in the telecommunication market and technological advances has caused a decrease in the price of mobile phones, making them much more affordable for most countries (Baldé et al. 2017). In the study conducted by Li et al. (2013), it was found that mobile phones have become more and more available to people in both developed nations and developing nations. Second, in South Africa, since it was first introduced more than 26 years ago in South Africa, it was first a luxury technological device for the rich; however, now, more than 95% of the population of South Africa own one due to the rapid growth in mobile connectivity (McCrocklin 2021). A third explanation for why mobile phones are the most popular electronic device is their multi-functionality. Mobile phones have evolved significantly over the last decades, from being primarily used for communication to becoming multimedia devices (McCrocklin 2021). However, now it encapsulates multiple devices into one, making it the most used device.

Second, the results indicate that the average number of in-use mobile phones per capita is 1.6, which is within the range of the previous studies. This indicates that every University community member owns a mobile phone. According to a study by Islam et al. (2020) in Australia, the average number of in-use mobile phones per capita was 1.8. In China, Zhang et al. (2019) found that the average number of in-use mobile phones per capita was 1.2. To the author's knowledge, statistics on the average number of mobile phones per capita in South Africa were not available.

Third, this study found that mobile phones had a short lifespan among the survey population. One of the key factors contributing to the rapid increase of global e-waste quantities is the high rate of electronic device replacement or shorter possession lifespan. Users typically replace their electronic devices every three to four years (Cairns 2005). However, as the literature states, this depends on the type of electronic device in question. Kumar et al. (2013) suggest that computers have an average lifespan of three to five years among the different consumer electronics, and mobile phones are only two to three years. On average, this study found that the average possession lifespan of mobile phones amongst the survey population was 2.3 years, which agrees with previous studies. According to previous international studies on consumer waste mobile phone patterns, the average possession lifespan of mobile phones ranges from 1.67 to 4.35 years. Due to the growing dependence on smartphones as well as the availability of affordable smartphones, the average global smartphone replacement cycle has reached 1.9 years (Lu et al. 2015). In the USA, Statista Research Department (2022) found that the average possession lifespan of mobile phones for 2021 was 2.75 years. Bai et al. (2018) argue that mobile phone possession lifespan rapidly decreases yearly. According to Bai et al. (2018), the global average lifespan of mobile phones decreased from 2.61 to 2.24 years from 2017 to 2018. In Australia, Tröger et al. (2017) found that the average possession lifespan of mobile phones in Australia was 2.7 years, which, as they argue, is much shorter than a pair of jeans or a T-shirt. Earlier observations in 2012 by Polák & Drápalová (2012) found that the average possession lifespan was 4.35 years. Furthermore, according to the Global Mobile Consumer Survey 2019: South Africa, most mobile phone users replace their mobile phones within less than two years. This finding corroborates the ideas of several authors, who suggested that the lifespan of electronic devices is decreasing as technology advances (Lu et al. 2015; Tröger et al. 2017).

These results suggest shorter possession lifespan of mobile phones could be linked to planned obsolescence. Serval authors have linked mobile phone replacement (shorter lifespan) to planned obsolescence (Sandborn 2007; Packard 2011; Bartels et al. 2012; Barros & Dimla 2021). Sandborn (2007) suggests software obsolescence in smartphones can result in new software updates rendering another obsolete, or the update cannot be executed because the hardware cannot support it. Sandborn (2007) concludes this renders the mobile phone obsolete, and users usually replace the mobile phone with another device more frequently. This study further found that the inability to run new software updates, battery issues, and slow processors were among the top evidence of software and hardware obsolescence. This finding corroborates the ideas of Delaporte & Bahia (2021) who reported that mobile users replaced their devices every 21 months (1.9 years) mainly due to planned obsolescence. Barros & Dimla (2021) note that the reduced lifespan of components, such as the battery, hinders a smartphone's standard functionality, often resulting in a shorter lifespan. Overall, these results suggest high mobile phone consumption amongst the survey population, which aligns with the literature.

6.2.6.2 Reasons for mobile phone replacement

In the present study, the survey population gave five reasons for mobile phone replacement: new technology, software or hardware obsolescence, theft, contract renewal and damage or broken. Amongst these reasons, software or hardware obsolescence was the top mentioned amongst the survey population, which is one of the top reasons in the literature. However, other studies have found contradicting findings to this study. Studies conducted by Islam et al. (2020) in Australia found that mobile phone users mainly replace their mobile phones every 3.7 years due to device damage. Similarly, in Indonesia, Wibowo et al. (2022) reported that users replace their mobile phones every 2.6 years, primarily due to damage. A possible explanation for the deviations in results could be because of one and two; although Yin et al. (2014) studied 37.8% of the respondents who indicated that they changed their mobile phones due to obsolete software and hardware.

Mobile phone contract renewal as a reason for mobile phone replacement is an interesting finding worth mentioning, although it is not one of the top reasons. Mobile phone contract renewal has largely been overlooked in the waste mobile phone replacement literature. There may be a correlation between the short possession lifespan and mobile phone contract renewal. It can be suggested that the short 2.3 possession lifespan of mobile phones is attributed to the fact that many of the survey population replace their mobile phones every two years due to contract renewal.

6.2.6.3 Mobile phone disposal practices and recycling attitudes

The results of this study would agree with the literature regarding global e-waste disposal patterns. Numerous studies have demonstrated that storage is the top e-waste disposal practice worldwide (Tan et al. 2018; Islam et al. 2020; Nowakowski et al. 2020). The present study found six WMP disposal practices the survey population engaged in, with storage being the most dominant disposal practice. The results of this study match the observations of earlier international and national studies by Yin et al. (2014), Yla-Mella et al. (2015), Islam et al. (2020) and Uhunamure et al. (2021), which all found that people tend to store their obsolete EEE rather than dispose of it using proper practices. Earlier studies in China found that 47% of the respondents stored their obsolete mobile phones in their homes. A few years later, Bai et al.'s (2018) and Tan et al.'s (2018) studies showed that respondents stored their used WMP, with 79% and 62.1%, respectively. Similarly, in Australia, Islam et al. (2020) found that most respondents (43%) stored their WMP. In Limpopo, South Africa, Uhunamure et al. (2021) found that 86% of respondents stored their WMP.

As mentioned, most of the survey population agreed that recycling e-waste is very important and most strongly agreed that e-waste should be recycled. Surprisingly, the WMP recycling rate amongst the survey population was exceptionally low. However, these findings align with Islam et al. (2020), who found that only 14% of the study's respondents took their old mobile phones to be recycled. In the present study, the survey population's most significant obstacle to recycling WMP was due to their lack of awareness of e-waste recycling facilities. In previous literature, commonly cited obstacles that prevented people from recycling their WMP included the lack of awareness of e-waste recycling facilities. These results suggest that a possible reason for the high storage disposal practices could be a lack of awareness of e-waste recycling.

Another explanation for the high rate of WMP storage is the device's "perceived value". According to Ylä-Mella (2015), people tend to store their WPM devices because they perceive the device to have some form of monetary and sentimental value. In Ylä-Mella’s (2015) study it was found that in Finland, 85% of their respondents stored obsolete mobile phones at home, as they perceived that they would become of use in the future, despite respondents being nearby and convinced of e-waste recycling centres. Similarly, Tanskanen (2013) suggests that mobile phones, in particular, are stored in homes as reserves and for sentimental reasons because their owner perceives these devices have higher residential value than recycling them.

6.2.7 Implication of results

Literature has emphasised the importance of consumer knowledge and awareness of e-waste and e-waste disposal (as discussed in Chapter 3). Like other environmental issues, e-waste cannot wholly be eradicated; however, it could be controlled, and its impacts could be reduced. The University community (as consumers) and the University can play an essential role in ensuring successful e-waste management.

6.2.7.1 The University community

As literature has revealed, consumers play an essential role in e-waste management – they are both the consumers of e-waste (contributors to the problem) and, at the same time, the disposers of e-waste, and as Li et al. (2013) state, they hold the power of what happens to their devices once it reaches its EOL. Consumer knowledge and awareness are important factors in solving the e-waste problem and the success of any e-waste management strategy. As the results suggest, more knowledge and awareness about the hazardous materials and impacts of e-waste is necessary. Increasing knowledge and awareness about the hazardous materials found in e-waste and their impacts is required. Consumers need to know which toxic materials are found in e-waste and their environmental impacts. This might result in people feeling empowered and morally obligated to take responsibility for their choices related to e-waste disposal. Moreover, this study calls for increasing awareness raising of the e-waste recycling available on campus and continuously informing the University community about e-waste management strategies at Stellenbosch and how recycling e-waste contributes to the environment and human health.

6.2.7.1 Stellenbosch University

Lim-Wavde et al. (2017) and Bagozzi (1992) suggest that universities as educational institutions can play a crucial role in increasing e-waste awareness in their community. Although the study found that the University has implemented strategies to increase e-waste awareness, it is suggested that the University raise awareness about the impacts of e-waste and the hazardous materials found in e-waste. Stellenbosch University, as an educational institution, could play an important role in raising awareness about e-waste and e-waste recycling amongst its staff and students, which is an important factor in the success of e-waste management, solving e-waste problems and reducing e-waste quantities and adverse impacts. The current e-waste strategy is focused on empowering pro-environmental behaviour by consumers; therefore, it is recommended that the University integrate and prioritise raising consumer education and information on campus. This could be done by creating more awareness campaigns on campus focusing specifically on the hazardous nature of e-waste, its impacts on the environment and human health, and the importance of e-waste recycling. These initiatives should form part of the continued recycling initiatives and should be done more regularly. Another way to increase awareness and information is that the University could provide more information about e-waste recycling available on campus, i.e., putting up posters at strategic places on campus. By harnessing and collaborating with existing student and other outreach societies, the establishment of an e-waste recycling society on campus should be promoted. Making use of and disseminating information on various social media platforms will also further expand these activities. Finally, the development or incorporation of smart technology like apps could also see maps and locations of e-waste and other recycling facilities being promoted on such platforms.

6.3 CONCLUSION

In conclusion, the findings of this study suggest that the survey population lacks the knowledge about e-waste recycling on campus, as well as the hazardous materials in e-waste and how it can impact both the environment and human health. The survey population requires more information and education, and Stellenbosch University can play an important role. This will result in more recycled e-waste on campus by the survey population and ultimately help aid the e-waste problem.

CHAPTER SEVEN: CONCLUSION

7.1 INTRODUCTION

This study sought to document and investigate the quantity of e-waste management generated at Stellenbosch University and analyse the current e-waste management systems employed. Furthermore, this study aimed to explore the University community's e-waste knowledge, attitudes, and behaviours.

The central objectives of this study were as follows:

1. Conduct a literature review on the past and current discourses on e-waste.
2. Document and analyse e-waste management systems and practices employed at Stellenbosch University and investigate their alignment with sustainable e-waste practices.
3. Document and analyse the University community's knowledge, awareness and attitudes related to e-waste.
4. Identify the amount of e-waste generated at Stellenbosch University.
5. Explore the primary disposal methods and reasons for the disposal of waste mobile phones amongst the University community.
6. Identify strategies and recommendations that could enhance current e-waste management practices at Stellenbosch University.

This chapter will conclude the study by summarising the key research findings concerning the research aims and objectives and discussing the value and contributions thereof. Finally, this chapter will conclude with the critical limitations of this study and recommendations for future research.

7.2 REVISITING OBJECTIVES OF THE STUDY

E-waste is a global environmental issue and is rising at an alarming rate. Consumers of e-waste can play an important role in reducing the global quantities of e-waste and its adverse effects, and adequate knowledge and awareness are critical. E-waste management strategies should include priories of consumer education and information, which may potentially avoid harmful disposal practices. Therefore, understanding consumer e-waste knowledge, awareness, attitudes, and behaviour are important.

Stellenbosch University, as an institution highly dependent on EEE for its daily operation, generates high amounts of e-waste, accumulating a total of 6 678 kg in 2019, 2 714 kg in 2020, 4 847 kg in 2021 and 7 599 kg in 2022. (Objective 2). The University is committed to sustainability and therefore implemented two e-waste management strategies focused on recycling, i.e., the Non-Asset Registered E-waste and the Stellenbosch Asset E-waste – targeting both e-waste generated by the institutions and the University community (Objective 3). The results of this study indicate that e-waste recycling on campus was low due to a lack of knowledge about the e-waste recycling strategy on campus. Although the University has implemented strategies for raising awareness about e-waste recycling, the results suggest that more awareness amongst the survey population is needed.

The study sought to investigate the University community of Stellenbosch University's knowledge, awareness, and attitudes about e-waste. The results indicate that the survey population knew and understood what e-waste is and recognised a global e-waste problem. However, they had limited knowledge about the hazardous materials found in e-waste and its impacts on the environment and human health (Objective 4). Further findings show that mobile phones were the most used electronic device amongst the survey population, with software and hardware obsolescence the primary reason for WMP disposal (Objective 5). Although the survey population had a strong sentiment towards e-waste recycling, storage was the most dominant means of WMP disposal due to a lack of awareness about e-waste recycling facilities available to them (Objective 5).

The University community, as consumers of EEE, as the results suggest, needs more awareness and knowledge about the hazardous materials and their impacts and the e-waste recycling facilities available to them. Stellenbosch University, as an educational institution, could play a crucial role in raising e-waste awareness and knowledge about e-waste and e-waste recycling amongst its University community. This is an important factor for successful e-waste management and reducing its quantities of e-waste and adverse impacts. E-waste strategies should be focused on empowering pro-environmental behaviour amongst consumers; therefore, it is recommended that the University integrate and prioritise raising consumer education and information on campus. This could be done by creating e-waste awareness campaigns on campus focusing specifically on the hazardous nature of e-waste, its impacts on the environment and human health, and the importance of e-waste recycling (Objective 6). Furthermore, the University could increase awareness and information by providing more information about recycling on campus, i.e., putting up posters located at strategic places on campus. E-waste recycling on campus could be promoted through a collaborative approach with existing students and other outreach societies by establishing an e-waste recycling society on campus (Objective 6). It could be further recommended that the University create an e-waste recycling society on campus, allowing any member of the University community to join (Objective 6). Various social media platforms could be used to disseminate information to further expand these activities. Finally, the University could develop and incorporate smart technology like apps that could provide maps and locations of e-waste and recycling facilities on campus (Objective 6).

Overall, these findings suggest that the survey population needs more knowledge and awareness about e-waste recycling, hazardous materials and their impacts. Adequate consumer knowledge and awareness about e-waste are crucial factors in solving the e-waste problem. As an educational institution, Stellenbosch University can play a crucial role in increasing e-waste knowledge and awareness, as well as e-waste management.

7.3 LIMITATIONS

Several significant limitations need to be considered. First, the study did not evaluate the reuse and refurbishment of waste mobile phones amongst the survey population. It should be mentioned, according to the WH (as discussed in Chapter 2), reduce, reuse and refurbishment is the most favourable and sustainable waste management technique, above recycling. The present study focused on the University community's attitudes and behaviour towards recycling; however, Stellenbosch University's e-waste management strategies focused on recycling. Second, a notable shortage is the small sample size of the interviews conducted with Facilities Management at the university. Third, the current investigation was limited by the COVID-19 pandemic, which prevented face-to-face data collection and interviews and questionnaires with the two target groups had to be conducted online. This prevented the researcher from asking follow-up questions if the answers were not detailed enough or gaining better insight. Furthermore, the researcher could not probe the respondents. However, online data collection presented its benefits; it was less time-consuming, more convenient as data was digitally stored, and easier to approach respondents. Fourth, although all the questions of the online questionnaire were answered by each respondent, due to the design of the questionnaire, some of the questions have not been fully answered. This prevents collecting a more in-depth understanding of specific answers. This limitation means that study findings need to be interpreted cautiously. Future research should conduct data collection face-to-face or redesign the online questionnaire by setting a minimum word count for each response, potentially ensuring more in-depth answers.

7.4 FUTURE RESEARCH CONSIDERATIONS AND RECOMMENDATIONS

This research has revealed several questions that require further investigation. A national study involving e-waste knowledge and awareness among consumers should be conducted. Future research should investigate consumers' attitudes and behaviour towards e-waste reuse and refurbishment. This research would be valuable in understanding how reuse and refurbishment could be integrated into e-waste management strategies at universities and in the national government. Finally, future research could compare this study at other South African universities.

(Word Count: 34 965)

REFERENCES

Aboelmaged MG 2020. Acceptance of e-waste recycling among young adults: An empirical study. *In 2020 IEEE Conference on Technologies for Sustainability* 23(25): 1-6.

Ajayi VO 2017. Primary sources of data and secondary sources of data. *Benue State University* 1(1): 1-6.

Ajzen I & Fishbein M 1973. Attitudinal and normative variables as predictors of specific behaviour. *Journal of Personality and Social Psychology* 27(1): 41-45.

Ajzen I 1991. The theory of planned behaviour. *Organizational Behaviour and Human Decision Processes* 50(2): 179-211.

Ajzen I 2005. *Attitudes, Personality and Behaviour*. Berkshire: McGraw-Hill education.

Alabaster G, Asante KA, Bergman A, Birnbaum L, Brune-Drisse MN & Buka I 2013. *The Geneva declaration on e-waste and children's health 2013* [Online]. Available from: https://child-health-research.centre.uq.edu.au/files/4872/Geneva%20Declaration%20final.pdf [Accessed 18 September 2021].

Ali AS & Akalu ZK 2022. E-waste awareness and management among people engaged in e-waste selling, collecting, dismantling, repairing, and storing activities in Addis Ababa, Ethiopia. *Environmental Health Insights* 16 (3): 333-356.

Amasuomo E & Baird J 2016. The concept of waste and waste management. *Journal of Management and Sustainability* 6(4): 88-90.

Arpith V & Patil S 2020. Knowledge, attitude, and practice of e-waste amongst medical students, Dharwad. *International Journal of Medical Science and Public Health* 8(9): 488-491.

Asare M 2015. Using the theory of planned behaviour to determine the condom use behaviour among college students. *American Journal of Health Studies* 30(1): 43-44.

Atasu A & Subramanian R 2012. Extended producer responsibility for e-waste: Individual or collective producer responsibility? *Production and Operations Management* 21(6): 1042-1059.

Awasthi S, Verma M, Mahesh AK, Khan MI, Govindaraju G, Rajavelu A, Chavali PL, Chavali S & Dhayalan A 2018. DDX49 is an RNA helicase that affects translation by regulating mRNA export and the levels of pre-ribosomal RNA. *Nucleic Acids Research* 46(12): 6304-6317.

Azodo AP, Ogban PU & Okpor J 2017. Knowledge and awareness implication on e-waste management among Nigerian Collegiate. *Journal of Applied Sciences and Environmental Management* 21(6): 1035-1040.

Bagozzi RP 1992. The self-regulation of attitudes, intentions, and behaviour. *Social Psychology Quarterly* 55(2): 178-204.

Bai H, Wang J & Zeng AZ 2018. Exploring Chinese consumers' attitude and behaviour toward smartphone recycling. *Journal of Cleaner Production* 188: 227-236.

Baldé CP, Forti V, Gray V, Kuehr R & Stegmann P 2017. *The global e-waste monitor 2017: Quantities, flows and resources.* Geneva: United Nations University.

Baldé CP, Wang F, Kuehr R & Huisman J 2015. *The global e-waste monitor–2014, United Nations University*. Bonn: ISBN Print.

Barros M & Dimla E 2021. From planned obsolescence to the circular economy in the smartphone industry: An evolution of strategies embodied in product features. *Proceedings of the Design Society* 1: 1607-1616.

Bartels B, Ermel U, Sandborn P & Pecht MG 2012. *Strategies to the prediction, mitigation and management of product obsolescence.* Hoboken: John Wiley & Sons.

Basel Convention 2019. *Entry into force of amendment to UN treaty boosts efforts to prevent waste dumping* [Online]. Available from: http://www.basel.int/Default.aspx?tabid=8120 [Accessed 22 June 2021].

Basu R 2009. Solid waste management-a model study. *Journal of Management* 6(2): 20-24.

Bem DJ 2021. *Writing the empirical journal article. The compleat academic.* New York: Psychology Press.

Benson E 2021. *The Basel Convention: From hazardous waste to plastic pollution* [Online]. Available from: https://www.csis.org/analysis/basel-convention-hazardous-waste-plastic-pollution [Accessed 22 August 2022].

Beranek W 1992. Solid waste management and economic development. *Economic Development Review* 10(3): 49-54.

Bhat V & Patil Y 2014. E-waste consciousness and disposal practices among residents of Pune city. *Procedia-Social and Behavioural Sciences* 133: 491-498.

Bhutta MKS, Omar A & Yang X 2011. Electronic waste: A growing concern in today's environment. *Economics Research International* 2011: 1-8.

Borthakur A & Govind M 2017. Emerging trends in consumers' e-waste disposal behaviour and awareness: A worldwide overview with special focus on India. *Resources Conservation and Recycling* 117: 102-113.

Borthakur A & Govind M 2019. Computer and mobile phone waste in urban India: An analysis from the perspectives of public perception, consumption and disposal behaviour. *Journal of Environmental Planning and Management* 62(4): 717-740.

Bovea MD, Ibáñez-Forés V, Gallardo A & Colomer-Mendoza FJ 2010. Environmental assessment of alternative municipal solid waste management strategies: A Spanish case study. *Waste management* 30(11): 2383-2395.

Breivik K, Armitage JM, Wania F & Jones KC 2014. Tracking the global generation and exports of e-waste. Do existing estimates add up? *Environmental Science & Technology* 48 (15): 8735-8743.

Brookes E 2021. *The theory of planned behaviour* [Online]. Available from: https://www.simplypsychology.org/theory-of-planned-behavior.html [Accessed 21 February 2023].

Bryman A & Cramer D 2012. Quantitative data analysis with IBM SPSS 17, 18 & 19: A guide for social scientists. *The American Statistician* 66(4): 41-241.

Brynard DJ, Hanekom SX & Brynard P 2014. *Introduction to research*. Pretoria: Van Schaik.

Burney SM & Hussain S 2008. *Monograph on inductive & deductive research approach* [Online]. Available from: https://www.researchgate.net/profile/Hussain-Saleem/publication/331330927_Inductive_and_Deductive_Research_Approach/links/5d0749d492851c900442dcb7/Inductive-and-Deductive-Research-Approach.pdf [Accessed 16 October 2020].

Cairns C 2005. E-waste and the consumer: Improving options to reduce, reuse and recycle. In Pro*ceedings of the IEEE International Symposium on Electronics and the Environment.* New Orleans: IEEE.

Chandler AJ, Eighmy TT, Hjelmar O, Kosson DS, Sawell SE, Vehlow J, Van der Sloot HA & Hartlén J 1997. *Municipal solid waste incinerator residues*. Amsterdam: Elsevier.

Chatterjee S 2012. Sustainable electronic waste management and recycling process. *American Journal of Environmental Engineering* 2(1): 23-33.

Cheremisinoff NP 2003. *Handbook of solid waste management and waste minimization technologies*. Oxford: Butterworth-Heinemann.

Chibunna JB, Siwar C, Begum RA & Mohamed AF 2012. The challenges of e-waste management among institutions: A case study of UKM. *Procedia-Social and Behavioural Sciences* 59: 644-649.

Cibrario D 2018. *To ensure sustainable waste services, we much value waste workers and make sure they are in decent jobs* [Online]. Available from:

https://www.2030spotlight.org/sites/default/files/spot2018/chaps/Spotlight_Innenteil_2018_sdg11_cibrario.pdf [Accessed 11 April 2020].

Cobbing M 2008. *Toxic tech: Not in our backyard. Uncovering the hidden flows of e-waste* [Online]. Available from: *https://www.ecotic.ro/wp-content/uploads/2015/07/846472a0b4ca943a0345dfb44e9af06fd82d9931.pdf* [Accessed 23 April 2021].

Collis J & Hussey R 2014. *Collecting qualitative data.* London: Palgrave.

Conner M & Armitage CJ 1998. Extending the theory of planned behaviour: A review and avenues for further research. *Journal of Applied Social Psychology* 28(15): 1429-1464.

Costoff D 2020. E-waste: *Producers vs consumers [Online]*. Available from: https://projects2014-2020.interregeurope.eu/fileadmin/user_upload/tx_tevprojects/library/file_1626780535.pdf [Accessed 22 August 2022].

Creswell JW 1999. *Mixed-method research: Introduction and application*. San Diego: Academic Press.

Crowe S, Cresswell K, Robertson A, Huby G, Avery T & Sheikh A 2011. The case study approach. *BMC Medical Research Methodology* 11(1): 1–9.

Daum K, Stoler J & Grant RJ 2017. Toward a more sustainable trajectory for e-waste policy: A review of a decade of e-waste research in Accra, Ghana. *International Journal of Environmental Research and Public Health* 14(2): 135-146.

Davis G & Herat S 2008. Electronic waste: The local government perspective in Queensland, Australia. *Resources, Conservation and Recycling* 52(8-9): 1031-1039.

de Souza RG, Clímaco JCN, Sant'Anna AP, Rocha TB, do Valle RDAB & Quelhas OLG 2016. Sustainability assessment and prioritisation of e-waste management options in Brazil. *Waste Management* 57: 46-56.

De Vries A & Stoll C 2021. Bitcoin's growing e-waste problem. *Resources, Conservation and Recycling* 175: 105-901.

DEA (Department of Environmental Affairs) 2011. *National waste management strategy* [Online]. Available from: https://www.dffe.gov.za/sites/default/files/docs/nationalwaste_management_strategy.pdf [Accessed 15 September 2012].

DEA (Department of Environmental Affairs) 2012. *National waste information baseline report.* Pretoria: Department of Environmental Affairs.

DEA (Department of Environmental Affairs) 2018. Industry waste tyre management plan. Tyre waste abatement and minimisation initiative of South Africa [Online]. Available from: https://cer.org.za/wp-content/uploads/2018/03/Proposed-industry-waste-tyre-management-plans.pdf [Accessed 15 September 2021].

DeJonckheere M & Vaughn LM 2019. Semi-structured interviewing in primary care research: A balance of relationship and rigour. *Family Medicine and Community Health* 7(2): 57-65.

Delaporte A & Bahia K 2012. *The state of mobile internet connectivity* [Online]. Available from: https://www.gsma.com/r/wp-content/uploads/2021/09/The-State-of-Mobile-Internet-Connectivity-Report-2021.pdf [Accessed 22 February 2022].

Dhas DB, Vetrivel SC & Mohanasundari M 2021. E-waste management: An empirical study on retiring and usage of retiring gadgets. *AIP Conference Proceedings* 2387(1): 23-45.

e-Stewards 2013. *The globally responsible way to recycle your electronics* [Online]. Available from: http://www.estewards.org/the-ewaste-crisis/ [Accessed 7 April 2021].

Edmonds CN, Goel S, Nakagome H, Kemp W & Lindström E 2019. *Decent work in the management of electrical and electronic waste (e-waste)*. Geneva: ILO Publications.

Elytus 2019. *E-waste & it's negative effects on the environment* [Online]. Available from: https://elytus.com/blog/e-waste-and-its-negative-effects-on-the-environment.html#:~:text=When%20improper%20disposal%20of%20e,the%20area%20in%20the%20future [Accessed 13 April 2022].

ENVASS 2020. *The waste management hierarchy concept* [Online]. Available from: https://www.envass.co.za/the-waste-management-hierarchy-concept/ [Accessed 15 September 2021].

EPA (United States Environmental Protection Agency) 2009. *Persistent organic pollutants: A global issue, a global response* [Online]. Available from: https://www.epa.gov/international-cooperation/persistent-organic-pollutants-global-issue-global-response [Accessed 13 April 2021].

Eriksson P & Kovalainen A 2008. *Research philosophy: Qualitative methods in business research.* Thousand Oaks: Sage Publications.

EU (European Union) 2012. Directive 2012/19/EU of the European Parliament and of the Council of 4 July 2012 on Waste Electrical and Electronic Equipment (WEEE). *Official Journal of the European Union* 197(55): 22-34.

Ewert A & Baker D 2001. Standing for where you sit: An exploratory analysis of the relationship between academic major and environment beliefs. *Environment and Behaviour* 33(5): 687-707.

Faryadi Q 2019. PhD thesis writing process: A systematic approach how to write your methodology, results and conclusion. *Creative Education* 10(4): 766–783.

Ferronato N & Torretta V 2019. Waste mismanagement in developing countries: A review of global issues. *International Journal of Environmental Research and Public Health* 16(6): 10-60.

Finlay A & Liechti D 2018. *E-waste assessment of South Africa. eWASA policy report* [Online]. Available from: http://www.ngopulse.org/sites/default/files/eWaste%20Assessment.pdf [Accessed 7 March 2021).

Forti V, Baldé CP, Kuehr R & Bel G 2020. *The global e-waste monitor 2020: Quantities, flows, and the circular economy potential.* Geneva: United Nations University.

Gagliardi AR & Dobrow MJ 2011. Paucity of qualitative research in general medical and health services and policy research journals: Analysis of publication rates. *BMC Health Services Research* 11(1): 1-7.

Gaidajis G, Angelakoglou K & Aktsoglou D 2010. E-waste: environmental problems and current management. *Journal of Engineering Science and Technology Review* 3(1): 193-199.

Gaille B 2018. *Observations of phenomena provide evidence of input processes that is verifiable through case studies* [Online]. Available from: https://brandongaille.com/12-case-study-method-advantages-and-disadvantages/ [Accessed 3 April 2020].

Gangwar C, Choudhari R, Chauhan A, Kumar A, Singh A & Tripathi 2019. Assessment of air pollution caused by illegal e-waste burning to evaluate the human health risk. *Environment International* 125: 191-199.

Grant CA, Wallace LM, Spurgeon PC, Tramontano C & Charalampous M 2018. Construction and initial validation of the e-work life scale to measure remote e-working. *Employee Relations* 41(1): 16–33.

Grant R 2019. E-waste challenges in Cape Town: Opportunity for the green economy? *Urbani-izziv* 30(30): 5–23.

Gupt Y & Sahay S 2015. Review of extended producer responsibility: A case study approach. *Waste Management & Research* 33(7): 595-611.

Gurauskienė I 2008. Behaviour of consumers as one of the most important factors in e-waste problem. *Environmental Research, Engineering & Management* 46(4): 55-65.

Halim L & Suharyanti Y 2019. E-waste: Current research and future perspective on developing countries. *International Journal of Industrial Engineering and Engineering Management* 1(2): 25-42.

Hansmann R, Bernasconi P, Smieszek T, Loukopoulos P & Scholz RW 2006. Justifications and self-organization as determinants of recycling behaviour: The case of used batteries. *Resources, Conservation and Recycling* 47(2): 133-159.

Hazra T & Goel S 2009. Solid waste management in Kolkata, India: Practices and challenges. *Waste management* 29(1): 470-478.

Heacock M, Kelly CB, Asante KA, Birnbaum LS, Bergman ÅL, Bruné MN, Buka I, Carpenter DO, Chen A, Huo X & Kamel M 2016. E-waste and harm to vulnerable populations: A growing global problem. *Environmental Health Perspectives* 124(5): 550-555.

Hoornweg D & Bhada-Tata P 2012. *What a waste: A global review of solid waste management*. Washington: World Bank Publications.

Hoornweg D & Thomas L 1999. *What a waste: Solid waste management in Asia*. Washington: World Bank Publications.

https://www.dffe.gov.za/sites/default/files/reports/environmentoutlook_chapter13.pdf [Accessed 15 September 2021].

Huang J, Nkrumah PN, Anim DO & Mensah E 2014. E-waste disposal effects on the aquatic environment: Accra, Ghana. *Reviews of Environmental Contamination and Toxicology* 229(6): 19–34.

Illés A & Geeraerts K 2016. *Illegal shipments of e–waste from the EU to China*. London: Palgrave Macmillan.

Islam MT, Dias P & Huda N 2020. Waste mobile phones: A survey and analysis of the awareness, consumption and disposal behaviour of consumers in Australia. *Journal of Environmental Management* 275: 111-115.

Johns Hopkins 2022. *What Is Coronavirus?* [Online]. Available from: https://www.hopkinsmedicine.org/health/conditions-and-diseases/coronavirus [Accessed 23 February 2021].

Kawulich BB 2005. Participant observation as a data collection method. *Forum, Qualitative Social Research* 6(2): 324-356.

Kaza S, Yao L, Bhada-Tata P & Van Woerden F 2018. *What a waste 2.0: A global snapshot of solid waste management to 2050*. Washington: World Bank Publications.

Kemp S 2022. *Digital 2021: Global Overview* [Online]. Available from: https://datareportal.com/reports/?tag=Global+Overview [Accessed 3 July 2021]

Khan AA & Ashraf S 2015. E-waste: A menace to mankind. *Journal of Integrated Community Health* 2015(1-2): 62-66.

Kim S, Xu X, Zhang Y, Zheng X, Liu R, Dietrich K, Reponen T, Ho SM, Xie C, Sucharew H & Huo X 2019. Metal concentrations in pregnant women and neonates from informal electronic waste recycling. *Journal of Exposure Science & Environmental Epidemiology* 29(3): 406-415.

Kivunja C & Kuyini AB 2017. Understanding and applying research paradigms in educational contexts. *International Journal of Higher Education* 6(5): 26-41.

Kosior, E. and Mitchell, J., 2020. Current industry position on plastic production and recycling. In *Plastic waste and recycling*. Academic Press.

Kumar A, Holuszko M & Espinosa DCR 2017. E-waste: An overview on generation, collection, legislation and recycling practices. *Resources, Conservation and Recycling* 122(113): 32-42.

Kumar S, Singh R, Singh D, Prasad R & Yadav T 2013. Electronics-waste management. *International Journal of Environmental Engineering and Management* 4(4): 389-396.

Kwatra S, Pandey S & Sharma S 2014. Understanding public knowledge and awareness on e-waste in an urban setting in India: A case study for Delhi. *Management of Environmental Quality: An International Journal* 25(6): 752-765.

Laeequddin M, Kareem W, Sahay V & Tiwari AK 2022. Factors that influence the safe disposal behaviour of e-waste by electronics consumers. *Sustainability* 14(9): 4981-4989.

Law Insider 2017. *Campus community definition* [Online]. Available from: https://www.lawinsider.com/dictionary/campus-community [Accessed 16 October 2020].

Lebbie TS, Moyebi OD, Asante KA, Fobil J, Brune-Drisse MN, Suk WA, Sly PD, Gorman J & Carpenter DO 2021. E-waste in Africa: A serious threat to the health of children. *International Journal of Environmental Research and Public Health* 18(16): 84-88.

LeCompte MD & Schensul JJ 1999. *Analysing & interpreting ethnographic data*. Maryland: Rowman Altamira.

Lee K & Krauss SE 2015. Why use qualitative research methods to understand the meaning of clients' experiences in healthcare research? *International Journal of Public Health and Clinical Sciences* 2(4): 1-6.

Lepawski J 2015. The changing geography of global trade in electronic discards: Time to rethink the e-waste problem. *The Geographical Journal* 181(2): 147-159.

Leroy P 2021. *Education is key to help consumers be circular* [Online]. Available from: https://tcocertified.com/circular-electronics-day-case/education-is-key-to-help-consumers-be-circular/ [Accessed 2 June 2022].

Li J, Liu L, Zhao N, Yu K & Zheng L 2013. Regional or global WEEE recycling. Where to go? *Waste management (Elmsford)* 33(4): 923-934.

Licy CD, Vivek R, Saritha K, Anies TK & Josphina CT 2013. Awareness, attitude and practice of school students towards household waste management. *Journal of Environment* 2(6): 147-150.

Lim-Wavde K, Kaumana RJ & Dawson GS 2017. Household informedness and policy analytics for the collection and recycling of household hazardous waste in California. *Resources, Conservation and Recycling* 120(4): 88–107.

Lovo S & Rawlings SB 2022. *The health burden of e-waste: The impact of e-waste dumping sites on child mortalit working paper 9916.* Available from:

https://www.econstor.eu/bitstream/10419/265951/1/cesifo1_wp9916.pdf [Accessed 23 August 2022].

Lu C, Zhang L, Zhong Y, Ren W, Tobias M, Mu Z, Ma Z, Geng Y & Xue B 2015. An overview of e-waste management in China. *Journal of Material Cycles and Waste Management* 17(1): 1-12.

Lundgren K 2012. *The global impact of e-waste: Addressing the challenge*. Geneva: International Labour Organization Publications.

Lydall M, Nyanjowa J & James Y 2017. *Mapping South Africa's waste electrical and electronic equipment (WEEE) dismantling, pre-processing and processing technology landscape* [Online]. Available from: https://www.ewasa.org/wp-content/uploads/2018/04/weee_technology_landscape_assessment_report.pdf [Accessed 15 August 2020].

Machete F 2017. Environmental health risks associated with e-waste exposure in Badplaas, Carolina and Elukwatini landfills, Republic of South Africa. *African Journal of Science, Technology, Innovation and Development* 9(6): 679-684.

Mallick R & Bajpai SP 2019. Impact of social media on environmental awareness. *Environmental Awareness and The Role of Social Media* 5(2): 140-149.

Maloney MP, Ward MP & Braucht GN 1975. A revised scale for the measurement of ecological attitudes and knowledge. *American Psychologist* 30(7): 787.

Marchettini N, Ridolfi R & Rustici M 2007. An environmental analysis for comparing waste management options and strategies. *Waste Management* 27(4): 562-571.

Marsh ATM, Yang T, Adu-Amankwah S & Bernal SA 2021. Utilization of metallurgical wastes as raw materials for manufacturing alkali-activated cements. *Waste and Byproducts in Cement-Based Materials* 35–383.

Martin ME, Newman SD, Aber JD & Congalton RG 1998. Determining forest species composition using high spectral resolution remote sensing data. *Remote Sensing of Environment* 65(3): 249-254.

Mason J 2002. *Qualitative researching*. London: Sage Publications.

Maxwell JA 2012. *Qualitative research design: An interactive approach*. London: Sage Publications.

Mazumder R, Sujatha Devi P, Bhattacharya D, Choudhury P, Sen A & Raja M 2007. Ferromagnetism in nanoscale Bi Fe O 3. *Applied Physics Letters* 91(6): 062-510.

McCrocklin S 2021. *Mobile Penetration in South Africa* [Online]. Available from: https://www.geopoll.com/blog/mobile-penetration-south-africa/ [Accessed 6 August 2021].

Meyer A 2015. Does education increase pro-environmental behavior? Evidence from Europe. *Ecological Economics* 16(1): 108-121.

Mhlanga T 2018. *South Africans are drowning in e-waste* [Online]. Available from: https://mg.co.za/article/2018-03-16-00-south-africans-are-drowning-in-e-waste/ [Accessed 24 May 2021].

Miliute-Plepiene J 2019. *E-waste and raw materials: From environmental issues to business models* [Online]. Available from: https://ewaste.education/pdf/E-M@S_IVL_eminingbook_English.pdf [Accessed 20 June 2021].

Miller C 2018. *How one e-waste recycler uses education to incentivize the right behaviors* [Online]. Available from: https://sustainablebrands.com/read/behavior-change/how-one-e-waste-recycler-uses-education-to-incentivize-the-right-behaviors [Accessed 2 June 2022].

Miner KJ, Rampedi IT, Ifegbesan AP & Machete F 2020. Survey on household awareness and willingness to participate in e-waste management in Jos, Plateau State, Nigeria. *Sustainability* 12(3): 1047-1065.

Mishra S, Shamanna BR & Kannan S 2017. Exploring the awareness regarding e-waste and its health hazards among the informal handlers in Musheerabad area of Hyderabad. *Indian Journal of Occupational and Environmental Medicine* 21(3): 143.

Mouton J 1983. Qualitative and quantitative methodologies in the social sciences. *South African Journal of Sociology* 14(4): 124-131.

Moyo T, Sadan Z, Lotter A & Petersen J 2022. Barriers to recycling e-waste within a changing legal environment in South Africa. *South African Journal of Science* 118: 1-8.

Murthy V & Ramakrishna S 2022. A review on global e-waste management: Urban mining towards a sustainable future and circular economy. *Sustainability* 14(2): 647-655.

Nethaji-Mariappan VE, Karthik S, Vineeth KS & Varthamanan S 2017. E-waste management and assessment: A review. *International Journal of ChemTech Research* 10(2): 924–936.

Nnorom IC, Ohakwe J & Osibanjo O 2009. Survey of willingness of residents to participate in electronic waste recycling in Nigeria: A case study of mobile phone recycling. *Journal of Cleaner Production* 17(18): 1629-1637.

NNREC (The Norwegian National Research Ethics Committee states) 2016. *Guidelines for research ethics in the social sciences, humanities, law and theology* [Online]. Available from: https://www.forskningsetikk.no/globalassets/dokumenter/4-publikasjoner-som-pdf/60127_fek_guidelines_nesh_digital.pdf [Accessed 14 April 2021].

Nowakowski P, Szwarc K & Boryczka U 2020. Combining an artificial intelligence algorithm and a novel vehicle for sustainable e-waste collection. *Science of The Total Environment* 730: 138-726.

Nuwematsiko R, Oporia F, Nabirye J, Halage AA, Musoke D & Buregyeya 2021. Knowledge, perceptions, and practices of electronic waste management among consumers in Kampala, Uganda. *Journal of Environmental and Public Health* 2021(10): 384-642.

Oberti I & Paoletti I 2020. Da. Ma. Tra: Material traceability database. *Digital Transformation of the Design, Construction and Management Processes of the Built Environment* 6(1): 85-93.

Olla P & Toth J 2010. E-waste education strategies: Teaching how to reduce, reuse and recycle for sustainable development. *International Journal of Environment and Sustainable Development* 9(3): 294-309.

Ongondo FO, Williams ID & Cherrett TJ 2011. How are WEEE doing? A global review of the management of electrical and electronic wastes. *Waste Management* 31(4): 714–730.

Packard V 2011. *The waste makers*. New York: Ig Publishing.

Park JK, Hoerning L, Watry S, Burgett T & Matthias S 2017. Effects of electronic waste on developing countries. *Advances in Recycling & Waste Management* 2(2): 1-6.

Patton MQ 1987. *How to use qualitative methods in evaluation*. Second edition. Newbury Park: Sage Publications.

Patton MQ 2014. *Qualitative research & evaluation methods: Integrating theory and practice.* Fourth edition. Thousand Oaks: Sage Publications.

Plonsey R & Barr RC 2007. *Quantitative Approach*. New York: Springer.

Polák M & Drápalová L 2012. Estimation of end-of-life mobile phone generation: The case study of the Czech Republic. *Waste Management* 32(8): 1583-1591.

Pradhan JK & Kumar S 2014. Informal e-waste recycling: Environmental risk assessment of heavy metal contamination in Mandoli industrial area, Delhi, India. *Environmental Science and Pollution Research* 21(13): 7913-7928.

Prasad M, Vithanage M & Answesha B 2019. *Handbook on WEEE management: International best practices and case studies*. Oxford: Butterworth-Heinemann.

Princeton University Environmental Health Safety 2017. *Chemical-specific protocols- aqua regia* [Online]. Available from: https://ehs.princeton.edu/laboratory-research/chemical-safety/chemical-specific-protocols/aqua-regia [Accessed 22 August 2022].

Puckett J, Byster L, Westervelt S, Gutierrez R, Davis S, Hussain A & Dutta M 2002. *Exporting Harm: The high-tech trashing of Asia.* Seattle: Basel Action Network Publications.

Richa K, Babbitt CW, Nenadic NG & Gaustad G 2017. Environmental trade-offs across cascading lithium-ion battery life cycles. *The International Journal of Life Cycle Assessment* 22(1): 66-81.

Robinson BH 2009. E-waste: An assessment of global production and environmental impacts. *Science of the Total Environment* 408(2): 183-191.

RTS 2021. *What is urban mining*? [Online]. Available from https://www.rts.com/blog/what-is-urban-mining/ [Accessed on 4 April 2021].

Sadan Z 2019. Exploring the potential for local end processing of e-waste in South Africa. Unpublished Master's Thesis. Cape Town: University of Cape Town [Online]. Available from: https://core.ac.uk/download/pdf/288496912.pdf [Accessed 8 March 2021].

Salhofer S 2017. E-waste collection and treatment options: A comparison of approaches in Europe, China and Vietnam. *Source Separation and Recycling* 63(6): 227-227.

Sandborn P 2007. Software obsolescence-complicating the part and technology obsolescence management problem. *IEEE Transactions on Components and Packaging Technologies* 30(4): 886-888.

Sansom 2018. *The theory of planned behaviour* [Online]. Available from: https://ascnhighered.org/ASCN/change_theories/collection/planned_behavior.html#:~:text=The%20Theory%20of%20Planned%20Behavior%20assumes%20that%20individuals%20act%20rationally,for%20the%20decision%2Dmaking%20process [Accessed 21 February 2023].

Santhakumar V, Shephard K & Gupta R 2020. *Do higher levels of education make people environment-friendly.* Karnataka: Azim Premji University.

Sari DP, Masruroh NA & Asih AMS 2021. Consumer intention to participate in e-waste collection programs: A study of smartphone waste in Indonesia. *Sustainability* 13(5): 27-59.

Saunders M, Lewis P & Thornhill A 2007. *Research methods*. Fourth edition. Harlow: Pearson Education Limited.

Sepúlveda A, Schluep M, Renaud FG, Streicher M, Kuehr R, Hagelüken C & Gerecke AC 2010. A review of the environmental fate and effects of hazardous substances released from electrical and electronic equipment during recycling: Examples from China and India. *Environmental Impact Assessment Review* 30(1): 28-41.

Shah A 2014. *An assessment of public Awareness regarding e-waste hazards and management strategies* [Online]. Available from: https://digitalcollections.sit.edu/isp_collection/1820/ [Accessed 28 February 2021].

Sharma A, Vaish A & Sharma 2020. Detailed review of ball end magnetorheological fluid finishing process. *WSEAS Transactions on Heat and Mass Transfer* 15: 163-173.

Shittu OS, Williams ID & Shaw PJ 2021. Global e-waste management: Can WEEE make a difference? A review of e-waste trends, legislation, contemporary issues and future challenges. *Waste Management* 120(9): 549-563.

Silverman D 2013. *A very short, fairly interesting and reasonably cheap book about qualitative research.* Second edition. Los Angeles: Sage Publications.

Singh KD 2015. Creating your own qualitative research approach: Selecting, integrating and operationalizing philosophy, methodology and methods. *Vision* 19(2): 132-146.

Sivathanu B 2016. User's perspective: Knowledge and attitude towards e-waste. *International Journal of Applied Environmental Sciences* 11: 413-423.

Smith C 2009. Reducing campus e-waste through product stewardship ecycling programs adopting a management strategy that maximizes institutional participation. *University business solution for higher education management*.

Someya T, Bao Z & Malliaras GG 2016. The rise of plastic bioelectronics. *Nature* 540(7633): 379-385.

Song Q, Wang Z & Li J 2014. E-waste management and assessment in Macau. *Ecological Indicators* 30(2): 138–147.

Sothun C 2012. Situation of e-waste management in Cambodia. *Procedia Environmental Sciences* 16: 535-544.

Stake RE 2010. *Qualitative research: Studying how things work*. New York: Guilford Press.

Statista 2022. *Number of smartphone subscriptions worldwide from 2016 to 2021, with forecasts from 2022 to 2027* [Online]. Available from: https://www.statista.com/statistics/330695/number-of-smartphone-users-worldwide/ [Accessed March 2022].

Statista Research Department 2021. *Consumer electronics report 2021* [Online]. Available from: https://www.statista.com/study/55488/consumer-electronics-market-report/ [Accessed 18 May 2021].

Statista Research Department 2022. *Replacement cycle length of smartphones in the United States 2014-2025, in years* [Online]. Available from: https://www.statista.com/statistics/619788/average-smartphone-life/ [Accessed 6 February 2022].

Stellenbosch University [n.d.]. *Waste on campus* [Online]. Available from: https://www0.sun.ac.za/sustainability/pages/services/waste/on-campus.php [Accessed 20 August 2022].

Stellenbosch University 2022. *Student Enrolments Overview* [Online]. Available from: https://app.powerbi.com/view?r=eyJrIjoiY2UzMThjNjktYzk4YS00ODg0LTk3MTMtMmM5OTI3OTE4NTI0IiwidCI6ImE2ZmEzYjAzLTBhM2MtNDI1OC04NDMzLWExMjBkZmZjZDM0OCIsImMiOjh9&pageName=ReportSection2eed1b06354b01ae250a [Accessed 12 October 2020].

StEP Initiative (Solving the e-waste problem initiative) 2014. S*olving the e-waste problem (StEP) white paper: One global definition of e-waste* [Online]. Available form: https://www.step-initiative.org/files/_documents/whitepapers/StEP_WP_One%20Global%20Definition%20of%20E-waste_20140603_amended.pdf [Accessed 23 March 2020].

Sthiannopkao S & Wong MH 2013. Handling e-waste in developed and developing countries: Initiatives, practices, and consequences. *Science of the Total Environment* 463: 1147-1153.

Strausss A & Corbin J 1998. *Basics of qualitative research: Techniques and procedures for developing grounded theory.* Los Angeles: Sage Publications.

Tan Q, Duan H, Liu L, Yang J & Li J 2018. Rethinking residential consumers' behaviour in discarding obsolete mobile phones in China. *Journal of Cleaner Production* 195: 1228-1236.

Tanskanen P 2013. Management and recycling of electronic waste. *Acta Materialia* 61(3): 1001-1011.

Tchobanoglous G, Theisen H & Vigil S 1993. Integrated solid waste management: Engineering principles and management issues. *Water Science and Technology Library* 8(1): 63-90.

The E-waste Tragedy 2014. [Film]. Cosima Dannoritzer. dir. Spain: Televisión Española.

The World Bank 2019. *Solid waste management* [Online]. Available from: https://www.worldbank.org/en/topic/urbandevelopment/brief/solid-waste-management [Accessed 15 September 2021].

Tiseo 2022. *Global waste generation - statistics & facts* [Online]. Available from: https://www.statista.com/statistics/916625/global-generation-of-municipal-solid-waste-forecast/ [Accessed 24 March 2021].

Tröger N, Wieser H & Hübner R 2017. *Smartphones are replaced more frequently than T-shirts. Patterns of consumer use and reasons for replacing durable goods*. Vienna: Chamber of Labour.

Tsirulnik G 2022. *Mobile phone ranked most used electronic device: Forrester* [Online]. Available from: https://www.marketingdive.com/ex/mobilemarketer/cms/news/research/7473.html [Accessed 3 July 2021].

Tue NM, Takahashi S, Suzuki G, Isobe T, Viet PH, Kobara Y, Seike N, Zhang G, Sudaryanto A & Tanabe S 2013. Contamination of indoor dust and air by polychlorinated biphenyls and brominated flame retardants and relevance of non-dietary exposure in Vietnamese informal e-waste recycling sites. *Environment International* 51: 160-167.

Uhunamure SE, Nethengwe NS, Shale K, Mudau V & Mokgoebo M 2021. Appraisal of households' knowledge and perception towards e-waste management in Limpopo province, South Africa. *Recycling* 6(2): 39-45.

UNEP (United Nations Environment Programme) 2015. *Technical guidelines on transboundary movements of electrical and electronic waste and used electrical and electronic equipment, in particular regarding the distinction between waste and nonwaste under the Basel Convention* [Online]. Available from: http://www.basel.int/Implementation/PublicAwareness/NewsFeatures/Ewastetechnicalguidelines/tabid/5122/Default.aspx [Accessed 23 August 2021].

UNEP (United Nations Environmental Programme) 2011. *Basel Convention on the control of transboundary movements of hazardous wastes report* [Online]. Available from: https://wedocs.unep.org/bitstream/handle/20.500.11822/8385/-Basel%20Convention%20on%20the%20Control%20of%20Transboundary%20Movements%20of%20Hazardous%20Wastes%20-20113644.pdf?sequence=2&amp%3BisAllowed= [Accessed 22 August 2022].

UNEP (United Nations Environmental Programme) 2012. *The Convention- Overview* [Online]. Available from: http://www.pops.int/TheConvention/Overview/tabid/3351/Default.aspx [Accessed 24 August 2022].

UNEP (United Nations Environmental Programme) 2016. *Contributions to the 2030 agenda for sustainable development* [Online]. Available from: https://sustainabledevelopment.un.org/content/documents/10239COP%20Rotterdam%20Convention%20contribution%20recd%202016-May-9.pdf [Accessed 22 August 2022].

UNEP (United Nations Environmental Programme) 2022. *Status of ratifications* [Online]. Available from: http://www.pic.int/Countries/Statusofratification/PartiesandSignatories/tabid/1072/language/en-US/Default.aspx [Accessed 24 August 2022].

UNIDO (United Nations Environmental Industrial Development Organisation) 2013. *Stockholm Convention* [Online]. Available from: https://www.unido.org/our-focus-safeguarding-environment-implementation-multilateral-environmental-agreements/stockholm-convention [Accessed 24 August 2022].

United Nations Industrial Development Organization (UNIDO) 2019. *UNIDO annual report 2019* [Online]. Available from: https://www.unido.org/sites/default/files/files/2020-05/Annual%20Report%202019%20%28Eng%29.pdf [Accessed 23 August 2021].

UNTC (United Nations Treaty Collection) 2022. *Basel Convention on the control of transboundary movements of hazardous wastes and their disposal: Basel, 22 March 1989* [Online]. Available from: https://treaties.un.org/Pages/ViewDetails.aspx?src=IND&mtdsg_no=XXVII-3&chapter=27&clang=_en [Accessed 22 August 2022].

US Environmental Protection Agency (EPA) 2016. Electronic products generation and recycling methodology Review (Online). Available from: https://www.epa.gov/sites/default/files/2016-

12/documents/electronic_products_generation_and_recycling_methodology_review_508.pdf [Accessed 12 August 2021].

Van Ewijk S & Stegemann JA 2016. Limitations of the waste hierarchy for achieving absolute reductions in material throughput. *Journal of Cleaner Production* 132 (19): 122-128.

Vergara SE & Tchobanoglous G 2012. Municipal solid waste and the environment: A global perspective. *Environment and Resources* 37(37): 277-309.

Verma SS 2021. *Living with electronics: the good and the bad* [Online]. Available from: https://www.electronicsforu.com/technology-trends/tech-focus/healthcare-electronics-devices [Accessed 24 August 2021].

White MJ & Hunter LM 2009. Public perception of environmental issues in a developing setting: Environmental concern in coastal Ghana. *Social Science Quarterly* 90(4): 960-982.

White PR, Franke M & Hindle P 1995. *Integrated solid waste management: A lifecycle inventory*. Berlin: Springer.

WHO (World Health Organisation) 2013. *Guidance on solid waste and health* [Online]. Available from: https://www.who.int/tools/compendium-on-health-and-environment/solid-waste#:~:text=Solid%20waste%20refers%20to%20any,solid%20waste%20are%20produced%20annually [Accessed 15 September 2021].

WHO (World Health Organisation) 2020. *Food safety: Persistent organic pollutants (POPs)* [Online]. Available from: https://www.who.int/news-room/questions-and-answers/item/food-safety-persistent-organic-pollutants-(pops)#:~:text=Persistent%20organic%20pollutants%20(POPs)%20are,human%20health%20and%20the%20environment [Accessed 22 August 2022].

WHO (World Health Organisation) 2021. *Soaring e-waste affects the health of millions of children, WHO warns* [Online]. Available from: https://www.who.int/news/item/15-06-2021-

soaring-e-waste-affects-the-health-of-millions-of-children-who-warns [Accessed 14 September 2021].

Wibowo N, Nurcahyo R & Gabriel DS 2022. Environmental awareness factor of used cell phones. *Global Journal of Environmental Science and Management* 8(1): 87-100.

Widmer R, Oswald-Krapf H, Sinha-Khetriwal D, Schnellmann M & Böni H 2005. Global perspectives on e-waste. *Environmental Impact Assessment Review* 25(5): 436-458.

Williams PT 2005. *Waste treatment and disposal*. New York: John Wiley & Sons.

Worrell E, Allwood J & Gutowski T 2016. The role of material efficiency in environmental stewardship. *Annual Review of Environment and Resources* 41(1): 575-598.

Xu X, Yang H, Chen A, Zhou Y, Wu K, Liu J, Zhang Y & Huo X 2012. Birth outcomes related to informal e-waste recycling in Guiyu, China. *Environment International* 33(1): 94-8.

Yan Z 2019. *Encyclopaedia of mobile phone behaviour*. Pennsylvania: Information Science Reference.

Yin J, Gao Y & Xu H 2014. Survey and analysis of consumers' behaviour of waste mobile phone recycling in China. *Journal of Cleaner Production* 65: 517-525.

Yin RK 2009. Case study research: Design and methods. *The Canadian Journal of Action Research* 14(1): 69-71.

Ylä-Mella J, Keiski RL & Pongrácz E 2015. Electronic waste recovery in Finland: Consumers' perceptions towards recycling and re-use of mobile phones. *Waste Management* 45: 374-384.

Zhang K 2018. Theory of planned behaviour: Origins, development and future direction. *International Journal of Humanities and Social Science Invention* 7(5): 76-83.

Zheng X, Huo X, Zhang Y, Wang Q, Zhang Y & Xu X 2019. Cardiovascular endothelial inflammation by chronic co-exposure to lead (Pb) and polycyclic aromatic hydrocarbons from preschool children in an e-waste recycling area. *Environmental Pollution* 246: 587-596.

APPENDICES

APPENDIX A

Ethical Clearance Approval Letter

UNIVERSITEIT
STELLENBOSCH
UNIVERSITY

NOTICE OF APPROVAL

REC: Social, Behavioural and Education Research (SBER) - Initial Application Form

4 August 2021

Project number: 22193

Project Title: E-waste Management, Practices, Knowledge and Behaviour: A Case Study of Universities in the Western Cape

Dear Miss TL Jefthas

Co-investigators:

Your response to stipulations submitted on 29/07/2021 11:53 was reviewed and approved by the REC: Social, Behavioural and Education Research (REC: SBE).

Please note below expiration date of this approved submission:

Ethics approval period:

Protocol approval date (Humanities)	Protocol expiration date (Humanities)
7 July 2021	6 July 2024

GENERAL REC COMMENTS PERTAINING TO THIS PROJECT:

INVESTIGATOR RESPONSIBILITIES

Please take note of the General Investigator Responsibilities attached to this letter. You may commence with your research after complying fully with these guidelines.

If the researcher deviates in any way from the proposal approved by the REC: SBE, the researcher must notify the REC of these changes.

Please use your SU project number (22193) on any documents or correspondence with the REC concerning your project.

Please note that the REC has the prerogative and authority to ask further questions, seek additional information, require further modifications, or monitor the conduct of your research and the consent process.

CONTINUATION OF PROJECTS AFTER REC APPROVAL PERIOD

You are required to submit a progress report to the REC: SBE before the approval period has expired if a continuation of ethics approval is required. The Committee will then consider the continuation of the project for a further year (if necessary).

Once you have completed your research, you are required to submit a final report to the REC: SBE for review.

Included Documents:

Document Type	File Name	Date	Version
Recruitment material	Recruitment_Emails_MA	27/04/2021	
Informed Consent Form	Consent form_Final	27/04/2021	
Privacy Impact Self-Assessment Report	Privacy Impact Self-Assessment	27/04/2021	1
Request for permission	Letter_UCT	28/04/2021	1
Request for permission	Letter_UWC	28/04/2021	1
Request for permission	Letter_CPUT	28/04/2021	1
Data collection tool	Questionnaires	29/04/2021	1

Page 1 of 3

Principal Investigator Responsibilities

Protection of Human Research Participants

As soon as Research Ethics Committee approval is confirmed by the REC, the principal investigator (PI) is responsible for the following:

Conducting the Research: The PI is responsible for making sure that the research is conducted according to the REC-approved research protocol. The PI is jointly responsible for the conduct of co-investigators and any research staff involved with this research. The PI must ensure that the research is conducted according to the recognised standards of their research field/discipline and according to the principles and standards of ethical research and responsible research conduct.

Participant Enrolment: The PI may not recruit or enrol participants unless the protocol for recruitment is approved by the REC. Recruitment and data collection activities must cease after the expiration date of REC approval. All recruitment materials must be approved by the REC prior to their use.

Informed Consent: The PI is responsible for obtaining and documenting affirmative informed consent using **only** the REC-approved consent documents/process, and for ensuring that no participants are involved in research prior to obtaining their affirmative informed consent. The PI must give all participants copies of the signed informed consent documents, where required. The PI must keep the originals in a secured, REC-approved location for at least five (5) years after the research is complete.

Continuing Review: The REC must review and approve all REC-approved research proposals at intervals appropriate to the degree of risk but not less than once per year. There is **no grace period.** Prior to the date on which the REC approval of the research expires, **it is the PI's responsibility to submit the progress report in a timely fashion to ensure a lapse in REC approval does not occur.** Once REC approval of your research lapses, all research activities must cease, and contact must be made with the REC immediately.

Amendments and Changes: Any planned changes to any aspect of the research (such as research design, procedures, participant population, informed consent document, instruments, surveys or recruiting material, etc.), must be submitted to the REC for review and approval before implementation. Amendments may not be initiated without first obtaining written REC approval. The **only exception** is when it is necessary to eliminate apparent immediate hazards to participants and the REC should be immediately informed of this necessity.

Adverse or Unanticipated Events: Any serious adverse events, participant complaints, and all unanticipated problems that involve risks to participants or others, as well as any research-related injuries, occurring at this institution or at other performance sites must be reported to the REC within **five (5) days** of discovery of the incident. The PI must also report any instances of serious or continuing problems, or non-compliance with the RECs requirements for protecting human research participants.

Research Record Keeping: The PI must keep the following research-related records, at a minimum, in a secure location for a minimum of five years: the REC approved research proposal and all amendments; all informed consent documents; recruiting materials; continuing review reports; adverse or unanticipated events; and all correspondence and approvals from the REC.

Provision of Counselling or emergency support: When a dedicated counsellor or a psychologist provides support to a participant without prior REC review and approval, to the extent permitted by law, such activities will not be recognised as research nor the data used in support of research. Such cases should be indicated in the progress report or final report.

Final reports: When the research is completed (no further participant enrolment, interactions or interventions), the PI must submit a Final Report to the REC to close the study.

On-Site Evaluations, Inspections, or Audits: If the researcher is notified that the research will be reviewed or audited by the sponsor or any other external agency or any internal group, the PI must inform the REC immediately of the impending audit/evaluation.

APPENDIX B

Institutional Permission Approval Notice

UNIVERSITEIT • STELLENBOSCH • UNIVERSITY
jou kennisvennoot • your knowledge partner

INSTITUTIONAL PERMISSION:

AGREEMENT ON USE OF PERSONAL INFORMATION IN RESEARCH

Name of Researcher: Tammy Jefhtas

Name of Research Project: E-waste Management, Knowledge, Attitudes and Behaviour: A Case Study of Universities in the Western Cape

Service Desk ID: IG-2286

Date of Issue: 27 May 2021

The researcher has received institutional permission to proceed with this project as stipulated in the institutional permission application and within the conditions set out in this agreement.

1 WHAT THIS AGREEMENT IS ABOUT	
What is POPI?	1.1 POPI is the Protection of Personal Information Act 4 of 2013. 1.2 POPI regulates the entire information life cycle from collection, through use and storage and even the destruction of personal information.
Why is this important to us?	1.3 Even though POPI is important, it is not the primary motivation for this agreement. The privacy of our students and employees are important to us. We want to ensure that no research project poses any risks to their privacy. 1.4 However, you are required to familiarise yourself with, and comply with POPI in its entirety.
What is considered to be personal information?	1.5 'Personal information' means information relating to an identifiable, living, individual or company, including, but not limited to: 1.5.1 information relating to the race, gender, sex, pregnancy, marital status, national, ethnic or social origin, colour, sexual orientation, age, physical or mental health, well-being, disability, religion, conscience, belief, culture, language and birth of the person; 1.5.2 information relating to the education or the medical, financial, criminal or

1
Institutional Permission Standard Agreement: 13 March 2017 V1

APPENDIX C

Participant Imitation Email

E-waste Management, Practices, Knowledge and Behaviours: A Case Study of Stellenbosch University

TJ Tammy Jefthas
To: Jefthas, TL, Miss [19132085@sun.ac.za]
Tue 4/12/2022 3:26 AM

Dear Student,

My name is Tammy Jefthas, a master's student from the Faculty of Arts and Social Sciences. I would like to invite you to participate in my study titled: *E-waste Management, Practices, Knowledge, and Behaviour: A Case Study of Stellenbosch University.*

This study seeks to investigate students' knowledge, behaviours and practices of e-waste at Stellenbosch University. I invite you to complete a questionnaire which will take approximately 20 minutes to complete. The questionnaire will contain questions covering 1) sentiment towards recycling, 2) e-waste knowledge and awareness, 3) e-waste attitude and awareness and 4) waste mobile phones and disposal methods.

By participating in this study, you will have the opportunity to enter a lucky draw to stand a chance to win a Takealot or Superbalist voucher to the value of R800.

To participate in the survey please follow this link: Click here to take the survey

Your participation is entirely voluntary, and you are free to decline to participate. If you do say no, it will not affect you negatively in any way whatsoever. You are also free to withdraw from the study at any point, even if you do agree to take part.

This study has been approved by the Research Ethics Committee: Social Behavioural and Education Research (REC: SBE)- Reference: 22193. You will be asked to provide informed consent before answering any questions or taking part in any tasks. All information that you provide will be kept strictly confidential and secure. If any aspect of the study makes you feel uncomfortable, you can withdraw from the study at any time

Your participation will be valuable and greatly appreciated!

Tammy Jefthas

Reply Forward

APPENDIX D

Online Questionnaire Consent Form

PARTICIPANT INFORMATION LEAFLET AND CONSENT FORM FOR ONLINE SURVEYS/QUESTIONNAIRES

TITLE OF RESEARCH PROJECT: *E-waste Management, Practices, Knowledge and Behaviours: A Case Study of Stellenbosch University.*

I would like to invite you to take part in a research project which involves the completion of an online questionnaire. Your participation is **entirely voluntary** and you are free to decline to participate or to stop completing the questionnaire at any time, even if you have agreed to take part initially. However, once you have submitted your completed questionnaire online, you will no longer be able to withdraw your responses as there will be no way of linking your responses back to you.

What is the study about?

My name is Tammy Jefthas and I am Geography and Environmental Studies student, and would like to invite you to participate in a research project that forms part of my Masters of Arts dissertation. This study will look at the quantity of e-waste generated at Stellenbosch University, as well as how the university manages and disposes of e-waste generated at the institution. Furthermore, this study will look at the university community's (staff and students) knowledge, attitudes and practices of e-waste, focusing on waste mobile phones.

Why are you being asked to participate?

You are being asked to participate in the study as you are a current student or staff member at Stellenbosch University. Your responses to the online questionnaire will be valuable in determining e-waste practices, knowledge and behaviour amongst the university community.

This study consists of an online questionnaire.

Participating in the study will entail completing an online questionnaire that consists of questions encompassing demographic details, sentiment towards recycling, e-waste knowledge and awareness, waste mobile phone disposal and attitudes and perception of e-waste. This questionnaire will take approximately 20 to 30 minutes to complete.

Will you benefit from taking part in this research?

The results of the study will not benefit you directly. The results of the study can be used to inform recommendations for improving e-waste management strategies and disposal methods at Stellenbosch University. By participating in this study, you will have the opportunity to enter a lucky draw to stand a chance of winning a prize to the value of R800. If you wish to be entered for the lucky draw, you can provide your email address at the end of the questionnaire.

Are there any risks involved in your taking part in this research?

By participating in this study, there are no foreseeable direct risks involved. To ensure the anonymity of all participants and responses no personal details such as names, student numbers, email addresses and phone numbers will be required to participate in this study.

You can phone the Principal Investigator of this study, Tammy Jefthas at 0749574593 and 19132085@sun.ac.za if you have any questions about this study or encounter any problems. This study has been approved by the **Research Ethics Committee: Social, Behavioural and Education Research at Stellenbosch University (Project ID#22193).** The study will be conducted according to the ethical guidelines and principles of South Africa's Department of Health Ethics in Health Research: Principles, Processes and Studies (2015).

REC: SBE ICF for online surveys, December 2021

RIGHTS OF RESEARCH PARTICIPANTS:
You have the right to decline answering any questions and you can exit the survey at any time without giving a reason. If you have questions, concerns or complaints regarding your rights as a research participant, please contact Mrs Clarissa Robertson [cgraham@sun.ac.za; 021 808 9183] at the Division for Research Development.

You will receive a copy of this information and consent form for you to keep safe here.

By clicking START SURVEY you are confirming that you are over 18 years old; have read and understood the above explanation about the study, and you agree to participate. You also understand that your participation in this study is strictly voluntary.

REC: SBE ICF for online surveys, December 2021

APPENDIX E

Facilities Management Questionnaire

UNIVERSITEIT·STELLENBOSCH·UNIVERSITY
jou kennisvennoot • your knowledge partner

E-waste Management and Knowledge, Attitudes and Practices: A Case Study of Stellenbosch University

Managers Questionnaire

Section A: Personal Profile

1. Gender | Male | Female |

2. Employment Position ______________________

Section B: E-waste Management and Strategies

3. Does your university have a e-waste management policy and/strategies, if yes could you explain it?

....
....
....

4. To what extent do you agree or disagree with the following statement?

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
A) There is limited information available on e-waste recycling/management at the university					
B) Our university has the potential to generate a large volume of e-waste					
C) The university should do more to create awareness about e-waste student about e-waste					

UNIVERSITEIT STELLENBOSCH UNIVERSITY

....
....
....

13. What are some of the challenges of the e-waste management systems?
....
....
....

Section C: Electronic equipment and E-waste Generation

14. How many of the following is at your university?

	Currently in use	**Obsolete/Redundant**
Desktop computer/Laptop		
Printers/photocopiers/scanners/fax machines		
Computer Screens		
Air-conditioning Units		
TV		
Projectors		

15. How many e-waste was collected each year from 2010-2020?
....
....
....

16. Of this how many was recycled? If recycled, do you have any knowledge of this?
....
....
....

Thank You!!

APPENDIX F

University Community Online Questionnaire

Questionnaire ID

Stellenbosch
UNIVERSITY
IYUNIVESITHI
UNIVERSITEIT

E-waste Management, Practices, Knowledge and Behaviours: A Case Study of Stellenbosch University

Staff and Students Questionnaire

Section A: Participant Profile

1. Gender……………………………………………
2. Age…………………………………………………………
3. Faculty ……………………………………………
4. Employment Position/Study year…………………………………………………………

Section B: Sentiment Towards Recycling

5. Do you consider yourself environmentally conscious? Please justify your answer.

……

……

……

6. Do you believe that the environment has been negatively affected in the past ten years?

……

……

……

7. How important do you think recycling the following waste types are?

	Not Important	Somewhat Important	Important	Very Important
Batteries				
Electronics				
Paper				
Glass				
Plastic				
Metals				

8. Have you participated in recycling activities before?
    a. Yes, I currently/have recycled
    b. No, I have not participated in recycling before

9. Do you recycle any of the following?

Batteries	
Electronics	
Paper	
Glass	
Plastic	
Metal	

10. How far are you willing to travel to drop off your waste?
    a. Less than 1 Km
    b. 1 Km to 5 Km
    c. 5 Km to 10 Km
    d. More than 10 Km
11. What would prevent you from bringing your waste and recyclables to collection or drop-off points?
    a. Lack of drop-off containers nearby
    b. Lack of knowledge about proper recycling
    c. Lack of transport
    d. Lack of time
    e. Do not care
    f. Other reasons……………………………………………

Section C: Knowledge and Awareness

12. Have you heard the term e-waste before? If yes, elaborate, please.

……
……
……

13. From the items in the table below, check the item that you would consider as e-waste?

Item		Item	
Laptop		Charging cable	
TV		Mobile phone	
Chair		Camera	
Fan		Milk carton	
Glass		Monitor	
Computer		Plastic bag	
Printer/Scanner		Paper cup	
Stew		E-reader	
Video game console		Plastic bottle	
Keyboard		Lamp	

14. In your opinion, do you think there is an e-waste problem? Please motive your answer.

....

....

....

15. Rate your knowledge and awareness of the following questions from 1-5. (Where 1= Very poor, 2=poor, 3=okay, 4=good, 5=very good)

	Very Poor 1	Poor 2	Okay 3	Good 4	Very Good 5
A) How much do you know about the national waste management policy?					
B) How much do you know about the national e-waste management policy and strategies?					
C) How much do you know about the materials used in e-waste?					
D) How much do you know about the effects of e-waste on the environment?					
E) How much do you know about the effects of e-waste on human health?					
F) Are you aware of any valuable materials found in e-waste?					
G) Are you aware of any toxic materials found in e-waste?					

16. To what extent do you agree with the following statements:

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
A) Globally, there is currently a massive e-waste problem					
B) Globally, there is currently a massive e-waste problem in South Africa					
C) Broken, obsolete or redundant electronic devices are harmful to the environment					
D) Broken, obsolete or redundant electronic devices are harmful to human health					
E) E-waste should be disposed of in landfills					
F) E-waste should be incinerated (burnt)					
G) E-waste should be collected (recycled)					

17. Do you have access to e-waste collection/drop-off points?
    a. Yes
    b. No
18. Are you aware of any e-waste management systems or initiatives on campus? If yes, please elaborate.
    ....
    ....
    ....
19. To what extent do you agree with the following statement?

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
There is enough awareness of e-waste on campus					

20. Are you aware of any e-waste recycling or e-waste drop-off points on campus?
    ....
    ....
    ....
21. Are you aware of the e-waste recycling bins on campus? If yes, what colour are these bins and where are they located?
    ....
    ....
    ....
22. Have you recycled any e-waste in any of the e-waste bins on campus? If yes, what was it?
    ....
    ....
    ....
23. If there were more e-waste bins on campus, would you use them?
    ....
    ....
    ....
24. Do you have any recommendations for the university in terms of awareness raising about e-waste or management of e-waste on campus?
    ....
    ....
    ....

Section D: Attitude and Perception

25. Do you think e-waste management and recycling is important?

....

....

....

26. To what extent do you agree with the following statements? Please justify your answer in the space provided.

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Justify
A) Our university has the potential of generating large volumes of e-waste						
B) There is limited knowledge, information and clarity on the universities e-waste management and recycling						
C) The university should do more to create awareness about e-waste student about e-waste						
D) I refrain from upgrading mobile phones as long as the one I have still worked						
E) I should consider limiting the number of mobile phones I own by only buying if I really need it						
F) I shall educate myself on the material used in my mobile phone						
G) I notice the problem of increasing amounts of e-waste globally						
H) I feel everyone should take better responsibly of their waste mobile phones						

27. To what extent are you willing to bring the following e-waste to drop-off points/containers on campus?

	Not willing at all	Not very willing	Maybe	Willing	Very willing
A) Mobile phones					
B) TV's and Monitors					
C) Pc's and Laptops					
D) Large home appliances (e.g., fridges, washing machine)					
E) Medium home appliances (e.g., microwave, household heating and ventilation equipment, A/C)					
F) Small home electronic equipment (e.g., radio, music instrument, audio set, video recorder, speakers, household tools, vacuum cleaner, printer, leisure equipment, food preparation equipment)					
G) Other small electronic equipment (Cameras, portable audio and video devices, lamp, router, mice, keyboard, driver, headphones, remote control, irons, clocks, hairdryer, toys, game console)					

Section E: Waste Mobile Phones and Disposal Methods

28. Which of these electronic devices do you use the most often? Rank from 1-5 (1= most often used, 5= least often used)

Electronic Equipment	Rank
Desktop computer	
Laptop	
Tablet	
Mobile Phone	
E-reader	

29. Why did you rank the specific device as most often used?

....

....

....

30. How many mobile phones do you currently have?

A) In use	
B) Working but not in use	
C) Broken	

31. How many mobile phones have you changed in the past 5 years?

....

....

32. How do you usually procure your mobile phone (s)? Please motivate your answer. E.g., buy, gift

....

....

....

33. How do you treat your obsolete mobile phones?
    a. Throwaway as normal waste
    b. Sell as scrap metal
    c. Sell as second-hand goods
    d. Bring to collection points/locations for recycling
    e. Leave in storage
    f. Other

34. What would you cite as the primary reasons for getting a new mobile phone?

....

....

....

Thank You!