INTEGRATED FRAMEWORK FOR MODELLING THE MANAGEMENT OF ELECTRONIC WASTE IN SAUDI ARABIA

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Declaration

I, Hasan Alameer, declare that the research entitled 'Integrated Framework For Modelling The Management Of Electronic Waste In Saudi Arabia' is not more than 65,000 words in length including quotes and exclusive of tables, figures, appendices, bibliography, references and footnotes. This thesis contains no material that has been submitted previously, in whole or part, for the award of any other academic degree or diploma. Except where otherwise indicated, this study is my own work.

Name: Hasan Alameer

Date: 22/03/2015

Signature: [redacted]

Dedication

To my dear father . . .

I hope that you are now pleased with my achievements. Now you can be proud of what has been accomplished.

This is a reminder that you have made me stronger, better, and more fulfilled than I could have ever imagined. You made me want to achieve greatness!

To my wife ...

Thank you from the bottom of my heart for your patience and endurance of many hardships.

Standing beside me, and that your efforts were on the upswing was the secret.

I dedicate you this achievement to share me outcome of this success.

To my beloved Rehaf . . .

How much you suffered during my study!

How much pain you experienced due to my absence!

Here, I dedicate this achievement to you. For a while, I might’ve lost the world in which you live, but I gained a universe of knowledge. Can I be forgiven for all that I have done to get here? I want you to be sure that I can, and my love for you will last as long as I live.

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Abbreviations

BAN	Basel Action Network
CD	Compact Disc
CEDARE	Centre for Environment and Development for the Arab Region and Europe
CRT	Cathode Ray Tubes
CSR	Corporate Social Responsibility
DVD	Digital Versatile Disk
EEE	Electronic And Electrical Equipment
EPR	Extended Producer Responsibility
EU	European Union
E-WASTE	Electronic Waste
G8	Group of 8 Countries
GCC	Gulf Cooperation Council
GDP	Gross Domestic Product
GeSI	Global e-Sustainability Initiative
HP	Hewlett Packard
ICC	THE International Computer Company
IT	Information Technology
KSA	Kingdom of Saudi Arabia
LCD	Liquid Crystal Display
MCI	Ministry of Commerce and Industry

MCIT	Ministry of Communications and Information Technology
MENA	Middle East And North Africa
NGO	Non-Government Organisations
NGO	Non-Governmental Organization
OECD	Organisation for Economic Co-operation and Development
OPEC	Organisation of Petroleum Exporting Countries
P&G	Procter & Gamble
PACE	The Partnership for Action on Computing Equipment
PC	Personal Computer
PME	Presidency of Metrology and Environment Protection
POM	Put On The Market
PVC	Polyvinyl Chloride
REACH	Registration, Evaluation, Authorisation And Restriction Of Chemicals
RT	Reliability Test
SAICM	Strategic Approach to International Chemicals Management
SASO	Saudi Standards and Quality Organisation
SENS	Swiss Foundation for Waste Management
SGS	(Société Générale de Surveillance
SPSS	Statistical Package for the Social Sciences software
SR	Saudi Riyal
StEP	Solving the E-waste Problem
SVTC	Silicon Valley Toxics Coalition

SWICO	The Swiss Economic Association for the Suppliers of Information, Communication and Organizational Technology
UAE	United Arab Emirates
UK EIA	United Kingdom Environment Investigation Agency
UK	United Kingdom
UN	United Nations
UNEP	United Nations Environment Program
UPI	United Press International
US	United States
USA	United states of America
USEPA	United States Environmental Protection Agency
WEEE	Waste Electronic And Electric Equipment
WHO	World Health Organisation

Abstract

Waste is now electronic, and the landscape of electronic waste management is changing radically. Besides a rapidly growing world population, globalisation is driving the demand for electronic products. Electronic products have a diverse and complex composition. Elements like iron and aluminium and materials like plastics and glasses constitute the bulk of the e-waste, and they contain almost 80% of Waste Electronic and Electric Equipment -WEEE- by weight. The rest contains valuable components and toxic materials. Toxic materials like lead, arsenic, cadmium, selenium, hexavalent chromium, and flame retardants badly affect people and the environment. The World Health Organisation (WHO) estimated that 215 tons of computer waste contain 2 tons of arsenic, 3 tons of mercury, and 10 tons of lead on average. The electronic revolution, as it turns out, is plagued with waste, and disposing of e-waste is a looming threat in Saudi Arabia, with informal recycling activities growing very fast. Although the reusing and recycling of e-waste have environmentally positive impacts in general, citizens are often uncertain of which obsolete management option is preferred.

This research explores how the Saudi people can accept a new concept of treating old electronic equipment. The objective was to examine the attitudes and perspectives of the citizens of Saudi Arabia on e-waste management to develop effective e-waste management practices. Five hundred questionnaires were sent out to citizens of Saudi Arabia. Interviews with open-ended questions were also conducted with the officials of the Ministry of Environmental Affairs in Saudi Arabia, local NGOs, leading experts, and senior managers. The received answers showed no formal e-waste management practices in Saudi Arabia. These results led to several conclusions and recommendations. As there are only a few private projects, raising awareness is a must with regard to not only society but also legislation and institutions. Based on this need, this study proposed an e-waste management model for the government. This model not only addresses policy challenges effectively in the light of worldwide experiences but also provides knowledge of the technological aspects that are at the core of actions that need to be taken. Overall, this study represents a timely and rich source of knowledge that is valuable not only in formulating policy, but also in informing consumers and organisations grappling with the problem of e-waste management in Saudi Arabia.

An important challenge for the kingdom is developing further procedures, processes, and materials that enable greater WEEE directives. Legislation, largely being driven by Europe, is starting to take effect in developed countries, and there is now a clear need to adopt similar legislation in the kingdom. This research contributes to the efforts of the government of the Kingdom of Saudi Arabia and other Arab nations in the areas of (i) elimination of health and environmental hazards, (ii) conservation of resources, (iii) increasing energy efficiency, and (iv) overall economic growth. This study encourages policy makers to adopt this model for treating e-waste and to legislate related terms and instructions. For example, adopting an e-waste recycling model enables the conservation of precious and finite natural resources such as water, minerals, and timber, and the recycling of e-waste is most likely going to facilitate a significant reduction of energy requirements. Since the scope of this research covers the life spans and replacement patterns of electronic devices that have comparatively short life spans and high replacement frequencies, future research could be conducted to cover other electronic devices that generate e-waste, such as refrigerators, televisions, washing machines, etc. This would cover an entire range of electrical and electronic devices, providing vital information for policy makers.

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Chapter 1 Introduction

This chapter starts with the background of the study, followed by an overview of e-waste management in the Kingdom of Saudi Arabia. The next part is dedicated to the problem statement, which includes the research problem, scope of the research, and focus of the research problem. Then this chapter goes on to explain the research questions, objectives, and significance of the study. The chapter concludes with the limitations of the research and organisation of the remaining chapters.

1.1. Background

Electronic equipment significantly influences the ways that society relates, and it is impossible to ignore the hugely positive impacts of society's use of electronics. Nevertheless, important concerns also exist in relation to the flow of electronics deemed out of date by consumers (for example, by families, corporations, public agencies, and schools) around the world. These worries strengthen as manufacturing and adoption rates, triggered by technological advancements relevant to these devices, increase worldwide. For example, a recent report from the United Nations (UN) on cellular phone subscriptions says that the number of cell phones per person in the United States and China increased by 139% and 725% from 2000 to 2009, respectively (United Nations 2011).

The widespread production of electrical and electronic equipment (EEE) has become one of the largest and fastest-growing manufacturing activities worldwide. Factors like the rising demand for information and communications technology (IT) equipment, rapid obsolescence of electrical and electronic products, and rapid economic and technological progress, have largely contributed to the increased production of various EEE (Kurian 2007). This has resulted in a sheer increase in the quantity of waste electrical and electronic equipment (WEEE). WEEE represents old, end-of-life, or abandoned electronic and electrical devices and appliances discarded by the original owners (E-waste Guide 2007). There are growing global concerns regarding waste generated from these pieces of equipment. According to an estimate, approximately 40 million tons of WEEE are generated every year worldwide (Huisman et al. 2008; Schluep et al. 2009).

Compared to the expenditures on product development, marketing, and sales, a smaller amount of resources has been devoted to the end-of-use management of electronic equipment, such as reusing, recycling, and landfilling. In the last 20 years or so, some nations and regions have focused on the management of this complex waste stream. The oldest and possibly the most successful electronic waste (e-waste) or WEEE system, is the one found in Switzerland, with recycling rates of approximately 9.8 kg of e-waste per person per year (Khetriwal et al. 2009). The Swiss Economic Association for the Suppliers of Information, Communication and Organizational Technology (SWICO), and the Swiss Foundation for Waste Management (SENS), the two e-waste systems in the country, collect and recycle a vast portfolio of electronics, including information technology (IT) and office equipment products and home appliances (Hischier et al. 2005; Khetriwal et al. 2009). Moreover, with the implementation of the WEEE Directive and under the principle of extended producer responsibility (EPR), the members of the European Union (EU) have been adopting regulations to properly manage e-waste (European Commission–WEEE Directive 2003). The overall goals of the WEEE regulations include improvement of equipment design, collection at the end of use, environmentally sound treatment and material recovery at the end of life, and consumer awareness. The original recycling rate target for the WEEE Directive is 4 kg per person per year, which includes a vast range of products—large and small household appliances, IT and telecommunication products, and consumer equipment (European Commission–WEEE Directive 2003). Although enforcement started in 2003, the implementation time frame for the WEEE regulations varied from country to country, on the basis of factors such as negotiations with stakeholders and transfer from previous country-specific WEEE regulations to EU WEEE regulations (Magalini and Huisman 2007, 143). In Asia, Japan and South Korea have experience managing e-waste, including TVs, refrigerators, washing machines, air conditioners, and PCs (Kahhat et al. 2008; Terazono et al. 2006). Japan instituted its law for the promotion of effective utilisation of resources in 1991 (Japan Ministry of Economy, Trade & Industry, 2016).

In North America, several American states and Canadian provinces have e-waste programs, including California, Maine, Alberta, British Columbia, Manitoba, Ontario, and Saskatchewan, and many other North American locations are in the process of adopting e-waste collection and recycling systems (Gregory and Kirchain 2008; Kahhat et al. 2008). Following the lead of the abovementioned e-waste management systems and, in some cases, learning from previous experiences, other countries like Saudi Arabia have adopted or plan to adopt strategies to handle e-waste.

E-waste has a diverse and complex composition. Elements like iron and aluminium and materials like plastics and glasses, constitute the bulk of the e-waste, and they contain almost 80% of WEEE by weight (E-waste Guide 2007). The rest contains valuable components and toxic materials (Bhuie et al. 2004). Toxic materials like lead, arsenic, cadmium, selenium, hexavalent chromium, and flame retardants badly affect people and the environment (Schelup et al. 2009). The World Health Organisation (WHO) estimated that 215 tons of computer waste contain 2 tons of arsenic, 3 tons of mercury, and 10 tons of lead on average (Wang et al. 2011). This stresses the need for managing e-waste appropriately to avoid potential damage to the health of people and the environment.

1.2. E-waste management in Saudi Arabia

The technology revolution of the 1990s enabled all business stakeholders, including those in the Kingdom of Saudi Arabia, to rely heavily on electronic mail and commerce involving the use of a large number of electronic and electrical devices (Sinha 2004). Attention to e-waste management from policy makers has been largely focused on environmental impacts related to landfills and informal recycling activities, also known as backyard recycling in Saudi Arabia. The kingdom has celebrated several international environmental agreements related to marine life, perilous waste, and conservatory gases. It signed the Kyoto Protocol in 2005 and has stated its desire to join the International Renewable Energy Agency has also recently hosted the first Gulf Environment Forum in Jeddah in March 2010. Despite the government's determined strategies, the Saudi Arabian environmental marketplace remains embryonic. This is simply not enough, given that environmentally dreadful conditions cost approximately 5% of the gross domestic product of Arab countries. Strangely enough, revenues from oil are helping to finance a new push to develop green technology in Saudi Arabia.

The kingdom's populace is expanding fast, growing younger, richer, and more urban. This demographic truth has resulted in exponential growth in energy demands and is putting more pressure on urban environments. It is also driving the government's investment in infrastructure as well as environmentally friendly technologies. In spite of this, consideration of e-waste management in Saudi Arabia is often missing. Moreover, the supply chain for new electronics as well as the flow of e-waste is increasing. The rapid increase in the usage of technology and economic activities in the kingdom, has caused new environmental problems in the form of e-waste management. E-waste includes obsolete electronic equipment, devices, and gadgets no longer being used and that had reached their end of life (Kim et al. 2011). E-waste contains several elements like copper and lead; other materials like plastic, chemicals, and glass; and precious metals like silver, gold, platinum, and palladium. E-waste also contains hazardous heavy metals (Luttropp and Johansson 2010). The inclusion of these toxic elements in e-waste considerably changes the perception of this type of waste and suggests that landfilling is not the best way to dispose of it. The contents of e-waste are harmful to people and the environment if not properly treated at their end of life. In order to contain the potential danger to people and to the environment, it becomes imperative that a special system for their collection and reuse or disposal is developed and implemented. The electronic revolution, as it turns out, is plagued with waste in Saudi Arabia. Although the reusing and recycling of e-waste have environmentally positive impacts in general, citizens are often uncertain of which WEEE management option is preferred.

1.3 Theoretical basis

This thesis is supported by stakeholder theory, as the primary research concerns the private organisation's adoption of corporate social responsibility, and users' rising awareness of the need for responsible disposal of their electronic waste. Öberseder, Schlegelmilch and Murphy (2013) explained that corporations are concerned about their public image in society, in part due to the rise of social media, where potential damage to corporate reputation may occur if the corporation is not seen to be supporting environmental sustainability. Further, Atasu and Wassenhove (2012) noted that a successful model for waste management should be based on integrated policy, legislation and the acceptance of the stakeholders, both firms and citizens.

1.4. Problem statement

A more affluent lifestyle in Saudi Arabia has resulted in increased acquisitions and purchases of electrical and electronic equipment and devices (Ramzy et al. 2008). The growing significance of

IT in the global economic context, coupled with the falling prices of electronic equipment, has led to the creation of several challenges for the reusing and recycling of electronic equipment. Although the use of these equipment and devices does not pose a problem, their rapid reuse and their end-of-life treatment pose certain challenges (Sushant et al. 2010). The constant advancements and changes in the functional capabilities and features of these equipment have led to such devices turning into garbage (Kang and Schoenung 2005). Ramzy et al. (2008) observe that there has been no growth in the processes related to the collection, reusing, and recycling of e-waste matching the extent of the significant growth in the production of e-waste.

Saudi Arabia, as one of the developing countries, uses a large volume of electronic and electrical equipment (EEE). The task remains a vivid critical overview of the actual ways of managing such equipment when they turn into waste. The criticality of the examination extends to the identification of potential sources for extended resource recovery. Certainly, a large portion of e-waste is being landfilled (Allam and Inouen 2009). Incidences of informal recycling activities, including actions of backyard recyclers, cannot be ruled out (Cobbing 2008). With improper end-of-life treatment, substances such as lead, polyvinyl chloride, and/or brominated fire retardants are likely to dissipate into the environment and ultimately cause harm to human beings (Birnbaum and Staskal 2004; Chen et al. 2009). This makes a study of the attitudes and perspectives of the citizens of Saudi Arabia on e-waste management, important for developing an effective e-waste management process in the kingdom. Sustainable development calls for the evolution of a special system of collection and a management option to handle e-waste appropriately.

1.5. Research problem and Scope of the study

The overview of the problem, explained previously, focused on the problems that need to be addressed. This subsection contains two sections: the first specifies areas of the problem that need to be focused on during the research, and the second contains the scope of the research.

1.5.1. Issues for research

E-waste is an emerging problem as computers, cell phones, and other electronic products become obsolete or stop working efficiently. The introduction of innovative EEE with new functions and features stimulates the desire of consumers to purchase the latest equipment (Singh and Sididque 2012). This, in turn, leads to the rapid increase in the manufacture and sale of new models. Kim et al. (2011) observe that e-waste has now become a global concern. Increased e-waste growth and its dumping, raise global concerns regarding resource efficiency and pressing concerns of potential dangers to humans and the environment (Lee et al. 2007). The e-waste problem is lengthy and complex. It starts with the manufacture of a new electrical or electronic product, its purchase, and its eventual disposal at its end of life (Shih 2001). Lee et al. (2007) classify e-waste into the following four categories: electronic devices such as computers, servers, mainframes, monitors, and televisions; telecommunication devices such as cellular phones and pagers, calculators, audio and video devices, printers and scanners, fax machines, refrigerators, air conditioners, water machines, and microwaves; recording devices such as DVDs, CDs, floppies, and tapes, printing cartridges, and automobile catalytic converters; and electronic components such as chips, processors, and motherboards, industrial electronics such as sensors, alarms, sirens, and security devices, and automobile electronic devices.

It is evident that all of these electronic items are available in large quantities in Saudi Arabia, and the global phenomena of increased e-waste growth and its dumping are equally applicable to Saudi Arabia as well. Disposing of e-waste is a looming threat in Saudi Arabia. Regulatory framework or comprehensive e-waste management mechanisms do not exist in the country. In the absence of those people opt to use whatever method is convenient for them to dispose of e-waste without considering the consequences of their actions. Formulating legislations, a regulatory framework, and a comprehensive e-waste management mechanism require information on existing perceptions, attitudes, and commitment of people with respect to e-waste disposal. Since that is lacking, there is a vacuum in the spectrum of e-waste disposal that needs to be addressed soon as inadequacy in terms of needed information would hamper any future initiative to address the problem.

There are no official statistics available on e-waste collection in the kingdom, and there is no specific research on how such waste dumped in landfills (Allam and Inouen 2009). This leads to serious concerns for environmentalists and also local citizens of Saudi Arabia. Hence, it is vital to look at the problem of e-waste disposal from the perspective of people's perceptions and attitudes, as success in any initiative for addressing the issue depends on the commitment of the people who use and dispose of electronic devices and appliances, creating e-waste.

1.5.2. Scope of the study

The spectrum of e-waste disposal extends to many areas, such as legislations and regulatory frameworks and e-waste disposal processes and recycling mechanisms as well as human aspects. Similarly, there is a wide range of electrical devices and appliances and it is practically impossible to encompass those in the research. Hence, the scope of the research was confined to the following:

1. E-waste disposal, focusing on perceptions, attitudes, and knowledge on e-waste of people and relevant Saudi Arabian officials and authorities
2. Electrical devices that have a comparatively short life span and a high replacement frequency, which are most significant in e-waste management such as small kitchen appliances
3. The existing status with respect to an e-waste management system in Saudi Arabia.

1.6. Research questions

Based on a review of the available literature and the primary data collected using an appropriate research method, this thesis endeavours to find plausible answers to the following research questions:

1. What are the attitudes and perception of the citizens of Saudi Arabia with respect to e-waste and its management?
2. What are the challenges to effectively managing e-waste in the Kingdom of Saudi Arabia?
3. What are some global policy interventions and other ways to help implement an effective e-waste management program in Saudi Arabia?

1.7. Research objectives

The general objective of this thesis is to gain a deeper understanding of the impact of e-waste on people and the environment. This then leads to a better understanding of ways to effectively manage e-waste in Saudi Arabia and includes a comprehensive understanding of the methods of collecting e-waste and recycling e-waste. This study examines the descriptions, analyses, and comparisons of prevalent global practices regarding e-waste management and the application of such practices in the context of the Kingdom of Saudi Arabia.

There are no official statistics available on e-waste collection in the kingdom, and there is no specific research on how such waste is dumped in landfills (Allam and Inouen 2009). This leads to serious concerns the environmentalists and also local citizens of Saudi Arabia. Thus, the specific objectives of this study are to

1. identify the problems and challenges of managing e-waste in a global context
2. compare the prevalent practices worldwide regarding proper e-waste management and their application in the Saudi Arabian context;
3. assess the attitudes and perceptions of the citizens of Saudi Arabia regarding the effective management of e-waste; and
4. learn lessons from global e-waste management practices and make appropriate recommendations for policy interventions for the implementation of an effective e-waste management system within Saudi Arabia.

1.8. Significance of the study

The purpose of this study is to provide a deeper understanding of the issue of e-waste management as the citizens of Saudi Arabia perceive it. By reviewing the literature on e-waste management practices in different countries across the world, this thesis expects to enhance the existing knowledge on the importance of e-waste management. This study forms the basis for designing several policy frameworks concerning e-waste management from an environmental protection perspective. The study also serves the purpose of being a reference to learning institutions and other platforms to encourage further research on the topic of e-waste management.

The findings will contribute to the efforts of the government of the Kingdom of Saudi Arabia and other Arab nations in the areas of (i) elimination of health and environmental hazards, (ii) conservation of resources, (iii) increasing energy efficiency, and (iv) overall economic growth. For example, e-waste recycling will enable the conservation of precious and finite natural resources such as water, minerals, and timber, and the recycling of e-waste is most likely going to facilitate a significant reduction of energy requirements. Thus, this research will make a significant contribution that will help policy makers to deal with the issue of managing environmental impacts. Since legislations or regulatory frameworks do not exist in the country, the government's regulatory authorities have to initiate action soon to formulate such legislations, a regulatory framework, and enforcing mechanisms to facilitate effective and efficient e-waste management. The success of such initiatives is beneficial to environmental protection and largely depends on the commitment of the people. Hence, the results of the research would bring in adequate analytical reviews on the subject of people's perceptions, attitudes, and commitment with respect to e-waste disposal and would provide supporting information to the government's regulatory authorities for a future initiative to address the problem of e-waste disposal in the country.

1.9. Organisation of the thesis

The organisation of the chapter is depicted at figure 1

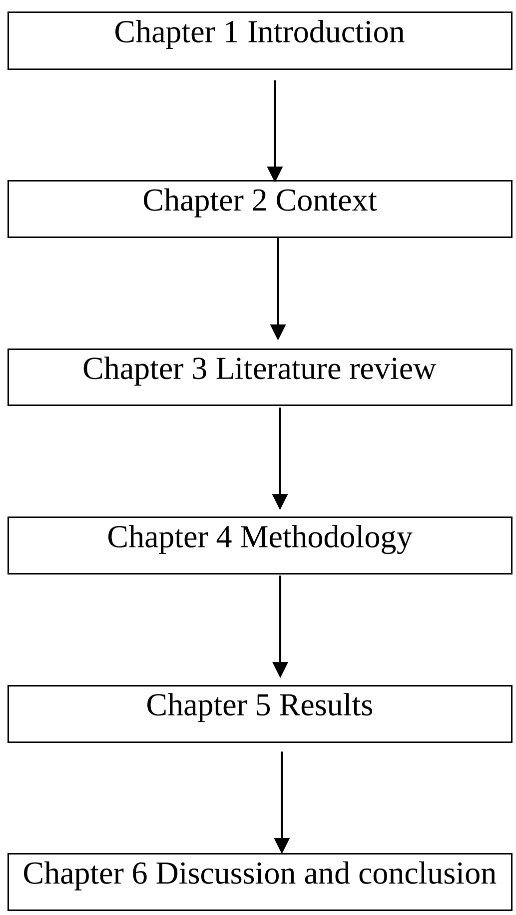


Figure 1 *Organisation of thesis*

Figure 1 depicts the chapters of the thesis. Chapter 1 introduces the issue of electronic and electrical waste management in Saudi Arabia. Chapter 2 describes the commercial environment and the issues regarding electronic and electrical waste accumulation in the country. The global issues are described in chapter 3, literature review, together with international guidelines and national initiatives around the world. Chapter 4 moves to the methodology adopted, which is a mixed methods study, describing the sampling techniques, data collection through quantitative and qualitative data collection, and the analyses used for the data. Chapter 5 moves to the results for both approaches (quantitative and qualitative) and chapter 6 completes the research with a discussion and conclusion.

1.10. Chapter summary

Chapter 1 introduces the context of the problem, which concerns management of electronic and electrical waste in Saudi Arabia. The issues involved in such waste are presented, leading to establishing the research problem, research objectives and questions, and the theoretical basis for the thesis. This is followed by the significance of the study and the chapter is completed with a brief explanation of the thesis contents. The next chapter moves on to the context of the research, which concerns the management of electronic and electrical waste in Saudi Arabia.

Chapter 2 Context

This thesis considers issues regarding waste products in Saudi Arabia, in particular, waste from personal electronic devices, that is, desk and mobile computers and fixed and mobile phones. There are significant issues arising regarding such waste, as unless managed, it contributes to a range of air, water and ground pollution issues, and may affect the health of users and non-users. This chapter discusses the significance of waste in Saudi Arabia, and the factors that led to the situation the Kingdom now experiences.

This chapter comprises an overview of Saudi Arabia, its economy and its waste treatment practices. A discussion on electronic waste issues is included.

2.1 Overview of Saudi Arabia

When the modern Kingdom was established in 1932, the Arabian Peninsula was an agricultural society that depended on farming and commerce – especially date exports and trade generated by pilgrims coming to Makkah and Madinah. It lacked the infrastructure needed to support the kind of economic and social development envisioned by its founder, King Abdulaziz bin Abdulrahman Al-Saud. The discovery of oil in commercial quantities in 1938 changed that. Soon after World War II, steady oil exports provided the funds to build a basic infrastructure of roads, airports, seaports, schools and hospitals (Ramady 2013).

In 1970, Saudi Arabia introduced the first of a series of ongoing five-year development plans to build a modern infrastructure. The result has been a steady transformation of the country into a modern, sophisticated state. The Kingdom offers a highly developed infrastructure to support economic growth and investment, free public education and health care systems for all citizens, world-class research and health care facilities and an extensive social services program (Royal Embassy of Saudi Arabia 2013). As part of its ongoing agenda, the Kingdom has updated its academic curricula and encouraged young Saudis to study in universities across the world. The country is proceeding with Saudisation, that is, replacement of expatriate professionals with trained and experienced nationals to promote economic development and maintain rising living standards in the country (Hertog 2014).

2.2 Economy

Saudi Arabia's economy is based on the oil profits that have been fuelling the economy for over six decades (Al-Rasheed 2010). To meet the social and economic needs of the country, the World Bank suggested a series of five-year development plans to better direct the country's expenditure with the first proposal, mainly social and economic infrastructure, in 1970 (Alshuwaikhat 2005). Succeeding plans allocated budget expenditure from facilities to improving standards of service delivery and raising the educational standard to allow Saudis to take over the management and 'knowledge' jobs from expatriates. From the end of the 20th century, a policy of privatisation allowed dominant firms to re-establish in the private sector and encourage competition by opening up opportunities for foreign investment. This culminated in entry to the World Trade Organisation in 2005 (Kattuah 2013). The privatisation program included an efficient financial system to meet World Bank demands, and to attract foreign investment (Al-Rasheed 2010). Ramady (2013) explained that Saudisation, the process of replacing expatriates with experienced and qualified Saudis, and the 2011 Nitaqat or compliance measures, were aimed at both placing youth and women in work, and diversifying the economy from oil revenues.

Figure 2 *Saudi oil production 1973 - 2014*

Although part of the Organisation of Petroleum Exporting Countries (OPEC), Saudi Arabia uses its position either for its national purposes as in the 1980s, or to maintain equanimity in world economics as in 1990, when Iraq invaded Kuwait and exports were halted from both countries (figure 2.4; Alkhathlan et al 2013). Since then, production quotas were managed to maintain stability within world demand whilst other OPEC and non-OPEC members gradually increased their exports Prices also impact oil revenues, and in 2008 these reached $US148 per barrel (Alkhathlan et al. 2013). However, oil prices remain volatile and in November 2014 were $US72 as Saudi Arabia brought down the price as it sought to protect its market share (News.com.au 2014).

2.3 Saudi waste treatment

This section discusses the early concerns in the literature regarding waste management for Saudi Arabia, then the available regulatory framework for waste. This is followed by discussion from the media regarding waste issues that concern commentators.

2.3.1 Early concerns on waste

Saudi Arabia's first concern for waste treatment was waste water. Al-Rehaili (1997) explained that late last century only a third of wastewater was treated in central treatment facilities, that the majority was treated through septic tanks and cesspools. The goal was to have all municipal wastewater treated in appropriate facilities. Water policies that previously exploited underground sources were abandoned in the 1990s as authorities realised that groundwater was not being replenished. Further, Saudi Arabia was at great risk of pathogens in wastewater due to the number of hajji that entered the country each year (Al-Rehaili, 1997).

The other waste issues in 20th century Saudi Arabia were hospital waste, oil industry waste and household waste. Al-Zahrani et al. (2000) explained that at the time, Saudi Arabia was generating 23,000t of hazardous waste each year; although it was not explained how this was disposed. Nevertheless, Al-Zahrani et al. pointed to separation of biological waste, radioactive waste, bed waste and kitchen waste and the imminent preparation of a national disposal policy. Fakhru'l-Razi et al. (2009) explained that contaminated water containing organic and inorganic compounds is generated by oil and gas industry processes. This waste is treated by a variety of physical, chemical, and biological methods; however, space constraints on offshore platforms use compact systems that do not remove small dissolved elements or oil particles and may produce a hazardous sludge. Onshore, the authors suggest that biological pre-treatment of oily wastewater is environmentally friendly and of low cost; although the nature of the contaminants vary the treatment methods (Fakhru'l-Razi et al. 2009).

2.3.2 Regulatory agencies on waste

The Saudi Geological Survey's (2014) Environmental Geology Department is the agency responsible for environmental maintenance, clearance of pollutants and hazardous wastes, and monitoring disposal facilities. The Department identifies potential contaminants, investigates the logistics of moving hazardous waste and publishes risk assessments. Its responsibilities include assessment and reporting on:

- fuel leakage and spills for soil and groundwater contamination
- mining activities
- hazardous liquid and solid waste collection, transport and disposal
- environmental and indoor radon detection and metering.

The department's aims include raising public awareness of low-level radioactivity, ionizing radiation and electromagnetic fields in the environment, and it is currently pursuing this (Saudi Geological Survey 2014).

However, Royal Decree M/34 states that hazardous materials management, that is, enforcement, is assigned to the General Presidency of Meteorology and Environmental Protection. Article 14 of the Decree sets out standards for 'manufacturing, transporting, recycling, treating and disposing of hazardous, toxic and radioactive materials and wastes' (Verisk 2009, p.2). Verisk, ultimately a United States advisory group, noted that although at the time no inventory of hazardous materials was published, Saudi cities such as Jubail and Yanbu established a regulatory system for chemical control, an Environmental Permit to Operate. Firms in the industry under this system must also retain on file current safety notes in Arabic and English and notify city authorities (the Royal Commission on Environmental regulations) annually of the nature and quantity of hazardous materials stored. Verisk also reported that the Ministry of

Commerce and Industry issued import licences for commercial chemicals, excepting explosives (Ministry of Interior), pharmaceuticals (Ministry of Health), and those imported by national industries (Ministry of Industry and Electricity). Given the number of overlapping agencies at the various levels of government, there appears to be no means of determining a particular responsible authority for the management of electronic waste.

2.3.3 Municipal waste

Domestic waste across the Gulf countries, according to Alhumoud (2005), would benefit from greater recycling to assist the urban environment. Alhumoud advocated for separating from source beyond the then current cardboard and paper, using regulation and financial incentives. At that time, landfill costs and the opportunity for dumping were such that recycling program were not feasible, due to options and transport and collection costs. Further there were no obvious users of recycled waste due to a negligible manufacturing sector. Only metals would have some value. Government environment policies across the Gulf countries existed but were not practised (Alhumoud 2005).

There is some evidence that Saudi Arabia generates 13.6mt of municipal waste annually, with recycling accounting for up to 15 per cent of the waste stream diverted through informal pathways (Alnuwairan 2014; Zafar 2013). However, this may include construction and commercial waste, which is a considerable proportion of the waste stream. Arguably, it is managed by the producers through the private sector. Alnuwairan reported that current recycling initiatives in the country have not yet developed to a stage where it is an accepted practice in the community. Similar to Alhumoud (2005), Alnuwairan called for limitations on landfill, cooperation between municipal and national agencies to reduce waste and enforcement of the recycling regulations. This included separation of organic and recyclable wastes at source, and separate collection. Unless this was developed, the private industry would not invest in waste management facilities that could treat waste and offer optional disposal techniques such as those trialled in the United Kingdom (Alnuwairan, 2014).

Another aspect of municipal solid waste was producing energy from decaying matter. Khan and Kaneesamkandi (2013) point to the possibility of trapping biogas from all sources: human waste, agricultural waste and municipal waste, claiming 1.75kg of waste per person per day (some 19mt of waste annually). There are more than 30 industry categories that produce waste amenable to anaerobic digestion treatment, including beverages, dairies, fish and meat processing industries and pulp and paper firms.

In Jeddah, as an example of municipal waste management, Zafar (2013) explained that some 4.5 thousand tonnes of waste per day (14mt pa) is produced in the municipality (domestic and commercial) and transported to Buraiman landfill facility, above and east of Jeddah. This is a large facility, with capacity between 30 and 40 years. However, it is also the recipient of Jeddah's sewerage wastewater transported by truck tankers and treated at the site where the dam now covers an area of 288ha. Zafar stated that aquifer leakage has reached Jeddah and is closing on to residences in the outskirts of the city. There were issues regarding the dam’s weak walls in the Jeddah floods of 2010, although Alhamid (2014) stated that the Jeddah Municipality, together with the Civil Defence and Ministry of Transport were working to alleviate the threat by draining and levelling the lake before the 2014-2015 monsoon season.

2.3.4 Electronic waste

As noted, the Chemical Safety and Hazardous Wastes group at the Presidency of Meteorology and Environment has the carriage of electronic waste management. At an interview with the group’s Director, Alhamid (2012) reported that the country produced 2.7 million tonnes of electronic each year, and that there were plans for the appropriate treatment of such wastes according to Saudi regulations and international standards. The group had approached the private sector with an aim of reducing the rate of increase of all waste, and assisting the private sector in recycling ventures and materials and energy recovery. Further, regulations were to be enforced to prevent importing sub-standard items. Matters such as establishing standards for electronic items were to be established (Alhamid 2012).

The industry at the time was regulated by government agencies for the disposal and management of electronic wastes; another agency regarding collection of wastes; and

> others to regulate the circulation of electronics before they become wastes . . .. some traders buy them to recycle them or fix usable materials and sell them abroad as used electronics’ (Alhamid 2012, p. 1).

The Director continued the report, stating that the Chambers of Commerce and Industry in Riyadh, Jeddah and the Eastern province had briefs for investors on opportunities emerging in waste management. Preparations were under way to launch an awareness campaign for the public regarding recycling (Alhamid 2012). Al-Otaibi (2014) reported that the Royal Commission of Jubail commenced such a recycling campaign for the month of November, preparatory of an international conference on recycling machinery for industrial waste in December. Recycling bins were set up around the city (Al-Otaibi, 2014).

2.4 Chapter summary

In terms of waste management storage, the physical characteristics of the peninsula represent contrasts where hazardous waste may remain ‘dormant’ for many years. However, the nature of the Arabian Peninsula with its periodic dust storms, infrequent but heavy rains with subsequent lateral flooding, and the possibility of earthquake in the north-west zones can quickly expose waste that was improperly stored or indeed, dumped. This section described the risk for Saudi Arabia of hazardous chemicals or flying debris in the event of a climatic event, or a lesser risk from earthquakes or sea flooding.

In the next section, whilst the Kingdom has a robust economy and an increasingly educated citizenry, the complex nature of governance tends to complacency in the population. Until something presents an unavoidable issue, such as Jeddah’s ‘Musk Lake’, there is little reason to voice complaint. With recycling of waste in Jubail as an excellent illustration, authorities tend to ‘showcase’ elements of the environment, such as recycling bins distributed prior to a conference.

As electronic wastes’ accumulative issues have not yet reached a critical point, there may not be the public or authorities’ will to tackle the issue in Saudi Arabia. There is certainly no commercial benefit in recovery, given depressed metal prices, nor international approval in sending recovered materials to developing countries, given the potential hazards to workers. The next chapter moves to the literature review, including international standards.

Chapter 3. Literature Review

E-waste is growing at an explosive rate. Electronics consists of a broad range of devices now designed with increasingly shorter life spans, which means that every new promotion will produce its old electronic rubbish. Of the millions of tons of e-waste collected worldwide, as the United States Environmental Protection Agency (2011) reported, this had reached 73 million tons in 2009, at least 75% of them were stockpiled. Computer owners stored the outdated model as though there is some way to convalesce its fading value, but the PC is one item that does not acquire value over time. At some point, stocked computers and electronics enter the waste flow (USEPA 2011). Most of these consumer devices are landfilled in Saudi Arabia, often involving the shipping of electronics for salvage to countries with cheap labour and lax environmental laws. The electronic revolution, as it turns out, is plagued with waste.

The developing countries have not developed such sophisticated systems for disposing of the e-waste. What inspired this dissertation was a complete oversight of the Saudi Arabian government—both in terms of where used equipment might end up (creating potential environmental hazards) and in terms of human beings' health and security. This literature review provides a deeper understanding of the issue of e-waste management as the citizens of Saudi Arabia perceive it. By reviewing the literature on e-waste management practices in different countries worldwide, the literature is expected to enhance the existing knowledge on the importance of e-waste management. This forms the basis for designing several policy frameworks concerning e-waste management from an environmental protection perspective in Saudi Arabia. This also serves the purpose of this chapter, which is to review the literature on the current e-waste management practices and, particularly, provide for the perceptions of citizens of Saudi Arabia for reusable and recyclable e-waste. This chapter conducts a systematic review to determine the current state of research. The limitations of a systematic review lie in the paper selection process. However, this paper tried to minimise the risk by following Webster and Watson's (2002) proven course of action for the creation of a successful literature review. This restriction of the sources for quality articles leads to reliable results about the citizens' perceptions of e-waste management in the Kingdom of Saudi Arabia.

3.1. Scope of review

The review of the existing literature shows that Saudi Arabia has no specific policy or regulation on e-waste management. However, there are a number of actions aimed at protecting the environment and human settlements. Today, with rising volumes of e-waste and safety threats to public health and to the environment here in Saudi Arabia and overseas, many scholars believe it is time for a more sensible approach, a nationwide policy, on e-waste management. The government of Saudi Arabia could take a cue from the states and computer firms that stepped up to the challenge and pass federal legislation. Like the EU, the kingdom could ensure that its electronic goods are safer for consumers and the workers who produce them, and the companies will take them back and recycle them responsibly when they are obsolete. The problems regarding transportation, handling, and disposal have to be discussed at the soonest; else they might cause harmful effects on the environment.

The task remains a vivid critical overview of the actual ways of managing such equipment when they turn into waste. The criticality of this literature review extends to the identification of potential sources for extended resource recovery and the avoidance of pollution. It is believed that a large portion of e-waste is being landfilled in Saudi Arabia (Allam & Inouen 2009). Incidents of informal recycling activities, including actions of backyard recyclers, cannot be ruled out (Cobbing 2008). With an improper end-of-life treatment, substances such as lead, PVC, and/or brominated fire retardants are likely to waste into the environment and ultimately cause harm to human beings (Birnbaum & Staskal 2004; Chen et al. 2009). This makes the study on the attitudes and perspectives of the citizens of Saudi Arabia on e-waste management relevant in developing an effective e-waste management process in the kingdom. Sustainable global development calls for the evolution of a special system of collection and a management option to handle e-waste appropriately.

Allam and Inouen (2009) conducted a survey on e-waste activities in 22 Arab states. This study has identified the current trends of e-waste management in the Arab countries. They used a survey and sent 300 questionnaires to NGOs, IT companies, and several organisations of the governments involved. The results proved that there is no formal practice on e-waste management in most of the Arab states, but this study also assumed that e-waste management practice is in its preliminary phase. Most of the countries, including Saudi Arabia, have partnerships and ongoing collaborative projects with governments, private organisations, and NGOs. An example is that the National Committee on Hazardous Waste in Saudi Arabia, as the Saudi Gazette (2012) reported, discussed and drafted some important rules on recycling and dumping waste. There are no official statistics available on e-waste collection in the kingdom, and there is no specific research on how such waste is dumped in landfills.

3.2. Structure of review

The introduction provided the scope and focus of this literature review. It set the scene, discussed relevant information, and reviewed most relevant journal articles available. The next section will review both primary and secondary sources and demonstrate a combination of the themes and concepts acknowledged within them. The themes acknowledged would be the *definition of e-waste*, *global e-waste management*, *issues considered in the development of an e-waste management program*, and *comparative studies on e-waste management*. This conceptual framework will determine the structure of the literature review and extend the major points and the most important information from the literature available. It also discusses and tries to evaluate every literature in great depth, particularly the ones that have significance to this review. The key findings will be highlighted and discussed in this section.

3.3. Definition of e-waste

Considering the framework of this literature review, it is essential to define e-waste by taking into consideration that e-waste is subject to transnational movement. Lye, Ofori, and Savage (2010) found it best to adopt a common definition. That definition includes characterisation and classification of e-waste in the Middle East, in compatibility with the Basel Convention and other nationwide legislations such as the EU's WEEE directive, to help the easy implementation and enforcement of the subject locally in the Kingdom of Saudi Arabia. A number of countries have their own definitions, interpretation, and use of the term e-waste. The most widely accepted definition of e-waste is per EU directive, followed by a number of EU countries and other countries in Europe (Lye et al. 2010). Allam and Inauen (2009) described e-waste as a popular and familiar term used for any electrical or electronic appliance that has reached its end of life. Yet there is no standard definition of e-waste.

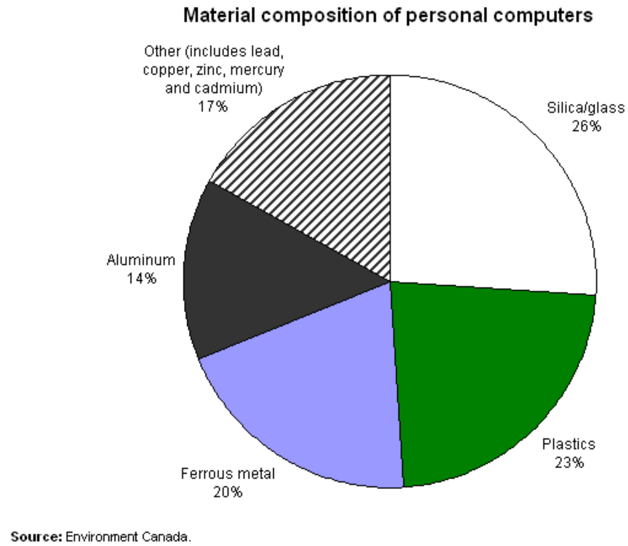
There are marked discrepancies in the definitions of e-waste. They relate to the meaning of the term “discarded” as relevant to any equipment and the definition of the equipment itself referred to in the definition (Ravi 2012). Although most of the definitions describe the equipment to which the term discarded is related, they provide only general or indicative descriptions of the equipment. This is because the descriptions are bound to change over time with the advent of new and improved models and versions. However, Askarzai (2011) provides the most comprehensive definition of e-waste and suggests that the definition of e-waste used for electric and electronic waste includes a wide range of household appliances such as refrigerators and air conditioners, computers and stereo systems, as well as handheld digital devices and cell phones. This definition is most suitable for this paper.

3.4. Hazards of E-waste

The term “e-waste” was recently coined in the market of harmful and hazardous electronic substances. Sahu and Agrawal (2008) argued that e-waste has taken a on new burgeoning meaning since the recent boom in the IT sector. Dwivedy and Mittal (2010) also suggest that the electronics industry generates an enormous amount of waste, which is not properly handled and is just dumped.

The Basel Action Network (BAN), one of the most influential NGOs in the e-waste arena, and the Silicon Valley Toxics Coalition, SVTC (2002) mutually conducted a challenging study on e-waste and stated that e-waste is a problem not only in terms of quantity but also in terms of its being a source toxic ingredients - such as the lead, beryllium, mercury, cadmium, hexavalent chromium, and brominated flame retardants—that pose major work-related and environmental health threats. This combined effort of BAN and SVTC (2002) has listed a number of threats that are relevant to the scope of this literature review. Computer and TV displays have an average four to eight pounds of lead each. Monitor glass contains about 20% lead by weight. Cell phones also contain lead, mercury, cadmium, and other dangerous chemicals. When these components are illicitly dumped and crushed in landfills, lead is released into the environment, posing a hazardous legacy for current and future generations. Consumer electronics already make up 40% of lead found in landfills. About 70% of the heavy metals (with mercury and cadmium) found in landfills come from electronic equipment dumps. These heavy metals and other harmful substances found in electronics can pollute groundwater and pose other environmental and public health hazards (BAN & SVTC 2002). Lead can also cause harm to the central and peripheral nervous systems, blood system, and kidneys in humans. It builds up the environment and has highly severe and chronic toxic effects on plants, animals, and microorganisms. Children experience growth defects and loss of mental ability, even at low levels of exposure. Furthermore, mercury found in many electronic products often leak when they are discarded. The existence of halogenated hydrocarbons—used in aerosols, insulating material, the plastic industry, cryogenic fluid, etc.—in computer plastics may result in the development of dioxin if the plastic is burned up. Antilla et al.'s (1995) earlier study reinforced this and found the prevalence of cancer among Finnish personnel who are exposed to halogenated hydrocarbons**.** The existence of these chemicals also makes computer recycling mainly dangerous to employees and the surrounding environments (BAN & SVTC 2002, p. 1).

While reviewing the mechanical recycling of EEE products, Cui and Forssberg (2003) suggested that electronic products vary in hazardous content, high-value content, and ease of recycling. E-waste legislation stems from growing concerns regarding the environmental impacts of this waste stream. Cui and Forssberg (2003) further suggested that electrical equipment contains materials that can cause environmental problems if they are disposed of to landfill or incinerated. Spalvins, Dubey, and Townsend (2008) suggested that hazardous substances are found in components, such as printed-circuit boards, cables, wirings, plastic casings containing flame retardants, display equipment, including cathode ray tubes, batteries and accumulators, capacitors, resistors and relays, and connectors. Spalvins et al. (2008) also reinforced BAN and SVTC's (2002) report that the landfilling of WEEE risks the leaching of heavy metals, including lead, cadmium, and mercury, into groundwater or the evaporation of mercury in the air (Spalvins et al. 2008). These are illustrated in figure 3.



Source: Statistics Canada, 2009, p.1

Figure 3 *Material composition of personal computers*

3.5 Evolution of e-waste management

The real environmental problem of the 20th century was that scientific and hi-tech developments increased the ability to extract resources from nature, process them, and use them (Grossman 2007). Sadly, this has not offered parallel and similar insight into how these resources can be returned to their environmental origin or how they could be entered into a new cycle of extraction, processing, and use. Where does electronic detritus go once expired? Many of the resources extracted from nature are used in unsustainable activities and end up as waste. El Haggar (2007) calls this situation a "cradle-to-grave," in which the products have a "lifetime" and are dumped after they are used, ending up in a "grave" (a landfill, for example). If this were to continue unabated, this may end up completely depleting the natural resources. The only way, El Haggar concludes, to avoid this dead end is to develop public awareness and newer production techniques that use resources in an alternative cradle-to-cradle situation.

Such a conclusion provides an effective guide for thinking through the remainders of e-waste. However, this is not a conventional rendering of history. This evolution is a more normal practice of classification and description signals, in Michel Foucault's account, the beginning of the "modern episteme" (Gugleta 2011). Waldfogel (2009) surveyed gift giving during Christmas for more than a decade and estimated that each Christmas cost $25 billion yearly and that this huge sum is wasted on presents that are not desired or used and end up in a landfill. A reason for this, he described, is that people are bombarded with complex marketing tricks that fuel their desire and dull their reasoning power. Waldfogel (2009) suggests that it is time to consider restrITions on the marketing designed to sell products that are not produced sustainably.

The marketing of the electronics industry to cities and nations over the last 30 years relied on the assertion that electronic production processes are clean and safe for ecosystems and workers. However, Pellow and Park (2002) and Smith, Sannonfeld, and Pellow (2006) concluded that electronic workers experience occupational illness three times the rate of workers in any other manufacturing sector and that employees face up to 1,000 chemicals on any single workstation. Moreover, workers in e-waste recycling plants confront significant chemical hazards (Reuther 2002).

In a historical analysis, Galbraith (1958, p.89) found that a major contributor to the increasing use is the “massive pressure of modern merchandising”. In the last five decades, Galbraith argued, those pressures have been amplified globally, realising what America dreamt as a global ambition, and a message consumer wealth is possible, desirable, and deserved. Galbraith found it reasonable to ask if advertising created the prelude to a disaster, yet it does not have to end badly (Galbraith 1958).

However Kaushal and Nema’s (2012) theory for e-waste management describes the same processes through which electronics end up in the debris, including what happens to the electronic residues in their complex circuits before the dumping. Just as there are material, social, economic infrastructures supporting the development and circulation of electronics, so too are there elaborate infrastructures for removing e-waste. Underground, global, and peripheral residue turns up in spaces during the life and death of electronics (Kaushal & Nema 2012).

No profile for electric/electronic scrap could be made because these items are classified under countless different commodity/custom codes (De Araujo et al. 2008). And the power of the network of e-waste stretches even farther because the Western world is responsible for an environmentally-friendly dumping of waste due to its prosperity. Schuler (2008) found the route of e-waste from the consumer to the export broker’s storage bin hard to outline and the contents of those storage bins perhaps rationalised in a different way. However, Zhang (2011) suggests that Britain's Environment Agency, the EU's Network for Implementation and Enforcement of International Law, the Basel Action Network, Greenpeace International, and several other NGOs worldwide did their job well in tracing the global route of some e-waste shipments. The EU has provided the world a good start in regulating hazardous materials in high-tech electronics and in setting up systems for recycling used equipment. Yet satirically, Goosey (2007) argued that one of the EU directives' basic features is also facilitating the export of e-waste. Since there are no "transfrontier shipment issues within the EU," says the UK Environment Agency's waste e-waste reports, not much documentation is required for cargo travelling by truck within the EU destined for ports like Rotterdam. The sheer volume of container traffic through the port, says Goosey (2007), makes it hard to notice mis-declarations of the kind that allows e-waste to be shipped abroad—often illicitly—for environmentally unsound recycling.

What inspired this dissertation was the complete oversight of the Saudi Arabian government—both in terms of where used equipment might end up (creating potential environmental hazards) and in terms of human beings' health and security. This literature review provides a deeper understanding of the issue of e-waste management as the citizens of Saudi Arabia perceive it. By reviewing the literature on e-waste management practices in different countries worldwide, the literature is expected to enhance the existing knowledge on the importance of e-waste management. This forms the basis for designing several policy frameworks concerning e-waste management from an environmental protection perspective in Saudi Arabia. It also serves as a reference for learning institutions and other platforms to support further research on the topic of e-waste management.

3.6. Global management of e-waste

The landscape of e-waste management worldwide is noticeably changing. Besides a rapidly increasing world population, a number of empirical analyses and books have shown that globalisation is driving the demand for electronic products, resulting in the increasing prices of many materials (Cui & Zhang 2008; Davis & Heart 2008; Leeman 2008; Martin et al. 2007; Raghupathy et al. 2010). Shortage absolutely looms for some special resources, such as indium. Recycled electronic products and reusable materials increasingly crisscross the world. This creates both opportunities and challenges for global e-waste management.

3.6.1. Global production

The production of electronic equipment is increasing worldwide. Both technological innovation and market growth continue to speed up the replacement of equipment, resulting in a significant increase in e-waste. Cui and Zhang (2008), in a review on the metallurgical recovery of metals from e-waste, examined that the number of PCs use around the world has surpassed 1 billion units, which will become obsolete in the next five years. They have also estimated that in 2005 the volume of household e-waste was up to 20 million tons worldwide (Cui & Zhang 2008).

With the development of technology, Davis and Heart (2008) argued that the lifetime of EEE is decreasing. The lifetime of computers has decreased from 4.5 to 2 years in the period 1992 to 2005, thus generating a large amount of e-waste to as much as 20 to 50 million tons yearly in the world (Davis & Heart 2008). Only in India, Raghupathy et al. (2010) said that 330,000 tons of e-waste generated in 2007 is expected to go up 470,000 tons by 2011. The e-waste contained expensive, costly, and hazardous elements such as iron, copper, gold, silver, cadmium, mercury, etc. To meet the environmental norms for perilous waste disposal and protection of natural resources globally, Raghupathy et al. (2010) suggest that there be a growing concern for the safe recycling of e-waste.

3.6.2. European Union

The EU has dealt with the e-waste problem through the WEEE Directive, which establishes the requirements for the disposal of all electronic equipment. Lemann (2008) provides a basic and comprehensive book on waste management. Lemann suggests that all European countries are expected to enforce the directive from 2007 through domestic electronic stewardship plans. Producers of devices affected by the directive are expected to register with the domestic authority charged with administering the program. For household e-waste, Lemann (2008) suggests that the EU directive holds the manufacturer responsible for the costs associated with the environmentally sound disposal of its products. All new electronic products purchased for commercial purposes will be disposed of at the producer's expense. When a business is replacing old equipment, the producer of the new equipment will be responsible for the proper disposal of their customers' old equipment. The purchasing business will be responsible, however, when the equipment they are buying does not fulfil the same function as that which they already own.

Producers may be allowed, however, to negotiate the cost for e-waste disposal with commercial clients in their supply contracts (Lemann 2008).

Because of the dangerous nature of e-waste and the high cost of its safe disposal, Martin, Mayers, and France (2007) argued that some of Europe's e-waste are exported to developing countries, for either reuse or scrap—often in violation of the international law. However, the ways in which European member states implement e-waste recycling system have significantly impacted their environmental and economic performance. Dempsey and McIntyre (2008) categorised the compliance approaches for WEEE in European countries as "noncompetitive or competitive." Several countries in Europe have implemented a single nationwide-compliance system for WEEE compliance. Single nationwide-compliance systems have been the standard approach for countries with legislation prior to the implementation of the WEEE Directive. Producers in Sweden, Norway, Belgium, the Netherlands, and Switzerland joined in the Producer Responsibility Operations.

While these schemes are very proficient at collecting and treating WEEE, Avila (2006) expressed concern that there are monopolies and that an inbuilt lack of competition led to higher recycling costs. Although these schemes can tender recycling and transport services, Avila (2006) suggests that producers are faced with no choice as to whom they join to demonstrate their compliance.

3.6.3. Compliance

The lowest cost is important to manufacturers who wish to compete at the end of product life (Hristev 2006). Hewlett-Packard (HP) is among many companies who wish to compete throughout the product's life cycle. Producers and companies compete on raw material costs, manufacturing and operational costs, distribution, service, and of course, end of life. The obligation of a legal framework at the end of life does not prevent the continuation of competition at this point too (Hristev 2006). However, HP, P&G, Electrolux, and Sony Europe established the European Recycling Platform in 2002 to encourage competition within member states' compliance systems. Germany, France, Spain, the UK, and several other countries have established competitive compliance schemes (table 1).

Table 1
Single compliance system versus competitive compliance system

Single compliance system		Competitive compliance system			
Belgium	*Malta*	Austria	Hungary	Poland	UK
Cyprus	*Netherlands*	Denmark	Ireland	Portugal	
Estonia	*Norway*	Finland	Italy	Slovakia	
Greece	*Sweden*	France	Latvia	Slovenia	
Luxembourg	*Switzerland*	Germany	Lithuania	Spain	

Source: Dempsey 2012, slide 2.

The difference between the single and competitive systems in table 1 relates to control of waste flows, duplication, and inefficiencies in the system (Dempsey 2012). Dempsey pointed to a mix, where there is a clearinghouse for each type of waste (single system) which would then give economies of scale as smaller recyclers fed into the system, selling their materials at a market price. However, economic conditions are crucial in recycling, as secondary materials, especially plastics, are generally more expensive than the primary product. Transport from the source of collection, local, regional or international contributes significantly to feedstock costs, thus the responsibility falls to governments to contribute to costs (Bing et al. 2013).

To facilitate competition between different compliance schemes, Schnurer (2007) suggests that some countries have established a clearinghouse. This body allocates waste arising in municipal sites to compliance schemes based on the responsibility of their member companies. This ensures that all separately collected waste is recycled and that producers take responsibility for a fair allocation of different types of collection site. Other countries have facilitated competition through a simple clearinghouse or through other means such as tradable evidence notes (Schnurer 2007).

3.6.4. Electronic recycling in developing countries

One of the strongest arguments in opposition to the global e-waste trade is that it is mainly driven by informal electronic recycling activities in developing countries. According to BAN, in

2005, 50% to 80% of used electronics shipped from the United States ended up in informal recycling facilities in developing countries such as China. Although the methodology of BAN's study is vague, these results are widely used to influence policies and regulations worldwide. What are the real characteristics of the flow of used electronics around the world? Understanding this is a complex task, particularly because used electronics are not tracked in the trade statistics of most nations and because many different small-scale operations (e.g., brokers, recyclers, refurbishers, resellers, donation agencies, and web-auction services) are part of this annulled supply. Various research groups have proposed methodological approaches to quantify and characterise this flow. For example, Yoshida, Tasaki and Terazono (2009) applied algorithms to measure material flows. Lepawsky and McNabb (2010) used proxies to estimate the international flow of used electronics. Moreover, Kahhat and Williams (2009) implemented a shipment-level trade analysis and developed a methodology to characterise and quantify the export of used computers and monitors from North America to the rest of the world.

Results from some of these and other related studies suggest that the flow of used computers and TVs is driven mainly by the reuse market rather than by the informal recycling market. For example, Yoshida and Terazono (2010) studied the export of secondhand TVs from Japan to the Philippines. The analysis included the tracking of cargo containers, interviews with exporters and importers of secondhand electronics in Japan and the Philippines, respectively, and interviews with local dealers and consumers in the destination country. The study reported that 30% of the imported TVs were sold immediately upon arrival, and the rest entered the local repair and refurbishment process before being sold for recycling. The breakage rate during shipment varied from 0.3% to 17%, depending on shipment conditions (Yoshida & Terazono 2010). In addition, Kahhat and Williams (2009) proved that Peru imported more than 500,000 used desktop computers, 46% of their total imported desktops, between 2002 and 2009; more than 87% of these were reused, in some cases after local repair and refurbishment, instead of being recycled in the country. The United States is the primary exporter of used computers to Peru, accounting for 57% to 76% of the trade in used computers (Kahhat & Williams 2009). The import of new desktop computers increases every year, and although the importation of used desktop computers decreased between 2005 and 2006, it remained relatively constant in the following years (Kahhat & Williams 2009).

The United Kingdom's Environmental Investigation Agency (2011) revealed UK's hazardous export to developing countries. A quick Google search for used or refurbished computers will find many such business descriptions. Some of these exports are for legitimate reuse; however, which of those are not for legitimate reuse is almost impossible to tell without visiting the dealers and tracking individual shipments. Huge containers that may hold as many as 1,000 computers are loaded on ships at U.S., European, Middle Eastern, and Pacific ports bound for African and Asian destinations (UK EIA 2011). Adding to the difficulty of tracking these shipments is the fact that several different companies, including freight consolidators—some located in countries far from both buyers and sellers—are responsible for moving these goods. A recycler in Saudi Arabia, for example, may not be aware who is unloading or receiving the firm's goods in Pakistan (UK EIA 2011).

If reuse is a driving force in the used electronics trade, then Kahhat et al. (2008) found it important to focus on end-of-life management in the countries where the goods are shipped. For example, as mentioned previously, in Peru at least two end-of-life management practices—open burning of insulated copper cables and landfilling of leaded glass—need to be addressed. Enhancement of recycling infrastructures in destination countries using a transferable recycling fee imposed on those imported used computers in the country of origin is one proposition (Kahhat et al. 2008).

Moreover, the supply chain for new electronics, as well the flow of e-waste, is global (Kahhat et al. 2008). Every country has its own definitions of harmful e-waste, as discussed above, so it can be a real quagmire regulating where electronics can or cannot be sent for recycling. For example, Australia has ruled that circuit boards are perilous waste and, under the Basel Convention, cannot be sent to Singapore, China, Indonesia, Thailand, and India, although they can be sent from Australia to OECD countries (Organisation for Economic Co-operation and Development) (Kahhat et al. 2008). Kahhat et al. described that another way around this problem is to rid the equipment of toxics. Things are moving in that direction, slowly but surely. Lead is perhaps coming out of the solder used in circuit boards, but many other toxics—for which no substitutes have yet been found—remain, and the e-waste being processed will, for some time, be that of older generations of equipment (Kahhat et al. 2008).

Over the previous decade, the Australian Bureau of Statistics (2010) revealed that the generation of e-waste—used or obsolete electronic products such as PCs, photocopiers, cell phones, pagers, and fax machines—has been growing alarmingly in Australia, as elsewhere in the developed world. Over 1.5 million computers were dumped in landfills in 2006, and the volume has been increasing since then. Considine (2009) reported that, between 1999 and 2009, 37 million computers and 17 million TVs were dumped in landfills and just 4.5% of cell phones, 1.5% of computers, and less than 1% of TVs were refurbished or recycled.

Recycled electronics generated in a particular country may be managed in another country. Thus, the transboundary flow of e-waste, particularly from developed to developing countries, has also been a focus of international and national legislation. The Basel Convention of 1992 regulates the flow of hazardous waste (including some categories of e-waste with no reuse potential) between countries by requiring prior notification between the two signatories' trade partners. In addition, many countries (e.g., China, Vietnam, and Indonesia) have domestic legislation that controls the importation of e-waste, including used electronics with reuse potential (Considine 2009).

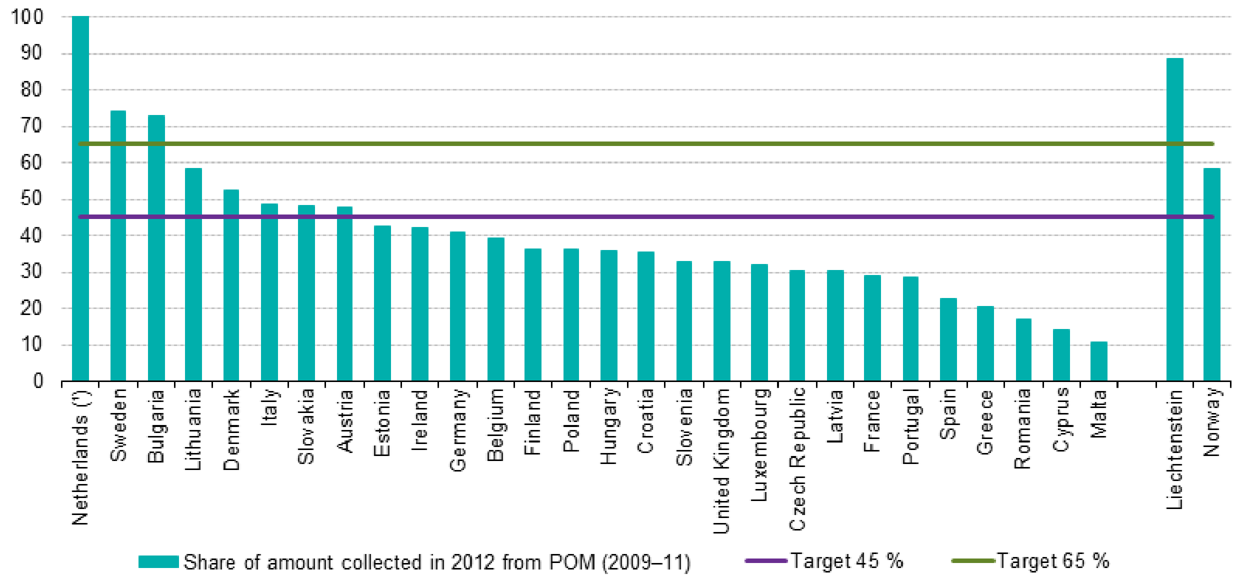
3.6.5. Basel Action Network

European member states signed the Basel Convention on the export of lethal waste (the United States rejected to do so), but there were still concerns over whether it was obligatory (Considine 2009). Since Europe was willing to prevent the export of lethal waste, the BAN squad has been back to China and reported that, while nearly all e-waste originates from the United States, it is still "flowing out of Europe" (Considine 2009). BAN also believed that European waste over and over again ends up in developing countries (e.g., in India and Pakistan). Thus, because of the WEEE, "ecological protection" in the global North may occur hand in hand with environmental injustice in the global South as policies like this often hazardously shift to poor nations (Considine 2009).

Similarly, Osibanjo and Nnorom (2007) suggested that containers holding as many as 1,000 computers are loaded on ships in the U.S, European, Middle Eastern, and Pacific ports bound for African and Asian destinations. Adding to the difficulty of tracking these shipments is the fact that several different companies, including freight consolidators (some located in countries distant from both buyers and sellers), are responsible for moving these goods. A recycler in Saudi Arabia, for example, may not be aware of who is unloading or receiving his goods in Pakistan (Odsibanjo & Nnorom 2007). Veit (2005) examined the different pricing strategies that are seen across the various implementation regimes in Europe. Using a basket of products, Veit (2005) suggested that the average cost of recycling in non-competitive systems are €6.33 per product of WEEE, more than double the €2.93 per product average cost of competing schemes.

When the environment for electronics recycling providers is more competitive, the retract and recycling costs of retired electronic equipment are lower (Grossman 2007). The prices are considerably lower in Spain, Austria, and Germany, which have competitive recycling systems, compared with costs in the Netherlands, Belgium, Norway, and Switzerland, which have noncompetitive compliance systems. For example, to reuse a device costs customers less than 1 euro cent in Spain, 2 euro cents in Austria, 41 euro cents in Belgium, and 1.33 euros in Switzerland (Grossman 2007).

Electronic products significantly influence the way global societies relate, and it is not possible to ignore the huge positive impacts of electronics used by societies (Huisman et al. 2008). Huisman et al. (2008) estimated the growth in EEE sold in the EU market at 2.5% to 2.7% every year. Prior to the implementation of the EU WEEE Directive, Germany was collecting and treating e-waste within its legislative and infrastructural framework. Over the period, the German e-waste management system exceeded the minimum collection and recovery and recycling targets as stipulated in the WEEE Directive 2003. However, the UN University's report states that Germany is able to collect less than 50% of e-waste arising, and the quality of the collection of e-waste is not up to the level for providing proper treatment. The following figure (4) provides information on the European Union's electronic and electrical items put on the market (POM), and waste collected and treated between 2009 and 2011.



(¹) Data for the Netherlands collected in number until 2011.

Source: Eurostat 2016

Figure 4 *European Union e-waste collection rate 2009-2011*

Figure 4 shows the collection rate for WEEE in 2012 as a percentage of the average weight of EEE put on the market in the three preceding years (2009–11). The optimum targets of 45 per cent and 65 per cent for waste collection are shown (Eurostat 2016).

The European WEEE waste stream has an annual growth of between 3% and 5% (Khetriwal, Kraeuchi & Widmer 2009). The latest figures state that 10.3 million tons per year (equivalent of almost 19 kg per inhabitant) of EEE are put on the European market. In addition to this, 8.3 to 9.1 million tons of e-waste are produced per year. However, only 2.2 million tons are estimated as being collected and treated in 2005 (almost 5 kg per individual) within the EU, amounting to only a 25% recovery rate of WEEE (Khetriwal et al. 2009). Pitchel (2005) stated that European studies estimate that the volume of e-waste is rising by 3% to 5% every 12 months, roughly three times faster than the traditional municipal solid waste stream.

Goals of the WEEE regulations include the improvement of equipment design, the collection at the end of use, an environmentally sound treatment, material recovered at the end of life, and consumer awareness (Khetriwal et al. 2009). The original recycling rate target for the WEEE Directive was 4 kg per person per year, which includes a vast range of products: large and small household appliances, IT and telecommunication products, and consumer equipment (European

Commission–WEEE Directive 2003). In response to that directive, Magalini and Huisman (2007) argued that although enforcement started in 2003, the implementation time frame for the WEEE regulation varied from country to country on the basis of factors such as negotiations with stakeholders and the transfer from previous country-specific WEEE regulations to the EU WEEE. The studies of Kahhat et al. (2008) and Terazono et al. (2006) suggested that in Asia, Japan and South Korea have vast experience managing e-waste such as TVs, refrigerators, washing machines, air conditioners, and computers. Gregory and Kirchain (2008) suggested that in North America, several American states and Canadian provinces had e-waste programs. Following the lead of the aforementioned e-waste management systems and, in some cases, learning from past experiences, other countries worldwide have or plan to adopt strategies to handle e-waste. For example, Manomaivibool and Vassnadumrongdee (2011) suggested that Thailand is currently developing an e-waste management system that will potentially increase e-waste recycling in the formal domestic sector.

3.6.6. E-waste Management

The culture of a country impacts a successful e-waste management system in country A will function in country B is typically made (Williams et al. 2008). Kahhat et al. (2008) reinforced the argument of Williams et al. (2008) and further suggested that the e-market for Returned Deposit program proposed the structure and underlying culture of the country—that is, a preference for economic rather than regulatory incentives. While ensuring proper postconsumer management options, the proposed system creates a competitive market for asset management companies, including refurbishers and recyclers (Kahhat et al. 2008).

In an early review of e-waste management Widmer et al. (2005) argued that while most of the global studies on e-waste management focus on the recycling and disposal of computers, these devices comprise only a portion of the e-waste stream. Grossman (2010) suggested that the frequency of electronics—the insertion of microchips into such a wide range of systems and objects—means that the types of waste that emerge from electronics proliferate. Microchips recast the extent of computing beyond the medium-sized memory machines that occupy desktops to encompass miniature devices and distributed systems. Grossman (2010) pointed out that they can be found in computers and toys, microwave ovens, mobile phones, flyswatters, and network architectures—all of which contribute to the stock of e-waste. While the uses of these devices differ considerably, the material and technological resources that contribute to their functionality have a shared substrate with plastic and copper, solvents and silicon (Grossman 2010). In a guidance manual on e-waste, the United Nations Environment Program (2005) describes that electronics typically are composed of more than 1,000 different materials, components that form part of a material program that is across the board and spans from microchips to electronic systems.

A study on e-waste management by Herat (2007) focused on its increase and control, as well as the environmental dilemmas that come with the exportation of waste. Some other studies—including those of Su, Jin, and Yang (2010) as well as Sarmiento and Thomas (2010)—also considered environmental factors when discussing the issue of e-waste management. While these studies provide invaluable information about the volume, distribution, and policies surrounding e-waste, the overriding intention is to situate e-waste within a material and cultural discussion of electronic technologies. Waste is not just sheer matter, so arguably, the methods for studying waste might also account for more empirical processes of waste making. However, a comprehensive view that integrates the perceptions of citizens has been completely missing to date.

3.7. E-waste management programs

Advances in technology have made life easier and more efficient, but with the downside of the increasing explosion of e-waste. In the area of e-waste management, a concrete expression of the development is evident in concepts such as the cradle-to-grave approach, the product stewardship concept, life cycle management and assessment, and the promotion of best available programs as a means to achieve environmentally sound e-waste management.

3.7.1. Three *R*s and Circular economy

Global municipalities, environmentalists, businesses, and manufacturers are concerned about the hazards of disposing e-waste, which has led to searching for ways to reduce their environmental impact. Merino-Blanco and Razzaque (2011) suggested to the G8 Environment Ministers in 2008 to adopt the concept of the three *R*s (reduce, reuse, recycle) as the main objective of their meeting and to adopt the Kobe 3R Action Plan. Japan provides a successful example of the three

*R*s initiative, while China adopts the "circular economy" approach (Merino-Blanco & Razzaque 2011). Circular economy balances economic development with environmental and resource protection. This initiative puts emphasis on the most efficient use of recycling its resources and on environmental protection.

3.7.2. Life cycle initiative

Another approach is the Life Cycle Initiative, launched by the UN Environment Program and the Society of Environmental Toxicology and Chemistry which enables resource users to reduce a product's resource use and environmental emissions while improving its socioeconomic performance through the life cycle (Merino-Blanco & Razzaque 2011). The paradigm change is perhaps most obvious in the Basel Convention, which is the oldest treaty dealing with the menace of e-waste (Merino-Blanco & Razzaque 2011). The Basel Convention originally featured pervasive general obligations related to the minimisation of harmful e-waste production, proximity of disposal, and environmentally sound e-waste management programs and thus did not focus entirely on prevention and control (Merino-Blanco & Razzaque 2011).

Consequently, the world has seen what many consider to be a near-disastrous increase of e-waste materials. The UN has estimated that more or less 50 million tons of e-waste is introduced into the environment every year (Swissinfo 2009). The Basel Convention has been updated to include provisions for rendering illegal the exploration of harmful electronic materials from wealthy countries to developing countries. According to the Basel Convention report, 101 countries exported more than 11 million tons of hazardous waste to 51 poor countries in 2006, creating a disastrous environmental situation in many parts of the world (Swissinfo 2009).

The Basel Convention takes a comprehensive approach to mitigating the illegal distribution of toxic, poisonous, and infectious waste products. E-waste materials are significantly toxic (and eco-toxic), but the Basel Convention has proven powerless to accomplish its stated goals because of the difficulty of policing illicit exportation activities. The Basel Convention, while it has proven effective in many ways, should also be judged in light of the proliferation of waste smuggling that continues to ruin communities throughout Southeast and Far East Asia. The Basel Convention "is a successful story, but this is mostly elapsed," according to Perrez. "The supposed ‘toxic colonialism’ has become against the law and the trade in contaminated waste from developed to developing countries has been notably reduced” (Swissinfo 2009, p.1.).

One of the convention’s most notable successes lies in the extent to which international corporations, the chief producers of electronic communications technology, have been encouraged to alter their business practices and join together to establish a coalition to ensure that manufacturers bear responsibility for the toxic nature and environmental consequences of their products. Some of the largest producers of IT products, including Sony and Phillips, have agreed to emphasise environmental responsibility in their manufacturing and business practices.

The convention has created an environment in which new paradigms can replace old ways of looking at waste disposal. The convention draws on the principles of “environmentally sound management” and the “integrated-life-cycle approach” to product development and manufacture (UNEP 2006, p.1). “It sets out incentives and tools for minimizing the generation of wastes, treating wastes as near as possible to where they were generated, and minimizing movements of hazardous wastes” (UNEP 2006, p.1). In this endeavour, the Basel Convention may be considered a success in having encouraged in situ recycling and remediation efforts in many parts of the world. The Middle East, Qatar, and other Arab world countries have used the convention’s example to rethink their approach to e-waste management. Ultimately, the convention is primarily concerned with encouraging the development of partnerships that represent the most effective and responsive ways in which to handle e-waste management.

3.7.3. Cradle-to-grave approach

The EU has been leading the way in dealing with e-waste management. The cradle-to-grave (Lemann 2008) approach requires producers to take back electronic products at the end of their functional lives for repair, manufacture, or recycling, and e-waste is banned in landfills. Japan is also adopting cradle-to-grave standards for electronic devices and appliances. Grossman (2010) argued that the United States produces roughly about half of the world’s e-waste and recycles only about 10% of it, but that is changing. Canada, which geographically is as sprawling and diverse as the United States and has a smaller population, seems to be tackling the challenge of e-waste with less distress than its neighbour to the south (Grossman 2010).

3.7.4. Global networks and prevention approach

Environmental justice and labour rights activist networks such as the International Campaign for Responsible Technology and the Computer TakeBack Campaign have had responses from several states Maine, Washington, California, and Maryland; the EU; companies such as Dell, Lenovo, HP, and Compaq; and the University of California to establish a system to enact policies to reduce the input of toxic materials in production processes, to make sure there is a takeback of electronics at the end of life to salvage them, to proscribe the use of prison labour for recycling, and to stop the export of these materials to other countries (Jones 2012). Schuler (2008) suggested that other growing awareness programs on e-waste management have spawned highly profitable e-cycling businesses.

According to the European Environment Bureau (2010), the only real continuing solution is a prevention approach that gets toxic materials out of electronic products by using a greener design. For example, Sony Electronics got rid of toxic lead solder used to attach electronic parts together as well as potentially harmful flame retardants from almost all of its electronic products. The company has replaced old cathode ray tubes (which contain large quantities of contaminated lead) used in TV sets and computers with liquid crystal displays, which are more energy-efficient and have fewer hazardous materials (European Environment Bureau 2010). E-waste is just one of many types of solid hazardous wastes.

3.7.5. Chemicals management

As an entity of the United Nations Environment Program, the Strategic Approach to International Chemicals Management (SAICM) promoted chemicals management in developing countries and to raise awareness of the fact that e-waste management is a crosscutting aspect of global sustainable development (Grim, Fairbrother & Rattner 2012).

In this particular framework, Grim et al. (2012) noted that the Basel Convention established multisectoral partnerships to design new programs to environmentally sound e-waste management, to organise theme-specific workshops regionally, and to support the convention's relevant initiatives. Fourteen such centres have been in operation under the Basel Convention for several years, with varying degrees of success (Grim et al. 2012). Loganathan (2011), noted that the joint use of regional centres by the Basel and Stockholm Conventions was adopted in 2008–2009. Grim et al. (2012) further suggested that efforts could be made by the government to increase the interest in the conventions of developed and developing country parties alike as well as nongovernmental associates by launching solid initiatives intended to help the practical management of e-waste. In the framework of the Basel Convention, for example, Grim et al. (2012) suggested that one idea would be to picture an official recognition of e-waste treatment, the disposal of recycling facilities. This would allow consumers in all countries access to a wide range of appropriate facilities and create a unified treatment standard worldwide, thus facilitating control of government agencies and allowing multinationals to operate according to the same standards of every country (Grim et al. 2012).

From the analysis of Grim et al. (2012), one can suggest that new partnerships could be launched, for example, by pairing Saudi Arabia with a company that has particular interests or operations in this country, for the joint development of e-waste management projects. In addition, Hieronymi, Kahhat and William (2012) suggested that institutions could engage in promoting environmentally sound e-waste management as good business: e-waste can be perceived as raw materials subject to trade; consequently, they make up a product within the limits of environmentally sound e-waste management principles.

3.7.6. European initiatives

In a comprehensive study on International Environmental Law, Fitzmaurice (2010) argued that efforts could be extended beyond the constant process of synergies between the Basel and Stockholm Conventions to organisations within the UN system that deal in some way or another with the sound environmental management of e-waste These include, Fitzmaurice (2010) suggested, the Chemicals Branch of UNEP's Division of Technology, Industry and Economics, which acted as the provisional secretariat to the Rotterdam and Stockholm Conventions and provided organisational support to the negotiation of SAICM. The organisation launched the Solving the E-waste Problem (StEP) initiative which aims to formulate global and far-reaching solutions for e-waste management together with all stakeholders (StEP 2009). In 2008, the StEP initiative and Basel Convention Secretariat signed a memorandum of understanding, and efforts were then undertaken for the secretariat to become a member of StEP (StEP 2009).

Besides the Basel and Stockholm Conventions, UN programs, and several prevention strategies, Dempsey and McIntye (2008) suggested that the product stewardship initiative is emerging as a practical and cost-effective method for the collection and dumping of e-waste. Placing the responsibility of dumping e-waste on the shoulders of the sellers, manufacturers, or the purchaser is emerging as the only viable solution for the disposal of e-waste. Dempsey and McIntyre (2008) applied this concept to a range of products from toxic paints to batteries, computers, cell phones, televisions, CD and DVD players, and all potential e-waste products. The aspiration of product stewardship movement remains the same—zero waste—and its application can take different forms. In certain cases, a deposit fee in advance can be added to the purchasing price in which the purchaser pays the cost up front for the collection and dumping of e-waste. Deposits that customers pay in certain nations for glass, plastic bottles, and aluminium cans can be taken as an example. It can also be structured as an industry-funded program where sellers take back used electronic and electrical items at no cost to the purchaser. The primary goal to achieve will be to reroute e-waste from ending up in landfills (Dempsey & McIntyre 2008).

Another European authority with potential oversight of electronic waste is the European Chemicals Agency, with its REACH (registration, evaluation, authorisation and restriction of chemicals) legislation to control, in part, consumer electronics disposal (European Chemical Agency 2016).

3.7.7. Product stewardship

The product stewardship initiative has increased in the last decade, and governments are looking at ways and means of incorporating electronics and electrical equipment in this strategy (Murphy & Hill 2012). For example, in the United States, Murphy and Hill (2012) suggest that federal legislation, the Mercury-Containing and Rechargeable Battery Management Act requires manufacturers to establish a free and convenient program for recycling nickel-cadmium batteries. There are over 30,000 places at businesses that collect old rechargeable batteries. As shown, the product stewardship initiative has the potential to address the e-waste material crisis (Murphy & Hill 2012).

Grossman (2007) argued that America and other countries around the world are not literate in product stewardship. People can be motivated to adopt e-waste recycling by installing the right and acceptable method of product stewardship. Product stewardship calls for setting up a vast collection network of e-waste and a sound recycling process. However, even more critical will be educating and motivating consumers to participate. Experience shows that recycling programs can fail if a means of participation is not created (Grossman 2007).

Recycling will always be an important component of remedial measures, but many countries are opting to approach the challenge from a pre-emptive standpoint. In the Middle East, there is broad support for “green chemistry,” in which products are designed without toxic chemicals. The UN has applied pressure in the Middle East and other parts of the globe in the interest of establishing a “harmonisation system,” in which chemicals typically used in electronics and other products are labelled and classified (Jacobsohn 2012). The aim of this program is to help consumers and producers easily identify the nature of potentially toxic chemicals typically used in manufacturing. It is expected that this will not only protect consumers from harmful chemicals, but also make product stewardship easier at the “end use” part of the cycle (Jacobsohn 2012).

Saudi Arabia is on the cutting edge of the “green” trend in the Middle East. In addition to “green chemistry,” the kingdom is active in the research and implementation of solar energy and other aspects of energy and environmental development. Reducing the waste stream at the end of the product’s life cycle is an area of particular concern in countries that either utilise landfills as a solution or export e-waste to third world countries, an illegal practice under the regulations of the Basel Convention (Zafar 2012). This contributes significantly to the introduction of toxic chemicals into third world environments and is an increasingly worrisome health risk. Dumping, storing, and recycling all cause negative health effects through skin contact and inhalation (Zafar 2012).

The presence of toxic chemicals in electronics and e-waste impacts everyone who comes into contact. E-recycling workers have been shown to have accelerated levels of flame retardants in their bloodstream, probably through prolonged exposure to toxic material in contaminated indoor air (Zafar 2012). Most Middle Eastern countries have outsourced e-waste disposal agreements with countries in Southeast Asia, China, and India, which is contributing significantly to contaminated air and water supplies. Toxic materials in e-waste includes plastics, metals, and ceramics and can include cobalt, indium, and antimony, which are potentially hazardous special metals that make safe disposal highly problematic (Zafar 2012). The potential of green chemistry to alleviate the harmful environmental and health effects of these materials is readily apparent.

There have been calls by organisations such as BAN, an environmental NGO, to ban the importing of toxic e-waste materials into developing countries. However, many observers insist that a better, more responsible product stewardship offers the best hope for remediating the problem. Part of the difficulty in stopping the practice is that the importation of e-waste represents something of a growth industry in the third world, creating local jobs and helping to establish economic ties between developed countries and their less-developed trading partners. One important, yet often overlooked, aspect of product stewardship is the high turnover rate for electronic products, particularly in the Middle East, the West, and other technologically advanced regions. Product stewardship may also refer to mitigating the “dispose of culture so that PCs are not replaced every second year is one way of dealing with the rising e-waste predicament” (Aburawa 2012, p.1).

Thus, there is a mind-set problem to overcome in countries like Saudi Arabia. Product stewardship is about changing attitudes and old habits. Encouraging a more efficient use of electronics can be achieved, just as water and soil conservation has been achieved in many parts of the world. Thus, product stewardship is a means of protecting all parts of the environment and in third world countries particularly. In early 2012, a BAN representative noted that “e-waste is a toxic waste that needs to be dealt with and not traded with—we need to stop exporting our problems to others to deal with” (Aburawa 2012 p.1). The practice of exporting e-waste under the premise that they are being sent for “repair” adds a level of difficulty to the discouragement and interdiction of exportation.

In the Middle East and North African countries (MENA), there is a decided lack of safe, accountable e-waste management and recycling services, further emphasising the need for an essential change in product stewardship. United Arab Emirates–based EnviroServe is the only company in the region that works with the Middle East and North African countries in the areas of e-waste management and recycling (Hassanin 2010). There is certainly a lack of public demand for coordinated and accountable e-waste management in the area, although the public contribution in the reusing process is still part of this play. This is an example of behavioural product stewardship: in Saudi Arabia and other Middle Eastern countries, companies have started offering customers incentives if they will be more supportive and willing to do the same without reasons (Hassanin 2010).

Multinational companies are also partnering with Middle Eastern nations in an attempt to alter consumer behaviour and engender more responsible product stewardship. Nokia, Motorola, Dell, HP, and Canon are among the corporations working with governments to try and initiate take back programs for end of life products (Hassanin 2010). This initiative is all the more important given the noted lack of recycling facilities in the Middle East. Saudi Arabia and Bahrain have passed the most progressive legislation governing the disposal and management of e-waste, but in a small country like Bahrain, managing product stewardship by influencing consumer behaviour is of paramount importance given the severe lack of landfill space and disposal facilities.

One of the most promising developments in the MENA area is the burgeoning public-private joint venture in e-waste management. This model holds strong potential for other countries of the world and could do much to reduce the environmental pressures imposed on those underdeveloped countries, which have become little more than dumping grounds for unwanted refuse. There could also be commercial advantages to the corporate-government cooperation in the Middle East, which take many forms, ranging from takeback and recycling programs to large regionally based landfills, possibly becoming the foundation for a provincial e-waste reusing trade hub (Hassanin 2010). Thus, if third world countries can turn the importation of e-waste materials into a new source of taxable revenue, so too can Saudi Arabia and its neighbours in the MENA region. At the very least, the region can point to a promising collaboration and a marshalling of public and private resources in resolving what all agree represents a significant environmental threat.

Bahrain’s Zain, National Mobile Phone has combined forces with EnviroServe and the Bahraini government to establish an e-waste recycling campaign that is in its second year of operation. This collaboration is the first ever that offered the public the opportunity to get rid of old and unusable mobile phones (Corporate Social Responsibility (CSR) Middle East 2012). The primary reason for the campaign is to safely dispose of potentially harmful electronic devices, but it has also raised public consciousness of the e-waste threat. “We believe that (the campaign) has made the public more aware of the danger of carelessly disposing of mobile phones and batteries which make up the bulk of e-waste” (CSR Middle East 2012, p.1). In effect, Zain has created a product stewardship partnership with the public that has raised environmental awareness to a new level. Zain’s initiative has engendered a remarkably heightened sense of civic responsibility and environmental stewardship.

By choosing to be responsible product and environmental stewards, Bahraini citizens are taking an active role in preserving their air, water, and soil. This is just one of several public-private enterprises in the Middle East that reflects a growing civic acceptance of shared responsibility. “What makes this campaign especially significant is that it represents the power of a simple act of civic responsibility,” said Zain’s Corporate Communications manager Samya Hussein (CSR Middle East 2012, p.1).

3.7.8. Arab technology firms

United Nations Environment Program (UNEP) and Centre for Environment and Development for the Arab Region and Europe (CEDARE) conducted a joint study in 2011–2012 to identify all the relevant actors and activities in the e-waste field in the Arab region. The main influencers were the governmental organisations; the companies producing, selling, or delivering IT services; and the nongovernmental organisations (NGOs) addressing different issues in the e-waste field. The study aims to provide an overview of all available information and the current situation and practices in the target region. This study also outlines the available laws and regulations affecting the state of e-waste management and profiles the key stakeholders. Challenges facing e-waste in the Arab countries are the growing number of hazardous substances in EEE, need of e-waste technology, inventory and knowledge, need for e-waste policies and set of laws, and e-waste exports from Arab countries. This report identified potentials for managing e-waste as

- developing e-waste management guidelines and regulations,
- developing national/regional action plan for e-waste,

- implementing and harmonising control systems for trans-border movement of used EEE,
- encouraging the principle of extended producer responsibility,
- mounting the appreciative of stakeholders and conducting national awareness campaigns, and finally
- developing e-waste management standards and encouraging the setting up of pilot recycling facilities.

A study by Allam and Inauen (2009) to identify e-waste management practices found no authorised e-waste management sector. The results of this study are based on five global companies, four local companies, and four NGOs found active in nine Arab countries. Most of the similar studies concluded that e-waste projects are in their preliminary stages in the Arab region, as suggested by Allam and Inauen (2009). Private sector companies are active in Egypt and United Arab Emirates (UAE) by supporting the collection of used mobile phones, batteries, and refurbishment/recycling. One Saudi Arabian company, the International Computer Company (ICC), has signed an agreement in Austria in January 2012 with the global company EXITCOM, which specialises in the manufacturing and recycling of electronic products, to establish an EXITCOM branch in Saudi Arabia. This will be the first-ever Arab company working in the field of recycling electronic products (Saudi Gazette 2012).

However, EnviroServe is one of the most active IT remediation companies in the region. EnviroServe partners with the UAE Federal Environmental Agency to collect, sort, and categorise e-waste into “green” and “amber” waste (Menon 2010). This partnership is effective at appropriately organising and recycling metals, plastic, glass and paper waste (green), and amber waste, including fluorescent tubes, monitors, and batteries (Menon 2010). The EnviroServe/UAE government partnership is indicative of a growing regional awareness of the benefits of public/private cooperation. There is an international component to the UAE e-waste remediation campaign, as EnviroServe’s operations in the Emirates are overseen by the UN Environment Program office in Bahrain and the Ministry of Environment and Water in the UAE.

Environmental and remediation problems go hand in hand with economic growth in Middle Eastern countries, and few industries reflect this conflIT more than the IT sector. In Saudi Arabia, IT has grown very rapidly, having emerged from nothing in 2005 to nearly 50%

penetration by 2011, with mobile penetration having increased from 60% to nearly 200% (Waverman, Coyle & Souter 2011, p.2). With one of the world's highest telecommunications penetration rates, Saudi Arabian IT companies are in the midst of a growth trend driven by the tremendous IT expansion in the Kingdom. Altogether, Saudi Arabia's IT market is one of the region's largest and represents 68% of the total in the Arabian Gulf region (U.S.-Saudi Arabian Business Council 2012).

The Saudi government is riding the crest of the current wave, having announced that it will spend more than $800 million in the implementation of an e-government program that will entail the development of infrastructure, applications, and services to provide e-communications government services. Both Saudi and international IT companies are involved in the expansion, including Intel. Such an ambitious expansion project and the nascent stage of the e-waste management industry in the Arab world in general has created a potentially harmful bottleneck. With IT production and acquisition accelerating in the Kingdom, the need for e-waste management services is growing apace with the demand for infrastructure and equipment.

A number of programs pair Middle Eastern companies, governments, and environmental groups. These initiatives are aimed at confronting the e-waste problem in the Middle East, which is understood to be the most pressing environmental challenge faced by the region:

- GeSI – Global e-Sustainability Initiative is a global partnership of IT companies that promote sustainable development by promoting technology.

- StEP – Solving the E-waste Problem is an initiative comprised of multiple organisations dedicated to solving the burgeoning e-waste problem. In addition to IT companies, StEP includes governments, NGOs, and members of the scientific community.

- PACE – The Partnership for Action on Computing Equipment is an initiative sponsored by the Basel Convention aimed at remediating/recycling end-of-life products (Moubasher 2009).

Participants in, and observers of, these programs all point to the benefits to be derived from involvement in these initiatives and to the steps that must be taken to mitigate what soon could become an unmanageable situation. CEDARE manager Hossam Allam notes that

> partnership and knowledge transfer are the two key issues for joining the StEP initiative. There is a need to apply an environmental and economical sound for E-waste

management system in the Middle East and North Africa in cooperation with the StEP member (Solving the e-waste problem (StEP) 2016, p.1).

It should be remembered that in establishing partnerships, businesses must make the same kind of fiscal decisions with which they would be confronted in the normal transacting of commerce.

Financial concerns are part of the decision-making process for companies that contemplate on forming remedial partnerships within, and beyond, the Arab world. A GeSI program report notes that companies that join abatement and remediation initiatives have three key concerns:

- Investment – Companies must determine if their investment in the venture is reasonable—if it is too high, it may discourage the company from becoming involved.
- Risk and feasibility – If the investment risk is too high, or the program is poorly organised and managed, companies may be discouraged from taking part in such a partnership.
- Level of involvement – Corporate entities are more apt to join a remedial venture if they see that other companies are devoting their own resources to the venture (Global e-Sustainability Initiative (GeSI) 2012).

The fact that many Middle Eastern IT companies are taking an activist stance on e-waste reflects the rapid technological development in the Gulf region. IT companies there, have the advantage of operating in a more technologically sophisticated environment than the other Middle Eastern states. The Gulf nations, most of which have digitalised their networks, can boast of IT and Internet penetration levels that approximate those in the West. However, countries in other parts of the Arab world, such as the Levant region, still struggle with providing basic communications services, such as reliable phone access. Despite the regional disparity in IT capability, the Middle East is considered one of the most important emerging markets in the world for technology services, and a potential model for IT waste remediation and recycling strategies. In the Middle East, IT companies are in the vanguard of this movement.

Clearly, the private sector is aware of the problem and is more than willing to address the problem head-on. Even multibillion-dollar companies are using terms such as “social responsibility” and “environmental stewardship” in describing their level of commitment to the management of e-waste. Habiba al-Marashi, chairman of the Emirates Environmental Group, said that the scope of the challenge requires the involvement of everyone concerned.

> The private sector in the Arab world is playing a leading role parenthetically by starting takeback programs for certain electronic products as an element of their corporate social responsibility (CSR). This has been a widespread practice in other nations and the likelihood of implementing a parallel system is being studied by different units" (Ewaste Guide 2009, p.1).

An example of this type of joint, corporate/public cooperation is the partnership agreement between EnviroServe and Canon Middle East to ensure "the suitable demolition and recycling of 'end of life' Canon . . . products (Ewaste Guide 2009, p.1). EnviroServe officials point out that joint cooperation is essential given the fact that the resources needed to properly recycle e-waste are lacking in the Middle East, predominantly given that the outcome of recycling is the recovery of resources for recycling.

> There is no electronic waste reprocessing technology as such in the UAE or in the Arab World; this (EnviroServe) helps the recycling process by gathering e-waste across the Middle East. It then separates out this e-waste physically and sends the more complex environmental elements, such as cartridges, batteries, motherboards and data cables, to licensed recycling services in European countries (Ewaste Guide 2009, p.1).

This is the kind of environmentally responsible processing those companies and governments in the Middle East seek to establish, and which can help deter the environmental destructiveness wrought by the exportation of waste to the underdeveloped world.

As part of the developed world, IT companies in the Kingdom and in some parts of the Middle East are playing actively in the management of communications technology waste disposal. More than civic-minded generosity is at work here: IT companies in the Middle East are helping develop remedial solutions in a region where emergent technological capabilities are making e-waste disposal a matter of grave concern. This initiative has serious implications not only for the Middle East but for countries in Southeast Asia and other parts of the developing world.

3.7.9. E-waste management in Asia

Recycling e-waste in its current form is largely unmanageable and conducted on a small scale in countries in Southeast and Far East Asia. Importers in these countries rely on the large number of EEE that is disposed in the developed countries. These products are purchased and shipped to these countries, and those which are in working condition are salvaged and resold. Working computer cathode ray tube monitors are fitted with locally manufactured televisions and sold to consumers. Mobile phones and electrical equipment which are in working condition are resold in these countries. Others are salvaged for working parts which are used in repair works.

Importing countries earn a significant income from refurbishing and using discarded PCs and mobile phones and recovering precious metals from them. Areas in China, India, and Pakistan are actively involved in this work. Recovering precious metals from circuit boards and other electronic equipment is quite hazardous to human health but offers baseline incomes for the people who are involved in these activities. Laws and rules barring extraction of precious metals from electronic equipment and lead from used/discarded batteries either are non-existent or are not implemented in these countries.

In China, the absence of government regulation has made a full-blown business venture out of e-waste recycling. This is a dangerous proposition given that the desirable materials extracted from e-waste material, such as the gold found in microchips, also come with by-products that are highly undesirable and extracted through processes exposure to which is clearly unhealthy. A BBC report found that a landfill in Guiyu, located in southern China's Guangdong Province, which is full of e-waste refuse, has caused substantial peripheral damage to the nearby village and its immediate surroundings. The soil is so saturated with heavy metals, including lead and chromium, that the area's groundwater supplies are now unsafe for human consumption (Moskvitch 2012). In fact, the village has the highest recorded levels of cancer-causing dioxins in the world. Worse, children in the community show a very high rate of lead poisoning (Moskvitch 2012).

China, India, and many countries in Southeast Asia have been for years "open for business" to countries looking for an easy solution to their e-waste management problems. The United States, for example, has the highest "turnover" rate for electronic communications devices, with more than 300,000 mobile phones and 130,000 computers being thrown away every day (Moskvitch 2012). However, in recent years it has been found that an increasing amount of the e-waste found in landfills and storage facilities throughout Asia comes from within the host countries themselves. As of 2012, half of the e-waste currently being accepted and processed in China comes from within China itself. Tougher e-waste exportation laws in the United States and the EU have helped to create this situation. Essentially, it comes down to supply and demand. Landfills in underdeveloped Asian countries have for years made substantial profits from accepting toxic electronic communications material. With the flow from abroad being restricted, domestic sources are increasingly being cultivated.

Nevertheless, China subscribed to the Basel Convention on the transport of electronic waste with its Regulations on Recovery Processing of Waste Electrical and Electronic Products, 2008, which was to come into force in 2011 (Sepúlveda et al. 2010). As Zeng et al. (2012) pointed out, China's manufacturing and waste experiences as regards electronic and electric waste were very different to that of the European Union. Subsequently in 2016, a revised regulation was announced. As part of that announcement, the 'frequently asked questions' section explained the background of the regulations relevant to this research (Ferris 2016). In the first set of regulations, the Ministry of Information Industry had apparently restricted their scope to information technology and a strict definition of the hazardous substances of cadmium, lead and mercury; arguably as to separate domestic and export/import businesses. In the 2016 regulations, these distinctions are removed and the Chinese regulations broadly follow the Basel Convention (Ferris 2016).

Similarly, India introduced its 'e-Waste management and handling rules in 2011 (India Ministry of Environment and Forests, 2016). These rules extended to electrical and electronic materials, and were modified in 2015. However, as Sthiannopkao and Wong (2013) explained, the rules were just that and not a law, as China introduced.

Underdeveloped countries that accept e-waste are not equipped to safely handle the processing of toxic materials, such as plastics and heavy metals. "The emission of these harmful substances is mainly the result of the primitive techniques used in extracting metals from used products, such as open burning of the E-wastes" (Terazono et al. 2006, p.x). Even when useful materials are extracted, the remaining harmful materials are dumped, which creates substantial health and environmental problems (Terazono et al. 2006). Climactic problems are involved as well, particularly in India and Southeast Asia, where high temperatures, humidity, and heavy rainfalls cause leachate that can rapidly find its way into the environment. When the majority of the leachate is generated by e-waste, as is often the case, it can pose a serious threat to groundwater and to tillable soils (Terazono et al. 2006).

Terazono et al. (2006) propose an application of the doctrine of "reduce and reuse" as a means of mitigating the e-waste problem. Reducing the generation of IT waste material is in keeping with the principle of product stewardship. As previously noted, this is a matter of changing consumer behaviour and reducing wasteful purchasing habits; for instance, “consumers in developed countries often purchase new computers to obtain a newer model, not because their current computer is broken” (Terazono et al. 2006, p.x). Merely, the more prolonged the life of the product, the less e-waste would be produced and the less toxic material would be introduced into the environment. To promote the idea of “reuse,” producers should manufacture more common or readily interchangeable parts, which would also considerably alleviate the burden on the environment.

Majority of the processing of e-waste throughout Asia is done by hand, by minimum-wage workers whose jobs it are to perform the hazardous work of cracking open monitors to obtain copper or to burn the wires to recover the metal inside the plastic. These activities, while apparently innocuous, over time expose workers to high levels of dioxins that are introduced through inhalation or through skin contact (Puckett et al. 2002). In rural China or India, places where the technology required to efficiently and safely process waste products does not exist, villagers must manually extract the valuable components and materials in old computers, cell phones, and other IT products. Minimising the volume of e-waste, which is expected to peak in the next few years, would improve the health and life expectation of countless natives of Southeast and Far East Asia.

Many such examples exist throughout Asia, which has the distinction of having become a dumping ground for much of the refuse produced by wasteful, developed countries, especially the United States. The world’s wealthy economies have treated the international dumping of e-waste with indifference. “Rather than having to face the problem squarely, the United States and other rich economies that use most of the world’s electronic products and generate most of the E-Waste, have made use of a convenient, and until now, hidden escape valve—exporting the E-Waste crisis to the developing countries of Asia” (Puckett et al. 2002).

The reality of e-waste recycling is to be found throughout Asia, in places where waste brokers repeatedly go to turn “a quick buck” (Puckett et al. 2002). According to the Basel Convention report, this fosters a situation in which the people of Asia are caught between a choice of “poverty and poison” (Puckett et al. 2002). It is an international trade in toxins, the reality of “brute global economics,” that keeps e-waste flowing between countries and creates entire villages of people living in mounds of lethal filth (Puckett et al. 2002). The people who are caught up in this cynical system are not as much the victims of exploitative waste management practices as they are caught up in an international trade made possible by the ignorance and wastefulness of the most extravagantly consumptive economies in history.

According to the Basel directive, recycling itself is part of a sham industry used to justify the dumping of e-waste. In fact, the exportation of e-waste is transacted under the “green” guise of recycling. Recycling is a cheap and easy way to unload waste without having to go to the expense of rendering it less toxic for those whose job it is to break it all down into its component parts. Thus, the idea that people scratching out a living by doing “recycling” work in the villages of Vietnam, Pakistan, rural China, and other Asian countries are involved in the worthwhile and noble preservation of the environment perpetuates an engineered and carefully maintained myth. In such a scenario, the only true “winners” are the brokers, those who facilitate the exportation of e-waste and make money by taking the producer’s material and are paid again for exporting it to Asia (Puckett et al. 2002).

Although many countries have taken legal action aimed at banning the exportation of hazardous waste, the more realistic solution (at least in the short term) is to manage the “downstream” situation by calling for the manufacture of cleaner components and by prohibiting the introduction of new materials found to be toxic and dangerous to recycle. Ultimately, the best way to protect vulnerable people living in underdeveloped countries is to make the manufacturers responsible for products that contain harmful components. To accomplish this, educating the public regarding the dangers of uncontrolled production of IT components, both at home and abroad, is necessary. Given that the United States, the largest producer of IT products, is the only country to have rejected the Basel Convention, attacking the problem at its source is the best way to improve the situation on an international level.

Communications technology is advancing at an exponential rate. When one considers the speed at which new products are being produced, and older generation models discarded, the prospects are ominous for Asian countries that receive the bulk of e-waste from the West and other developed regions. The highly labour-intensive waste management operations in Southeast and Far East Asia are clearly unprepared and ill-equipped to deal with the sheer volume of material that streams in from countries looking for a cheap and convenient dumping ground for their refuse.

3.8. Global comparison of Saudi e-waste management

To understand why e-waste was exported in Saudi Arabia, it was helpful to know first why landfill dumping has become a real concern these days. The literature reviewed in the previous sections provided sufficient proofs that the global concerns centre largely on the waste's increasing level and the harmful ingredients, such as lead and mercury, it possibly contains. Increased awareness has motivated global waste management and governmental agencies to reflect on the likely effects of e-waste to human health and the environment and has led to better efforts to reroute e-waste from the landfilled dumps (Grossman 2007). This section reviews the studies on the e-waste management trends in Saudi Arabia compared with different countries.

The concerns regarding e-waste production and requirement of best practices for management are generic in nature and in most cases lack awareness among communities (Grossman 2007). Specifically, the available literature demonstrated that best practices on e-waste management target governments as sources of problems but not the communities deriving the need for e-waste management infrastructure. This analogy is common in developing countries; and a comparison between the studies of Saudi Arabia and various developed, and developing, countries provides some useful lessons for improving e-waste management practices.

Improving waste management is of paramount importance in Saudi Arabia, a country where the use of mobile phones, computers, and other communications technology devices is as widespread as anywhere in the world. Yet according to Akram Elyas, vice president of a Saudi IT company, International Computer Company (ICC) the Kingdom is severely lagging in recycling technology "for products and wastes" (Saudi Gazette 2012):

> The Kingdom suffers like the rest of the Arabian Gulf countries, from the high volume of e-waste, because of the overwhelming use of electronic gadgets, especially mobile phone and computers, where statistics estimated that the Kingdom produces approximately 3 million tons per year of e-waste (Saudi Gazette 2012).

In an attempt to address the problem, the Saudi company formed a partnership with EXITCOM, a global company that specialises in various forms of recycling. The new venture comprises the first Saudi-based company specifically formed to recycle electronics and IT products (Saudi

Gazette 2012). The ICC-sponsored initiative was formed in anticipation of the expected rise in mobile phone and computer production, which could top 500% in many countries over the next decade. As e-waste represents the fastest-growing form of waste in the world, the partnership's focus will be to establish new technologies and processes intended to control the rising tide of e-waste in the Kingdom. ICC is an appropriate advocate for e-waste remediation in Saudi Arabia, having done perhaps more than any other company to promote the "culture of computers and information technology" in Saudi Arabia (Saudi Gazette 2012).

In a December 2012 interview with the Arab News, Sulaiman al-Zabin, director of Chemical Safety and Hazardous Wastes at the Presidency of Meteorology and Environment (PME), noted that Saudi Arabia is a pioneer in the field of waste management. Al-Zabin said that the Saudi government will, among other things, significantly slow the rates at which e-waste is produced and encourage the private sector to continue the growing trend of partnership with the government. Ultimately, the Saudi government intends to upgrade the country's recycling, energy recovery, and metal reclamation programs (Arab News 2012). Saudi Arabia has a vision of, and a track record in, recycling various forms of waste, yet awareness and experience are in short supply in many parts of the Middle East, as it is in many parts of the globe.

Unfortunately, sales and the use of IT devices in places like India, Latin America, China, and parts of Africa far outstrip the ability of these countries to deal with such rapid growth. Effective e-waste collection and recycling plants are not present in sufficient numbers to adequately protect native populations from the toxic effects of inadequate remediation (Jones 2012). As previously noted, developed countries like the United States have sufficiently sophisticated recycling facilities to deal with the massive growth in e-waste expected in the coming decades. However, in countries like Nigeria and China, which are seeing significant increases in consumption, such is not the case. Unable to satisfactorily recycle their e-waste, these countries are especially vulnerable to the illegal and destructive influx of e-waste from foreign sources (Jones 2012).

As a regional leader in waste recycling, Saudi Arabia may be in a position to aid underdeveloped countries, having been forced by the need to create its own remedial establishment. Perhaps the most important lesson Saudi Arabia can impart is how to encourage cooperation between the public and private sectors. Pooling resources is the most effective and expedient way to combine a country's resources and create a common sense of purpose. In 2009, the Kingdom took full advantage of the opportunity to show what cooperative action can do. The Second International Recycling and Waste Management exhibition, held in Riyadh, "served as an indicator of the potential for more growth in one of the busiest cities of the giant kingdom" (Clean Middle East 2013).

One of the most important points of differentiation that emerged at the Riyadh exhibition was that Saudi Arabia is capable of maintaining its own waste management and recycling industry, whereas most other Gulf Cooperation Council (GCC) countries must import the necessary equipment and services. As previously mentioned, Saudi Arabia and Bahrain have the region's most progressive laws overseeing waste management policies. Outside of these two Gulf nations, the majority of MENA's recycling is done outside of the region at facilities in Europe and Asia (Hassanin 2010). Recently, the member states of the EU passed legislation that provides for the safe extraction of metals from e-waste, part of a 10-year plan designed to remediate everything from laptop computers to used televisions (UPI 2012). Beginning in 2016, all EU nations will be required to ensure that 45% of electrical and electronic equipment be gathered for recycling. By 2019, that requirement will rise to 65% (UPI 2012).

EU Environment Commissioner Janez Potonik said that Europe's recycling technologies and the high standards to which manufacturers will be held present substantial opportunities for the EU. "We now need to open new collection channels for electronic waste and improve the effectiveness of existing ones" (UPI 2012). At the commercial level, the directive calls on retailers to accept old equipment for free without requiring the consumer to purchase a new product. Although this directive has created some dissatisfaction, particularly among "big box" stores, it is generally agreed that the new EU legislation will be universally beneficial because it creates a uniform code for all concerned. Another aim of the EU measure is to reduce the exportation of e-waste from Europe to West Africa, where illegal disposal practices have resulted in chronic health problems for residents. As many as 100,000 tons of e-waste is exported annually from Britain to Ghana, Nigeria, and other West African nations, where it is disposed of without regard to environmental or health effects (UPI 2012).

Europe can point to a history of e-waste recycling that surpasses programs in any other developed part of the world. The dumping of e-waste in landfills was made illegal in the early

1990s, whereas Switzerland established Europe’s first recycling facility dedicated to the remediation of e-waste. Europe has exceeded most e-waste requirements that have been enacted in Saudi Arabia and other Middle Eastern countries. In 2005, consumers have been permitted to return e-waste to where they were first purchased or to various collection and recycling facilities throughout the EU. For the most part, the burden of recycling lies with manufacturers in Europe.

The United States has adopted a vastly different approach to e-waste recycling and management than the EU. Relevant legislation in the United States is primarily developed and enacted at the state level. As such, the issue has been deeply affected by the political wrangling between Democrats and Republicans. The United States has largely ignored the Basel Convention and attempts to establish uniform codes of conduct, which is reflected by the predominance of e-waste exportation by the Americans. A recent article in Canada’s Financial Post announced that the United States sends as much as 90% of its e-waste to Africa and Asia, to countries where little or no legislation is in place to govern e-waste disposal (McNally 2009).

Recently, a research has been conducted at the University of California, Irvine, on household willingness to recycle e-waste in a sample containing 3,000 randomly selected California residents (Saphoresa et al. 2007). The research was conducted based on principal component analysis of environmental attitudes and behaviours of respondents. Three constructs, “Money and the Environment,” “General Environmental Attitudes,” and “Environmental Activism” were used to measure the willingness to recycle e-waste. The findings of the research suggest that public education recycling programs should target teenagers or younger adults. Recycling should be made more convenient for older adults; proximity to recycling centres is important. If public funds are limited, recycling centres should first be established in communities that offer curbside collection of conventional household recyclables (Saphoresa et al. 2007). This study also concludes that, to be effective, e-waste policies need to be informed by a sound understanding of people’s willingness to recycle, and suggests creating educational programs for students all the way to high school and targeting recycling campaigns at young adults.

The United States has state-of-the-art recycling facilities and, by an act of Congress, provides funding in the millions of dollars for new research initiatives to be enacted by academic and commercial sources to develop new means for processing e-waste. Numerous states have lagged behind other parts of the country and the federal government by resorting to outmoded and unsafe means of remediation. However, the passage of new legislative acts has changed this state of affairs. Today, the recognition of the environmental dangers of e-waste is widespread, and a concerted effort exists among state governments to segregate e-waste from other forms of refuse. However, despite its technological advantages and financial resources, the United States has much to learn from countries such as Saudi Arabia, which seeks to stem the tide of e-waste exportation by instituting its own aggressive recycling programs.

3.8.1. E-waste Management in the Middle East

In the past decade, many reports have been written on e-waste management in the entire Middle Eastern region (e.g., Hassanin 2010; Dyes 2009). Hassanin (2010), in a regional report on Middle East and North Africa, states that Arab countries are comparatively newcomers in the area of e-waste management. However, Saudi Arabia's regulations, regulating this country's policy on e-waste management, are the most advanced in the Middle East. Saudi Arabia has recently witnessed a rapid growth in mobile phone and Internet usage. The proper removal of e-waste in the MENA countries is costly, and developed countries wanted them to clear out their e-waste in landfills. Hassanin (2010) suggests that e-waste of IT is one of the quickest and increasingly dangerous wastes in these countries. The Basel Convention created 14 regional centres in the Middle East. Since 1998, the Basel Convention Regional and Coordinating Centre (BCRC) has been established in Cairo, Egypt. Hassanin (2010) found BCRC is particularly important at the moment because no provincial plan and legislation is in place for e-waste management in the area. The governments of many Arab countries are aware of this necessity owing to the rising volume of e-waste, and they expected to speed up this process. In Morocco, for example, civilians demanded rapid e-waste solution, and this demand mainly comes from the private sector, with the support from national and local governments.

In a guide, Dyes (2009) suggested that the CEDARE had started to look into e-waste and climate-change issues within the region. National governments, with the help of private companies, are addressing the need for a "takeback" program for the end-of-life cycle of the EEE. Dyes (2009) too suggests that Middle Eastern countries are in need of a proper e-waste management technology that offers an appropriate removal of e-waste and revitalization of resources to be used in a new manufacturing cycle. The United Arab Emirates–based EnviroServe works together with MENA governments for proper e-waste management and reprocessing. In 2008, the UAE has passed a law to control and preside over the reprocessing of cell phones. In the same way, both Egypt and the UAE composed and cast off e-waste physically by producing some income for recyclers available in their localities. Dyes (2009) suggests that this action does entail that e-waste management in Middle Eastern countries is a discriminatory process and principally cracks down on eco-friendly (and precious) parts of the IT e-waste, lacking appropriate dumping of the nonrecyclable products. Thus, Dyes' (2009) report concludes that establishing a joint recycling service for the Arab world could be likely, with support from a provincial group.

In Saudi Arabia, the PME has placed greater emphasis on addressing and controlling the problem of human health hazards arising out of emitting pollutants in the atmosphere and improper disposal of hazardous waste. The General Environmental Regulations and Rules for Implementation in the Kingdom of Saudi Arabia define means of sound environmental management of hazardous substances and waste and its requirements in conjunction with the Basel Convention in 1989 controlling transboundary shipment of harmful waste and its disposal. Hazardous substances are defined as materials that harmfully affect human life or adversely affect the environment, such as toxic, infectious, inflammable, explosive, or ionised radiations.

Mitigating the harmful effects of e-waste is, primarily, a matter of identifying and segregating different kinds of waste. EnviroServe's division manager Mariam Hanafy said companies and individuals must do a better job of organising their waste, particularly e-waste. There is no group or corporation that gets through the waste and separates recyclable paper, plastic, glass or metals" (Ewaste Guide 2009). If companies in the Arab states begin to separate e-waste, it will be a big step toward processing and recycling e-waste instead of simply dumping it in a landfill. In the Middle East, EnviroFone, a division of EnviroServe, collects e-waste from throughout the Middle East specifically to ensure that this hazardous waste is not simply generically included with other waste streams (Ewaste Guide 2009).

EnviroFone and other Middle Eastern companies, such as ICC, are on a mission to reverse a trend seen in all parts of the world. Despite calls for recycling, and spurious claims by countries that they recycle, as much as 85% of e-waste, at the end of its initial use, is shipped directly to landfills or is incinerated. Only 10% to 15% is actually separated from the general waste flow and sent for recycling (Ewaste Guide 2009). Clint Wheelock, a representative of Pike Research, said that just throwing away e-waste material is simply too easy and cost-effective rather than going to the trouble of segregating it for recycling. Wheelock said, however, that indications suggest that corporations are showing a greater awareness of the need to organise waste. Many companies in the more developed countries in the Middle East, including Saudi Arabia, Bahrain, and the UAE, are making a concerted effort to ensure that e-waste is properly processed.

Saudi Arabia, Bahrain, and the UAE are at the cutting edge of environmental responsibility in the Middle East. However, other members of MENA have begun to follow in their footsteps. In 2010, Qatar’s Ministry of Environment drafted a legislation intended to regulate the safe management of e-waste. This law, which was the first of its kind in the region, is very specific in the requirements it sets for dealers in IT products and regulations governing how customers are to process their old and defunct electronic gadgets (Gulf News 2010). Qatar has also enacted the country’s first-ever e-waste recycling program to deal with cast-off mobile phones and other electronic devices. The Qatari communications company (Qtel) has established a remediation program in Qatar that allows citizens to simply drop off cell phones and laptops at collection sites, from which they are taken to offshore processing centres.

The Qatar pickup program is modelled on a similar initiative introduced by EnviroServe in the UAE. In Morocco, the government has enacted a recycling program along the same lines. Morocco has for several years faced an imbalance between a “spike” in the use of mobile phones, laptop computers, and televisions and a decided lack of resources capable of properly disposing these materials (Hassanin 2010). Morocco has been something of an anomaly in the Middle East, in that the push for recycling and greater environmental responsibility has primarily come from the public, whereas in many parts of the MENA region, the call for better and more responsible remediation has originated in the private sector, with several companies having partnered with their governments in several instances. EnviroServe has been the only company to act regionally.

In the MENA region, e-waste management is rapidly becoming a multi-stakeholder proposition (Hassanin 2010). Companies have realised that promoting recycling and environmental stewardship is good business, particularly in Middle Eastern countries, where land-use issues keep landfill space at a premium. However, plans are in place to create a regional landfill to make maximum use of this option.

The environmental remediation company SGS (Société Générale de Surveillance, 2013), which has offices in Dubai in the UAE, is one of the leading landfill management corporations in the world. It specialises in the kind of waste management technology that Middle Eastern countries need to help manage the growing problem of e-waste. A regional landfill in this part of the world would need to take into account many environmental factors, including specific needs concerning soil, water, and ventilation. A Middle Eastern landfill containing e-waste would need to

- prevent leachate from entering the soil and water supplies,
- be constructed to withstand pressures caused by subsidence,
- be constructed so that expansion and modifications can easily be enacted,
- be equipped to measure the effects of biogas and toxins on air quality, and
- be continually monitored for the possible long-term effects of pollutants (SGS 2013).

A growing movement also exists that aimed at a more integrated waste management model, of which landfills are only a minimal part. This approach sees "waste" in terms of "resources," in that refuse is recycled with the aim of reusing it in some form. This comprehensive system is used throughout Europe, where standards for environmental quality are among the highest in the world. Integrated waste management utilises waste prevention and avoidance, recycling of used materials, and the sorting/segregating of waste materials (Waste Management World 2011). Energy recovery is a crucial aspect of integrated waste management. Waste streams that cannot be recycled are repurposed and reused as an energy source, specifically for heat and/or electricity generation (Waste Management World 2011).

One of the most important benefits of an integrated waste management system is that it mitigates the need for landfills by as much as 95%. It is an entire waste management complex with minimal community effects. A typical integrated waste management layout would include

- waste pre-treatment and sorting facility,
- a facility for composting and digestion,
- a plant designed to convert waste to energy,
- a construction and demolition facility,

- an area set aside for landfill, and
- wastewater treatment (Waste Management World 2011).

Perhaps the most important capability of an integrated waste management facility is its segregation of waste streams, which is a key in the remediation of e-waste materials. Qatar's integrated waste management plant officially went into operation in mid-2011. It is capable of handling 2,300 tons of domestic solid waste and 5,000 tons of construction and demolition waste each day (Waste Management World 2011). The Qatari facility, which covers approximately 3 square kilometres near Mesaieed (Mosques), is designed to divert up to 95% of material that would otherwise end up in a landfill. The facility includes waste-sorting facilities, recycling facilities, composting, waste-to-energy-conversion technology, and a landfill (Waste Management World 2011). The Qatari installation is one of the largest facilities in the MENA region specifically designated to process and convert waste. Its construction in Qatar costs more than $1 billion. Metals, such as those found in e-waste materials, are separated and recycled, thus avoiding the problems associated with long-term decay in a landfill.

The Qatari waste management project was funded through the Ministry of Municipal Affairs and Agriculture, which sought a holistic approach to the management of all waste flows in Qatar. The integrated waste management facility is an excellent example of public sector leadership on the issues of recycling and waste management, which has been somewhat rare in many parts of the Middle East. The predominant movers in this area have been private sector entities, which have been successful at motivating governments to become involved in the process. The integrated approach to waste management holds tremendous potential in the Middle East, where land and many of the physical resources necessary for more traditional approaches are scarce.

3.9. Theories concerning e-waste management

Theorists have taken several approaches to exploring e-waste management. Lauridsen and Jørgensen (2010) considered the theoretical stance of the European Union when it developed its WEEE directive, concluding that the separate areas of electronics and waste management were tied through 'the underlying regulatory principle of extended producer responsibility' (Lauridsen & Jørgensen 2010, p.486). In drafting the directive, the European Union authors were conflicted over interpretations of sustainability, a simplistic overview of each area, and decision by fiat, all of which resulted in the elimination of waste management as the main outcome of the directive.

In studying research attention to the e-waste directive, Atasu and Wassenhove (2012) found that studies concerned the social welfare implications of such policies to develop optimal policy instruments such as laws and commercial structures. Further, optimising the elements of recycling as e-waste collection, preparation and resale does not address the end-product, that is, the use of such materials. The energy and resources necessary to extract all elements of a product to duplicate the item anew were found to be counter-productive. Lieder and Rashid (2015) pointed out that manufacturing industry had long been aware of recycling; collecting and selling offcuts during the manufacturing process, collecting and processing glass, metals and some chemicals. These systems were highly dependent on the development of integrated supply chains where a steady supply of feedstock was available from both primary and secondary sources, hence the trade in recycled materials to developing countries with strong supply chains. Further, Atasu and Wassenhove (2012) analysed the approaches taken by various governments, and concluded that the recycling systems including e-waste, were developed on existing practices in manufacturing industry and legislation based on the e-waste section of the Basel Convention.

Returning to the social aspects of collecting e-waste, Saphores, Ogunseitan and Shapiro (2012) studied factors that would encourage greater recycling in the United States, finding that services such as kerbside collection and awareness of the harmful effects of chemicals in batteries were conducive to improved recycling rates. Similar to the ‘circular economy’ model developed by Lieder and Rashid (2015), the conclusions by Saphores et al. (2012) were localised, based on the systems and practices of the various states of America. Lastly, Le et al. (2012) explored urban Vietnamese in their recycling practices with e-waste using the theory of planned behaviour. Le et al. found that perceived behavioural control was the prime predictor, followed by subjective norm. Predictors included previous recycling behaviour and interest in economic benefit.

Thus each country’s e-waste policy must be relevant to the conditions under which it developed. In Saudi Arabia’s case, implementing extensive e-waste collection and processing systems would merely show that the items were all imported and would have to be returned back through their supply chains, or forwarded through another chain to a specialised recycling entity, generally in a developing economy.

3.10. Gap in literature

This study concerns the attitudes of Saudi Arabians to recycling e-waste, government policy decisions, and experiences of other countries in managing e-waste. As an importer of electrical and electronic goods, Saudi Arabia lacks the manufacturing infrastructure to process e-waste and depends on supply chains as an electronics and electrical goods market, and another supply chain system in removing some of the more valuable waste. There is a gap in the literature regarding direct research on the Saudi government's policies and practices on e-waste, and the attitudes of Saudis towards sorting their waste before disposal. This research is intended to address that gap.

3.11 Conceptual (stakeholders) model

As concluded from the literature review, a model for an appropriate Saudi e-waste management model depends on country-specific characteristics and modelling their research has been used by other researchers, such as Walther, Spengler and Queiruga (2008) in their study of e-waste systems in Spain. However, Truttmann and Rechberger (2006) nominate e-waste constants in the majority of countries such as supply chains for retailers, consumers and recyclers. These are assisted and constrained by government policies, legislation and consumer guides. Stakeholders in the product supply chain share responsibility to efficiently manage e-waste. Lifset and Lindhqvist (2002) emphasised the shared responsibility to manage the environmental impacts of a product across its life cycle. The stakeholders (population) for this study and their relationships are shown in figure 5.

Source: Adapted from Slideshare 2014, s.13

Figure 5 *Stakeholders in e-waste management*

3.12. Conclusion

The literature reviewed so far provides a deeper understanding of the issue of e-waste management as the citizens of Saudi Arabia perceive it. By reviewing the literature on e-waste management practices in different countries worldwide, this literature was expected to enhance the existing knowledge on the importance of e-waste management and form the basis for designing several policy frameworks concerning e-waste management from an environmental protection perspective in Saudi Arabia.

This review also served a purpose of this chapter, which was to review the literature on the current e-waste management practices and, particularly, provide the perceptions of citizens of Saudi Arabia regarding reusable and recyclable e-waste. This review has shown that Saudi Arabia has no specific policy or regulation regarding proper e-waste management. The next chapter provides the methodology of this thesis.

Chapter 4 Methodology

This chapter presents the primary research for the study, which concerns Saudi Arabians views on the collection, processing and reuse of their electrical and electronic waste. In the previous chapters, the second and third research questions were partially answered, namely the Kingdom's policies and practices regarding e-waste, and the international experiences with such waste. The gap in the literature was determined as investigating improvements to recycling rates by the Saudi public: their views, practices, and intentions. This also described the first research question.

The discussion begins with the research approach, and this is followed by a short discussion on the population and sample of electrical and electronic end users in Saudi Arabia. The survey instrument is then described. Data collection and analysis are discussed, and this is followed by validation and the ethical statement.

4.1. Research design

This research comprises a mixed-methods study which combines the two world view approaches by researchers: a positivist paradigm, which leads to a quantitative study, and an interpretivist paradigm that is undertaken through a qualitative data analysis (Denscombe 2014). Social research can adopt a quantitative or qualitative approach depending on the nature of the research questions.

The research approaches use different techniques for data collection. The qualitative approach is subjective, using techniques of case studies, focus groups, or personal interviews to collect data (Bryman 2012). In contrast, the quantitative approach is generally objective and depends on numerical data collection using a questionnaire-based survey and statistical and mathematical analyses of data for reporting outcomes. With a quantitative approach, the researcher is external to the data, whereas in qualitative research the author can become a part of the research. Qualitative research is based on the inputs provided by the respondents considering the social context and their circumstances (Bryman 2012). As this is a mixed-methods study, using aspects of both, data collection and analysis concern a larger quantitative data collection by survey to establish numerical data for analysis, and a smaller qualitative data collection and analysis can be undertaken to explore the concepts through interviews with people knowledgeable in the field (Denscombe 2014).

The two forms of data collection, quantitative and qualitative, have issues and benefits. Bryman (2012) noted that an anonymous quantitative-aligned questionnaire results in fixed data from closed questions, the results of which cannot be queried or further explored by the researcher. Nevertheless, such data can be replicated and validated if the sample is sufficient, the questions well-phrased and the outcomes are clear. This is a useful aspect for longitudinal or comparative studies, where the results can be compared over time and location, often phrased as the *what* of the research outcomes. On the other hand, qualitative studies involve interviews and semi-open questions allow the interviewer to ask further questions to gain rich data and explain the *why* for the thesis. Therefore, combining both approaches both validates the qualitative data analysis and informs the results of the quantitative data analysis.

4.2 Population and sample

The population for the quantitative section of this research was illustrated in the conceptual model of stakeholders at figure 5. However, as described, this encompassed individuals as being part of the supply chain of traders and resellers for electrical and electronic goods, then again as end-users of the items. The population therefore consisted of Saudi adults as owners and users of such goods. A random sampling technique and consequent connections (snowballing) was chosen (Bryman 2012). Potential participants were identified through a commercial listing of electronic and electrical traders, distributors and retailers. The commercial firms and their customers were invited to contribute to the study by giving their email or postal address, thus agreeing to be participants.

For the quantitative phase of the study, a sample of 500 was selected as representative of Saudi end-users (Levy & Lemeshow 2013). The sampling took place in March 2013, when 300 questionnaires were sent by email, and 200 by post.

The qualitative section of this mixed methods research concerned a targeted sample of knowledgeable government representatives and retailers of electrical and electronic goods who could comment on the findings from the survey. These were two representatives from the Presidency of Meteorology and the Environment, two representatives from non-government offices, that is, trade associations concerned with importing electrical and electronic equipment, four representatives from waste management firms, and two importers and assemblers (manufacturers).

4.3 Survey instruments

To answer the research question regarding Saudis' experiences with electrical and electronic items, and their views and practices regarding their disposal, a questionnaire was prepared, with questions on e-waste knowledge in Arab countries informed by Girma (2010). The questions were constructed to avoid ambiguity and enhance reliability and validity. This included the online administration of the questionnaire, followed by, if possible, a short follow-up interview to further explore the questions asked in the survey (Bryman, 2012).

The survey questionnaire was developed and tested with a focus group of working adults. The questionnaire was then pretested among 30 individuals. Pretesting is particularly important when data are to be collected via self-administered questionnaires because interviewers will not be available to clarify questions' meanings or probe incomplete answers (Bryman, 2012). Issues were resolved and the revised questionnaire was then supported.

Sections for the quantitative survey comprised data concerning demographic information, practices in purchasing electrical and electronic goods, methods for disposal, and knowledge of e-waste systems in the country. The questionnaire was measured using dichotomous, multiple-choice and open-ended questions (appendix 1). The structure of the quantitative questionnaire is shown as table 2.

Questions for the qualitative survey were formulated from the research questions, that is, government policy on e-waste and how it was to be implemented, the associations' and managers' views on the e-waste industry and what they saw as users' attitudes to disposing of used items. The questions varied depending on the interviewee's position, however, the open-ended questions were directed towards improving recycling rates by the Saudi public.

Table 2
Structure of quantitative survey

Variable	Question no(s)	Description
Demographics	1	Gender
	2	Education level
	3	Employment status
Details of electronic equipment and replacement pattern	4 and 5	Number of cell phones held
	6 and 7	Cell phone replacement pattern
	8, 9, and 10	Number of computers held
	11	Computer components replacement pattern
	12	Frequency of obtaining technical support
	13	Computer replacement pattern
	14	Electronic products replacement pattern
Preference for e-waste disposal	15	Cell phone disposal method
	16	Computer components disposal method
	17	Computer disposal method
	18	Most preferred recycling option
	20	Accepting recycling costs
Preference for recycling	19	Preference for disposal through recycling
Knowledge on e-waste	21	Knowledge of significance in recycling e-waste

4.4 Data collection

Data collection took place in March 2013, both the quantitative survey and the qualitative interviews. The questionnaire was sent as an e-mail attachment, along with a cover letter to the respondents. As noted, respondents' e-mail addresses were obtained from customers of firms in the industry who supplied their email addresses, so that the locations of the participants were not known. The email consisted of a covering letter explaining the nature of the study and the ethical constraints of the university. The questionnaire was on a link, and the receiver was asked to fill out the questionnaire online. Of the 300 sent out, 285 (95%) were returned which was a high rate of return for a questionnaire. For those participants who had left a street address, the mail-out consisted of the questionnaires and the covering letter and self-addressed, stamped return envelopes. The return rate for postal questionnaires was low at 78 responses (39%), and some were not completed. There were 13 questionnaires omitted due to incompleteness. In all, 350 relatively complete responses were obtained (Enders, 2010).

For the qualitative data collection, semi-structured interviews were conducted by telephone and in person, as the participants in some cases could not make appointments to be interviewed. Representatives from the Presidency of Meteorology and the Environment were separately interviewed in their offices in one visit, each lasting about 30 minutes. The two manufacturers, different firms, were subsequently also interviewed in their respective premises, and these times varied between 20 and 45 minutes, the latter due to interruptions. The representatives from the trade association (Chamber of Commerce) and waste management firms declined to be interviewed in their offices, but answered questions by arranged telephone calls. Durations of these interviews were from about 10 minutes to 15.

In interviewing experts, Rowley (2012) advised that the research problem (questions) should be matched with the experts. In this case, the public sector representatives were an obvious choice for government policy, and the association representatives could similarly advise on the supply chain practices for importers, producers, retailers and waste disposal firms. Two manufacturers could advise on their recycling practices for their goods, whilst the waste management firms could describe their firms' position in the e-waste cycle. Interview questions were leading, as Rowley suggested, based on the research problem and asking the interviewees for responses to the problem of e-waste and their views and suggestions on improving recycling rates. Interviews were recorded in Arabic, transcribed and translated into English. Notes were also taken during the interviews.

4.5 Data analysis

Data were analysed using Statistical Package for the Social Sciences software (SPSS) and a Microsoft Excel and Microsoft Access. Before analysing, the data need to be edited and coded, with blank responses properly handled. Returned questionnaires from the various data collection methods were checked for incompleteness and inconsistencies. Inconsistencies here meant there may be some questions left unanswered by the respondents, but by observing their answers for the remaining sections of the questionnaire, the logical responses for the unanswered questions can be obtained. Refinement of data could also be done by contacting the respondents through phone to get the correct data and shed light on the data inconsistencies.

A form was created in Microsoft Access to reflect the questionnaire. Each response to the items in the questionnaire would be keyed into the form. Text answers were keyed in as text, and numerical scales were entered as numbers. To reduce error, the numerical items and some text items had a predefined value list. After data entry, every 10th questionnaire entered (20) was checked for accuracy.

The frequency distributions (counts and percentages) were tabulated for all questions with a categorical response (nominal or ordinal) and the results summarised, based upon whether the majority (more than 50% of the participants) agreed or disagreed with the items. The skewness of the distributions (e.g. whether the highest frequencies were located at the high or low end of the scales) was recorded where applicable. The findings are presented in three different sub-sections which include demographic characteristics, electronic device ownership, background about recycling, and willingness to recycle.

Relationships among the variables can be tested for statistical significance using the chi-square test of independence (Smith, Gratz, & Bousquet, 2009). The joint frequency distribution of two categorical variables can be analysed with the chi-square statistic to determine whether the variables are statistically independent or associated. The null hypothesis in a chi-square test of independence is that an n (number) of classifications are independent, and the alternative hypothesis is that the n (number) classifications are dependent. The assumptions of chi-square test are independence of observations; mutual exclusivity of row and column; and that no expected frequency should be less than 1 and no more than 20 per cent of the expected frequencies should be less than 5. (Smith, Gratz, & Bousquet, 2009):

4.6. Validity

Validity refers to the structural integrity of the research; that is soundly based and rational in its execution. For example, items on a questionnaire must relate to the construct being measured. Content validity refers to the relationships between the items in the survey and ensures they measure different variables. Thus drafting questions should ensure that there is not a parallel response possible in the answers to ensure that questions cover the full range of the construct. As noted by Lynn (1986), researchers compute two types of content validity indices. The first type involves the content validity of individual items and the second involves the content validity of the overall scale. One means of ensuring content validity is to use knowledgeable professionals or academics to assess content validity according to the research questions; Lynn advised at least three persons should do so (Field, 2003).

A pretesting of the questionnaire was conducted to examine its reliability. As noted, 30 adults were tested and data were examined for stability using test-retest reliability to ascertain the suitability of the identified instruments for the main survey. The stability of the questionnaire was examined by performing test-retest reliability on all instruments, administered twice over time gap between the two pretesting surveys. The stability was examined using paired-samples correlation. The results of the indicators are presented in Appendix 3, and the results show that the correlations of all the indicators remain within the range of 0.813 and 0.989. Since all the correlations are above the accepted level of 0.80, the correlations can be considered valid.

4.7. Ethics

Approval was received from the University’s ethics committee to conduct a mixed-methods study as there were two methods of data collection, including the recruitment of study participants, comments about the sample size, data collection instruments, and data analysis.

4.8 Chapter summary

This chapter summarised the methodology used to conduct the primary research. As the research questions were constructed to explain the status of managing electrical and electronic waste in Saudi Arabia at the time, 2013, the research design took into account the goods supply systems, the government and industry policies regarding such waste, and the practices of end-users in disposing of their used items. A mixed-method study was deemed to answer the research questions through the use of a high-volume distributed questionnaire to end-users of e-goods regarding their awareness, attitudes, and practices of e-waste disposal. To inform these data, expert interviewees were approached to understand the structure of waste management in Saudi Arabia, and the response to e-waste pollution and its future minimisation.

Data analyses were explained for both phases of the study, validation of the research steps, and the ethical statement was described. The next chapter moves to the results for these analyses and the discussion of the implications for e-waste in Saudi Arabia. .

Chapter 5. Results and discussion

This chapter presents first the results for the research design and data collection and analysis for both the quantitative and qualitative phases of the thesis as described in the previous chapter. The quantitative results comprise a participant profile, descriptive analysis and validation.

This is followed by the results of the qualitative analysis. The second part of the chapter contains the thesis discussion, and this is presented as end users, government, associations and the retailers/waste managers.

5.1. Demographic characteristics

The demographic characteristics of the participants comprise gender, age, educational attainment and employment. These are presented in turn.

Gender Table 3 shows the gender of the participants, 217 men and 133 women. This shows that nearly two-thirds (62%) of the sample were men and a third (38%) were women. In Saudi Arabia, women tend not to respond to surveys, as they generally defer to their male relatives.

Table 3
Gender of participants

Gender	Frequency	Percentage
Male	217	62
Female	133	38
Total	350	100

Age The age cohorts of the participants are presented in table 4. This shows the majority (79.6%) were under the age of 38 years, whilst the highest cohort represented were aged 23 to 27 years. This broadly depicts the youthful population profile of Saudi Arabia.

Table 4
Age of participants

Ages in years	Frequency	Percentage*
18 - 22	47	13.4
23 - 27	83	23.7
28 - 32	74	21.1
33 - 37	75	21.4
38 - 42	38	10.9
43 - 47	26	7.4
48 - 52	6	1.7
53 and above	1	0.3
Total	350	100

* Percentages rounded.

Education attainment: The educational levels of the participants again reflect the wider population, where education was widely available only from the 1980s. The age profile above is reflected in the level of education attainment, again broadly in line with the wider Saudi population. In the sample, 43.6 per cent of the participants do not have tertiary qualifications, whilst over a quarter (27.4%) have university qualifications.

Table 5
Educational attainment of participants

Education level	Frequency	Percentage*
Primary school	18	5.1
Secondary school	135	38.5
Diploma	101	28.8
University graduate	70	20.0
Postgraduate	26	7.4
Total	350	100

* Percentages rounded.

Employment. These results reflect the Saudi population to a certain degree, where there is a very low rate of women's labour market participation, therefore the unemployment rate of 5 per cent is low. Further, Saudis prefer working in the public sector, therefore the difference between the private sector, especially with self-employed included (57.4%) is high. However, the retirement rate is expected; few Saudis work after 50 years of age.

Table 6
Employment status of participants

Employment	Frequency	Percentage*
Unemployed	18	5.1
Self-employed	36	10.3
Public sector	80	22.8
Private sector	165	47.1
Retired	51	14.6
Total	350	100

* Percentages rounded

Other characteristics The respondents were predominantly Saudi (92%) and married (60.6%). Of the non-Saudis who participated (8%), five per cent of all the participants stated that they had been residents for more than ten years. There is a higher proportion of non-Saudis in the country, however, these are mainly skilled and semi-skilled workers and would presumably not be purchasing the electrical and electronic goods that may be viewed as luxury items by foreigners. For income status, the highest proportion of respondents reported a monthly income of between 10,000 and 13,999 SR ($A3490 -$A4896) (20.3%, n=71). There were more people with an income lower than this bracket (55.4%, n=194) than higher than this bracket (24.3%, n=85). This again is reflective of the wider Saudi population.

Summary The demographics of the participants were reasonably aligned to the Saudi population profile, with the exception of the low rates of women participants, non-Saudis, and the low rate of unemployed. Thus the responses from the participants as a sample are reasonably representative of the wider population and this adds to the validity of the quantitative phase of the research.

5.2 Usage patterns of electrical and electronic items

This section reports the results of the descriptive statistical analyses; frequency and means of the ages of the devices, and the frequencies and means of the replacements.

Computers Table 7 presents the frequency and percentages of personal computers and laptops. This relates to household ownership.

Table 7
Desktop and laptop household ownership

Computer ownership	Frequency	Percentage
None	9	2.6
One	9	2.6
Two	105	30.0
Three	201	57.4
Four or more	26	7.4
Total	350	100

This table shows that the majority (57.4%) of respondents' households owned three computers, with 30 per cent owning two, thus 87.4 percent had two or three computers. Of interest was the small number with no computer or just one (5.2%), especially as computer ownership only became relevant through the internet around 2005. The mean computer ownership was 2.42 (s.d. 1.211). The prevalence of computers is an important factor for consideration of e-waste.

Further, the majority of respondents reported that they had 1-2 tablets in their household (64.5%, n=226), although the next largest proportion had no tablets (20%, n=70). A similar number (20%, n=70) had a printer. Again, a majority (79%) had one or more flatscreen televisions at home.

Table 8 shows the rate of replacement for the households' personal computers and laptops.

Table 8
Computer replacement

Period	Frequency	Percentage
Less than one year	52	14.8
1–2 years	148	42.5
2–3 years	132	37.6
Over 3 years	18	5.1
Total	350	100

Table 8 shows that Saudis as participants to this study dispose of their computers within three years of purchase (94.9%), mean 2.38 years (s.d. 0.918). This signifies that there is a regular turnover of these devices which contributes to the waste problem.

Mobile phones Table 9 shows household ownership of mobile phones by the participants' households.

Table 9
Mobile phone household ownership

Mobile phone ownership	Frequency	Percentage
None	24	6.8
One	35	10.0
Two	118	33.9
Three	127	36.2
Four or more	46	13.1
Total	350	100

The majority of the participants' households in table 9 owned two or three mobile phones (70.1%). However, there was a substantial number of households that had three or more of the devices (49.3%), so that this had significance regarding frequency of disposal. The mean ownership was 2.65 (s.d. 0.764).

Replacement patterns for mobile phones is shown at table 10.

Table 10
Mobile phone replacement

Period	Frequency	Percentage
Less than one year	35	10.0
1–2 years	115	33.0
2–3 years	140	39.9
3–4 years	48	13.7
Over 4 years	12	3.4
Total	350	100

Of interest, table 10 shows that the participants' households replaced their mobile phones regularly, with 82.9 per cent upgrading under three years. A mere 17.1 per cent kept their devices for three or more years. The mean was 2.68 years (s.d. 0.949). This has implications for growing quantities of waste.

Computer peripherals Computer peripherals include screens, keyboards, mouses, drives. Saudis replaced computer parts regularly, as table 11 shows.

Table 11
Computer peripherals replacement

Period	Frequency	Percentage
Less than one year	69	19.7
1–2 years	103	29.3
2–3 years	124	35.6
3–4 years	36	10.3
Over 4 years	18	5.1
Total	350	100

Table 11 shows that the participants purchased computer peripherals on a continuing basis, with 49 per cent renewing such equipment every two years (mean 2.52 years, s.d. 1.077), thus contributing to waste

Summary The participants' experiences regarding duration of ownership of mobile phones, computers and computer peripherals shows that Saudis are higher users of these electronic devices. Over two-thirds of the study's sample had 2 or 3 mobiles, whilst nearly one-half had three or more; further these were retained on average for 2.7 years before upgrading. Well over half (57.4%) of the participants had three personal computers or laptops, with average households owning 2.4 such devices, which they renew every 2.4 years on average. Peripheral computer parts such as keyboards and drives were also popular items, and nearly half of the participants (49%) replacing such items every two years. Together with high television ownership, these findings point to considerable quantities of discarded electrical and electronic items in Saudi Arabia.

5.3. Disposal of used items

The respondents were asked how they disposed of obsolete electronic equipment: mobile phones, computers and other electronic devices. They were also asked how any recycling plan should be funded.

Disposal Table 12 reports on the participants' manner of disposing of their used devices when they upgrade.

Table 12
Method of disposal of electronic devices

Disposal method	Mobile phones		Computers		Other	
	No.	%	No.	%	No.	%
Recycler	44	12.5	27	7.7	9	2.6
Returned to retailer	18	5.2	9	2.5	18	5.1
Donated to charity	27	7.7	62	17.7	0	0
Resale	18	5.1	9	2.6	9	2.6
Other	243	69.5	243	69.5	314	89.7
Total	350	100	350	100	350	100

Other than putting devices in with other waste (69.5% phones and computers, 89.7% other), table 12 shows that Saudis may give them to a recycler (12.5% phones, 7.7% computers, 2.6% other), or dispose of them through charities (7.7% phones, 17.7% computers) or selling the device on (5.1% phones, 2.6% computers and other electronics). Few (5.2% phones, 2.5 computers, 5.1% other) return them to the store, which would appear to be the most likely solution for smaller devices, particularly if retailers encouraged returns.

Recycling preferences. Table 13 shows the preferences of Saudis for potential recycling schemes.

Table 13
Preference for potential recycling schemes

Recycling system	Frequency	Percentage
Home collection - free	43	12.3
Home collection - paying collector	17	5.1
Home collection - sell	200	57.0
Collection centre – free	36	10.2
Collection centre – sell	54	15.4
Total	350	100

Perhaps not surprisingly, table 13 showed the majority (57%) would prefer to sell their used equipment to someone who came to their home, whilst the next preference (15.4%) was to take used electronics to a collection centre to sell. The most likely scenario, paying someone to collect the equipment, was disregarded by the majority (94.6%).

Education was a factor in the responses regarding who should pay for recycling. On being requested who should pay for any recycling scheme, 45.9 per cent did not answer (36 per cent were school educated), 22.6 per cent (all graduates) thought manufacturers should pay, and 13.7 per cent (all diplomates) thought it was the government's task. Further 5.1 per cent of the sample who thought that the cost of recycling was their (user) responsibility, and all these responses were from participants who had finished high school. The notion of the retailer paying was predominantly the selection of diplomates. However, the large proportion with no comment tends to diffuse any finding for this section.

Summary Saudis as study participants did not show great concern for recycling of electronic waste, with about 70 per cent directing their phones and computers to waste, and this was higher for other equipment such as televisions. Arguably, they saw used equipment, even if only two or three years of use, as having little value given the proliferation of new designs and changing technologies, such as internet enabled devices. Their preferences were for someone to pay them for their discarded equipment, but the high return of no answer somewhat negated any finding. Of interest was that those who did answer were divided by their education levels in their choices of whom they saw as responsible for electronics, with graduates thinking the manufacturer should pay and the school leavers to a degree taking responsibility for their equipments' disposals.

5.4 Tests of significance

The assumption of independence of observations was met as the sampling of one variable did not affect the choice of any other variable included in the analysis; the assumption of mutual exclusivity of row and column variables was met as no combination of the variables overlapped with each other; and the assumption of large expected frequencies was met as none of the expected frequencies were less than 5. Some variable categories were collapsed to ensure that the third assumption of chi-square test is satisfied. A 0.05 level of significance was used as the criteria for statistical significance. The results which yielded statistically significant results are summarised below.

5.4.1 Gender

Gender significance with e-waste practices were tested for computer and laptop ownership, length of ownership, disposal of equipment, and attitudes towards recycling. These results are reported in turn.

Computer ownership The association between the gender of the participants and the number of desktop computers at home was tested at table 14. The association between these variables was significant, χ^2 (4, N = 350) = 13.036, p=.011 < .05. A larger proportion of females were associated with larger number of desktop computers at home.

Table 14
Test for independence: gender and desktops

Q How many of the following new or second hand equipment do you have at your household? – Desktop computers		Gender		Total
		Male	Female	
0	Frequency	41	18	59
	% within gender	18.6%	13.8%	16.9%
1	Frequency	90	38	128
	% within gender	40.9%	29.2%	36.6%
2	Frequency	44	31	75
	% within gender	20.0%	23.8%	21.4%
3	Frequency	26	17	43
	% within gender	11.8%	13.1%	12.3%
4 or more	Frequency	19	26	45
	% within gender	8.6%	20.0%	12.9%
Total	Frequency	220	130	350
	% within gender	100.0%	100.0%	100.0%

Laptop ownership A further test established that there was a similar relationship between households with women and laptops' occurrence (χ^2 [4, N = 350] = 10.022, p=.04 < .05.)

Discarding computer peripherals Testing for association between gender of the participants and discarding equipment (older technology monitors) found a significant association: χ2 [1, N = 350] = 5.366, p = .021 < .05. A larger proportion of males were associated with discarding monitors.

Another analysis tested for discarding of newer technology (LCD) monitors (table 15). The association between these variables was significant, χ^2 (1, N = 350) = 4.999, p = .025 < .05. Thus males were again prominent in potential e-waste through discarding their LCD monitors.

Table 15
Gender influence on discarding LCD monitors

Have you ever discarded any of the following equipment? - LCD		Gender		Total
		Male	Female	
No	Frequency	202	127	329
	% within gender	91.8%	97.7%	94.0%
Yes	Frequency	18	3	21
	% within gender	8.2%	2.3%	6.0%
Total	Frequency	220	130	350
	% within gender	100.0%	100.0%	100.0%

Gender and length of laptop ownership relationships were tested using a chi-square test of independence (table 16). The association between these variables was significant, $\chi 2$ (4, N = 350) = 10.864, $p = .028 < .05$. Women were more likely to retain their devices than men.

Table 16
Gender influence on retaining laptops

Length of ownership: laptop		Gender		Total
		Male	Female	
No laptop	Frequency	16	8	24
	% within gender	7.3%	6.2%	6.9%
1-12 months	Frequency	32	12	44
	% within gender	14.5%	9.2%	12.6%
13-24 months	Frequency	31	19	50
	% within gender	14.1%	14.6%	14.3%
25-36 months	Frequency	53	18	71
	% within gender	24.1%	13.8%	20.3%
37-48 months	Frequency	88	73	161
	% within gender	40.0%	56.2%	46.0%
Total	Frequency	220	130	350
	% within gender	100%	100%	100%

Similarly, it was found that women retained their printers longer than men ($\chi 2$ [4, N = 350] = 12.665, $p = .013 < .05$).

Awareness of toxic materials in devices The results of a chi-square test of independence regarding gender and knowledge of dangerous materials in electronic products were significant (χ^2 [1, N = 350] = 4.118, p = .042 < .05). Women participants were more aware of toxicity than the men (see table 17).

Table 17
Gender differences in toxicity awareness

Do you know that electronic devices contain dangerous materials such as lead, mercury, and cadmium?		Gender		Total
		Male	Female	
No	Frequency	104	47	151
	% within gender	47.3%	36.2%	43.1%
Yes	Frequency	116	83	199
	% within gender	52.7%	63.8%	56.9%
Total	Frequency	220	130	350
	% within gender	100%	100%	100%

Summary Testing for relationships between the variables resulted in the findings that the women participants were more likely than the men to have more computers and laptops at home, and to retain their devices for longer. They also had better awareness of the toxicity of their devices. Men were found to discard their monitors at a greater rate than women.

5.4.2 Nationality differences

Of the small proportion of non-Saudis, a significant difference was found regarding their knowledge of toxic elements in electronic devices to that of Saudis (χ^2 [1, N = 350] = 5.850, p = .016 < .05). This is shown at table 18.

Table 18
Nationality differences in toxicity awareness

Do you know that electronic devices contain dangerous materials such as lead, mercury, and cadmium		Nationality		Total
		Saudi	Non-Saudi	
No	Frequency	145	6	151
	% within nationality	45%	21.4%	43.1%
Yes	Frequency	177	22	199
	% within nationality	55%	78.6%	56.9%
Total	Frequency	322	28	350
	% within nationality	100%	100%	100%

5.4.3 Age differences

The influence of age on other variables was tested using the chi-square test of independence. Ownership of devices, device purchase decisions, and recycling preferences were also tested. The results are presented in this section.

Age and ownership. The older cohort age groups were found to have fewer tablets than the younger participants (χ^2 [4, N = 350] = 9.684, p = .046 < .05) (table 19).

Table 19
Age significance with tablet ownership

How many tablets do you have in your household?		Age		
		Under 28 years	28 years or over	Total
0	Frequency	25	45	70
	% within age	19.2%	20.5%	20.0%
1	Frequency	38	92	130
	% within age	29.2%	41.8%	37.1%
2	Frequency	45	51	96
	% within age	34.6%	23.2%	27.4%
3	Frequency	17	19	36
	% within age	13.1%	8.6%	10.3%
4 or more	Frequency	5	13	18
	% within age	3.8%	5.9%	5.1%
Total	Frequency	130	220	350
	% within age	100%	100%	100%

The next significant test results related to length of ownership of televisions and personal computers. In both tests, more participants in the younger age cohort group people retained their equipment for longer compared to older age group: χ^2 (4, N = 350) = 12.711, p = .013 < .05 for televisions and χ^2 (4, N = 350) = 11.537, p = .021 < .05) for desktops. This may be that these items are less important for the younger cohort than the older. The desktop computer test results are depicted at table 20.

Table 20
Age influence on retention of desktop computer

For how long did you retain your last desktop computer?		Age		Total
		Under 28 years	28 years or over	
No computer	Frequency	39	53	92
	% within age	30.0%	24.1%	26.3%
1-12 months	Frequency	7	34	41
	% within age	5.4%	15.5%	11.7%
13-24 months	Frequency	18	21	39
	% within age	13.8%	9.5%	11.1%
25-36 months	Frequency	10	27	37
	% within age	7.7%	12.3%	10.6%
37-48 months	Frequency	56	85	141
	% within age	43.1%	38.6%	40.3%
Total	Frequency	130	220	350
	% within age	100%	100%	100%

On the other hand, the results for retaining a laptop differed from the personal computer, with the younger participants replacing their laptops faster than the older group (χ^2 [1, N = 350] = 8.785, p = .003 < .05). This result also held true for tablets, that is, the younger group obtained new tablets more often that those over the age of 28 years (χ^2 [1, N = 350] = 11.639, p = .001 < .05).

The youthful interest in the mobile devices (laptops and tablets) over personal computers and televisions was illustrated in the next test, that of the reasons for purchasing devices. This was shown to be the case, as younger people expressed more interest in such devices. The association between these variables was significant, χ^2 (2, N = 350) = 9.084, p = .011 < .05. See table 21.

Table 21
Age influence on purchasing decisions

What is the main factor that attracts you to buy new electronic devices		Age		Total
		Under 28 years	28 years or over	
New technologies & features	Frequency	63	71	134
	% within age	48.5%	32.3%	38.3%
Need for work or study	Frequency	62	137	199
	% within age	47.7%	62.3%	56.9%
New design & style	Frequency	5	12	17
	% within age	3.8%	5.5%	4.9%
Total	Frequency	130	220	350
	% within age	100%	100%	100%

Age and disposal of devices. Participants were questioned on their recycling knowledge regarding electrical and electronic waste. As expected, more of the younger group were aware of recycling schemes, either local or elsewhere, than the older group (χ^2 [1, N = 350] = 4.106, p = .043 < .05), table 22.

Table 22
Age influence on awareness of recycling schemes

Are you aware of recycling of electronic or electrical equipment in Saudi Arabia or elsewhere?		Age		Total
		Under 28 years	28 years or over	
No	Frequency	83	163	246
	% within age	63.8%	74.1%	70.3%
Yes	Frequency	47	57	104
	% within age	36.2%	25.9%	29.7%
Total	Frequency	130	220	350
	% within age	100%	100%	100%

Preference for selling used devices in relation to the age of the individual was then tested, with a significant result of the youthful cohort preferring resale: χ^2 (2, N = 350) = 10.712, p = .005 < .05 (table 23).

Table 23
Age effects on resale of devices

If the equipment was sold, who would you sell it to?		Age		Total
		Under 28 years	28 years or over	
Scrap collector	Frequency	15	33	48
	% within age	11.5%	15.0%	13.7%
Secondhand market	Frequency	103	140	243
	% within age	79.2%	63.6%	69.4%
Other	Frequency	12	47	59
	% within age	9.2%	21.4%	16.9%
Total	Frequency	130	220	350
	% within age	100%	100%	100%

Summary There were differences established between the two age groups, under 28 years and 28 years and over. The younger age group were more enthusiastic about new mobile technologies, buying more tablets and replacing their tablets and laptops faster than the other group. Of interest, the younger group kept their televisions and personal computers longer, which arguably reflects a lower interest in these items than the senior group. The younger group were more knowledgeable than the older group about recycling schemes, and they were aware of a value to this waste through resale.

5.4.4 Student status and education differences

Potential differences between the participants based on their student status were then explored. Significant results were obtained using the chi-square test of independence were performed on this dimension and mobile phones, replacing laptops, and recycling awareness. This was followed by educational attainment, where again mobile phone ownership and recycling knowledge were significant.

Student status Students had fewer mobile phones in their households than the non-students χ^2 (4, N = 350) = 10.009, p = .040 < .05, presented at table 24.

Table 24
Student status on mobile phones in household

How many mobile phones do you have in your household?		Employment status		Total
		Student	Non-student	
0	Frequency	32	53	85
	% within student status	34.8%	20.5%	24.3%
1	Frequency	7	25	32
	% within student status	7.6%	9.7%	9.1%
2	Frequency	16	36	52
	% within student status	17.4%	14.0%	14.9%
3	Frequency	4	21	25
	% within student status	4.3%	8.1%	7.1%
4 or more	Frequency	33	123	156
	% within student status	35.9%	47.7%	44.6%
Total	Frequency	92	258	350
	% within student status	100%	100%	100%

Replacement of laptop was a significant variable, based on employment status. Students replaced their laptops more frequently than non-students χ^2 (1, N = 350) = 6.936, p = .008 < .05. Knowledge of recycling was the last significant item using the control variable of student status, and students were more knowledgeable regarding recycling schemes than non-students: χ^2 (1, N = 350) = 6.592, p = .010 < .05.

Education attainment The results for mobile phone saturation (χ^2 [4, N = 350] = 31.230, p < .001) showed that participants who had secondary school or tertiary qualifications at diploma level had more mobile phones at home compared to people with further education (table 25).

Table 25
Education status and mobile phone ownership

How many mobile phones do you have in your household?		Education: Diploma or under	Education: University qualifications	Total
0	Frequency	5	80	85
	% within education	5.3%	31.4%	24.3%
1	Frequency	10	22	32
	% within education	10.5%	8.6%	9.1%
2	Frequency	13	39	52
	% within education	13.7%	15.3%	14.9%
3	Frequency	6	19	25
	% within education	6.3%	7.5%	7.1%
4 or more	Frequency	61	95	156
	% within education	64.2%	37.3%	44.6%
Total	Frequency	95	255	350
	% within education	100%	100%	100%

Whilst recycling knowledge differed significantly, the most knowledgeable about recycling schemes were those with diploma or under as their educational attainment: χ^2 (1, N = 350) = 4.178, p = .041 < .05. This result could be viewed as indicative of years since participants were exposed to an educational environment, where institutions actively pursue social goals such as recycling of wastes including e-waste.

Summary As may be expected, students purchased new technology and knew about recycling more so than the non-students. However, they also had fewer mobile phones in their households, which may reflect device preferences. Educational attainment results did not conform as expected, with lower educational qualifications associated with more mobile phones and greater awareness of e-waste disposal schemes. This may reflect a younger cohort.

5.4.5 Incomes difference

Significant differences were established between the income levels of the participants and the variables by chi-square test of independence. These variables were number of laptops in the household and whether any had been replaced; and the length of ownership for devices. Sale of used equipment and recycling knowledge were also found to be significant differences based on income.

Computer ownership Income levels influenced laptop ownership, with those on higher incomes having more laptops in their households χ^2 (4, N = 350) = 13.852, p = .008 < .05 (table 26).

Table 26
Income level and laptop ownership

How many laptops are in your household?		Monthly income SR: Less than 14,000	Monthly income SR: 14,000 or more	Total
0	Frequency	60	7	67
	% within income	22.6%	8.2%	19.1%
1	Frequency	111	34	145
	% within income	41.9%	40.0%	41.4%
2	Frequency	42	14	56
	% within income	15.8%	16.5%	16.0%
3	Frequency	23	14	37
	% within income	8.7%	16.5%	10.6%
4 or more	Frequency	29	16	45
	% within income	10.9%	18.8%	12.9%
Total	Frequency	265	85	350
	% within income	100%	100%	100%

Income was also found to be a significant indicator of laptop replacements, with those on higher incomes replacing their devices when those on lower incomes had not: χ^2 (4, N = 350) = 4.664, p = .031 < .05.

However, the length of ownership of desktops was unexpected, as more participants on higher incomes replaced these items less often than those on lower incomes: χ^2 (4, N = 350) = 12.013, p = .017 < .05. See table 27.

Table 27

Income level and length of ownership of desktop

How long did you own your last desktop before replacing it?		Monthly income SR: Less than 14,000	Monthly income SR: 14,000 or more	Total
No desktop	Frequency	81	11	92
	% within income	30.6%	12.9%	26.3%
1-12 months	Frequency	27	14	41
	% within income	10.2%	16.5%	11.7%
13-24 months	Frequency	30	9	39
	% within income	11.3%	10.6%	11.1%
25-36 months	Frequency	25	12	37
	% within income	9.4%	14.1%	10.6%
37-48 months	Frequency	102	39	141
	% within income	38.5%	45.9%	40.3%
Total	Frequency	265	85	350
	% within income	100%	100%	100%

A similar result was found for ownership of tablets, where those participants on lower incomes replaced their tablets more often than those on higher incomes (χ2 [4, N = 350] = 11.286, p = .024 < .05). These outcomes could indicate that the lower income participants were students, and thus preferred the newer technologies; or they had to replace their device to meet their learning goals.

Recycling In knowledge about recycling schemes in Saudi Arabia and elsewhere, testing the variable against income levels was found to be significant χ2 (1, N = 350) = 3.918, p = .048 < .05. A larger proportion of people with a lower income were associated with more knowledge of recycling of e-waste compared to people with relatively higher income.

Further, in the potential for resale of their used devices, participants on lower incomes were more likely to sell their old devices on the second-hand market than those on higher incomes: χ^2 (2, N = 350) = 12.474, p = .002 < .05. This is presented at table 28.

Table 28
Income status and sale of used equipment

If the equipment was sold, who would you sell it to?		Monthly income SR: Less than 14,000	Monthly income SR: 14,000 or more	Total
Scrap collector	Frequency	34	14	48
	% within income	12.8%	16.5%	13.7%
Secondhand market	Frequency	196	47	243
	% within income	74.0%	55.3%	69.4%
Other	Frequency	35	24	59
	% within income	13.2%	28.2%	16.9%
Total	Frequency	265	85	350
	% within income	100%	100%	100%

Summary Higher income levels were significant indicators of computer ownership, with that participant group having the resources to buy more devices: desktops and tablets. However, lower income levels were significant indicators of recycling knowledge and resale preference, where those participants may have been students.

5.5 Results of the qualitative phase

Interviews were conducted with Saudi public agency and industry representatives on the status of e-waste management, which in 2013, was more in a planning stage than operational. E-waste management was challenging as the country was producing approximately 3 million tons of e-waste annually (Arabnews 2012). The study also revealed that Arab countries lose about SR 5 billion annually because of their failure to recycle e-waste.

A policy for hazardous wastes is based on the Saudi environment regulation law, but there is no comprehensive e-waste management policy. In discussions, representatives from the Presidency of Meteorology and Environment explained that the government was developing an e-waste management policy and forming an administrative structure to address the issue. There was a lack of e-waste recycling projects in Saudi Arabia; the Saudi International Computer Company signed an agreement with the Germany-based Exitcom (www.exitcom.de) to establish the first recycling plant in Saudi Arabia in 2012 (Saudi Gazette 2012).

However, whilst the agency representatives interviewed were aware that e-waste management is an issue in Saudi Arabia, the agencies such as the Ministry of Telecommunication and IT, Ministry of Commerce and Industry, Saudi Standards and Quality Organisation, and General Presidency of Metrology and Environment (PME) were unclear about the functions and responsibilities entrusted to each institution on e-waste management. The authorities and officials believe that there should be a progress in the following areas of e-waste management to address the issue of e-waste management:

- Policy on importing electronic products
- Policy for retailers and producers with respect to responsibilities and accountability for e-waste
- Collection and transportation of e-waste
- Recycling of e-waste
- Antidumping regulations

The lead agency, the Presidency for Meteorology and the Environment, was in the process of setting specifications for electronics and environmental standards in the supply chain from importers through to disposal of waste. The Presidency aimed to provide a favourable environment for the private sector to actively engage in e-waste management. The government is encouraging the private sector to invest in recycling, energy recovery, and metal reclamation ventures, while placing restrictions on the import of electronic devices below international standards. In addition, the Saudi Chambers of Industry and Commerce were developing recycling supply channel guidelines for its member firms that would include e-waste.

5.6 Discussion

In the quantitative results, the results revealed significant differences. On gender differences, women had more devices and kept them longer than men. Also they were more aware of toxicity (heavy metals) in the devices, and the non-Saudis were also significantly different to Saudis on this factor.

Not surprisingly, those under 28 years of age had more laptops and held on to them longer, whilst those over 28 years who had tablets replaced them less often. Younger people and those on lower incomes sold their devices more readily as they knew more about recycling. Interestingly, those with less education had more mobile phones and tended to buy devices more frequently than their counterparts, whilst offsetting their costs through recycling.

There is little comparison that can be made with the literature with these findings. Internet Live Stats (2015) reported that in 2014, Saudi Arabia ranked 30th in the world's users of the internet, although penetration was under 60 per cent, permitting more growth in usage, as many other countries were over 80 per cent.

Recycling of electronic waste for Saudis appears to be through a secondhand market which allows the devices to be used either for their original purpose, or by selling as scrap, landfill disposal or export. Al-Zabin (Arab News 2012) noted that the Kingdom has a government agency to administer its policies on hazardous waste, including components of electronic devices.

5.6.1 Future for electronic waste systems

Since the primary research study in 2013, little progress on e-waste systems appears to have emerged. Global economic conditions since 2008 resulted in subdued prices for virgin materials, which placed recycled materials as uneconomic to recover. Reports at a Bureau of International Recycling (2015) convention in Dubai confirmed that for the Gulf countries, waste electrical and electronic equipment was exported through firms to their facilities in Asia and Europe for recycling. Saudi Arabia's legislation regarding such waste remained under general hazardous. Indian representatives at the convention expected 26 per cent growth in their country's e-scrap market for the following years, whilst China was exploring potential automation for the waste industry. China's growth in e-waste was assisted by the government's enforcement of regulation on its smaller firms who did not have appropriate environmental systems. In the United States, a report to the Bureau of International Recycling (2015) convention valued the country's domestic electronics recycling industry over $US20 billion per year, directly and indirectly employing 45,000 people. Nevertheless, each state regulated its e-waste management and there were significant differences in systems, goals, and economic benefits across the country. For example, some states mandated that used goods be returned to the retailer/producer, whilst others had collection systems in place. Older technologies such as cathode ray tubes in monitors and televisions remained a potential problem. Further, the valuable metals in electronic components were being phased out and replaced by plastics and fibreglass, and future e-waste would have even less value (Bureau of International Recycling 2015).

In a report on the status of the Basel convention regarding hazardous waste, Lepawsky (2015) explained that the Convention came into force in 1992, and in 2004 for producers to take back electrical waste and the emerging field of electronic waste (WEEE Directive). The Convention focussed on transfer of waste (and inherent toxicity problems) across national borders. It was premised on exploitation and potential harm to vulnerable humans in sorting such waste. Lepawsky pointed out that the goal was to reduce the flow of potential toxicity from electrical and electronic waste components from countries designated as Annex VII under the Basel Convention ('developed' countries) to other nations ('developing' countries). As Lepawsky alludes, the notion of developed to developing countries has changed dramatically from 1996, when electronic and electrical waste transfer from the former economies to the latter peaked at 35 per cent. In 2012, e-waste volumes between the two classifications had dropped to less than one per cent of such trade; Annex VII countries were shipping some 73 – 82 per cent of electrical and electronic waste amongst themselves in that year. The non – Annex VII countries were also trading some 25 per cent of total waste between those economies, and their remaining waste went to Annex VII countries. This conforms to the Saudi report at the convention of Bureau of International Recycling (2015).

In this report, Lepawsky (2015) pointed out that besides the nominal notions of developing and developed economies, Saudi Arabia being an example of such confusion, the increase in e-waste trade necessitates a change in direction from one-answer solutions. Global e-waste trade was 6,500 tonnes in 1996, and in 2012 this grew to 140,000 tonnes, and Lepawsky stated that electronic devices and their lifecycles needed to be re-examined in view of the continuing proliferation of 'smart' electronics and their future ubiquity in daily life, and thus their eventual addition to the waste stream.

The results for this study were that a minority of participants was aware of the e-waste issues, which according to producers at the Dubai conference, is rapidly changing as producers move to different components in their devices (Bureau of International Recycling 2015). Apple Inc.

(2016) removed beryllium, mercury, lead, arsenic, potentially noxious plastics PVC and phthalates, and brominated flame retardants from its manufacturing processes. Other producers such as Hewlett Packard and Samsung follow these policies which over time will reduce the toxicity that the Basel Convention was addressing, that of cathode ray tubes in monitors and televisions, and older batteries: lead-sulphuric acid; nickel-cadmium. Lithium-ion batteries are not considered toxic, and are safe for landfill (Battery University, 2016). Further, due to its recent emergence as a technologically active society, Saudi Arabia has not had the history of older potentially toxic waste experienced by other affluent societies.

Whilst there remain concerns as older style electronics and electrical items appear in the waste stream, the incidence of toxicity in the system is reducing over time. There still remains the issue of waste and disposal of inert materials for devices, as Apple Inc. (2016) claimed of current and future products. However, there appears to be little economic value in waste materials when this incurs long supply chains and international transport. As other countries, Saudi Arabia must make decisions on managing waste that suits the country's circumstances.

5.7 Chapter summary

This chapter presented the results of the quantitative and qualitative research. The findings were that the participants had some knowledge of electronic and electrical waste issues, and there were minority attempts to recycle or properly dispose of their devices. This was not supported by the government's adherence to the Basel Convention, arguably because the many Saudi-based firms in recycling were sorting general waste for resources and were not concentrating on electronics due to the lack of opportunity for valuable material recovery.

The overview for the discussion was found to be that the Basel Convention's WEEE Directive was probably not relevant to Saudi Arabia, a consumer, rather than a producer. Further, Saudi Arabia was not a large producer of electrical and electronic products, nor was it a recipient of e-waste although the country's consumers were part of the product lifecycle. Nevertheless government policy should be proactive, supporting recycling programs and calling for producers to do more in promoting recycling, particularly with smaller mobile devices. The next chapter moves to conclusions and recommendations that complete the thesis.

Chapter 6 Conclusions and recommendations

The current global production of electronics waste is about 50 million tons each year. The growth of the global economy results in increased e-waste generation. The chemical composition of e-waste is constantly changing, and it contains many potential contaminants with unknown environmental impacts. Most e-waste is disposed of in landfills. About 80% of the electronics waste collected from recycling is exported to poor Countries, where it may experience “informal recycling,” often involving child labour, with little regard to human health or environmental protection. Informal recycling results in extremely localised contamination that then pervades the surrounding environment. This thesis has sought to examine the attitudes and perspectives of Saudi Arabia’s citizens regarding the subject of e-waste and its management. It has also attempted to set the scene for the more detailed coverage of specific areas covered in its chapters.

This chapter contains conclusions derived from analyses of data and the recommendations made to the stakeholders. The chapter consists of two parts: the first part contains conclusions derived through analyses of data, and the second part contains conclusions based on the recommendations made on the subject.

6.1. Conclusions

The conclusions derived from the study are indicated in this part in six sections. The first section contains the findings related to the ownership of electronic equipment and replacement period, followed by an existing method of disposing obsolete electronic devices and preferences for disposing obsolete electronic devices. The remaining sections cover the perception of people on paying for the recycling of e-waste, followed by the current status of e-waste management in Saudi Arabia. The conclusions terminate with the current status of global e-waste management.

6.1.1 Ownership and retention

The mean values of ownership of electronic equipment of the sample show that a family in Saudi Arabia owns 2.42 cellular phones and 2.65 computers. Similarly, the mean values of electronic devices’ replacement period show that a family in Saudi Arabia replaces the cell phones in 2.68 years, computer parts in 2.52 years, and computers owned by them in 2.38 years. This implies that the e-waste management system should be ready to accept 2.42 cellular phones and 2.65 computers from a family in Saudi Arabia in approximately every 2.5 years. These findings derived from the analyses provide significant information for future e-waste management planning in Saudi Arabia, and the authorities need to take into consideration the ownership and replacement pattern when making plans for e-waste management, including e-waste recycling capacities.

6.1.2. Disposal methods

The frequency distribution of respondents' present way of disposing obsolete cellular phones shows that only 12.5% opt to send their obsolete cellular phones to recyclers and that close to 70% of obsolete cellular phones are disposed through unrecognised means such as dumping and disposing as scrap. Similarly, when disposing of obsolete electronic components are considered, only a negligible percentage of 2.6% opt to send the obsolete electronic components to recyclers and close to 90% of obsolete electronic components are disposed through unrecognised means such as dumping and disposing as scrap. When the disposing of obsolete computers are considered, only 7.7% opt to send their obsolete computers to recyclers, and close to 70% of obsolete computers are disposed through unrecognised means such as dumping and disposing as scrap. When these findings are taken together, it shows that only a very low percentage of 2.6% to 12.5% dispose the obsolete electronic devices through recycling and that a massive percentage of 70% to 90% of families dispose obsolete electronic devices through unrecognised means such as dumping and disposing as scrap. These findings in the existing trend in disposing are significant in e-waste management as they reflect the existing status in electronic devices disposing among the people and the envisaged environmental problems due to the improper disposing of discarded electronic devices.

6.1.3. Disposal preferences

The analysis made on respondents' most preferred way of disposing obsolete electronic devices reveals that 72.4% of families prefer to sell the discarded electronic devices either in their own location or at recycling locations, which implies the preference of generating some income out of discarded electronic devices. When the most preferred location for disposing was analysed, it reveals that a great majority of around 74.4% prefer their obsolete electronic devices to be collected at their own location, and this implies the preference for convenience. These findings of preferences in disposing e-waste are significant in e-waste management as they provide vital information for e-waste management in the country, especially in formulating the plans for the collection of e-waste.

The analysis on the perception of people on who should pay for the recycling of e-waste reveals that nearly 50% have "no idea" about who should pay for the recycling, and this implies the lack of knowledge of the recycling process among the public. It also reveals that nearly 25% believe that the producer should pay for the recycling. The analysis reveals an interesting relationship between education levels and paying for recycling. It shows that almost all the respondents whose education level is graduate level and above have indicated that the producer should pay for recycling, while the education level of a great majority who stated that they have "no idea" about who should pay for recycling is high school and below. These analyses imply that people with a high education level have better knowledge about e-waste recycling processes.

6.2 Saudi e-waste system

The analysis on the current status of e-waste management in Saudi Arabia leads to the following conclusions.

The Kingdom of Saudi Arabia produces approximately 3 million tons of e-waste annually. The annual financial loss incurred by all Arab Countries amounts to SR 5 billion. E-waste are generally disposed through improper methods such as dumping. A proper system for the collection and transport of e-waste in the country does not exist. Private companies, however, are starting to play their roles in this matter. The International Computer Company (ICC) in Saudi Arabia, for example, has recently signed an agreement in Austria in January 2012 with the global company EXITCOM, which specialises in the manufacturing and recycling of electronic products, to establish EXITCOM KSA. This will be the first-ever Arab company working in the field of recycling electronic products (Saudi Gazette 2012).

Awareness about e-waste management among policy makers, authorities, and officials:

- The officials and authorities related to e-waste management are fairly knowledgeable about e-waste management in general.

- The officials and authorities are aware of the fact that e-waste management is an issue that needs to be addressed soon.

- They are also aware of the harmful substances in e-waste and the adverse consequences of the improper disposing of e-waste.

- Though the authorities and officials are aware of the institutions involved in e-waste management, they are not clear about the scope, boundaries, functions, and responsibilities entrusted to each institution in relation to e-waste management.

E-waste policy and regulatory framework. Saudi Arabia does not have a comprehensive policy or regulatory framework for e-waste management, and the following aspects have not been addressed:

- Policy on importing electronic products
- Policy for retailers and producers with respect to responsibilities and accountability for e-waste
- Collection and transport of e-waste
- Recycling of e-waste
- Antidumping regulations (see Figure 3)

At policy and regulatory levels, e-waste needs to be defined and brought under the purview of the Saudi Arabian regime. Thus, there is a need to clearly define e-waste and its composition. The composition will determine its coverage under hazardous waste, solid waste, or any other types of waste. The inclusion of e-waste in the existing regulatory framework will facilitate its management in Saudi Arabia (see figure 6).

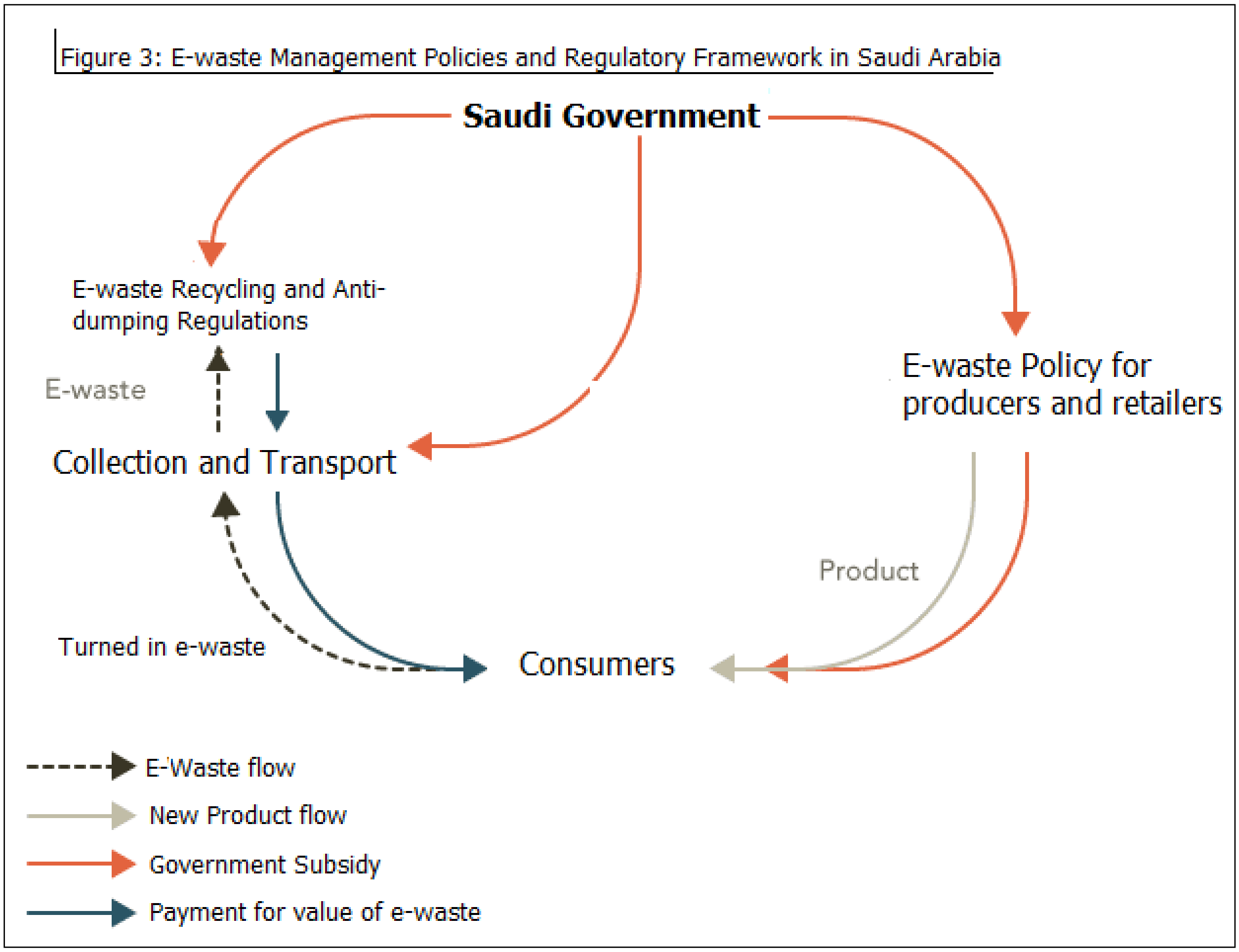


Figure 6 *Saudi e-waste management policy and system*

Figure 6 presents the e-waste management policies and regulatory framework for Saudi Arabia. This shows that the government will apply subsidies to "producers and retailers" with an e-waste policy designed by the government, e-waste recyclers with appropriate antidumping regulations, and an e-waste collection and transport department. Producers and retailers then apply these subsidies to the consumers. Finally, the consumers have to pay for e-waste recycling, collection, and transport when they purchase an electronic product. This will enable the development of an efficient e-waste collection, transport, recycling, and disposal system. This will need the design and establishment of an e-waste recycling facility and its integration with existing recyclers.

6.3 Global e-waste management

The conclusions derived with respect to the global status in e-waste management are indicated below:

Research in e-waste management. The global researches in e-waste management generally focus on the following three main aspects: (1) flows of wastes or used products between Countries and within the country, (2) hazardous substance emissions associated with the recycling process and the international movement of hazardous wastes, and (3) responsibility of producers for the collection and recycling of disposed electronic devices.

E-waste generation. In e-waste management, these conclusions have been derived with respect to the generation of e-waste. There is lack of reliable data on e-waste generation, and a comprehensive system does not exist. The available e-waste data are primarily based on sales data from the country, and estimations are carried out using material flow models and the product life cycle of electronic devices. There is no proper system to accurately and consistently identify the amounts of secondhand electronic products as it is not possible to distinguish new and secondhand goods among imports. This implies that inventories on e-waste and used electronic items are not maintained in a comprehensive manner in most Countries, including Saudi Arabia, and this would affect e-waste management planning.

Government policies. Government policies adopted in many Countries encompass several significant aspects. Many governments in the world are adopting the principle of the four *R*s: reduction, reuse, recycling, and recovery. This principle is supported by advanced high-tech procedures and activities as well as clean technology during the manufacturing and production stage and monitoring of activities during the postoperation stage. To implement this policy, governments have formulated supportive legislations and the appropriate framework in their respective Countries. There are few institutions that are directly and indirectly connected to e-waste management, such as Ministry of Communications and Information Technology (MCIT), Ministry of Commerce and Industry (MCI), Saudi Standards and Quality Organisation (SASO), and Presidency of Metrology and Environment Protection (PME). However, a clear picture does not exist with respect to the boundaries, functions, and responsibilities of each institution on e-waste management, and it is paramount to address this issue in order to facilitate effective e-waste management in Saudi Arabia.

Legislation and Regulatory Frameworks. The government regulatory framework promulgated in many Countries in the world covers legislations and regulations in several significant aspects. Some of these include introducing legislations that place restrictions on the improper disposal of e-waste, such as dumping and burning. Establishing restrictions and controls on the flows of e-waste or used products between Countries and within the country is another aspect. Legislations naming who should pay for the cost of recycling have been promulgated, and in many Countries, this responsibility has been entrusted to the producer through EPR in recycling. Legislations and regulations introducing restrictions and procedures in the collection and transport of e-waste as well as the import of e-waste have been promulgated. Legislations and regulations covering the recycling of e-waste, inclusive of the quality standards on machinery and configurations of the recycling process, have been promulgated.

6.4. Recommendations

The recommendations proposed are indicated in this part in three sections, commencing with recommendations relating to electronic equipment replacement period..

1. Conclusions regarding the life span and replacement pattern of electronic devices that have a comparatively low life span and high replacement frequency, such as computers and mobile phones, have revealed that Saudi Arabian families replace 2.42 cellular phones and 2.65 computers in approximately every 2.5 years. This finding can be taken as a guideline for future e-waste management planning in Saudi Arabia (for example, when making plans for e-waste collection, when working out capacities needed in e-waste recycling projects, and when working out funds needed in e-waste recycling).
2. The conclusions on the frequency distribution of respondents' modes of disposing electronic devices show that close to 70% of obsolete cellular phones, close to 90% of obsolete electronic components, and close to 70% of obsolete computers are disposed through unrecognised means such as dumping and disposing as scrap. These findings in the existing trend in disposing are significant in e-waste management as they reflect the environmental problem looming in Saudi Arabia, and it is recommended that authorities should take following action to prevent the adverse consequences of the improper disposing of discarded electronic devices. This includes taking immediate action and banning the dumping of discarded electronic devices. Immediate action needs to be taken to allocate suitable sites to collect discarded electronic devices and store them until the stocks are disposed through proper disposing methods.

3. The analysis made on respondents' most preferred way of disposing obsolete electronic devices reveals that 72.4% of families prefer to sell and generate some income out of discarded electronic devices, and a great majority of around 74.4% prefer their obsolete electronic devices to be collected at their own location. Hence, it is recommended that authorities should take the following action to facilitate the effective collection of discarded electronic devices.

4. An effective e-waste information collection system should be formulated to obtain data on discarded electronic devices held by Saudi families, which is inclusive of (1) the type of e-waste with each family, (2) the quantity of e-waste with each family, and (3) the location of such e-waste. An effective e-waste collection system should establish e-waste collection zones in each area based on the density of discarded electronic devices held by families. It should establish an effective e-waste collection mechanism to collect discarded electronic devices from their homes at regular intervals. In that system, a postpayment system should be established to make a payment to each family based on the average income that could be earned from each quantity of e-waste. This postpayment can be made even after completing the recycle process.

5. From the findings, it is clear that while the Saudi Arabian population's ever-increasing access to large quantities and types of electronics has numerous benefits, there are also serious issues that need to be addressed, not just at end of life but throughout a product's life cycle. A key challenge for the Saudi Arabian government is to develop further procedures, processes, and materials that will enable greater use to be made of WEEE. Legislation, largely being driven by Europe, is starting to react in developed Countries, and there is now a clear need to adopt similar legislation in Saudi Arabia. It will also be important that new environmentally related legislation, wherever it is implemented, does not differ substantially in scope from other similar legislations in a different region. Achieving a degree of harmonisation through an international standardisation process will become increasingly important as more environmental legislations are implemented in the coming few years. In attempting to achieve a harmonised approach to environmental regulation, particularly with legislations governing materials restrictions, there needs to be greater engagement between the electronics industry and policy makers so that legislators understand the environmental trade-offs inherent in materials

substitution. Additionally, the industry needs to become more proactive in negotiating how costs associated with the sustainability of best practices and resource efficiency can be absorbed in the economy without threats of inflation and to employment.

6. Although legislation can certainly contribute in forcing the recycling of more materials from WEEE, this study recommends that there also needs to be a shift in individual thinking in Saudi Arabia. This means a retreat from the commoditisation of electronics that has occurred in recent years to a situation where products have greater service lives before they are discarded and where refurbishment and reuse have an enhanced role. There are also opportunities for material suppliers to play a significant role in developing new materials that will not only make it easier to treat electronics waste but also provide valuable recycling sources for the producer of new products.

7. Finally, current informal recycling practices in Saudi Arabia need to be mitigated. However, creative solutions need to preserve the positive socioeconomic impact of informal recycling. Just eliminating these practices through the intensified control of illicit e-waste exports to developing countries or through the creation of strict local regulations to abolish informal recycling activities, are not solving the problem in part because the domestic generation of e-waste in Saudi Arabia with high informal recycling activities is growing very fast. Thus, supply for these activities will not necessarily be of international origin. In fact, the generation of obsolete computers in Saudi Arabia will surpass that of the developed world between 2016 and 2020. Moreover, strict local regulations on information recycling activities are not only unsuccessful but intensify the illicit practices surrounding these activities. Clearly, no one solution for the e-waste situation exists; rather, a combination of integrated creative solutions that acknowledge the complexity of an e-waste management system is necessary in Saudi Arabia.

8. This thesis recommends that the government of Saudi Arabia should consider adopting the following policies to regularise e-waste management through a national strategy. The government should adopt and promote the principle of four *R*s: reduction, reuse, recycling, and recovery. Then the government should formulate the legislations, regulatory framework, operational structure, and supporting administrative mechanism to implement the adopted policies. The government should adopt the policies of both

government and private sector participation in e-waste management. All possible encouragement should be given to the private sector, inclusive of foreign investors, to invest in e-waste recycling projects in Saudi Arabia. A suitable strategic approach should be adopted with respect to the transboundary movement of e-waste. Hence, policy decisions should be taken with respect to the boundaries, functions, and responsibilities of each institution on e-waste management to facilitate effective e-waste management and to prevent overlapping.

9. It is recommended that the government of Saudi Arabia should formulate legislations and regulatory framework incorporating these aspects in e-waste management chain (starting from EEE manufacture, production, import, consumption, e-waste generation, treatment, and disposal) to facilitate effective e-waste management. These aspects include antidumping legislations and a regulatory framework; collection and transport of e-waste within the country; import and export of e-waste; quality standards for e-waste recycle projects; responsibilities and accountability of importers, manufacturers, retailers, and owners towards e-waste; responsibility of bearing the cost for recycling; registration of e-waste collectors and recyclers; and establishment and maintenance of e-waste inventories.

6.3 Limitations

Every research study has some limitations. Throughout the process of conducting this research, there was limited of data available related to the generation, collection, transportation, and disposal of e-waste in Saudi Arabia. Data taken from various organisations indicated variations across different components. This research was also subjected to the following limitations:

- The sample of the study was limited to 500 people, and it is comparatively small in relation to the population of the country
- A closed question survey was used to facilitate data research in the quantitative section of the study which may have affected responses
- Since the research is confined to the stated scope of the data, the influences of variables outside the scope of the research remain intact untouched.

6.4. Suggestions for future research

Since the scope of this research covers the life span and replacement pattern of electronic devices that have a comparatively low life span and high replacement frequency, future research could be conducted to cover other electronic devices that generate e-waste such as refrigerators, televisions, washing machines, etc. This would cover an entire range of electrical and electronic devices, providing vital information for policy makers.

E-waste generation in Saudi Arabia is predicted primarily based on the sales data of the country, and estimations are carried out using material flow models and the assumed product life cycle of electronic devices, and there is a lack of information in e-waste data in Saudi Arabia. In the existing scenario, inventories on e-waste and used electronic items are not maintained in a comprehensive manner in Saudi Arabia, and this affects e-waste management planning. Hence, it is very important and desirable to conduct research in the generation of e-waste in Saudi Arabia to facilitate the establishment of e-waste inventories. The findings of such research would provide significant information for policy makers to facilitate the formulation of policies and strategies with respect to e-waste management.

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Appendix 1: Quantitative questionnaire

A – General Information

1. gender: ☐ Male ☐ Female

2. Nationality: ☐ Saudi ☐ Non-Saudi

3. Age-group:

☐ 18–22 years ☐ 23–27 years ☐ 28–32 years ☐ 33–37 years

☐ 38–42 years ☐ 43–47 years ☐ 48–52 years ☐ Above 53 years

4. Social status:

☐ Single ☐ Married ☐ Divorced ☐ Widower/Widow

5. Job:

☐ Still student ☐ Employed ☐ Nonemployed ☐ Employer

6. Qualification:

☐ High school or under ☐ Diploma

☐ Undergraduate degree or equivalent ☐ Postgraduate degree

7. Monthly income in Saudi riyal (SR):

☐ Less than 1,999 ☐ 2,000–5,999 ☐ 6,000–9.999 ☐ 10,000–13,999

☐ 14,000–17,999 ☐ 18,000–21,999 ☐ 22,000–25,999 ☐ More than 26,000

8. If not Saudi, how long have you been here?

☐ Less than 2 years ☐ 2–5 years

☐ 6–10 years ☐ More than 10 years

B – Owning EEE Devices

9. How many of the following new or secondhand equipment do you have at your household?

Equipment Please put ☑ in the exact number.	The total number of equipment in my household											
	0	1	2	3	4	5	6	7	8	9	10	>10
Desktop computers (PC)												
Notebook computers (laptops)												
Tablets (like iPad, Galaxy Tab)												
Flat screens (LCDs)												
Monitors (CRTs)												
Printers												
Telephones												
Mobile phones												
Televisions												
Photocopiers												
Fax machines												
Modems												
Others, specify please.												

9. Where did you acquire your equipment? (Tick 2 of the most common.)

☐ General distributor
☐ Retail outlet or shop
☐ Leased
☐ Formal secondhand market
☐ Informal secondhand market
☐ Others, specify please.

10. When do you usually replace your cell phone?

☐ I don’t have a cell phone ☐ Within 6 months ☐ 7–12 months ☐ 13–18 months
☐ 19–24 months ☐ 25–30 months ☐ After 31 months ☐ Only when I need

11. When do you usually replace your laptop?

☐ I don’t have a laptop ☐ Within 6 months ☐ 6–12 months ☐ 13–18 months
☐ 19-24 months ☐ 25–30 months ☐ After 31 months ☐ Only when I need

12. When do you usually replace your tablet?

☐ I don’t have a tablet ☐ Within 6 months ☐ 6–12 months ☐ 13–18 months
☐ 19–24 months ☐ 25–30 months ☐ After 31 months ☐ Only when I need

13. When do you usually replace your PC?

☐ I don’t have a PC. ☐ Within 6 months ☐ 6–12 months ☐ 13–18 months
☐ 19–24 months ☐ 25–30 months ☐ After 31 months ☐ Only when I need

14. What is the main factor that attracts you to buy new electronic devices?

☐ The new technologies and features
☐ The new design and style
☐ The personal need for work or study
☐ Others, specify please.

15. Who usually provides you the following devices?

Equipment Please put ☑ in the exact number.	The providers			
	I don't have it	Myself	My parents	My work
Desktop computers (PC)				
Notebook computers (laptops)				
Tablets (like iPad, Galaxy Tab)				
Flat screens (LCDs)				
Monitors (CRTs)				
Printers				
Telephones				
Mobile phones				
Televisions				
Photocopier				
Fax machines				
Modems				
Others, specify please.				

C. Background of Recycling

16. What do you do with the equipment when it is no longer useful?

☐ Store in own premises
☐ Sell as secondhand equipment
☐ Throw them away with general waste
☐ Give them to a recycler
☐ Disassemble to reuse some parts
☐ Return to the seller on a buy-back arrangement
☐ Donate to family, friends, etc.
☐ Give back at the store for a reduction on the price of a new equipment
☐ Others, specify please.

17. Have you ever discarded any of the following equipment?

☐ Desktop computers (PC)
☐ Monitors (CRTs)
☐ Flat screens (LCDs)
☐ Telephones
☐ Televisions
☐ Fax Machines
☐ Others (specify please)
☐ Notebook computers (laptop)
☐ PC accessories (including mouse and keyboard)
☐ Printers
☐ Mobile phones
☐ Photocopier
☐ Modems

18. For how long did you possess the equipment before you discarded it (it became obsolete)?

Equipment Please put ☑ in the exact number.	Time						
	I don't have it	1–12 months	13–24 months	25–36 months	37–48 months	49–60 months	More than 61 months
Desktop computers (PC)							
Notebook computers (laptops)							
Tablets (like iPad, Galaxy Tab)							
Flat screens (LCDs)							
Monitors (CRTs)							
Printers							
Telephones							
Mobile phones							
Televisions							
Photocopiers							
Fax machines							
Modems							
Others, specify please.							

19. In what condition was the equipment when you discarded it?

☐ Broken – unfixable ☐ Broken – fixable

☐ Working condition ☐ Others, specify please.

<u>D – Willing to Recycle:</u>

20. Are you concerned about environmental issues such as global warming and climate change?

☐ YES ☐ NO

21. Are you aware of the social and the environmental consequences of discarded electrical and electronic equipment? ☐ YES ☐ NO

22. Do you know that electronic devices contain dangerous materials such as lead, mercury, and cadmium? ☐ YES ☐ NO

23. Are you aware that some electronic parts may be profitably recycled?

☐ YES ☐ NO

24. If the equipment was sold, whom did you sell it to?

☐ The scrap collector ☐ The secondhand market ☐ Others, please specify.

25. Would you be ready to pay your discarded equipment to be collected and recycled?

☐ YES ☐ NO

26. If there are companies that collect old electronic and electrical equipment, would you be ready to give away your e-waste free?

☐ YES ☐ NO

27. If there are companies located in Saudi Arabia, would you agree to deal with them and give them your old/unused electronic and electrical equipment for recycling?

☐ YES ☐ NO

28. Are you aware of what happens to the equipment you have discarded?

☐ YES ☐ NO

29. What environmental consequences have you noticed of discarded electrical and electronic equipment?

……………………………………………………………………………………………………

……………………………………………………………………………………………………

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……………………………………………………………………………………………………

Appendix II: Final interview questions: Saudi officials and authorities

General Information:

Date: ………………………………... Interviewee: ………………………………

Name of institution: ………………… Position: ………………………………….

Principal activity of the institution: ………………………………………………………

Type of institution:

☐ Government ☐ Private co. ☐ International NGO ☐ Informal business

☐ Others (specify) ………………………………………………………

Address:

PO Box……………….…. Code:…………………….. Location…………………

Town……………………... District…………………… Province…………………

Telephone:………………… Fax………………………. E-mail……………………

Website:…………………………………………………

Agenda:

1. In your view, how is situation of electronic waste in Saudi Arabia?
2. What effect is e-waste having on your ministry/institution?
3. What are some of the opportunities of e-waste?
4. What are the negative effects of e-waste?
5. What actions are being taken to benefit from the opportunities (if any) and minimize the negative effects (if any)?
6. Do you have e-waste management policy in the ministry/institution? If there is, get a copy
7. If no, why is there no e-waste policy and do you see a need for one?
8. What is your general view of e-waste management in Saudi Arabia?
9. Which Ministry/institution should be tasked with the responsibility of coming up with a national e-waste policy. , by who? Ministry of Telecommunication & IT (MCIT), Ministry of Commerce and Industry (MCI), Saudi Standards, Metrology and Quality Organization (SASO), or General Presidency of Metrology and Environment protection (PME)?
10. Should the quality of imported computers and accessories (new & second-hand) be audited and regulated? If yes, by who? (SASO, MCIT, CITC,YESSER, or MCI)
11. What key issues should the national e-waste policy take into consideration?

Appendix 3: Pre-testing of questionnaire: test retest reliability analysis

Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	Cell phones owned & Cell phones owned -RT	40	.813	.000
Pair 2	No. of cell phones & No. of cell phones - RT	40	.960	.000
Pair 3	Cell phone replacing & Cell phone replacing - RT	40	.955	.000
Pair 4	Cell phone replacing frequently & Cell phone replacing frequently- RT	40	.823	.000
Pair 5	Laptop owned & Laptop owned - RT	40	.920	.000
Pair 8	computer parts replacing & computer parts replacing - RT	40	.974	.000
Pair 9	Technical advice needed & Technical advice needed - RT	40	.967	.000
Pair 10	Computer replacements in & Computer replacements in RT	40	.964	.000
Pair 11	Recycle E-products & Recycle E-products - RT	40	.968	.000
Pair 12	Disposing used cell phones & Disposing used cell phones - RT	40	.989	.000
Pair 13	Disposing used electronic components & Disposing used electronic components - RT	40	.989	.000
Pair 14	Disposing used computers & Disposing used computers - RT	40	.986	.000
Pair 15	E-waste Disposing Preference & E-waste Disposing Preference - RT	40	.982	.000
Pair 16	Who should pay for safe recycling & Who should pay for safe recycling - RT	40	.989	.000
Pair 17	Willingness for E-waste Recycling & Willingness for E-waste Recycling - RT	40	.979	.000
Pair 18	Knowledge on E-waste Recycling & Knowledge on E-waste Recycling - RT	40	.979	.000