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RECOVERY AND DISPOSAL OF OZONE DEPLETING SUBSTANCES: A CASE STUDY OF THE REFRIGERATOR REBATE SCHEME IN GHANA.

BY

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DECLARATION

I hereby declare that this work is the result of my own research and that neither in whole or in part has this work been presented for the award of another degree elsewhere, with the exception of references to other works which I have duly acknowledged.

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ABSTRACT

The increasing threat of climate change and its devastating effects has increased the quest for sustainable mitigation and adaptation measures. Refrigerators contain significant amounts of ozone-depleting substances and greenhouse gases which are released into the atmosphere during their disposal contributing to ozone depletion, global warming and climate change. Using the refrigerator rebate scheme in Accra and Tema as a case study, a triangulation of quantitative and qualitative research design was employed using interviews, questionnaires and direct observation techniques to collect data from key staff of stakeholder institutions and individuals. Laboratory analyses were also carried out to determine the amount of CFC-11 in the polyurethane insulating foam of each discarded refrigerator. The results show that though there are enough relevant institutions available for the implementation of the rebate scheme and for the recovery of the ODS that are contained in these appliances they lack the necessary legal backing and state of the art recycling technologies to carry out their operations effectively. In addition, with the 4,000 refrigerators recycled so far, Ghana's contribution to the reduction of ozone depletion and global warming is only 130 kg of CFC-11 equivalent and 1,413,300 kg of CO_2 equivalent respectively. It is therefore recommended, among other things, that appropriate laws and technologies are put in place towards a more sustainable refrigerator management system.

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DEDICATION

This thesis is dedicated to my wife, Mrs. Elikplim Akos Klevor for her patience and support. It is also dedicated to my children, Delayram and Nyuiadeva for their tolerance and encouragement. Finally, I dedicate it to my students for their inspiration and understanding during my course of study in this University.

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With all their support notwithstanding, I take sole responsibility of all shortcomings in this work.

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LIST OF ABBREVIATIONS AND ACRONYMS

BA- Blowing Agent

DfE- Design for Environment

EEE-Electrical and Electronic Equipment

EOL -End-of-life

EPA -Environmental Protection Agency

EPR- Extended Producer Responsibility

GWP - Global Warming Potential

GSS - Ghana Statistical Service

GHG- Greenhouse gas

MP- Montreal Protocol

NOU - National Ozone Unit

ODS-Ozone-Depleting Substance

ODP - Ozone-depletion Potential

OECD - Organisation for Economic Cooperation and Development

PCBs - Polychlorinated biphenyls

PUR- Polyurethane

R11- trichlorofluoromethane

R12- dichlorodifluoromethane

RAL- German Institute for Quality Assurance and Certification

UNDP - United Nations Development Programme

UNEP- United Nations Environment Programme

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LIST OF DEFINITIONS

Article 5 Country: any party to the Montreal Protocol that is a developing country and who's annual calculated level of consumption of the controlled substances in Annex A (of the Montreal Protocol) is less than 0.3 kilograms per capita.

Destruction Facility-a facility where the destruction of the ODS takes place and which meets the screening criteria for destruction technologies set out in the report, as may be updated from time to time, by the UNEP Technology and Economic Assessment Panel (TEAP) Task Force on Destruction Technologies.

Domestic fridges - refrigerators of a typical domestic design with a storage capacity of up to 180 litres with or without a separate deep-freeze compartment.

Domestic fridge-freezers - refrigeration appliances of a typical domestic design with a storage capacity ranging from 180 to 350 litres with a separate deep-freeze compartment.

Domestic chest freezers - deep-freeze appliances of a typical domestic design with a storage capacity up to 500 litres.

Reclaim - to reprocess used ODS refrigerants or blowing agents, typically by distillation, to specifications similar to that of virgin product specifications

Recovery - to remove ODS refrigerants and blowing agents in any condition from a system and store in an external container.

Recovery Machine - a machine/equipment used to extract refrigerant.

Recovery Facility - the facility where the recovery of ODS refrigerants and blowing agents takes place

Recycle- to extract ODS refrigerants from an appliance and clean using oil separation and single or multiple passes through filter-driers, which reduce moisture, acidity, and particulate matter

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Refrigerant Identifier – a portable unit that allows the reliable identification or detection of percentage composition (not all) of CFCs, HCFCs, HFCs, Hydrocarbons and air content of a substance.

Retrofit - a process by which the equipment currently using an ODS refrigerant is made to run on a non-ODS refrigerant

Servicing - any act of repair, maintenance, testing and troubleshooting of parts, including mechanical and electrical components of an existing refrigeration and air conditioning equipment.

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CHAPTER ONE

GENERAL INTRODUCTION

In the history of civilization climatic optimums are associated more with prosperity and progress, ice ages-with hardships and catastrophes. (Peter Kaznacheev, Institute of Economic Analysis, Moscow, August 2004)

1.0. Background

The above epigraph captures the essence and significance of how recent extreme weather conditions and climate change concerns have given cause for some political and green environmental leaders to warn humanity of the possible calamity that lies ahead if urgent sustainable steps are not taken to save our planet (Brigden et al, 2005; Puckett, 2002). It further gives insights and justification why in October 1988, experts from 100 countries met in Toronto, Canada, to discuss the enrichment of greenhouse gases (GHG) in the atmosphere, particularly carbon dioxide (CO_2), and the influence on climate change (Hackl and Mauschitz, 2008). Following from that scientific meeting, the Toronto target, which was a demand to all governments to reduce CO_2 emissions by 20% and to increase energy efficiency by 10 per cent, both by 2005 on the basis of the data from 1988 was formulated (Hackl and Mauschitz, 2008).

Significantly, these targets were to become the first step to stop global warming. As a result of the Toronto conference and its global echo, the United Nations organized the UN Conference on Environment and Development (UNCED), which was held in Rio de Janeiro in June 1992. During that conference, politicians and representatives of governments from 158 countries had the opportunity to discuss the problem of GHG

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emissions and the effects on climate change and finally the Framework Convention on Climate Change (UNFCCC, 1994) was signed in New York in September 1992.

Following the obligations of this convention, in December 1997 the Kyoto Protocol was set up and came into force in 2006 (United Nations, 1998). According to this protocol, in addition to CO_2 five other greenhouse gases, namely methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6), were added to the list of gases to be controlled and to be reduced. The parties that signed the Protocol have to produce annual National Inventory Reports that include the details of measures set up for GHG reductions and their results. In addition to the general obligations, the Kyoto Protocol also contains requirements for special factors and emission sources. In particular, waste management is mentioned three times.

The Kyoto Protocol stipulated that the 38 industrialized countries listed in Annex B shall reduce their GHG emissions according to quantified emission limitations, which is also listed, such that for the years 2008 to 2012 an average reduction of 5.2%, based on 1990 levels, will be achieved. Within the framework of the European Union (EU) the overall target is 8%. These protocols and measures were deemed necessary in view of the incontrovertible evidence manifestation (Hackl and Mauschitz, 2008). A former UK Prime Minister in 2005 provided his "watertight evidence" on the present state of the world by providing some to the observed impact of climate change. He noted:

i. The 10 warmest years on record have all been since 1990. Over the last century average global temperatures have risen by 0.6 degrees Celsius: the most drastic temperature rise for over 1,000 years in the northern hemisphere.

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ii. Extreme events are becoming more frequent. Glaciers are melting. Sea ice and snow cover is declining. Animals and plants are responding to an earlier spring. Sea levels are rising and are forecast to rise another 88cm by 2100 threatening 100 million people globally that currently live below this level.

iii. The number of people affected by floods worldwide has already risen from 7 million in the 1960s to 150 million today (Martin Ågerup et al, 2004).

The waste sector is an important contributor to climate change. For example, methane (CH_4) produced at solid waste disposal sites contributes approximately 3-4 per cent of the annual global anthropogenic greenhouse gas emissions (Monni et al, 2006). Indeed, emissions from solid waste disposal are expected to increase with increasing population and affluence with its attendant increase in Gross Domestic Product, GDP (Monni et al, 2006). On the other hand, many cost-efficient emission reduction options are available.

Consequently, solutions to these extreme global warming and ozone depletion, which solid waste contributes significantly, and which is expected to increase with increasing population and gross domestic product (GDP) are to be found in the 1997 Kyoto Protocol (KP), which demands that countries cut their GHG emissions because as it were, carbon emissions are responsible for global warming. What remains unclear is the economic implications and the extent of geographical distribution of the impact of the strict implementation of the Kyoto Protocol. It is estimated that the cost of complying with Kyoto between 1990 and 2100 is about US$ 1.75 trillion (Kessel, 2000). This will raise the cost of doing business and alternative means of development means slapping punitive taxes on everyone. It has also been established that the KP is anti economic growth. Studies have shown that economic growth in Kyoto countries

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(EU 15, Canada and Japan) between 1997-2003 was 2 per cent while it was 3.1 per cent in 10 non-Kyoto developed countries (USA, Australia, Taiwan, Korea, Hong Kong, Singapore, Israel, Mexico, Cyprus and Malta). Under the same period most poor Kyoto countries recorded less than 2 per cent growth. Ghana's annual growth rate is about 0.7 per cent and may reach 1.7 per cent in ten years after Kyoto enters into force. Complying with Kyoto means this insignificant gain will be whittled away.

Indeed, in September, 2012, the Alliance of Small Island States (SIS), the Least Developed Countries (LDCs), and the Africa Group, which together represent over a billion people most vulnerable to the impacts of climate change, expressed worry about the environmental integrity of the Kyoto Protocol (Smith-Asante, 2012). In a joint statement issued to mark the close of the UN climate change negotiations in Bangkok, Thailand, the group said "*We are concerned that the environmental integrity of the Kyoto Protocol, which is the only international treaty that legally binds developed countries to lower emissions, and thus our lone assurance that action will be taken, is eroding before our eyes*." (Smith-Asante, 2012). In relation to this, a former British Prime Minister Tony Blair, intimated passionately, "*It is the poorest countries in the world that will suffer most from severe weather events, longer and hotter droughts and rising oceans. Yet it is they who have contributed least to the problem. That is why the world's richest nations in the G8 have a responsibility to lead the way for the strong nations to better help the weak*" (Martin Ågerup et al, 2004). For example, Ghana's emission as a percentage of global CO_2 emissions in the 1990s was 0.0 per cent just as many others in Africa (Martin Ågerup et al, 2004). In fact, Sub-Saharan Africa recorded 2.1 per cent throughout the late 1990s (Martin Ågerup et al, 2004). .

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Ultimately, the least developing countries, with the support of China, adopted a common position which called for a fair, balanced and credible relationship between the poor and rich countries, particularly, when some advanced countries blatantly refused to sign the protocol while poor countries were virtually bullied to ractify (Martin Ågerup et al, 2004). On February 24 2005, Ghana's Parliament urged all countries to sign the Kyoto Protocol because in its view the 55 per cent cap set for emissions reduction by the 141 ratifying countries was too slow for our warmed planet (Martin Ågerup et al, 2004). Members expressed disgust about the fact that whilst the 141 countries had pledged to cut carbon emissions by 5.2% below 1990 levels by 2012, 35 of the world's developed countries supposedly responsible for a chunk of the emissions had not done enough to reduce CO_2 (Martin Ågerup et al, 2004).

Ghana has further urged all parties to fulfil their pledges and commitments under the global agreements and provide clear and unambiguous commitments on fast-start funding and of the climate Green Fund (Ayittey, 2011). It is also averred that in order to beat back the threat posed by global warming, the citizenry should be sensitized, especially vehicle owners and those in businesses such as the mining and cement industries, among others to be mindful of how waste is managed. That admonishing is right but to link it to global warming without any credible scientific basis is worrying.

Meanwhile Ghana's commitment to climate change mitigation practices has manifested in the introduction of several policies and interventions. In 2013, the country published a national climate change policy under the guidance of the National Climate Change Committee (NCCC) (MESTI, 2013). The vision of the policy states inter alia: "*To ensure a climate-resilient and climate compatible economy while*

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achieving sustainable development through equitable low-carbon economic growth for Ghana" (MESTI, 2013). The government has also instituted certain regulations with the view of achieving set targets in the climate change related issues. The Energy Efficiency Regulations, 2008 (LI 1932) for example, among other things prohibits the importation, distribution, or sale of used refrigerators, while the Energy Efficiency Standards and Labeling Regulations, 2009 (LI 1958) bans the importation and sale of CFCs and used refrigerators containing CFCs. Subsequently, the government, with the support of its development partners has set up a rebate scheme to mop up the CFC related appliances in use and to promote energy-efficient non-CFC appliances. Following the passage of the above LIs the rebate system has been piloted in selected localities in the country since 2012. Understanding the prospects and challenges of the scheme will not only aid policy formulation, but more importantly, the success of a nationwide efficient functioning of the scheme cannot be based on empirical vacuum. This thesis fill this knowledge vacuum by examining the current requirements of the above-mentioned rebate system and discuss some additional policies and measures that have to be undertaken in the field to make it viable.

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1.1 Problem Statement

Gilpin (1996) defines waste as the "*unwanted materials arising entirely from human activities which are discarded into the environment*". This notion that waste results entirely from human activities is corroborated by Jessen (2002) who asserted that "*waste is human creation*." Waste in general has become a life companion. Increasing urbanization and increased economic fortunes has made waste reach an epic role, warranting improved management systems to minimize its negative impacts on humanity. The situation appears gargantuan in most developing countries as the

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developed nations have made much better headway regarding instituting proper waste management practices (Manhart, 2012).

In recent decades waste management has become a problem in most developing countries. Instituting proper waste management practices is necessary to overcome the negative effects associated with increasing economic growth and rising standards of living. The main targets of modern advanced waste management are prevention, recovery of materials and energy and finally the treatment and safe disposal of inactive residues without any risk for future generations, implemented by the precautionary principle. Since the Toronto conference on climate change, it has become evident that global efforts have to be mobilised in order to mitigate the emissions of greenhouse gases, especially carbon dioxide, methane and nitrous oxide. For methane, a dominant source is the organic waste that is deposited in solid waste disposal sites, generating landfill gas. Other sources of greenhouse gases have been traced to the use of CFCs as refrigerants and blowing agents in refrigeration systems. Indeed, prior studies show that when released into the atmosphere, CFCs damage the ozone layer and contribute to global warming (Anderson, 2009; Ruan and Xu, 2011).

Global warming or climate change is the measurable increase in the average temperature of earth's atmosphere, oceans, and landmasses caused by emissions of greenhouse gases that trap the outgoing heat from the earth (UNEP, 2010). Scientists believe earth is currently facing a period of rapid warming brought on by rising levels of heat-trapping gases (GHG) in the atmosphere. It must be stated that since the beginning of the industrial revolution in the mid-1700s, however, human activities have added more of these gases into the atmosphere. For example, levels of carbon dioxide, a powerful greenhouse gas, have risen by 35 percent since 1750, largely from

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the burning of fossil fuels such as coal, oil, and natural gas (Kessel, 2000). In the mid 1980s more greenhouse gases such as CFCs and HCFCs have joined the mix (Mégie, 2006), making the atmosphere act like a thickening blanket that traps more heat. These observations led the United Nations Intergovernmental Panel on Climate Change (IPCC) to conclude in its 2007 assessment report that "*increases in anthropogenic greenhouse gas concentrations are very likely to have caused most of the increases in global average temperatures since the mid-20th century"* **(**UNEP, 2012).

Meanwhile, studies have indicated that the global effects of climate change include the heating up of the polar regions of the Northern hemisphere and rapid melting of polar ice sheets and glaciers leading to rising sea level, dwindling agricultural production and increased incidence of some diseases such as malaria, dengue fever and yellow fever. Globally, there have been various interventions pioneered by global conventions and protocols. These have culminated in measures such as carbon capture through forest preservation and afforestation, alternative energy sources that release less GHGs, international agreements and replacements programs, all aimed at curbing climate change.

Significantly, household refrigerators are among other electronics whose end-of-life management can contribute to increasing global GHG emissions. In Ghana, the current refrigerator disposal practices make it possible for large quantities of these CFCs and HCFCs to be released into the atmosphere. Thus if improperly recovered and disposed, the Ozone Depleting Substances (ODS) contained in these refrigerators are released into the atmosphere where they destroy the ozone layer which protects the earth from the harmful UV rays of the sun.

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In the main, lack of formal management practices of this waste, fuelled by the high rate of unemployment in the country has created a market niche for young men who adopt rudimentary approaches in managing them in order to make a living. The informal disposal methods used by these scrap dealers do not have any strategy towards the recovery of the ODSs resulting in the emission of large quantities into the atmosphere. In addition, these workers themselves are exposed to hazardous chemicals from the refrigerators such as used oil, PCB and mercury which according to earlier studies cause skin, eye, and respiratory tract irritation, cancer and damage to the liver, brain, immune system, reproductive system (Okolo, 2013), nervous system (Baird and Cann, 2008), and endocrine system (Hara, 1985).

The government rebate scheme is therefore a policy intervention aimed at ensuring responsible disposal of refrigerators through proper recovery and disposal of the CFCs and other embedded hazardous substances. Ultimately, it is hoped that this will contribute to energy security by reducing electricity consumption, contribute to climate change mitigation by avoiding greenhouse gas emission and prevent health calamity. It is estimated that the manual stripping of the insulating foam as is currently the practice with the refrigerators collected under the scheme releases about 100 times more CFC into the environment than treatment in a state-of- the-art fridge recycling plant (Dehoust and Schuler, 2010), a practice the rebate scheme is intended to address.

1.2 Objectives

The overall objective of this study was to find out the viability of the refrigerator rebate scheme as one of the pathways by the government to reduce anthropogenic-induced climate change.

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The specific objectives that guided the study were:

1. To examine current management approaches to EOL refrigerator disposal in Ghana.
2. To identify the institutional and regulatory frameworks for managing used refrigerators in Ghana.
3. To evaluate the viability and sustainability of the refrigerator take-back scheme.
4. To make recommendations for policy consideration towards a more sustainable used electronics management system in Ghana.

1.3 Research Questions

The following questions were answered in the course of this study:

1. What are the current methods of disposing used refrigerators in Ghana?
2. What are the institutional and regulatory frameworks available towards the management of used refrigerators in Ghana?
3. How viable and sustainable is the refrigerator take-back scheme?
4. How can the refrigerator take back scheme be improved upon towards a more sustainable used electronics management in Ghana?

1.4 Hypothesis

The hypotheses of the study are that:

1. The choice of refrigerator disposal method of residents depends on their locality.
2. The choice of refrigerator disposal method of residents depends on their level of education.

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3. The medium of awareness of the rebate scheme depends on the educational level of residents.

1.5 Justification

After the official pilot period, no academic research has been conducted to ascertain the prospects of the scheme in its nationwide application. This study thus fills this knowledge gap and contributes towards efforts of mitigating the effects of climate change and ozone depletion.

In a number of countries such as Germany, Turkey, U.S.A., China, Sweden and Italy, extensive studies have been carried out using various methods, to determine the amount of Ozone Depleting substances contained in old refrigerators. (Svanström and Ramnäs, 1995,1996; Macchi-Tejeda, Opatova and Leducq, 2007; Chen and Cao, 2011; Sansotera et al, 2013; Scheutz et al, 2007; Yazici et al, 2013). Little information however is available in Ghana concerning the amount of Ozone depleting substances contained in the refrigerators that are disposed and recycled both by informal and formal means. This research provides the information required to quantify the CFC emission of each refrigerator improperly disposed. This brings into focus the environmental effects of the current methods used in the disposal of used refrigerators in Ghana. It will help policy makers to regulate and encourage safe appliance recycling, as well as proper and responsible disposal of hazardous components through programs and laws.

Lastly, if all old refrigerators are collected and properly recycled, the ODS refrigerants recovered can be sold on the international market through the carbon credit scheme. In addition, both the country and individuals will make huge savings on their energy bill since the replacement refrigerators are more energy-efficient. It

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will also help the nation in her attainment of the Kyoto and Montreal protocol objectives to which Ghana is a signatory.

1.6 Thesis Organization

This thesis was organized into five chapters. Chapter One entails the introduction, problem statement and the objectives of the study. Chapter Two presents a survey of relevant and related previous studies to the project. It focuses on key elements of refrigerator management and waste management policy. Chapter Three describes the sampling procedures, laboratory analysis, field observations, interviews conducted and all other strategies adopted in the methodology in order to collect data. The findings were presented and discussed in Chapter Four within the context of the research questions and objectives. Finally, Chapter Five draws conclusions on the major findings of the study, gives recommendations for policy consideration and outlines areas for further research.

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CHAPTER TWO

REVIEW OF LITERATURE

2.1 Introduction

This chapter examines the literature related to the current study. The broad issues covered in this discussion include the issue of waste with special focus on electronic waste management and refrigerator disposal practices. The rebate scheme, which has been piloted as a possible pathway to abate some of the challenges emanating from the current management practices will also be interrogated. It is hoped that this will not only situate the study in the appropriate theoretical framework but more importantly to provide enough justification to the current study.

2.2 Managing Electronic waste; an Overview.

In the developed world waste management practices are designed along the approach of Integrated Waste Management, IWM. According to the World Resource Foundation (as cited in Baabereyir, 2009), IWM is "*the use of a range of different waste management options rather than using a single option*". According to Baabereyir (2009), the approach does not only involve the selection and application of appropriate technologies, techniques and management practices to design a programme that achieves the objectives of waste management but it also brings together all stakeholders affected by the waste management regime to participate in waste management. Furthermore, issues such as social, cultural, economic and environmental factors are considered in the design of an IWM project (Schubeller *et al* as cited in Baabeyire, 2009).

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In Europe and other parts of the developed world waste management is not a sole responsibility of political authorities. In Germany, for example the passage of the German Packaging Ordinance in 1991 placed the responsibility of waste management on the shoulders of producers. This law required the producers of products sold in Germany to take back, reuse, and/or recycle the packaging associated with their products (Fishbein cited in Theurer, 2010). This Extended Producer Responsibility (EPR) which is a sustainable approach to waste management also seeks to increase co-ordination between the producers of goods, retailers, manufacturers, the public, local authorities and all concerned with the management of waste and reusable materials and equipment.

In the developed world waste management programmes are targeted towards waste prevention, reduction, re-use and recycling. These targets have become the components of what is commonly known as the waste hierarchy (Figure 2.1) in which various strategies for waste management are ranked in order of environmental friendliness, from best to worst (Girling cited in Baabeyire, 2009). In the hierarchy, waste prevention and reduction are placed at the apex, an indication that the best way to deal with waste is to prevent its production and, where this is not possible, to produce less of it. Where waste is unavoidable a sustainable approach is to encourage re-use and recycling of products to prevent them from getting into the waste stream. Where waste prevention/reduction, re-use and recycling are economically impossible, waste is processed to recover their intrinsic values such as energy and fertilizer. At the other extreme, disposal is placed at the bottom, an indication that it should be the last resort among the strategies for managing waste.

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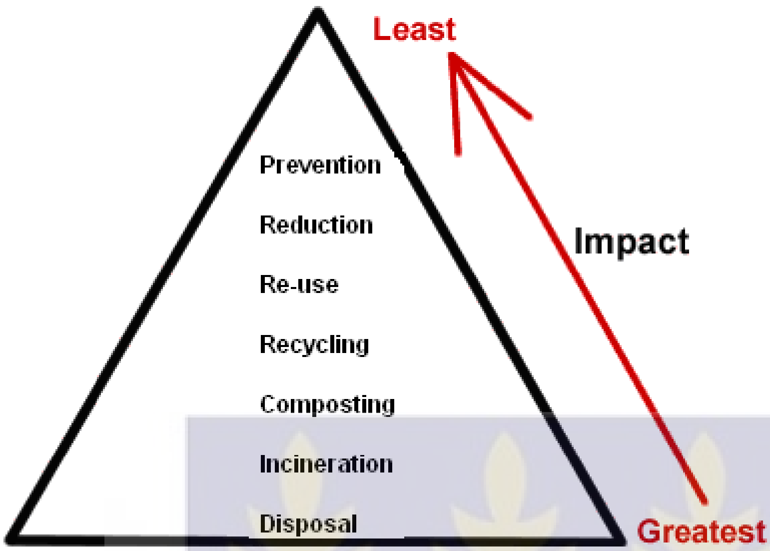
Figure 2.1: The waste hierarchy



Source: adopted from Baabeyire (2009)

In spite of the enormous benefits associated with sustainable waste management strategies such as re-use and recycling, only a handful of developing countries are able to put them into practice. In spite of efforts by metropolitan and municipal authorities to improve waste management, most countries in the developing world still resort to strategies at the bottom of the waste hierarchy (Puopiel, 2010). Most African cities still grapple with the mere removal of waste from human settlements with hardly any arrangements for recycling. Apart from a few informal recyclers, the bulk of solid waste collected by municipalities in most developing countries is disposed of in landfills (Oteng-Ababio, 2009). Thus developing countries in general remain at the bottom of the waste hierarchy, dumping most of their waste in uncontrolled landfills or open dumps or, worse still, in rivers and other water bodies (Baabeyire, 2009). The recent flood in Accra on June 3, 2015 is a testimony of the consequences of drains that have been choked with solid waste. If this trend should continue, the concept of sustainable waste management will, for a very long time, remain a distant dream in developing countries.

Within the last 20 years rapid urbanization and technological advancement has led to an increase in the volume and a change in the content of waste with plastics and electronic waste particularly becoming a problem. E-waste is electrical and electronic equipment that is no longer suitable for use or that the last owner has discarded (Schluep et al, 2011). This includes but not limited to personal computers, laptops, refrigerators, television sets, air conditioners, washing machines and cell phones. E-waste is a relatively new waste stream; refrigerators were not mass produced until the

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1950s (Ruan and Xu, 2011) and computers have only become affordable within the last 20 years (Theurer, 2010). The spectrum of e-waste management practices spans from open burning as practiced in developing countries to fully automated recycling as practiced in the developed world (Theurer, 2010).

According to Wäger, Hischier and Eugster (2011), in Switzerland, Waste Electrical and Electronic Equipment (WEEE) are separated from other types of waste by households and companies from where they are collected for recovery and recycling. This is corroborated by Theurer (2010) as being the standard practice in countries within the European Union with special reference to Germany. Another key element of effective e-waste management in Europe and other developed countries is the passage and enforcement of relevant legislation. One of the main legislations related to e-waste management in Europe is the Waste Electrical and Electronic Equipment (WEEE) (Directive 2002/96/EC). The key aims of the WEEE Directive according to (Savage et al, 2006) are to:

i) Reduce WEEE disposal to landfill;

ii) Provide for a free producer take-back scheme for consumers of end-of-life equipment from 13 August 2005;

iii) Improve product design with a view to both preventing WEEE and to increasing its recoverability, reusability and/or recyclability;

iv) Achieve targets for recovery, reuse and recycling of different classes of WEEE;

v) Provide for the establishment of collection facilities and separate collection systems of WEEE from private households;

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vi) Provide for the establishment and financing of systems for the recovery and treatment of WEEE, by producers including provisions for placing financial guarantees on new products placed on the market.

Closely linked to the WEEE Directive is the Complementary Directive 2002/95/EC on the restriction of the use of certain hazardous substances in electrical and electronic equipment. This seeks to reduce the environmental impacts of WEEE throughout all stages of the equipment's lifecycle, particularly at the end-of life stage, by encouraging the end-of-life management of the product, eco-design, life cycle thinking and extended producer responsibility (Sawhney et al, 2008).

Another key element of an effective e-waste management plan adopted by developed nations is the concept of Extended Producer Responsibility (EPR). By definition, EPR is an "*environmental policy approach in which a producer's responsibility, physical and/or financial, for a product is extended to the post-consumer stage of a product's life cycle*" (OECD, 2001:18). Physical responsibility refers to the direct or indirect handling of the product at the end of its life span, whereas, financial responsibility refers to the payment for most or all of the end-of-life costs by the producer (OECD, 2001). The goal is to transfer the burden of product disposal away from the local government and taxpayer to the producer, where "*the environmental costs of treatment and disposal could then be incorporated into the product*" (OECD 2001:18). Overall, EPR policies have three main characteristics:

(1) A focus on EOL waste management to encourage environmental redesign,

(2) Physical/financial shift of responsibilities from municipalities/tax payer to producer and

(3) Meeting explicit targets for waste reduction (Nicol & Thompson, 2007).

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EPR is sometimes backed by law. In Germany, for example, with the passage of the Electrical and Electronic Equipment Act in 2005, any producer who wishes to sell electronic products in Germany must register with the Federal Environmental Agency and agree to be financially responsible for the transportation and appropriate disposal of products sold by them (Theurer, 2010).

Due to the inability of many Ghanaians to afford brand new products, large consignments of used and old fashioned electronic and electric equipment discarded mainly in Europe and North America are imported. According to Greenpeace International, (2008), containers filled with old and often broken down electronic gadgets arrive in Ghana from Germany, UK, Korea, Switzerland and the Netherlands under the false label of "second-hand goods". Electrical and electronic equipment contains valuable metals like copper, iron, gold, silver, aluminium and germanium. E-waste collection and subsequent retrieval and recycling of these metals have therefore become an important economic activity providing income for thousands of small, partly informal enterprises in Ghana (Amoyaw-Osei et al, 2011). Unfortunately, proper recycling facilities, management systems, regulation, EPR and industry standards do not exist. As a result, e-waste handlers and recyclers work in appalling conditions, constantly exposing themselves and communities nearby to serious hazards (Oteng-Ababio, 2012).

Manhart et al (2011) and Manhart, (2012) observe that e-waste collection and management in Ghana and Nigeria is largely informal characterized by waste scavengers who move all around the cities with handcarts to collect e-waste with other metal-containing waste from landfills or homes and offices. According to Oteng-Ababio (2011), the e-wastes are dismantled manually with tools such as

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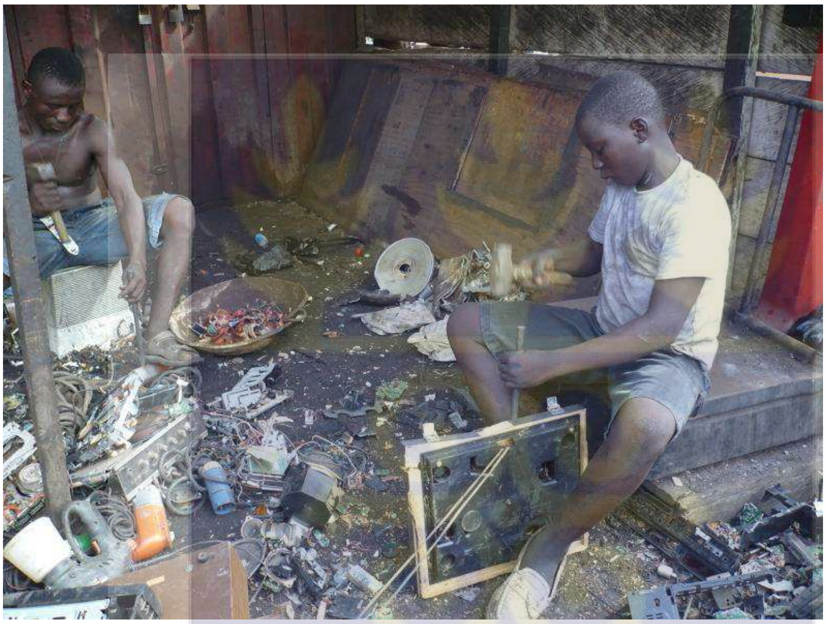
hammers, screwdrivers, chisels and hack saws after which the materials are burnt openly to recover metals and the residual fractions dumped at landfill sites. This is done without any recovery of hazardous substances such as PCBs, mercury and ODS contained in these appliances.

Figure 2.2: Scrap dealers dismantling e-waste.



Source: Manhart, (2012)

INTEGRI PROCEDAMUS

Figure 2.3: Workers at Agbogbloshie burning e-waste.

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Source: Okolo, (2013)

2.3 Refrigerator Disposal Practices

According to Wethje (2005) and Hodson et al (2010), waste appliances are scrapped and shredded together with other metals in an open-air car shredder in the United States and the shredder residue, deposited in landfills. This is consistent with what happens in other developed countries as noted by Hodson (2008) in the United Kingdom, Stoop and Lambert (1998) and Lambert and Stoop, (2001) in the Netherlands and Nicol (2008) in Canada. During the shredding the CFC-12 and the oil from the refrigerator's cooling system leaks into the environment whilst the CFC-11 present in the polyurethane foam is partly emitted into the atmosphere. After shredding the metallic parts are separated with a magnet and the nonferrous fractions (plastic, glass and foam) are disposed of in a landfill from where residual ODS in the foam is further released into the atmosphere (Stoop and Lambert, 1998; Lambert and Stoop, 2001; Nicol, 2008). In another method practiced in the Netherlands (Stoop and Lambert, 1998) and Germany (Dehoust and Schuler, 2010), the mixture of refrigerant and oil is drained out of the refrigerating system using a vacuum pump for separation. Afterwards, the refrigerator carcass is manually dismantled to separate the ferrous and

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non-ferrous metals from the plastics and PUR foam. However, the manual dismantling releases some ODS into the atmosphere (Dehoust, and Schuler, 2010). Still in the Netherlands, Stoop and Lambert, (1998) noted that the refrigerant is drained as in the previous method after which the PUR foam is pressed into a matrix with small holes using a Koller mill and dumped in a landfill from where CFC-11 is gradually released into the atmosphere.

Another method applied in Sweden according to Lambert and Stoop, (2001) is that the oil and CFC-12 are drained from the cooling circuit and directly incinerated in a rotary kiln. The compressor is removed and shredded after which the refrigerator carcass is cut open with pneumatic scissors, mixed with domestic waste and incinerated in a grid kiln. Apart from the CFC-11 that escapes during the cutting stage the remainder is completely destroyed in the incinerator-kiln.

The most current state-of-the-art recycling technology of waste refrigeration appliances as practiced in the United States (Jacobsen and Dunham, 2004; Wethje, 2005), Sweden (Scheutz and Kjeldsen, 2002) and Germany (Dehoust and Schuler, 2010) involves treatment in fully encapsulated plants minimizing CFC-11 losses to the environment. The appliances are broken apart and shredded, the secondary raw materials are individually recovered and harmful components or substances are separated for disposal or destruction. Table 2.1 shows the foam recovery and recycling techniques used in selected European countries while Figure 2.4 shows a modern refrigerator recycling plant in operation.

Table: 2.1: Foam recycling/recovery techniques used in five European countries

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Country	Foam recycling/techniques
Denmark	Crushing of R/F in a sealed facility→treatment of exhaust air stream by catalysis →HCl/HF + shredded foam (incineration)
Sweden	Shredding in closed units →collection of air→ treatment of exhaust air stream by condensation→CFCs + shredded foam (incineration)
Germany	Crushing of R/F in a sealed facility→separation of PU foam→pore and matrix degasification→ion condensation of exhaust air→ CFC (purity 99.9%) + shredded foam (incineration +landfill)
Netherlands	Shredding of R/F→ degasification→ (H)CFCs incineration. 100% reuse of degassed foam (powder) as adsorption material – after reuse it goes to a cement kiln for incineration
Ireland	No recovery of CFCs in insulation foam in R/F. Residue (including foam) from iron and steel recovery plants are Landfilled

Source: (Scheutz and Kjeldsen, 2002). NB: R/F = Refrigerator/Freezer.

Figure 2.4: A stage 2 refrigerator processing plant in operation

(Source: SEG, 2007)

Scheutz and Kjeldsen (2002) observes that Denmark, Sweden, Germany, and Netherlands all had regulations that covered handling of insulation foam in

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refrigerators before December 31, 2001. In Ghana however, since there are no laws that mandates the treatment of refrigerators using prescribed technologies, there is no injunction on the stakeholders to invest the capital necessary to purchase BATs for the treatment. In addition, the high cost of treatment methods and lack of regulatory priority for blowing agent recovery have deterred scrap metal handlers from installing them. The available literature revealed that, refrigerator disposal practices in Ghana are not different from the methods used for the disposal of e-waste in general as described earlier.

2.4 Refrigerator Replacement Programs

From the consumers' viewpoint, replacement decisions depend on the tradeoffs between higher equipment costs for more efficient refrigerators and lower annual energy costs. Consequently, incentives or subsidies are commonly used to facilitate refrigerator replacement programs. For example, in 1993, the Sacramento Municipal Utility District in the U.S.A. offered a $100 compensation for replacing old refrigerators with new models (Bos, 1993). Studies by Kim, Keoleian and Horie (2006) and Pratt and Miller (1998) indicate that U.S. states including New York, Indiana, Wisconsin, and Iowa have been offering refrigerator replacement programs for low income households. Utility companies have also supported refrigerator replacement programs as a demand side management strategy. Kim et al, (2006) in particular noted that these programs are producing positive outcomes achieving 50–70% electricity use reductions and more than $50 per year of electricity cost savings. In a study, Geller et al (2006) suggests that governments should provide funds that are used to develop and commercialise new technologies, educate consumers on appliance efficiency standards and provide incentives to encourage consumers to purchase products that are significantly more efficient than the minimum standards.

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Can et al (2011) identify three basic categories of policy tools that can be used to increase energy efficiency in private households:

1) Regulatory tools, such as limit values or minimum requirements for new appliances
2) Informational tools (such as labels, information campaigns), and
3) Financial incentives (direct subsidies, subsidized loans, indirect subsidies).

In their study, Rüdenauer and Fischer (2011) also identify four criteria that are necessary for stimulating early replacement in take-back schemes. They are as follows:

1) The scheme must provide an appropriate financial incentive to consumers; otherwise there will be no reason to dispose of an old but still functioning appliance prematurely.
2) The scheme must be limited in terms of time or budget; otherwise consumers will just await the end of their appliance's technical life assuming that the incentive will still be in place by then. On the other hand, they must be long enough to support market transformation.
3) The return and proper disposal of the old appliance must be part of the scheme, otherwise it may continue to be operated as a spare device or supplied to the second–hand market.
4) The implementation of an effective system for the take–back of old appliances supports early replacement. In many EU countries, as a consequence of the WEEE directive, shops are obliged to accept any discarded appliances that customers bring back, independently of its brand or place of purchase

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Although these criteria were recommended for implementation in the United States, they are, nonetheless, in the opinion of the researcher, suitable for Ghana and can be implemented without modification.

2.5 Types of Replacement Programs

Utility companies operate a number of different types of programs regarding these appliances. According to Calwell and Reeder (2001) the most basic type is an upgrade program, which simply encourages people to purchase more efficient appliances than the standard model at the point of sale. The inducements to upgrade may be in the form of rebates to customers. Upgrades have been the dominant program type for more than a decade (Calwell and Reeder 2001). They ignore the fate of the old appliance being replaced by the customer.

A second program type is a replacement and recycling program. According to Calwell and Reeder (2001), this program type is exactly like the first one; it provides an efficiency incentive when a customer comes to the store to buy a new appliance. But it also provides incentives and convenient pickup for the old refrigerator, provided it is in working condition. Those units are then fully dismantled and recycled at an approved facility. Some replacement and recycling programs will only pay incentives if customers both recycle their old model and purchase an energy–efficient new one. Other programs pay separate incentives for either action by itself (Calwell and Reeder, 2001)

Some replacement programs wait until customers come to the store to buy a new model before marketing the availability of recycling services for the old unit. Other programs actively seek to persuade customers to replace and recycle their inefficient appliances early, before they would normally begin shopping for a new appliance.

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This is often called an early replacement program (Calwell and Reeder, 2001; Rüdenauer and Fischer, 2011) – a slight variant of the standard replacement and recycling program.

A third program type is a retirement program. According to Calwell and Reeder (2001), it primarily targets second refrigerators. It does not seek to replace the old unit with another one, but rather aims simply to permanently pull it out of use and recycle it, saving all of the energy it would have consumed for the number of years of its remaining life. According to Calwell and Reeder (2001), these programs are most amenable to co–funding by e–waste recycling companies, since some second appliances are not operational (and thus not eligible for incentives), yet could be made operational with a simple repair and returned to service. The refrigerator rebate scheme in Ghana is a replacement and recycling program where customers get incentives only if they both surrender their old appliances for recycling and purchase energy-efficient new ones.

2.6 Types of Financial incentives

Financial incentives provided during the implementation of take–back schemes may take various forms. According to Rüdenauer and Fischer (2011), direct subsidy to consumers is one of the most popular financial instruments used. The basic idea is to provide consumers of particularly efficient appliances (who are at the same time disposing of an old appliance) with a financial reward. If the measure is limited in terms of time or budget, early replacement will be stimulated. If it is planned on a long–term basis (i.e. over several years), early replacement is stimulated to a smaller extent, as there is no urge to replace the old appliance unit as quickly as possible.

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In the design of subsidies, Rüdenauer and Fischer (2011) identified a number of conceptual questions that must be answered in order to ensure the success of the program:

1) What is the target group (e.g. restriction to low income households or households with particularly energy–intensive appliances?)
2) What appliance groups are to be promoted? (e.g. refrigerators or air conditioners)
3) What are the criteria for subsidy/requirements to be met by the appliance? (e.g. functional)
4) What is the amount of subsidy (high enough to have visible effects; low enough to avoid free riders; differentiated according to appliance type and efficiency? differentiated for household income?)
5) What is the duration of the measure?
6) Which organization implements the premium payment (e.g. by retailers or national agency?) and take–back of the obsolete appliances?

As a tool designed largely on direct subsidy, the rebate scheme in Ghana answers the various questions asked by Rüdenauer and Fischer, (2011) to ensure success: i.e.

1) Target group? Ghanaian residential consumers only.
2) Appliance groups to be promoted? 2-star to 5-star rated refrigerators with net capacity of 100 to 450 litres
3) Criteria for subsidy/requirements to be met by the appliance? Old but functioning refrigerators
4) Amount of subsidy? GH₵150 – GH₵200, depending on the size and energy efficiency of the refrigerator

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5) Duration? 3 years beginning 19th September, 2012 or till funds run out, whichever comes first (Ghana Energy Commission, 2013).

6) Organization implementing the premium payment and take–back of the old appliances? Retail outlets/participating shops (Ghana Energy Commission, 2013).

However, Rüdenauer and Fischer, (2011) noted that subsidies are often effective, but not always cost effective, as a result of abuse by free riders. To be cost effective, measures should focus on very innovative appliances currently still having high purchase prices, but a good potential for reducing them by economies of scale.

A variant of the consumer subsidy is the “free giveaway”. For example, a popular measure in a number of countries, including Ghana (Agyarko, 2013), has been the distribution of free energy saving light bulbs. The effects are contested, however. First, free giveaways may destroy markets for these appliances. Secondly, free appliances are often not installed by consumers, limiting the effect. As a result some countries such as the UK no longer use this type of program (Rüdenauer and Fischer, 2011). A further variant is to just offer an incentive for disposal of the old appliance, without subsidizing the new one. This can take the form of a bonus for having an old appliance removed.

Can et al (2011) observes that fiscal incentives for consumers can take the form of tax credits or tax deductions. A tax credit reduces the taxes the consumer pays, and a tax deduction lowers the consumer’s taxable income. The percentage of the credit or deduction varies by country and generally has a maximum limit. Rüdenauer and Fischer (2011) and Can et al (2011) further observe that a variant of this is to reduce the sales tax (e.g. VAT) rate and hence the selling price for highly efficient appliances. Whiles Can et al (2011) indicates that this is a very popular form of

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financial incentive implemented by governments across countries, Rüdenauer and Fischer (2011) suggests that this tool is not recommendable for household appliances for a number of reasons namely; the low purchase price of household appliances, high administrative cost of implementation and the nontransparent nature of the subsidy to the consumer.

Can et al (2011) observes that indirect subsidy is an innovative tool developed in Japan and Korea to promote low carbon lifestyle. In this system consumers obtain credit "points" stored on “carbon cashbag” cards instead of money upon the purchase of a highly efficient product. Then, these points can be traded for certain products or services such as public transport, basic utility charges, and purchases of other appliances or tickets to cultural events.

Rüdenauer and Fischer (2011) observes that a variant of indirect subsidy is that consumers can acquire vouchers or bonus points when they buy other products, or as a bonus on their salary, which can then be used to purchase highly efficient appliances. Rüdenauer and Fischer (2011) further observes that the advantage of such indirect subsidies as compared to the disbursement of money is that the type of products or services that the credit points can be used for can be influenced. This can at least reduce direct rebound effects when subsidies or refunds are used to patronise high-carbon goods or services.

According to Rüdenauer and Fischer (2011), bonus/malus programmes aim at adjusting the price of energy-using products according to their efficiency. When buying a highly efficient appliance, an allowance (bonus) is granted to the consumer, while he or she must pay an additional amount (malus) on purchase of a particularly

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inefficient product. When buying an appliance of average energy consumption, neither a bonus nor a malus does accrue (Rüdenauer and Fischer, 2011).

Access to capital through subsidized low-or zero-interest loans eliminates the hurdle of high upfront costs for purchasing an energy-efficient product. The energy savings offset the consumer's cost to repay the loan over time (Can et al, 2011). Loans can be offered by governments, independent agencies, utility companies, or third-party financing institutions like ESCOs (Energy Services Companies) or banks (Rüdenauer and Fischer, 2011).

According to Singh (2011), upstream and midstream incentives can also be used. In this system, producers (upstream) are given financial incentives to produce and sell more highly efficient appliances or to reduce their prices. Such incentives may, for example, take the form of tax credits per unit produced (Nadel and Kushler, 2000) or of a grant if certain criteria are met (Singh, 2011) (for example, reduction of carbon emissions). Such incentives are particularly effective when the market is dominated by a few large producers that are present in all countries (Can et al, 2011). Also, according to Fawcett et al, (2000) sales and distribution agencies (midstream) receive financial incentives to sell particularly efficient appliances. Hence, they will preferentially offer these appliances highlighting them in their sales advertisements. As compared to incentives offered directly to consumers, benefits of upstream or midstream incentives include lower transaction costs, lower incentives and lower total costs for the state (Singh, 2011; Fawcett et al, 2000). On the other hand, Rüdenauer and Fischer (2011) observes that these instruments contribute less to consumer awareness and sensitization. Also, compared to end-user rebates, it is mostly retailers and manufacturers who profit financially. Table 2.2 gives a brief summary of

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examples of appliance replacement programs and types of incentives used in various countries.

Table 2.2: Examples of Appliance Replacement Programs from selected countries

Country	Name of Program	Appliance Covered	Type of Incentive	Success
UK	Refrigerator rebate scheme	A defined range of refrigerating appliances	Rebate (price discount or cash back)	45,000 units sold in excess of target
Malta	Rebate scheme for energy-efficient domestic appliances	Dishwashers, Refrigerators, Freezers, Washing machines, Tumble dryers, Air Conditioning unit	Direct subsidy to consumers	50% - 90%
USA	Electric appliance turn-in program	Refrigerators, freezers, room air conditioners	Cheque or savings bond	240,000 appliances (60% refrigerators, 30% room air conditioners, 10% freezers)
Italy	Tax deduction for highly efficient appliances	Cold appliances, TV, Computers	Tax reduction	Market share increase up to 67.5%
Japan	Eco-point scheme	Air conditioners, refrigerators, TV	"Ecopoints" that could be used for a range goods and services	30% increase in sales.
Poland	Poland efficient lighting project	CFLs, compatible luminaires	Direct subsidy to manufacturers.	1.2 million lamps, 57,000 luminaires subsidised. Retail prices of lamps reduced by \$5.91. Prices of energy saving lamps fell by 34%. Market penetration of energy saving lamps in households increased from 11.5% to 33.2%. GHG savings estimated at 2.79 million tonnes of CO_2 at least

Source: Summarized from Rüdenauer and Fischer, (2011).

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2.7 Legislation Affecting Refrigerators

Refrigerators are regulated under an assortment of international legislations covering various components of their design and content. As electronic gadgets, their disposal is regulated by laws governing waste electric and electronic equipment (WEEE) such as the Basel Convention. Due to the ozone depletion and global warming potentials of the refrigerants and blowing agents, they are also controlled by the Vienna and Climate Change Conventions as well as the Montreal and Kyoto Protocols. As a result of their transboundary inflow into Africa, they equally come under the Bamako Convention as shown in Table 2.3 (UNEP, 2012; Kessel, 2000; Knopp et al, 2001; UNEP, 2000; UNEP, 1999).

As a way of enforcing the international treaties, local laws needed to be put in place to implement the provisions and meet the various targets enshrined in each treaty. Currently, Ghana has no specific legislation providing best management practices or policies towards the management of end-of-life refrigerators. However, there are a number of laws and regulations that have some relevance to the control and management of hazardous waste that may be contained in these refrigerators but they do not address the dangers posed to humans and the environment. An example is the Environmental Protection Agency Act, 1994 (Act 490). Although this Act does not make specific reference to e-waste, it provides a framework for the management of hazardous substances that may be contained in these equipment.

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Table 2.3: International Environmental Laws affecting Refrigerators

IEL	Year of entry into force in Ghana	Main provisions	Implementing agency in Ghana
Vienna Convention for the Protection of the Ozone Layer.	1989	Parties shall take measures to protect human health and the environment against adverse effects from human activities which modify the Ozone layer.	EPA
Montreal Protocol on Substances that Deplete the Ozone Layer.	1992	Parties shall protect the ozone layer by taking precautionary measures to control total global emissions of substances that deplete it, with the ultimate objective of their elimination.	EPA, UNDP
Basel Convention on the Control of Transboundary Movements of Hazardous waste and their Disposal.	2005	Parties shall protect human health and the environment against the adverse effects resulting from the generation, management, transboundary movements and disposal of hazardous and other wastes.	EPA, CEPS
Bamako Convention on the ban of the Import into Africa and the Control of Transboundary Movement and Management of Hazardous Waste within Africa.	2005	All Parties shall take appropriate legal, administrative and other measures within the area under their jurisdiction to prohibit the import of all hazardous wastes into Africa from non-Contracting Parties.	EPA, CEPS
UNFCCC	1995	Each party shall adopt national policies and take corresponding measures on the mitigation of climate change, by limiting its anthropogenic emissions of greenhouse gases.	EPA
Kyoto Protocol to the UNFCCC	2005	Industrialized countries shall take national measures to reduce GHG emissions.	EPA

Source: Knop et al, 2001

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The absence of specific primary legislation dealing with EOL refrigerators does not however, imply that Ghana has not implemented regulations or other measures addressing hazardous substances or wastes, or their management and disposal. The literature review has shown that there are different laws that address the issue from different perspectives (Table 2.4), thereby creating a plethora of measures that may be duplicative or contradictory or leaving gaps which make coordinated implementation difficult. As observed by Schluep et al (2011), a further difficulty is the fact that these laws are expected to be enforced by different government departments and agencies or levels of government (Table 2.4), so there is no uniform approach to dealing with these chemicals. Each of these institutions operates on its own law even though the subject matter is the same – hazardous chemicals (Government of Ghana, 2010).

An example of a specific regulation with relevance to e-waste is the Energy Efficiency Regulations, 2008 (LI 1932) which among other things prohibits the importation, distribution, or sale, of used refrigerators, used refrigerator-freezers, used freezers and used air-conditioners. In order to achieve the full benefits of LI 1932, the Energy Efficiency Standards and Labeling Regulations, 2009 (LI 1958) was passed with the objective of enforcing minimum energy efficiency standards for household refrigerating appliances through the use of energy efficiency labels. The number of shops, dotted around the country, dealing in used refrigerators and air conditioners without energy efficiency labels is a testimony that enforcement of these regulations still remains a challenge.

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Table 2.4: Local laws affecting refrigerators in Ghana

Act/LI	Year of entry into force	Main/Relevant provision	Implementing agency	Remark/weakness
Environmental Protection Agency Act, 1994 (Act 490)	1994	Proposes the establishment of a hazardous chemicals committee to monitor the importation, exportation, manufacture, distribution, sale, use, and disposal of hazardous chemicals.	EPA, CEPS	No specific reference to e-waste
Energy Efficiency Regulations, 2008 (LI 1932)	2008	Prohibits the importation, distribution, or sale, of used refrigerators, used refrigerator-freezers, used freezers and used air-conditioners.	Energy Commission, CEPS	No reference to management of EOL refrigerators
Energy Efficiency Standards and Labelling (Household Refrigerating Appliances) Regulations, 2009 (LI 1958)	2009	Prohibits the importation, storage, sale, distribution and disposal of refrigerators unless the refrigerator bears an energy efficiency label.	Energy commission, Ghana Standards Authority, CEPS	Silent on environmentally-friendly recovery of ODS from refrigerator cabinets
Management of ozone depleting substances and products regulations, 2005 (LI 1812)	2005	Prohibits the manufacture or importation of ozone depleting substances or products designed to use them.	EPA, CEPS	Implementation is on course

Source: Pwamang, 2014

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According to ICF (2008), environmental policies can be implemented using mandatory/regulatory approach or voluntary approach. A mandatory approach utilizes legal requirements (such as laws) for prescribing policies, whereas voluntary approaches can consist of a wide variety of arrangements from co-operation between industry organizations or agreements reached between industry and government authorities. There are debates, however, over which approach is more satisfactory. Industry officials are of the opinion that voluntary initiatives are most cost effective as they achieve environmental goals far cheaper than regulations would (ICF, 2008). Sheehan and Spiegelman (2005) agree that regulations tend to create monopolistic enterprises, which suppress market competition. On the other hand, Gibson and Jynes in Quinn (2003) argue that voluntary programs lack the credibility of regulations, do not have clear objectives and goals, and fail to achieve stated targets. In addition, Toffel (2002) states that voluntary initiatives, more often than not, prove to be less effective than regulatory standards. The refrigerator rebate scheme in Ghana, as it currently stands, can best be described as a voluntary scheme because its implementation is not backed by any law and both the implementing authorities as well as residents are not bound by any regulation either to do or not to do anything.

2.8 Rationale and Objectives Refrigerator Rebate Scheme in Ghana

As stated above, the refrigerator rebate scheme is a voluntary approach to refrigerator management. As already stated, it was started as a pilot refrigerator rebate and exchange scheme in Accra and its environs on 19th September, 2012 by the Energy Commission. The main objective is to promote appliance energy efficiency and to transform the refrigerating appliances market in Ghana (Ghana Energy Commission, 2013). Studies have shown that there are about 2,000,000 old refrigerators in the country which are not energy efficient (CSIR-Institute of Industrial Research, 2008).

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The target for this project is to replace 50,000 of such old fridges with more energy efficient ones in order to save an estimated 35 million units of electricity for consumers (Ghana Energy Commission, 2013). The project also aims at recovering chlorofluorocarbons which are deleterious to the ozone layer from the old fridges.

The management of the program is a partnership between the Energy Commission and the EPA, with their interests equally divided between energy conservation and environmental protection. The project is also expected to pave the way and show the proper methods for recycling refrigerators. To that extent, City Waste Management Company imported specialized equipment for recovering the banned CFC refrigerants which are still running in refrigerators in most homes across the country.

2 .9 Institutions involved in the refrigerator rebate scheme

Figure 2.5 illustrates the hierarchical structure of the various institutions that play major roles in the implementation of the rebate scheme.

Figure 2.5: Institutional hierarchy governing the rebate scheme.

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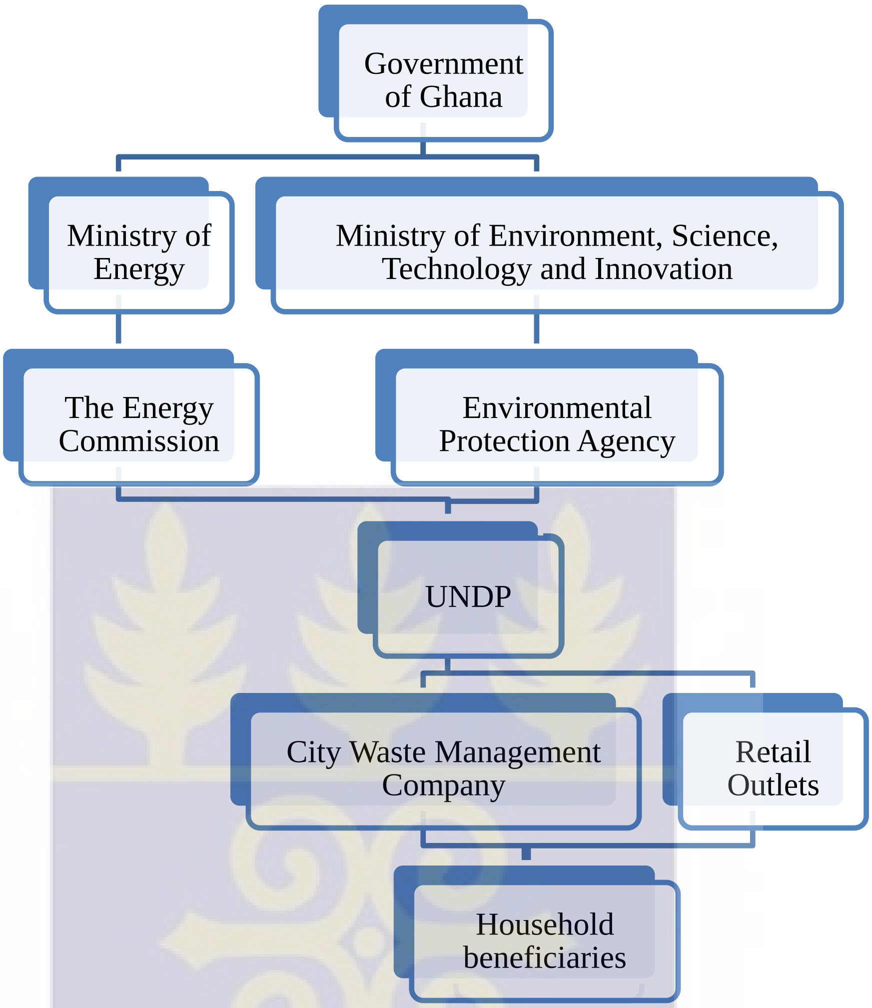

Source: Energy Commission, 2013

The EPA was established by the Environmental Protection Agency Act, 1994 (EPA, 2002). Its functions, among others, as outlined by Act 490 is to prescribe standards and guidelines relating to the pollution of air, water, land and any other forms of environmental pollution including the discharge of waste and the control of toxic substances. To this extent, the EPA exercises regulatory authority over the activities of individuals and companies such as the scrap dealers and the City Waste Management Company to ensure that they, by their actions, do not release substances that are hazardous or potentially dangerous to the quality of the environment. They also have a National Ozone Unit which monitors the quantities of CFCs collected from the EOL refrigerators (Pwamang, 2014).

The Energy Commission was established by the Energy Commission Act, 1997 to regulate and manage the utilization of energy resources in Ghana and to co-ordinate policies in relation to them (Ministry of Energy and Petroleum, 2013). It is also the

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energy policy advisor to the Minister for energy and to the extent that it is the institution that rolled out the refrigerator rebate scheme, their input cannot be ignored in this study

The City Waste Management Company Limited in Kwabenya, Accra has the capacity to recycle end of life refrigerators and air conditioners (Energy Commission, 2013). The facility has the capacity to recycle about 100 refrigerator units per day (Energy Commission, 2013) and is the only refrigerator recycling plant operational under the scheme.

2.10 The Refrigerator Rebate Scheme in Ghana: Processes and Procedures

Some refrigerator take–back programs mainly try to capture old refrigerators for recycling at the time a new model is purchased and delivered. Other programs exclusively target second refrigerators, with no program element to simultaneously encourage the purchase of an efficient new model (Calwell and Reeder, 2001). Only a small fraction of programs surveyed create an explicit link between the purchase of a new energy star model and the recycling of an operational older one. The refrigerator rebate scheme in Ghana is an example of a replacement and recycling program in which customers receive incentives only if both conditions are met, greatly increasing the likelihood of cost effectiveness. Per the policy tools prescribed by Can et al (2011), Ghana's scheme is implementing energy labels, information campaigns and financial incentives to execute the program (Energy Commission, 2013). All the four criteria identified by Rüdenauer and Fischer (2011) for successful early replacement programs as discussed earlier have been put in place.

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Firstly, appropriate financial incentive in the form of discount between GH₵150 and GH₵200 (direct subsidy), depending on the size and energy efficiency of the refrigerator, is given to any customer who turns in an old appliance to purchase a more energy efficient one. Consumers can also obtain subsidized/ low – interest loans from Ecobank Ghana Limited to purchase energy efficient appliances (Ghana Energy commission, 2013; Bonney, 2013). Secondly, limitation in terms of time or budget has been set. The Government of Ghana is providing GH¢1million per year for the next three years on first come first served basis till the funds run out (Ghana Energy commission, 2013). Thirdly return and proper disposal of the old appliance is ensured. The old appliances are collected by various participating outlets (ROWI, Electromart, Melcom, Appliance Masters and Cool World electrical retail stores) and sent to the City Waste Management degassing facility for proper disposal (Ghana Energy Commission, 2013; "City Waste Unveils Plant", 2013). Lastly, an effective system for the take–back of old appliances is in place such that participating shops accept any old but functional appliance that customers bring, irrespective of its brand or place of purchase.

2.11 Conclusion

This chapter has examined the literature related to proper management of waste with special reference to waste electrical and electronic equipment (WEEE). The primary focus was the examination of the current disposal practice of used refrigerators and how the practice impacts on the environment. The chapter also brought to the fore global and local regulatory frameworks governing the management of WEEE and the

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embedded potentials and challenges. The Ghanaian policy intervention – the refrigerator rebate scheme was also discussed and its potential as a substitute to the current informal practices was assessed. The next chapter takes a critical look at the methodology employed in the study.

CHAPTER THREE

MATERIALS AND METHODS

3.0 Introduction

This chapter presents the general approach and specific techniques adopted in addressing the objectives for the research. It begins with a discussion of the geographical setting followed by the research design pointing out the rationale for

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combining both the quantitative and qualitative methods in a single study. The chapter details out the various methodologies used in the selection of the research participants and for data collection. The chapter concludes with a look at how data was analyzed and some of the problems associated with the methodology adopted for the study.

3.1 The Study Area

The study was carried out in Accra and Tema where the Energy Commission piloted the rebate scheme. This provided enough justification for their selection for the study in a bid to ascertain the viability of the scheme and its eventual sustainability.

Accra is the national capital of Ghana and the largest urban centre in the country in terms of population, economy and GDP, and therefore has pre-eminence over all other cities in the country (Sonsore, 2003; Owusu and Oteng-Ababio, 2014). It is located on the south-east coastal plains of the country. The development of infrastructure and services and the creation of job opportunities made Accra an attractive location and induced an influx of population from all parts of the country and beyond. Since becoming the capital city, Accra has grown rapidly to engulf many surrounding rural settlements which now nest within the city as 'urban villages' (Songsore, 2003). The high concentration of population in the national capital has propelled the spillover of its population into surrounding districts and the rapid conversion of settlements in Accra's urban field into a concentration known as the Greater Accra Metropolitan Area (Owusu and Oteng-Ababio, 2014). The concentration of population, commercial and industrial activities in the Accra metropolis coupled with the lack of clear boundaries for what constitutes Accra places mounting pressure on the limited infrastructure and services including housing, transport, water supply, sanitation and waste disposal (Sonsore, 2003).

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According to the Ghana Statistical Service (2012), Metropolitan Accra accounts for about 25 percent of the country's urban population and contributes approximately 20 percent of the Gross Domestic Product (GDP). It also employs about 10 percent of the national workforce and one-third of the national urban workforce (GSS, 2013). The Accra Metropolis houses the majority of Ghana's industries and is the headquarters of most financial institutions, government ministries, NGOs and multinational corporations in the country.

Tema, which serves as the administrative capital of the Tema Metropolitan Assembly is a coastal city situated 25 kilometres east of Accra, the national capital. Until 1952, when the Government of Ghana decided to develop a deep seaport there, Tema was a small fishing village. Tema became an Autonomous Council in 1974 and was elevated to the status of a Metropolitan Assembly in December, 1990. It is the industrial city of Ghana and the biggest sea port in Ghana (Amoyaw-Osei et al, 2011) which serves the interests of neighbouring landlocked countries such as Mali, Niger and Burkina Faso. The Metropolis shares boundaries with the Ashaiman, Adentan, and Ledzokuku Krowor Municipalities to the west, Kpone Katamanso District to the east, Dangme West District to the North, and the Gulf of Guinea to the south.

Figure 3.1: A map of Accra and Tema showing the selected communities in the study area

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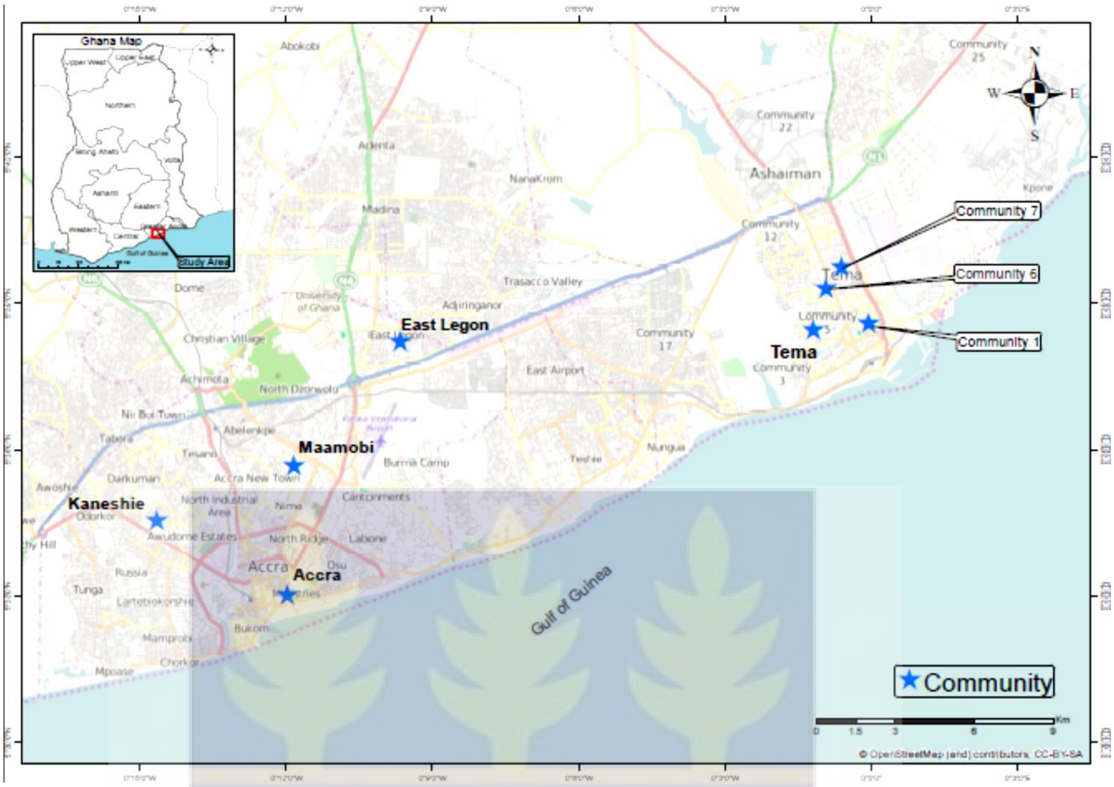

Source: Field work

3.2 Objectives-Methods Link

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Table 3.1 presents the objectives of the study and how these were fulfilled during the field work.

Table 3.1: Objective-Methods Link

Objective	Method
To examine current management approaches to used refrigerator disposal in Ghana	Site tours to observe at first-hand the operations of the City Waste Management Company, scrap dealers, second-hand fridge dealers and fridge technicians/refurbishers.
To identify the institutional and regulatory frameworks for managing used refrigerators.	Stakeholder interviews conducted with officials of the City Waste Management Company, Energy Commission, retail outlets and the EPA.
To evaluate the viability and sustainability of the take-back scheme.	A GC-MS laboratory analysis conducted on foam samples to measure the amount of CFC-11 and secondary data collected from the ODS laboratory for the amount of CFC-12.
To make recommendations for policy consideration towards a more sustainable used electronics management system in Ghana.	Stakeholder interviews conducted with officials of the City Waste Management Company, Energy Commission, EPA, retail outlets and the ODS consultant.

Source: Field work

3.3 Research Study Method

A triangulation of quantitative and qualitative research design was employed. According to Denzin (1989), Robson (1993), Bryman (2001), Preece (1998), Creswell (2003) and Bryman (2004), combining the quantitative and qualitative approaches provides an opportunity for one approach to complement another in a single study of social phenomena. They further advised that it is generally a good idea for social scientists to use more than one method of enquiry to improve the chances of getting better, more reliable data and to minimise the chances of biased findings. The

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combination of qualitative and quantitative methods also allowed for the data gathered by different methods to be crosschecked, thereby making the results of the study valid and credible (Bryman, 2004). Contrary to the above scholars, Guba and Lincoln (1985), Hughes (1999), Blaikie (2000), and Grix (2004), suggest that quantitative and qualitative methods are grounded in two incompatible epistemological principles. Therefore combining the two approaches is inappropriate. The criticisms notwithstanding, the mixed methods strategy of social investigation is fast becoming popular among researchers (Bryman, 2004).

The varied nature of the data required and the different sources from which they had to be gathered made the use of mixed methods approach appropriate. Consequent to this methodological approach, research tools associated with both quantitative and qualitative approaches were utilized in collecting the data. These were interviews, questionnaires, field observation and laboratory as well as documentary analyses.

3.4 The research population and sample

The residents of Accra and Tema are directly or indirectly involved in the usage of refrigerators and since the environmental effects arising from the improper disposal of these refrigerators affects all residents; the entire populations of the two communities are regarded as the study population for this research. In the 2010 Housing and Population Census, Accra recorded a total population of 1,848,614 (GSS as cited in Owusu and Oteng-Ababio, 2014) while Tema had a total of 402,637 (Owusu as cited in Owusu and Oteng-Ababio, 2014). For the purpose of the fieldwork, however, key stakeholders in the fields of refrigeration, waste recycling, energy, and environmental protection were selected for the study. Some of these stakeholders are refrigerator recycling companies, public institutions whose functions relate with the refrigerator

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rebate scheme, private professionals in the refrigeration industry, private businesses, and members of the general public as shown in Table 3.2.

Table 3.2: Key stakeholders in the study

Category of stakeholders	Actual participants selected for study
Refrigerator recycling companies	City Waste Management Company Ltd
Public institutions	Energy Commission, EPA
Private professionals	Refrigerator technicians, Refrigerant dealers, Second-hand refrigerator dealers Scrap dealers
Private business	Participating retail shops
General public.	Consumers/beneficiaries of the rebate scheme

Source: Field work

3.5 Selection of respondents for the study

After identifying the stakeholder groups among the study populations in the two study areas, the next task was to select those who would actually participate in the interview sessions and questionnaire survey as shown in Table 3.3.

Table 3.3: selected respondents

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Category of participants	Key personnel/ **No. of respondents**	**Key Information sought**
City Waste Management Company Limited	Managing Director/ **1**	To understand their refrigerator disposal methods and hence assess its environmental friendliness against international best practices.
Energy Commission	UNDP/GEF project coordinator, refrigerator energy efficiency project/**1**	The challenges, successes and aspirations of the rebate scheme.
Environmental Protection Agency	Head, National Ozone Unit/**1**	How they regulate the activities of the CWMCL and the quantity of CFCs collected so far under the scheme.
Refrigerator Technicians/Refurbishers	**5**	How their activities help to reduce CFC emissions or otherwise.
Refrigerant dealers	**5**	Availability and affordability of ozone-friendly refrigerants on the market as compared to CFCs and HCFCs; as well as their awareness of the ban on CFCs.
Scrap dealers	**10**	To understand their refrigerator disposal methods and hence assess its environmental friendliness against international best practices.
Retail outlets for the rebate scheme	Branch operations managers/**4**	Challenges, successes and aspirations, as partners in the implementation, of the take back scheme.
Consumers	**160**	Their knowledge of the presence of the rebate scheme and what it seeks to achieve, their willingness to subscribe to it, their challenges in trying to assess it and their suggestions for improvement.
Second-hand dealers	**5**	Whether second-hand fridges on sale contain CFCs.
ODS consultant for the scheme	**1**	Recommendations for improvement
Total	**193**	

Source: Field work

3.6 Data sources.

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The sources of data for the study incorporated both primary and secondary. The primary sources consist of results of the laboratory analysis and physical measurements carried out on the various samples. It also comprised data collected through interviews, questionnaires, schedules and field observations conducted at various sites as indicated earlier in addition to information collected from officials of the EPA and the Energy Commission. The secondary sources also comprised of the content analysis of literature gathered from various journals, publications and the relevant institutions.

3.7.0 Sampling Techniques

The techniques or the procedures the researcher adopted in selecting items for the sample include purposive sampling, snowball sampling, simple random sampling, and multi-stage sampling.

3.7.1 Purposive Sampling

In this type of sampling, items for the sample were selected deliberately by the researcher. The selection of appliances for testing was done purposively in order to ensure that only appliances containing CFC-11&12 were tested. It was also meant to achieve an appropriate distribution of appliance sizes. The participating retail shops (Cool world, Rowi, Somovision and Melcom) were also sampled by this method since they are the designated shops taking part in the rebate scheme. The Agbogbloshie scrap yard was also purposively sampled since it is the major hotspot of e-waste activity in Accra where the various disposal practices are representative of all other scrap yards. Other institutions such as the EPA, the Energy Commission and the City

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Waste Management Company Limited were purposively sampled since they are the only institutions of their kind in the country.

3.7.2. Snowball Sampling

This type of sampling is used when a group of people recommends potential participants for a study, or directly recruits them for the study. Those participants then recommend additional participants, and so on. This technique was used to sample the dealers in the refrigerant gases since their locations were not very easy to identify by individuals who did not have any trade relations with their activities. Thus, after each interview, the researcher asks from the previous respondent the location of the next respondent and so on.

3.7.3 Simple Random Sampling

Random sampling is the best technique of selecting a representative sample because it ensures that, the sample has the same composition and characteristics as the universe (Kothari, 2004). Since the participating retail shops have several branches in both Accra and Tema, the specific branches to be visited were decided through a simple random sampling technique. Cool world Accra branch, Rowi Adenta barrier, Somovision Tema Community 2 and Melcom Adabraka branches were selected. Using the register of refrigerator technicians in Accra and Tema obtained from their association (NARWOA), a simple random sample was conducted to select five technicians to be interviewed. Those who were selected were called on phone to book an appointment for the interview. Those who declined or could not be reached were immediately replaced.

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3.7.4 Multi-Stage Sampling Technique

The unplanned nature of many parts of the cities and the lack of household sample frames precluded the random selection of households. A multi-stage sampling technique was therefore utilized, the first stage of which involved selecting communities from three classes of residential areas, namely high, middle and low income areas, which classification was obtained from the Town and Country Planning Department. From the list obtained in each city a simple random sample was conducted to draw communities from each residential class (Table 3.4) in which households were selected by using a rough even distribution and those who gave their consent were interviewed. The number of questionnaires administered in each community was guided by information from the Town and Country Planning Department showing that the population of residents in low income, middle income and high income areas in most cities including Accra and Tema is roughly in the ratio 70% : 25% : 5%. The distribution of respondents in the various selected communities is shown in Table 3.5.

Table 3.4: Residential communities selected for the household survey

Residential status	**Study areas**	
	Accra	**Tema**
High income area	East Legon	Community 6
Middle income area	Kaneshie	Community 7
Low income area	Maamobi	Community 1

Source: Field work

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Table 3.5: Distribution of respondents in the selected communities

Residential Area	Number of Respondents		
	Accra	**Tema**	**Total**
Low income areas	70	40	110
Middle income areas	25	15	40
High income areas	5	5	10
Total	100	60	160

Source: Field work

3.8 Methods of data collection

Some of the data required were qualitative in nature and were best obtained through interviews while others were quantitative and thus, were elicited by means of questionnaires. Furthermore, aspects of the data were physically observable and were therefore gathered through direct field inspection or observation. There was also a range of published information including newspaper articles and other publications that yielded useful data for the study. The study, therefore, employed interviews, semi-structured questionnaires, field observation and documentary analysis, drawing upon the strengths of these different methods to improve the quality and validity of the data. Questionnaires, interview guides, voice recorders, a camera, gas chromatograph, mass spectrometer, electronic weighing scale and a refrigerant identifier were used in gathering data for the study.

3.9.1 Interviews

The interview technique was employed to obtain data from a number of stakeholder groups in the study namely; the refrigerator technicians, the refrigerant dealers, the scrap dealers and the consumers. According to Robson (1993) most people are more

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willing to talk in an interview than the case would be if they were asked to write or fill out a questionnaire. The main advantage of the choice of interview for these categories of respondents over questionnaires was the fact that it created the opportunity for the interviewees to ask for clarification when they did not understand a question since most of them may not have attained higher level formal education. Furthermore, the interviewer was able to ask for elaborations on answers given by interviewees. Additionally, the presence of the interviewer guaranteed that all questions were answered or, at least, attempted by the interviewee which ensured a high response rate. Moreover, it was possible to check on the reliability of a response by asking the same question differently and at different stages of the interview.

Five refrigerator technicians were interviewed to ascertain whether they follow best practices aimed at minimizing CFC emissions during their operations or otherwise. Their knowledge of the ban on CFCs was also sought and in cases where they were found to be ignorant on the subject the opportunity was used to educate them. Five refrigerant dealers were interviewed. A key interest was to ascertain the availability and affordability of ozone-friendly refrigerants such as HFC-134a and HFC-152a on the Ghanaian market as compared to CFCs and HCFCs as well as their awareness of the ban on CFCs. Ten scrap dealers were interviewed to understand their refrigerator disposal methods and hence assess its environmental friendliness against international best practices. A key interest in the five second hand fridge dealers interviewed was to find out whether second-hand fridges on sale contain CFCs. One hundred and sixty household respondents were interviewed to find out their knowledge of the presence of the rebate scheme and what it seeks to achieve, their willingness to subscribe to it, their challenges in trying to assess it and their suggestions for improvement. The key

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interest in interviewing the ODS consultant on the rebate scheme was to find out how the scheme can be improved upon.

3.9.2 Questionnaires

The appeal of the questionnaire partly stemmed from its cheapness and quickness in terms of administration, the absence of the interviewer effect and its convenience for correspondence. This technique was used to collect data from the City Waste Management Company Limited, the Energy commission and the EPA. The suitability of the method for these categories of respondents was drawn from the fact that they were required to provide information from kept records which needed some time to reference. Additionally, the time the researcher showed up may not be convenient for an interview since these are formal institutions where business takes place.

3.9.3 Field Observation

According to Yin (1994), observations are a form of evidence that do not depend on verbal behaviour and the method enables the investigator to observe the phenomenon under study directly. The visits to the premises and workstations of the various respondents afforded the researcher the opportunity to observe their operations at first hand. The researcher therefore took keen interest in and observed the operations of the City Waste Management Company, the scrap dealers and the technicians and where necessary, took notes and photographs of their operations.

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Figure 3.2: Officials of the EPA inspecting old fridges at the premises of the CWMCL

Source: Field work

Figure 3.3: The mobile degassing plant at the premises of the CWMCL

Source: Field work

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Figure 3.4: Workers of CWMCL cutting a fridge open to extract PUR foam.

Source: Field work

3.9.4 Laboratory Analysis

In order to determine the amount of CFC-11 in the insulation foam of the refrigerators, polyurethane (PU) foam samples were taken from sampled refrigerators and the quantity of CFC-11 analyzed by a GC-MS process. In order to be able to compare data from appliances of comparable sizes (i.e. containing comparable amounts of PU foam and CFC blowing agent) and to establish a conservative basis for data evaluation, only refrigerator-freezer appliances of capacity between 180 to 350 litres were selected for sampling. For the purposes of this project, only units manufactured prior to 1993 were selected for sampling because prior to 1993 the BA used was mostly CFC-11. The serial number code information was used to ensure that the appliances were manufactured prior to 1993.

From each of four appliance manufacturers; General Electric, Whirlpool, Maytag and Frigidaire, samples were taken from two old appliances with rigid polyurethane foam

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blown with CFC-11. The eight refrigerator units were labeled G1, G2, W1, W2, M1, M2, F1 and F2. Since the foam is not homogenous throughout the unit, panels, of dimensions 10 cm x 10 cm were cut off from the top, bottom, rear, left and right sides, using a reciprocating saw, a total of 40 samples, leaving the plastic casing and the metal exterior of the refrigerator unit attached to the foam. Samples were not taken from the door since the presence of shelves and storage boxes makes it non-uniform. The edges of the panels were quickly sealed with aluminum tape immediately after removal from the unit to prevent the release of CFC-11. Taped foams were then labeled and sealed in aluminium foil bags and stored in the refrigerator at 10℃ prior to analysis due to the high volatility of CFCs.

One core foam sample with 10mm diameter from each of the five panels from each refrigerator unit was cut out from the center of the panels with a sharp cork borer after removing the plastic casing and metal exterior attached to the foam. In order to compare results from different experiments, foam samples were measured with an electronic sliding gauge to ensure that they generally had the same shape and size, i.e., a cylinder with a diameter of 10mm and a height of 10mm. The samples were then weighed and placed in 1000 cm^3 glass sample bottles. The bottles were sealed with PTFE-coated silicon septa and aluminium screw caps. All samples were cut in triplicates, so that the total number of bottles containing foam samples from the refrigerator foam panels was 24. The total mass of foam material in each bottle was between approximately 0.55 g and 0.75 g.

After the samples were placed into the bottles, the heating method was applied to enhance the extraction of CFC-11 from foam samples as used by Scheutz et al (2010). An alternative method is solvent extraction, which according to Scheutz and Kjeldsen,

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(2002) is equally efficient. However, the heating method, being simpler and less labour intensive, was chosen to be used exclusively in this study. The 1000 cm^3 glass bottles with PU samples were incubated in an oven for 48hr at 140 ℃. The bottles were subsequently cooled down to room temperature, and then, gas samples were drawn from the headspace and injected into a gas chromatograph (GC) coupled with a mass spectrometer (MS) for analysis.

CFC-11 analyses were performed on Shimadzu QP-2010 Plus EI gas GC-MS by direct on-column injections. The gas samples were injected manually on Carbon Plot column (30 m x 0.32 mm x 1.50 μm; Agilent J&W Scientific Inc.). The injected gas sample volume was 50 μL throughout the experiments. Helium was used as carrier gas with a flow set at 2.15 mL/min, and a sample split of 1:3 was used. CFC-11 was analyzed with an isothermal column temperature of 180 ℃. Calibration curve was constructed by injection of a liquid CFC-11 standard dissolved in cyclohexane for a mass range of 15–40 ng. CFC-11 used for gas standards was obtained in high purity from Fluorochem Ltd. CFC-11 was detected and quantitated based on the compound specific mass/charge (m/z ion) ion (101) and a retention time of approximately 5 min.

An experiment was performed to demonstrate the effectiveness of the heating procedure to drive out the halocarbons. Four separate foam core samples were subjected to four successive heating cycles. After GC analysis between each cycle, the bottle was opened and the headspace flushed with air to remove the halocarbons and the sample reheated for 48 hours at 140 °C.

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To evaluate the quantity of CFC-11 loss during foam sampling, samples were cut out, weighed and placed into the bottles in a sealed glove bag of bulk volume 80 L. A fan was placed into the glove bag to mix the air content, and after each sample cut, an air sample was taken from the glove bag by a gas-tight syringe and directly analyzed for CFC-11 to quantify the CFC-11 loss during cutting.

3.10 Secondary Sources of Data

The analysis of documents is yet another important source of data for social science research. Part of the information for this study was obtained from both the traditional documentary sources such as reports and journal articles as well as from media sources both print and electronic. As part of the data collection process, these sources were critically examined for information relating to the issue of ozone layer depletion and EOL refrigerator management in Ghana and elsewhere. A number of studies are available that had investigated aspects of the problem under study. These were reviewed to draw relevant data for this study. The documentary data thus obtained was used to supplement the information gathered from the interviews, the household questionnaire survey and field observations.

3.11 Data Processing and Analysis

Recordings from interviews were transcribed for analysis. Questionnaire responses were captured using CSPro (Census Processing Software). Before this was done, open-ended responses in the questionnaires were coded for easy data capture and analysis. Images from the camera were edited, printed and added to the report for clarity and emphasis. All Quantitative data including data from the physical and chemical laboratory measurements were entered into the Predictive Analytic Software

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and analysed using chi square and regression analysis statistical tools. Charts were also generated from the data using excel.

3.12 Problems Encountered

While the study has been successful in collecting and analysing data to address the research objectives, it is still limited in a number of ways. These include the limited financial and logistical resources for the data collection exercise. As a result, the household survey was limited to a total of 160 households. A larger sample would have captured the views of more residents to increase the representation of householders in the study. Another situation that reduced the number of householders to include in the study was the lack of sample frames and street maps that would have facilitated the process of selecting householders for the study. This made the process of selecting the participating communities and households cumbersome and time consuming. Even with the help of two field assistants, considerable time was spent in selecting households for the survey.

The interviews were also limited to a few key staff of the institutions that participated in the study. Wider involvement of the staff of these institutions including lower level administrative staff would also have afforded an opportunity to hear from a much larger and representative audience for the fieldwork which, no doubt, would yield richer and more elaborate data for the research.

The language barrier was another factor which may have affected the quality of data gathered for the study. Even though English is the official language in Ghana, some respondents, in both the household questionnaire survey and the semi-structured interviews for informal scrap collectors and fridge technicians, could not express

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themselves well in English. Interviews with such respondents were, therefore, conducted through an interpreter or in some cases in the relevant Ghanaian languages and the responses recorded in English. Without doubting the fluency of the interviewer and the interpreter in the local languages involved, the translation process could possibly lead to a loss of meaning of what the respondents actually said and thus affect the quality of information obtained.

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CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Introduction

This chapter presents the results of the field work. The broader objective is to ascertain whether the rebate system will be acceptable to the Ghanaian populace and consumers. The fieldwork, as already stated, was conducted among consumers who participated in the pilot phase of the implementation of the system. The results presented therefore cover the present state of EOL refrigerator management in Ghana. Attempts were also made to identify gaps in policy, practice and technology in the management of used refrigerators in Ghana. The discussion focuses on current management approaches to end-of-life refrigerator disposal including the accompanying institutional and regulatory frameworks as well as the evaluation of the viability and sustainability of the refrigerator rebate scheme.

4.2 Socio-demographic characteristics of household respondents

As already mentioned in the methodology, a total 160 household respondents were surveyed at the study locations comprising 100 in Accra and 60 in Tema. Table 4.1 shows the socio-demographic traits of the household respondents and covers occupation, employment sector, level of education attained and locality. The rationale was to establish the socio-demographic background of consumers in these parts of Tema and Accra.

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Table 4.1: socio-demographic characteristics of household respondents

	Frequency	Percentage involved
1. Educational level		
Never attended school	8	5.0
Primary	10	6.3
JHS/middle school	18	11.2
Secondary	44	27.5
Post-secondary	44	27.5
Tertiary	36	22.5
2. Occupation		
Professional/technical related	24	15.0
Administrative/executive/managerial	6	3.8
Clerical	22	13.7
Sales	30	18.8
Services	24	15.0
Agric./animal husbandry/fishing	24	15.0
Production related	22	13.7
Unemployed	8	5.0
3. Employment sector		
Public	24	15.0
Private formal	46	28.8
Private informal	56	35.0
Semipublic/parastatal	20	12.5
NGO/international	6	3.7
Other	8	5.0
4. Locality		
Low income area*	110	68.8
Middle income area**	40	25.0
High income area***	10	6.2

*Maamobi, Tema Community 1; **Kaneshie, Tema Community 7; ***East Legon, Tema Comm. 6

Source: Field work

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The educated class dominated the survey with 77.5 percent of all respondents attaining at least secondary school education. This puts them at a better position to assimilate the import of the rebate scheme and probably subscribe to it. They are also the category of people who are more likely to be employed since secondary school education is the least academic qualification required to be employed in the formal sector. Only 5 percent of all respondents are unemployed and are therefore not likely to afford to purchase a new fridge or raise the price difference needed to exchange their old fridges under the rebate scheme.

Over 50% percent of all respondents work in the informal and other sectors where regular monthly income is not assured and getting access to credit facility is difficult. This makes it difficult for them to raise the amount needed to purchase a new fridge or take advantage of the credit facility component of the rebate scheme in order to acquire a more energy-efficient refrigerator. This trend has dire implications for the scheme since there seems to be an over reliance on the public-formal sector in its design and implementation. As already discussed in the methodology, about 70% of the population live in low income communities and therefore lack the wherewithal to take advantage of the rebate scheme notwithstanding all its benefits.

INTEGRI PROCEDAMUS

4.3 Fridge Acquisition and Disposal Characteristics of Household Respondents

Table 4.2 presents the results of the household survey showing the number of fridges in each household, the year of acquisition, how they were acquired and whether they were brand new or second-hand when acquired.

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Table 4.2 Fridge acquisition characteristics of household respondents

	Frequency	Percentage involved
1. No. of fridges present		
1	90	56.3
2	50	31.2
3	12	7.5
None	8	5.0
2. Year of acquisition		
1980-1993	52	32.5
1994-2004	22	13.8
2005 or later	34	21.2
1980-1995 and 1996-2004	28	17.5
1996-2004 and 2005 or later	12	7.5
Not certain	12	7.5
3. Mode of acquisition		
Bought	132	82.5
Given by friend/relative	10	6.3
Bought and given by friend/relative	18	11.2
4. State of fridge acquired		
Brand new	68	42.5
Second-hand	82	51.3
Brand-new and second-hand	10	6.2

Source: Field work

More than one third (38.9%) of all respondents surveyed had more than one fridge at home. This is consistent with the findings of Calwell and Reeder, (2001) which

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indicated that of all the major types of home appliances, refrigerators are the most likely to be found in quantities of two or more per household. This trend has implications for energy consumption of households because as indicated by Kim et al (2005), refrigerators and freezers are one of the most energy consuming home electrical appliances accounting for 14% of household electrical energy consumption. The implications are even grimmer in Ghana because as indicated by the Ghana Energy Commission (2013), refrigeration appliances consume an average of nearly 1200kwh per year which is approximately three times more energy than the maximum allowed in more developed countries.

About one-third (32.5%) of all respondents acquired their fridges before 1993. This implies that they contain CFCs and HFCs since according to Manhart et al (2011), most devices manufactured before 1993 contain refrigerants and foam blowing agents with a high ozone depleting and global warming potential. It goes without saying therefore that if these fridges do not pass through the rebate scheme for proper disposal and recovery of the CFC within, all the CFC will end up in the atmosphere. The age of these refrigerators also has further implications for energy consumption because as indicated by Kim et al (2006), refrigerators manufactured between 1985 and 2002 with foams blown with CFC-11 or HCFC-141b consume 21% more electricity per year after 10 years.

Even though 82.5% of respondents bought their fridges, 6.3% acquired them as gifts from friends and relatives whiles 11.2% of those who have more than one fridge had at least one as a gift. What this means is that instead of recycling their old fridges, some people would rather give them as gifts to friends and relatives. The implications

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are that these fridges remain in use for much longer periods with their consequential issues of energy consumption as discussed earlier.

The household survey also reveals that 51.3 per cent of respondents bought second-hand refrigerators as opposed to 42.5 per cent who bought brand new. This shows that people, for one reason or another, have some preference for used refrigerators over new ones. Two reasons can be adduced for this trend; it is either because the used appliances are cheaper or because they are more available. The latter reason corroborates the findings made by Pwamang (2014) which indicated that used e-equipment imported into the country form 70 per cent as against 30 per cent for brand new ones.

This trend has dismal implications because according to Rüdenauer and Gensch (2007), the typical life-span of cooling and freezing appliances in Europe, where the majority of the second-hand electronics emanate from, is between 14 and 17 years. Therefore, majority of devices that reach end-of-life in Europe are still based on the CFCs (11 and 12) or HFC-134a. In fact, according to Holst as cited in Manhart (2011), only 15% of the cooling and freezing equipment that reached end-of-life in Germany in 2008 were based on hydrocarbons with much lower global warming potential. As Ghana and other West African countries meet their demand for household appliances to a large extent by the import of devices which were diverted from waste collection in European countries, it can be concluded that a large amount of imported second-hand refrigerators contains CFCs or HFCs. As these devices are mostly refurbished and used for several further years, the end-of-life stream of cooling and freezing equipment in Ghana will continue to have very high shares of CFC and HFC appliances in the near future.

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In addition to ozone depleting substances (ODS) and other greenhouse gases, older refrigerators and freezers especially contain other fractions of concern, which include mercury switches and PCB-containing capacitors. The PVC of cable insulations is also of concern when heated or burned because the burning emits harmful gases. Furthermore, the cooling circuits of absorption refrigerators contain ammonia and chrome-VI, so that proper end-of-life management of these devices is very critical. Further implications for energy consumption of old fridges as discussed earlier also come into focus.

4.4 Current Management Approaches to EOL Refrigerator Disposal in Ghana

The management approaches adopted by customers/households, scrap dealers and the City Waste Management Company are presented.

4.4.1 Households

Table 4.3 presents the results of a household survey to establish the refrigerator disposal characteristics of residents in the study area.

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Table 4.3 Fridge disposal characteristics of household respondents

	Frequency	Percentage involved
1. No. of fridges discarded within the last 2 years		
1	56	35.0
2	4	2.5
None	100	62.5
2. Mode of disposal		
Discarded with other waste	2	1.3
Give/sell to scrap collectors	8	5.0
Give/sell to friends/family	16	10.0
Exchanged in the rebate scheme	30	18.7
Reuse	104	65.0

Source: Field work

The results show that most (62.5%) residents do not discard their old refrigerators. Instead, they keep the appliances and re-use (65%) them for other purposes as shown in Figures 4.1 and 4.2. Apart from that, the refrigerators are discarded together with other waste, given or sold to scrap scavengers, and given or sold to friends or relatives.

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Figure 4.1: Reuse of old refrigerators in households

Source: Manhart, 2012

Figure 4.2 Reuse of refrigerator carcasses after removal of metallic parts.

Source: Manhart, 2012

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Closely linked to the disposal characteristics is the method of acquisition. As discussed earlier, individuals rely on friends and relatives for second-hand gifts. Therefore, instead of recycling the old appliances, people would rather give or sell at low costs to friends and relatives. Conversely, rather than purchasing a new appliance people would rather accept cheaper ones from friends, relatives or second-hand dealers. In the household survey, only 18.7 per cent of respondents disposed their appliances using the rebate scheme. This is because they are either not aware of the presence of the scheme, they don't have enough money to pay for the price difference of the new fridges or they simply don't find it necessary.

4.4.1.1 Correlation between Residential area, Educational level and Method of disposal

Regression analysis was conducted to establish a causal relationship between the independent variable which is the locality of respondents (High income area, low income area and middle income area) and the disposal characteristics (discard together with other waste, give or sell to scrap collectors, give or sell to friends/family, exchange under the rebate scheme and reuse) which is the dependent variable. The Analysis revealed that the locality of respondents significantly influence the disposal characteristics as indicated by the global test of significance ($F=21.707$, $P<0.05$). This means the disposal characteristics are jointly determined by the locality of the respondents. However, when an individual test of significance was conducted using the t-test at 95% confidence level (5% level of significance) it revealed that, exchange under the rebate scheme, reuse, give or sell to friends/family and give or sell to scrap collectors were the disposal characteristics significantly influenced by the locality of respondents. The results indicated that respondents from high income areas will either exchange their fridges under the rebate scheme or sell/give it to friends/family as a way of disposing them as indicated by the high correlation

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coefficient of 0.35 and 0.25 respectively. The respondents from middle income areas and low income areas however use the rebate scheme and reuse respectively as disposal methods. This result is confirmed by the cross tabulation result between residential area and method of refrigerator disposal. Discard together with other waste however was not significantly determined by the locality. An Adjusted R^2 of 0.692 means, 69% of the variation in the disposal characteristics is accounted for by the respondents' locality which is statistically a good fit. Table 4.4 illustrates the regression results of the localities and disposal characteristics of respondents whiles Table 4.5 shows the cross tabulation between the residential areas and method of refrigerator disposal.

A regression analysis was done to ascertain whether the educational level of respondents has a significant influence on their disposal characteristics. The regression results revealed that the educational level of respondents significantly determines the disposal method used ($F=6.270$, $P<0.05$). When the t-test was used to conduct an individual test of significance at 95% confidence level, only reuse and exchange under rebate scheme as disposal methods were significantly influenced by the level of education ($P<0.05$). However, discard together with other waste, give or sell to scrap collectors and give or sell to friends/family were not significant ($P>0.05$).

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Table 4.4 Regression results of localities and disposal characteristics of respondents

	Localities											
Disposal method	**High income areas**				**Middle income areas**				**Low income areas**			
	Beta	t-value	p-value	SE	Beta	t-value	p-value	SE	Beta	t-value	p-value	SE
Discard together with other waste	0.00	0.00	1.00	0.36	0.00	0.00	1.00	0.26	0.00	0.00	1.00	0.26
Give or sell to scrap collectors	0.00	0.00	1.00	0.23	0.00	0.00	1.00	0.17	0.00	0.00	0.02*	0.17
Give or sell to friends	0.25	0.00	0.02*	0.21	0.00	0.00	1.00	0.16	0.00	0.00	1.00	0.16
Exchanged under rebate scheme	0.35	2.23	0.03*	0.15	0.78	8.13	0.00**	0.11	0.15	8.13	0.07	0.11
Reuse	0.65	8.15	0.23	0.09	0.15	2.23	0.03*	0.06	0.78	0.03	0.03*	0.06
Adjusted $R^2 = 0.69$ Estimated standard error = 0.24												

*Significant at 0.05 level ** Significant at 0.01

Source: Field work

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Table 4.5 Locality of respondents and mode of fridge disposal cross tabulation

	Mode of disposal										
Locality	Discard with other waste	%	Give/sell to scrap collectors	%	Give/sell to friends/ relatives	%	Rebate scheme	%	Reuse	%	Total
Low income areas	3	2.7	6	5.5	13	11.8	30	27.3	58	52.7	110
Middle income areas	0	0.0	7	17.5	3	7.5	14	35.0	16	40.0	40
High income areas	0	0.0	1	10.0	2	6	6	60.0	1	10.0	10
Total	3		14		18	50	50		75		160

Source: Field work

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Table 4.6 shows the regression results of the relationship between educational level of respondents and disposal methods used. A cross tabulation result shown in Figure 4.3 illustrates the finding that most respondents reuse rather than discard their old refrigerators irrespective of their educational level.

Table 4.6: Regression results of educational level and disposal characteristics of respondents

Model	Unstandardized coefficients		Standardized coefficient	T	p-value
	B	**Std. Error**	**Beta**		
(constant)	3.667	2.848		1.287	
Discard together with other waste	-1.833	1.288	-0.149	-1.423	0.159
Give/sell to scrap collectors	0.250	0.843	0.040	0.296	0.768
Give/sell to friend /family	0.417	0.770	0.91	0.541	0.590
Exchange under the rebate scheme	1.212	0.525	0.346	2.308	0.024
Reuse	0.622	0.299	0.217	2.081	0.041

Source: Field work

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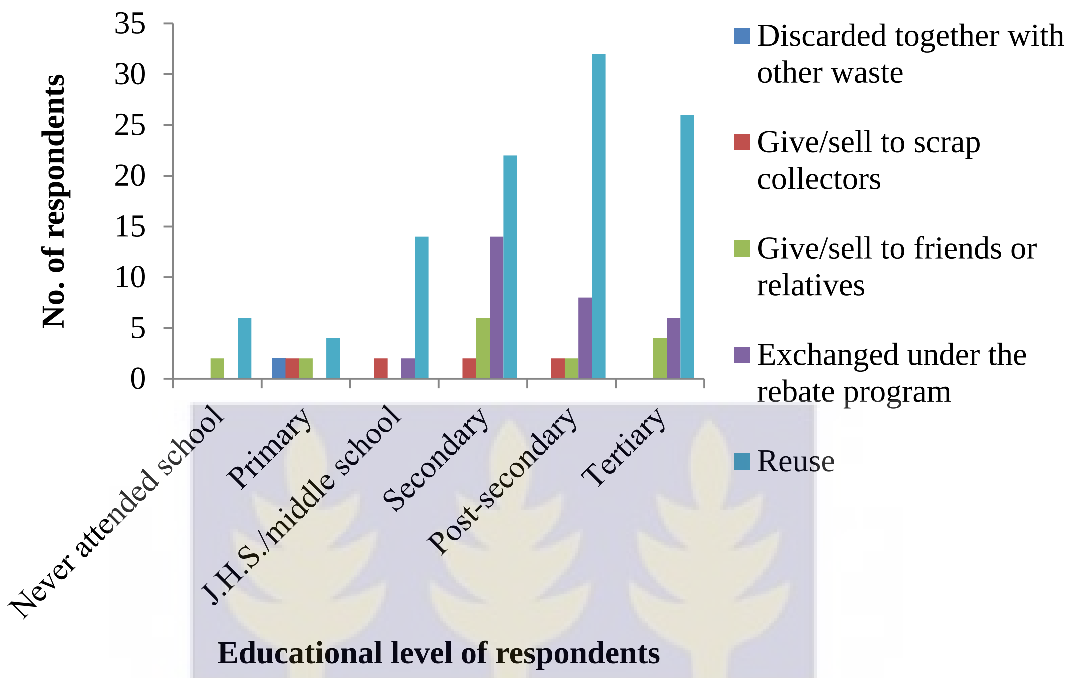
Figure 4.3: A cross tabulation of educational level and disposal method



Source: Field work

The cross tabulation further reveals that even though the educated class are subscribing to the rebate scheme more than the less educated, the correlation is not a direct one. That is, the choice of the rebate scheme as a refrigerator disposal method is not directly proportional to the height of the respondent on the educational ladder.

4.4.2 Scrap Dealers

The process of end-of-life refrigerator management by scrap dealers begins with young men patrolling the streets of Accra scavenging for old appliances. Refrigerators and freezers are mostly collected by informally operating individuals and groups that pick up the obsolete devices from households and shops. Usually, these people pay between GH₵5.0 and GH₵10 for one device depending on the size. The refrigerators and freezers are then transported to the Agbogbloshie metal scrap yard by handcart or some times on foot, where they are manually dismantled. The young metal workers of

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secondary school age or younger, popularly called 'scrap boys', focus only on the recovery of steel, copper and aluminium.

Figure 4.4: Scrap dealers dismantling a refrigerator at Agbogbloshie

Source: Field work

Figure 4.5: Scrap dealers dismantling a fridge at Agbogbloshie

Source: Field work

Other fractions, including CFCs, plastics and foam, do not undergo any particular management. The plastics and the foam are routinely burned as discussed earlier or discarded as shown in Figure 4.6

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Figure 4.6 discarded insulating foam after extraction of metal parts

(Source: Manhart et al, 2011)

4.4.3 City Waste Management Company

Refrigerators that come under the management of the City Waste Management Company are those collected under the rebate scheme. Refrigerators are collected from residents who sent their appliances for exchange under the rebate scheme. The refrigerators are then transported to the recycling plant where the refrigerant is recovered followed by oil separation using a mobile recovery facility in a semi-automated process. This is followed by manual extraction of the compressor and the cooling grid behind the unit. The refrigerator carcass is then dismantled manually to separate the various fractions; plastics, glass, ferrous metals, aluminium, copper and polyurethane foam. The foam is not given any further treatment but stored up in polythene bags indefinitely. The project coordinator for the Energy Commission however mentioned in an interview with the researcher that talks are underway with Zoomlion Ltd, a waste collection and recycling company, to build special incinerators for the destruction of the polyurethane foam together with its CFC content.

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Figure 4.7: Stage one recycling of a refrigerator in progress at the CWML

Source: Field work

4.5 Institutional Frameworks: Responsibilities and Capacities

The list of institutions and other stakeholders in Ghana who are involved in the management of EOL refrigerators have been presented in chapters two and three. The City Waste Management facility has the capacity to recycle about 100 refrigerator units per day but is currently unable to meet that target as a result of the small number of refrigerators collected. According to the UNDP/GEF project coordinator of the refrigerator energy efficiency project, 4,000 fridges have been exchanged so far under the scheme. For the fact that the scheme has been in operation for about 19 months now shows that, on average the plant is only able to recycle not more than 10 refrigerators daily. As a result work is not done on daily basis but as and when there is a substantial number of fridges. A total of 26 young men and women work on degassing and dismantling the refrigerators. Some of the workers were former scrap dismantlers from the Agbogbloshie scrap yard who have been employed. The small

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number of refrigerators being collected has not only reduced the capacity of the degassing plant but also reduced the potential of reducing the unemployment rate in the community since additional workers cannot be employed. Opportunity however exists for technology transfer since the workers are introduced to an advanced and environmentally friendly way of dealing with these old refrigerators as compared to the crude methods they were used to at the scrap yard.

The company goes round the retail shops to collect the refrigerators that have been exchanged under the scheme and brings them to the facility for recycling. When the refrigerators are brought to the facility there are two processes that they are taken through. First they are examined to determine the refrigerant they contain by looking at the label on the compressor. This check is important to avoid cross contamination. However, this check is proving to be unreliable in some cases where the refrigerant might have been changed by technicians during repair. After the examination, the refrigerant is recovered, the oil separated and the gas stored into cylinders awaiting export for destruction.

The second process after the refrigerant recovery is to dismantle the refrigerator carcass and to remove the insulating foam manually (Figure 4.8) and store them in polythene bags (Figure. 4.9) to prevent further release of the blowing agent into the atmosphere.

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Figure 4.8 manual stripping of PU foam. **Figure 4.9 PU foam stored in poly bags**

Source: Field work

The manual dismantling is currently the standard practice since according to the UNDP/GEF project coordinator of the refrigerator energy efficiency project at the Energy Commission and the head of the National Ozone Unit at the EPA, the quantity of foam generated so far is not enough to warrant the setting up of a state of the art treatment plant for recovering the CFC from the foam. However, according to Dehoust and Schuler (2010), manually dismantling the refrigerator to strip the polyurethane insulating foam releases about 100 times more CFC into the atmosphere than treatment in a state of the art recycling plant. The implication therefore is that not until Ghana installs the state of the art technology for destroying the CFC-11 in the foam there will be shortfalls in the contribution towards the mitigation measures put in place to arrest the depletion of the ozone layer and its attendant consequences.

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The Energy Commission is one of two principal implementing stakeholders of the scheme. According to the UNDP/GEF project coordinator of the refrigerator energy efficiency project, the Commission carries out education and public awareness campaigns on various media platforms (TV, radio, newspaper, social media), to sensitise the general public to subscribe to the program. Shop attendants have also been trained to explain the scheme to customers who visit the shops.

The role of the EPA in the implementation of the rebate scheme is that of regulation, education and monitoring to ensure environmental protection. According to the Head of the National Ozone Unit, the Agency ensures that the technology and the methods adopted are environmentally-friendly to avoid the release of ozone depleting substances in these fridges into the atmosphere. In that regard the EPA has inspected the refrigerant recovery plant used by the City Management Company and is satisfied that it meets international standards for stage one recycling of refrigerators.

The EPA has also established an office within the premises of the recycling company manned by the ODS consultant for the scheme who monitors on daily bases to ensure that proper procedure is followed in the recovery of the refrigerant and the insulating foam in order to minimize the release of ODS into the atmosphere. It also has a laboratory within the same office fitted with equipment to identify, weigh, keep records and store the recovered refrigerants in readiness for export and subsequent destruction since Ghana does not have the technology to destroy them. According to the ODS consultant for the EPA and the UNDP, it is cheaper to export the gases for destruction outside the country than to set up the destruction facility here in Ghana.

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Figure 4.10: Recovered CFC-12 in cylinders awaiting export at the EPA ODS lab.

Source: Field work

The EPA assists the Energy Commission in educating the general public on methods of refrigerator disposal, the effects of the continuous depletion of the ozone layer, the inefficiency of the second-hand fridges and hence the benefits of the rebate scheme. So far they have trained about 5,000 technicians on best practices to limit ODS release, according to the head of the National Ozone Unit. They have also trained officials of the Customs Division of the Ghana Revenue Authority on how to analyse new fridges at the ports before entry into the country in order to ensure that only fridges containing ozone-friendly refrigerants are allowed into the country.

The retail outlets participating in the project are Appliance Masters, Electromart, Melcom, Rowi, and Cool world electrical retail stores. Their role is three fold; to collect old appliances (that is, to serve as points of exchange for the rebate scheme), to sell new energy-efficient and ODS-free appliances and educate the general public

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on the scheme. Basically, they receive the old refrigerators that the customer wants to replace and test them to ensure that they are cooling. Then they explain to the customer how the whole system works in terms of calculating the rebate. If the new fridge has two stars the customer enjoys a rebate of GH₵150 and if it is a three or more star-rated fridge he/she enjoys GH₵200. If the customer has enough money he/she goes ahead to choose the new fridge and pays the difference. If a customer did not have enough money to pay for the new fridge he/she has selected, the retail shop can arrange, as part of the scheme, for the customer to obtain a loan from Ecobank so he/she can buy the new fridge.

The shops have also displayed posters to advertise the scheme to their clients. It is also their responsibility to ensure that all the terms and conditions of the scheme are adhered to. Systems are also put in place to verify the true identity and nationality of the clients.

4.6 Regulatory Framework

The various regulations affecting refrigerators in Ghana were presented in chapter two. For all the things that these regulations cover, it appears well and good. However, whiles there are quite a number of very important areas that the laws did not cover; there are weaknesses and limitations in those areas they touched on. None of the above mentioned regulations is a waste management legislation and as such do not effectively define roles and responsibilities for stakeholders. Other issues concerning collection, transportation, storage and recycling are left undetermined.

Best management practices related to management of refrigerators are absent from the regulations. It is difficult for the regulating agencies such as the EPA to provide direction when they themselves have no procedural guidelines to follow by law. Critical practices regarding collection, storage, refrigerant recovery, emissions reduction, and what should be done with the degassed refrigerator carcasses are not provided.

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Failure to highlight the linkages between the controlled products and recycling actually places great strain on the environment since there is no legal prescription for residents and even regulators to adhere to in the disposal of these equipment at the end of their useful lives. The result is a landfill burdened with broken down equipment and heightened activity of scrap dealers using environmentally-deleterious methods of recycling whiles everybody looks on without knowing what to do; regulators and residents alike.

No legislation addresses the recovery of halocarbons routinely released from insulating foams during the recycling process. During an interview with the head of the National Ozone Unit at the EPA, he stated that the recovery and treatment of the polyurethane foam was not considered because of a number of reasons. According to him blowing agent recovery is not a priority since the quantity of foam generated from appliance recycling constitutes a small fraction and the cost of specialized treatment technology is high.

No guidance on the hazardous components, such as refrigerant oils, PCB capacitors and mercury switches, is provided. Recovery of oil is not mandated during decommissioning, despite containing approximately 20% dissolved refrigerant. This is in sharp contrast with The Code of Practice for Refrigeration and Air Conditioning (Department of Environmental and Natural Resources, 2005) which recommends that all equipment have both the refrigerant and oil fully recovered before disposal.

LI 1812 mandates ODS importers, distributors and sellers to keep record of their operations and forward same to the Executive Director of the EPA. However, the

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technicians who actually use the controlled substances are not required by law to keep any record and nobody is mandated by law to inspect same. Record keeping will give the EPA the ability to track refrigerants currently in use and technicians must be able to show where every gram of refrigerant was used. When decommissioning end of life refrigerators, repairing or servicing, the refrigerant in these appliances is not tracked like bulk refrigerants. Record keeping is then left to the "honour system" as any technician could vent the refrigerant into the atmosphere and choose not to keep records, as no one would be aware of their activities.

In the enforcement of LI 1932, the Energy Commission seems to be laying emphasis on the importation aspect of the ban but neglecting the distribution and sale of these same equipment. This one-sided approach will fuel smuggling activities such that once the fridges are able to escape the vigilance of the Customs officials, the distributors and the sellers can have a field day. Probably that is the situation now because the ban has been in force for over a year but some second-hand shops still have supplies.

The same argument can be made for the importation of refrigerants. Interviews conducted with some technicians within Accra and Tema revealed that they still use CFC-12 in their operations whiles the refrigerant dealers deny having stocks. This phenomenon can only be attributed to smuggling. The number of shops, dotted around the country, dealing in refrigerators and air conditioners without energy efficiency labels is a testimony that enforcement of LI 1958 still remains a challenge.

4.7 Viability of the Rebate Scheme

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Like any other project, targets have been set regarding the number of fridges to be collected, quantities of CFCs to be recovered with its corresponding contribution towards the mitigation of ozone depletion and global warming as well as the amount of energy to be saved from the project. The ability of the project to achieve these set targets makes it viable or otherwise.

4.7.1 Quantity of CFC-11 in EOL Refrigerators

The results of the laboratory analysis performed on insulation foam panels of the eight refrigerator units from four different manufacturers (General Electric, Whirlpool, Maytag and Frigidaire) is shown in Table 4.7 as average values of the three measurements from each refrigerator unit.

Table 4.7: Average blowing agent (CFC-11) content in foam from eight refrigerator units produced by four manufacturers

Refrigerator foam panel	Mean (mgCFC-11/g PU)	Standard deviation(mgCFC-11/g PU)	Minimum (mgCFC-11/g PU)	Maximum(mgCFC-11/g PU)
G1	145.33	3.51	136	149
G2	119.33	3.51	116	139
W1	134.00	4.58	124	139
W2	134.00	4.58	130	132
M1	135.33	4.73	116	139
M2	122.67	6.11	113	132
F1	135.33	6.03	129	141
F2	119.33	8.50	113	129

Source: Field work

With regard to the effectiveness of the heating procedure the results showed that at least 99% of CFC-11 was driven out in the first heating step. The results of the analysis carried out to quantify the amount of CFC-11 released during cutting showed that the loss from cutting of foam samples was negligible. As shown in Table 4.6 the heating method released between 113 and 149mg CFC-11/g PU.

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Generally, very little CFC-11 is released from PU foam due to its low diffusion rate depending on the product and foam manufacturer. Scheutz et al (2010) reports that virtually no BA is released during the life of the refrigerator. On the contrary, (Ashford et al, 2004) opines that during the lifetime of a refrigerator, CFC-11 might be released from the foam through three phases: first year phase (including foam manufacture and installation); use phase (typically 15– 50 years) and disposal (end of life). It has been reported that first year release from a refrigerator unit is 4 per cent, while the annual release rate in the following years is 0.5 per cent (Johnson, 2004) or 0.25 per cent (Mcculloch et al, 2001). According to BRE as cited by Yazici et al (2013) the original quantity of CFC-11 in the PU foam of a newly manufactured refrigerator varied between 70 and 154 mg/g PU. Given that the refrigerators analyzed in this study initially contained CFC-11 within the given range, and CFC-11 loss rate was similar to the rates reported by McCulloch et al. (2001), then the remaining CFC-11 in 2013 can be calculated to be 64–140 mg CFC-11/g PU.

This range is slightly lower than the range determined in this study (113 and 149 mg CFC-11/g PU). Scheutz et al (2010) on the other hand, reported the CFC-11 content of a pre-1993 manufactured refrigerator at its disposal phase as 116–182 mg CFC-11/g PU, which is consistent with the results of this study. The minor differences result most likely from the varying quantities of CFC-11 used by different manufacturers (Scheutz et al, 2007; Dehoust and Schuler, 2010).

According to (Agyarko, 2013), there are about 2.7 million old refrigerators in Ghanaian households. Given that a refrigerator contains 4,400 g PU foam on average (Dehoust and Schuler, 2010) one refrigerator would contain 497–656 g CFC-11 at the time of its disposal. As a result, 1,342–1,771 metric tons of CFC-11 (1,341,900–1,771,200 kg) are expected to be banked in 2.7 million old refrigerators that are still in

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use in Ghana. This quantity of CFC-11 will exert an ozone depleting potential (ODP) of 1,342–1,771 metric tons, considering that CFC-11 has an ODP of 1.0. Likewise, its contribution to global warming will be in the range of 6.4–8.4 million metric tons of CO_2 equivalent taking into account that the global warming potential (GWP) of CFC-11 is 4,750.

4.7.2 Quantity of ODS recovered under the rebate scheme

According to Pwamang (2013) and "City Waste Unveils Plant" (2014), 4,000 fridges have been turned-in, scraped, and the refrigerant recovered and stored under the scheme so far. Data collected from the ODS laboratory of the EPA shows that 133.330 kg of CFC-12 have been collected so far awaiting destruction. Considering that the ODP of CFC-12 is 1.0, the amount collected so far accounts for 130 kg of ozone depleting potential. Likewise, its global warming potential amounts to 1,413,300 kg of CO_2 equivalent since the GWP of CFC-12 is 10,600.

As discussed earlier, CFC-11 is not recovered from the polyurethane insulating foam from the refrigerators collected under the scheme; otherwise, as calculated earlier the removal of 4,000 refrigerators from the system would have amounted to the recovery of 1,988–2624 kg CFC-11.

The contribution made so far towards the mitigation of ozone depletion and global warming as evident in the values discussed above is just a drop in the ocean. Given that the scheme is set to last for three years with a target of 50,000 refrigerators it is expected that within the 15 to 18 months that it has been operating now it should have met at least have of the target. Contrary to expectation, the 4,000 fridges collected and the corresponding amounts of CFC recovered is nowhere near the expected target of

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the project. If this trend continues for the other half of the lifespan of the scheme then viability is a distant dream.

4.7.3 Challenges of the Rebate Scheme

The recycling facility has problems with non-reliable electricity supply which is a national problem. This increases their cost of operation if they had to use fuel generators. The recycling facility is also challenged with space. They operate from a small rented premises and are threatened with eviction. Another challenge the company is facing is getting a market for some of the ferrous metals which could not be used by the steel manufacturing companies in Tema. The ban on the export of ferrous metals is also a big challenge because the company is facing problems trying to sell the metals, since the metals from the fridges are not of high quality. There are issues of refrigerant identification prior to recovery because in some cases the refrigerant has been changed by some technicians who had worked on the appliance earlier. So relying on the label on the compressor at the back can be deceptive and create problems of cross contamination.

Financial challenges seem to be having a toll on the scheme even in its early stages as the Energy Commission is considering a downward adjustment of the initial 50,000 target. The general public seems to be dissatisfied with the amounts offered as rebate and kept asking for an upward review of the incentive. In the household survey conducted, 16.3 per cent of respondents asked for an increment in the rebate amount, being the request with the second highest frequency (Table 4.8)

Table: 4.8 suggestions for improvement from the general public

Suggestions	Frequency	Percentage

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1.	Increase the number of collection centres	26	16.3
2.	Other	4	2.5
3.	No idea	14	8.8
4.	Increase the incentive amount	26	16.2
5.	Improve the quality of the new fridges	14	8.7
6.	Increase education/awareness creation	28	17.5
7.	Include first-time buyers	16	10.0
8.	Extend program to air conditioners	8	5.0
9.	Accept non-functional fridges	8	5.0
10.	Extend program to commercial fridges	8	5.0
11.	Reduce the cost of new fridges	8	5.0

Source: Field work

Lack of knowledge and apathy on the part of the general public are also challenges plaguing the program. As shown in Table 4.8, 17.5 per cent of respondents are asking for increased awareness and education. This is especially crucial for people with low levels of formal education. The household survey also reveals that 22.5 per cent of respondents who have no knowledge of the scheme are those whose level of education is secondary school and above (Table 4.9). A chi square analysis was therefore performed to find out whether the respondents' awareness of the scheme is significantly influenced by their level of education. The chi square statistics revealed that whether a respondent was aware of the existence of the rebate scheme or not did not significantly dependent on his/her level of education ($x^2 = 4.023, p = 0.546$). All the challenges enumerated are threats to the viability of the scheme if no urgent steps are taken to address them.

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4.8 Sustainability of the scheme

Studies have shown that currently, CFCs are released (Dehoust and Schuler, 2010), recyclable resources are sent to landfill (Stoop and Lambert, 1998) and old energy intensive appliances are refurbished for further use (Calwell and Reeder, 2001). As the negative effects of climate change continue to build momentum globally, efforts to reverse this trend must start locally by properly managing refrigerators and other white goods once they reach the end of their useful lives.

4.8.1 Education and Public Awareness Creation

For the project to be sustainable it requires a very aggressive public awareness campaign in order to educate the populace on the importance of the program. This is an uphill task considering that the illiteracy rate is quite high. Even for those who are literates but not scientifically inclined, it is still difficult for them to appreciate issues of climate change, global warming and ozone depletion not to mention the disagreements that exist between scientists concerning the realities of these phenomena. The current level of awareness is not enough to make the program sustainable. Considering that 77.5 per cent of all respondents in the household survey have had at least secondary education (Table 4.9), it is interesting that 33.75 per cent deny knowledge (Table 4.9) whiles 17.5 per cent called for more education as a way of improving upon the workings of the scheme as discussed earlier. This is consistent with the chi square test result reported above.

Table 4.9: Cross tab of Educational level and awareness of the scheme by respondents

Educational level of respondents	Awareness of scheme		Total
	Yes	No	
Never attended school	4	4	8
Primary	4	6	10

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J.H.S./middle school	10	8	18
Secondary	34	10	44
Post-secondary	28	16	44
Post-secondary	26	10	36
Total	106	54	160

Source: Field work

The survey also revealed that the media was the most appealing source of information on the scheme for the educated class whiles the less educated people relied on other sources for information as shown in Figure 4.11.

The medium of awareness of the rebate scheme was analysed to find out if it is significantly dependent on the educational level of the respondents. The chi test statistics was the main tool used for the analysis. It revealed that radio, friends, newspaper, and social media were significantly dependent on the educational level of the respondents whiles television and the retail shop were not significantly dependent on the level of education of the respondents. Table 4.10 illustrates the chi square and the probability values for the various media of awareness creation.

INTEGRI PROCEDAMUS

Figure 4.11 cross tabulation of educational level and medium of awareness of respondents

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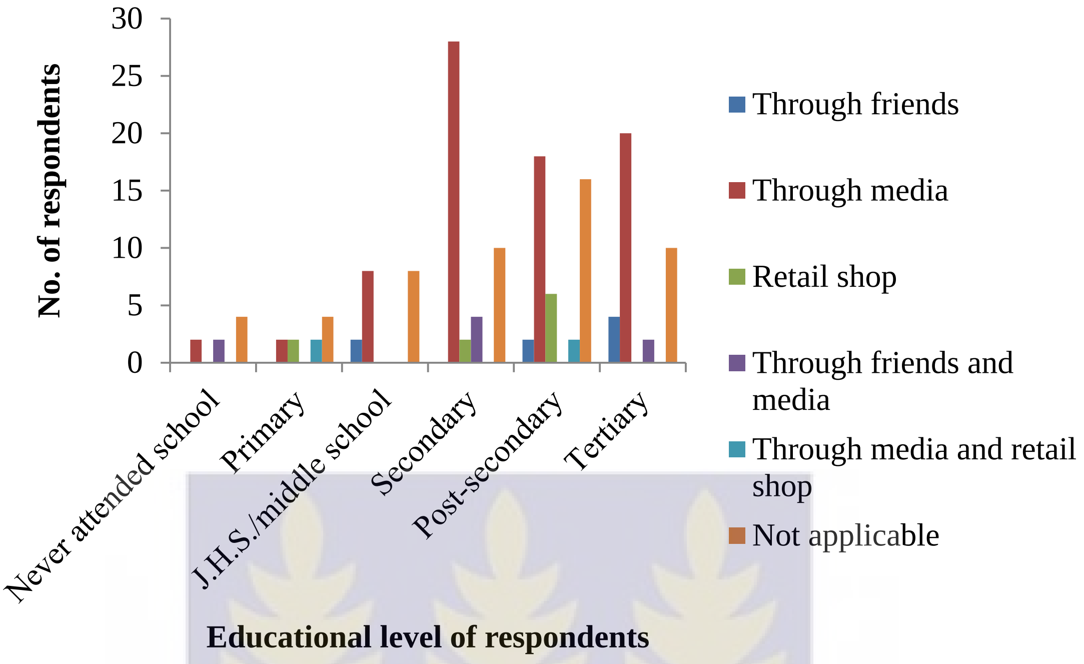

Source: Field work

Table 4.10: Results of chi square analysis of educational level and medium of awareness

Medium of awareness	Chi square value	p-value
Radio	14.40	0.01
Television	8.59	0.13
Friends	27.57	0.00
Newspaper	19.16	0.00
Social media	12.42	0.03
Retail shop	19.30	0.12

Source: Field work

The level of understanding the people get of the program will inform their state of conviction and impressions they carry about it. The household survey shows that 12.5 per cent of respondents have the opinion that the program is not necessary, 56.3 per cent say it is good, whiles only 6.3 per cent are convinced that it is very good (Table 4.11). One respondent who is a university professor said; "*the refrigerator in my*

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office is the one I have been using since I joined the university in 1995 and it is working perfectly, why should I change it? Another respondent who is a refrigerator technician said; "*these new refrigerators they are giving to the people are not strong, I believe that the old fridges are stronger. One of my customers took his fridge there and they told him there was something wrong with it so he should go and repair it first and he brought to me. After I fixed it he decided to take it home. As for me I think this program is not necessary",* he concluded.

Table 4.11: Public impression of the rebate scheme

Impression	Frequency	Percent
Not necessary	20	12.5
Good	90	56.3
Very good	10	6.3
Not applicable	40	25.0

Source: Field work

4.8.2 Cost of new refrigerators and the rebate incentive

The cost of new refrigerators vis-à-vis the rebate incentive is one of the potential threats to the sustainability of the program. Since the ban on the importation of second-hand fridges came into force the prices of new fridges have gone up astronomically. In a survey of prices of new refrigerators on the Ghanaian markets it shows that the prices have experienced between 30% and 50% price increment for the period December 2012 to December 2013 as shown in Table 4.12.

Table 4.12: Prices of brand new refrigerators in 2012 and 2013

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Brand/Type	Volume/L	Price, 2012/GH₵	Price, 2013/GH₵
1. Ocean, chest freezer	320L	980	1,274
2. Hisense chest freezer	320L	890	1,246
3. Tamashi chest freezer	400L	850	1,275
4. LG fridge	180L	400	560
5. LG fridge freezer	250L	570	798
6. Whirlpool fridge-freezer	250L	650	845
7. Sumsung fridge-freezer	250L	520	780

Source: Field work

This trend is certainly not encouraging people to go for the new fridges. If anything at all, it will rather encourage people to go for the second-hand ones which are cheaper. In fact, the percentage increase in the price of the new fridges has annulled the rebate incentive and renders it non-existent and unattractive. Individuals would therefore prefer to repair and continue to use old fridges, unless the repair cost is comparatively higher, rather than buy new ones which they cannot afford.

4.9 Chapter Summary

This chapter presented and discussed the results of the field work with the aim of answering the various research questions. Attempts were made to bring out the various management approaches currently used by households, scrap dealers and the City Waste Management Company in the disposal of end-of-life refrigerators

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including the institutional and legal frameworks governing refrigerator management in Ghana. The chapter also evaluated the viability of the rebate scheme and its sustainability for the future. The conclusions drawn from the study and the recommendations are presented in the next chapter.

CHAPTER FIVE

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CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The objective of the study was to evaluate the management of end of life refrigerators in Ghana based on the three major themes of management approaches, institutional and legal frameworks and viability and sustainability. The management approach assessed the processes and methods adopted by households, scrap dealers and the rebate scheme in the management of end of life refrigerators. Institutional and legal framework examined the responsibilities and capacities of the various institutions involved in the implementation of the rebate scheme as well as the adequacy, compliance and enforcement of the existing regulations on refrigerator management in Ghana. Viability examined the possibility of the program achieving its set targets whiles under sustainability the study assessed the ability of the current practices and technology to keep the scheme going towards the achievement of its aims and objectives.

The study draws three major conclusions on the current approaches to refrigerator management. With regards to management by households, the study concludes that the proportion of consumers who use an environmentally friendly approach, that is exchanging their fridges under the rebate scheme for subsequent recovery of the CFC, is too small to make any significant impact towards the mitigation of ozone depletion and global warming. On management by scrap dealers, the study concludes that their approach to end of life refrigerator management is completely deleterious to the environment. On the management approach adopted by the City Waste Management Company, the study concludes that whereas the recovery of the refrigerant from the cooling circuit is environmentally friendly and thus making some contribution

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towards the mitigation of ozone depletion and global warming, the management approach adopted towards the polyurethane foam is inadequate towards the reduction of CFC emissions.

Three important conclusions were drawn from the analysis of the institutional responsibilities and capacities. In terms of the institutional responsibilities, the study concludes that the level of education and awareness created concerning the refrigerator rebate scheme is inadequate accounting for a huge knowledge gap among customers on the existence of the program and its benefits, both economic and environmental. In terms of institutional capacity, the study concluded that even though the degassing plant used by the City Waste Management Company has the capacity of degassing 100 fridges per day the small number of fridges collected under the scheme is making the plant to underperform. The study further concludes that the company lacks capacity in terms of technology to handle the polyurethane foam in an environmentally friendly manner.

Two conclusions were drawn under the legal frameworks which measures the adequacy, compliance and enforcement of existing regulation. Firstly, the study concludes that there are no laws governing the treatment of e-waste in general and EOL refrigerators in particular. Secondly, the study concludes that the existing regulations are not waste management regulations and therefore are woefully inadequate in the provision and prescription of guidelines, responsibilities and penalties towards an environmentally friendly refrigerator management system in Ghana.

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Under viability and sustainability, the study concludes that the prevailing systems and conditions in terms of the number of fridges collected vis a vis the target, the current level of ignorance on the scheme and high cost of brand new fridges compared to the rebate discount, the scheme is anything but viable and sustainable.

5.2 Recommendations for Policy Consideration

Having reviewed and discussed the various aspects and dimensions of the recovery of ozone depleting substances through the refrigerator rebate scheme the following recommendations are offered for policy consideration.

5.2.1 Regulation

It is recommended that:

- A regulatory approach, instead of the current voluntary approach, be adopted towards the implementation of the rebate scheme to ensure strict adherence to standards and regulations towards a more effective and goal-driven program.

- The Environmental Protection Agency leads the crusade to enact/amend laws towards the regulation and treatment of e-waste, ODS waste, and end of life refrigeration appliances. The following checklist of requirements is proposed for inclusion in the ODS regulation:

1. No new installations of CFC refrigeration and air-conditioning systems, either mobile or stationary, should be permitted.
2. Charging HFC systems with CFCs and retrofitting HFC systems to use CFCs should be banned.

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3. CFCs or HCFCs should not be permitted for flushing or pressure testing of refrigeration and air-conditioning systems before recharging.
4. Leaks should be identified and repaired before the system is recharged.
5. The refrigerant should be recovered when the system is repaired or scrapped and re-used whenever possible instead of vented to the atmosphere.
6. Only authorized companies or individuals with certified competence and adequate equipment should be allowed to purchase ODS and service equipment containing ODS refrigerants.
7. Regular maintenance and preventive leak detection should be required for refrigeration and air-conditioning equipment containing more than 3kg of refrigerant.
8. Clear responsibilities regarding refrigerants that cannot be re-used on site should be provided.
9. The sale of refrigerants in cans containing less than 1kg should be banned.
10. The sale of refrigerants should be restricted to authorized companies.
11. Requirements on record keeping of service and maintenance should be spelt out.

5.2.2 Education, Training and Public Awareness

It is recommended that education and training for service technicians, Customs Division of the Ghana Revenue Authority and the general public on ODS release and ODS control should be intensified to ensure a holistic and all hands on deck approach towards the fight to mitigate the release of ozone depleting substances. It is further recommended that service technicians should be trained to begin to do the following:

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1. Repair leaks before recharging (thereby reducing the need for future recharges as well as reducing energy consumption and wear);
2. Recover the refrigerant for re-use instead of venting it to the atmosphere at servicing or scrapping;
3. Stop flushing with CFCs to clean and dry out systems;
4. Stop charging HFC systems with CFC-12;
5. Conduct regular maintenance and preventive controls;
6. Retrofit CFC systems to alternative refrigerants;
7. Improve system design and locate systems so that maintenance and leak detection are facilitated;
8. Design new systems for low charge and non-ODS refrigerants

It is also recommended that:

- Public education on the rebate scheme should be extended to churches and other social gatherings to drive home the message by repackaging the message in order that it will appeal to the ordinary Ghanaian, explain down to earth to the scientific illiterates, and bust all the myths.

- The Customs Division should also be supplied with and trained to use equipment such as refrigerant identifiers, manifold gauges, leak detectors, mass spectrometers and gas chromatographs in order to detect ODS at the point of entry into the country.

- Sanctions applied to smugglers that have been caught in illegal trade in ODS should be made well known in the mass media. This can send important signals to all importers on the risks involved in illegal import.

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- Minimum servicing equipment such as leak detectors, vacuum pump, and vacuum gauge be subsidised to enable technicians acquire them and work according to the Code of Practice they have been trained for.

5.2.3 Best Available Technology

It is recommended that:

- The best recycling technologies and standards be employed towards the management of ODS waste in refrigeration equipment from the appliance collection, pre-treatment, demanufacturing, ODS destruction and secondary processing stages including the handling of other hazardous components.

- Home pick-up component be introduced such that appliances can be picked up from people's homes. This will limit the event of cooling circuit damage resulting in refrigerant loss since the pick-up team will be trained in handling the appliances as against residents who might not be skilled in appliance handling for the purpose of preventing damage to the cooling circuit. This will also boost the number of appliances collected since some residents just feel lazy or do not have time to carry their appliances to the collection centres. This must be accompanied by advertised telephone numbers that residents can call in case someone wishes to turn an appliance in.

- In order to ensure that appliances turned in for recycling will not be resold or reused; they should be disabled shortly after testing.

- A fully automated treatment plant that is completely situated in a sealed environment be installed.

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- RAL Quality Assurance for the Demanufacturing of Refrigeration Equipment is used to ensure sound quality assurance standards for all stages of the fridge demanufacturing process.

5.2.4 Financial Incentives

The financial incentive administration and system should be revised towards a more appealing regime that will engender maximum participation for equal economic and environmental benefits. The following suggestions are recommended for policy consideration for a more appealing financial incentive administration.

1. The current incentive amount of between GH₵150 to GH₵200 should be increased to between GH₵200 to GH₵300 to reflect the increasing prices of the refrigerators on the market.
2. The rebate awarded should not be tied to the purchase of a new refrigerator. Patrons should be allowed a room of options that they can use their incentives for things such as school fees, basic utility charges, and purchases of other appliances or tickets to entertainment events. This will enable people who wish to dispose a second refrigerator without replacement to take part.
3. First-time buyers should be considered for an incentive. This will encourage them to purchase more energy-efficient refrigerators than a low cost energy consuming appliance.
4. There should be no limits on the number of rebates per person. All persons should be given the opportunity to exchange as many fridges as they wish so long as they qualify per the procedure of the scheme. This will encourage those who have multiple fridges at home to exchange all of them under the program.

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5. For the sake of the environmental benefits that will accrue from the recovery of the CFCs from the appliance cooling circuit and insulating foam, appliances that have been found to contain ODS but are not functioning due to some other electrical reason, should be accepted with a smaller incentive so that the ODS can be properly recovered. This will encourage more people who have non-functional appliances to turn them in for proper treatment and ODS recovery.

5.2.5 Extended Producer Responsibility (EPR)

An effective Product Stewardship Scheme should be introduced as a form of Extended Producer Responsibility to enable importers, distributors and sellers of ODS and ODS-containing appliances to become financially and physically responsible for taking back end of life products and managing them through reuse, recycling or safe disposal. It is further proposed for policy consideration in Ghana that:

1. An importer of ODS-containing equipment be required to register with the EPA and pay a levy in respect of importation of the appliances into the country.
2. The levy should cater for
   a. The costs of the collection, treatment, ODS recovery and environmentally sound disposal and recycling of an EOL appliance.
   b. The establishment of an ODS Waste Recycling Fund to provide financial support for the management of EOL appliances and reduce the adverse impact of hazardous components on human health and the environment.
   c. The construction and maintenance of ODS appliance recycling and treatment plants.
   d. The support of research into methods of electronic waste prevention, control and management.

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e. The education of the general public on the responsible disposal of ODS appliances and the negative effects of CFCs through programs and publications.

f. Incentives for the collection and disposal of ODS appliances.

3. A distributor or wholesaler of ODS-containing equipment be required to take back used or discarded electronic equipment distributed or sold by it for recycling purposes.

5.2.6 Secondary Processing

- While the metal fractions can be sold to any metal recycling company for further processing, the polystyrene is of quite good quality and free from additives like flame retardants. Therefore, it can be passed on to the plastic recycling industry. In Ghana, there are several recyclers of thermoplastics, which could make use of this material. The glass fraction can be fed into local glass recycling industries or sent to a glass recycler for use as an aggregate in concrete. The oil from the cooling circuit can be processed for reuse in other industrial equipment. Since Ghana has now become an oil producing country, the PUR powder can be reprocessed into pellets called *'ÖKO-PUR'*, designed to mitigate oil and chemical spills.

- The mixed plastic fraction is composed of various types of plastics including thermosets and elastomers, which cannot be recycled. Therefore, this fraction should be incinerated in cement kilns or waste incinerators. The recovered CFCs could be treated in certified facilities using any of the destruction technologies approved by the UNEP Task Force on Destruction Technologies.

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Alternatively, small scale plasma ovens could be imported and installed in Ghana.

- The researcher further suggests that any of the two cement manufacturing companies (GHACEM and Diamond Cement) in the country should be consulted for a possible modification of their cement kilns for the additional purpose of ODS destruction. The advantages of this choice are:

1. The initial cost for the modification is low ($23,000) as compared to that of constructing a new destruction facility ($435,000) (ICF International, 2010)
2. The modification is relatively easy as compared to the construction of a new facility.
3. It has large destruction capacity.
4. The acidic by-products of the process are neutralised by the alkaline environment of the cement kiln without additional neutralization equipment.

Overall, if Ghana is able to undertake the necessary modifications and ODS destruction commences, it will become the only country to have such a facility in Africa and hence other countries may export their ODS to Ghana for destruction, bringing some foreign exchange to the country.

- The hazardous fractions need to undergo specific treatment and disposal. PCB-containing capacitors can be treated under the "PCB Management in Ghana, from Capacity Building to Elimination"; a UNDP-funded project that will provide the needed infrastructure and management plan.

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5.3 Strengths of the study

Among other things, the strength of this research lies in the triangulation of methods (interviews, questionnaires, field observation, laboratory and documentary analyses) in a single study which allowed for the use of different strategies to collect data from a range of sources. The use of the direct field observation technique provided an opportunity to obtain first-hand information on the activities of scrap scavengers and dismantlers. The interview technique allowed for dialogue with key stakeholders in the refrigeration, energy and e-waste sectors to generate rich qualitative data for the analysis of the research themes. Furthermore, the use of questionnaires in the household survey enabled the coverage of a reasonable number of households in the two cities. The triangulation of methods also provided the opportunity to crosscheck the various sources of data, which greatly improved the validity of the data, gathered for the study.

The study was also able to explore the issues surrounding the topic from the perspectives of different stakeholders including a private sector waste company, some public sector institutions and householders in the different socio-economic groups. This multi-source approach provided an opportunity to get a more rounded perspective on the refrigerator recycling problem.

Finally, familiarity with the research environment gave a further boost to the fieldwork conducted for the research. Apart from being familiar with the two cities which served as sites for the field investigation, knowledge of the Ghanaian cultural context made it possible to overcome many situations which would otherwise, pose constraints to the data collection process.

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5.4 Implications for further research

The present study has examined the adequacy of the programs, practices and technology available in Ghana towards limiting the release of ozone depleting substances into the atmosphere focusing on the Refrigerator Rebate Scheme within Accra and Tema. In the course of the study, however, a number of themes have been identified that critically affect the organisation of refrigerator and ODS waste management but which remain under researched in Ghana. These areas include appropriate strategies and technologies for ODS waste management, rebate scheme financing, the governance of refrigerator and ODS management, landfilling of PUR waste, the toxicokinetics and health effects of the fluorinated hydrocarbon refrigerants, refrigerator energy consumption and efficiency, extended producer responsibility, the economics of electronics recycling, CFC smuggling and the health effects of PCBs and mercury from refrigeration appliances. These and other aspects of refrigerator management critically impact the environment but are beyond the scope of the present study. Full-scale investigation in these areas is therefore recommended to create greater understanding of refrigerator management issues and pave the way for an improved and sustainable environmental management in Ghana.

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APPENDICES

APPENDIX 1

INSTITUTE FOR ENVIRONMENTAL AND SANITATION STUDIES

UNIVERSITY OF GHANA

Refrigerator Management Survey

(Information on recycling of refrigerators to recover Ozone depleting substances provided by officials of the City Waste Management Company Limited)

This questionnaire is being administered to assess the effectiveness of practices and technology for reducing the release of ozone depleting substances in Ghana. The study is purely for academic purposes and the information will be treated confidentially. Your genuine response is very much needed for the success of the exercise.

Tick (√) where appropriate and provide answers to open ended questions

A. Regulation

1. Is your recycling equipment certified by the EPA? □ Yes □ No

2. How often does the EPA inspect your operations for compliance? □annually □quarterly

3. What does the EPA look for during the inspection? (please check all that apply)
□Validity of operating license □Proper recovery and management of refrigerant □Proper recovery and management of mercury □ Proper recovery and management of used oil □ Proper recovery and management of PCBs □Proper recovery and management of ODS foam blowing agent □ Proper recovery and recycling of metals, plastics, and Glass □Material Safety Data Sheet □Safety wear □first aid kit □certificate of technicians

4. How often does the EPA audit your paperwork and record keeping? □annually □quarterly

5. Are there any recycling and reuse targets set under current legislation or stipulated within your waste management license? □ No □ Yes (please specify
...……………………………………………………………………………
……………………………………………………………………………
……………………………………………………………………………
……………………………………………………………………………
……………………………………………………………...

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6. Are there any fines or penalties for violating any required practice or regulation? □ No □Yes (please specify
...……………………………………………………………………………
………………………………………………………………………………
………………………………………………………………………………
………………………………………………………………………………
…………………………………………………………...

B. Appliance Collection

7. Is there any cost associated with residents dropping off their refrigerators at local collection centers? □ No □Yes (please specify
...……………………………………………………………………………
………………………………………………………………………………
………………………………
8. How many local collection depots are within your collection zone? ……………………………
9. How many regional collection teams do you employ? ……………………………………………
10. How much of your collection is hired out to third parties? …………………………………...
11. What is the procedure if an independent person drops units off at your facility?
………………………………………………………………………………
………………………………………………………………………………
………………………………
12. What are the procedures for properly loading the collection trucks to ensure no refrigerant escapes?
………………………………………………………………………………
………………………………………………………………………………
………………………………………………………………………………
………………………………………………………………………………
…………………………………………………………
13. Is it your responsibility to ensure that refrigerators are in a clean state (i.e.no organic matter left within refrigerator)? □ No □Yes
14. Do collection teams inspect units at collection points for cleanliness? □ No □Yes
15. Can collection teams reject a refrigerator on site? □ No □Yes (please specify reason for rejection
...……………………………………………………………………………
………………………………………………………………………………
………………………………
16. Does CWMCL collect refrigerators that have been dumped in landfill sites?) □ No □Yes

C. Recycling

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17. How many refrigerators must be processed to keep your business viable or profitable?
………………………………………………………………………………………………………
18. How many refrigerators do you process in a typical year?
…………………………………………
19. What is the cost per unit to recycle a refrigerator?
…………………………………………………
20. What is the year of manufacture of refrigerators that come for recycling?
□1979 or earlier □1979 to 1995 □1995 to 2004 □2005 and after

21. Does CWMCL recover mercury switches? □ No □Yes
If yes, how do you dispose them?
…………………………………………………………………..
22. How do you identify and treat PCB-containing capacitors?
……
23. Is there any removal of refrigerant oils from the compressor prior to recycling?
□No □Yes
If yes, what do you do with the oil?
……
24. Does CWMCL have any type of abatement program to counteract the negative effects of mercury or oil leaks during recycling? □ No □Yes (please specify
...………
25. Does CWMCL know what is happening, in terms of recycling, with other types of equipment that contains ODS (i.e. air-conditioners, water coolers, etc.)? □ No □Yes (please specify
...………
26. What is the name of your refrigerator recycling system?
………………………………………………………………………………………………………
27. How much did it cost to purchase?
…………………………………………………………………

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28. What is the life span of this system?
…………………………………………………………...

29. Do you recycle commercial refrigeration equipment? □ No □Yes

30. Do you recover hydrocarbon refrigerants (e.g. propane, butane, pentane, etc)? □ No □Yes

D. **Reuse**

31. What criteria are used to determine if a refrigerator can be reused?
……………………………………………………………………………………
……………………………………………………………………………………
……………………………………………………………………………………
…………………………………………………

32. What criteria are used to determine if a refrigerant can be reused?
……………………………………………………………………………………
……………………………………………………………………………………
……………………………………………………………………………………
…………………………………………………

33. Is the recovered refrigerant restored to its original like-new condition? □ No □Yes

34. Are compressors reused after they have been removed? □ No □Yes

E. Waste

35. How many kilograms of material from the dismantled refrigerators, is sent to the landfill each year?
……………………………………………………………………………………
………..

36. What happens if refrigerators are rejected when they are received at the plant?
……………………………………………………………………………………
……………………………………………………………………………………
……………………………………

37. What do you do with the polyurethane insulation foam?
……………………………………………………………………………………
……………………………………………………………………………………
……………………………………………………………………………………
…………………………………………………

F. Hazardous Wastes/ODS

38. Do you recover ODS foam blowing agents? □ No □Yes

39. What is your contingency plan in the event one of your refrigeration containers has a leak?

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

40. How do you identify the refrigerant type prior to extraction from the unit?
……………………………………………………………………………………
……………………………………………………………………………………
………………………………

41. Is there mixing of refrigerant types (i.e. R-12, R-134a, etc.)? □ No □Yes

G. Extra

42. Currently, who is responsible for providing education and awareness to residents regarding recycling of refrigerators? □CWMCL □Energy Commission □EPA □ECG

H. Final Thoughts

Is there any further information that you would like to provide about your appliance recycling program which was not covered in a specific area of this survey?

Thank you very much for your input

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APPENDIX 2

INSTITUTE FOR ENVIRONMENTAL AND SANITATION STUDIES

UNIVERSITY OF GHANA

Refrigerator Management Survey

(Information on recycling of refrigerators to recover Ozone depleting substances provided by officials of the Energy Commission, Ghana)

This questionnaire is being administered to assess the effectiveness of practices and technology for reducing the release of ozone depleting substances in Ghana. The study is purely for academic purposes and the information will be treated confidentially. Your genuine response is very much needed for the success of the exercise.

Tick (√) where appropriate and provide answers to open ended questions

A. Introduction

1. Does Accra currently have a system in place for the management of domestic appliances that contain an ozone depleting or global warming substance (such as a refrigerator or freezer, or any other appliance which may contain an ODS based insulating foam) at the end-of-life/post consumer stage? □ No □Yes (please specify
…………………………………………………………………………………………
…………………………………………………………………………………………
………………………………

B. Appliance Collection

2. Is there a standardized procedure for residents to turn in ODS/GHG appliances for recycling?
□ No □Yes (please explain
…………………………………………………………………………………………
…………………………………………………………………………………………
…………………………………………………………………………………………
…………………………………………………………………………………………
…………………………………………………………………

3. What is the procedure when a resident calls and wants to dispose of an appliance which contains ODS refrigerant (i.e. who should the resident call)?
…………………………………………………………………………………………
………………

4. How are appliances typically transported to the processing facility? □resident drop off □metropolitan/private contractor collection □collection by recycling company

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5. What is the scope of the project (i.e. how many refrigerators or kg of ODS or kWh of power does the program target)?

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

C. Refurbishment

6. If an appliance destined for disposal is found to still be in working condition, what happens to it? □it is refurbished for reuse □it is recycled □it is sold as second hand

7. What is the typical value of a refurbished appliance (i.e. the resale cost or the inherent worth of recoverable parts)?

…………………………………………………………………………………………...

8. If a resident's refrigerator breaks down, is he/she still eligible to participate in the program? □No □Yes, with incentive □Yes, without incentive

D. Energy Efficiency

9. Are there any programs or incentives that encourage the purchase of new energy efficient appliances, such as Energy Star certified models? □No □Yes

10. If yes, what types of incentives are given to residents as encouragement to recycle their appliance? □Direct subsidies □tax credits □credit points □Bonus/malus □Subsidized/ Low-interest Government loans □other (specify………………………………….

11. On a yearly average, typically how much energy is saved (in kWh) from the removal of older appliances (chiefly refrigerators) from the market?

……………………………………………………

12. How much GHG has been prevented from being released through the removal of these appliances up to date? (Both by emissions from refrigerators and electric power generators)

……………………………………………………………………………………………
………………..

E. End-of-Life Fees

13. Is there any cost levied against the resident at the time of disposal? □No □Yes If yes, what are these costs associated with? □ODS extraction □refrigerator pick-up □transportation □help build the necessary infrastructure for an appliance-recycling program

G. Decommissioning/Processing

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14. Who is typically responsible for ensuring that refrigerant (CFCs, HCFCs, and HFCs) has been responsibly removed from the unit prior to recycling? □recycling company □Energy Commission □EPA □AMA □UNEP

15. What is the most common method of refrigerant extraction at the recycling plant? □active recovery method □ blue bottle method

16. Is there an ID system in place, such that an evacuated unit can easily be identified as refrigerant free? □ No □ Yes, via a sticker □Yes, via barcode

17. What happens to the refrigerant once it has been removed? □recycled □recharged □reclaimed □ destroyed □stored indefinitely

18. If destroyed, to which facility is it sent? ………

19. Are there any laws in place that stipulate the mandatory recovery of ODS and GHG (i.e. CFCs 11 &12, HCFC 22, and HFC 134a)? □ No □Yes (please specify ………………………………………………………………………………………

………………………………………………………………………………………

………………………………

20. On average, how many ODS/GHG-containing refrigerators are processed at the recycling plant on a……………….. basis (i.e. daily, weekly, monthly, yearly)?..

21. Are mercury switches and capacitors containing PCB's recovered prior to recycling? □No □Yes

22. Are refrigerant oils (i.e. mineral oils) recovered prior to recycling? □No □Yes
If yes, how is it processed to remove the refrigerant?
………………………………………………………………………………………
………………………………………………………………………………………
………………………………………………………………………………………
………………………………………………

23. What application is the recovered oil put to?
………

H. Resource Recovery

24. What is done with the steel after the unit has been dismantled? □recycled □sold on the local market □exported

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25. What is typically done with the other component parts post dismantling (i.e. copper, aluminium, glass, and plastic)? □recycled □sold on the local market □exported

26. What is the current market price for these recoverable resources per kg?
a. Aluminium:……………………………………………………………………………
b. Copper:………………………………………………………………………………
c. Steel:…………………………………………………………………………………
d. Glass:…………………………………………………………………………………
e. Plastic:………………………………………………………………………………

27. If possible, please list the total amount (in kg) of resources recovered over the lifespan of the refrigerator management project.
a. CFCs (11, 12, or both):…………………………………………………………………
b. HFC:……………………………………………………………………………………
c. Refrigerant oil:…………………………………………………………………………
d. Polyurethane foam:……………………………………………………………………
e. Aluminium:……………………………………………………………………………
f. Copper:…………………………………………………………………………………
g. Glass:…………………………………………………………………………………
h. Plastic:………………………………………………………………………………
i. Mercury switches (if applicable):……………………………………………………

I. Polyurethane Foam Treatment

28. How are CFCs or GHGs that are housed in the insulating foams dealt with? □They are recovered and stored □They are recovered and destroyed □They are not recovered

29. What management system is in place to deal with foam after its removal from the appliance? □incineration □land filling □shredding □recycling □other (specify…………………………....)

30. What cost is typically associated with ODS recovery from foam (if applicable)?
………………………………………………………………………………………………
………………..

J. Extended Producer Responsibility

31. What is the role of the manufacturer in the recycling program?
□funding □education □appliance collection □recycling □None □other (specify………………

32. What is your assessment of the role the manufacturer plays in the recycling program?
□Poor □satisfactory □Good □Very Good □Excellent

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APPENDIX 3

INSTITUTE FOR ENVIRONMENTAL AND SANITATION STUDIES

UNIVERSITY OF GHANA

Refrigerator Management Survey

(Information on recycling of refrigerators to recover Ozone depleting substances provided by personnel of National Ozone Unit, EPA)

This questionnaire is intended to capture information regarding all relevant program(s) and procedure(s) in place in Ghana for collecting and destroying ODS contained in refrigerators.The study is purely for academic purposes and the information will be treated confidentially. Your genuine response is very much needed for the success of the exercise.

A: General procedures for collecting appliances and handling ODS contained in appliances

Please describe the procedures in place in Ghana for collecting refrigerated appliances and recovering and treating ODS contained in appliances by checking all boxes that apply and providing explanatory text in the space below.

1. **Description of program**
   □ Voluntary government program □ mandatory government program
   □ Voluntary industry initiative □ other; please specify…………………

2. Operating entities (i.e. who runs the program?)
   □ Central government □ local/metropolitan assembly □ equipment manufacturers □ electricity company □ industry organization (specify………...) □ industry-government collaboration □ other (please specify ……..

3. **Drivers for Establishing Appliance Collection Program**
   □ Regulatory requirement for reducing ODS emissions □ regulatory requirement for e-waste treatment □ energy savings □ other (please specify……………………………

4. **Program Scope**

4a. what is the geographical scope of the appliance collection program?
Appliances are collected from
□ Accra region/metropolis □ several regions/metropolis (specify…………….
□nationwide

4b. what refrigerated appliances are collected under the program?
□ Domestic refrigerators and freezers □room air conditioners □mobile air conditioners □ Commercial refrigerators

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B: Detailed procedures: How appliances are handled

Please describe the path that refrigerated appliances follow, outlining where appliances are generally taken and by whom they are generally handled from the point where they leave the consumer to the point where they are disassembled.

5. Consumer Disposal

How do consumers dispose of refrigerated appliances?

□ Appliances are brought to a central location □appliances are picked-up from homes

□ Appliances are brought to retail shops

5b. Size of Consumer Population Served (number of households)………………………………………

5d. Entities Involved and Specific Roles Played

Entity Role

1. ……………………………………

   ………………………………………….

2. ……………………………………

   ………………………………………….

3. ……………………………………

   ………………………………………….

4. ……………………………………….

   ………………………………………….

6. Appliance Collection and Storage

6a. what entities collect refrigerated appliances?

□ Retail shops □electricity company □energy commission □recycling company □AMA

6b.Through what means are appliances transported to a facility before being disassembled?..

6c. what is the average distance they are transported?...................................km

7. Appliance Disassembly and ODS Collection

How many disassembly facilities are operational under the program?..............................

C: Legal Framework

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Please describe the legal framework in place pertaining to the treatment of ODS-containing appliances at end of life in the space below.

8. Describe any law in place that governs the treatment of ODS-containing appliances at the time of disposal (e.g., laws prohibiting venting of refrigerant).

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

………………………………………

9. Describe any laws in place that assign responsibility for the disposal of ODS-containing appliances to specific stakeholders. For example, are local governments mandated to perform a certain administrative role (such as collecting appliances separate from general waste), or are appliance retailers/manufacturers mandated to provide take-back programs?

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

………………………………………

10. Describe any other government influences that have shaped the programs/processes in place in Ghana for properly disposing of appliances (e.g., voluntary programs to encourage industry to responsibly dispose of refrigerated appliances).

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

………………………………………

D: Treatment of ODS Refrigerant

Please describe the procedures in place in Ghana for handling ODS refrigerant recovered from appliances by checking all boxes that apply and providing explanatory text in the space below.

11. Refrigerant Reclamation (Recycling)

11a. Is refrigerant reclaimed (recycled)?

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□ Yes, in Ghana □ Yes, in another country (specify………………………………..

□ No □ other (e.g. it is stored indefinitely) (please specify……………………………………

11b. On average, how far must ODS refrigerant be transported from the facility where it is recovered to the facility where it is reclaimed (in km)?...

11c. How long is ODS refrigerant typically stored before being reclaimed (in days)?...

11d. Where is ODS refrigerant typically stored before being reclaimed?......................................

12. Refrigerant Destruction

12a. Is refrigerant destroyed?

□Yes, in country □ Yes, in another country (specify…………………………………

□Other (e.g. it is stored indefinitely) (please specify…………………………………

12b. On average, how far must ODS refrigerant be transported from the facility where it is recovered to the facility where it is destroyed?..km

12d. Where is ODS refrigerant typically stored before being destroyed?.......................

12e.What technologies are used for the destruction of refrigerant (please check all that apply)?

□cement kilns □Argon plasma arc □Nitrogen plasma arc □Reactor Cracking □Rotary kiln □Liquid injection Incineration □Gaseous fume oxidation □Microwave plasma □inductively coupled radio frequency plasma □Gas phase catalytic dehalogenation

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□Superheated steam reactor □No idea □other (please specify…………………………………………………..

E: Treatment of ODS foam

Please describe the procedures in place in Ghana for handling ODS foam contained in appliances by checking all boxes that apply and providing explanatory text in the space below.

13. Is foam recovered from the appliances?

□ Yes (specify procedure used

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………

□ No; foam is

□ shredded □ incinerated □ landfilled □ stored indefinitely

14. If foam is recovered, is the blowing agent contained in the foam destroyed or reclaimed?

□ Destroyed (specify technology used……………………………………………………….. □ Reclaimed (specify technology used…………………………………………………………..

15. On average, how far must ODS foam blowing agent be transported from the facility where it is recovered to the facility where it is destroyed/reclaimed?...km

16. How long is ODS foam blowing agent typically stored before being destroyed?...............days

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17. Where is ODS foam blowing agent typically stored before being destroyed?...........................

F: Financing and Incentives

In the spaces below, please describe the annual cost and source of financing for appliance collection/disposal, as well as any incentives or disincentive for participation in the program.
Please also provide additional cost information, as available—such as the cost per kilogram for reclaiming or destroying refrigerant. For all responses, please indicate the currency in which costs are provided.

18. Total Appliance Collection/Disposal Costs

18a. What is the total annual cost associated with the appliance collection/disposal program, and what entity(ies) incur(s) this cost? If possible, please specify the approximate number of appliances associated with this cost. If disaggregated data is available on the cost of individual program components (e.g., appliance collection, transportation of appliances, disassembly, ODS recovery, destruction, and/or reclamation), please specify
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18b. Are any fees charged to entities to offset the costs of the programs/procedures? For example, are appliance owners charged a fee at the time of appliance collection, or appliance manufacturers charged an upfront fee as part of producer responsibility laws? If so, please specify the amount the entities must pay and to which entities those fees go.
………………………………………………………………………………………
………………………………………………………………………………………
………………………………………………………………………………………
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18c. If no fees are charged, please describe how the appliance collection/disposal program or procedures are funded. If different components of the program (e.g., appliance collection, transportation, disassembly, and handling of ODS) are funded differently, please describe.

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19. Incentives

What, if any, incentive is offered to appliance owners to dispose of their appliances through the program? How is the cost of the incentive covered?
……
……
………………………………

20. Disincentives
Are there any disincentives for non-participation in the appliance collection program (e.g. penalties such as fines or prison time)? If so, please describe the disincentives and the entities for whom they apply (e.g., are fines assessed for appliance dismantlers who fail to destroy the ODS refrigerant, or are there penalties for consumers who fail to turn in their appliances?).
………………………………………………………………………………………
………………………………………………………………………………………
………………………………………………………………………………………
……………………………………

G: Statistics

Please complete the questions below related to the outcomes of programs/processes in place for the collection and disposal of ODS-containing appliances.

21. How many refrigerated appliances have been collected each year? Please complete the table below
to the best of your ability

	Number of units	
Appliance type	2012	2013
Refrigerators		
Freezers		
Others (specify………………		

22. How many units of each appliance type do you anticipate will be collected per annum in the future?

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Number of units		
Appliance type	2014	2015
Refrigerators		
Freezers		
Others (specify……………….		

23. In total, how many refrigerated appliances are generated each year within the program's territory? (Please specify number by appliance type, if known)

……………………………………………………………………………………………
……………………………………………………………………………………………
…………………………
24. Of the total number of appliances disposed of by consumers within the given territory each year, what percent of those units are collected by the program?

……………………………………………………………………………………………
………
25. Of the total number of appliances disposed within the program's territory each year (whether collected through the program or not), what percent have the ODS refrigerant recovered?

……………………………………………………………………………………………
……………
26. Of the total number of appliances disposed within the program's territory each year (whether collected through the program or not), what percent have the ODS foam recovered?

……………………………………………………………………………………………
……………
27. What is the average amount of refrigerant and foam that is recovered per appliance?

Appliance type	Average amount per appliance	
	ODS refrigerant	ODS blowing agent in foam
Refrigerators		
Freezers		

H: Monitoring and Evaluation

The questions below aim to elicit insight into what and how appliance collection and disposal procedures have been implemented successfully up to date in Ghana.

28. Is the effectiveness of the program/procedures being monitored?
□ Yes □ No
If yes, which entity carries out the monitoring?

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……

Please attach a copy of any past assessment reports or summarize the findings overleaf.

29. In what areas have the program/procedures achieved success (i.e., the stated goals)?

……

In these areas, what have been the keys to success?

……

30. In what areas are the program/procedures lagging behind target (i.e., the stated goals)? For example, has the program been successful in collecting ODS but not destroying it?

……

31. What could be done to improve the success of the program/procedures?

……

32. Do any external factors divert appliances disposed within your program's territory from being channeled through the program, which may ultimately undermine the recovery of ODS refrigerant from disposed appliances? For example, do economic factors cause appliances to end up in the hands of scrap metal recyclers that may not recover ODS refrigerant from appliances?

……

33. What could be done to better ensure that appliances are channeled through the program to guarantee refrigerant recovery at end-of-life?

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34. Apart from the current program/processes in place, have any other approaches been implemented for the collection and disposal of appliance in the past and considered unsuccessful (e.g., different incentive structures)?

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

35. Are stakeholders generally supportive of the program(s)? Please describe experiences that show supportive and non-supportive stakeholder behavior (be as specific as possible).

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

36. Has the current legal framework led to the establishment of effective processes for ensuring the proper treatment of ODS-containing appliances in Ghana? Have any lessons been learned with regard to how the legal framework should best be structured?

…………………………………………………………………………………………
…………………………………………………………………………………………
…………………………………………………………………………………………
…………………………………………………………………………………………
……………………………………………………....

I: Conditions critical for success

The questions below aim to elicit insight into what conditions may be required for appliance collection/disposal approaches to succeed in subsequent programs or in other countries.

37. What framework conditions—demographic, geographical, cultural, legal and economic may be required for similar programs/procedures to succeed in subsequent attempts or elsewhere? (E.g. strict regulatory environment, better consumer education.)

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

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…………………………………………………………………………………………
…………………………………………………
38. What infrastructure would be required for similar programs/procedures to achieve greater success in the future or elsewhere? (E.g. enhanced hazardous waste handling procedures, access to destruction facilities.)
…………………………………………………………………………………………
…………………………………………………………………………………………
…………………………………………………………………………………………
…………………………………………………………………………………………
…………………………………………………
39. From capacity and legal standpoints, could subsequent programs or other countries make use of existing infrastructure in Ghana, such as ODS destruction technologies? (Please consider any restrictions on hazardous waste shipment, such as the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal).
…………………………………………………………………………………………
…………………………………………………………………………………………
…………………………………………………………………………………………
…………………………………………………………………………………………
…………………………………………………

Additional comments

Is there any further information that you would like to provide about the appliance recycling program, which was not covered in a specific area of this survey?

Thank you very much for your input

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APPENDIX 4
SURVEY FOR REFRIGERANT DEALERS IN ACCRA

1. Use "Y" to indicate a refrigerant in stock and "N" to indicate not in stock.

Refrigerant	In stock	Price/kg (GH₵)
CFC-12		
HCFC-22		
HFC-134a		
HFC-152a		
R-502		
CFC-11		
CFC-114		
R-500		
R-502`		
R-420A		
R-421B		
R-426A		
R-422C		
R-428A		
R-600a		
Other (specify…………		
Other (specify…………		

2. Are you certified to deal in refrigerants? □Yes □No

3. Where do you get your supply from? □from wholesalers □from importers □I import myself (state country
……………………………………………………………………………………………………

4. How do you store your stock?
………………………………………………………………………………………………………

5. Do you have a leak detector □No □Yes (specify type……………………

6. Do you check for leaks? □No □Yes, with a leak detector □Yes, by other means (explain
…………………………………………………………………………………………
…………………………………………………………………………………………
…………………………

7. How often do you check for leaks? □daily □weekly □monthly □other (specify
………………………………………………………………………………………..

8. What do you do when you detect a leak?
…………………………………………………………………………………………
…………………………………………………………………………………………
…………………………

9. Do gases leak out during filling (when buying or selling) □Yes □No

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10. Do customers require a certificate in order to purchase any gas? □Yes □No

11. Do you know that CFCs have been banned since 2010? □Yes □No

12. If Yes, do you know why the ban? □No □Yes (explain
……………………………………
………………………………………………………………………………
………………………………………………………………………………
………………………………

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APPENDIX 5
SURVEY FOR REFRIGERATOR TECHNICIANS IN ACCRA

1. What are you experienced in? Training ( ) Installation ( ) Servicing ( ) Maintenance ( ) Commissioning ( ) Retrofitting ( ) System design ( ) Manufacture ( )

2. Do you have experience of any of these systems? Domestic ( ) Commercial ( ) Cold storage ( ) Freezers ( ) Chillers ( ) Transport ( ) Marine ( ) Mobile air-conditioning ( ) General air-conditioning ( )

3. What quantity of refrigerant do you handle in one year (kg)? 1 - 10 ( ) 10 - 100 ( ) 100 - 1000 ( ) >1000 ( )

4. What average refrigerant charge is usual in the systems you most often work on (kg)?
   0 - 1 ( ) 1 - 5 ( ) 5 - 10 ( ) 10 - 50 ( ) > 50 ( )

5. What type of refrigerants do you work with? R11 ( ) R12 ( ) R22 ( ) R502 ( ) R134a ( )
   R404a ( ) R407c ( ) Ammonia ( ) Other, specify

6. What level of training have you received? Craft ( ) Technician ( ) Diploma ( )
   Degree ( ) On the job ( )

7. When did you last receive any formal training? In the last year ( ) 1 - 5 years ago ( )
   5 - 10 years ago ( ) Longer than 10 years ( ) Never ( )

8. Do you sometimes vent refrigerant during the servicing/repair/maintenance of equipment? Yes ( ) No ( )
9. Do keep record of your operations No ( ) Yes ( )

10. If yes, what type of records do you keep? Date of service ( ) type of service ( ) quantity of refrigerant used ( )

11. How long do you keep your records for? Less than three years ( ) three years ( ) more than three years ( )

12. Which of the following tools and equipment do you have? Tube cutter ( ) capillary tube cutter ( ) flaring tool ( ) reamer ( ) tube bender ( ) tube expander ( ) pressure gauge ( ) refrigerant recovery unit ( ) refrigerant transfer hose ( ) piercing pliers ( ) charging hose ( ) leak detector [specify: electronic leak

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detector ( ) UV leak detector ( ) ultrasound leak detector ( ) refrigerant monitor ( ) halide torch ( ) leak detection spray ( ) soap solution ( ) oil stain ( )] refrigerant identifier ( ) refrigerant charging scale ( )

13. Do you experience refrigerant leaks in your operations? No ( ) Yes ( )

14. If yes, what types of leakages are they? Gradual leaks during normal operation ( ) catastrophic losses during normal operation ( ) deliberate but necessary venting during servicing/maintenance ( ) losses from EOL refrigerators

15. Which of the following sources of leaks have you or your technicians experienced or repaired in the last 24 months, please tick indicate with (Y/N)

a. Brazed joints
b. Condenser failure
c. Return bend on evaporators or condensers
d. Piercing and line tap valves
e. Pressure switches connection
f. Copper capillary tube
g. PVC flexible hose lines on HP/LP
h. Thermostatic expansion valve

16. Do you know that CFCs have been banned since 2010? □Yes □No
17. If Yes, do you know why the ban? □No □Yes (explain
……………………………………
……………………………………………………………………………………
……………………………………………………………………………………
………………………………

Thank you for your input

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APPENDIX 6

INSTITUTE FOR ENVIRONMENTAL AND SANITATION STUDIES

UNIVERSITY OF GHANA

Refrigerator Management Survey

Questionnaire for households

This questionnaire is being administered to assess the effectiveness of practices and technology for reducing the release of ozone depleting substances in Ghana. The study is purely for academic purposes and the information will be treated confidentially. Your genuine response is very much needed for the success of the exercise.

Tick (√) where appropriate and provide answers to open ended questions

1. Do you or did you have refrigerators in your house? Yes [ ] No [ ]
2. How many refrigerators did you discard during the past two years? 1 [ ] 2 [ ] 3 [ ] 4 [ ] 5 [ ] none [ ]
3. How many refrigerators do you currently have in your house? 1 [ ] 2 [ ] 3 [ ] 4 [ ] 5 [ ] none [ ]
4. In which year did you get the fridge? 1979 or earlier [ ] 1980-1995 [ ] 1996-2004 [ ] 2005 and after [ ] not certain
5. How did you get the fridge? Bought [] given [] other [] please specify……………………………………………………………………
6. Was the fridge brand new or second-hand when you got it? Brand-new [ ]   Second-hand [ ] not certain [ ]
7. How did you discard the fridge?

   Discard together with the other wastes for municipal waste collection [

   Give / sell to scrap collectors [ ]Pay to the collector? [ ]

   Give / sell to friends or relatives? [ ] Sent to the recycling station / centre[ ]

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Exchanged under the rebate program [ ] not discarded [ ]others [ ][Pls. specify] ……………………………………………………….

8. Are you aware of the refrigerator rebate scheme? Yes [ ] No [ ]
9. How did you know about it? Through friend [ ] through the media [ ] at the retail shop [ ] N/A [ ] other (specify……………………………..
10. What are your general impressions of the program? Not good [ ] Not necessary [ ] Good [ ] very good [ ] excellent[ ] N/A [ ]
11. What do you suggest can be done to improve the implementation of the program?

    Increase the number of collection centres [ ] Increase the incentive amount [ ] Improve the quality of the new fridges [ ] Intensify education/awareness creation [] Include first-time buyers [ ] Extend program to air conditioners [ ] Accept non-functional fridges [ ] Extend program to commercial refrigerators [ ] Reduce the cost of new fridges [ ] other [ ] No idea [ ]N/A [ ]
12. Age of respondent: 18-35 [ ] 36-59 [ ] 60+ [ ]
13. Educational background of respondent: never attended school [] Primary [ ] J. H. S/middle school [ ] secondary [ ] post-secondary [ ] tertiary [ ]
14. Occupation/economic activity of respondent: professional, Technical & related worker [ ] Admin., Executive & Managerial worker [ ] Clerical worker [ ] Sales worker [ ] Service worker [ ] Agric., Animal husb. & fishing [ ] Production and related worker [ ] unemployed [ ]
15. Employment sector of respondent: Public [ ] Private formal [ ] Private informal [ ] Semipublic or parastatal [ ] NGO or international [ ] other []

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APPENDIX 7

Results of the laboratory analysis on foam samples from refrigerators

Refrigerator foam panel	Mean (mgCFC-11/g PU)	Standard deviation(mgCFC-11/g PU)	Minimum (mgCFC-11/g PU)	Maximum(mgCFC-11/g PU)
G1	145.33	3.51	136	149
G2	119.33	3.51	116	139
W1	134.00	4.58	124	139
W2	134.00	4.58	130	132
M1	135.33	4.73	116	139
M2	122.67	6.11	113	132
F1	135.33	6.03	129	141
F2	119.33	8.50	113	129

Refrigerator foam panel	1 mgCFC-11/gPU	2 mgCFC-11/gPU	3 mgCFC-11/gPU
G1	145	149	142
G2	119	116	123
W1	130	139	133
W2	130	139	132
M1	139	130	137
M2	124	116	128
F1	141	136	129
F2	113	129	116

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